DEPARTMENT OF THE ARMY
US ARMY CENTER FOR HEALTH PROMOTION AND PREVENTIVE MEDICINE
5158 BLACKHAWK ROAD
ABERDEEN PROVING GROUND MD 21010-5403

MCHB-TS-EWS

26 May 2006

MEMORANDUM FOR Deputy Assistant Secretary of the Army, Environment, Safety, and Occupational Health (DASA-ESOH/Mr. Addison D. Davis), 110 Army Pentagon, Washington, DC 20310-0100

SUBJECT: Performance and Health Risk Assessment of Commercial-Off-The-Shelf (COTS) Individual Water Purifiers, Water Supply Management Program, Project No. 31-EC-03E0

1. Subject report, sponsored by your office and funded by the Army Studies Program, is enclosed. This project assessed the performance and health risks of COTS individual water purifiers for use by individual warfighters to provide emergency treatment of field drinking water.

2. Address any questions or comments to Mr. Todd Richards, Program Manager, Water Supply Management, commercial (410) 436-3919, DSN 584-3919, or email at todd.richards@us.army.mil.

Michael B. Cates

Encl

MICHAEL B. CATES
Brigadier General, VC
Commanding

Readiness thru Health

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
26 MAY 2006	**final**	**01-10-2004 to 28-04-2006**

4. TITLE AND SUBTITLE
Performance and Health Risk Assessment of Commercial Off-the-Shelf Individual Water Purifiers

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
William Bettin; Arthur Lundquist; Steven Clarke; Steven Richards

5d. PROJECT NUMBER
31-EC-03E0

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM),5158 Blackhawk Road,APG,MD,21010

8. PERFORMING ORGANIZATION REPORT NUMBER
31-EC-03E0

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Department of the Army, ATTN: SAUS-OR, Office of the Deputy Under Secretary of the Army for Operations Research, Washington, DC, 20310

10. SPONSOR/MONITOR'S ACRONYM(S)
DUSA(OR); ASA(I&E)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
ESOH05002

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
The original document contains color images.

14. ABSTRACT

This project assessed the performance and health risks of commercial-off-the-shelf (COTS) individual water purifiers (IWP) for use by individual warfighters to provide emergency treatment of field drinking water. This project had three discrete objectives: 1)develop a military-use specific protocol for testing the efficiency and functionality of IWPs in producing microbiologically safe drinking water; 2) gather and assess technical information on COTS IWPs and develop a shareable database of this information, and 3) develop simple, direct recommendations for the warfighter on the lowest-risk IWPs to use. The Project Team successfully developed a military-use specific protocol for testing the efficiency and functionality of IWPs in producing microbiologically safe drinking water. NSF International has published this protocol as "NSF Protocol P248 Emergency Military Operations Microbiological Water Purifiers." The Project Team successfully developed a comparative, searchable, relational database of the technical specifications, operating characteristics, and pathogen removal capabilities of available COTS IWPs. This information has been packaged into a shareable web-based IWP information tool, located at http://usachppm.apgea.army.mil/WPD. The Project Team successfully completed operational and Multi-Criteria Decision Making (MCDM) analysis to develop simple, direct recommendations for the warfighter on the lowest-risk IWPs to use.

15. SUBJECT TERMS

water; purifier; water purifier; purification; water purification; individual water purifier; IWP; commercial; COTS; COTS IWP; protocol; purifier protocol; database; health risk; MCDM; decision model; model; multi-criteria decision model; evaluation model; user profile; Army Study Program; decision analysis; operational analysis; IWP recommendations; IWP combinations; filter; disinfectant; water filter; water disinfectant; drinking water; emergency purifier; emergency; NSF Protocol P248; NSF Protocol; pathogen; pathogen removal; chlorine; disinfection; oxidant; filtration; iodine; ultraviolet; chlorine dioxide; osmosis

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**1**	**664**	

U.S. Army Center for Health Promotion and Preventive Medicine

USCHPPM

WATER SUPPLY MANAGEMENT PROGRAM
PROJECT NO. 31-EC-03E0
PERFORMANCE AND HEALTH RISK ASSESSMENT OF COMMERCIAL-OFF-THE-SHELF INDIVIDUAL WATER PURIFIERS

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U.S. Army Center for Health Promotion and Preventive Medicine

The U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM) lineage can be traced back over 50 years. This organization began as the Army Industrial Hygiene Laboratory, established during the industrial buildup for World War II, under the direct supervision of The Army Surgeon General. Its original location was at the Johns Hopkins School of Hygiene and Public Health. Its mission was to conduct occupational health surveys and investigations within the Department of Defense's (DOD's) industrial production base. It was staffed with three personnel and had a limited annual operating budget of $3,000.

In 1960, the laboratory became internationally known as the U.S. Army Environmental Hygiene Agency or AEHA. Its mission expanded to support the worldwide preventive medicine programs of the Army, DOD, and other Federal agencies when directed by the Army Medical Command or the Office of The Surgeon General, through consultations, support services, investigations, on-site visits, and training.

On 1 August 1994, AEHA was redesignated the U.S. Army Center for Health Promotion and Preventive Medicine with a provisional status and a commanding general officer. On 1 October 1995, the nonprovisional status was approved with a mission for providing preventive medicine and health promotion leadership, direction, and services for America's Army.

The mission of USACHPPM is to provide health promotion and preventive medicine leadership and services to counter environmental, occupational, and disease threats to health, fitness, and readiness in support of the National Military Strategy. Its vision is to be the world class center of excellence for the systematic prevention of environmental, occupational, and disease threats to the health performance of individuals and populations.

The Center has been reorganized and reengineered to support the Army of the future. The USACHPPM now has three subordinate commands located in Fort Meade, Maryland; Fort McPherson, Georgia; and Fort Lewis, Washington; to provide responsive regional health promotion and preventive medicine support across the U.S. There are also two CHPPM overseas commands in Landstuhl, Germany and Camp Zama, Japan who contribute to the success of USACHPPM's increasing global mission.

The USACHPPM remains strong and at the forefront of prevention-based programs worldwide. The future will involve meeting multiple challenges, from demonstrating the effectiveness of health promotion and preventive medicine to integrating force health protection, health risk assessment, population health and injury prevention into the life-cycle model of the soldier. The USACHPPM will continue to work closely with sister services to support the continuum of military operations to be faced in the coming years.

DEPARTMENT OF THE ARMY
US ARMY CENTER FOR HEALTH PROMOTION AND PREVENTIVE MEDICINE
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EXECUTIVE SUMMARY
WATER SUPPLY MANAGEMENT PROGRAM
PROJECT NO. 31-EC-03E0
PERFORMANCE AND HEALTH RISK ASSESSMENT OF COMMERCIAL-OFF-THE-SHELF INDIVIDUAL WATER PURIFIERS

1. PURPOSE. This project assessed the performance and health risks of commercial-off-the-shelf (COTS) individual water purifiers (IWP) for use by individual warfighters to provide emergency treatment of field drinking water. This project had three discrete objectives: 1) develop a military-use specific protocol for testing the efficiency and functionality of IWPs in producing microbiologically safe drinking water; 2) gather and assess technical information on COTS IWPs and develop a shareable database of this information, and 3) develop simple, direct recommendations for the warfighter on the lowest-risk IWPs to use.

2. CONCLUSIONS.

a. Protocol. The Project Team successfully developed a military-use specific protocol for testing the efficiency and functionality of IWPs in producing microbiologically safe drinking water. NSF International has published this protocol as "NSF Protocol P248 Emergency Military Operations Microbiological Water Purifiers."

b. Database. The Project Team successfully developed a comparative, searchable, relational database of the technical specifications, operating characteristics, and pathogen removal capabilities of available COTS IWPs. This information has been packaged into a shareable web-based IWP information tool, located at http://usachppm.apgea.army.mil/WPD.

c. Develop IWP Recommendations. The Project Team successfully completed operational and Multi-Criteria Decision Making (MCDM) analysis to develop simple, direct recommendations for the warfighter on the lowest-risk IWPs to use.

d. Additional Testing. The MCDM analysis was constrained by performance test data limitations. Very few IWPs were proven, via independent protocol-based testing, to remove all pathogens of concern. There is a need to perform independent testing to obtain additional high-confidence pathogen removal performance data.

3. RECOMMENDATIONS.

a. Protocol. Conduct future IWP pathogen removal performance testing in accordance with the NSF International test protocol "NSF Protocol P248 Emergency Military Operations Microbiological Water Purifiers."

b. Database. Personnel considering the purchase and use of IWPs should refer to the USACHPPM's web-based IWP information tool at http://usachppm.apgea.army.mil/WPD for guidance.

c. Develop IWP Recommendations. Due to the narrow spread of scores among the MCDM analysis top-scoring IWPs, there will likely be several acceptable low-risk IWPs for any situation. Users should consider the characteristics and required tradeoffs of their unique situation to select a low-risk, useful IWP from the MCDM top scorers. Even with the noted MCDM results limitations, consider the three IWPs below as generally recommended, based on their described strengths.

(1) Consider the SweetWater® Purifier from Mountain Safety Research, Inc., as the highest-scoring overall filter-based IWP. It is commercially packaged as a combination filter and disinfectant. It removes all four pathogens of interest. For use in conditions requiring a very small and lightweight IWP, however, the filter's size and weight make it an unsuitable option.

(2) Consider the Micropur MP 1 Tablets from Katadyn North America, Inc., as the highest-scoring overall disinfectant-based IWP. It removes all four pathogens of interest, and is very lightweight. However, it has a detrimental effect on the taste and odor of the water, and it has a long purification time. Both of these weaknesses are common to the disinfectant-based IWPs considered in this Project.

(3) Consider the First Need Deluxe from General Ecology, Inc., as the highest-scoring filter-only IWP. The Project Team rated this IWP, based on technology, for expected removal of all four pathogens of interest. Protocol-based test data is required to confirm this. It is the smallest and lightest device of the General Ecology, Inc., family of IWPs. For use in conditions requiring a very small and lightweight IWP, however, its size and weight make it an unsuitable option.

(4) Consider device combinations as an option to increase pathogen removal capabilities and reduce risk in using IWPs. Combinations were not evaluated in this study, but this concept would have the potential to provide a greater range of capabilities.

d. Recommendations for Additional Testing. IWP manufactures and concerned government agencies should perform independent protocol-based testing to obtain additional high-confidence pathogen removal performance data. USACHPPM should update this Project's MCDM analysis and results as new data becomes available.

® SweetWater is a registered trademark of Mountain Safety Research, Inc., Seattle, WA. Use of trademarked products does not imply endorsement by the U.S. Army, but is intended only in identification of a specific product.

Performance and Health Risk Assessment of COTS Individual Water Purifiers

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PROJECT NO. 31-EC-03E0
PERFORMANCE AND HEALTH RISK ASSESSMENT OF
COMMERCIAL-OFF-THE-SHELF INDIVIDUAL WATER PURIFIERS

1. REFERENCES. Appendix A contains a list of references used in developing this report.

2. PURPOSE. This project assessed the performance and health risks of commercial-off-the-shelf (COTS) individual water purifiers (IWP) for use by individual warfighters to provide emergency treatment of field drinking water. This project had three discrete objectives: 1) develop a military-use specific protocol for testing the efficiency and functionality of IWPs in producing microbiologically safe drinking water; 2) gather and assess technical information on COTS IWPs and develop a shareable database of this information, and 3) develop simple, direct recommendations for the warfighter on the lowest-risk IWPs to use.

3. AUTHORITY. The office of the Deputy Assistant Secretary of the Army for Environment, Safety and Occupational Health sponsored this project's proposal to the FY2005 Headquarters Department of the Army (HQDA) Army Study Program. As per email message dated 29 July 2004, subject: FY 05 Army Studies Program – Results, the proposal was selected and approved by the HQDA Study Program Coordination Committee as a funded FY2005 HQDA Army Study Program Project.

4. BACKGROUND.

a. Project Problem Statement. A mission critical need exists to assess the performance and health risks of COTS water purifiers used by individual Soldiers to provide emergency treatment of field water supplies. Water supply remains a critical requirement for warfighter sustainment on the battlefield. Emergency IWPs are a critical component of water supply. They provide microbiologically safe water to keep Soldiers mission-ready in cases where they do not have access to Army-provided water supply. Current approved emergency purifiers are time consuming and may produce non-microbiologically safe water. As a result, units and Soldiers today are using un-tested and un-approved COTS purifiers. Because the performance of these COTS purifiers has not been evaluated, their use poses a health risk through the ingestion of waterborne contaminants that may render the warfighter combat-ineffective.

b. Proposed Benefit to the Army. This project will support the Global War on Terrorism in sustaining a campaign-capable expeditionary Army by providing the means to assess and identify safe, effective COTS water purifiers for emergency individual use. It will also enable the Future Force concept of sustainment during extended autonomous operations. This project

will enhance Army capabilities for joint, interagency, and multinational full-spectrum operations by extending force sustainment capabilities in identifying a safe, effective COTS water purifier for emergency individual use.

c. History.

(1) Currently fielded individual water purification options for the warfighter include iodine tablets and chlor-floc tablets. Neither of these methods fully meets the needs of modern warfighters in terms of ease of use, volume of water produced, or confidence that the final product is microbiologically safe. Many small, hand-operated "water purifiers," including both filtration- and disinfection-based devices, have been commercially developed in recent years for campers and hikers. Military personnel have shown interest in using them. As a result, some companies have donated their devices to deployed units, and then claimed military "approval" as a marketing tool. Other military units have used unit funds to purchase devices to take with them on deployments. Individual warfighters have even purchased their own devices for field use as an alternate to currently fielded options.

(2) However, none of the COTS devices currently on the market have been tested or approved by the U.S. Army Medical Command or the Office of the Surgeon General. Some manufacturers make claims about the efficiency and functionality of their devices in producing microbiologically safe drinking water. However, few have complete, independent, protocol-based test results to substantiate their claims. Thus, units and individual warfighters are largely left to their own judgment as to which devices to purchase. Their purchases are often guided primarily by the packaging and marketing, rather than device performance or quality. This puts the warfighter at risk of contracting waterborne diseases through the ingestion of waterborne pathogens.

(3) While some limited study and evaluation of select commercial IWPs has been conducted, there was no single military-use specific protocol for testing the efficiency and functionality of IWPs in producing microbiologically safe drinking water. Nor has any DOD organization conducted a detailed technical study, to include gathering and assessing available test data, to provide recommendations as to which commercially available devices are best suited for use by deployed personnel. The U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM) has received many requests from Soldiers and commanders, asking for recommendations on which COTS water purifiers they should purchase. In response, USACHPPM developed an Information Paper with basic information to help guide purchases (reference 1). However, the guidance in this Information Paper is limited and the number of COTS devices available on the market has increased, thus creating a need for a more comprehensive and updated study.

d. Scope and Objectives. This project's efforts will include information gathering, data assessment, expert-panel evaluation, decision analysis, and document development. This project

will produce guidance and recommendations to help the warfighter select quality individual water purification devices that will provide adequate volumes of microbiologically safe drinking water in deployed environments throughout the world. It will produce a test protocol by which to measure and compare the pathogen removal performance of IWPs. To accomplish its stated purpose, this project will meet three discrete objectives:

(1) Develop a military-use specific protocol for testing the efficiency and functionality of IWPs in producing microbiologically safe drinking water. This completed protocol will specify and then guide consistent performance testing of IWPs so that results can be meaningfully compared and used in decision analysis.

(2) Gather and assess technical information on COTS IWPs and develop a shareable database of this information. This effort will involve evaluating IWP design, and assessing its pathogen removal capabilities, to include evaluating and assessing existing performance testing data. Completion of this objective will produce a searchable database of COTS individual water treatment devices that can be used to compare the capabilities of such devices to each other, to the protocol, and to determine their applicability to military operational needs.

(3) Develop simple, direct recommendations for commanders, logisticians, Preventive Medicine personnel, and the individual warfighter on the lowest-risk IWPs to use.

e. Personnel. The following USACHPPM personnel comprised the COTS IWP Army Study Program Project Team: MAJ William Bettin, Art Lundquist, Steve Clarke, and Dr. Steve Richards. See Appendix B for a list of other personnel who contributed to this project.

5. METHODOLOGY AND PROCEDURES.

a. Project Plan. Figure 1 shows the project plan to meet the three project objectives, and fulfill the overall project purpose. Note that there are three distinct thrusts of effort in the plan, each producing one of the stated project objectives. Note also that the three thrusts of effort come together in the Multi-Criteria Decision Making (MCDM) analysis step, which is the basis for our final device recommendations.

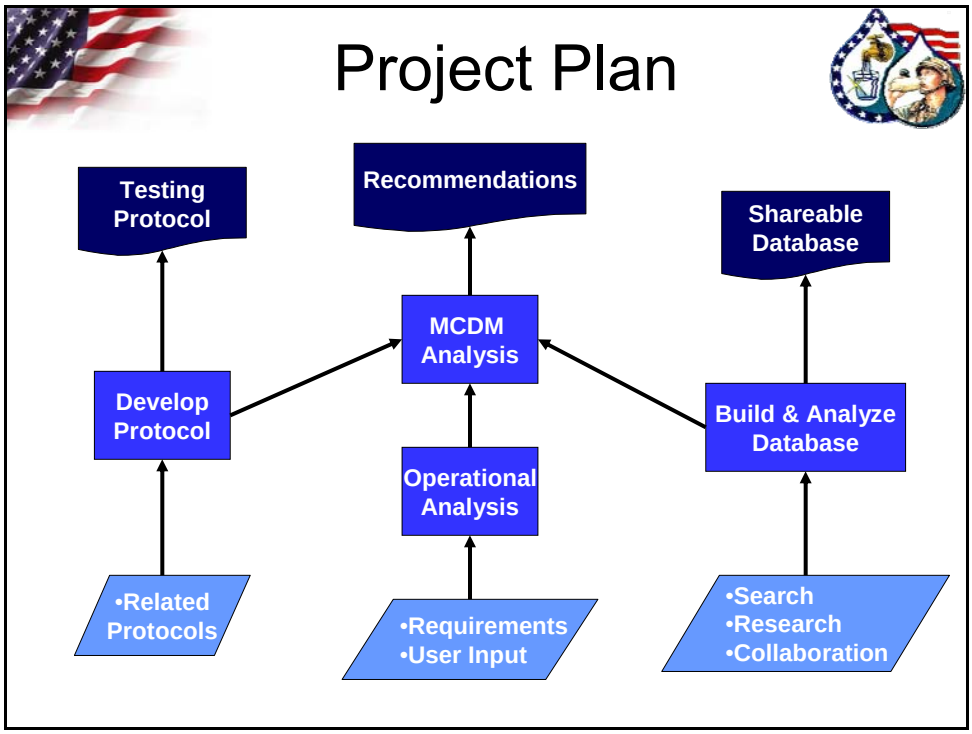


Figure 1. Project Plan

b. Protocol.

(1) The discrete project objective of the Testing Protocol thrust of effort was to develop a military-use specific protocol for testing the efficiency and functionality of IWPs in producing microbiologically safe drinking water. Rather than rely on incomplete or manufacturer pathogen removal performance data, this test protocol was to be the single performance measure by which to test and compare different COTS IWPs. This test protocol was to be published by a reputable third party, NSF International.

(2) This project's procedure for developing a military-use IWP test protocol was to:

- Develop a draft based upon existing U.S. Environmental Protection Agency (EPA) and NSF purifier protocols (references 2, 3 and 4), and on similar protocol development work conducted by the Joint Medical Field Water Sub-Group of the Joint Environmental Surveillance Working Group.
- Include unique considerations for military use.
- Include updated information on test pathogens.
- Staff initial draft to Subject Matter Experts (SMEs) selected by the Project Team.

- Staff the revised draft to NSF International.
- Transmit the final draft to NSF International for publishing.

c. Database.

(1) The discrete project objective of the Database thrust of effort was to develop a comparative, searchable, relational database of the technical specifications and pathogen removal capabilities of available COTS IWPs for use in MCDM analysis, and then to package this information into a shareable application.

(2) This project's procedure for completing the IWP database thrust of effort was to:

- Gather Information.
- Evaluate pathogen removal performance.
- Develop database information for MCDM analysis.
- Develop database information into a shareable application.

d. Develop IWP Recommendations.

(1) The discrete project objective of the Develop Recommendations thrust of effort was to develop simple, direct recommendations for the warfighter on the lowest-risk IWPs to use. The Project Team engaged the Edgewood Chemical Biological Center (ECBC) Decision Analysis Team (DAT) to develop and implement a MCDM-based evaluation of COTS IWPs. The ECBC DAT performed as the lead facilitator in this thrust of effort.

(2) The ECBC DAT developed the procedure for this effort. The key steps in this procedure were to:

- Form the MCDM evaluation team and identify participants
- Perform operational and requirements analysis; develop user profiles
- Identify and describe IWPs (based on project's Database effort)
- Convene panel of user-representative experts to validate user profiles and develop MCDM evaluation model
- Convene panel of technical experts to assess IWPs against the MCDM evaluation model
- Develop specific recommendations on using IWPs

(3) The final report of the ECBC DAT project work, presented in Appendix C, gives a detailed description of this procedure.

e. Assumptions and Limitations.

(1) Water purifiers considered in this project were for use at the individual level. In application, this meant primarily handheld purifiers.

(2) IWPs were considered for use by a deployable military population. Unique characteristics of a military population, relevant to this project and with respect to health risks from waterborne contaminants include:

- Generally fit and healthy
- Generally of age between 18-55 years
- No immuno-compromised members
- No pregnant members

(3) IWPs were considered for short-term, emergency use. They were not considered for routine use, for use as the sole source of drinking water, or for use longer than 7 days.

(4) Drawing on the previous two assumptions, this project only considered risks from ingestion of waterborne pathogens. By design, this project excluded the consideration of other waterborne contaminants. Thus water purification performance was solely a function of waterborne pathogen removal performance.

(5) Only commercially available devices were considered in this project. IWPs were evaluated as commercially packaged, and according to the commercially-packaged manufacturer's instructions for use. No developmental or prototype IWPs were considered.

(6) Only devices that were designed for individual use and marketed for pathogen reduction or inactivation were considered. Devices that were designed solely for reduction of chlorine, lead, and/or taste and odor, etc., were not included in this survey

(7) IWP cost was not considered in the MCDM analysis. Since each potential IWP user would likely have different cost constraints, cost-benefit trade-offs would be unique to each user. Thus the project team could not characterize it for analysis. Cost information was collected during the Database effort of this project, and was included in the shareable database.

(8) The MCDM analysis was constrained by data limitations. Few IWPs had complete, third-party produced test data by which to verify their pathogen removal performance. As a result, the technical expert panel convened for the MCDM analysis relied heavily on their professional experience and judgment to assess IWP performance.

6. FINDINGS AND DISCUSSION.

a. Protocol.

(1) The Project Team and select USACHPPM SMEs (see Appendix B) successfully developed a military-use specific protocol for testing the efficiency and functionality of IWPs in producing microbiologically safe drinking water. The Project Team solicited input for this protocol from SMEs within other Department of Defense (DOD) organizations, including the U.S. Navy Environmental Health Center, the U.S. Navy Bureau of Medicine, the U.S. Air Force Institute for Operational Health, the U.S. Air Force 311th Human Systems Wing, the U.S. Army Proponency Office for Preventive Medicine, the U.S. Army Deputy Chief of Staff for Logistics, and the U.S. Army Infantry Center and School.

(2) Significant protocol components developed and added during this project included: 1) a listing of desirable characteristics and operational capabilities that impact device suitability for use in various emergency military field scenarios; 2) the specification that the IWP manufacturer or vendor, together with the equipment testing organization, produce a written, device-specific test plan and forward it for review to the government review agency before testing, and 3) an updated discussion and specification of the selection of microorganisms for testing.

(3) The Project Team contacted NSF International, as a recognized and reputable third-party entity in test protocols, about publishing its military-use specific protocol. In line with their mission to support "public health safety and protection of the environment by developing standards" NSF International agreed to publish this Project's test protocol. The Project Team staffed the final draft protocol with NSF International, made appropriate revisions, and then transmitted the final protocol to NSF International for publishing as "NSF Protocol P248 Emergency Military Operations Microbiological Water Purifiers" (reference 5). An excerpt of this published test protocol is included at Appendix D. NSF has retained distribution control of the full test protocol. For a copy, contact NSF International, 789 Dixboro Road, Ann Arbor, MI 48105. Phone: (734) 769-8010; Telex: 753215 NSF INTL; FAX: (734)769-0109; E-mail: info@nsf.org, or Web: http://www.nsf.org

b. Database.

(1) Data Collection.

(a) The Project Team attempted to evaluate all commercially available IWPs that could be commercially purchased by warfighters stationed within the continental United States (CONUS). The Project Team performed a market survey to identify and gather information on all devices available at retailers within the CONUS or worldwide on the Internet. As part of this market survey, the Project Team attempted to contact all identified IWP manufacturers to request detailed technical information and performance test data. In all cases, the Team informed the

manufacturer of the nature of the ongoing project as the basis for the request. Some manufacturers did not respond to the Team's contact attempts. For these manufacturers' devices, the Team only collected publicly available product information. A few manufacturers requested meetings, which were granted, to deliver this information to the Team. The goal of this market survey was to identify all COTS devices that were designed for individual use and marketed for pathogen reduction or inactivation. Devices that were designed solely for reduction of chlorine, lead, and/or taste and odor, etc., were not included in this survey.

(b) In the recent past, the U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC) has conducted study and evaluation of IWPs. TARDEC was willing to share this information, so the Project Team collaborated with them in order to benefit from their experience and knowledge, and to receive technical information and test data to use in this Project's database. The Project Team also collaborated with the U.S. Air Force 311th Human Systems Wing (HSW), who was conducting their own market survey on field medic water purification devices. The 311th HSW shared the final report of their study (reference 6). Relevant information from that study was also added to this Project's database.

(c) The survey of available COTS IWPs revealed 68 devices produced by 27 manufacturers. Of these, 53 devices used filtration as the primary means of pathogen reduction, and 15 devices used disinfection as the primary means of pathogen inactivation.

(2) Data Evaluation.

(a) Pathogen Removal Performance. Evaluation of IWP pathogen removal performance was a key part in the development of database information for use in the MCDM analysis. Laboratory testing results were critical to a high-confidence evaluation of this performance. The Project Team made deliberate and exhaustive efforts to locate and review all available laboratory test results showing device efficacy at pathogen reduction/inactivation. Sources of data included, but were not limited to, web searches, direct manufacturer contact (through correspondence or in person), previous market surveys, and contact with other DOD organizations. The Project Team evaluated the quality of test data based on the following characteristics: 1) how closely the testing followed an applicable test protocol; 2) the degree of independent, third-party status of the testing organization; 3) the degree to which testing was conducted in accordance with manufacturer-specified device operating conditions, and 4) the degree to which testing was device-specific, versus based on technology or product family similarities. The results, for each IWP for which test data were evaluated, are presented in the "Effectiveness Against Microbial Pathogens" section of each Device Evaluation in Appendix E.

(b) In the absence of data, the treatment technology used by the device became the primary basis for determining pathogen removal performance. To assist in the technology-based evaluation of IWP pathogen removal performance, the Project Team developed Technical Information Papers (TIPs) on each of the six types of treatment technology employed, collectively, to remove/inactivate pathogens in the IWPs considered. The six types of treatment

technology were: chlorine disinfection, iodine disinfection, chlorine dioxide disinfection, electrochemically generated oxidant disinfection, ultraviolet light disinfection, and filtration (which includes removal by the mechanisms of straining, depth filtration, osmotic membranes, adsorption, and ion exchange). These TIPs are presented in Appendix F. The results of technology-based evaluation of each IWP are also presented in the "Effectiveness Against Microbial Pathogens" section of each Device Evaluation in Appendix E.

(c) Using performance test data and/or the knowledge of treatment technologies as presented in the TIPs, the Project Team rated the pathogen removal performance of each IWP with a three-check system developed for this project. Explanation of the three-check rating system used for this project is presented in Appendix G. Results of the three-check system rating are presented in the Table of "Expected Performance Against Microbial Pathogens" in each Device Evaluation in Appendix E.

(d) IWP Characteristics. The Project Team obtained a commercially packaged version of each evaluated IWP. They were inspected to verify technical details, manufacturer-specified device operating instructions, and weight and size characteristics. They were also inspected to evaluate ease of use and overall design. These results are also presented in the Device Evaluation of each IWP considered, in Appendix E.

(3) IWP Screening for MCDM Analysis.

(a) At the time of this Project step, the Team had identified 66 water purifying devices through the market survey. Initial review of the devices indicated that some of them were not feasible candidates for meeting the needs of the warfighter. In order to select only the feasible devices for detailed MCDM analysis, the Project Team along with the ECBC DAT, conducted a screening phase. Threshold requirements, based on information developed by the MCDM user-representative expert panel, were determined for each of the four user profiles. The user profiles are described below in paragraph 6.c.(1). Each device was then evaluated against those requirements. If a device did not meet the minimum requirements for a profile, it was not included in the MCDM analysis for that profile. The minimum standards developed for screening devices are all based on measures from the evaluation model. The minimum screening standards are listed in Section 3.5 of the ECBC DAT Final Report, located at Appendix C. In most cases, the screening level represents the bottom of the performance scale. Some devices did not have enough information available to conduct the evaluation. For these devices, it was noted that more information was needed, and the device was not included in the detailed assessment. In all cases, the manufacturer was contacted and given the opportunity to provide data for their device(s).

(b) For each device screened, rationale was documented to justify which profiles that device was applicable to. Using the screening process, 32 devices were eliminated from all profiles. However, due to the Project Team's professional interest, three of the screened-out devices were included in all profiles as noted exceptions. After the screening, 36 of the original

66 devices remained to be evaluated for user profile A, 35 devices for user profile B, 34 devices for user profile C, and 17 devices for user profile D. The results of this screening, including the justifications for the elimination of devices from the evaluation, are presented in the ECBC DAT Final Report (see Appendix C of the report) located at Appendix C.

c. Develop IWP Recommendations. The Project Team, facilitated by the ECBC DAT, conducted operational and MCDM decision analysis to develop simple, direct recommendations for the warfighter on the lowest-risk IWPs to use. The ECBC DAT Final Report, located at Appendix C, presents the full detail on the findings and discussions generated through this effort. A summary of the key findings and discussion follows, below.

(1) Operational and Requirements Analysis – User Profile Development. The Project Team, with input from the user-expert representatives, developed four user profiles to describe the broad spectrum of military missions in which an IWP would be needed. The profiles are not intended to be all-encompassing, but they help to define the different requirements that an IWP will likely have to meet to achieve various military missions. The user profiles are based on and described by three primary attributes, as listed below. For each attribute, there are two options that characterize the profile.

(a) Attribute #1: Mission – Stationary or On-the-Move. In a stationary mission, no movement is required to complete the mission except for initial deployment to the mission location by vehicle. The service member does not have to carry the IWP for more than a short distance daily (e.g., ½ mile or less). Normally the mission occurs in one location with minimal movement and under generally secure conditions. In an on-the-move mission, the service member must continually move to complete the mission. This mission includes tactical movement, under generally low-security conditions and/or in combat conditions, with little time for the service member to spend on non security-related efforts.

(b) Attribute #2: Transportation – Hand-Carried or Vehicle Transported. In the hand-carried situation the IWP is physically carried by the service member when the device is moved from location to location. The service member has the burden of carrying the IWP for undetermined distances. In the vehicle transported situation the IWP is moved with other gear by a vehicle when required. The service member only has to carry the IWP a very short distance to a drop-off location for a vehicle to deliver the IWP to the new mission location. This attribute is primarily applicable only to the on-the-move mission; in the stationary mission the IWP does not need to be transported (except for the initial transportation to the mission location, which is generally done by vehicle).

(c) Attribute #3: Water Sustainment – Emergency Use or Augment Planned Use. This attribute describes length of use and daily water requirements. In the emergency use situation the IWP is needed for 1 day or less, and the amount of water required is no more than 5 liters. In this situation the need to purify water is unexpected and short-term. In the augment planned use situation the length of time the IWP is needed is up to 7 days, and the amount of

water required is 15 liters per day. In this situation the ability to make water allows the mission to continue even in situations where the conventional water supply is inadequate.

(d) Each of the three attributes has two options, which results in eight possible combinations (i.e., user profiles). However, as noted above for the transportation attribute, there is no transportation requirement for stationary missions, so the possible combinations are reduced from eight to six. The user representatives were able to further limit the number of user profiles to four by combining all emergency use water sustainment attribute combinations into one user profile. This one emergency use profile covers both mission types (stationary and on-the-move) and both types of transportation requirements (hand-carried and vehicle transported). The following table describes and provides brief examples for each of the four IWP user profiles.

User Profile A	User Profile B	User Profile C	User Profile D
Mission: stationary **Transportation:** hand-carried or vehicle transported (see note below) **Water Sustainment:** augment planned use **Length of Use:** up to 7 days **Daily Water Requirement**: 15L/day for up to 7 days **Description:** base camp/fixed location operations **Examples**: • Initial Base Camp Setup o IWP needed until TWPS or ROWPU becomes operational, or until logistics are set-up to procure potable water (e.g., re-supply of bottled water). • Remote Base Camp Frequently Becomes Isolated o Camp operates without a TWPS or ROWPU. Potable water normally brought in. There are known probable (semi-planned) interruptions caused by weather delays, for example, that interrupt the re-supply of water to camp. IWP can be used to provide enough water for a week with mission degradation. • Forward Observer • Reconnaissance	**Mission:** on-the-move **Transportation:** vehicle transported **Water Sustainment:** augment planned use **Length of Use:** up to 7 days **Water Requirement:** 15L/day for up to 7 days **Description:** vehicle-based operations **Examples:** • Extended Autonomous Operations/Unit of Action • Sustained Operations (e.g., advance to Baghdad) o Service Member must move continually to locate and engage the enemy. Not enough water is carried to complete operation so IWP needs to augment the difference. • Convoy Operations (Unstable Conditions) o There are known probable (semi-planned) interruptions caused by weather delays, for example, that delay a convoy arriving at its final destination as planned. IWP can be used to provide enough water for a week with mission degradation.	**Mission:** on-the-move **Transportation:** hand-carried **Water Sustainment:** augment planned use **Length of Use:** up to 7 days **Water Requirement:** 15L/day for up to 7 days **Description:** dismounted operations **Examples:** • Special Operations Unit o Because of mission to keep a low profile the unit cannot be re-supplied with potable water. Mission requires unit to move continually in order to locate and engage with enemy. Need to make water with IWP from local water source. • Dismounted Patrol o Service Member is in a firefight and not able to disengage to re-supply. Need to make water with IWP from local water source.	**Mission:** stationary or on-the-move **Transportation:** vehicle transported or hand-carried (see note below) **Water Sustainment:** emergency use **Length of Use:** 1 day **Water Requirement:** 5L for 1 day **Description:** short term unexpected emergency use during conditions of otherwise robust water re-supply. Includes situations with a loss of mission capability. **Examples:** • Convoy Operations (Stable Conditions) o Because of an unforeseen delay, the convoy cannot arrive at its final destination before it depletes the potable water it carried for the trip. IWP can supply enough water for 1 day in order to survive under possible reduced mission capabilities. • Remote Base Camp Becomes Unexpectedly Isolated o Camp operates without a TWPS or ROWPU. Potable water normally re-supplied. In this situation, the ability to re-supply water has been unexpectedly interrupted. Re-supply should occur within 24 hours. IWP can supply enough water for 1 day in order to survive under possible reduced mission capabilities. • Reconnaissance • Forward Observer • Dismounted Patrol. • Downed pilot

Note: For stationary missions, the only transportation requirement will be the initial transportation, when the IWP is moved by vehicle (typically) to the mission location.

Table. Characteristics of User Profiles

(2) Evaluation Model

(a) The ECBC DAT used MCDM decision analysis methodology for this Project. The core of the MCDM method is the identification of evaluation criteria, against which options are assessed. Several factors were considered during development of the evaluation criteria. First, evaluation criteria needed to differentiate the devices, so the criteria had to be relevant and discriminating. Criteria also had to be independent, so that aspects measured in one criterion were not repeated in another criterion. Finally, it was important to focus on the criteria that were the most important to the decision process.

(b) For this study, an initial set of evaluation criteria was developed by the Project Team and the ECBC DAT. The criteria were primarily based upon a review of several requirements documents, including the U.S. Army Chemical School's draft Joint Initial Capabilities Document for the Nuclear, Biological, and Chemical Environment Personal Hydration System (reference 7), the U.S. Army Infantry School's draft Capabilities Development Document for Individual Water Treatment Device (reference 8), and the U.S. Marine Corps' Statement of Need for the Individual Water Purifier (reference 9). The user profiles were also used as a reference to develop the criteria.

(c) On 27-28 July 2005, a panel of user experts (see Appendix A) met with the Project Team and the ECBC DAT to review, modify, and finalize the initial criteria and user profiles. The criteria were structured as a hierarchy, which is referred to as the evaluation model. The highest level of the model consisted of three criteria categories, or goals: Performance, Operational, and Logistics. At the next level of the model, some goals were broken into sub-goals (e.g., Pathogen Removal). The lowest level of the model was formed when each goal or sub-goal was further broken down into evaluation measures (e.g., Bacteria Removal). The measures are what the devices were assessed against. A decision support software tool, Logical Decisions for Windows (LDW), was used to develop and document the evaluation model. Figure 2 depicts the evaluation model, with goals and sub-goals represented by rectangles, and measures represented by ovals. Note that the basic structure of the model (goals and measures) is the same for each of the four user profiles.

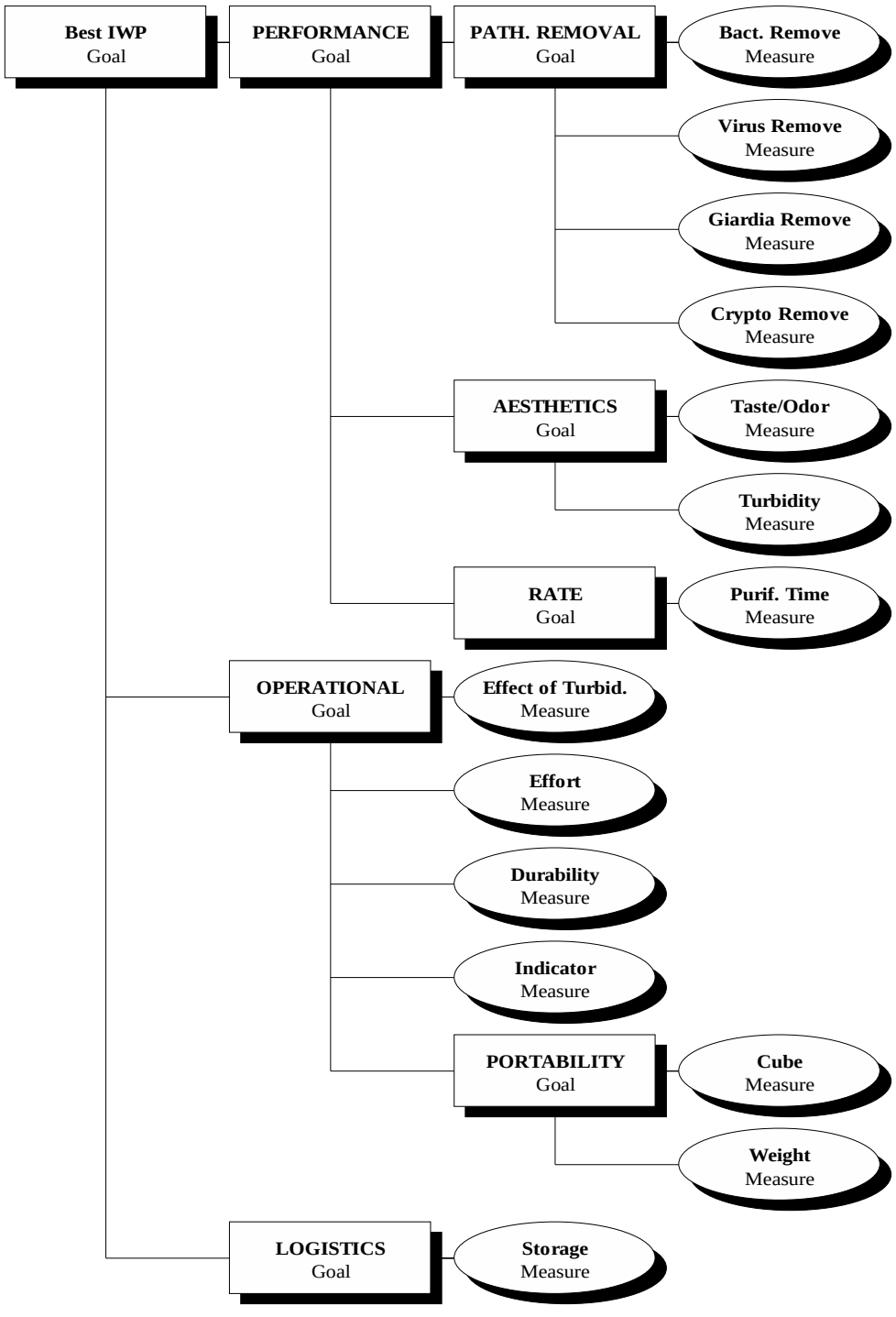


Figure 2. IWP Evaluation Model

Note that the model is comprised of both quantitative and qualitative measures. For example, the *Purification Time* measure is a quantitative criterion, measured in numerical units (minutes). The *Durability* measure is an example of a qualitative measure, better assessed in more subjective terms (adjectival descriptors, e.g., high/medium/low).

(d) For each criterion, shown as an oval in the Evaluation Model in Figure 2, the user-representative expert panel developed definitions and performance scales. The panel also developed weights for each goal and criterion, based on the importance of each goal/measure relative to the others. The full detail of their development is presented in the ECBC DAT Final Report, located at Appendix C.

(3) Technical Expert Panel Evaluation.

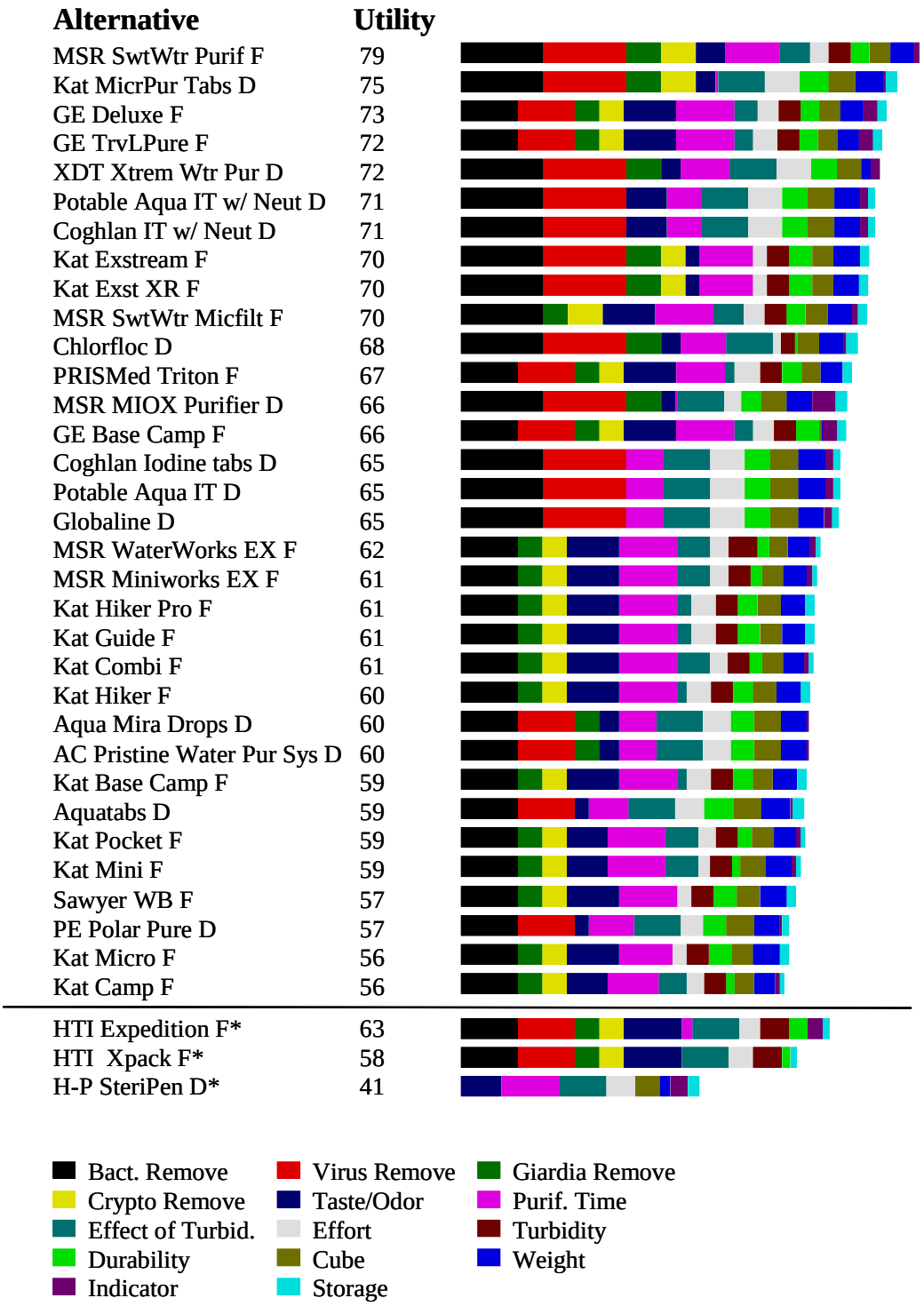
(a) On 24-25 August 2005, a panel of technical experts (see Appendix B) met with the Project Team and the ECBC DAT to evaluate the feasibility-screen purifiers against the evaluation model for each user profile. Starting with Profile A, the experts evaluated each device against each measure in the evaluation model. The panel discussed each device, using the data presented in the device evaluation papers as well as their own expertise and judgment. Discussion continued until a consensus was reached, at which point a score was assigned, based on the performance scale in the evaluation model. Scoring rationale was documented when required. This process was repeated until each device had been assessed against each measure for Profile A. For Profiles B, C, and D, each device was then re-evaluated for those measures that had different performance scales from Profile A.

(b) The panel performed a consistency check of the scores to ensure that all devices were scored accurately relative to the performance scales and relative to each other. A few corrections were made and approved by the technical experts. The panel's scores are presented in the ECBC DAT Final Report in Appendix C (see Figure 3 and Appendix D of the report).

(4) MCDM Results and Analysis.

(a) Using the technical expert panel's scores, the ECBC DAT generated MCDM results and analyzed them. The LDW software translated each assigned score to a converted score on a scale from 0-100. This conversion was based on the assigned score for the device and the associated utility for that measure (see section 3.4 of Appendix C). An overall score was then generated using a linear additive approach, in which the converted score for each measure was multiplied by the measure weight, and then summed across all measures. This resulted in an overall score and a ranking for each device.

(b) An example of the MCDM results is shown in Figure 3. The stacked bar chart displays overall scores and rankings relative to the 14 evaluation measures. The colored bars to



*Note: The HTI Expedition F, HTI Xpack F, and the H-P SteriPen D did not meet the minimum criteria for this scenario. Exceptions were made to allow them to be included in the analysis.

Figure 3. Stacked Bar Ranking for Profile A

the right of each device illustrate the proportion each measure contributed to the overall score for each technology. The width of each sub-bar reflects both the weight of the measure and the score a device received. The four Pathogen Removal measures are listed first, followed by the remaining measures in order of decreasing weight. The converted and overall scores, and their presentation in stacked bar charts, for Profiles B-D are presented in the ECBC DAT Final Report in Appendix C.

(c) The ECBC DAT also performed further results analysis from several perspectives. In addition to 1) analyzing the overall score and ranking relative to goals and measures (stacked bar charts described above), they 2) analyzed the performance of individual devices to identify strengths and weaknesses, and 3) conducted sensitivity analysis to identify how results would be affected by different goal/measure weights. The results of these further analyses are also are presented in the ECBC DAT Final Report (Section 4) in Appendix C.

7. CONCLUSIONS.

a. Protocol. The Project Team successfully developed a military-use specific protocol for testing the efficiency and functionality of IWPs in producing microbiologically safe drinking water. NSF International has published this protocol as "NSF Protocol P248 Emergency Military Operations Microbiological Water Purifiers." An excerpt of this published test protocol is included at Appendix D. NSF has retained distribution control of the full test protocol. For a copy, contact NSF International, 789 Dixboro Road, Ann Arbor, MI 48105. Phone: (734) 769-8010; Telex: 753215 NSF INTL; FAX: (734) 769-0109; E-mail: info@nsf.org; Web: http://www.nsf.org.

b. Database. The Project Team successfully developed a comparative, searchable, relational database of the technical specifications, operating characteristics, and pathogen removal capabilities of available COTS IWPs. This information is presented in the Device Evaluation of each IWP considered in this project, in Appendix E. This information was used to conduct the MCDM analysis. This information has also been packaged into a shareable IWP information tool. USACHPPM Information Management Division (IMD) has prepared this information tool for web-based employment. Instructions for accessing and using this IWP information tool are presented in Appendix H.

c. Develop IWP Recommendations. The Project Team, facilitated by the ECBC DAT, successfully completed operational and MCDM decision analysis to develop simple, direct recommendations for the warfighter on the lowest-risk IWPs to use. The ECBC DAT Final Report, located at Appendix C, presents the full detail on the conclusions generated through this effort. Select conclusions are listed below:

(1) IWP-Specific Conclusions. Due to the close range of scores for the devices in all Profiles, the MCDM results alone do not show any single compelling, clear-cut best IWP. This

narrow spread of scores among the top-ranked IWPs of each profile indicates that individual tradeoffs will be required to select preferred devices. In light of these MCDM results limitations, three devices can be distinguished from the other devices due to specific strengths, as described below.

(a) The SweetWater® Purifier from Mountain Safety Research, Inc., (MSR SwtWtr Purif F) is a filter-based IWP that is commercially packaged with final-step disinfectant. It ranked 1st in Profiles A and B, and 2nd in Profile C. It is one of only two devices that received the maximum pathogen removal score for all four pathogens of interest. For Profile D, however, its size and weight make it unsuitable.

(b) The Micropur MP 1 Tablets from Katadyn North America, Inc., (Kat MicrPur Tabs D) is the highest-scoring disinfectant-based device. It ranked 2nd in Profiles A and B, and 1st in Profiles C and D. It is one of only two devices that received the maximum pathogen removal score for all four pathogens of interest. However, it gives a disinfectant taste and odor to the purified water, and requires a long purification time to achieve its maximum pathogen removal score. Both of these weaknesses are common to disinfectant-based devices that claim to remove pathogenic cysts.

(c) The First Need Deluxe from General Ecology, Inc., (GE Deluxe F) is the highest ranked filter-only device in Profiles A-C. The filter increases cube and weight, but overall it performs very well; if EPA testing was successful this device would rank highest overall. It is very similar to other General Ecology, Inc., devices evaluated, but its smaller size and weight makes this device preferred over the other General Ecology, Inc., devices.

(2) User Profile-Specific Conclusions. Given the range of user requirements defined by the four user profiles, it is unlikely a single device will meet all user needs. MCDM results by user profile, however, rank which IWPs score best against the modeled user's needs of each unique profile. These profile-wise results indicate low-risk IWPs to consider using in the types of scenarios described for each user profile. A potential IWP user could match their mission requirements to the most applicable user profile, and then review that profile's MCDM results to determine which IWPs best meet their need for a low-risk, useful IWP.

(a) User Profile A, B, and C. The two top-scoring IWPs in the MCDM analysis for User Profiles A, B, and C were the SweetWater® Purifier from Mountain Safety Research, Inc., (MSR SwtWtr Purif F) and the Micropur MP 1 Tablets from Katadyn North America, Inc., (Kat MicrPur Tabs D). The MSR SwtWtr Purif F is a filter and Kat MicrPur Tabs D is a disinfectant, so they were also the top-scoring filter-based and top-scoring disinfectant-based IWPs for this User Profile. They are the only two devices that received the top rating of "three checks" (see Appendix G for definition of rating system) for removal of all four considered pathogens.

(b) User Profile D. The cube and weight constraints of User Profile D limit the number of acceptable devices for the profile that perform well in pathogen removal. The top-scoring IWP in the MCDM analysis for User Profiles D was a disinfectant-based IWP, the Micropur MP 1 Tablets from Katadyn North America, Inc., (Kat MicrPur Tabs D). It was the only device that received the top rating of "three checks" (see Appendix G for definition of rating system) for removal of all four considered pathogens. Only one filter-based IWP was considered in this profile, and its MCDM score was low.

(c) The ECBC DAT Final Report (Section 4.1), located at Appendix C, presents the full MCDM analysis results and detailed discussion of the results for each profile.

(3) IWP Combinations. Device combinations are an option to increase pathogen removal capabilities. Combinations were not evaluated in this study, but this concept would have the potential to provide a greater range of capabilities. For example, by combining a filter and disinfectant device, the user could have a greater potential to remove all pathogens; however, a combination such as this might have other detrimental effects such as increased size and weight.

d. Additional Testing.

(1) The MCDM analysis was constrained by performance test data limitations. As a result, the expert panel relied heavily on vendor-supplied information. There is a need to perform independent testing to obtain additional high-confidence performance data. If additional test data becomes available for an IWP, its pathogen removal performance rating can be updated and new MCDM results and recommendations generated.

(2) Very few devices were proven, via independent protocol-based testing, to remove all four pathogens. Several IWPs have the technology potential to do so, but this potential needs protocol-based test confirmation. Again, as additional test data becomes available for an IWP, its pathogen removal performance rating can be updated and new MCDM results and recommendations generated.

8. RECOMMENDATIONS.

a. Protocol. Conduct future IWP pathogen removal performance testing in accordance with the NSF International test protocol "NSF Protocol P248 Emergency Military Operations Microbiological Water Purifiers". An excerpt of this published test protocol is included at Appendix D. NSF has retained distribution control of the full test protocol. For a copy, contact NSF International, 789 Dixboro Road, Ann Arbor, MI 48105. Phone: (734) 769-8010; Telex: 753215 NSF INTL; FAX: (734) 769-0109; E-mail: info@nsf.org; Web: http://www.nsf.org.

b. Database. Personnel considering the purchase and use of IWPs should refer to the USACHPPM's web-based IWP information tool. Instructions for accessing and using it are presented in Appendix H. Though all of the information contained in this report will be available through the web-based tool, IWP users can also refer to information on technical specifications, operating characteristics, and pathogen removal capabilities presented in the IWP Device Evaluations in Appendix E.

c. Develop IWP Recommendations.

(1) Due to the narrow spread of scores, even among the top-scoring several IWPs of each profile, there will likely be several acceptable low-risk IWPs for any situation. Consider the characteristics and required tradeoffs of your situation to select a low-risk, useful IWP from the MCDM top scorers. Select recommendations, based on the MCDM analysis, are listed below, first as IWPs with unique identified strengths and then as top scorers for each User Profile.

(2) Even with the MCDM results limitations, consider the three IWPs below as generally recommended, based on their described strengths:

(a) Consider the SweetWater® Purifier from Mountain Safety Research, Inc., (MSR SwtWtr Purif F) as the highest-scoring overall filter-based IWP (ranks 1st or 2nd in Profiles A-C). It is commercially packaged as a combination filter and disinfectant. It removes all four pathogens of interest. For Profile D, however, the filter's size and weight makes it an unsuitable IWP.

(b) Consider the Micropur MP 1 Tablets from Katadyn North America, Inc., (Kat MicrPur Tabs D) as the highest-scoring overall disinfectant-based IWP (ranks 1st or 2nd in all User Profiles). It removes all four pathogens of interest, and is very lightweight. However, it has a detrimental effect on the taste and odor of the water, and it has a long purification time (both of these weaknesses are common to all disinfectant-based IWPs).

(c) Consider the First Need Deluxe from General Ecology, Inc., (GE Deluxe F) as the highest-scoring filter-only IWP for Profiles A-C. The Project Team rated this IWP, based on technology, for expected removal of all four pathogens of interest. Protocol-based test dated is required to confirm this. It is the smallest and lightest device of the GE family of IWPs. For Profile D, however, the filter's size and weight makes it an unsuitable IWP.

(3) Consider User Profile-based results to select low-risk, useful IWPs. Assess mission requirements and select the most applicable User Profile. Review that profile's MCDM results to determine which IWPs best meet needs for a low-risk, useful IWP.

(a) For User Profiles A, B, and C, first consider the two MCDM top-scoring IWPs: SweetWater® Purifier from Mountain Safety Research, Inc., (MSR SwtWtr Purif F) and Micropur MP 1 Tablets from Katadyn North America, Inc., (Kat MicrPur Tabs D). These two IWPs were the top-scoring filter-based and top-scoring disinfectant-based IWPs for User Profiles A, B, and C. For further consideration, add situation specifics and consider several of the Profile's top scorers to select a low-risk, useful IWP.

(b) For User Profile D, consider first the MCDM top-scoring IWP, Micropur MP 1 Tablets from Katadyn North America, Inc., (Kat MicrPur Tabs D). For further consideration, add situation specifics and consider several of the Profile's top scorers to select a low-risk, useful IWP.

(4) The ECBC DAT Final Report (Section 5.0), located at Appendix C, presents detailed discussion of IWP recommendations.

(5) Consider device combinations as an option to increase pathogen removal capabilities and reduce risk in using IWPs. Combinations were not evaluated in this study, but this concept would have the potential to provide a greater range of capabilities.

d. Recommendations for Additional Testing.

(1) Perform independent protocol-based testing to obtain additional high-confidence performance data. As additional test data becomes available for an IWP, update its pathogen removal performance rating and generate new MCDM results and recommendations.

(2) Confirm, via independent protocol-based testing, the pathogen removal performance of IWPs identified with the technology potential to remove all four pathogens considered. Pathogen removal performance was the most important factor for a low-risk IWP. Identified potential should be confirmed by testing in order to update MCDM results and make further recommendations on low-risk IWPs.

William J. Bettin

WILLIAM J. BETTIN
MAJ, MS
Chief, Field Water Section

APPROVED BY:

Todd E. Richards

TODD E. RICHARDS, P.E.
Program Manager
Water Supply Management

APPENDIX A

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APPENDIX B

PROJECT PARTICIPANTS

Name	Organization	Role
MAJ William Bettin	USACHPPM	Study Team Lead
Art Lundquist	USACHPPM	Study Team
Steve Clarke	USACHPPM	Study Team
Steve Richards	USACHPPM	Study Team
Dick Burrows	USACHPPM	Protocol Developer
John Brokaw	USACHPPM	Protocol Developer
John Walther	ECBC	Decision Analyst
Scott Kooistra	ECBC	Decision Analyst
Lindsey Wurster	ECBC	Decision Analyst
Rochelle Bautista	USA Infantry Center, DCD	User Expert
Jay Dusenbury	TARDEC	User Expert
Wayne Kabat	HQDA – Army G-4	User Expert
Alex Papadopoulos	USMC Combat Developments	User Expert
CDR Jack Beaujon	NAVSEA	Technical Expert
John Brokaw	USACHPPM	Technical Expert
Scott Nielsen	TARDEC	Technical Expert
Christopher Penthany	Natick Soldier Center	Technical Expert
CAPT Joanna Rentes	AFIOH/RSE	Technical Expert
Bill Varnava	NAVFAC	Technical Expert

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APPENDIX C

INDIVIDUAL WATER PURIFIER STUDY REPORT

Prepared by:
Edgewood Chemical Biological Center Decision Analysis Team

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Individual Water Purifier Study Report

3 February 2006

Edgewood Chemical Biological Center Decision Analysis Team
Lindsey Wurster
John Walther
Scott Kooistra

Center for Health Promotion and Preventive Medicine
MAJ Bill Bettin
Art Lundquist
Steve Clarke
Steve Richards

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Individual Water Purifier Study Report

1.0 Introduction

This study was performed to evaluate commercially available individual water purifiers (IWPs) that might be taken to the field by deploying military units. The study was sponsored/approved as part of the Headquarters, Department of the Army (HQDA) Army Study Program and performed during FY05 by the United States Army Center for Health Promotion and Preventive Medicine (USACHPPM).

In the study, a large number of commercial, off-the-shelf IWP devices were identified and procured by USACHPPM. Data was gathered on each device and documented in a database. A Multi-Criteria Decision Model was developed, and the devices were assessed relative to that model by a panel of experts.

This report describes the decision analysis process used to assess the IWP devices and provides the results of that assessment. Recommendations are provided as to which devices are most appropriate for various scenarios of use.

2.0 Background

Water supply is a critical requirement for service member sustainment on the battlefield, and emergency individual water purifiers are a critical component of water supply. Emergency individual water purifiers provide microbiologically safe water to keep soldiers mission-ready in cases where they do not have access to an Army-provided water supply. Current approved emergency purifiers are time consuming to use and may not produce microbiologically safe water. As a result, units and soldiers today are procuring and using commercial-off-the-shelf (COTS) water purifiers that may not be adequately tested and are not approved for military use. This presents potential health risks through the ingestion of waterborne contaminants that may render the service member combat ineffective.

The USACHPPM submitted a proposal to the HQDA Army Study Program to address this problem. The proposal included a three-pronged approach: develop a testing protocol, build a database, and make recommendations concerning use of these COTS IWP devices. The proposal was approved as part of the FY05 program, and the study was initiated in second quarter FY05.

The objective of the study was to evaluate COTS IWP devices and to recommend the best available devices for procurement and use, based on ability to provide adequate volumes of microbiologically safe drinking water in environments throughout the world where service

members are deployed. As part of the study, USACHPPM conducted an extensive market survey to identify available IWP devices, and also developed a database that was used to help assess the IWP devices.

The Edgewood Chemical Biological Center (ECBC) Decision Analysis Team (DAT) supported USACHPPM by developing and implementing an approach to evaluate the IWP devices. That approach is described in the next section.

3.0 Evaluation Process

The approach used to assess the IWP devices employed a logical, structured decision analysis process, which included thorough documentation of the results and rationale so that final recommendations could be readily explained and defended. This process comprised five phases:

1. Form study team and identify participants
2. Perform operational and requirements analysis
3. Identify and describe IWP devices
4. Develop evaluation model
5. Assess IWP devices

This section of the report describes each of the five phases in detail. That is followed by the analysis of results, and then the study's conclusions and recommendations.

3.1 Study Team and Participants

A study team was formed as the first step of the evaluation process. The core study team consisted of USACHPPM personnel supporting the Army Study Program project, and decision analysts from the DAT. The study team identified user representatives and technical experts to participate in subsequent study steps.

The user representatives' primary role was to articulate the needs of the service member. The technical experts were selected for their knowledge and expertise in water purification technologies, which they would use to assess the various IWP devices. The decision analysts were responsible for developing and implementing the evaluation approach, facilitating the study team through the process, and analyzing the results.

The study was performed in a collaborative fashion, using facilitated decision conferences to accomplish most of the project goals. The study participants are listed in Appendix A.

3.2 Operational and Requirements Analysis - User Profile Development

The user representatives on the study team met to discuss how the IWP might be used. Based upon those discussions, four User Profiles were developed to describe the broad spectrum of military missions (i.e., operational situations) in which an IWP would be needed. The profiles are not intended to be all-encompassing, but they help to define the different requirements that an IWP will likely have to meet to achieve various military missions.

The user profiles are based on and described by three primary attributes, as listed below. For each attribute, there are two options that characterize the profile.

1. Mission: *Stationary* or *On-the-Move.*

   In a stationary mission, no movement is required to complete the mission except for initial deployment to the mission location by vehicle. The service member does not have to carry the IWP for more than a short distance daily (e.g., ½ mile or less). Normally the mission occurs in one location with minimal movement and under generally secure conditions.

   In an on-the-move mission, the service member must continually move to complete the mission. This mission includes tactical movement, under generally low-security conditions and/or in combat conditions, with little time for the service member to spend on non security-related efforts.

2. Transportation: *Hand-Carried* or *Vehicle Transported.*

   In the hand-carried situation the IWP is physically carried on/by the service member when the device is moved from location to location. The service member has the burden of carrying the IWP for undetermined distances.

   In the vehicle transported situation the IWP is moved with other gear by a vehicle when required. The service member only has to carry the IWP a very short distance to a drop-off location for a vehicle to deliver the IWP to the new mission location.

   This attribute is primarily applicable only to the on-the-move mission; in the stationary mission the IWP does not need to be transported (except for the initial transportation to the mission location, which is generally done by vehicle).

3. Water Sustainment (Length of Use and Daily Water Requirements): *Emergency Use* or *Augment Planned Use.*

In the emergency use situation the IWP is needed for one day or less, and the amount of water required is no more than 5 liters. In this situation the need to purify water is unexpected and short-term.

In the augment planned use situation the length of time the IWP is needed is up to seven days, and the amount of water required is 15 liters per day. In this situation the ability to make water allows the mission to continue even in situations where the conventional water supply is inadequate.

Each of the three attributes has two options, which results in eight possible combinations (i.e., user profiles). However, as noted above for the transportation attribute, there is no transportation requirement for stationary missions so the possible combinations are reduced from eight to six. The user representatives were able to further limit the number of user profiles to four by combining all emergency use water sustainment attribute combinations into one user profile. This one emergency use profile covers both mission types (stationary and on-the-move) and both types of transportation requirements (hand-carried and vehicle transported).

Table 1 describes and provides brief examples for each of the four IWP user profiles. For Profiles A-C, use of the IWP is generally planned; the service member expects that the conventional water supply will be limited during the mission. Use of the IWP will allow service members to continue and complete the mission. In the most extreme of scenarios that fall into Profiles A-C, the IWP may need to provide up to 15 L of purified water per day for up to 7 days. For the emergency profile, Profile D, there is a short-term, unanticipated need for an IWP. In this case, the IWP must provide only a reasonable minimum amount of water to ensure short-term survival. The mission capability of the service member may degrade in this profile.

The requirements described in the user profiles served as the foundation for the evaluation models, as described later in Section 3.4.

User Profile A	User Profile B	User Profile C	User Profile D
Mission: stationary **Transportation:** hand-carried or vehicle transported (see note below) **Water Sustainment:** augment planned use **Length of Use:** up to 7 days **Daily Water Requirement**: 15L/day for up to 7 days **Description:** base camp/fixed location operations **Examples**: • Initial Base Camp Setup o IWP needed until TWPS or ROWPU becomes operational, or until logistics is set-up to procure potable water (e.g., resupply of bottled water). • Remote Base Camp Frequently Becomes Isolated o Camp operates without a TWPS or ROWPU. Potable water normally brought in. There are known probable (semi-planned) interruptions caused by weather delays, for example, that interrupt the resupply of water to camp. IWP can be used to provide enough water for a week with mission degradation. • Forward Observer • Reconnaissance	**Mission:** on-the-move **Transportation:** vehicle transported **Water Sustainment:** augment planned use **Length of Use:** up to 7 days **Water Requirement:** : 15L/day for up to 7 days **Description:** vehicle-based operations **Examples:** • Extended Autonomous Operations/Unit of Action • Sustained Operations (e.g., advance to Baghdad) o Service Member must move continually to locate and engage the enemy. Not enough water is carried to complete operation so IWP needs to augment the difference. • Convoy Operations (Unstable Conditions) o There are known probable (semi-planned) interruptions caused by weather delays, for example, that delay a convoy arriving at its final destination as planned. IWP can be used to provide enough water for a week with mission degradation.	**Mission:** on-the-move **Transportation:** hand-carried **Water Sustainment:** augment planned use **Length of Use:** up to 7 days **Water Requirement:** : 15L/day for up to 7 days **Description:** dismounted operations **Examples:** • Special Operations Unit o Because of mission to keep a low profile the unit cannot be re-supplied with potable water. Mission requires unit to move continually in order to locate and engage with enemy. Need to make water with IWP from local water source. • Dismounted Patrol o Service Member is in a firefight and not able to disengage to resupply. Need to make water with IWP from local water source.	**Mission:** stationary or on-the-move **Transportation:** vehicle transported or hand-carried (see note below) **Water Sustainment:** emergency use **Length of Use:** 1 day **Water Requirement:** 5L for 1 day **Description:** short term unexpected emergency use during conditions of otherwise robust water resupply. Includes situations with a loss of mission capability. **Examples:** • Convoy Operations (Stable Conditions) o Because of an unforeseen delay, the convoy cannot arrive at its final destination before it depletes the potable water it carried for the trip. IWP can supply enough water for 1 day in order to survive under possible reduced mission capabilities. • Remote Base Camp Becomes Unexpectedly Isolated o Camp operates without a TWPS or ROWPU. Potable water normally resupplied. In this situation, the ability to resupply water has been unexpectedly interrupted. Resupply should occur within 24 hours. IWP can supply enough water for 1 day in order to survive under possible reduced mission capabilities. • Reconnaissance • Forward Observer • Dismounted Patrol. • Downed pilot

Note: For stationary missions, the only transportation requirement will be the initial transportation, when the IWP is moved by vehicle (typically) to the mission location.

Table 1: Characteristics of User Profiles

3.3 Device Descriptions

USACHPPM attempted to evaluate every commercially available device obtainable by soldiers stationed within the continental United States. A survey was performed to identify and include all devices available at retailers within the continental United States or worldwide on the Internet. It did not matter where the device originated; only if it was available. The objective of the survey was to identify all devices that were designed for individual use and marketed for pathogen reduction or inactivation. Devices that were designed solely for reduction of chlorine, lead, and/or taste and odor, etc., were not included in this survey.

To evaluate the pathogen reduction/inactivation ability of the devices, laboratory testing results were critical. Every effort was made to locate and review all available laboratory results showing device efficacy at pathogen reduction/inactivation. Sources of data included, but were not limited to, web searches, direct manufacturer contact (through correspondence or in person), previous market surveys, and contact with other DoD organizations. In the absence of data, the treatment technology used by the device became the primary basis for determining efficacy. All devices evaluated were obtained and personally inspected, and all devices were evaluated as commercially packaged and operated as instructed by the manufacturer directions.

The survey of available COTS IWP devices revealed 66 devices produced by 28 manufacturers. Of these, 51 devices used filtration as the primary means of pathogen reduction, and 15 devices used disinfection as the primary means of pathogen inactivation.

Information was collected on each device and recorded in a database developed for this study. The database includes both test results and physical properties of the devices. Device evaluation papers were developed based on this information; these papers were used by the technical experts during their evaluation of the devices.

Table 2 below lists all devices considered, their manufacturer, the device name abbreviation, and the type of device. For the remainder of this report, the device name abbreviations in this table will be used as the reference for the devices. An “F” or “D” following the abbreviated name indicates whether the device is primarily a filter or disinfectant device, respectively.

Manufacturer	Device Name	Device Abbreviation	Device Type
Advance Chemicals Ltd.	Pristine Water Purification System	AC Pristine Water Pur Sys D	chlorine dioxide liquid
Coghlan's	Emergency Drinking Water Germicidal Tablets	Coghlan Iodine tabs D	iodine tablets
Coghlan's	Emergency Drinking Water Germicidal Tablets with Neutralizer	Coghlan IT w/ Neut. D	iodine tablets with neutralizer
Deatrick & Associates, Inc. (distributor)	Chlor-Floc	Chlorfloc D	chlorine tablets with flocculant aid
General Ecology, Inc.	First Need Base Camp	GE Base Camp F	proprietary carbon, microfilter hand pump
General Ecology, Inc.	First Need Deluxe	GE Deluxe F	proprietary carbon, microfilter hand pump
General Ecology, Inc.	First Need Trav-L-Pure	GE TrvLPure F	proprietary carbon, microfilter hand pump
Hydration Technologies, Inc.	HydroWell Expedition	HTI Expedition F	osmotic membrane hydration pack
Hydration Technologies, Inc.	X Pack	HTI Xpack F	osmotic membrane bag
Hydro-Photon, Inc.	SteriPEN	H-P SteriPen D	ultraviolet light generator
Katadyn North America, Inc.	Base Camp	Kat Base Camp F	glass fiber microfilter gravity filter
Katadyn North America, Inc.	Camp	Kat Camp F	ceramic microfilter gravity filter
Katadyn North America, Inc.	Combi	Kat Combi F	ceramic microfilter hand pump
Katadyn North America, Inc.	Exstream Water Bottle	Kat Exstream F	microfilter, iodine resin water bottle
Katadyn North America, Inc.	Exstream XR Water Bottle	Kat Exst XR F	microfilter, iodine resin water bottle
Katadyn North America, Inc.	Guide	Kat Guide F	glass fiber microfilter hand pump
Katadyn North America, Inc.	Hiker	Kat Hiker F	glass fiber microfilter hand pump
Katadyn North America, Inc.	Hiker Pro	Kat Hiker Pro F	glass fiber microfilter hand pump
Katadyn North America, Inc.	Micro Water Bottle	Kat Micro F	glass fiber microfilter water bottle

Manufacturer	Device Name	Device Abbreviation	Device Type
Katadyn North America, Inc.	MicroPur MP 1 Tablets	Kat MicrPur Tabs D	chlorine dioxide tablets
Katadyn North America, Inc.	Mini	Kat Mini F	ceramic microfilter hand pump
Katadyn North America, Inc.	Pocket	Kat Pocket F	ceramic microfilter hand pump
McNett Corporation	Aqua Mira Drops	Aqua Mira Drops D	chlorine dioxide liquid
Medentech	Aquatabs	Aquatabs D	chlorine tablets
Mountain Safety Research, Inc.	MiniWorks EX	MSR Miniworks EX F	ceramic microfilter hand pump
Mountain Safety Research, Inc.	MIOX Purifier	MSR MIOX Purifier D	mixed oxidant liquid generator
Mountain Safety Research, Inc.	SweetWater Microfilter	MSR SwtWtr Micfilt F	glass fiber microfilter hand pump
Mountain Safety Research, Inc.	SweetWater Purifier	MSR SwtWtr Purif F	glass fiber microfilter hand pump, chlorine disinfectant liquid
Mountain Safety Research, Inc.	WaterWorks EX	MSR Waterworks EX F	ceramic microfilter, membrane microfilter hand pump
Polar Equipment, Inc.	Polar Pure	PE Polar Pure D	iodine crystals
PRISMedical Corporation	Triton	PRISMed Triton F	microfilter, carbon gravity filter
Sawyer Products	Water Bottle	Sawyer WB F	hollow fiber microfilter water bottle
Wisconsin Pharmacal Company, LLC.	Globaline	Globaline D	iodine tablets
Wisconsin Pharmacal Company, LLC.	Potable Aqua	Potable Aqua IT D	iodine tablets
Wisconsin Pharmacal Company, LLC.	Potable Aqua with Neutralizer	Potable Aqua IT w/ Neut D	iodine tablets with neutralizer
Xinix Disinfection Technologies, Inc.	Xtreme Water Purifier	XDT Xtrem Wtr Pur D	chlorine dioxide liquid

Table 2: Device Names

3.4 Evaluation Model

3.4.1 Model Overview

A structured decision analysis process was used for the IWP assessment. This process has been used by the ECBC DAT for numerous similar studies over the past several years. Decision analysis is a structured process for decision-making based on established principles of operations research. The decision analysis process is composed of systematic development and examination of alternative courses of action to define and clarify available choices and associated advantages and disadvantages. It also includes thorough documentation of results and associated rationale so that final recommendations can be readily explained and defended.

This section describes how the evaluation model was developed and presents the primary elements of the model: the evaluation criteria, definitions and performance scales, and weights.

3.4.2 Evaluation Criteria

The decision analysis methodology used for this study is referred to as Multi-Criteria Decision Making (MCDM). At its core is the identification of evaluation criteria, against which options are assessed. Several factors were considered during development of the evaluation criteria. First, evaluation criteria should differentiate the devices, so the criteria had to be relevant and discriminating. Criteria also had to be independent, so that aspects measured in one criterion were not repeated in another criterion. Finally, it was important to focus on the criteria that were the most important to the decision process.

For this study, an initial set of criteria was developed by a subset of the study team. The criteria were primarily based upon a review of several requirements documents, including the US Army Chemical School's draft Joint Initial Capabilities Document (ICD) for the Nuclear, Biological, and Chemical Environment Personal Hydration System (NEPHS), the US Army Infantry School's draft Capabilities Development Document (CDD) for Individual Water Treatment Device (IWTD), and the US Marine Corps' Statement of Need for the Individual Water Purifier. The user profiles (reference Section 3.2) were also used as a reference to develop the criteria.

On 27-28 July 2005, a panel of user experts (see Appendix A) met with the USACHPPM study team and the Decision Analysis Team to review, modify, and finalize the initial criteria and user profiles.

The criteria were structured as a hierarchy, which is referred to as the evaluation model. The highest level of the model consisted of three criteria categories, or goals: Performance, Operational, and Logistics. At the next level of the model, some goals were broken into sub-goals (e.g., Pathogen Removal). The lowest level of the model was formed when each goal or sub-goal was further broken down into evaluation measures (e.g., *Bacteria Removal*). The measures are what the devices were assessed against.

A decision support software tool, Logical Decisions for Windows (LDW), was used to develop and document the evaluation model. Figure 1 below depicts the evaluation model, with goals and sub-goals represented by rectangles, and measures represented by ovals. Note that the basic structure of the model (goals and measures) is the same for each of the four user profiles.

The study team decided to exclude cost from the potential evaluation criteria, since each potential IWP user would likely have different cost constraints, resulting in cost-benefit trade-offs that would be unique to each user.

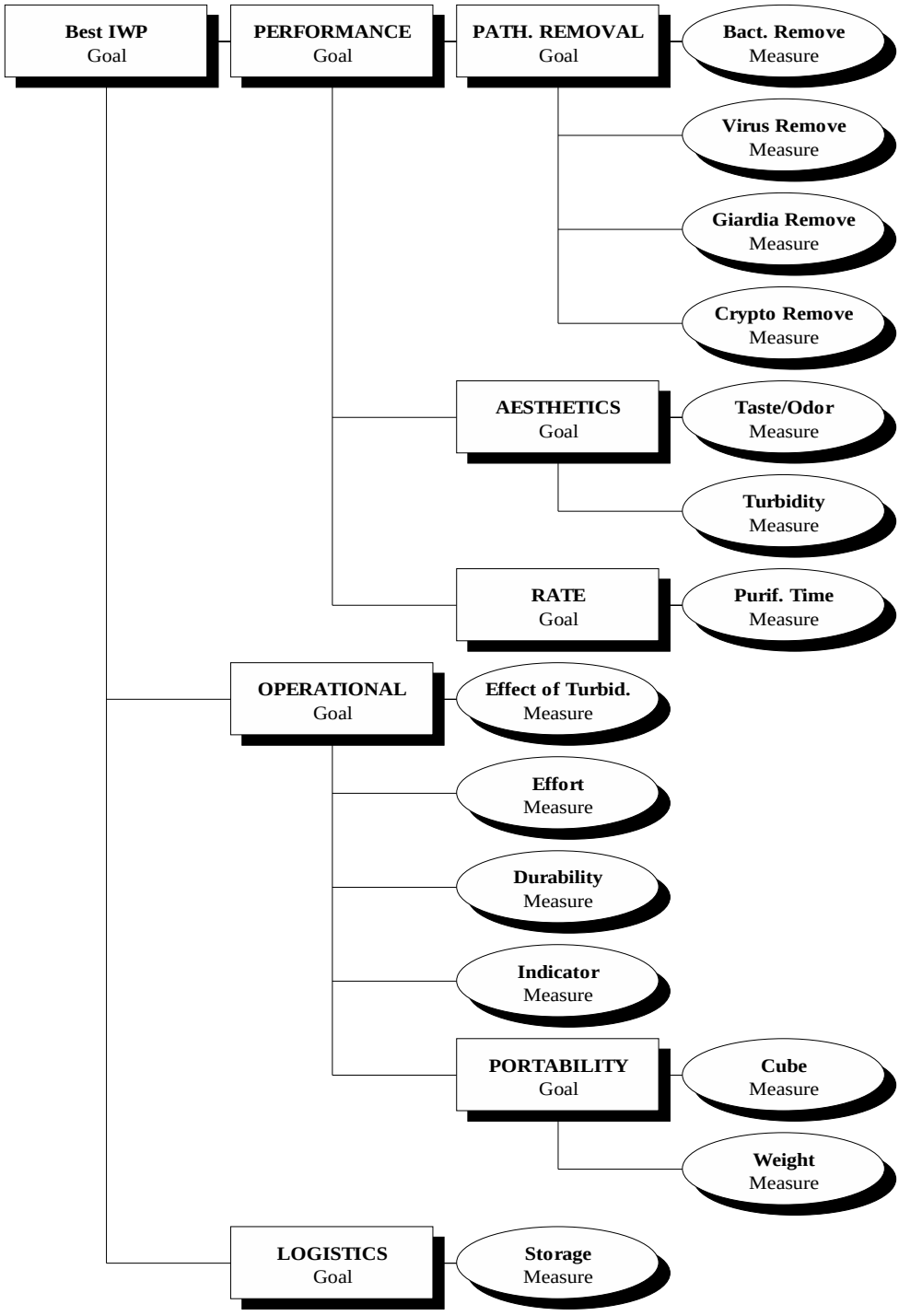


Figure 1: IWP Evaluation Hierarchy

The model is comprised of both quantitative and qualitative measures. For example, the *Purification Time* measure is a quantitative criterion, measured in numerical units (minutes). The *Durability* measure is an example of a qualitative measure, better assessed in more subjective terms (adjectival descriptors, e.g., high/medium/low).

3.4.3 Definitions and Performance Scales

Definitions and performance scales were developed for each measure. Measure definitions are narrative descriptions that must be adequately and appropriately stated and clearly understood. The measure definitions and categories (representing the three main model goals) are shown in Table 3 below.

#	Criterion Name	Definition
Performance		
1	Bacteria Removal Effectiveness	Ability to achieve a 6- log reduction in bacteria microbial pathogens from worst-case source water (Type 2 water per the EPA protocol standard [cold, turbid]).
2	Virus Removal Effectiveness	Ability to achieve a 4- log reduction in virus microbial pathogens from worst-case source water (Type 2 water per the EPA protocol standard [cold, turbid]).
3	*Giardia* Cyst Removal Effectiveness	Ability to achieve a 3- log reduction in *Giardia* cyst microbial pathogens from worst-case source water (Type 2 water per the EPA protocol standard [cold, turbid]).
4	*Cryptosporidium* Oocyst Removal Effectiveness	Ability to achieve a 3- log reduction in *Cryptosporidium* oocyst microbial pathogens from worst-case source water (Type 2 water per the EPA protocol standard [cold, turbid]).
5	Aesthetics - Taste and Odor	Reduces objectionable taste and odor in final product. It is ideal for the IWP to reduce taste or odor in source water and to not impart any objectionable taste or odor to product water.
6	Aesthetics – Turbidity	Ability of IWP to reduce turbidity (i.e., cloudiness).
7	Rate - Purification Time	Time it takes to purify 1 liter of water. This is not an average. Determining minimum wait time to produce 1 liter of water.
Operational		
8	Effect of Turbidity	Impact of turbidity on proper operations of IWP (ability to produce water). (The impact of turbidity on pathogen reduction is included in the pathogen reduction ratings and is not included in this criterion.)

#	Criterion Name	Definition
9	Effort Required	Amount of dedicated effort required to purify amount of water needed per user profile. Required effort includes set-up, deployment/use, ease of use and training required, and cleaning and maintenance requirement (e.g., filter replacement) during maximum length of use (1 day or 7 days based on user profile). Any effort that could occur (e.g., cleaning filter) outside the length of use of the user profile (1 day or 7 days) without affecting the IWP's performance is not included in this criterion.
10	Process Failure Indicator	Indication of failure of IWP to perform as intended due to: unexpected failure, maintenance required, and/or capacities exceeded/end-of-life.
11	Durability	Ability of IWP (including device and all consumables required to complete mission) to withstand drops, rough handling, etc. during transport and use. Includes quality of design, construction, and materials.
12	Cube	Cubic size of IWP (including device and all consumables required to complete mission [for User Profiles A-C, 15 liters/day must be produced (105 liters in 7 days) and for User Profile D, 5 liters must be produced in 1 day]).
13	Weight	Weight of IWP (including device and all consumables required to complete mission as defined by the user profile).
Logistics		
14	Storage	Conditions (e.g., temperature, humidity) required for maximum life (life cycle of the device) of IWP and consumables.

Table 3: Measure Definitions

The performance scales served as the "rating scheme" used to evaluate the devices, and represented the different levels of performance that could be expected among all the devices for each measure.

Some performance scales are continuous (e.g., numeric range of *Weight*), while others are discontinuous, or discrete levels referred to as labels (e.g., ability to reduce *Turbidity* (Aesthetics)). These two examples are shown below.

Weight

Utility	Performance Scale
100	1 gram
0	3,632 grams (8 pounds)

Aesthetics -Turbidity

Utility	Performance Scale
100	Very high
75	High
50	Medium
25	Low
0	None

Performance scales are expressed as utility functions, which convert the different units for all the performance scales to common units. To set relevant endpoints and to establish appropriate intermediate utility values, the IWP device characteristics had to be well defined. Utility values of 100 and 0 were assigned to the high and low end of each performance scale. Intermediate level utilities were derived through various elicitation techniques focused on the relative importance of moving to-and-from various points on the utility function. In several cases the intermediate points were simply reference points, and allowances were made to score anywhere along the scale.

Figure 2 shows the utility function for the *Purification Time* measure in Profile B. This utility curve is referred to as a "risk seeking" curve; where the rate of utility increases rapidly as the desired end of the scale is approached. Utility can also be defined by risk averse and constant functions.

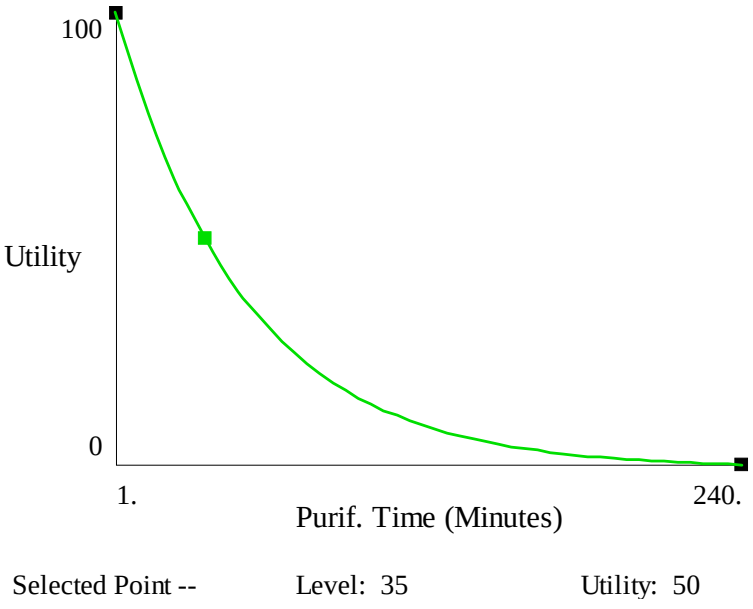


Figure 2: Purification Time Measure Utility Curve Example

The performance scales were the same for most user profiles, however three measures differed depending on the profile, as described below:

Purification Time – lowest level endpoint was 8 hours for Profile A (longer time is more acceptable in a stationary/base camp situation), and 4 hours for Profiles B-D.

Cube – lowest level endpoint was 8,000 cm^3 (8 liters (L)) for Profile A, 4,000 cm^3 (4L) for Profile B, 2,000 cm^3 (2L) for Profile C, and 500 cm^3 (0.5L) for Profile D (allowable volumes become more constrictive as need to be mobile with less support increases).

Weight - lowest level endpoint was 3,632g (8 pounds (lbs)) for Profile A, 1,816g (4 lbs) for Profile B, 908g (2 lbs) for Profile C, and 227g (0.5 lbs) for Profile D (allowable weight becomes more constrictive as need to be mobile with less support increases).

3.4.4 Weights

The final model development step was to develop weights for the goals and measures, based on the importance of each goal/measure relative to the others. 100 points were distributed amongst the measures. The weighting process considers both relative priority and the concept of swing weighting. Swing weighting compares the effects of moving from the lowest point on the performance scale to the highest for any measure in relation to a similar move for any other measure. An example of this was determining whether it was more important to move from "None" to "Very high" for the *Turbidity* (Aesthetics) measure or to move from "3,632g" to "1g" for the *Weight* measure.

Two different techniques were used to establish weights. One method was the Analytic Hierarchy Process (AHP). In this method, AHP weights were derived through pairwise comparisons, in which the user representatives compared each measure to every other measure, and assessed which measure was more important, and by how much.

The Smarter Method weighting technique was also used. In this process, the user representatives rank-ordered the measures, and an algorithm generated a weight for each measure that is dependent on its rank and the number of measures. After generating initial weights via AHP or Smarter, the user representatives adjusted the weights using direct entry.

The weights that were developed were different for each of the four user profiles. The user representatives generated the weights for Profile A first, and then adjusted those weights to account for the different requirements of the other three profiles. The following discussion summarizes the structure of the weights and the differences among the four user profiles.

Profile A:

Due to the stationary nature of this profile, pathogen removal and aesthetics are the most important, while operational factors such as size and weight are not as critical.

- Most important to the user was Pathogen Removal (40% of model weight), defined by the four measures of *Bacteria*, *Virus*, *Giardia*, and *Cryptosporidium Removal*. Within Pathogen Removal, *Bacteria* and *Virus* were most important.

- Second most important was Aesthetics (15% of model), defined as *Taste/Odor* and *Turbidity* reduction.

- Next most important was Rate, defined as *Purification Time* (10%) and Portability (10%), defined by the two measures *Cube* and *Weight*.

- Most of the remaining model weight (23%) was distributed amongst the four Operational measures, in order, *Effect of Turbidity*, *Effort Required*, *Durability*, and *Indicator*. The final 2% was allotted to *Storage*.

Profiles B and C:

For these profiles, aspects related to transportation and field use of the device became more important.

- Pathogen Removal remained most important to the user, however the weight was reduced from 40% in Profile A to 36% for Profiles B and C. Within Pathogen Removal, *Bacteria* and *Virus* remained the most important.

- Unlike Profile A, the second most important aspect for Profiles B and C were *Purification Time* (15% of the model) and Portability (15%), defined by the two measures *Cube* and *Weight*.

- Next most important for Profiles B and C was Aesthetics (9%), defined as *Taste/Odor* and *Turbidity* reduction.

- As in Profile A, most of the remaining model weight (23%) was distributed amongst four of the Operational measures, in order, *Effect of Turbidity*, *Effort Required*, *Durability*, and *Indicator*. The final 2% was allotted to *Storage*.

Profile D:

In this profile, aspects related to portability and use in an isolated field environment became more important.

- Pathogen Removal remained most important to the user, however the weight was reduced to 28%. Within Pathogen Removal, *Bacteria* and *Virus* remained the most important. There were some other differences between Profiles D and A, as described below.

- Second most important in Profile D was Portability (24%), defined by the two measures *Cube* and *Weight*.

- Next most important for Profile D was *Purification Time* (12%), followed by *Effort Required* (10%).

- Most of the remaining model weight (23%) was distributed amongst, in order: *Durability*, *Effect of Turbidity*, *Storage*, and *Indicator*. The final 4% was allotted to the Aesthetics measures, *Taste/Odor* and *Turbidity*. This is also different from Profile A, where Aesthetics were much more important and *Storage* was the lowest weighted measure.

The weights and performance scales for the four evaluation models are summarized in Table 4 below.

Measure	Type of Scale	User Profile A		User Profile B		User Profile C		User Profile D	
		Scale	Wgt	Scale	Wgt	Scale	Wgt	Scale	Wgt
Bacteria Removal Effectiveness	**Label**	100 - 3 Checks* 85 - 2 Checks 70 - 1 Check 0 - 0 Checks	14	100 - 3 Checks* 85 - 2 Checks 70 - 1 Check 0 - 0 Checks	12.6	100 - 3 Checks* 85 - 2 Checks 70 - 1 Check 0 - 0 Checks	12.6	100 - 3 Checks* 85 - 2 Checks 70 - 1 Check 0 - 0 Checks	9.8
Virus Removal Effectiveness	**Label**	100 - 3 Checks* 85 - 2 Checks 70 - 1 Check 0 - 0 Checks	14	100 - 3 Checks* 85 - 2 Checks 70 - 1 Check 0 - 0 Checks	12.6	100 - 3 Checks* 85 - 2 Checks 70 - 1 Check 0 - 0 Checks	12.6	100 - 3 Checks* 85 - 2 Checks 70 - 1 Check 0 - 0 Checks	9.8
***Giardia* Cyst Removal Effectiveness**	**Label**	100 - 3 Checks* 85 - 2 Checks 70 - 1 Check 0 - 0 Checks	6	100 - 3 Checks* 85 - 2 Checks 70 - 1 Check 0 - 0 Checks	5.4	100 - 3 Checks* 85 - 2 Checks 70 - 1 Check 0 - 0 Checks	5.4	100 - 3 Checks* 85 - 2 Checks 70 - 1 Check 0 - 0 Checks	4.2
Cryptosporidium Oocyst Removal Effectiveness	**Label**	100 - 3 Checks* 85 - 2 Checks 70 - 1 Check 0 - 0 Checks	6	100 - 3 Checks* 85 - 2 Checks 70 - 1 Check 0 - 0 Checks	5.4	100 - 3 Checks* 85 - 2 Checks 70 - 1 Check 0 - 0 Checks	5.4	100 - 3 Checks* 85 - 2 Checks 70 - 1 Check 0 - 0 Checks	4.2

Measure	Type of Scale	User Profile A		User Profile B		User Profile C		User Profile D	
		Scale	Wgt	Scale	Wgt	Scale	Wgt	Scale	Wgt
Aesthetics - Taste and Odor	**Continuous**	100 - significantly reduces taste and odor of source water; treatment does not impart taste or odor to product water. 70 - no effect on taste or odor (does not remove or impart any taste or odor). 25 - imparts some taste or odor to product water; does not remove taste or odor from source water. 0 - imparts strong taste and/or odor.	10	100 - significantly reduces taste and odor of source water; treatment does not impart taste or odor to product water. 70 - no effect on taste or odor (does not remove or impart any taste or odor). 25 - imparts some taste or odor to product water; does not remove taste or odor from source water. 0 - imparts strong taste and/or odor.	7	100 - significantly reduces taste and odor of source water; treatment does not impart taste or odor to product water. 70 - no effect on taste or odor (does not remove or impart any taste or odor). 25 - imparts some taste or odor to product water; does not remove taste or odor from source water. 0 - imparts strong taste and/or odor.	7	100 - significantly reduces taste and odor of source water; treatment does not impart taste or odor to product water. 70 - no effect on taste or odor (does not remove or impart any taste or odor). 25 - imparts some taste or odor to product water; does not remove taste or odor from source water. 0 - imparts strong taste and/or odor.	3
Aesthetics - Turbidity	**Label**	100 - very high 75 - high 50 - medium 25 - low 0 - none	5	100 - very high 75 - high 50 - medium 25 - low 0 - none	2	100 - very high 75 - high 50 - medium 25 - low 0 - none	2	100 - very high 75 - high 50 - medium 25 - low 0 - none	1
Purification Time	**Cont.**	100 - 1 minute 0 - 8 hours	10	100 - 1 minute 0 - 4 hours or more	15	100 - 1 minute 0 - 4 hours or more	15	100 - 1 minute 0 - 4 hours or more	12

Measure	Type of Scale	User Profile A		User Profile B		User Profile C		User Profile D	
		Scale	Wgt	Scale	Wgt	Scale	Wgt	Scale	Wgt
Effect of Turbidity	**Label**	100 - Turbidity has no effect on operation of IWP 70 - IWP has a Pre-filter, primary filter is cleanable 65 - IWP has a Pre-filter, primary filter is less cleanable 60 - IWP does not have a Pre-filter, primary filter is cleanable 50 - IWP has a pre-filter, primary filter is backwashable 40 - IWP has multiple pre-filters, primary filter has small pore size 30 - IWP has multiple pre-filters 20 - IWP has a Pre-filter, primary filter is not cleanable 0 - IWP does not have a pre-filter, primary filter is not cleanable	8	100 - Turbidity has no effect on operation of IWP 70 - IWP has a Pre-filter, primary filter is cleanable 65 - IWP has a Pre-filter, primary filter is less cleanable 60 - IWP does not have a Pre-filter, primary filter is cleanable 50 - IWP has a pre-filter, primary filter is backwashable 40 - IWP has multiple pre-filters, primary filter has small pore size 30 - IWP has multiple pre-filters 20 - IWP has a Pre-filter, primary filter is not cleanable 0 - IWP does not have a pre-filter, primary filter is not cleanable	8	100 - Turbidity has no effect on operation of IWP 70 - IWP has a Pre-filter, primary filter is cleanable 65 - IWP has a Pre-filter, primary filter is less cleanable 60 - IWP does not have a Pre-filter, primary filter is cleanable 50 - IWP has a pre-filter, primary filter is backwashable 40 - IWP has multiple pre-filters, primary filter has small pore size 30 - IWP has multiple pre-filters 20 - IWP has a Pre-filter, primary filter is not cleanable 0 - IWP does not have a pre-filter, primary filter is not cleanable	8	100 - Turbidity has no effect on operation of IWP 70 - IWP has a Pre-filter, primary filter is cleanable 65 - IWP has a Pre-filter, primary filter is less cleanable 60 - IWP does not have a Pre-filter, primary filter is cleanable 50 - IWP has a pre-filter, primary filter is backwashable 40 - IWP has multiple pre-filters, primary filter has small pore size 30 - IWP has multiple pre-filters 20 - IWP has a Pre-filter, primary filter is not cleanable 0 - IWP does not have a pre-filter, primary filter is not cleanable	6

Measure	Type of Scale	User Profile A		User Profile B		User Profile C		User Profile D	
		Scale	Wgt	Scale	Wgt	Scale	Wgt	Scale	Wgt
Effort Required	Continuous	100 - Low effort (comparable to iodine tablets) 75 – Comparable to In-line filter 50 – Comparable to Miox Pen/ ceramic filter 25 – Comparable to General Ecology Deluxe filter 0 - Significant effort	6	100 - Low effort (comparable to iodine tablets) 75 – Comparable to In-line filter 50 – Comparable to Miox Pen/ ceramic filter 25 – Comparable to General Ecology Deluxe filter 0 - Significant effort	6	100 - Low effort (comparable to iodine tablets) 75 – Comparable to In-line filter 50 – Comparable to Miox Pen/ ceramic filter 25 – Comparable to General Ecology Deluxe filter 0 - Significant effort	6	100 - Low effort (comparable to iodine tablets) 75 – Comparable to In-line filter 50 – Comparable to Miox Pen/ ceramic filter 25 – Comparable to General Ecology Deluxe filter 0 - Significant effort	10
Process Failure Indicator	Continuous	100 - multiple engineered 75 - engineered 60 - positive 35 - general knowledge (color change) 0 - None	4	100 - multiple engineered 75 - engineered 60 - positive 35 - general knowledge (color change) 0 - None	4	100 - multiple engineered 75 - engineered 60 - positive 35 - general knowledge (color change) 0 - None	4	100 - multiple engineered 75 - engineered 60 - positive 35 - general knowledge (color change) 0 - None	4

Measure	Type of Scale	User Profile A		User Profile B		User Profile C		User Profile D	
		Scale	Wgt	Scale	Wgt	Scale	Wgt	Scale	Wgt
Durability	Continuous	100 - Very durable; able to withstand transport and use (iodine tablets) 0 - Least durable of alternatives evaluated (UV Pen)	5	100 - Very durable; able to withstand transport and use (iodine tablets) 0 - Least durable of alternatives evaluated (UV Pen)	5	100 - Very durable; able to withstand transport and use (iodine tablets) 0 - Least durable of alternatives evaluated (UV Pen)	5	100 - Very durable; able to withstand transport and use (iodine tablets) 0 - Least durable of alternatives evaluated (UV Pen)	7
Cube	Cont.	100 - 1 cm3 0 – 8,000 cm3	5	100 - 1 cm3 0 – 4,000 cm3	7.5	100 - 1 cm3 0 – 2,000 cm3	7.5	100 - 1 cm3 0 - 500 cm3	12
Weight	Cont.	100 - 28 grams (about 1 oz.) or less 0 – 3,632 grams (about 8 lbs)	5	100 - 28 grams (about 1 oz.) or less 0 – 1,816 grams (about 4 lbs)	7.5	100 - 28 grams (about 1 oz.) or less 0 - 908 (about 2 lbs)	7.5	100 - 28 grams (about 1 oz.) or less 0 - 227 grams (about 0.5 lbs)	12
Storage	Continuous	100 - Least susceptible to environmental conditions 0 - Most susceptible to environmental conditions	2	100 - Least susceptible to environmental conditions 0 - Most susceptible to environmental conditions	2	100 - Least susceptible to environmental conditions 0 - Most susceptible to environmental conditions	2	100 - Least susceptible to environmental conditions 0 - Most susceptible to environmental conditions	5

*Note: for a definition of the Checks scale, see Appendix B

Table 4: Criterion Performance Scales and Weights for all Profiles

3.5 Assessment Process

3.5.1 Screening Process

USACHPPM identified 66 water purifying devices through the market survey. Initial review of the devices indicated that many of them were not feasible candidates for meeting the needs of the service member relative to the four user profiles. To reduce the number of devices that would be evaluated against the detailed evaluation model (described in the previous section), an internal study team, composed of representatives from USACHPPM and the DAT, conducted a screening phase. In this phase, threshold requirements were determined for each user profile. Each device was then evaluated against those requirements. If the device did not meet the minimum requirements for that profile, it was not assessed against the detailed model for that profile. The minimum standards developed for screening devices are all based on measures from the evaluation model. In most cases, the screening level represents the bottom of the performance scale. The five minimum standards used for the screening are listed below:

- Pathogen Removal (this requirement was not user profile dependent)
  - All filter devices were required to remove bacteria by 6 log, *Giardia* cyst by 3 log, and *Cryptosporidium* oocyst by 3 log in accordance with the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers.
  - All disinfectant devices were required to inactivate bacteria by 6 log and viruses by 4 log.
- *Cube*
  - For Profile A, all devices must be 8,000 cm^3 (8 L) or less in volume.
  - For Profile B, all devices must be 4,000 cm^3 (4L) or less in volume.
  - For Profile C, all devices must be 2,000 cm^3 (2L) or less in volume.
  - For Profile D, all devices must be 500 cm^3 (0.5L) or less in volume.
- *Weight*
  - For Profile A, all devices must weigh 3,632g (8 lbs) or less.
  - For Profile B, all devices must weigh 1,816g (4 lbs) or less.
  - For Profile C, all devices must weigh 908g (2 lbs) or less.
  - For Profile D, all devices must weigh 227g (0.5 lbs) or less.
- *Purification Time*
  - For Profile A, all devices must purify water in 8 hours or less.
  - For Profiles B, C, and D all devices must purify water in 4 hours or less.
- *Storage*
  - All devices must have reasonable storage requirements for the user profile in question.

Some devices did not have enough information available to conduct the evaluation. For these devices, it was noted that more information was needed, and the device was not included in

the detailed assessment. In all cases, the manufacturer was contacted and given the opportunity to provide data for their device(s).

For each device screened, rationale was documented to justify which profiles that device was applicable to. Using these requirements, 32 devices were eliminated from all profiles, with rationale documented for why they were not considered further. However, due to the study team's professional interest, three of the screened out devices were included in all profiles as noted exceptions (HTI Xpack F, HTI Expedition F, and the H-P SteriPen D).

After the screening, 36 of the original 66 devices remained to be evaluated in Profile A, 35 devices in Profile B, 34 devices in Profile C, and 17 devices in Profile D. See Appendix C for the justifications for the elimination of devices from the evaluation.

3.5.2 Detailed Evaluation

On 24-25 August 2005, a panel of technical experts (see Appendix A) met with the USACHPPM study team and the DAT to evaluate the remaining devices against the detailed evaluation model for each user profile. Starting with Profile A, the experts evaluated each device against each measure in the evaluation model. The panel discussed each device, using the data presented in the device evaluation papers as well as their own expertise and judgment. Discussion continued until a consensus was reached, at which point a score was assigned, based on the performance scale in the evaluation model. Scoring rationale was documented when required. This process was repeated until each device had been assessed against each measure for Profile A.

For Profiles B, C, and D, each device was then re-evaluated for those measures that had different performance scales from Profile A.

A consistency check of the scores was performed to ensure that all devices were scored accurately relative to the performance scales and relative to each other. A few corrections were made and approved by the technical experts. The study team also modified the evaluation model in some cases to improve the ability of the model to discriminate between the different devices. For instance, Service Life was a measure that was included in the original model, but was then removed when 1) it became apparent that it provided no discrimination between the devices being evaluated, and 2) the team determined that the main components of Service Life were accounted for in other areas of the model.

The scores assigned to each device for Profile A are shown in Figure 3 below. For Profiles B, C, and D, the scores are shown in Appendix D.

	Bact. Remove	Virus Remove	Giardia Remove	Crypto Remove	Taste / Odor	Turbidity	Purif. Time	Effect of Turbid.	Effort	Durability	Indicator	Cube	Weight	Storage
AC Pristine Water Pur Sys D	One Check	One Check	One Check	Zero Checks	35	None	35	No effect	80	80	10	330	270	0
Aqua Mira Drops D	One Check	One Check	One Check	Zero Checks	35	None	35	No effect	80	80	10	330	270	0
Aquatabs D	One Check	One Check	Zero Checks	Zero Checks	25	None	30	No effect	85	100	10	120	30	100
Chlorfloc D	Three Checks	Three Checks	Three Checks	Zero Checks	35	Medium	20	No effect	25	10	10	1160	320	100
Coghlan Iodine tabs D	Three Checks	Three Checks	Zero Checks	Zero Checks	0	None	35	No effect	100	90	35	150	150	60
Coghlan IT w/ Neut D	Three Checks	Three Checks	Zero Checks	Zero Checks	70	None	40	No effect	95	90	35	300	300	60
GE Base Camp F	One Check	One Check	One Check	One Check	90	High	1	Mult prefilters small pore	60	80	60	5120	2800	80
GE Deluxe F	One Check	One Check	One Check	One Check	90	High	1	Prefilter, backwashable	60	65	60	1450	430	80
GE TrvLPure F	One Check	One Check	One Check	One Check	90	High	1	Mult prefilters small pore	70	65	60	1580	630	80
Globaline D	Three Checks	Three Checks	Zero Checks	Zero Checks	0	None	35	No effect	100	90	35	150	250	60
H-P SteriPen D	Zero checks	Zero Checks	Zero Checks	Zero Checks	70	None	1.5	No effect	85	0	75	820	1250	100
HTI Xpack F	One Check	One Check	One Check	One Check	100	Very high	480	No effect	70	30	0	8000	3632	60
HTI Expedition F	One Check	One Check	One Check	One Check	100	Very high	130	No effect	60	65	65	8000	3632	60
Kat Base Camp F	One Check	Zero Checks	One Check	One Check	90	High	2	Prefilter; not cleanable	70	70	0	1500	370	80
Kat Camp F	One Check	Zero Checks	One Check	One Check	70	High	12	No prefilter; cleanable	50	30	20	1500	620	40
Kat Combi F	One Check	Zero Checks	One Check	One Check	90	High	1	Prefilter; cleanable	50	45	20	1360	600	40
Kat Exst XR F	Three Checks	Three Checks	Three Checks	One Check	25	High	8	No prefilter; not cleanable	40	80	0	1400	230	80
Kat Exstream F	Three Checks	Three Checks	Three Checks	One Check	25	High	8	No prefilter; not cleanable	40	80	0	1400	200	80
Kat Guide F	One Check	Zero Checks	One Check	One Check	90	High	1	Multiple prefilters	70	75	0	1250	400	80
Kat Hiker F	One Check	Zero Checks	One Check	One Check	90	High	1	Prefilter; not cleanable	70	70	0	1050	310	80
Kat Hiker Pro F	One Check	Zero Checks	One Check	One Check	90	High	1	Multiple prefilters	70	70	0	1050	310	80
Kat Micro F	One Check	Zero Checks	One Check	One Check	90	High	8	No prefilter; not cleanable	40	80	0	1400	200	80
Kat MicrPur Tabs D	Three Checks	Three Checks	Three Checks	Three Checks	35	None	240	No effect	100	100	10	440	80	100
Kat Mini F	One Check	Zero Checks	One Check	One Check	70	High	2	Prefilter; cleanable	35	30	20	580	230	40
Kat Pocket F	One Check	Zero Checks	One Check	One Check	70	High	1	Prefilter; cleanable	50	50	20	1250	570	40
MSR Miniworks EX F	One Check	Zero Checks	One Check	One Check	90	High	1	Prefilter; cleanable	55	40	25	1400	460	40
MSR MIOX Purifier D	Three Checks	Three Checks	Three Checks	Zero Checks	25	None	240	No effect	50	70	100	560	230	100
MSR SwtWtr Micfilt F	Three Checks	Zero Checks	One Check	Three Checks	90	High	1	Prefilter, less cleanable	60	65	25	1260	320	80
MSR SwtWtr Purif F	Three Checks	Three Checks	Three Checks	Three Checks	50	High	6	Prefilter, less cleanable	55	65	25	1400	400	0
MSR WaterWorks EX F	One Check	Zero Checks	One Check	One Check	90	Very high	1	Prefilter; cleanable	55	40	25	1770	540	40
PE Polar Pure D	One Check	One Check	Zero Checks	Zero Checks	25	None	20	No effect	65	80	10	160	250	60
Potable Aqua IT D	Three Checks	Three Checks	Zero Checks	Zero Checks	0	None	35	No effect	100	90	35	150	150	60
Potable Aqua IT w/ Neut D	Three Checks	Three Checks	Zero Checks	Zero Checks	70	None	40	No effect	95	90	35	300	300	60
PRISMed Triton F	One Check	One Check	One Check	One Check	90	High	14	Prefilter; not cleanable	75	70	0	1800	500	80
Sawyer WB F	One Check	Zero Checks	One Check	One Check	90	High	2	No prefilter; not cleanable	40	80	0	1040	160	80
XDT Xtrem Wtr Pur D	Three Checks	Three Checks	Three Checks	Zero Checks	35	None	15	No effect	100	90	40	700	1400	0

*Note: for a definition of the Checks scale, see Appendix B

Figure 3: Assigned Device Scores for Profile A

4.0 Results Analysis

Once the scores were finalized, results were generated and analysis was performed. The LDW software translated each assigned score to a converted score on a scale from 0-100. This conversion is based on the assigned score for the device and the associated utility curve for that measure. An overall score was then generated using a linear additive approach, in which the converted score for each measure was multiplied by the measure weight, and then summed across all measures. This resulted in an overall score and a ranking for each device.

The converted and overall scores for Profile A are shown in Figure 4 below, while the converted and overall scores for Profiles B-D can be found in Appendix E. In all four figures, the column titled “Best IWP Goal” represents the overall score calculated for that device.

	Best IWP Goal	Bact. Remove	Virus Remove	Giardia Remove	Crypto Remove	Taste/Odor	Turbidity	Purif. Time	Effect of Turbid.	Effort	Durability	Indicator	Cube	Weight	Storage
MSR SwtWtr Purif F	79	100	100	100	100	50	75	94	65	55	65	25	72	82	0
Kat MicrPur Tabs D	75	100	100	100	100	35	0	4	100	100	100	10	91	96	100
GE Deluxe F	73	70	70	70	70	90	75	100	50	60	65	60	71	81	80
GE TrvLPure F	72	70	70	70	70	90	75	100	40	70	65	60	68	72	80
XDT Xtrem Wtr Pur D	72	100	100	100	0	35	0	83	100	100	90	40	86	32	0
Potable Aqua IT w/ Neut D	71	100	100	0	0	70	0	60	100	95	90	35	94	87	60
Coghlan IT w/ Neut. D	71	100	100	0	0	70	0	60	100	95	90	35	94	87	60
Kat Exstream F	70	100	100	100	70	25	75	91	0	40	80	0	72	91	80
Kat Exst XR F	70	100	100	100	70	25	75	91	0	40	80	0	72	90	80
MSR SwtWtr Micfilt F	70	100	0	70	100	90	75	100	65	60	65	25	75	86	80
Chlorfloc D	68	100	100	100	0	35	50	78	100	25	10	10	77	86	100
PRISMed Triton F	67	70	70	70	70	90	75	84	20	75	70	0	64	78	80
MSR MIOX Purifier D	66	100	100	100	0	25	0	4	100	50	70	100	89	90	100
GE Base Camp F	66	70	70	70	70	90	75	100	40	60	80	60	9	4	80
Coghlan Iodine tabs D	65	100	100	0	0	0	0	64	100	100	90	35	97	93	60
Potable Aqua IT D	65	100	100	0	0	0	0	64	100	100	90	35	97	93	60
Globaline D	65	100	100	0	0	0	0	64	100	100	90	35	97	89	60
HTI Expedition F	63	70	70	70	70	100	100	18	100	60	65	65	0	0	60
MSR WaterWorks EX F	62	70	0	70	70	90	100	100	70	55	40	25	65	76	40
MSR Miniworks EX F	61	70	0	70	70	90	75	100	70	55	40	25	72	80	40
Kat Hiker Pro F	61	70	0	70	70	90	75	100	30	70	70	0	79	86	80
Kat Guide F	61	70	0	70	70	90	75	100	30	70	75	0	75	82	80
Kat Combi F	61	70	0	70	70	90	75	100	70	50	45	20	73	73	40
Kat Hiker F	60	70	0	70	70	90	75	100	20	70	70	0	79	86	80
Aqua Mira Drops D	60	70	70	70	0	35	0	64	100	80	80	10	93	88	0
AC Pristine Water Pur Sys D	60	70	70	70	0	35	0	64	100	80	80	10	93	88	0
Kat Base Camp F	59	70	0	70	70	90	75	99	20	70	70	0	70	84	80
Aquatabs D	59	70	70	0	0	25	0	68	100	85	100	10	98	99	100
Kat Pocket F	59	70	0	70	70	70	75	100	70	50	50	20	75	75	40
Kat Mini F	59	70	0	70	70	70	75	99	70	35	30	20	88	90	40
HTI Xpack F	58	70	70	70	70	100	100	0	100	70	30	0	0	0	60
Sawyer WB F	57	70	0	70	70	90	75	99	0	40	80	0	79	93	80
PE Polar Pure D	57	70	70	0	0	25	0	78	100	65	80	10	97	89	60
Kat Micro F	56	70	0	70	70	90	75	91	0	40	80	0	72	91	80
Kat Camp F	56	70	0	70	70	70	75	87	60	50	30	20	70	72	40
H-P SteriPen D	41	0	0	0	0	70	0	99	100	85	0	75	84	39	100

Figure 4: Converted and Overall Device Scores for Profile A

The results analysis was performed from several perspectives, as described below; the LDW software provides some useful features to aid in these analyses.

- Overall scores and ranking relative to goals and measures (stacked bar charts).
  - Includes performance of all devices relative to each measure, to identify areas of technical challenge.
- Performance of individual devices, to identify strengths and weaknesses.
- Sensitivity graphs, to identify how results would be affected by different goal/measure weights.

The remainder of this section describes the analysis of results in detail. One of the most important findings of this analysis is that there are more similarities than differences among the results of the four profiles. Therefore, the results for Profile A are described first and in the greatest detail, while the results for the remaining profiles are described primarily in terms of how they differ from Profile A. Profiles B and C are discussed together because their results are so similar.

4.1 Rankings and Measures Assessment

4.1.1 User Profile A

OVERALL Results for Profile A:

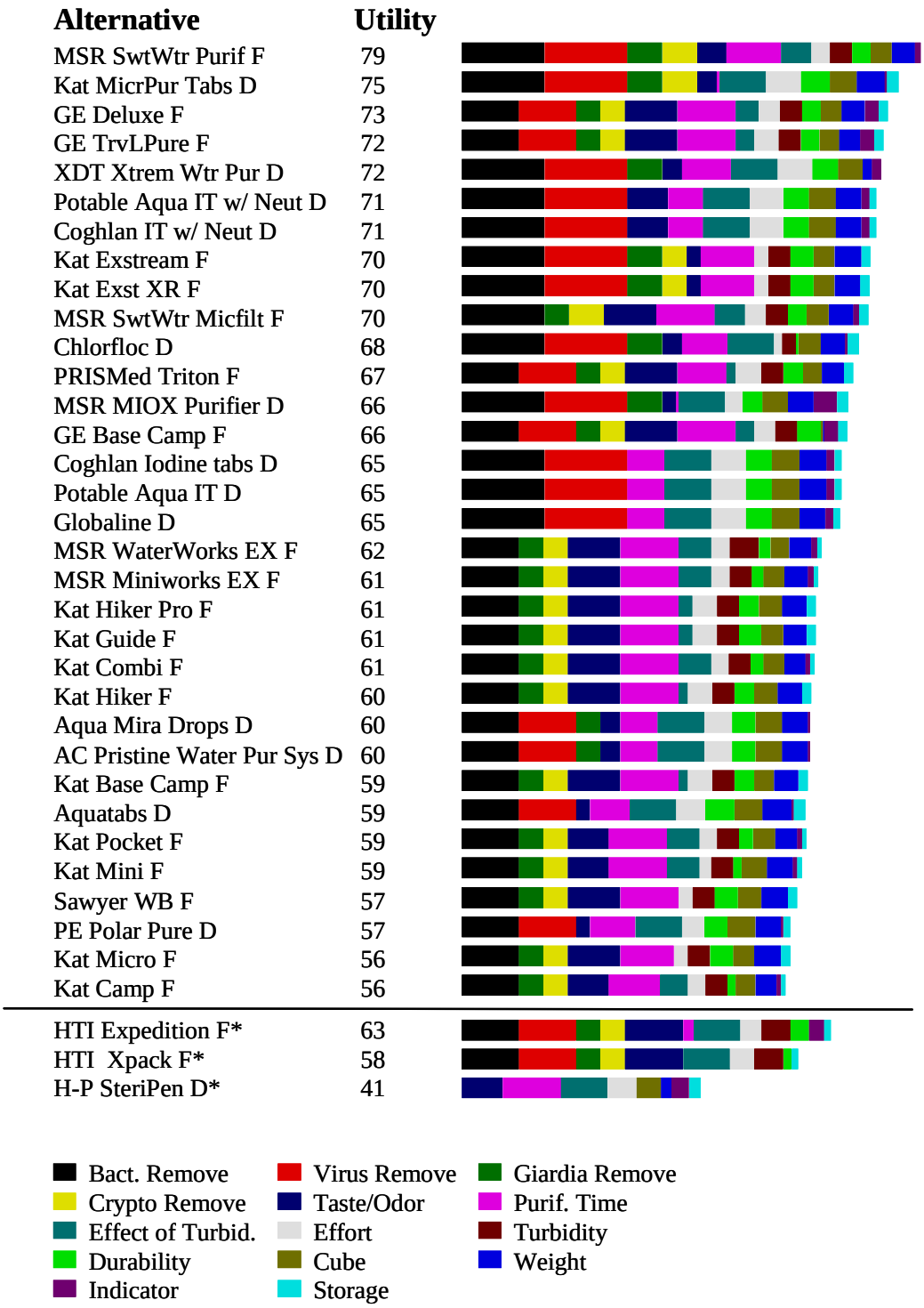
Thirty-six devices were evaluated in Profile A. Figure 5 shows a stacked bar chart which displays overall scores and rankings relative to the 14 evaluation measures. The colored bars to the right of each device illustrate the proportion each measure contributed to the overall score for each technology. The width of each sub-bar reflects both the weight of the measure and the score a device received. For all profiles, the four Pathogen Removal measures are listed first, followed by the remaining measure in order of decreasing weight (using Profile A weighting).

As seen in the figure, no device scored high on all attributes; overall scores for most devices are in the moderate range:

- The top score was 79 (out of 100 possible)
- The spread from best to worst for 35 of 36 devices was only 23 points (56 to 79)

The device scores fall into a “cascading” pattern, with no apparent tiers. The spread of scores among the devices ranked in the top half is fairly narrow, indicating individual tradeoffs will be required to select preferred devices.

The following discussion describes the Profile A results for the Performance goal, and then the results for the Operational and Logistical goals together.



*Note: the HTI Expedition F, HTI Xpack F, and the H-P SteriPen D did not meet the minimum criteria for this scenario. Exceptions were made to allow them to be included in the analysis.

Figure 5: Stacked Bar Ranking for Profile A

PERFORMANCE Results for Profile A:

PERFORMANCE addresses how well the device works, and encompasses removal of four pathogens, aesthetics (taste, odor, and turbidity removal), and time to purify. There was a wide range of results in this area, as described below.

Most devices have not undergone independent EPA-protocol testing for pathogen removal, as discussed below:

- Only two devices received a rating of "3 Checks" (see Appendix B for definition of Check scale) for removal of all four pathogens (MSR SwtWtr Purif F and Kat MicrPur Tabs D).
- Two other devices were rated "3 Checks" for removal of three pathogens (*Bacteria, Virus*, and *Giardia*), but only "1 Check" for *Cryptosporidium* removal (Kat Exstream F and Kat Exst XR F)
- Three devices were rated "3 Checks" for removal of three pathogens (*Bacteria, Virus*, and *Giardia*), but "Zero Checks" for *Cryptosporidium* removal (Chlorfloc D, MSR MIOX Purifier D, XDT Xtrem Wtr Pur D).
- Six devices were rated "1 Check" for all four pathogens (GE Base Camp F, GE Deluxe F, GE TrvLPure F, HTI Xpack F, HTI Expedition F, PRISMed Triton F). If EPA testing was successful, the GE Deluxe F, GE TrvLPure F would score the highest overall in this profile, and the PRISMed Triton F would rank third.

Bacteria should not be an issue:

- All devices but one (H-P SteriPen D) received at least a "1 Check" rating for *Bacteria Removal* (based on screening criteria, all devices must meet this criterion – the H-P SteriPen D was included as a noted exception).

Aesthetics (taste, odor, and turbidity removal) is not a problem for most filter systems, but is a problem for disinfectants:

- Most filter devices scored 70 or higher for *Taste/Odor* and *Turbidity* (exceptions are Kat Exstream F, Kat Exst XR F and MSR SwtWtr Purif F (due to disinfectant solution)).
- Most disinfectant devices scored 35 or lower for *Taste/Odor* and *Turbidity*
  - Exceptions for *Taste/Odor*: Potable Aqua IT w/ Neut D, H-P SteriPen D, Coghlan IT w/ Neut D
  - Exceptions for *Turbidity*: Chlorfloc D (due to flocculant)

Purification Time should not be an issue for Profile A:

- Most (32) devices were 40 minutes or less, well within the user constraints. Almost half can purify in 2 minutes or less.

OPERATIONAL and LOGISTICS Results for Profile A:

OPERATIONAL and LOGISTICS address how burdensome the devices are to use in the field. They encompass the *Effect of Turbidity*, *Effort*, *Durability*, presence of an *Indicator*, portability (*Cube* and *Weight*), and *Storage*. Overall, most devices should not present a burden for use in the field, given the constraints of Profile A.

Cube and *Weight* should not be an issue for Profile A:

- Most devices scored high (70 or higher) for these measures.
- Two devices did not meet the minimum criteria for *Cube* and *Weight* (HTI Xpack F and HTI Expedition F) but were included in the analysis as noted exceptions.

In general, *Effect of Turbidity*, *Effort*, *Durability*, and *Storage* do not present a significant concern, as most devices scored high (greater than 50) in those areas. However, *Effect of Turbidity* is a concern for most filter devices.

One concern in this area is *Process Failure Indicator*, as most devices (30) scored 40 or lower.

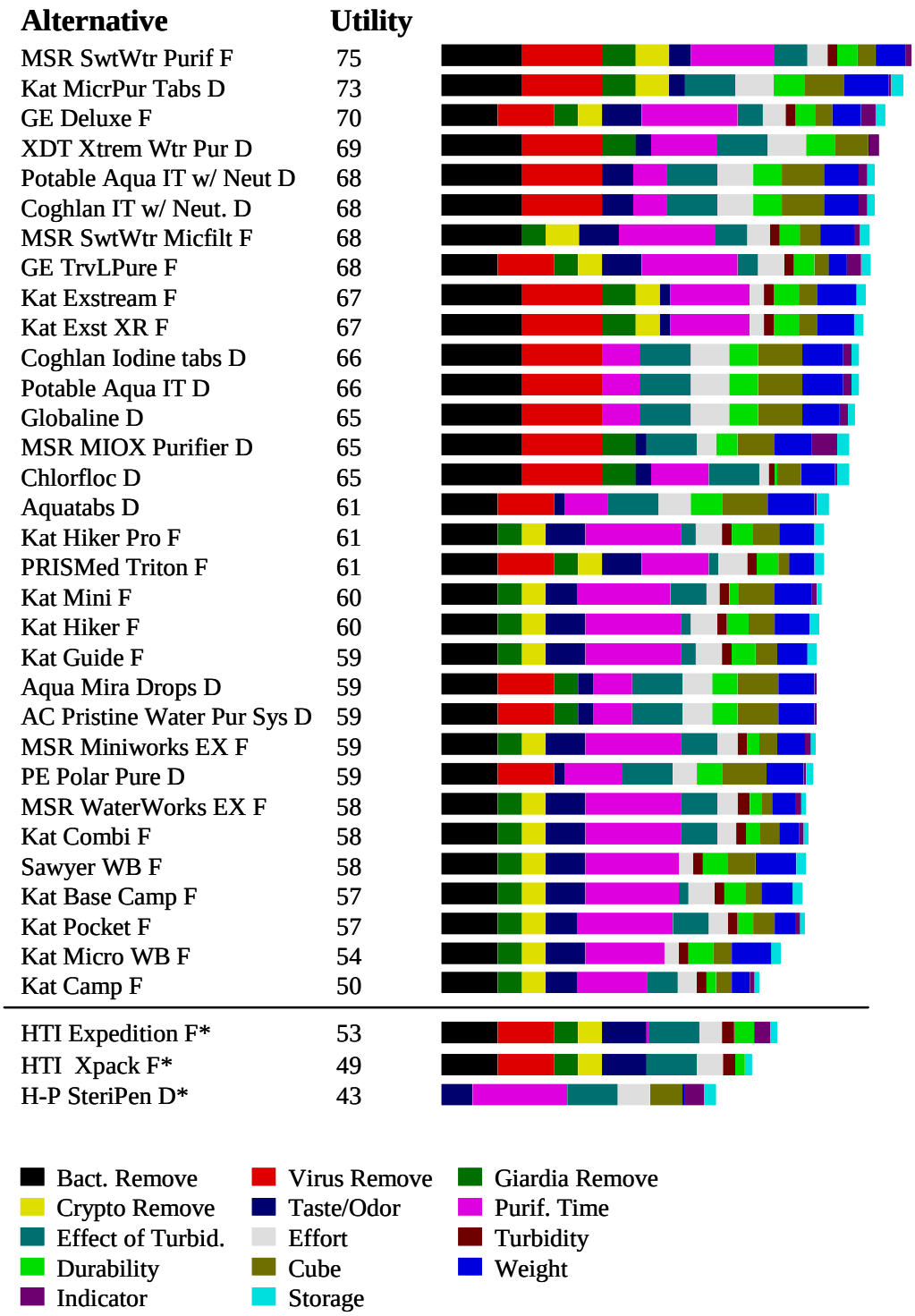
4.1.2 User Profiles B and C

OVERALL Results for Profiles B and C:

Thirty-five devices were evaluated for Profile B, and 34 devices for Profile C. Figures 6 and 7 show the stacked bar charts for Profiles B and C, respectively. As in Profile A, no device scored high on all attributes; overall scores for most devices are in the moderate range:

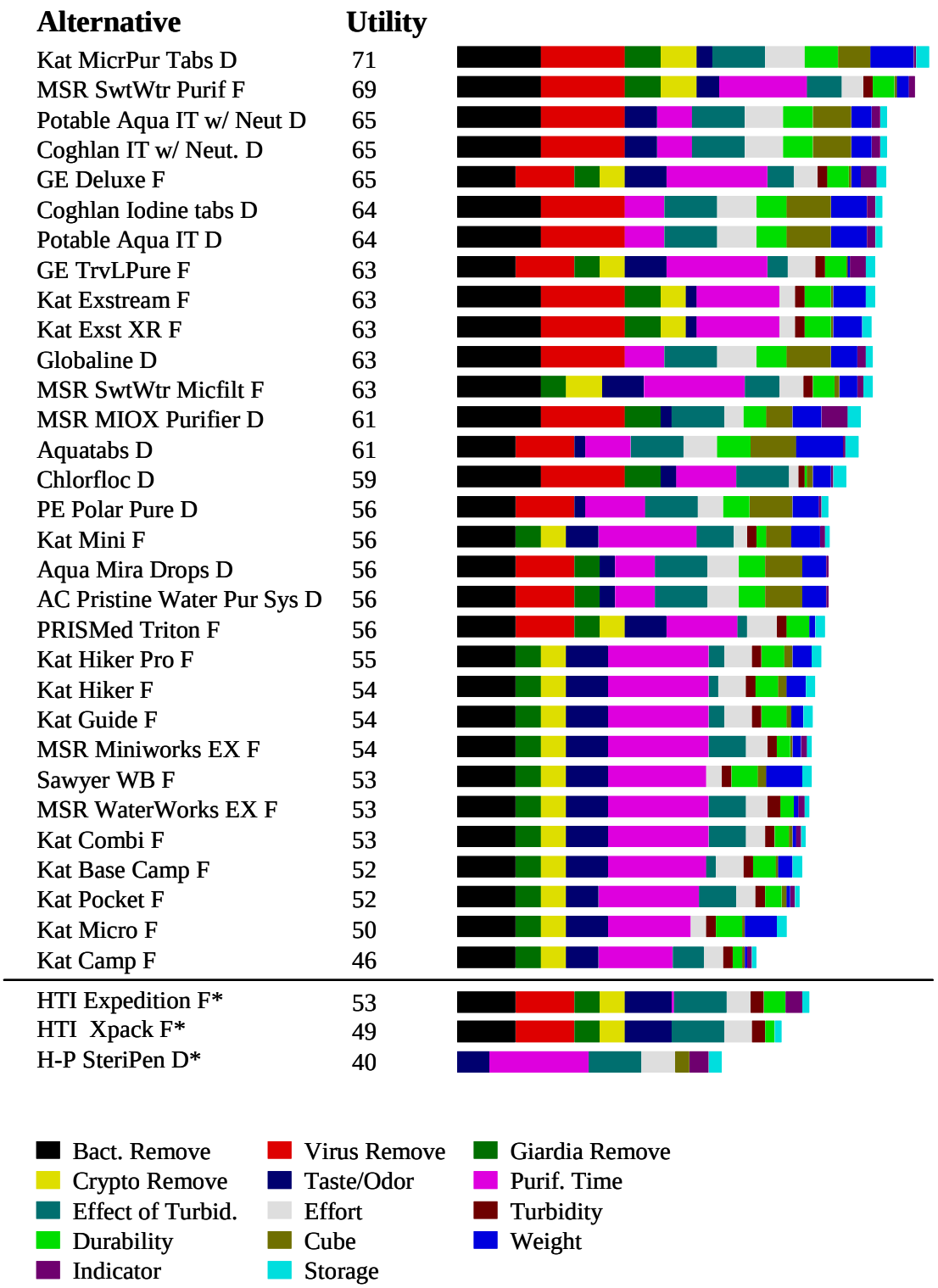
- The top score was 75 for Profile B (out of 100 possible), and 71 for Profile C.
- The spread from best to worst for Profile B for 32 out of 35 devices was only 21 points (49 to 70), and the spread for 30 out of 34 devices in Profile C is only 16 points (49 to 65).

As in Profile A, the device scores fall into a “cascading” pattern, with no apparent tiers. The spread of scores between the devices ranked in the top half is fairly narrow, indicating individual tradeoffs will be required to select preferred devices.



*Note: the HTI Expedition F, HTI Xpack F, and the H-P SteriPen D did not meet the minimum criteria for this scenario. Exceptions were made to allow them to be included in the analysis.

Figure 6: Stacked Bar Ranking for Profile B



*Note: the HTI Expedition F, HTI Xpack F, and the H-P SteriPen D did not meet the minimum criteria for this scenario. Exceptions were made to allow them to be included in the analysis.

Figure 7: Stacked Bar Ranking for Profile C

PERFORMANCE Results for Profiles B and C:

Results for PERFORMANCE, which encompasses removal of four pathogens, aesthetics (taste, odor, and turbidity removal), and time to purify, were very similar to Profile A (see section 4.1.1).

The pathogen removal data is the same as in Profile A. The only differences in this area are the result of certain devices being included in Profile A but not in Profiles B and C. The two differences are:

- For Profile C, only two devices (instead of three) were rated "3 Checks" for *Bacteria, Virus*, and *Giardia*, but "Zero Checks" for *Cryptosporidium*.
- For Profiles B and C, five devices (instead of six) were rated "1 Check" for all four pathogens. Also, PRISMed Triton F would not score in the top of the ranking even if EPA testing data were available.

As in Profile A, Aesthetics (taste, odor, turbidity removal) is not a problem in Profiles B and C for most filter systems, but is a problem for disinfectants.

Purification Time is slightly more of an issue for Profiles B and C than it was for Profile A:

- 20 devices received a score of 70 or above, which corresponds to a time of 15 minutes or less. 14 of these devices can purify in two minutes or less. All but four devices were within 40 minutes. The concern is that the 40-minute marker was well within user constraints for Profile A, however in Profiles B and C a purification time of 40 minutes corresponds to a score of only 35.
- One device (HTI Xpack F) did not meet the minimum level for *Purification Time*, and its score should be lower than shown.

OPERATIONAL and LOGISTICS Results for Profiles B and C:

These areas encompass the *Effect of Turbidity, Effort, Durability*, presence of an *Indicator*, portability (*Cube* and *Weight*), and *Storage*. The results for Profiles B and C are mostly similar to Profile A, with the exception of *Cube* and *Weight*.

Cube and *Weight* are slightly more of a concern for Profile B than they were in Profile A:

- Most devices scored high (70 or higher) or mid-range (30-70) for these measures. In Profile A, the majority of the devices scored above 70. In Profile B, less than half the devices scored above 70.

Cube and *Weight* are a concern for Profile C:

- Approximately half the devices scored less than 30 for *Cube* and *Weight*.

- Only nine devices scored high (70 or higher) for *Cube*, and five devices scored high for *Weight* (in Profile A, most devices scored above 70 for *Cube* and *Weight*).

Two devices did not meet the minimum criteria for *Cube* and *Weight* (HTI Xpack F and HTI Expedition F), and their scores should be lower than shown.

As in Profile A, *Effect of Turbidity, Effort, Durability*, and *Storage* generally do not present a significant concern, as most devices scored high (greater than 50) in those areas. However, *Effect of Turbidity* is a concern for most filter devices.

As in Profile A, *Process Failure Indicator* is a concern for Profiles B and C, as most devices scored 40 or lower.

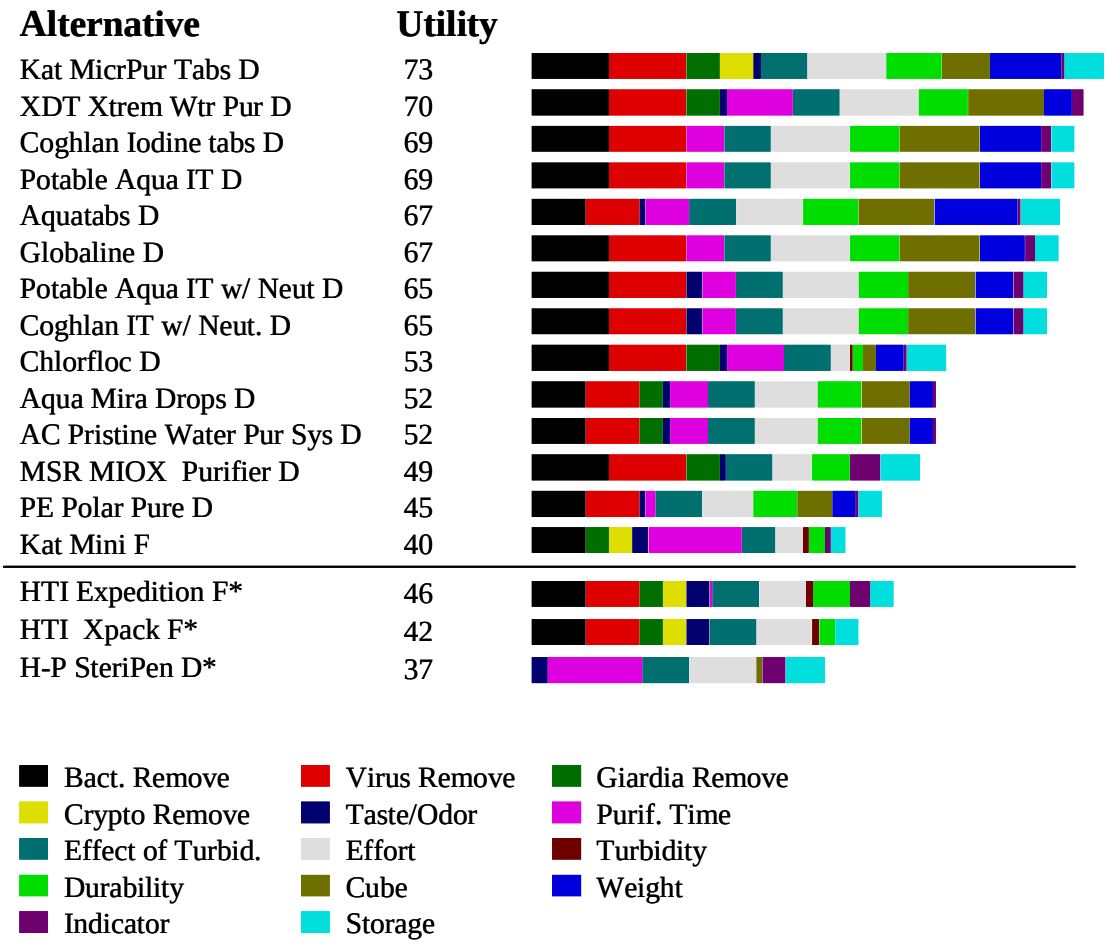
4.1.3 User Profile D

OVERALL Results for Profile D:

Seventeen devices were evaluated for Profile D. Figure 8 shows the stacked bar chart for Profile D. As in the other Profiles, no device scored high on all attributes; overall scores for most devices are in the moderate range:

- The top score was 73 (out of 100 possible).
- There is a larger spread from best to worst; for 16 devices the spread is 36 points (37 to 73).

Although the top eight devices have a rather narrow point spread, as a group they score significantly higher than the other 9 devices. The scoring gap is primarily due to their higher scores for *Cube* and *Weight*, which are weighted the highest in this Profile, relative to the other Profiles.



*Note: the HTI Expedition F, HTI Xpack F, and the H-P SteriPen D did not meet the minimum criteria for this scenario. Exceptions were made to allow them to be included in the analysis.

Figure 8: Stacked Bar Ranking for Profile D

PERFORMANCE Results for Profile D:

There was a wide range of results for PERFORMANCE, which encompasses removal of four pathogens, aesthetics (taste, odor, and turbidity removal), and time to purify, as described below.

Pathogen removal scores remain the same as in Profile A. The differences in Profile D results reflect where a device from Profile A was not evaluated in Profile D, or where the smaller number of devices results in different conclusions. The result is that there are fewer devices in Profile D that receive high scores for Pathogen Removal compared to the other profiles.

- Most devices have not undergone independent EPA-protocol testing for all four pathogens:
  - Only one device received a rating of "3 Checks" for all four pathogens (Kat MicrPur Tabs D).
  - Three devices were rated "3 Checks" for *Bacteria, Virus,* and *Giardia,* but "Zero Checks" for *Cryptosporidium* (Chlorfloc D, MSR MIOX Purifier D, XDT Xtrem Wtr Pur D).
  - Two devices were rated "1 Check" for all four pathogens (HTI Xpack F, HTI Expedition F); however, having EPA test results for these devices would not significantly alter their performance against the evaluation model.

- As in all other profiles, bacteria removal should not be an issue:
  - All devices but one (1) received at least a "1 Check" rating for Bacteria (based on screening criteria, all devices must meet this criteria – the H-P SteriPen D was included as a noted exception).

- Unlike the other scenarios, Cyst removal may be an issue in Profile D:
  - 8 devices received "Zero Checks" for *Giardia* removal.
  - 13 devices received "Zero Checks" for *Cryptosporidium* removal.

- Again as in Profile A, Aesthetics (taste, odor, turbidity removal) is not a problem in Profile D for most filter based devices, but is for disinfectant devices
  - All filter devices score 70 or higher for *Taste/Odor* and *Turbidity*
  - Most disinfectant devices score 35 or lower for *Taste/Odor* and *Turbidity*
    - Exceptions for *Taste/Odor*: Potable Aqua IT w/ Neut D, H-P SteriPen D, Coghlan IT w/ Neut D
    - Exceptions for *Turbidity*: Chlorfloc D

- Unlike Profile A, *Purification Time* is a concern for Profile D:
  - Only four devices scored above 50 (corresponding to a time of about 28 minutes). Only two devices can purify in 2 minutes or less.
  - One device (HTI Xpack F) did not meet the minimum criterion for *Purification Time,* and its score should be lower than shown.

OPERATIONAL and LOGISTICS Results for Profile D:

- OPERATIONAL and LOGISTICS address how burdensome the devices are to use in the field. It encompasses the *Effect of Turbidity, Effort, Durability,* presence of an *Indicator,* portability (*Cube* and *Weight*), and *Storage*. Given the constraints of Profile D, some devices will be burdensome to use in the field. This is based on the increased cube and weight constraints of this Profile.

- Unlike Profile A, portability (*Cube* and *Weight*) is a concern for Profile D:
  - Approximately half the devices scored less than 30 for *Cube* and *Weight.*
  - Only 2 devices scored high (70 or higher) for *Weight*, and 7 devices scored high for *Cube*. In Profile A, the majority of the devices scored above 70.
  - Two devices did not meet the minimum criteria for *Cube* and *Weight* (HTI Xpack F, HTI Expedition F), and their scores should be lower than shown.

- *Effect of Turbidity* is not an issue for this profile – all devices scored 100, with the exception of the Kat Mini F, which scored a 70. In Profile A, most devices scored above 50 for this criterion, but the results were not as universally high as they were in Profile D. This is due to the lesser number of filter devices evaluated in Profile D.

- Most devices scored high (greater than 50) for *Effort*, *Durability*, and *Storage*

- As in all other profiles, *Process Failure Indicator* is a concern:
  - Most devices scored 35 or lower.

4.2 Performance of Individual Devices

In this part of the analysis, the scores for each device were reviewed relative to each measure to identify where each device scored well and where it scored poorly, i.e. strengths and weaknesses. LDW generates bar charts that help with this analysis. An example chart for the AC Pristine Water Pur Sys D for Profile A is shown in Figure 9 below. In this chart, the width of each colored bar represents the weight given to that measure, while the height of the bar represents how the device scored for that measure. The chart shows that this device scored fairly high for three of the highest weighted measures (*Virus* and *Bacteria Removal* and *Purification Time*), but fairly low for another important measure (*Taste/Odor*). The device also scores very high for several measures that are not weighted high (e.g., *Cube*), but very low for some low-weighted measures (e.g., *Turbidity*).

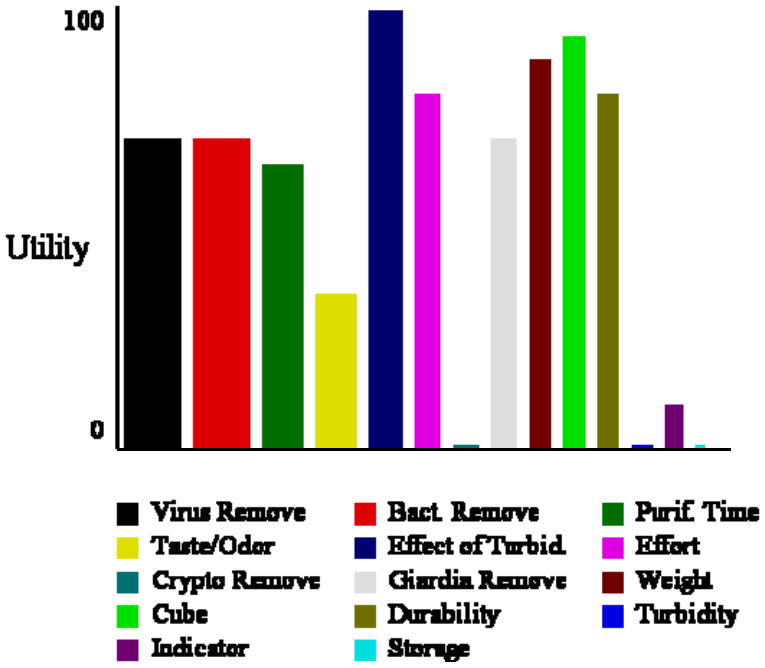


Figure 9: Bar Chart for AC Pristine Water Pur Sys D

Table 5 below summarizes the strengths and weaknesses analysis. The table was generated by comparing the score for each evaluated device to the scores of the other evaluated devices, relative to each measure, and noting attributes that stand out, either positively or negatively, for each device. Pathogen Removal was addressed somewhat differently in the table, since that is the most highly weighted area; the performance of every device (not just those that stand out) is summarized relative to the four Pathogen Removal measures.

The analysis also takes into account the strengths and weaknesses that are common to each of the two classes of devices, filters and disinfectants, as described below.

In general, filters purify water more quickly than disinfectants since most often the user simply pumps the water through the filter without any additional wait time. Disinfectant devices require little or no work on the part of the user, often simply adding tablets or drops to the raw water, but require a wait time for disinfection to occur. Devices that are beyond the common purification time for their class are noted in the table.

Another important attribute of these devices is how turbid water affects their operation and product water aesthetics. In operational terms, turbid waters will eventually clog most filtration devices. The ability of a filter to limit this clogging, as well as the ability of the device to be restored through cleaning, are attributes of each individual device. Since filters reduce the particulates in turbid water, the purified water will appear clearer than the raw water.

Disinfectants are not affected by turbid waters from an operational standpoint (pathogen inactivation is not considered here) but, in contrast to filtration devices, disinfectants do not reduce the turbidity of the raw water.

Exceptions exist for devices that do not strictly follow these generalizations, and they are noted in the table as well.

Device	Strengths	Weaknesses
MSR SwtWtr Purif F	• Proven effective against all four pathogens with independent testing • Cleanable filter • Filter reduces taste and odor	• Special storage conditions recommended • Cube and weight increasingly burdensome with on the move profiles • Disinfectant imparts taste and odor
Kat MicrPur Tabs D	• Proven effective against all four pathogens with independent testing • Minimal effort required • Lightweight	• Very slow purification time
GE Deluxe F	• Expected to be effective against all four pathogens • Filter reduces taste and odor	• Potential for cross contamination during cleaning • Cube and weight increasingly burdensome with on the move profiles
GE TrvLPure F	• Expected to be effective against all four pathogens • Filter reduces taste and odor	• Filter not cleanable • Cube and weight increasingly burdensome with on the move profiles
XDT Xtrem Wtr Pur D	• Proven effective against bacteria, viruses, and *Giardia* cysts with independent testing • Minimal effort	• Not effective against *Cryptosporidium* oocysts • Multiple bottles required • Special storage conditions recommended
Potable Aqua IT w/ Neut D	• Proven effective against bacteria and viruses with independent data • Minimal effort	• Not effective against *Giardia* cysts or *Cryptosporidium* oocysts
Coghlan IT w/ Neut D	• Proven effective against bacteria and viruses with independent data • Minimal effort	• Not effective against *Giardia* cysts or *Cryptosporidium* oocysts
Kat Exstream F	• Proven effective against bacteria, viruses, and *Giardia* cysts with independent testing • Expected to be effective against *Cryptosporidium* oocysts • Filter reduces taste and odor	• Disinfectant imparts taste and odor • Filter not cleanable • Highly affected by turbid waters • Cube and weight increasingly burdensome with on the move profiles

Device	Strengths	Weaknesses
Kat Exst XR F	• Proven effective against bacteria, viruses, and *Giardia* cysts with independent testing • Expected to be effective against *Cryptosporidium* oocysts • Filter reduces taste and odor	• Disinfectant imparts taste and odor • Filter not cleanable • Highly affected by turbid waters • Cube and weight increasingly burdensome with on the move profiles
MSR SwtWtr Micfilt F	• Proven effective against bacteria and *Cryptosporidium* oocysts with independent testing • Expected to be effective against *Giardia* cysts • Cleanable filter • Filter reduces taste and odor	• Not effective against viruses • Cube and weight increasingly burdensome with on the move profiles
Chlorfloc D	• Proven effective against bacteria, viruses, and *Giardia* cysts with independent testing • Reduces turbidity	• Not effective against *Cryptosporidium* oocysts • Moderately high effort required • Imparts taste and odor
PRISMed Triton F	• Expected to be effective against all four pathogens • Filter reduces taste and odor	• Filter not cleanable • Slow purification time for a filter
MSR MIOX Purifier D	• Proven effective against bacteria, viruses, and *Giardia* cysts with independent testing • Engineered process failure indicators	• Not effective against *Cryptosporidium* oocysts. • Moderate effort required • Very slow purification time • Imparts taste and odor
GE Base Camp F	• Expected to be effective against all four pathogens • Filter reduces taste and odor	• Comparatively large and heavy • Filter not cleanable
Coghlan Iodine tabs D	• Proven effective against bacteria and viruses with independent data • Minimal effort	• Not effective against *Giardia* cysts or *Cryptosporidium* oocysts • Imparts strong taste and odor
Potable Aqua IT D	• Proven effective against bacteria and viruses with independent data • Minimal effort	• Not effective against *Giardia* cysts or *Cryptosporidium* oocysts • Imparts strong taste and odor

Device	Strengths	Weaknesses
Globaline D	• Proven effective against bacteria and viruses with independent data • Minimal effort	• Not effective against *Giardia* cysts or *Cryptosporidium* oocysts • Slow purification time • Imparts strong taste and odor
MSR Waterworks EX F	• Expected to be effective against bacteria, *Giardia* cysts and *Cryptosporidium* oocysts • Multiple microfilters • Filter reduces taste and odor • Cleanable filter	• Not effective against viruses • Ceramic filter comparatively fragile
MSR Miniworks EX F	• Expected to be effective against bacteria, *Giardia* cysts and *Cryptosporidium* oocysts • Filter reduces taste and odor • Cleanable filter	• Not effective against viruses • Ceramic filter comparatively fragile
Kat Hiker Pro F	• Expected to be effective against bacteria, *Giardia* cysts and *Cryptosporidium* oocysts • Filter reduces taste and odor	• Not effective against viruses • Filter not cleanable
Kat Guide F	• Expected to be effective against bacteria, *Giardia* cysts and *Cryptosporidium* oocysts • Filter reduces taste and odor	• Not effective against viruses • Filter not cleanable
Kat Combi F	• Expected to be effective against bacteria, *Giardia* cysts and *Cryptosporidium* oocysts • Filter reduces taste and odor	• Not effective against viruses • Ceramic filter comparatively fragile
Kat Hiker F	• Expected to be effective against bacteria, *Giardia* cysts and *Cryptosporidium* oocysts • Filter reduces taste and odor	• Not effective against viruses • Filter not cleanable
Aqua Mira Drops D	• Expected to be effective against bacteria, viruses, and *Giardia* cysts	• Not effective against *Cryptosporidium* oocyst • Special storage conditions recommended
AC Pristine Water Pur Sys D	• Expected to be effective against bacteria, viruses, and *Giardia* cysts	• Not effective against *Cryptosporidium* oocysts • Special storage conditions recommended

Device	Strengths	Weaknesses
Kat Base Camp F	• Expected to be effective against bacteria, *Giardia* cysts and *Cryptosporidium* oocysts • Filter reduces taste and odor	• Not effective against viruses • Filter not cleanable
Aquatabs D	• Expected to be effective against bacteria and viruses • Lightweight	• Not effective against *Giardia* cysts and *Cryptosporidium* oocysts • Imparts taste and odor
Kat Pocket F	• Expected to be effective against bacteria, *Giardia* cysts and *Cryptosporidium* oocysts • Cleanable filter	• Not effective against viruses • Ceramic filter comparatively fragile
Kat Mini F	• Expected to be effective against bacteria, *Giardia* cysts and *Cryptosporidium* oocysts • Cleanable filter	• Not effective against viruses • Ceramic filter comparatively fragile
Sawyer WB F	• Expected to be effective against bacteria, *Giardia* cysts and *Cryptosporidium* oocysts • Reduces taste and odor	• Not effective against viruses • Filter not cleanable • Highly affected by turbid waters • Cube and weight increasingly burdensome with on the move profiles
PE Polar Pure D	• Expected to be effective against bacteria and viruses • Large production capacity	• Not effective against *Giardia* cysts and *Cryptosporidium* oocysts • Imparts taste and odor
Kat Micro F	• Expected to be effective against bacteria, *Giardia* cysts and *Cryptosporidium* oocysts • Filter reduces taste and odor	• Not effective against viruses • Filter not cleanable • Highly affected by turbid waters • Cube and weight increasingly burdensome with on the move profiles
Kat Camp F	• Expected to be effective against bacteria, *Giardia* cysts and *Cryptosporidium* oocysts • Cleanable filter	• Not effective against viruses • Ceramic filter comparatively fragile • Slow purification time for a filter

Device	Strengths	Weaknesses
HTI Expedition F	• Expected to be effective against all four pathogens • Reduces taste and odor • Not affected by turbid water	• Very slow purification time • Very large and heavy
HTI Xpack F	• Expected to be effective against all four pathogens • Reduces taste and odor • Not affected by turbid water	• Extremely slow purification time • Very large and heavy
H-P SteriPen D	• Fast purification time • Engineered process failure indicator	• Not expected to be effective against any of the four pathogens • Intended for low turbidity waters • Comparatively fragile

Table 5: Strengths and Weaknesses of Individual Devices

4.3 Sensitivity Analysis

Sensitivity analysis allows the analyst or decision maker to assess how the results produced by an evaluation model would be affected by varying the weights of the measures or goals. A typical approach is to vary the weights of individual measures by a reasonable amount to see if the overall ranking of the alternatives is affected. A reasonable change in weight might be defined as doubling or halving the weight; if no or few rankings changed among the devices, particularly among the top ranked devices, the measure would not be considered sensitive.

Figure 10 below shows a sensitivity graph for the *Virus Removal* measure from Profile A. The vertical line represents the weight assigned to this measure, while the colored lines represent the individual devices. The order in which the device lines intersect the weight line represents the overall ranking of the devices. Moving the vertical line to the left or the right represents changes in the weight (decreasing or increasing, respectively) of this measure. For example, the intersection of the current weight line (14%) and the Kat MicroPur Tabs D line shows this device to score 2nd overall. If the weight is increased (weight line moved to the right), Kat MicroPur Tabs D remains 2nd, but if the weight line is decreased (weight line moved to the left), this device will rank several places lower.

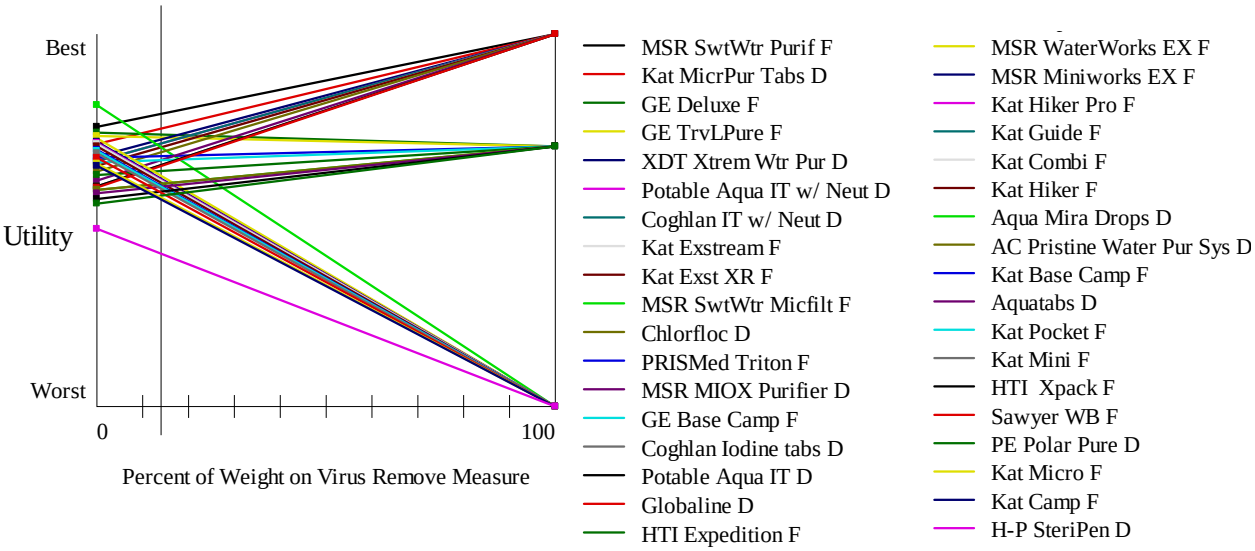


Figure 10: Sensitivity Graph for Virus Removal, Profile A

For this study, only a limited sensitivity analysis was performed. In part, sensitivity analysis was not practical given the number of devices under consideration, as well as the number of measures and profiles. Sensitivity analysis was also not likely to provide much insight into the results and recommendations because of the high weighting for Performance, the closeness in overall scores, and the fact that disinfectant devices and filter devices perform as a

class quite differently relative to several measures. For example, filter devices tend to score poorly for *Effect of Turbidity*, so if that measure is weighted higher the filter devices will generally rank lower overall, while the converse would be true for the disinfectant devices.

Sensitivity analysis would be useful if a particular user wished to focus on a subset of the devices and had specific interest in particular attributes. This could easily be done using the models developed and documented in this report. As an example of this, if a user was not highly concerned about removal of viruses, he could review the sensitivity graph in Figure 10 (*Virus Removal*) and see that the MSR SwtWtr Micfilt F, which ranks 10th based on the current weight, would actually be the 1st ranked device overall if *Virus Removal* was weighted very low (about 4%).

5.0 Conclusions/Recommendations

This assessment was constrained by data limitations; the expert panel relied heavily on vendor-supplied information. There is a need to perform independent testing to obtain additional performance data. If testing or additional data becomes available, the assessment could be updated and new assessments/recommendations generated.

Given the range of user requirements as seen in the four user profiles, it is unlikely a single device will meet all user needs. A potential IWP user could, however, match their mission requirements to the most applicable user profile and review the evaluation results to determine which IWP would be best suited for their needs.

Another option is to consider device combinations. These were not evaluated in this study, but this concept would have the potential to provide a greater range of capabilities. For example, by combining a filter and disinfectant device, the user could have a greater potential to remove all pathogens; however a combination such as this might have other detrimental effects such as increased size and weight.

Devices were evaluated as packaged/instructed; it is possible individual users could also make modifications/adjustments that might result in increased capabilities. For example, many disinfectants with short contact times of the chemical with the water (as per instructions) are only effective against bacteria and viruses, however some of these devices may have the potential to be effective against cysts if the exposure time is increased. From the perspective of the evaluation, the net change in score would be positive (the increase in the pathogen removal score would be greater than the decrease in the *Purification Time* score).

Very few devices have been proven to remove all four pathogens. There are several others that are likely to, but need to be confirmed by EPA-protocol testing. Given the cube and weight constraints of Profile D, there are significantly fewer acceptable devices for this Profile that do well at pathogen removal.

Due to the close range of scores for the devices in all Profiles, it was difficult to make recommendations based solely on the overall results generated by the evaluation model. However, there are five devices which can be distinguished from the other devices due to specific strengths, which are described below.

- MSR SwtWtr Purif F is a combination filter and disinfectant, which results in the best overall performance (ranks 1st or 2nd in Profiles A-C). It is one of two devices proven to remove all four pathogens of interest, however the filter increases size and weight, which makes it unsuitable for Profile D.

- Kat MicrPur Tabs D is the best disinfectant device (ranked 1st or 2nd in all four Profiles). It is one of two devices proven to remove all four pathogens, and is very lightweight. However, it has a detrimental effect on the aesthetics of the water, and has the longest purification time of all devices (4 hours). Both of these weaknesses are common to all disinfectant devices that claim to be able to remove cysts.

- GE Deluxe F is the highest ranked filter-only device in Profiles A-C. The filter increases cube and weight, but overall it performs very well; if EPA testing was successful this device would rank highest overall. It is very similar to other GE devices (such as the GE Base Camp F and the GE TrvLPure F), but its smaller size and weight makes this device preferred over the other GE devices.

- Aquatabs D is the smallest device, but can only inactivate two pathogens and scores low on several measures.

- Kat Mini F is the only filter device small enough to be used in all four user profiles, but it ranked in the lower half of all profiles (last in Profile D).

Appendix A: Study Participants

Table 6 below contains the name, organization, and role of each participant in this IWP study.

Name	Organization	Role
MAJ William Bettin	USACHPPM	Study Team Lead
Art Lundquist	USACHPPM	Study Team
Steve Clarke	USACHPPM	Study Team
Steve Richards	USACHPPM	Study Team
John Walther	ECBC	Decision Analyst
Scott Kooistra	ECBC	Decision Analyst
Lindsey Wurster	ECBC	Decision Analyst
Rochelle Bautista	USA Infantry Center, DCD	User Expert
Jay Dusenbury	TARDEC	User Expert
Wayne Kabat	HQDA – Army G-4	User Expert
Alex Papadopoulos	USMC Combat Developments	User Expert
CDR Jack Beaujon	NAVSEA	Technical Expert
John Brokaw	USACHPPM	Technical Expert
Scott Nielsen	TARDEC	Technical Expert
Christopher Penthany	Natick Soldier Center	Technical Expert
CAPT Joanna Rentes	AFIOH/RSE	Technical Expert
Bill Varnava	NAVFAC	Technical Expert

Table 6: Study Participants

Appendix B: Definition of Checks Scale

1, 2, or 3 Checks indicate the IWP consistently provides adequate protection from microbial pathogen groups by achieving at least a 6-log reduction in bacteria, 4-log reduction in virus, 3-log reduction in *Giardia* cysts (if information on log reduction for *Giardia* cysts in not available but information for *Cryptosporidium* oocyst is, then a 3-log reduction in *Cryptosporidium* oocyst is equivalent to a 3-log reduction in *Giardia* cysts), or a 3-log reduction in *Cryptosporidium* oocyst.

- 3 Checks: This score is based on independent testing using the EPA test protocol under manufacturer-specified device operating conditions. Independent testing is considered neutral and impartial. These data are the most robust and challenging data and, subsequently, means there is very little uncertainty in the effectiveness of this device. This score means the device poses the lowest risk to the soldier from getting sick.

- 2 Checks: This score is based on in-house/manufacturer testing using the EPA test protocol under manufacturer-specified device operating conditions (e.g., production rate, capacity). These data are more robust and more adequately challenge the device than IWPs that earn 1 Check. However, there is still some uncertainty in the effectiveness of the device because of the concern for the potential lack of impartiality and objectivity of the testing data. This score means the device poses less risk to the soldier.

- 1 Check: The score is based on evaluation of general scientific knowledge of treatment technology (e.g., filtration theory), disinfection/removal studies conducted using general technology (e.g., disinfection study using an iodine solution), device-specific testing not using the EPA test protocol, or device-specific testing (in-house or independent) using the EPA test protocol but not under manufacturer-specified device operating conditions. This evaluation method must be used because there are no device-specific testing data using the EPA test protocol in which the device was tested at the manufacturer's recommended operating conditions (e.g., production rate, capacity). Although expected to consistently provide microbial pathogen protection, the device still poses some level of health risk to the soldier as there is a level of uncertainty in the effectiveness of the device.

- 0 Checks: This score is based on available data, lack of data, or general scientific knowledge of the treatment technology. The IWP is not expected to consistently provide protection through adequate log reductions in pathogens. Using an IWP with this score poses the greatest risk to the soldier from getting sick.

Appendix C: Device Screening

Table 7 below shows the rationale for any device that was eliminated from the evaluation during the screening phase of the assessment (reference section 3.5.1). It also notes those devices for which not enough information was available, and those which were included in the evaluation as noted exceptions.

A red cell in the table below indicates that the device was not evaluated for the corresponding profile, while a green cell indicates that that device was evaluated for the corresponding profile. Those devices which have their name cell highlighted in green do not meet the screening criteria, but will be evaluated as the noted exceptions.

Note: the comment "Waiting for more information" in the "Other Reasons and Additional Comments/Rationale" column indicates that at the time of the screening assessment, information on that device was not available. Those devices were not evaluated in the detailed evaluation, as this data was not received in time for consideration in this study.

#	IWP Device Name	Type	User Profile A Rating	User Profile B Rating	User Profile C Rating	User Profile D Rating	Most Comprehensive Reason to Eliminate	Other Reasons and Additional Comments/ Rationale
1	**H-P SteriPen D**	Other	Red	Red	Red	Red	2. Disinfectant IWP not expected to meet disinfectant pathogen removal criteria (i.e. reduce bacteria by 6 log and viruses by 4 log).	Device not expected to meet pathogen log inactivation requirements in turbid water. Does not meet screening criteria; however this will be evaluated anyway due to professional interest.
2	**APT/BW Tech - Aquasak Inline Filter**	Filter	Red	Red	Red	Red	1. Filter IWP does not meet filter pathogen removal criteria (i.e. reduce bacteria by 6 log, *Giardia* cyst by 3 log, and *Cryptosporidium* oocyst by 3 log).	Manufacturer provided data does not show 6-log bacterial removal

#	IWP Device Name	Type	User Profile A Rating	User Profile B Rating	User Profile C Rating	User Profile D Rating	Most Comprehensive Reason to Eliminate	Other Reasons and Additional Comments/ Rationale
3	**APT/BW Tech - Survivor 4i**	Filter	Red	Red	Red	Red	1. Filter IWP does not meet filter pathogen removal criteria (i.e. reduce bacteria by 6 log, *Giardia* cyst by 3 log, and *Cryptosporidium* oocyst by 3 log).	Manufacturer provided data does not show 6-log bacterial removal
4	**APT/BW Tech - Water Bottle**	Filter	Red	Red	Red	Red	1. Filter IWP does not meet filter pathogen removal criteria (i.e. reduce bacteria by 6 log, *Giardia* cyst by 3 log, and *Cryptosporidium* oocyst by 3 log).	Manufacturer provided data does not show 6-log bacterial removal
5	**Aquamira Water Bottle and Filter**	Filter	Red	Red	Red	Red	1. Filter IWP does not meet filter pathogen removal criteria (i.e. reduce bacteria by 6 log, *Giardia* cyst by 3 log, and *Cryptosporidium* oocyst by 3 log).	No data provided; rating based on knowledge of technology (2 micron filter not expected to reduce bacteria by 6 log).
6	**Bota of Boulder - Sports Bottle**	Filter	Red	Red	Red	Red	1. Filter IWP does not meet filter pathogen removal criteria (i.e. reduce bacteria by 6 log, *Giardia* cyst by 3 log, and *Cryptosporidium* oocyst by 3 log).	No data provided; rating based on knowledge of technology (2 micron filter not expected to reduce bacteria by 6 log).
7	**Bottoms-Up Water Bottle**	Filter	Red	Red	Red	Red	1. Filter IWP does not meet filter pathogen removal criteria (i.e. reduce bacteria by 6 log, *Giardia* cyst by 3 log, and *Cryptosporidium* oocyst by 3 log).	No data provided; rating based on knowledge of technology (2 micron filter not expected to reduce bacteria by 6 log).
8	**Camelbak - Inline Microfilter**	Filter						Waiting for more information.

#	IWP Device Name	Type	User Profile A Rating	User Profile B Rating	User Profile C Rating	User Profile D Rating	Most Comprehensive Reason to Eliminate	Other Reasons and Additional Comments/ Rationale
9	**CuZn Sport Bottle**	Filter	Red	Red	Red	Red	1. Filter IWP does not meet filter pathogen removal criteria (i.e. reduce bacteria by 6 log, *Giardia* cyst by 3 log, and *Cryptosporidium* oocyst by 3 log).	No data provided; rating based on assumption of pore size rating by analogy to other systems (assumed 2 micron filter not expected to reduce bacteria by 6 log). Company verifies 1 micron pore size. Does not change evaluation.
10	**DHK - ReFresh Military Canteen**	Filter	Red	Red	Red	Red	1. Filter IWP does not meet filter pathogen removal criteria (i.e. reduce bacteria by 6 log, *Giardia* cyst by 3 log, and *Cryptosporidium* oocyst by 3 log).	Limited test data does not support adequate bacteria removal.
11	**DHK - ReFresh Water Bottle**	Filter	Red	Red	Red	Red	1. Filter IWP does not meet filter pathogen removal criteria (i.e. reduce bacteria by 6 log, *Giardia* cyst by 3 log, and *Cryptosporidium* oocyst by 3 log).	Limited test data does not support adequate bacteria removal.
12	**DJ Int - PureSip Straw**	Filter						Waiting for more information.
13	**Flip-Top Straw Filter Bottle**	Filter	Red	Red	Red	Red	1. Filter IWP does not meet filter pathogen removal criteria (i.e. reduce bacteria by 6 log, *Giardia* cyst by 3 log, and *Cryptosporidium* oocyst by 3 log).	No data provided; rating based on knowledge of technology (2 micron filter not expected to reduce bacteria by 6 log).
14	**GE Base Camp F**	Filter	Green	Red	Red	Red	7. Weighs 4 lbs or more and/or cube is 4 liters or more.	7L in size, weight less than 8 lbs.
15	**GE Deluxe F**	Filter	Green	Green	Green	Red	5. Weighs 0.5 lbs or more and/or cube is 0.5 liters or more.	Weight is 1lb, cube 1.45L; requires no consumables

#	IWP Device Name	Type	User Profile A Rating	User Profile B Rating	User Profile C Rating	User Profile D Rating	Most Comprehensive Reason to Eliminate	Other Reasons and Additional Comments/ Rationale
16	**GE TrvLPure F**	Filter	Green	Green	Green	Red	5. Weighs 0.5 lbs or more and/or cube is 0.5 liters or more.	Weight is approx 1.5lb, 1.58L; requires no consumables
17	**HTI - HydroPack**	Filter	Red	Red	Red	Red	8. Weighs 8 lbs or more and/or cube is 8 liters or more.	Single use, one device only produces 2L; requires 8 devices for a 15L day (weighs 3.1 lbs for 1 day, or 20.4lbs (53 devices) for 105L over 7 days). Weight is 4lbs for 5L in one day; some potential use in Profile D Does not meet screening criteria.
18	**HTI - HydroWell 24**	Filter	Red	Red	Red	Red	8. Weighs 8 lbs or more and/or cube is 8 liters or more.	Stationary, designed for a group. Size is 23L.
19	**HTI Expedition F**	Filter	Red	Red	Red	Red	8. Weighs 8 lbs or more and/or cube is 8 liters or more.	5.1L volume for 30L of water; additional charges needed for additional capability. Charges add enough weight to raise total significantly above 8lb. Profiles A-D device and charges are 16lbs and 10L size. Profile D weight is 2lbs, size is 3L. Does not meet screening criteria; however this will be evaluated anyway due to professional interest.

#	IWP Device Name	Type	User Profile A Rating	User Profile B Rating	User Profile C Rating	User Profile D Rating	Most Comprehensive Reason to Eliminate	Other Reasons and Additional Comments/ Rationale
20	**HTI Xpack F**	Filter	Red	Red	Red	Red	8. Weighs 8 lbs or more and/or cube is 8 liters or more.	Requires 4 devices to produce 15L/day; will need additional electrolyte charges for 7 days of production. 20lb weight and 8.8L size for 105L production capability (Profiles A-C). 2lb weight and 0.54L size for 5 L/d (Profile D). Does not meet screening criteria; however this will be evaluated anyway due to professional interest.
21	**Ingram - Survival Straw**	Filter						Waiting for more information.
22	**Seychelle In-Line Eliminator**	Filter	Red	Red	Red	Red	1. Filter IWP does not meet filter pathogen removal criteria (i.e. reduce bacteria by 6 log, *Giardia* cyst by 3 log, and *Cryptosporidium* oocyst by 3 log).	No data provided; rating based on knowledge of technology (2 micron filter not expected to reduce bacteria by 6 log).
23	**Innova - Heavy Duty Biological Bottle**	Filter						Waiting for more information.
24	**Innova - Inline Filter**	Filter						Waiting for more information.
25	**Kat Camp F**	Filter	Green	Green	Green	Red	5. Weighs 0.5 lbs or more and/or cube is 0.5 liters or more.	1.5L size. 0.8lb
26	**Kat Combi F**	Filter	Green	Green	Green	Red	5. Weighs 0.5 lbs or more and/or cube is 0.5 liters or more.	1.4L size. 1.3lb

#	IWP Device Name	Type	User Profile A Rating	User Profile B Rating	User Profile C Rating	User Profile D Rating	Most Comprehensive Reason to Eliminate	Other Reasons and Additional Comments/ Rationale
27	**Katadyn - Drip Ceradyn**	Filter	Red	Red	Red	Red	8. Weighs 8 lbs or more and/or cube is 8 liters or more.	>8L size. 7.3 lb
28	**Katadyn - Drip Gravidyn**	Filter	Red	Red	Red	Red	8. Weighs 8 lbs or more and/or cube is 8 liters or more.	>8L size. 7.3 lb
29	**Kat Exstream F**	Filter	Green	Green	Green	Red	5. Weighs 0.5 lbs or more and/or cube is 0.5 liters or more.	After 100L, virus cartridge requires replacement. Volume of bottle includes holding water; however device is still a perceptible burden for transporting.
30	**Kat Exst XR F**	Filter	Green	Green	Green	Red	5. Weighs 0.5 lbs or more and/or cube is 0.5 liters or more.	After 100L, virus cartridge requires replacement. Volume of bottle includes holding water; however device is still a perceptible burden for transporting.
31	**Kat Guide F**	Filter	Green	Green	Green	Red	5. Weighs 0.5 lbs or more and/or cube is 0.5 liters or more.	
32	**Kat Hiker F**	Filter	Green	Green	Green	Red	5. Weighs 0.5 lbs or more and/or cube is 0.5 liters or more.	
33	**Kat Hiker Pro F**	Filter	Green	Green	Green	Red	5. Weighs 0.5 lbs or more and/or cube is 0.5 liters or more.	
34	**Kat Micro F**	Filter	Green	Green	Green	Red	5. Weighs 0.5 lbs or more and/or cube is 0.5 liters or more.	No virus capability. Requires filter replacement after 100L.
35	**Kat Mini F**	Filter	Green	Green	Green	Green		Weight <0.5lb. Size is 0.57L, just over profile D threshold, but including.
36	**Kat Pocket F**	Filter	Green	Green	Green	Red	5. Weighs 0.5 lbs or more and/or cube is 0.5 liters or more.	1.3L size. 1.3lb

#	IWP Device Name	Type	User Profile A Rating	User Profile B Rating	User Profile C Rating	User Profile D Rating	Most Comprehensive Reason to Eliminate	Other Reasons and Additional Comments/ Rationale
37	**Kat Base Camp F**	Filter	Green	Green	Green	Red	5. Weighs 0.5 lbs or more and/or cube is 0.5 liters or more.	1.5L size. 1.7lb
38	**McNett - Frontier Straw**	Filter	Red	Red	Red	Red	1. Filter IWP does not meet filter pathogen removal criteria (i.e. reduce bacteria by 6 log, *Giardia* cyst by 3 log, and *Cryptosporidium* oocyst by 3 log).	No data provided; rating based on knowledge of technology (2 micron filter not expected to reduce bacteria by 6 log).
39	**MSR Miniworks EX F**	Filter	Green	Green	Green	Red	5. Weighs 0.5 lbs or more and/or cube is 0.5 liters or more.	Weight of approx 1 lb and volume approx 1.4L
40	**MSR SwtWtr® Micfilt F**	Filter	Green	Green	Green	Red	5. Weighs 0.5 lbs or more and/or cube is 0.5 liters or more.	Weight of approx 0.8 lb and volume approx 0.8L
41	**MSR SwtWtr® Purif F**	Filter	Green	Green	Green	Red	5. Weighs 0.5 lbs or more and/or cube is 0.5 liters or more.	0.9lb, 1.3L
42	**MSR Waterworks EX F**	Filter	Green	Green	Green	Red	5. Weighs 0.5 lbs or more and/or cube is 0.5 liters or more.	Weight of approx 1+ lb and volume approx 1.7L
43	**Clearbrk Portable Water Filtration System**	Filter	Red	Red	Red	Red	1. Filter IWP does not meet filter pathogen removal criteria (i.e. reduce bacteria by 6 log, *Giardia* cyst by 3 log, and *Cryptosporidium* oocyst by 3 log).	No data provided; rating based on assumption of pore size rating by analogy to other systems (assumed 2 micron filter not expected to reduce bacteria by 6 log). No response from company - assume 2 micron pore size

#	IWP Device Name	Type	User Profile A Rating	User Profile B Rating	User Profile C Rating	User Profile D Rating	Most Comprehensive Reason to Eliminate	Other Reasons and Additional Comments/ Rationale
44	**Pre Mac - Model MWP**	Filter	Red	Red	Red	Red	1. Filter IWP does not meet filter pathogen removal criteria (i.e. reduce bacteria by 6 log, *Giardia* cyst by 3 log, and *Cryptosporidium* oocyst by 3 log).	Does not remove cysts
45	**Pre Mac - Model PWP**	Filter	Red	Red	Red	Red	1. Filter IWP does not meet filter pathogen removal criteria (i.e. reduce bacteria by 6 log, *Giardia* cyst by 3 log, and *Cryptosporidium* oocyst by 3 log).	Does not remove cysts
46	**Pre Mac - Model SWP**	Filter	Red	Red	Red	Red	1. Filter IWP does not meet filter pathogen removal criteria (i.e. reduce bacteria by 6 log, *Giardia* cyst by 3 log, and *Cryptosporidium* oocyst by 3 log).	Does not remove cysts
47	**Pre Mac - Travel Well**	Filter	Red	Red	Red	Red	1. Filter IWP does not meet filter pathogen removal criteria (i.e. reduce bacteria by 6 log, *Giardia* cyst by 3 log, and *Cryptosporidium* oocyst by 3 log).	Does not remove cysts
48	**Pres 2 Pure Field Canteen**	Filter	Red	Red	Red	Red	1. Filter IWP does not meet filter pathogen removal criteria (i.e. reduce bacteria by 6 log, *Giardia* cyst by 3 log, and *Cryptosporidium* oocyst by 3 log).	No data provided; rating based on knowledge of technology (2 micron filter not expected to reduce bacteria by 6 log).
49	**PRISMed Triton™ F**	Filter	Green	Green	Green	Red	5. Weighs 0.5 lbs or more and/or cube is 0.5 liters or more.	Just over 1lb, just under 2L
50	**Sawyer - In Line Filter**	Filter	Red	Red	Red	Red	10. Other.	Device not yet commercially available.

#	IWP Device Name	Type	User Profile A Rating	User Profile B Rating	User Profile C Rating	User Profile D Rating	Most Comprehensive Reason to Eliminate	Other Reasons and Additional Comments/ Rationale
51	**Sawyer WB F**	Filter	Green	Green	Green	Red	5. Weighs 0.5 lbs or more and/or cube is 0.5 liters or more.	Device volume is 1L.
52	**Seychelle Survivor Water Bottle**	Filter						Waiting for more information. Combination filter and chlorine tabs.
53	**Aqua Mira Drops D**	Disinfectant	Green	Green	Green	Green		
54	**Aquatabs D**	Disinfectant	Green	Green	Green	Green		Can reduce bacteria and viruses based on knowledge of technology.
55	**Chlorfloc D**	Disinfectant	Green	Green	Green	Green		
56	**Coghlan Iodine tabs D**	Disinfectant	Green	Green	Green	Green		Identical to Globaline D and Potable Aqua IT D. Will be evaluated together as COTS version of military iodine tablets for comparison purposes.
57	**Coghlan IT w/ Neut. D**	Disinfectant	Green	Green	Green	Green		Identical to Coghlans Iodine tabs D with the additional taste and odor neutralizer tablet.
58	**Globaline D**	Disinfectant	Green	Green	Green	Green		Identical to Coghlan Iodine tabs D and Potable Aqua IT D. Will be evaluated together as COTS version of military iodine tablets for comparison purposes.

#	IWP Device Name	Type	User Profile A Rating	User Profile B Rating	User Profile C Rating	User Profile D Rating	Most Comprehensive Reason to Eliminate	Other Reasons and Additional Comments/ Rationale
59	**Kat MicrPur Tabs D**	Disinfectant	Green	Green	Green	Green		
60	**MSR MIOX Purifier D**	Disinfectant	Green	Green	Green	Green		Although device in carrying case is 1L, separate components total 0.25L (justification for profile D).
61	**PE Polar Pure D**	Disinfectant	Green	Green	Green	Green		Crystalline iodine
62	**Potable Aqua IT D**	Disinfectant	Green	Green	Green	Green		Identical to Globaline D and Coghlan Iodine tabs D. Will be evaluated together as COTS version of military iodine tablets for comparison purposes.
63	**Potable Aqua IT w/ Neut. D**	Disinfectant	Green	Green	Green	Green		Identical to Potable Aqua IT D with the additional taste and odor neutralizer tablet.
64	**AC Pristine Water Pur Sys D**	Disinfectant	Green	Green	Green	Green		
65	**RediClean**	Disinfectant						Waiting for more information.
66	**XDT Xtrem Wtr Pur D**	Disinfectant	Green	Green	Red	Red	6. Weighs 2 lbs or more and/or cube is 2 liters or more.	35g bottles, 35 bottles needed for 105L equals 2.7lbs

Table 7: Device Screening

Appendix D: Assigned Device Scores for Profiles B, C, and D

	Bact. Remove	Virus Remove	Giardia Remove	Crypto Remove	Taste/ Odor	Turbidity	Purif. Time	Effect of Turbid.	Effort	Durability	Indicator	Cube	Weight	Storage
AC Pristine Water Pur Sys D	One Check	One Check	One Check	Zero Checks	35	None	35	No effect	80	80	10	330	270	0
Aqua Mira Drops D	One Check	One Check	One Check	Zero Checks	35	None	35	No effect	80	80	10	330	270	0
Aquatabs D	One Check	One Check	Zero Checks	Zero Checks	25	None	30	No effect	85	100	10	120	30	100
Chlorfloc D	Three Checks	Three Checks	Three Checks	Zero Checks	35	Medium	20	No effect	25	10	10	1160	320	100
Coghlan Iodine tabs D	Three Checks	Three Checks	Zero Checks	Zero Checks	0	None	35	No effect	100	90	35	150	150	60
Coghlan IT w/ Neut. D	Three Checks	Three Checks	Zero Checks	Zero Checks	70	None	40	No effect	95	90	35	300	300	60
GE Deluxe F	One Check	One Check	One Check	One Check	90	High	1	Prefilter, backwashable	60	65	60	1450	430	80
GE TrvLPure F	One Check	One Check	One Check	One Check	90	High	1	Mult prefilters small pore	70	65	60	1580	630	80
Globaline D	Three Checks	Three Checks	Zero Checks	Zero Checks	0	None	35	No effect	100	90	35	150	250	60
H-P SteriPen D	Zero checks	Zero Checks	Zero Checks	Zero Checks	70	None	1.5	No effect	85	0	75	820	1250	100
HTI Xpack F	One Check	One Check	One Check	One Check	100	Very high	480	No effect	70	30	0	4000	1816	60
HTI Expedition F	One Check	One Check	One Check	One Check	100	Very high	130	No effect	60	65	65	4000	1816	60
Kat Base Camp F	One Check	Zero Checks	One Check	One Check	90	High	2	Prefilter; not cleanable	70	70	0	1500	370	80
Kat Camp F	One Check	Zero Checks	One Check	One Check	70	High	12	No prefilter; cleanable	50	30	20	1500	620	40
Kat Combi F	One Check	Zero Checks	One Check	One Check	90	High	1	Prefilter; cleanable	50	45	20	1360	600	40
Kat Exst XR F	Three Checks	Three Checks	Three Checks	One Check	25	High	8	No prefilter; not cleanable	40	80	0	1400	230	80
Kat Exstream F	Three Checks	Three Checks	Three Checks	One Check	25	High	8	No prefilter; not cleanable	40	80	0	1400	200	80
Kat Guide F	One Check	Zero Checks	One Check	One Check	90	High	1	Multiple prefilters	70	75	0	1250	400	80
Kat Hiker F	One Check	Zero Checks	One Check	One Check	90	High	1	Prefilter; not cleanable	70	70	0	1050	310	80
Kat Hiker Pro F	One Check	Zero Checks	One Check	One Check	90	High	1	Multiple prefilters	70	70	0	1050	310	80
Kat Micro WB F	One Check	Zero Checks	One Check	One Check	90	High	8	No prefilter; not cleanable	40	80	0	1400	200	80
Kat MicrPur Tabs D	Three Checks	Three Checks	Three Checks	Three Checks	35	None	240	No effect	100	100	10	440	80	100
Kat Mini F	One Check	Zero Checks	One Check	One Check	70	High	2	Prefilter; cleanable	35	30	20	580	230	40
Kat Pocket F	One Check	Zero Checks	One Check	One Check	70	High	1	Prefilter; cleanable	50	50	20	1250	570	40
MSR Miniworks EX F	One Check	Zero Checks	One Check	One Check	90	High	1	Prefilter; cleanable	55	40	25	1400	460	40
MSR MIOX Purifier D	Three Checks	Three Checks	Three Checks	Zero Checks	25	None	240	No effect	50	70	100	560	230	100
MSR SwtWtr Micfilt F	Three Checks	Zero Checks	One Check	Three Checks	90	High	1	Prefilter, less cleanable	60	65	25	1260	320	80
MSR SwtWtr Purif F	Three Checks	Three Checks	Three Checks	Three Checks	50	High	6	Prefilter, less cleanable	55	65	25	1400	400	0
MSR WaterWorks EX F	One Check	Zero Checks	One Check	One Check	90	Very high	1	Prefilter; cleanable	55	40	25	1770	540	40
PE Polar Pure D	One Check	One Check	Zero Checks	Zero Checks	25	None	20	No effect	65	80	10	160	250	60
Potable Aqua IT D	Three Checks	Three Checks	Zero Checks	Zero Checks	0	None	35	No effect	100	90	35	150	150	60
Potable Aqua IT w/ Neut D	Three Checks	Three Checks	Zero Checks	Zero Checks	70	None	40	No effect	95	90	35	300	300	60
PRISMed Triton F	One Check	One Check	One Check	One Check	90	High	14	Prefilter; not cleanable	75	70	0	1800	500	80
Sawyer WB F	One Check	Zero Checks	One Check	One Check	90	High	2	No prefilter; not cleanable	40	80	0	1040	160	80
XDT Xtrem Wtr Pur D	Three Checks	Three Checks	Three Checks	Zero Checks	35	None	15	No effect	100	90	40	700	1400	0

Figure 11: Assigned Device Scores for Profile B

	Bact. Remove	Virus Remove	Giardia Remove	Crypto Remove	Taste/ Odor	Turbidity	Purif. Time	Effect of Turbid.	Effort	Durability	Indicator	Cube	Weight	Storage
AC Pristine Water Pur Sys D	One Check	One Check	One Check	Zero Checks	35	None	35	No effect	80	80	10	330	270	0
Aqua Mira Drops D	One Check	One Check	One Check	Zero Checks	35	None	35	No effect	80	80	10	330	270	0
Aquatabs D	One Check	One Check	Zero Checks	Zero Checks	25	None	30	No effect	85	100	10	120	30	100
Chlorfloc D	Three Checks	Three Checks	Three Checks	Zero Checks	35	Medium	20	No effect	25	10	10	1160	320	100
Coghlan Iodine tabs D	Three Checks	Three Checks	Zero Checks	Zero Checks	0	None	35	No effect	100	90	35	150	150	60
Coghlan IT w/ Neut. D	Three Checks	Three Checks	Zero Checks	Zero Checks	70	None	40	No effect	95	90	35	300	300	60
GE Deluxe F	One Check	One Check	One Check	One Check	90	High	1	Prefilter, backwashable	60	65	60	1450	430	80
GE TrvLPure F	One Check	One Check	One Check	One Check	90	High	1	Mult prefilters small pore	70	65	60	1580	630	80
Globaline D	Three Checks	Three Checks	Zero Checks	Zero Checks	0	None	35	No effect	100	90	35	150	250	60
H-P SteriPen D	Zero checks	Zero Checks	Zero Checks	Zero Checks	70	None	1.5	No effect	85	0	75	820	909	100
HTI Xpack F	One Check	One Check	One Check	One Check	100	Very high	480	No effect	70	30	0	2000	908	60
HTI Expedition F	One Check	One Check	One Check	One Check	100	Very high	130	No effect	60	65	65	2000	908	60
Kat Base Camp F	One Check	Zero Checks	One Check	One Check	90	High	2	Prefilter; not cleanable	70	70	0	1500	370	80
Kat Camp F	One Check	Zero Checks	One Check	One Check	70	High	12	No prefilter; cleanable	50	30	20	1500	620	40
Kat Combi F	One Check	Zero Checks	One Check	One Check	90	High	1	Prefilter; cleanable	50	45	20	1360	600	40
Kat Exst XR F	Three Checks	Three Checks	Three Checks	One Check	25	High	8	No prefilter; not cleanable	40	80	0	1400	230	80
Kat Exstream F	Three Checks	Three Checks	Three Checks	One Check	25	High	8	No prefilter; not cleanable	40	80	0	1400	200	80
Kat Guide F	One Check	Zero Checks	One Check	One Check	90	High	1	Multiple prefilters	70	75	0	1250	400	80
Kat Hiker F	One Check	Zero Checks	One Check	One Check	90	High	1	Prefilter; not cleanable	70	70	0	1050	310	80
Kat Hiker Pro F	One Check	Zero Checks	One Check	One Check	90	High	1	Multiple prefilters	70	70	0	1050	310	80
Kat Micro F	One Check	Zero Checks	One Check	One Check	90	High	8	No prefilter; not cleanable	40	80	0	1400	200	80
Kat MicrPur Tabs D	Three Checks	Three Checks	Three Checks	Three Checks	35	None	240	No effect	100	100	10	440	80	100
Kat Mini F	One Check	Zero Checks	One Check	One Check	70	High	2	Prefilter; cleanable	35	30	20	580	230	40
Kat Pocket F	One Check	Zero Checks	One Check	One Check	70	High	1	Prefilter; cleanable	50	50	20	1250	570	40
MSR Miniworks EX F	One Check	Zero Checks	One Check	One Check	90	High	1	Prefilter; cleanable	55	40	25	1400	460	40
MSR MIOX Purifier D	Three Checks	Three Checks	Three Checks	Zero Checks	25	None	240	No effect	50	70	100	560	230	100
MSR SwtWtr Micfilt F	Three Checks	Zero Checks	One Check	Three Checks	90	High	1	Prefilter, less cleanable	60	65	25	1260	320	80
MSR SwtWtr Purif F	Three Checks	Three Checks	Three Checks	Three Checks	50	High	6	Prefilter, less cleanable	55	65	25	1400	400	0
MSR WaterWorks EX F	One Check	Zero Checks	One Check	One Check	90	Very high	1	Prefilter; cleanable	55	40	25	1770	540	40
PE Polar Pure D	One Check	One Check	Zero Checks	Zero Checks	25	None	20	No effect	65	80	10	160	250	60
Potable Aqua IT D	Three Checks	Three Checks	Zero Checks	Zero Checks	0	None	35	No effect	100	90	35	150	150	60
Potable Aqua IT w/ Neut D	Three Checks	Three Checks	Zero Checks	Zero Checks	70	None	40	No effect	95	90	35	300	300	60
PRISMed Triton F	One Check	One Check	One Check	One Check	90	High	14	Prefilter; not cleanable	75	70	0	1800	500	80
Sawyer WB F	One Check	Zero Checks	One Check	One Check	90	High	2	No prefilter; not cleanable	40	80	0	1040	160	80

Figure 12: Assigned Device Scores for Profile C

	Bact. Remove	Virus Remove	Giardia Remove	Crypto Remove	Taste/ Odor	Turbidity	Purif. Time	Effect of Turbid.	Effort	Durability	Indicator	Cube	Weight	Storage
AC Pristine Water Pur Sys D	One Check	One Check	One Check	Zero Checks	35	None	35	No effect	80	80	10	110	90	0
Aqua Mira Drops D	One Check	One Check	One Check	Zero Checks	35	None	35	No effect	80	80	10	110	90	0
Aquatabs D	One Check	One Check	Zero Checks	Zero Checks	25	None	30	No effect	85	100	10	40	10	100
Chlorfloc D	Three Checks	Three Checks	Three Checks	Zero Checks	35	Medium	20	No effect	25	20	10	290	80	100
Coghlan Iodine tabs D	Three Checks	Three Checks	Zero Checks	Zero Checks	0	None	35	No effect	100	90	35	30	30	60
Coghlan IT w/ Neut. D	Three Checks	Three Checks	Zero Checks	Zero Checks	70	None	40	No effect	95	90	35	60	60	60
Globaline D	Three Checks	Three Checks	Zero Checks	Zero Checks	0	None	35	No effect	100	90	35	30	50	60
H-P SteriPen D	Zero checks	Zero Checks	Zero Checks	Zero Checks	70	None	1.5	No effect	85	0	75	370	230	100
HTI Xpack F	One Check	One Check	One Check	One Check	100	Very high	480	No effect	70	30	0	501	230	60
HTI Expedition F	One Check	One Check	One Check	One Check	100	Very high	130	No effect	60	65	65	501	230	60
Kat MicrPur Tabs D	Three Checks	Three Checks	Three Checks	Three Checks	35	None	240	No effect	100	100	10	110	20	100
Kat Mini F	One Check	Zero Checks	One Check	One Check	70	High	2	Prefilter; cleanable	35	30	20	501	230	40
MSR MIOX Purifier D	Three Checks	Three Checks	Three Checks	Zero Checks	25	None	240	No effect	50	70	100	501	230	100
PE Polar Pure D	One Check	One Check	Zero Checks	Zero Checks	25	None	80	No effect	65	80	10	160	90	60
Potable Aqua IT D	Three Checks	Three Checks	Zero Checks	Zero Checks	0	None	35	No effect	100	90	35	30	30	60
Potable Aqua IT w/ Neut D	Three Checks	Three Checks	Zero Checks	Zero Checks	70	None	40	No effect	95	90	35	60	60	60
XDT Xtrem Wtr Pur D	Three Checks	Three Checks	Three Checks	Zero Checks	35	None	15	No effect	100	90	40	40	80	0

Figure 13: Assigned Device Scores for Profile D

Appendix E: Overall and Converted Scores for Profiles B, C, and D

	Best IWP Goal	Bact. Remove	Virus Remove	Giardia Remove	Crypto Remove	Taste/Odor	Turbidity	Purif. Time	Effect of Turbid.	Effort	Durability	Indicator	Cube	Weight	Storage
MSR SwtWtr Purif F	75	100	100	100	100	50	75	87	65	55	65	25	38	64	0
Kat MicrPur Tabs D	73	100	100	100	100	35	0	0	100	100	100	10	82	93	100
GE Deluxe F	70	70	70	70	70	90	75	100	50	60	65	60	36	62	80
XDT Xtrem Wtr Pur D	69	100	100	100	0	35	0	69	100	100	90	40	72	4	0
Coghlan IT w/ Neut. D	68	100	100	0	0	70	0	35	100	95	90	35	88	73	60
Potable Aqua IT w/ Neut D	68	100	100	0	0	70	0	35	100	95	90	35	88	73	60
MSR SwtWtr Micfilt F	68	100	0	70	100	90	75	100	65	60	65	25	45	72	80
GE TrvLPure F	68	70	70	70	70	90	75	100	40	70	65	60	31	38	80
Kat Exstream F	67	100	100	100	70	25	75	83	0	40	80	0	38	82	80
Kat Exst XR F	67	100	100	100	70	25	75	83	0	40	80	0	38	80	80
Potable Aqua IT D	66	100	100	0	0	0	0	40	100	100	90	35	94	87	60
Coghlan Iodine tabs D	66	100	100	0	0	0	0	40	100	100	90	35	94	87	60
Globaline D	65	100	100	0	0	0	0	40	100	100	90	35	94	78	60
MSR MIOX Purifier D	65	100	100	100	0	25	0	0	100	50	70	100	78	80	100
Chlorfloc D	65	100	100	100	0	35	50	60	100	25	10	10	50	72	100
Aquatabs D	61	70	70	0	0	25	0	46	100	85	100	10	95	97	100
Kat Hiker Pro F	61	70	0	70	70	90	75	100	30	70	70	0	57	72	80
PRISMed Triton F	61	70	70	70	70	90	75	71	20	75	70	0	24	53	80
Kat Mini F	60	70	0	70	70	70	75	97	70	35	30	20	77	80	40
Kat Hiker F	60	70	0	70	70	90	75	100	20	70	70	0	57	72	80
Kat Guide F	59	70	0	70	70	90	75	100	30	70	75	0	45	64	80
Aqua Mira Drops D	59	70	70	70	0	35	0	40	100	80	80	10	87	76	0
AC Pristine Water Pur Sys D	59	70	70	70	0	35	0	40	100	80	80	10	87	76	0
MSR Miniworks EX F	59	70	0	70	70	90	75	100	70	55	40	25	38	59	40
PE Polar Pure D	59	70	70	0	0	25	0	60	100	65	80	10	94	78	60
MSR WaterWorks EX F	58	70	0	70	70	90	100	100	70	55	40	25	25	48	40
Kat Combi F	58	70	0	70	70	90	75	100	70	50	45	20	40	41	40
Sawyer WB F	58	70	0	70	70	90	75	97	0	40	80	0	57	86	80
Kat Base Camp F	57	70	0	70	70	90	75	97	20	70	70	0	34	67	80
Kat Pocket F	57	70	0	70	70	70	75	100	70	50	50	20	45	44	40
Kat Micro WB F	54	70	0	70	70	90	75	83	0	40	80	0	38	82	80
HTI Expedition F	53	70	70	70	70	100	100	3	100	60	65	65	0	0	60
Kat Camp F	50	70	0	70	70	70	75	74	60	50	30	20	34	39	40
HTI Xpack F	49	70	70	70	70	100	100	-0	100	70	30	0	0	0	60
H-P SteriPen D	43	0	0	0	0	70	0	99	100	85	0	75	67	7	100

Figure 14: Converted and Overall Device Scores for Profile B

	Best IWP Goal	Bact. Remove	Virus Remove	Giardia Remove	Crypto Remove	Taste/Odor	Turbidity	Purif. Time	Effect of Turbid.	Effort	Durability	Indicator	Cube	Weight	Storage
Kat MicrPur Tabs D	71	100	100	100	100	35	0	0	100	100	100	10	65	86	100
MSR SwtWtr Purif F	69	100	100	100	100	50	75	87	65	55	65	25	7	24	0
Potable Aqua IT w/ Neut D	65	100	100	0	0	70	0	35	100	95	90	35	76	41	60
Coghlan IT w/ Neut. D	65	100	100	0	0	70	0	35	100	95	90	35	76	41	60
GE Deluxe F	65	70	70	70	70	90	75	100	50	60	65	60	6	21	80
Potable Aqua IT D	64	100	100	0	0	0	0	40	100	100	90	35	88	73	60
Coghlan Iodine tabs D	64	100	100	0	0	0	0	40	100	100	90	35	88	73	60
GE TrvLPure F	63	70	70	70	70	90	75	100	40	70	65	60	4	6	80
Kat Exstream F	63	100	100	100	70	25	75	83	0	40	80	0	7	64	80
Kat Exst XR F	63	100	100	100	70	25	75	83	0	40	80	0	7	59	80
Globaline D	63	100	100	0	0	0	0	40	100	100	90	35	88	53	60
MSR SwtWtr Micfilt F	63	100	0	70	100	90	75	100	65	60	65	25	10	37	80
MSR MIOX Purifier D	61	100	100	100	0	25	0	0	100	50	70	100	52	59	100
Aquatabs D	61	70	70	0	0	25	0	46	100	85	100	10	90	95	100
Chlorfloc D	59	100	100	100	0	35	50	60	100	25	10	10	13	37	100
PE Polar Pure D	56	70	70	0	0	25	0	60	100	65	80	10	87	53	60
Kat Mini F	56	70	0	70	70	70	75	97	70	35	30	20	50	59	40
Aqua Mira Drops D	56	70	70	70	0	35	0	40	100	80	80	10	74	48	0
AC Pristine Water Pur Sys D	56	70	70	70	0	35	0	40	100	80	80	10	74	48	0
PRISMed Triton F	56	70	70	70	70	90	75	71	20	75	70	0	1	14	80
Kat Hiker Pro F	55	70	0	70	70	90	75	100	30	70	70	0	17	39	80
Kat Hiker F	54	70	0	70	70	90	75	100	20	70	70	0	17	39	80
Kat Guide F	54	70	0	70	70	90	75	100	30	70	75	0	10	24	80
MSR Miniworks EX F	54	70	0	70	70	90	75	100	70	55	40	25	7	18	40
Sawyer WB F	53	70	0	70	70	90	75	97	0	40	80	0	17	72	80
MSR WaterWorks EX F	53	70	0	70	70	90	100	100	70	55	40	25	2	11	40
HTI Expedition F	53	70	70	70	70	100	100	3	100	60	65	65	0	0	60
Kat Combi F	53	70	0	70	70	90	75	100	70	50	45	20	7	8	40
Kat Base Camp F	52	70	0	70	70	90	75	97	20	70	70	0	5	29	80
Kat Pocket F	52	70	0	70	70	70	75	100	70	50	50	20	10	9	40
Kat Micro F	50	70	0	70	70	90	75	83	0	40	80	0	7	64	80
HTI Xpack F	49	70	70	70	70	100	100	-0	100	70	30	0	0	0	60
Kat Camp F	46	70	0	70	70	70	75	74	60	50	30	20	5	7	40
H-P SteriPen D	40	0	0	0	0	70	0	99	100	85	0	75	29	-0	100

*Note: Although some devices scored beyond the lower limit of the performance scale for some measures, these devices are exceptions, and the study team decided not to alter the performance scale to generate a more precise score. In these cases the converted score is shown as a "-0" in the above table.

Figure 15: Converted and Overall Device Scores for Profile C

	Best IWP Goal	Bact. Remove	Virus Remove	Giardia Remove	Crypto Remove	Taste/ Odor	Turbidity	Purif. Time	Effect of Turbid.	Effort	Durability	Indicator	Cube	Weight	Storage
Kat MicrPur Tabs D	73	100	100	100	100	35	0	0	100	100	100	10	51	75	100
XDT Xtrem Wtr Pur D	70	100	100	100	0	35	0	69	100	100	90	40	79	29	0
Coghlan Iodine tabs D	69	100	100	0	0	0	0	40	100	100	90	35	84	64	60
Potable Aqua IT D	69	100	100	0	0	0	0	40	100	100	90	35	84	64	60
Aquatabs D	67	70	70	0	0	25	0	46	100	85	100	10	79	87	100
Globaline D	67	100	100	0	0	0	0	40	100	100	90	35	84	47	60
Potable Aqua IT w/ Neut D	65	100	100	0	0	70	0	35	100	95	90	35	70	40	60
Coghlan IT w/ Neut. D	65	100	100	0	0	70	0	35	100	95	90	35	70	40	60
Chlorfloc D	53	100	100	100	0	35	50	60	100	25	20	10	15	29	100
Aqua Mira Drops D	52	70	70	70	0	35	0	40	100	80	80	10	51	24	0
AC Pristine Water Pur Sys D	52	70	70	70	0	35	0	40	100	80	80	10	51	24	0
MSR MIOX Purifier D	49	100	100	100	0	25	0	0	100	50	70	100	-0	-0	100
HTI Expedition F	46	70	70	70	70	100	100	3	100	60	65	65	-0	-0	60
PE Polar Pure D	45	70	70	0	0	25	0	12	100	65	80	10	37	24	60
HTI Xpack F	42	70	70	70	70	100	100	-0	100	70	30	0	-0	-0	60
Kat Mini F	40	70	0	70	70	70	75	97	70	35	30	20	-0	-0	40
H-P SteriPen D	37	0	0	0	0	70	0	99	100	85	0	75	7	-0	100

*Note: Although some devices scored beyond the lower limit of the performance scale for some measures, these devices are exceptions, and the study team decided not to alter the performance scale to generate a more precise score. In these cases the converted score is shown as a "-0" in the above table.

Figure 16: Converted and Overall Device Scores for Profile D

APPENDIX D

EXCERPT FROM NSF PROTOCOL P248

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NSF Protocol P248
Emergency Military Operations
Microbiological Water Purifiers

January 2006

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NSF Protocol P248
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Microbiological Water Purifiers

Protocol Developer

Prepared by U.S. Army Center for Health Promotion and Preventive Medicine (CHPPM) using a grant received from the Army Study Program Management Office.

Published by
NSF International
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Ann Arbor, Michigan 48105

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U.S. ARMY CENTER FOR
HEALTH PROMOTION AND PREVENTIVE MEDICINE

DIRECTORATE OF ENVIRONMENTAL HEALTH ENGINEERING
WATER SUPPLY MANAGEMENT PROGRAM

AND

NSF INTERNATIONAL

PROTOCOL FOR EVALUATING THE MICROBIOLOGICAL TREATMENT CAPABILITIES OF WATER PURIFIERS INTENDED FOR PERSONAL USE DURING EMERGENCY MILITARY OPERATIONS

USACHPPM Contributors:

W. DICKINSON BURROWS, Ph.D., P.E., DEE
STEVEN C. RICHARDS, Ph.D., P.E.
TODD E. RICHARDS, P.E.
MAJ WILLIAM J. BETTIN
ARTHUR H. LUNDQUIST, P.E.
JOHN K. BROKAW
STEVEN H. CLARKE, P.E.
SARA E. BIRKMIRE

January 2006

D-8

PREFACE

In the early 2000s, scientists and engineers in the Department of Defense (DoD) identified a mission critical need to assess the performance of commercial off-the-shelf (COTS) individual water purification devices. The military-issued emergency water purifiers in use since the World War II era required multiple time-consuming steps, and could in some cases provide a false sense of security, actually failing to produce potable (microbiologically safe for human consumption) water from available water sources, with no indication that such was the case. The comparatively recent appearance of a multitude of hand-held COTS individual water purifiers (IWP) was perceived by many to be the remedy to the problem. According to the commercial advertising campaigns, these devices were able to produce potable and palatable water from nearly any quality source, and could keep soldiers hydrated and mission-ready when they did not have access to Army-provided bulk water supplies. COTS IWPs began to proliferate among deploying units that were able to purchase them with unit charge cards, and among individual deploying soldiers who would obtain them at their own expense.

None of the IWPs had undergone rigorous DoD evaluations of their effectiveness and applicability to military missions, nor had they been evaluated and approved by any of the Services' Surgeon Generals. The primary concern for the lack of military and medical endorsement was for microbiological contaminants – bacteria, protozoan cysts, and viruses – that could rapidly reduce a soldier's mission readiness through acute gastro-intestinal distress or worse. The concern presented an unacceptable risk to deployed personnel in the eyes of the members of the Joint Medical Field Water Subgroup (JMFWSG) to the Joint Environmental Surveillance Workgroup (JESWG) which was chartered under DoD Health Affairs (HA). Consequently, a project was initiated to develop a test protocol that all IWPs intended to be marketed to the DoD could be subjected to, to determine their effectiveness in providing microbiological purification. Devices that successfully completed the test protocol could then be used by deployed individuals with a greater measure of assurance that the water they would obtain by using the devices would be of acceptable quality and would not cause acute illness or disease.

To this end, this protocol has been developed with the firm hope that vendors who desire to market their individual water purification devices to the military will use it to develop, evaluate, and improve their devices. The ultimate goal is to provide our warfighters the capability to individually produce sustainable quantities of microbiological contaminant-free drinking water, when necessary, from any fresh-water source that may be available to them during deployments.

The U.S. Army Center for Health Promotion and Preventive Medicine (CHPPM) received a grant from the Army Study Program Management Office to develop this protocol during FY 2005. CHPPM coordinated closely with personnel from the National Sanitation Foundation International who provided much guidance and assistance in developing the protocol and who graciously offered to publish it. CHPPM also solicited and received input from many other DoD organizations, who contributed significantly to the refinement of this Protocol, including the U.S. Navy Environmental Health Center , the U.S. Navy Bureau of Medicine, the U.S. Air Force

Institute for Operational Health, the U.S. Air Force 311th Human Systems Wing, the U.S. Army Proponency Office for Preventive Medicine, the U.S. Army Deputy Chief of Staff G-4, DALO-SMT, and the U.S. Army Infantry Center and School. The many efforts of individuals from all of these and other organizations is greatly appreciated.

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APPENDIX E

DEVICE EVALUATIONS

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Device #	Manufacturer	Device	Type	MCDM Abbreviation
1	Bota of Boulder, Inc.	Sports Bottle	filter	
2	BW Technologies Ltd	Aquapuretraveller	filter	
3	BW Technologies Ltd	Survivor 4(i)	filter	
4	BW Technologies Ltd	Survivor Inline Water Purification System	filter	
5	Camelbak Products, Inc.	Inline Microfilter	filter	
6	Clear Brook	Portable Water Filtration System	filter	
7	CuZn Water Filtration Systems, Inc.	Sports Bottle	filter	
8	DHK International, Inc.	ReFresh Water Bottle	filter	
9	DHK International, Inc.	ReFresh Military Canteen	filter	
10	DJ International	PureSip Straw	filter	
11	General Ecology, Inc.	First Need Base Camp	filter	GE Base Camp F
12	General Ecology, Inc.	First Need Deluxe	filter	GE Deluxe F
13	General Ecology, Inc.	First Need Trav-L-Pure	filter	GE TrvLPure F
14	Hydration Technologies, Inc.	HydroPack	filter	
15	Hydration Technologies, Inc.	HydroWell 24	filter	
16	Hydration Technologies, Inc.	HydroWell Expedition	filter	HTI Expedition F
17	Hydration Technologies, Inc.	X Pack	filter	HTI Xpack F
18	Ingram Water and Air Equipment	Survival Straw	filter	
19	Innova Pure Water, Inc.	Heavy Duty Biological Bottle	filter	
20	Innova Pure Water, Inc.	Inline Filter	filter	
21	Katadyn North America, Inc.	Base Camp	filter	Kat Base Camp F
22	Katadyn North America, Inc.	Camp	filter	Kat Camp F
23	Katadyn North America, Inc.	Combi	filter	Kat Combi F
24	Katadyn North America, Inc.	Exstream Water Bottle	filter	Kat Exstream F
25	Katadyn North America, Inc.	Exstream XR Water Bottle	filter	Kat Exst XR F
26	Katadyn North America, Inc.	Guide	filter	Kat Guide F
27	Katadyn North America, Inc.	Hiker	filter	Kat Hiker F
28	Katadyn North America, Inc.	Hiker Pro	filter	Kat Hiker Pro F
29	Katadyn North America, Inc.	Micro Water Bottle	filter	Kat Micro F
30	Katadyn North America, Inc.	Drip Ceradyn	filter	
31	Katadyn North America, Inc.	Drip Gravidyn	filter	

Device #	Manufacturer	Device	Type	MCDM Abbreviation
32	Katadyn North America, Inc.	Mini	filter	Kat Mini F
33	Katadyn North America, Inc.	Pocket	filter	Kat Pocket F
34	McNett Corporation	Aquamira Water Bottle and Filter	filter	
35	McNett Corporation	Frontier Straw	filter	
36	Mountain Safety Research, Inc.	MiniWorks EX	filter	MSR Miniworks EX F
37	Mountain Safety Research, Inc.	SweetWater® Microfilter	filter	MSR SwtWtr Micfilt F
38	Mountain Safety Research, Inc.	SweetWater® Purifier	filter	MSR SwtWtr Purif F
39	Mountain Safety Research, Inc.	WaterWorks EX	filter	MSR Waterworks EX F
40	PreMac International, Ltd	Model SWP	filter	
41	PreMac International, Ltd	Model MWP	filter	
42	PreMac International, Ltd	Model PWP	filter	
43	PreMac International, Ltd	Travel Well	filter	
44	PRISMedical Corporation	Triton	filter	PRISMed Triton F
45	Sawyer Products	In Line Filter	filter	
46	Sawyer Products	Water Bottle	filter	Sawyer WB F
47	Seychelle Environmental Technologies, Inc.	Flip-Top Straw Filter Bottle	filter	
48	Seychelle Environmental Technologies, Inc.	Flip-Top Straw Filter Bottle w/ Silverator	filter	
49	Seychelle Environmental Technologies, Inc.	Pres 2 Pure Field Canteen	filter	
50	Seychelle Environmental Technologies, Inc.	Pres 2 Pure Field Canteen w/ Silverator	filter	
51	Seychelle Environmental Technologies, Inc.	Bottoms-Up Water Bottle	filter	
52	Seychelle Environmental Technologies, Inc.	In-Line Eliminator w/ Silverator	filter	
53	Seychelle Environmental Technologies, Inc.	Survivor Water Bottle	filter	
54	Deatrick & Associates, Inc. (distributor)	Chlor-Floc	disinfectant	Chlorfloc D
55	Coghlan's	Emergency Drinking Water Germicidal Tablets	disinfectant	Coughlan Iodine tabs D
56	Coghlan's	Emergency Drinking Water Germicidal Tablets with Neutralizer	disinfectant	Coughlan IT w/Neut D
57	Continental Technologies, Inc.	RediClean	disinfectant	
58	Hydro-Photon, Inc.	SteriPEN	disinfectant	HP SteriPen D
59	Katadyn North America, Inc.	Micropur MP 1 Tablets	disinfectant	Kat MicrPur Tabs D
60	McNett Corporation	Aqua Mira Drops	disinfectant	Aqua Mira Drops D

Device #	Manufacturer	Device	Type	MCDM Abbreviation
61	Medentech	Aquatabs	disinfectant	Aquatabs D
62	Mountain Safety Research, Inc.	MIOX Purifier	disinfectant	MSR MIOX Purifier D
63	Polar Equipment, Inc.	Polar Pure	disinfectant	PE Polar Pure D
64	Advance Chemicals Ltd.	Pristine Water Purification System	disinfectant	AC Pristine Water Pur Sys D
65	Wisconsin Pharmacal Company, LLC.	Globaline	disinfectant	Globaline D
66	Wisconsin Pharmacal Company, LLC.	Potable Aqua with Neutralizer	disinfectant	Potable Aqua IT w/Neut D
67	Wisconsin Pharmacal Company, LLC.	Potable Aqua	disinfectant	Potable Aqua IT D
68	Xinix Disinfection Technologies, Inc.	Xtreme Water Purifier	disinfectant	XDR Xtrem Wtr Pur D

Summary:

68 Devices Total
53 Filters
15 Disinfectants
62 Devices Evaluated
56 Evaluation Papers
27 Manufacturers
18 Filter Manufacturers
12 Disinfectant Manufacturers

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ANNEX 1 TO APPENDIX E

DEVICE EVALUATION #1
BOTA OF BOULDER – OUTBACK™ WATER FILTRATION SYSTEM

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Device Evaluation 1: Bota of Boulder – Outback™ Water Filtration System

www.botaofboulder.com

Device Information

The Outback™ Water Filtration System is a handheld sports type squeeze bottle. The bottle is available in two sizes having a capacity of either 0.65 L (22 oz.) or 0.94 L (32 oz.). The bottle contains a filter cartridge that is assumed to consist of an activated carbon block depth filter that sits inside the top of the sports bottle between the bottle and the drink spout. The activated carbon filter is a 6 cm long hollow-core cylinder with a 0.8 cm thick wall. Water flows from outside through the filter wall into the hollow inside and out the drink spout. The filter is assumed to have an approximate 2 µm nominal pore size based on information from marketers of similar sports type squeeze bottles with carbon block depth filters. Information provided on the manufacturer's website claims this device removes 99.9% (3-log) *Cryptosporidium* oocysts and *Giardia* cysts based on results compiled by independent labs. Directions for use require the user to fill the bottle with water, insert the activated carbon filter, replace the cap and squeeze to produce water. For storage, the manufacturer recommends the filter be stored dry. Prior to the first use the filter must be flushed to remove filter particle fines.

Effectiveness Against Microbial Pathogens

No data was received showing the effectiveness of this product with respect to the USEPA Guide Standard Protocol for Testing Microbiological Water Purifiers (reference 1). The theory and practice of depth filtration has been widely studied and there has been significant research conducted on activated carbon block filtration (reference 2). In the absence of data specific to this device tested using reference 1, and based on general knowledge of depth filtration, this device should be capable of consistently reducing *Giardia* cysts and *Cryptosporidium* oocysts to the required minimum log reductions stated in reference 1 (i.e., 3-log) when used as directed. It is not expected to consistently reduce bacteria (6-log) and viruses (4-log). Based on general depth and carbon block filtration information, the Outback™ Water Filtration System is assigned one check for the reduction of *Giardia* cysts and *Cryptosporidium* oocysts and an X for bacteria and virus reduction (for an explanation of the rating checks click here).

™ Outback is a registered trademark of Bota of Boulder, Inc., Boulder, CO. Use of trademarked products does not imply endorsement by the U.S. Army, but is intended only in identification of a specific product.

Table. Expected Performance Against Microbial Pathogens.

Microbial Pathogen Type	Expected Disinfection Capability	Evaluation Rating	Primary Pathogen Reduction Mechanism
Bacteria	>6 log	X	-
Viruses	>4 log	X	-
Giardia cysts	>3 log	√	size exclusion
Cryptosporidium oocysts	>3 log	√	size exclusion

Production Rate and Capacity

Inherent to the production rate and capacity of filtration devices is the quality of the raw water source. Because it is a squeeze bottle, the actual production rate is dependent on the user. The production capacity is stated to be about 150 L. It is also recommended the filter be replaced every 6 months or as directed. Production capacity will vary widely with raw water quality (i.e., turbidity).

Cleaning, Replacement, and End of Life Indicator

This device cannot be backwashed to remove sediment from the filter. When the device becomes unusable due to decreased production rate, the clogged filter must be replaced. The bottle is dishwasher safe or can be hand washed. For practical purposes, the filter cartridges are not cleanable. The device contains no end of life indicator short of filter clogging.

Weight and Size

Dry weight	150 g.
Size (height x diameter)	24 cm x 7 cm

Cost

Bottle with filter	$20.00
Replacement filter	$ 9.00

Device Evaluation

No data was received that challenged the Outback™ Water Filtration System against reference 1. General research on depth and carbon block filtration indicates that this device should be capable of consistently reducing *Giardia* cysts and *Cryptosporidium* oocysts. This device is not likely capable of consistently reducing bacteria and viruses. Additional treatment is necessary to remove bacteria and viruses such as adding a disinfectant (e.g., chlorine, iodine, chlorine dioxide) to the bottle prior to filtering. The activated carbon should remove tastes and odors. This device, like all filters with small pore sizes, is highly affected by turbid (cloudy) waters. Since the device is not able to be backwashed to remove accumulated particulates, once clogged, the filter must be replaced. There is no indicator of process failure or end of device useful life.

Advantages

- Expected to consistently provide adequate protection from *Giardia* cysts and *Cryptosporidium* oocysts, although device-specific testing data using the USEPA protocol is not available.
- No wait time prior to consumption.
- Provides taste and odor reduction.

Disadvantages

- Not expected to be consistently effective against bacteria and viruses.
- Additional treatment required.
- Reduced production capacity when using high turbidity water.
- Not backwashable.
- No real-time indicator of process failure.

References

1. USEPA, 1989. Guide Standard and Protocol for Testing Microbiological Water Purifiers. *Federal Register*. 54:34067.

2. U.S. Army Center for Health Promotion and Preventive Medicine, 2005. *Technical Information Paper; Filtration in the Use of Individual Water Purification Devices,* Aberdeen Proving Ground, MD.

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ANNEX 2 TO APPENDIX E

DEVICE EVALUATION #2
BW TECHNOLOGIES LIMITED – AQUAPURETRAVELLER

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BW Technologies Limited – Aquapuretraveller

www.aquapuretraveller.com

Device Information

The BW Technologies Limited Aquapuretraveller is a handheld sports type squeeze bottle. The bottle has a capacity of approximately 0.65 L (22 oz). The bottle contains a filter cartridge using an activated carbon block depth filter surrounded by a plastic "sleeve" containing iodine resin beads. The filter cartridge is connected to the bottom of the drink spout. The filter cartridge is 6.5 cm (L) x 4 cm (Dia). The outside of the filter cartridge is a 0.2 cm thick plastic "sleeve" which acts to provide coarse filtration and houses iodine resin beads in a 0.1 cm space between the plastic sleeve and the carbon block filter. The iodine resin beads are designed to provide disinfection through direct contact with microbial pathogens as well as releasing iodine into solution for additional disinfection. The interior of the filter cartridge contains a hollow-core, cylindrical activated carbon block depth filter with a 0.8 cm thick wall. The carbon block filter is rated a 2 µm pore size. Water flow is radial, flowing from outside through the plastic "sleeve", iodine resin beads, and finally through the carbon block filter into the hollow inside and out the drink spout. Directions for use require the user to fill the bottle with water, replace the cap and shake (shaking releases iodine into the water), wait 15 minutes then use.

Effectiveness Against Microbial Pathogens

No data was received showing the effectiveness of this product with respect to the U.S. Environmental Protection Agency (USEPA) Guide Standard Protocol for Testing Microbiological Water Purifiers (reference 1). Independent data received (reference 2) that did not use the USEPA protocol and general knowledge of carbon block filtration and iodine disinfection indicate the device is capable of consistently reducing Giardia cysts and Cryptosporidium oocysts to the required minimum log reductions stated in reference 1 (i.e., 3-log) when used as directed. Data also indicate the device is not expected to consistently reduce bacteria (6-log) and viruses (4-log) when used as directed. The iodine resin beads will provide some disinfection upon contact with a microorganism; however, the short contact time provided due to the radial flow of water through the iodine sleeve prevents the resin beads from being more effective. The resin beads are also designed to provide a constant release of iodine into solution to provide additional disinfection capability. However, this process is highly variable since it is dependent upon the intensity of shaking the bottle and the level of water in the

bottle. Once the water level drops below the level of the filter cartridge, the water is no longer in contact with the resin beads which then cannot release additional iodine into solution. Determining the effectiveness of the iodine released into solution as a function of CT (iodine concentration times contact, or wait time) is difficult. Many variables must be considered including the rate of iodine dissolution (which is a function of shaking intensity) and usage. A rough CT estimate was calculated based on iodine dissolution data provided with the independent data (reference 2) and user directions. By assuming a constant rate of iodine dissolution and the directed 15-minute wait time, a CT of 6 mg-min/L is estimated. Based on this assumption, it is not likely that this device would be able to consistently meet minimum log reductions in reference 1 under more severe water quality conditions such as increased turbidity and lower temperatures. Additional virus and bacteria reduction can be achieved through extending the wait time beyond 15 minutes and routinely shaking the bottle to ensure presence of an iodine residual in the water. However, compared to devices using only a carbon block filter, this device can provide superior treatment with respect to reducing viruses and bacteria. Based on independent data not using the USEPA protocol and general knowledge of carbon block filtration and iodine disinfection, the BW Technologies Aquapuretraveller is assigned one √ for the reduction of Giardia cysts and Cryptosporidium oocysts and an X for bacteria and virus reduction (for an explanation of the rating checks click here).

Table. Expected Performance Against Microbial Pathogens When Used as Directed.

Microbial Pathogen Type	Expected Disinfection Capability	Evaluation Rating	Primary Pathogen Reduction Mechanism
Bacteria	> 6-log	X	size exclusion and disinfection
Viruses	> 4-log	X	disinfection
Giardia cysts	> 3-log	√	size exclusion
Cryptosporidium oocysts	> 3-log	√	size exclusion

Production Rate and Capacity

Inherent to the production rate and capacity of filtration devices is the quality of the raw water source. Because it is a squeeze bottle, the actual production rate is dependent on the user. The production capacity of the device is stated to be up to 350 L. However, production capacity will vary widely with raw water quality (i.e., turbidity).

Cleaning, Replacement, and End of Life Indicator

This device cannot be backwashed to remove sediment from the filter. When the device becomes unusable due to decreased production rate, the clogged filter cartridge must be replaced. The bottle can be hand washed. For practical purposes, the filter cartridges are not cleanable. The device contains no end of life indicator short of filter clogging.

Weight and Size

Dry weight	130 grams
Size (height x diameter)	22 cm x 7 cm

Cost

The Aquapuretraveller is not sold at stores in the United States. The device is available through online ordering and at stores outside of the United States.

Aquapuretraveller bottle with filter	$70.00
Replacement filter	$60.00

Device Evaluation

No data was received that challenged the Aquapuretraveller against reference 1. Independent data received that did not follow the reference 1 protocol and general research on carbon block filtration and iodine disinfection indicate this device should be capable of consistently reducing *Giardia* cysts and *Cryptosporidium* oocysts when used as directed. This device is not likely capable of consistently reducing bacteria and viruses when used as directed. Increasing the wait time beyond the directed 15 minutes and routinely shaking the bottle to ensure presence of an iodine residual that will help reduce bacteria and viruses prior to filtering. The activated carbon should remove tastes and odors in addition to iodine. This device, like all filters with small pore sizes, is highly affected by turbid (cloudy) waters. Since the device is not able to be backwashed to remove accumulated particulates, once clogged, the filter must be replaced. There is no indicator of process failure or end of device useful life. Although this device uses iodine, when used as directed it is not expected to cause any adverse health effects for healthy adults with no pre-existing thyroid condition or sensitivity to iodine. This device is not recommended for use by pregnant women (concern for fetus), people with known hypersensitivity to iodine, people with a history (or family history) of thyroid disease, and people from areas with chronic iodine deficiency (reference 3).

Advantages

- Expected to consistently provide adequate protection from *Giardia* cysts and *Cryptosporidium* oocysts, although device-specific testing data using the USEPA protocol is not available.
- Simple and effective.
- Provides taste and odor reduction.
- No adverse health effects expected in healthy adults with no iodine sensitivity.

Disadvantages

- Not expected to be consistently effective against bacteria and viruses. Extending the wait time prior to drinking beyond 15 minutes will provide additional virus and bacteria reduction.
- Reduced production capacity when using high turbidity water.
- Not backwashable.
- No real-time indicator of process failure.
- Not recommended for use by pregnant women or people with iodine sensitivity.

References

1. USEPA, 1989. Guide Standard and Protocol for Testing Microbiological Water Purifiers. *Federal Register*. 54:34067.

2. Independent laboratory data provided by BW Technologies, Ltd.

3. U.S. Army Center for Health Promotion and Preventive Medicine, 2005. *Technical Information Paper; Iodine in the Use of Individual Water Purification Devices,* Aberdeen Proving Ground, MD.

ANNEX 3 TO APPENDIX E

DEVICE EVALUATION #3
BW TECHNOLOGIES LIMITED – SURVIVOR 4(I)

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BW Technologies Limited – Survivor 4(i)

www.survivor4i.com

Device Information

The BW Technologies Limited Survivor 4(i) is a handheld sports type squeeze bottle in the shape of a military canteen. This device is the military version of the Aquapuretraveller. The canteen has a capacity of approximately 0.65 L (22 oz). The bottle contains a filter cartridge using an activated carbon block depth filter surrounded by a plastic "sleeve" containing iodine resin beads. The filter cartridge is connected to the bottom of the drink spout. The filter cartridge is 6.5 cm (L) x 4 cm (Dia). The outside of the filter cartridge is a 0.2 cm thick plastic "sleeve" which acts to provide coarse filtration and houses iodine resin beads in a 0.1 cm space between the plastic sleeve and the carbon block filter. The iodine resin beads are designed to provide disinfection through direct contact with microbial pathogens as well as releasing iodine into solution for additional disinfection. The interior of the filter cartridge contains a hollow-core, cylindrical activated carbon block depth filter with a 0.8 cm thick wall. The carbon block filter is rated a 2 µm pore size. Water flow is radial, flowing from outside through the plastic "sleeve", iodine resin beads, and finally through the carbon block filter into the hollow inside and out the drink spout. Directions for use require the user to fill the bottle with water, replace the cap and shake (shaking releases iodine into the water), wait a minimum of 15 minutes then use. Prior to use the filter must be flushed to remove carbon particle fines. When storing the device, BW Technologies recommends flushing the device with clean tap water then storing with a small amount of clean water in the canteen to keep the iodine resin beads in a moist environment.

Effectiveness Against Microbial Pathogens

No data was received showing the effectiveness of this product with respect to the U.S. Environmental Protection Agency (USEPA) Guide Standard Protocol for Testing Microbiological Water Purifiers (reference 1). Independent data received (reference 2) that did not use the USEPA protocol and general knowledge of carbon block filtration and iodine disinfection indicate the device is capable of consistently reducing Giardia cysts and *Cryptosporidium* oocysts to the required minimum log reductions stated in reference 1 (i.e., 3-log) when used as directed. Data also indicate the device is not expected to consistently reduce bacteria (6-log) and viruses (4-log) when used as directed. The iodine resin beads will provide

some disinfection upon contact with a microorganism; however the short contact time provided due to the radial flow of water through the iodine sleeve prevents the resin beads from being more effective. The resin beads are also designed to provide a constant release of iodine into solution to provide additional disinfection capability. However, this process is highly variable since it is dependent upon the intensity of shaking the bottle and the level of water in the bottle. Once the water level drops below the level of the filter cartridge, the water is no longer in contact with the resin beads which then cannot release additional iodine into solution. Determining the effectiveness of the iodine released into solution as a function of CT (iodine concentration times contact, or wait time) is difficult. Many variables must be considered including the rate of iodine dissolution (which is a function of shaking intensity) and usage. A rough CT estimate was calculated based on iodine dissolution data provided with the independent data (reference 2) and user directions. By assuming a constant rate of iodine dissolution and the directed 15 minute wait time, a CT of 6 mg-min/L is estimated. Based on this assumption, it is not likely that this device would be able to consistently meet minimum log reductions in reference 1 under more severe water quality conditions such as increased turbidity and lower temperatures. Additional virus and bacteria reduction can be achieved through extending the wait time beyond 15 minutes and routinely shaking the bottle to ensure presence of an iodine residual in the water. However, compared to devices using only a carbon block filter, this device can provide superior treatment with respect to reducing viruses and bacteria. Based on independent data not using the USEPA protocol and general knowledge of carbon block filtration and iodine disinfection, the BW Technologies Survivor 4(i) is assigned one √ for the reduction of Giardia cysts and *Cryptosporidium* oocysts and an X for bacteria and virus reduction (for an explanation of the rating checks click here).

Table. Expected Performance Against Microbial Pathogens When Used as Directed.

Microbial Pathogen Type	Expected Disinfection Capability	Evaluation Rating	Primary Pathogen Reduction Mechanism
Bacteria	> 6-log	X	size exclusion and disinfection
Viruses	> 4-log	X	Disinfection
Giardia cysts	> 3-log	√	size exclusion
Cryptosporidium oocysts	> 3-log	√	size exclusion

Production Rate and Capacity

Inherent to the production rate and capacity of filtration devices is the quality of the raw water source. Because it is a squeeze bottle, the actual production rate is dependent on the user. The production capacity of the device is stated to be up to 350 L. However, production capacity will vary widely with raw water quality (i.e., turbidity).

Cleaning, Replacement, and End of Life Indicator

This device cannot be backwashed to remove sediment from the filter. When the device becomes unusable due to decreased production rate, the clogged filter cartridge must be replaced. The bottle can be hand washed. For practical purposes, the filter cartridges are not cleanable. The device contains no end of life indicator short of filter clogging.

Weight and Size

Dry weight	190 grams
Size (height x width x depth)	21 cm x 12 cm x 8 cm

Cost

The Survivor 4(i) is not sold at stores in the United States. The device is available through online ordering and at stores outside of the United States.

Survivor 4(i) bottle with filter	$95.00
Replacement filter	$60.00

Device Evaluation

No data was received that challenged the Survivor 4(i) against reference 1. Independent data received that did not follow the reference 1 protocol and general research on carbon block filtration and iodine disinfection indicate this device should be capable of consistently reducing *Giardia* cysts and *Cryptosporidium* oocysts when used as directed. This device is not likely capable of consistently reducing bacteria and viruses when used as directed. Increasing the wait time beyond the directed 15 minutes and routinely shaking the bottle to ensure presence of an iodine residual that will help reduce bacteria and viruses prior to filtering. The activated carbon should remove tastes and odors in addition to iodine. This device, like all filters with small pore sizes, is highly affected by turbid (cloudy) waters. BW Technologies recommends pre-filtration or settling prior to using the Survivor 4(i) when treating high turbidity waters to extend the life of the device and achieve better treatment. Since the device is not able to be backwashed to remove

accumulated particulates, once clogged, the filter must be replaced. There is no indicator of process failure or end of device useful life. Although this device uses iodine, when used as directed it is not expected to cause any adverse health effects for healthy adults with no pre-existing thyroid condition or sensitivity to iodine. This device is not recommended for use by pregnant women (concern for fetus), people with known hypersensitivity to iodine, people with a history (or family history) of thyroid disease, and people from areas with chronic iodine deficiency (reference 3).

Advantages

- Expected to consistently provide adequate protection from *Giardia* cysts and *Cryptosporidium* oocysts, although device-specific testing data using the USEPA protocol is not available.
- Simple and effective.
- Provides taste and odor reduction.
- No adverse health effects expected in healthy adults with no iodine sensitivity.

Disadvantages

- Not expected to be consistently effective against bacteria and viruses. Extending the wait time prior to drinking beyond 15 minutes will provide additional virus and bacteria reduction.
- Reduced production capacity when using high turbidity water.
- Not backwashable.
- No real-time indicator of process failure.
- Not recommended for use by pregnant women or people with iodine sensitivity.

References

1. USEPA, 1989. Guide Standard and Protocol for Testing Microbiological Water Purifiers. *Federal Register*. 54:34067.

2. Independent laboratory data provided by BW Technologies, Ltd.

3. U.S. Army Center for Health Promotion and Preventive Medicine, 2005. *Technical Information Paper; Iodine in the Use of Individual Water Purification Devices,* Aberdeen Proving Ground, MD.

ANNEX 4 TO APPENDIX E

DEVICE EVALUATION #4
BW TECHNOLOGIES LIMITED – SURVIVOR INLINE WATER PURIFICATION SYSTEM

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BW Technologies Limited – Survivor Inline Water Purification System

www.survivor4i.com

Device Information

The BW Technologies Limited Survivor Inline Water Purification System is an in-line filter device designed for use with commercial hydration packs. The in-line filter contains a filter cartridge identical in design to BW Technologies Survivor 4(i) and Aquapuretraveller. The filter cartridge is contained in a sturdy plastic housing with separate inlet and outlet for connecting to the drink tube of a hydration pack. The filter cartridge consists of an activated carbon block depth filter surrounded by a plastic "sleeve" containing iodine resin beads. The filter cartridge is 6.5 cm (L) x 4 cm (Dia). The outside of the filter cartridge is a 0.2 cm thick plastic "sleeve" which acts to provide coarse filtration and houses iodine resin beads in a 0.1 cm space between the plastic sleeve and the carbon block filter. The iodine resin beads are designed to provide disinfection through direct contact with microbial pathogens as well as releasing iodine into solution for additional disinfection. The interior of the filter cartridge contains a hollow-core, cylindrical activated carbon block depth filter with a 0.8 cm thick wall. The carbon block filter is rated a 2 µm pore size. After installing the in-line filter on the drink tube line (fittings are included with the filter), water flows radially from outside the filter cartridge through the plastic "sleeve", the iodine resin beads, and finally through the carbon block filter into the hollow inside before exiting the filter housing. Before the first use, the filter must be flushed to remove carbon particle fines by spitting out the first few mouthfuls of water. BW Technologies strongly recommends that 2 chlorine tablets (i.e., aquatabs) be added to each 3L hydration pack refill to provide additional protection against microbial pathogens and keeping the hydration pack clean. When storing the device, BW Technologies recommends draining the in-line filter and washing the hydration pack prior to storage.

Effectiveness Against Microbial Pathogens

No data was received showing the effectiveness of this product with respect to the U.S. Environmental Protection Agency (USEPA) Guide Standard Protocol for Testing Microbiological Water Purifiers (reference 1). Independent data received (reference 2) that did not use the USEPA protocol and general knowledge of carbon block filtration and iodine disinfection indicate the device is capable of consistently reducing Giardia cysts and *Cryptosporidium* oocysts to the required minimum log reductions stated in reference 1 (i.e.,

3-log) when used as directed. It is not expected to consistently reduce bacteria (6-log) and viruses (4-log) when used as directed. The iodine resin beads will provide some disinfection upon contact with a microorganism; however, the short contact time provided due to the radial flow of water through the device prevents the resin beads from being more effective. Unlike the BW Technologies Survivor 4(i) and Aquapuretraveller which produce an iodine residual prior to filtering, the in-line filter will not provide a residual due to it's designed operation as an in-line filter. The directions strongly recommend the addition of chlorine tablets to a 3 L hydration pack prior to filtering. No recommended wait times are provided. This results in an approximate chlorine concentration of 3 mg/L. This will provide some reduction of viruses and bacteria. However, it is not expected to consistently provide 6-log bacteria and 4-log virus reduction in most water quality conditions such as higher turbidities and colder temperatures. Additional virus and bacteria reduction can be achieved by always adding a disinfectant such as chlorine, chlorine dioxide, or iodine to the hydration pack and waiting a period of time before use. Based on independent data not using the USEPA protocol and general knowledge of carbon block filtration and iodine disinfection, the BW Technologies Survivor Inline Water Purification System is assigned one √ for the reduction of Giardia cysts and *Cryptosporidium* oocysts and an X for bacteria and virus reduction (for an explanation of the rating checks click here).

Table. Expected Performance Against Microbial Pathogens When Used as Directed.

Microbial Pathogen Type	Expected Disinfection Capability	Evaluation Rating	Primary Pathogen Reduction Mechanism
Bacteria	> 6-log	X	size exclusion and disinfection
Viruses	> 4-log	X	disinfection
Giardia cysts	> 3-log	√	size exclusion
Cryptosporidium oocysts	> 3-log	√	size exclusion

Production Rate and Capacity

Inherent to the production rate and capacity of filtration devices is the quality of the raw water source. Because it is an in-line filter designed to be used with a hydration pack, the actual production rate is dependent on the user. The production capacity of the device is stated to be up to 350 L. However, production capacity will vary widely with raw water quality (i.e., turbidity).

Cleaning, Replacement, and End of Life Indicator

This device cannot be backwashed to remove sediment from the filter. When the device becomes unusable due to decreased production rate, the clogged filter cartridge must be replaced. The bottle can be hand washed. For practical purposes, the filter cartridges are not cleanable. The device contains no end of life indicator short of filter clogging.

Weight and Size

Dry weight	100 grams
Size (height x diameter)	13.5 cm x 5.5 cm

Cost

The Survivor Inline Water Purification System is not sold at stores in the United States. The device is available through online ordering and at stores outside of the United States.

Survivor Inline Filter	$70.00

Device Evaluation

No data was received that challenged the Survivor Inline filter against reference 1. Independent data received that did not follow the reference 1 protocol and general research on carbon block filtration and iodine disinfection indicate this device should be capable of consistently reducing *Giardia* cysts and *Cryptosporidium* oocysts when used as directed. This device is not likely capable of consistently reducing bacteria and viruses when used as directed. Always adding a disinfectant to the hydration pack and waiting a period of time before consuming will help reduce bacteria and viruses prior to filtering. The activated carbon should remove tastes and odors in addition to iodine. This device, like all filters with small pore sizes, is highly affected by turbid (cloudy) waters. Since the device is not able to be backwashed to remove accumulated particulates, once clogged, the filter must be replaced. There is no indicator of process failure or end of device useful life. Although this device uses iodine, when used as directed it is not expected to cause any adverse health effects for healthy adults with no pre-existing thyroid condition or sensitivity to iodine. This device is not recommended for use by pregnant women (concern for fetus), people with known hypersensitivity to iodine, people with a history (or family history) of thyroid disease, and people from areas with chronic iodine deficiency (reference 3).

Advantages

- Expected to consistently provide adequate protection from *Giardia* cysts and *Cryptosporidium* oocysts, although device-specific testing data using the USEPA protocol is not available.
- Simple and effective.
- Provides taste and odor reduction.
- No adverse health effects expected in healthy adults with no iodine sensitivity.

Disadvantages

- Not expected to be consistently effective against bacteria and viruses.
- Reduced production capacity when using high turbidity water.
- Not backwashable.
- No real-time indicator of process failure.
- Not recommended for use by pregnant women or people with iodine sensitivity.

References

1. USEPA, 1989. Guide Standard and Protocol for Testing Microbiological Water Purifiers. *Federal Register*. 54:34067.

2. Independent laboratory data provided by BW Technologies, Ltd.

3. U.S. Army Center for Health Promotion and Preventive Medicine, 2005. *Technical Information Paper; Iodine in the Use of Individual Water Purification Devices*, Aberdeen Proving Ground, MD.

ANNEX 5 TO APPENDIX E

DEVICE EVALUATION #5
CAMELBAK PRODUCTS, LLC – IN-LINE MICROFILTER

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Camelbak Products, LLC – In-Line Microfilter

www.camelbak.com

Device Information

The Camelbak Products, LLC, In-Line Microfilter is designed for use with commercial hydration packs. The In-Line Microfilter contains a 0.2 µm hollow fiber polysulfone membrane bundle primary filter and a carbon block prefilter. The hollow fibers are packed into a plastic housing and the open ends are oriented at the effluent side of the housing. The filter cartridge is contained in a sturdy plastic housing with separate inlet and outlet for connecting to the drink tube of a hydration pack. Water flows into the filter housing, through the carbon prefilter, then from the outside of the hollow fibers to the inside, and out of the open ends of the hollow fibers. The top of the hollow fiber filter cartridge is sealed with a hard epoxy with the open end of the hollow fibers flush with the epoxy surface; this forces water to flow into the hollow fibers for purification. The device, as purchased, includes the filter housing with quick release fittings attached, primary hollow fiber filter, two carbon prefilters, and an extra set of quick release fittings. The extra fittings allow for the microfilter to be spiced into Non-Hydrolink hydration pack reservoirs (e.g., hydration pack reservoirs without quick release fittings). This device is not marketed for virus reduction and will therefore require additional treatment.

Effectiveness Against Microbial Pathogens

No laboratory testing data was received challenging this device for pathogen reduction, such as following the U.S. Environmental Protection Agency (USEPA) Guide Standard (reference 1). General knowledge of carbon block and membrane filtration (references 2) indicate that this device should be capable of consistently meeting the minimum 6-log bacteria reduction, and 3-log reduction for *Giardia* cysts and *Cryptosporidium* oocysts as stated in reference 1. This device is not expected to consistently reduce viruses (4-log reduction). Based on general knowledge of size exclusion by membrane filtration, the Camelbak Products, LLC, In-Line Microfilter is assigned one √ for bacteria reduction, one √ each for the reduction of *Giardia* cysts and *Cryptosporidium* oocysts. The device receives an X for virus reduction (for an explanation of the rating checks click here).

Table. Expected Performance Against Microbial Pathogens.

Microbial Pathogen Type	Expected Disinfection Capability	Evaluation Rating	Primary Pathogen Reduction Mechanism
Bacteria	> 6-log	√	size exclusion
Viruses	> 4-log	X	-
Giardia cysts	> 3-log	√	size exclusion
Cryptosporidium oocysts	> 3-log	√	size exclusion

Production Rate and Capacity

Inherent to the production rate and capacity of filtration devices is the quality of the raw water source. Because it is an in-line filter, the actual production rate is dependent on the user. The production capacity is stated by the manufacturer to be up to 284 L, however, production capacity will vary widely with raw water quality (e.g., turbidity). No data was received indicating the performance of this device in turbid waters.

Cleaning, Replacement, and End of Life Indicator

This device cannot be backwashed to remove sediment from the filters (prefilter and primary). Device instructions state to rinse the prefilter as flow decreases. When the prefilter becomes clogged it must be replaced. The device is accompanied with two prefilters. After using the two prefilters until clogged, the manufacturer states to discard the complete device. The device contains no end of life indicator short of filter clogging.

Weight and Size

Dry weight (no accessories or tubing)	160 grams (estimated)
Size (height x diameter)	23 cm x 4 cm

Cost

Inline filter	$55.00

Device Evaluation

No data was received that challenged the Camelbak Products, LLC, In-Line Microfilter against microbial pathogens such as stated in the USEPA Protocol (reference 1). General knowledge of size exclusion by membrane filtration indicates that this device should be capable of consistently reducing bacteria, *Giardia* cysts, and *Cryptosporidium* oocysts to the required minimum log reductions stated in reference 1. This device is not expected to consistently reduce viruses (4-log). Additional treatment is necessary to reduce viruses such as adding a disinfectant (e.g., chlorine, iodine, chlorine dioxide) to the water. This device contains a carbon block prefilter to reduce particulate matter and reduce source water taste and odor. Since no data was received, there is no indication of the long term efficacy of this filter against pathogens or preventing clogging from turbid water. Use in turbid water is expected to clog the prefilter rapidly. Since the device is not able to be backwashed to remove accumulated particles, once clogged, the filter must be replaced. Once the device has been used, flow direction should not be reversed or cross contamination may occur. There is no indicator of process failure or end of device useful life.

Advantages

- Expected to consistently provide adequate protection from bacteria, *Giardia* cysts, and *Cryptosporidium* oocysts, although device-specific testing data using the USEPA Protocol was not received.
- No wait time prior to consumption.
- Simple and effective.

Disadvantages

- No data testing this device against the USEPA Protocol (reference 1).
- Not expected to be consistently effective against viruses.
- Reduced production capacity when using high turbidity water.
- Not backwashable.
- No real-time indicator of process failure.

References

1. USEPA, 1989. Guide Standard and Protocol for Testing Microbiological Water Purifiers. *Federal Register*. 54:34067.

2. U.S. Army Center for Health Promotion and Preventive Medicine, 2005. *Technical Information Paper; Filtration in the Use of Individual Water Purification Devices*, Aberdeen Proving Ground, MD.

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ANNEX 6 TO APPENDIX E

DEVICE EVALUATION #6

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Clearbrook – Portable Water Filtration System

www.h20warehouse.com/clear-brook

Device Information

The Clearbrook Portable Water Filtration System is a handheld sports type squeeze bottle. The bottle has a capacity of 0.65 L (22 oz). The bottle contains a filter cartridge using a silver-impregnated activated carbon block depth filter that sits inside the top of the sports bottle between the bottle and the drink spout. The activated carbon filter is a 6 cm long hollow-core cylinder with a 0.8 cm thick wall. Water flows from outside through the filter wall into the hollow inside and out the drink spout. The filter is assumed to have an approximate 2 µm nominal pore size based on information from marketers of similar sports type squeeze bottles with carbon block depth filters. Information provided on the bottle claims this device removes and reduces tastes and odors, various inorganic contaminants (e.g., copper, lead, chlorine), as well as *Cryptosporidium* oocysts, *Giardia* cysts, and *E. coli* bacteria. Directions recommend the use of the cleanest, clearest water whenever possible since dirty water may prematurely clog the filter and greatly reduce the life expectancy of the filter. To use, simply fill the bottle, insert the cartridge filter, affix cap and squeeze bottle to produce filtered water. Prior to the first use the filter must be flushed once to remove filter particle fines.

Effectiveness Against Microbial Pathogens

No data was received showing the effectiveness of this product with respect to the U.S. Environmental Protection Agency (USEPA) Guide Standard Protocol for Testing Microbiological Water Purifiers (reference 1). The theory and practice of depth filtration has been widely studied and there has been significant research conducted on activated carbon block filtration (reference 2). In the absence of data specific to this device tested using reference 1, and based on general knowledge of depth filtration, this device should be capable of consistently reducing *Giardia* cysts and *Cryptosporidium* oocysts to the required minimum log reductions stated in reference 1 (i.e., 3-log) when used as directed. It is not expected to consistently reduce bacteria (6-log) and viruses (4-log). The silver impregnated into the filter is not designed to reduce microbial pathogens in water being treated. Rather, it's purpose is to inhibit bacterial growth on the filter throughout the filter's useful life. Based on general depth and carbon block

filtration information, the Clearbrook Portable Water Filtration System is assigned one √ for the reduction of *Giardia* cysts and *Cryptosporidium* oocysts and an X for bacteria and virus reduction (for an explanation of the rating checks click here).

Table. Expected Performance Against Microbial Pathogens.

Microbial Pathogen Type	Expected Disinfection Capability	Evaluation Rating	Primary Pathogen Reduction Mechanism
Bacteria	> 6-log	X	-
Viruses	> 4-log	X	-
Giardia cysts	> 3-log	√	size exclusion
Cryptosporidium oocysts	> 3-log	√	size exclusion

Production Rate and Capacity

Inherent to the production rate and capacity of filtration devices is the quality of the raw water source. Because it is a squeeze bottle, the actual production rate is dependent on the user. The production capacity of the device is stated to be approximately 100 L when using raw, untreated water, and approximately 415 L when using municipally treated drinking water. Production capacity will vary widely with raw water quality (i.e., turbidity).

Cleaning, Replacement, and End of Life Indicator

This device cannot be backwashed to remove sediment from the filter. When the device becomes unusable due to decreased production rate, the clogged filter must be replaced. The bottle is dishwasher safe or can be hand washed. For practical purposes, the filter cartridges are not cleanable. The device contains no end of life indicator short of filter clogging.

Weight and Size

Dry weight	150 grams
Size (height x diameter)	28 cm x 7 cm

Cost

Bottle with filter	$30.00
Replacement filter	$15.00

Device Evaluation

No data was received that challenged the Clearbrook Portable Water Filtration System against reference 1. General research on depth and carbon block filtration indicates that this device should be capable of consistently reducing *Giardia* cysts and *Cryptosporidium* oocysts. This device is not likely capable of consistently reducing bacteria and viruses. Additional treatment is necessary to remove bacteria and viruses such as adding a disinfectant (e.g., chlorine, iodine, chlorine dioxide) to the bottle prior to filtering. There is a possibility that silver can leach from the cartridge filter and be consumed. Although no data was received evaluating the potential for silver leaching, it is not likely that using this device for short periods would cause any adverse health effects due to silver ingestion (reference 2). The activated carbon should remove tastes and odors. This device, like all filters with small pore sizes, is highly affected by turbid (cloudy) waters. Since the device is not able to be backwashed to remove accumulated particulates, once clogged, the filter must be replaced. There is no indicator of process failure or end of device useful life.

Advantages

- Expected to consistently provide adequate protection from *Giardia* cysts and *Cryptosporidium* oocysts, although device-specific testing data using the USEPA protocol is not available.
- No wait time prior to consumption.
- Simple and effective.
- Provides taste and odor reduction.

Disadvantages

- Not expected to be consistently effective against bacteria and viruses.
- Reduced production capacity when using high turbidity water.
- Not backwashable.
- No real-time indicator of process failure.

References

1. USEPA, 1989. Guide Standard and Protocol for Testing Microbiological Water Purifiers. *Federal Register*. 54:34067.

2. U.S. Army Center for Health Promotion and Preventive Medicine, 2005. *Technical Information Paper; Filtration in the Use of Individual Water Purification Devices,* Aberdeen Proving Ground, MD.

ANNEX 7 TO APPENDIX E

DEVICE EVALUATION #7
CUZN® – SPORT BOTTLE

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CuZn® – Sport Bottle

www.cuzn.com

Device Information

The CuZn® Sport Bottle is a handheld sports type squeeze bottle. The bottle has a capacity of 0.65 L (22 oz.). The bottle contains a filter cartridge that is assumed to consist of an activated carbon block depth filter that sits inside the top of the sports bottle between the bottle and the drink spout. The activated carbon filter is a 6 cm long hollow-core cylinder with a 0.8 cm thick wall. Water flows from outside through the filter wall into the hollow inside and out the drink spout. The filter has a 1 µm pore size. Information provided by CuZn® claims this device removes or reduces 99.99% (4-log) *Cryptosporidium* oocysts and *Giardia* cysts, 99.9% (3-log) *E. coli* bacteria, as well as various inorganic and organic contaminants. Directions for use require the user to fill the bottle with water and squeeze to produce water. Prior to the first use the filter must be flushed with two full bottles of water to remove filter particle fines.

Effectiveness Against Microbial Pathogens

No data was received showing the effectiveness of this product with respect to the U.S. Environmental Protection Agency (USEPA) Guide Standard Protocol for Testing Microbiological Water Purifiers (reference 1). The theory and practice of depth filtration has been widely studied and there has been significant research conducted on activated carbon block filtration (reference 2). In the absence of data specific to this device tested using reference 1, and based on general knowledge of depth and carbon block filtration, this device should be capable of consistently reducing *Giardia* cysts and *Cryptosporidium* oocysts to the required minimum log reductions stated in reference 1 (i.e., 3-log) when used as directed. It is not expected to consistently reduce bacteria (6-log) and viruses (4-log). Based on general depth and carbon block filtration information, the CuZn® Sport Bottle is assigned one √ for the reduction of *Giardia* cysts and *Cryptosporidium* oocysts and an X for bacteria and virus reduction (for an explanation of the rating checks click here).

® CuZn is a registered trademark of CuZn Water Filtration Systems, Inc., Fayetteville, AR. Use of trademarked products does not imply endorsement by the U.S. Army, but is intended only in identification of a specific product.

Table. Expected Performance Against Microbial Pathogens.

Microbial Pathogen Type	Expected Disinfection Capability	Evaluation Rating	Primary Pathogen Reduction Mechanism
Bacteria	> 6-log	X	-
Viruses	> 4-log	X	-
Giardia cysts	> 3-log	√	size exclusion
Cryptosporidium oocysts	> 3-log	√	size exclusion

Production Rate and Capacity

Inherent to the production rate and capacity of filtration devices is the quality of the raw water source. Because it is a squeeze bottle, the actual production rate is dependent on the user. The production capacity is stated at up to 325 L for microbiological contaminants and 80 L for other various chemical contaminants. However, production capacity will vary widely with raw water quality (i.e., turbidity).

Cleaning, Replacement, and End of Life Indicator

This device cannot be backwashed to remove sediment from the filter. When the device becomes unusable due to decreased production rate, the clogged filter must be replaced. The bottle is dishwasher safe or can be hand washed. For practical purposes, the filter cartridges are not cleanable. The device contains no end of life indicator short of filter clogging.

Weight and Size

Dry weight	150 grams
Size (height x diameter)	28 cm x 7 cm

Cost

Bottle with filter	$40.00
Replacement filter	$20.00

Device Evaluation

No data was received that challenged the CuZn® Sport Bottle against reference 1. General research on depth and carbon block filtration indicates that this device should be capable of consistently reducing *Giardia* cysts and *Cryptosporidium* oocysts. This device is not likely capable of consistently reducing bacteria and viruses. Additional treatment is necessary to remove bacteria and viruses such as adding a disinfectant (e.g., chlorine, iodine, chlorine dioxide) to the bottle prior to filtering. The activated carbon should remove tastes and odors. This device, like all filters with small pore sizes, is highly affected by turbid (cloudy) waters. Since the device is not able to be backwashed to remove accumulated particulates, once clogged, the filter must be replaced. There is no indicator of process failure or end of device useful life.

Advantages

- Expected to consistently provide adequate protection from *Giardia* cysts and *Cryptosporidium* oocysts, although device-specific testing data using the USEPA protocol is not available.
- No wait time prior to consumption.
- Simple and effective.
- Provides taste and odor reduction.

Disadvantages

- Not expected to be consistently effective against bacteria and viruses.
- Reduced production capacity when using high turbidity water.
- Not backwashable.
- No real-time indicator of process failure.

References

1. USEPA, 1989. Guide Standard and Protocol for Testing Microbiological Water Purifiers. *Federal Register*. 54:34067.

2. U.S. Army Center for Health Promotion and Preventive Medicine, 2005. *Technical Information Paper; Filtration in the Use of Individual Water Purification Devices,* Aberdeen Proving Ground, MD.

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ANNEX 8 TO APPENDIX E

DEVICE EVALUATION #8
DHK INTERNATIONAL, INC. – REFRESH™ PERSONAL WATER FILTRATION SYSTEM

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DHK International, Inc. – ReFresh™ Personal Water Filtration System

www.dhki.com

Device Information

The DHK International, Inc., ReFresh Water Filtration System is a handheld sports type squeeze bottle. The bottle has a capacity of 1 L (34 oz.). The bottle contains a filter cartridge that is stated to consist of (in order of flow direction): 0.4 µm membrane, granular activated carbon (GAC), resin cocktail (manufacturer termed DHK Ion Tek), GAC, 0.4 µm membrane. All membranes and resin are proprietary in material and formula. The device is operated by simply unscrewing the cap, filling with water, replacing the cap, and squeezing. There are two removable rubber gaskets in the cap, one to seal the filter cartridge to the cap and the other to seal the cap to the bottle. No instructions accompany the device stating filter conditioning, cleaning, or storage. In addition to the sports bottle, DHK also manufacturers a 1- and 2-quart canteen, termed Military Water Purification System. This device is stated to contain the identical treatment technology as the ReFresh bottle, but with increased filter capacity. The manufacturer claims pathogen reduction, and specifically names bacteria and *Cryptosporidium oocysts*. The carbon impregnated membranes should reduce taste and odor.

Effectiveness Against Microbial Pathogens

No data was received showing the effectiveness of this product with respect to the U.S. Environmental Protection Agency (USEPA) Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1). The theory and practice of membrane filtration has been widely studied (reference 2). The performance of the proprietary resin cannot be quantified without data demonstrating pathogen reduction. Data supplied by the manufacturer for a previously named device arbitrarily used garden soil to contaminate raw water, with testing not following a standard protocol. Results showed that when tested three times with water containing > 8000 bacteria (volume not stated), product water tested for bacteria was less than the detection limit twice and 68 during the third test. No information was supplied to determine the volume or flow rate of water tested, making results difficult to interpret for pathogen reduction efficacy. In the absence of data specific to this device tested against reference 1, and based on general knowledge of size exclusion by membranes, a device with a properly functioning 0.4 µm pore size should be capable of consistently reducing *Giardia* cysts and *Cryptosporidium* oocysts to the required minimum log reductions stated in reference 1 (i.e.,

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™ ReFresh a registered trademark of DHK International, Inc., Laguna Hills, CA. Use of a trademarked product does not imply endorsement by the U.S. Army, but is intended only in identification of a specific product.

3-log) when used as directed. It is not expected that this device will consistently reduce bacteria (6-log) or viruses (4-log). Based on general membrane filtration information, the ReFresh Water Filtration System and the Military Water Purification System are each assigned one √ for the reduction of *Giardia* cysts and *Cryptosporidium* oocysts and an X for bacteria and virus reduction (for an explanation of the rating checks click here).

Table. Expected Performance Against Microbial Pathogens.

Microbial Pathogen Type	Expected Disinfection Capability	Evaluation Rating	Primary Pathogen Reduction Mechanism
Bacteria	> 6-log	X	-
Viruses	> 4-log	X	-
Giardia cysts	> 3-log	√	size exclusion
Cryptosporidium oocysts	> 3-log	√	size exclusion

Production Rate and Capacity

Inherent to the production rate and capacity of filtration devices is the quality of the raw water source. Because it is a squeeze bottle, the actual production rate is dependent on the user. The production capacity is stated by the manufacturer to be up to 800 L. On the ReFresh bottle, no production capacity is stated, rather it recommends that the filter be replaced every 3 months. Production capacity will vary widely with raw water quality (i.e., turbidity).

Cleaning, Replacement, and End of Life Indicator

The manufacturer states that the filter is reversible and can be backwashed, but no instructions accompany the device. The device contains no end of life indicator short of filter clogging.

Weight and Size

Dry weight	170 grams
Size (height x diameter)	25 cm x 7 cm

Cost

Bottle with filter	$15.00
Replacement filter (2 pack)	$13.00

Device Evaluation

No data was received that challenged the ReFresh Water Filtration System or the Military Water Purification System against reference 1. Data that was supplied by the manufacturer followed no apparent protocol and lacked vital information on the testing procedure, prohibiting data interpretation. General research on size exclusion by membranes indicates that this device should be capable of consistently reducing *Giardia* cysts and *Cryptosporidium* oocysts. This device is not likely capable of consistently reducing bacteria and viruses. Additional treatment is necessary to remove bacteria and viruses such as adding a disinfectant (e.g., chlorine, iodine, chlorine dioxide) to the bottle prior to filtering. No information was received stating whether the 0.4 µm rating by the manufacturer was a absolute or nominal rating, which allows for a large range of pore size. The activated carbon in the filter cartridge should remove tastes and odors. This device, like all filters with small pore sizes, is highly affected by turbid (cloudy) waters. Despite the manufacturer statement that the filter cartridge is reversible, it is recommended that this not be done, unless the quality of the water is known, since cross contamination can occur. Additionally, this should only be done to backwash the filter, after which the cartridge should be reversed back to the original orientation prior to consumption. Manufacturer claims on the ReFresh bottle packaging states removal claims are for “normal tap water”. It is unclear what this means, as the device is marketed to be used “whenever and wherever”, yet removal claims are limited to “normal tap water”. There is no indicator of process failure or end of device useful life. No information was received on the storage life or required conditions for this device. It is not expected that the membranes will be degraded during storage, but it is unclear if the proprietary resin requires special storage consideration.

Advantages

- Expected to consistently provide adequate protection from *Giardia* cysts and *Cryptosporidium* oocysts, although device-specific testing data using the USEPA Protocol is not available.
- No wait time prior to consumption.
- Provides taste and odor reduction.

Disadvantages

- Not expected to be consistently effective against bacteria and viruses.
- Additional treatment required
- Reduced production capacity when using high turbidity water.
- No real-time indicator of process failure.

References

1. USEPA, 1989. Guide Standard and Protocol for Testing Microbiological Water Purifiers. *Federal Register*. 54:34067.

2. U.S. Army Center for Health Promotion and Preventive Medicine. (2005). *Technical Information Paper; Filtration in the Use of Individual Water Purification Devices,* Aberdeen Proving Ground, MD.

Device Evaluation Update – February 2006

Independent laboratory results for testing conducted by NSF International were received that tested the DHK International, Inc., ReFresh Water Filtration System against the USEPA Guide Standard. Testing was conducted using the ceramic candle portion of the protocol with a production volume of 4 L/day for 10.5 days. The flow rate was 1.9 L/min. Results indicated that this device did not meet the minimum log reduction requirements for any of the pathogens tested. Geometric average log reduction was 1.8 log bacteria, 0.0 log virus, and 0.7 log *Cryptosporidium*. Testing was terminated at day 6 due to all replicate devices developing a hole in the pleated area of the squeeze bottle. Since testing was stopped at day 6, these devices were not tested against the more challenging type 2 (turbid) water. Our original pathogen reduction ratings were X bacteria, X virus, √ *Giardia*, and √ *Cryptosporidium* based on device technology. Based on this new data, it is questionable whether cyst reduction is likely, and it is unclear why a manufacturer stated 0.4µm membrane filter did not adequately reduce cysts. Until additional data becomes available indicating otherwise, it should be assumed that this device is incapable of adequate pathogen reduction and the new pathogen reduction ratings should be X bacteria, X virus, X *Giardia*, and X *Cryptosporidium*.

Updated Table. Expected Performance Against Microbial Pathogens.

Microbial Pathogen Type	Expected Disinfection Capability	Evaluation Rating	Primary Pathogen Reduction Mechanism
Bacteria	> 6-log	X	-
Viruses	> 4-log	X	-
Giardia cysts	> 3-log	X	size exclusion
Cryptosporidium oocysts	> 3-log	X	size exclusion

Reference:

Independent laboratory testing conducted November 2005. Testing sponsored by the Department of the Air Force, Air Force Materiel Command.

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ANNEX 9 TO APPENDIX E

DEVICE #9
DHK INTERNATIONAL, INC. – REFRESH™ MILITARY CANTEEN

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ANNEX 10 TO APPENDIX E

DEVICE EVALUATION #10
DJ INTERNATIONAL – PURE SIP™ PERSONAL WATER PURIFIER

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DJ International – Pure Sip™ Personal Water Purifier

www.djisales.com

Device Information

The DJ International Pure Sip Personal Water Purifier is a portable straw water treatment device. The device consists of a cigar size plastic straw with pull open mouthpiece, three cyst filter discs and end caps for each end of the straw. The device incorporates filtration and disinfection through the use of, in order of flow direction, filter (unknown material and pore size), iodinated resin (34 gr.), filter disc (material and pore size not stated), granular activated carbon (4.5 gr.), and 3 µm cyst filter (material not stated, testing data received claims 1 µm pore size). The device is used by inserting one of three supplied cyst filters into the mouthpiece cap, then simply placing the bottom of the straw into water and pulling water through straw by mouth suction. The manufacturer recommends discharging the first two mouthfuls of water to purge carbon fines. Device instruction state that device life is determined by the length of time and periods of use required for the filters to become clogged. The cyst filter should be replaced when suction through the unit becomes difficult. After the three cyst filters are used the instruction state to discard device. The manufacturer claims that a safety feature exists whereby the "capacity to purify and disinfect the water is greater than the filtering capacity of each purifier. The filter will clog before the purifying capacity of the unit is exhausted." The activated carbon should reduce taste and odor of the source water as well as at least some of the residual iodine taste and odor imparted by the resin. This device is assigned the GSA# GS-07F-0167K under the company DJ International. The manufacturer has applied for but not been issued an NSN#. This device is produced by Water One, Inc., and distributed by DJ International. It is unclear which company holds the trademark registration for this device.

Effectiveness Against Microbial Pathogens

Several laboratory reports (reference 1) were received testing this device to modified versions of the U.S. Environmental Protection Agency (USEPA) Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 2). Independent data showed this device capable of reducing bacteria concentrations by > 6-log, however, only out to a volume of 10 L. No testing

™ Pure Sip is a registered trademark of DJ International, Oakland, CA. Use of a trademarked product does not imply endorsement by the U.S. Army, but is intended only in identification of a specific product.

data received tested this device beyond the 10 L capacity. Bacterial reductions did not meet the requirements of reference 2 after the stagnation periods required in the protocol. This indicates substantial regrowth of bacteria within the unit. Independent testing on cyst reduction using 3-4 µm latex spheres showed just over 2-log reduction testing only to a volume of just over 2 L. The laboratory report indicates the possibility of bypass through the unit. Viral reduction testing was performed several times by different independent laboratories. Results show that this device is not capable of meeting the > 4-log reduction, as required in reference 2. The elevated turbidity stage of the testing proved difficult for the device to meet the requirements, with multiple filter changes required to produce the proposed 10 L volume. No testing was performed out to the manufacturer estimated volume of the device. An important finding from this testing is the concentration of residual iodine in the effluent water. Results show up to 11 mg/L in the effluent water indicating little reduction by the activated carbon and concern for users susceptible to iodine. Test results and general knowledge of filtration and iodinated resin (references 3 and 4) indicates that this device would likely be able to reduce bacteria by > 6-log, and would not meet the requirements for *Giardia* cysts (3-log), *Cryptosporidium* oocysts (3-log), or viruses (4-log). This device is not expected to meet these requirements out to the manufacturer stated capacity due to premature clogging in turbid waters. Based on this information the DJ International Pure Sip™ Personal Water Purifier is assigned one √ for bacteria, and one X each for *Giardia* cysts, *Cryptosporidium* oocysts, and viruses (for an explanation of the rating checks click here). The following table summarizes the device's expected effectiveness against microbial pathogens, evaluation rating, and the mechanism by which pathogens are removed or inactivated:

Table. Expected Performance Against Microbial Pathogens when Used as Directed.

Microbial Pathogen Type	Expected Performance	Evaluation Rating	Inactivation/removal Mechanism
Bacteria	> 6-log	√	iodine disinfection
Viruses	> 4-log	**X**	-
Giardia cysts	not effective	**X**	-
Cryptosporidium oocysts	not effective	**X**	-

Production Rate and Capacity

Inherent to the production rate and capacity of filtration devices is the quality of the raw water source. The actual production rate and capacity is dependent on the user and raw water quality. During testing of this device the production rate was targeted at 65 - 70 mL/min. The stated capacity is 35 - 115 L.

Cleaning, Replacement, End of Life Indicator

When suction by mouth becomes difficult the cyst filter should be changed. After the third cyst filter is clogged the device is to be discarded. The device is not capable of being cleaned or backwashed. Instructions recommend discarding the first two mouthfuls of water during the first use to remove carbon fines. This device contains no end of life indicator short of clogging. The manufacturer stated shelf life is up to 3 years. No expiration date or date of production is stated on the device or packaging.

Weight and Size

The dry weight of the device is stated by the manufacturer to be 100 grams. Dimensions are 3 cm diameter x 16 cm length.

Cost

The Pur Sip™ Straw costs $10.80 with a minimum order of 50 units. This device has not received registration as a biocide by the USEPA and is therefore not permitted to be sold within the United States. The manufacturer claims continued distribution to military organizations.

Device Evaluation

Based on evaluation of available data, the DJ International Pure Sip™ Personal Water Purifier is expected to provide 6-log bacteria under most water quality conditions expected until the unit clogs. This device will not consistently provide a 3-log *Giardia* cyst, 3-log *Cryptosporidium* oocyst, or 4-log virus reduction or inactivation. Additional treatment is required meet the requirements of the USEPA Guide Standard (reference 2). Iodine resin disinfection is the primary mechanism of bacteria inactivation. The iodine resin inactivates bacteria, viruses, and some *Giardia* cysts through direct contact with the resin as well as through the iodine residual the resin imparts to the water. The device will also provide some filtration and adsorption of all relevant pathogens due to the granular activated carbon and cyst filter disc. This device contains no indicator of process failure on a real-time basis and the end of device useful life is based on filter clogging. The manufacturer claims filter clogging prior to exhaustion of the iodinated resin. Inherent to treatment devices using filtration is the likelihood of clogging when processing highly turbid raw water. As seen in the laboratory testing results, this device is highly susceptible to clogging from particulate matter. If this device is used with water containing even slight cloudiness, it is not expected that this device will meet the manufacturer stated production capacity of 35 - 115 L. Based on data received, there is the possibility of a significant iodine residual in the consumed water, despite the post-resin activated carbon. The iodine resin and residual are not expected to cause any adverse health effects to healthy adults with no

pre-existing thyroid conditions or sensitivity to iodine. This device is not recommended for use by pregnant women (concern for fetus), people with known hypersensitivity to iodine, people with a history (or family history) of thyroid disease, and people from areas with chronic iodine deficiency (reference 3). The iodine residual imparted by the resin can cause a medicinal taste and color the water. Since the water is consumed directly from the device, neutralizers and flavor aids cannot be used to mask the iodine taste. This device is not approved by the USEPA for sale in the United States as a biocide and therefore must be purchased outside of the U.S. The manufacturer claims distribution to military organizations but this has not been verified.

Advantages

- Independent testing using a modified USEPA Protocol suggests that this device will provide 6-log bacteria inactivation when treating most water quality conditions expected.
- Small and lightweight.
- Simple to use.
- No adverse health effects expected in healthy adults with no iodine sensitivity.

Disadvantages

- Not effective against virus, *Giardia*, or *Cryptosporidium*. Additional treatment is necessary.
- Not recommended for use by pregnant women or people with iodine sensitivity.
- Device cannot be backwashed. Reduced production capacity in turbid waters.
- Can impart color and medicinal taste.
- No real-time indicator of process failure.

References

1. Laboratory challenge data obtained from the manufacturer.

2. USEPA, Registration Division Office of Pesticide Program, Criteria and Standards Division Office of Drinking Water. (1987). *Guide Standard and Protocol for Testing Microbiological Water Purifiers.* Washington, D.C.

3. U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM). (2005). *Technical Information Paper; Iodine Disinfection in the Use of Individual Water Purification Devices,* Aberdeen Proving Ground, MD.

4. USACHPPM. (2005). *Technical Information Paper; Filtration in the Use of Individual Water Purification Devices,* Aberdeen Proving Ground, MD.

ANNEX 11 TO APPENDIX E

DEVICE EVALUATION #11
GENERAL ECOLOGY, INC. – FIRST NEED® BASE CAMP

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General Ecology, Inc. – First Need® Base Camp

www.generalecology.com

Device Information

The General Ecology, Inc., First Need® Base Camp is a portable pump water treatment device utilizing what the manufacturer calls a proprietary "structured matrix" media for pathogen reduction. According to the manufacturer, the reduction process consists of microfiltration (0.1 nominal, 0.4 absolute pore size), chemical adsorption, and electrochemical attraction. The proprietary media consists of a block of activated carbon treated to enhance retention of viruses and other microorganisms by way of association with the media surface. The device consists of a coarse metal screen pre-filter, finer mesh pre-filter cartridge, hand pump, filter canister within a stainless steel housing, and effluent spout. All components are connected by flexible tubing. The user places the influent tubing and coarse pre-filter into the raw water source, strokes the hand pump and water is forced through the device and out of the spout whereby a user supplied vessel captures the purified water. The device also comes with blue dye for filter canister integrity testing and a padded water resistant storage bag.

Effectiveness Against Microbial Pathogens

Results from an independent study using the General Ecology First Need Deluxe (reference 1 and 2) show that when challenged against the U.S. Environmental Protection Agency (USEPA) Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 3), that device met the pathogen log reductions, shown below, based on geometric averages of three identical devices. During testing, production capacity was set at 378 L per device and flowrate at 0.476 L/min, both below the manufacturer stated values. The First Need Base Camp device uses the same removal canister as the First Need Deluxe so similar results can be expected. Since the data reviewed was for not for the Base Camp and was for a production rate and capacity below the manufacturer stated rates, one √ is assigned for pathogen reduction (click here for rating explanation), indicating that expert opinion expects this device to meet the requirements of reference 1. More data, specific to this device, is required for a higher rating.

® First Need is a registered trademark of General Ecology, Inc., Exton, PA. Use of trademarked products does not imply endorsement by the U.S. Army, but is intended only in identification of a specific product.

Table. Expected Performance Against Microbial Pathogens.

Microbial Pathogen Type	Expected Disinfection Capability	Evaluation Rating	Primary Pathogen Reduction Mechanism
Bacteria	> 6-log	√	size exclusion
Viruses	> 4-log	√	electrostatic attraction
Giardia cysts	> 3-log	√	size exclusion
Cryptosporidium oocysts	> 3-log	√	size exclusion

Production Rate and Capacity

Inherent to the production rate and capacity of filtration devices is the quality of the raw water source. Manufacturer stated production rate is 1.9 L/min, and overall capacity of the media canister is 1900 L based on what the manufacturer calls "clean wilderness waters." Capacity will vary widely with raw water turbidity. The flowrate used during microbial pathogen studies was 0.476 L/min and 378 L, far below the 1.9 L/min and 1900 L manufacturer stated flowrate and production capacity during normal operation.

Cleaning, Replacement, and End of Life Indicator

The filter canister cannot be backwashed. When pumping becomes difficult during normal operation or when 1900L have passed through the device, the filter canister should be replaced. For long term storage the manufacturer recommends passing one pint of dilute bleach (1/6 tsp / pint) through the device then flushing the device and tubing with clean water. The prefilters can be backwashed by changing tubing configuration to reverse flow direction. The hand pump can be serviced by disassembling and cleaning. Device instructions state to conduct integrity testing prior to each trip, and if device freezes or is subject to shock loads. Integrity testing consists of adding provided blue food dye to water then pumping it through the device. If even the faintest of blue color is present in the processed water, the canister must be replaced.

Weight and Size

The dry weight of the device is estimated to be about 2000 grams. Dimensions are as follows:

Overall dimensions collapsed (height x width x length)	15 cm x 18 cm x 25 cm
Pressure vessel (diameter x height)	20 cm x 13 cm

Pump height	26.7 cm
Inlet hose with pre-filter	88.9 cm

Cost

Complete device	$557.00
Replacement canister	$75.00

Device Evaluation

No data was received specific to challenging the General Ecology, Inc., First Need Base Camp against reference 3. Based upon independent published data (reference 1) reviewed for the General Ecology First Need Deluxe, utilizing the same treatment technology, the First Need Base Camp should be capable of meeting the requirements of reference 3. Bacteria and cyst reduction based on size exclusion by microfiltration is a proven technology and an intact membrane will effectively reject these microbes (reference 4). Virus removal by the "structured matrix" is based on electrochemical attraction, and although shown to be effective under laboratory conditions, is not considered as consistent of a reduction mechanism as size exclusion. Virus attraction to solid surfaces is highly affected by virus type, charge, and water pH, and therefore, removal efficacy is highly variable (reference 5). There also exists the possibility for release of previously attracted viruses from this media under certain water quality conditions. Since this device utilizes electrochemical adsorption, the flowrate through the device can have a dramatic effect on pathogen reduction. To ensure safe water production, the device should not be operated above the flowrate of 0.476 L/min or beyond the production capacity of 378 L, the flowrate and capacity shown to meet the above pathogen reductions (reference 1). Users cannot be expected to regulate flowrate during production, adding uncertainty to the expected virus reduction claims, and stressing the importance of laboratory testing at device recommended conditions. This device requires no chemical addition and no wait time prior to water consumption. There is no indicator of process failure on a real-time basis, and end of device useful life is based on integrity testing, filter clogging, or by the user keeping track of the volume of water purified. Inherent to treatment devices utilizing small pore size membranes is the likelihood of clogging when processing highly turbid raw water. Although this device uses two backwashable pre-filters, this inherent disadvantage is still valid. According to manufacturer instructions, during backwashing of the canister, the pump influent is to be placed into clean water. This requires the user to have access to an additional clean container, as once the pump inlet is placed into the clean container it is now contaminated with raw water. The user's drinking water vessel should not be used as the source for backwashing. Integrity testing of the device, recommended before expected use and after freezing of device, entails visual inspection of product water after placing blue dye in the raw source. The ability of the user to detect slight

color change is uncertain, making this a questionable technique for determining device failure. Device instructions state not to allow device to freeze. Device temperature range stated at 33 - 145º F. No storage life is stated.

Advantages

- Independent testing for a device utilizing the same technology confirms bacteria, virus, and protozoan reduction in accordance with the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 3) at a reduced flowrate and production capacity.
- No chemicals required.
- No wait time prior to consumption.
- Pre-filters capable of backwashing to remove accumulated debris.

Disadvantages

- No data supplied for this specific device that shows pathogen reduction in accordance with the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 3).
- Testing for pathogen reduction efficacy was not conducted at manufacturer stated flow conditions, making applicability of results to actual use questionable.
- Electrochemical virus attraction by proprietary media is not widely proven technology and efficacy may be affected by raw water quality.
- No ability to backwash filter canister once clogged.
- Mechanical sieving inherently prone to clogging with high turbidity waters.
- No real-time indicator of process failure.

References

1. Gerba, C.P., and Naranjo, J.E., 2000. Microbiological Water Purification Without the Use of Chemical Disinfection. *Wilderness and Environmental Medicine*. 11:12-16.

2. Independent laboratory results of tests showing compliance with the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers, 1995. Provided by General Ecology.

3. USEPA, 1989. Guide Standard and Protocol for Testing Microbiological Water Purifiers. *Federal Register*. 54:34067.

4. U.S. Army Center for Health Promotion and Preventive Medicine, 2005. *Technical Information Paper; Filtration in the Use of Individual Water Purification Devices*, Aberdeen Proving Ground, MD.

5. Gerba, C.P., 1984. Applied and Theoretical Aspects of Virus Adsorption to Surfaces. *Advances in Applied Microbiology*. 30:133-168.

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ANNEX 12 TO APPENDIX E

DEVICE EVALUATION #12
GENERAL ECOLOGY, INC. – FIRST NEED® DELUXE

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General Ecology, Inc. – First Need® Deluxe

www.generalecology.com

Device Information

The General Ecology, Inc. First Need Deluxe is a handheld pump water treatment device utilizing what the manufacturer calls a proprietary "structured matrix" media for pathogen reduction. According to the manufacturer, the reduction process consists of microfiltration (0.1 nominal, 0.4 absolute pore size), chemical adsorption, and electrochemical attraction. The proprietary media consists of a block of activated carbon treated to enhance retention of viruses and other microorganisms by way of association with the media surface. The device consists of inlet tubing with pre-filter, enclosed canister containing the media, and a hand pump. The bottom of the canister is fitted with threads to attach directly to wide mouth drinking bottles, such as Nalgene® bottles, or the device can be held above any container suitable for receiving the treated water. An adaptor is available to allow the canister to directly attach to the fill port of personal hydration systems (e.g., Camelbak®). Using a bag included with the device, water may be produced by gravity flow without the need for pumping in what the manufacturer terms "matrix pumping."

Effectiveness Against Microbial Pathogens

Results from an independent study (references 1, 2) show that when challenged against the U.S. Environmental Protection Agency (USEPA) Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 3), this device meets the pathogen log reduction requirements, shown below, based on geometric averages of three identical devices for a production capacity of 378 L per device at a flowrate of 0.476 L/min. Pathogen reduction is based on size exclusion and electrostatic attraction as shown in the Table. Because this device was not tested according to the manufacturer stated flowrate and production capacity, one √ is

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® Nalgene is a registered trademark of Nalge Nunc International Corporation, Rochester, NY.
® Camelbak is a registered trademark of CamelBak Products, Inc., Petaluma, CA. Use of trademarked products does not imply endorsement by the U.S. Army, but is intended only in identification of a specific product.

assigned for pathogen reduction (click here for rating explanation), indicating that expert opinion expects this device to meet the requirements of reference 3, but no data was available to confirm pathogen reductions.

Table. Expected Performance Against Microbial Pathogens.

Microbial Pathogen Type	Expected Disinfection Capability	Evaluation Rating	Primary Pathogen Reduction Mechanism
Bacteria	> 6-log	√	size exclusion
Viruses	> 4-log	√	electrostatic attraction
Giardia cysts	> 3-log	√	size exclusion
Cryptosporidium oocysts	> 3-log	√	size exclusion

Production Rate and Capacity

Inherent to the production rate and capacity of filtration devices is the quality of the raw water source. Manufacturer stated production rate is 1.75 L/min, and overall capacity of the media canister is 500 L. Capacity will vary widely with raw water turbidity. The flowrate used during microbial pathogen studies was 0.476 L/min, far below the 1.75 L/min manufacturer stated flowrate recommended during normal operation.

Cleaning, Replacement, and End of Life Indicator

When pumping becomes difficult the canister can be backwashed according to manufacturer instructions. The hand pump is attached to the outlet of the canister and clean water is pumped in the opposite direction of normal operation. The manufacturer recommends passing dilute bleach through the device following backwash. Once the canister has reached the 500 L production capacity, or when backwashing does not restore flow, the canister must be discarded and replaced with a new unit. The hand pump and housing can be washed with mild detergent and clean water. Device instructions state to conduct integrity testing prior to each trip, and if device freezes or is subject to shock loads. Integrity testing consists of adding the provided blue food dye to water then pumping it through the device. If even the faintest of blue color is present in the processed water, the canister must be replaced.

Weight and Size

The dry weight of the device is 430 grams (does not include container for treated water). Dimensions are as follows:

Overall (height x width x length)	13 cm x 7 cm x 16 cm
Canister (diameter x height)	7 cm x 10 cm
Pump length	14 cm
Inlet tubing	91 cm
Prefilter length	8 cm

Cost

First Need® Deluxe	$93.00
Replacement canister	$42.00
Wide mouth adaptor for hydration packs	$5.25
Narrow mouth adaptor	$5.25

Device Evaluation

The General Ecology, Inc., First Need Deluxe has been shown, based on independent published data (reference 1), to be capable of meeting the requirements of reference 3 at a reduced flowrate. Bacteria and cyst reduction, based on size exclusion by microfiltration, is a proven technology and an intact membrane will effectively reject these microbes (reference 4). Virus removal by the "structured matrix" is based on electrostatic attraction, and although shown to be effective under laboratory conditions, is not considered as consistent of a reduction mechanism as size exclusion. Virus attraction to solid surfaces is highly affected by virus type, charge, and water pH, and therefore, removal efficacy is highly variable (reference 5). There also exists the possibility for release of previously attracted viruses from this media under certain water quality conditions. Since this device utilizes electrochemical adsorption, the flowrate through the device can have a dramatic effect on pathogen reduction. To ensure safe water production, the device should not be operated above the flowrate of 0.476 L/min or beyond the production capacity of 378 L, the flowrate and capacity shown to meet the above pathogen reductions (references 1,2). Users cannot be expected to regulate flowrate during production, adding uncertainty to the expected virus reduction claims, and stressing the importance of laboratory testing at device recommended conditions. The filter media contains activated carbon that uses adsorption for virus removal. The carbon has a finite number of sites for virus adsorption and, once exhausted, the ability of the device to remove viruses is questionable. This device requires no chemical addition and no wait time prior to water consumption. There is no indicator of process failure on

a real-time basis, and end of device useful life is based on integrity testing, filter clogging, or by the user keeping track of the volume of water purified. Inherent to treatment devices utilizing small pore size membranes is the likelihood of clogging when processing highly turbid raw water. Although this device uses a pre-filter and is able to be backwashed, this inherent disadvantage is still valid. The manufacturer claims that "matrix pumping" (gravity flow) will work even if canister is clogged. According to manufacturer instructions, during backwashing of the canister the pump influent is to be placed into clean water. This requires the user to have access to an additional clean container, as once the pump inlet is placed into the clean container it is now contaminated from the pump. The user's drinking water vessel should not be used as the source for backwashing. Manufacturer recommendations require the user to supply chlorine bleach for use during backwashing for long term storage. When backwashing, pumping in the reverse direction through the canister can possibly contaminate the effluent side of the canister with residue in the pump. This cross contamination is possible with or without bleach if chlorine resistant organisms are present in the pump. Integrity testing of the device, recommended before expected use and after freezing of device, entails visual inspection of product water after placing blue dye in the raw source. The ability of the user to detect slight color change is uncertain, making this a questionable technique for determining device failure. Device instructions state to store device in clean, dry area away from fumes but gives no storage life.

Advantages

- Independent testing confirms bacteria, virus, and protozoan reduction in accordance with the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 3) but at a reduced flowrate.
- No chemicals required.
- No wait time prior to consumption.
- Device capable of backwashing to restore clogged filter.

Disadvantages

- Electrochemical virus attraction by proprietary media is not widely proven technology and efficacy may be affected by raw water quality.
- Testing for pathogen reduction efficacy was not conducted at manufacturer stated flow conditions, making applicability of results to actual use questionable.
- Mechanical sieving inherently prone to clogging with high turbidity waters.
- Backwashing requires access to a clean container and household bleach with a potential for cross contamination.
- No real-time indicator of process failure.

References

1. Gerba, C.P., and Naranjo, J.E., 2000. Microbiological Water Purification Without the Use of Chemical Disinfection. *Wilderness and Environmental Medicine*. 11:12-16.

2. Independent laboratory results of tests showing compliance with the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers, 1995. Provided by General Ecology.
3. USEPA, 1989. Guide Standard and Protocol for Testing Microbiological Water Purifiers. *Federal Register*. 54:34067.

4. U.S. Army Center for Health Promotion and Preventive Medicine, 2005. *Technical Information Paper; Filtration in the Use of Individual Water Purification Devices,* Aberdeen Proving Ground, MD.

5. Gerba, C.P., 1984. Applied and Theoretical Aspects of Virus Adsorption to Surfaces. *Advances in Applied Microbiology*. 30:133-168.

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ANNEX 13 TO APPENDIX E

DEVICE EVALUATION #13
GENERAL ECOLOGY, INC. – FIRST NEED® TRAV-L-PURE

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General Ecology, Inc. – First Need® Trav-L-Pure

www.generalecology.com

Device Information

The General Ecology, Inc., First Need Trav-L-Pure is a handheld pump water treatment device utilizing what the manufacturer calls a proprietary "structured matrix" media for pathogen reduction. According to the manufacturer, the reduction process consists of microfiltration (0.1 nominal, 0.4 absolute pore size), chemical adsorption, and electrochemical attraction. The proprietary media consists of a block of activated carbon treated to enhance retention of viruses and other microorganisms by way of association with the media surface. The device consists of a black plastic housing containing a pump, filter canister, and two pre-filters. Raw water is poured through the first pre-filter and into the plastic housing. As the pump is operated, creating pressure on the down stroke only, water is forced through the second prefilter, up through the filter canister and out of the effluent spout. The user places a clean container under the spout to capture the purified water. The device is a single purification unit with plastic lid, blue dye for integrity testing, and a water resistant carrying bag with shoulder strap.

Effectiveness Against Microbial Pathogens

No data was received specific to this device. Results from an independent study using the General Ecology First Need Deluxe (reference 1, 2) show that when challenged against the U.S. Environmental Protection Agency (USEPA) Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 3), that device met the required pathogen log reductions, based on geometric averages of three identical devices. During testing, production capacity was set at 378 L per device and flowrate at 0.476 L/min, both below the manufacturer stated values. The Trav-L-Pure device uses the same removal canister as the First Need Deluxe so similar results can be expected. Since the data reviewed was for not for the Trav-L-Pure and was for a production rate below the manufacturer stated rate, one √ is assigned for pathogen reduction (click here for rating explanation), indicating that expert opinion expects this device to meet the requirements of reference 1. More data, specific to this device, is required for a higher rating.

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Table. Expected Performance Against Microbial Pathogens.

Microbial Pathogen Type	Expected Disinfection Capability	Evaluation Rating	Primary Pathogen Reduction Mechanism
Bacteria	> 6-log	√	size exclusion
Viruses	> 4-log	√	electrostatic attraction
Giardia cysts	> 3-log	√	size exclusion
Cryptosporidium oocysts	> 3-log	√	size exclusion

Production Rate and Capacity

Inherent to the production rate and capacity of filtration devices is the quality of the raw water source. Manufacturer stated production rate is 1.25 L/min, and overall capacity of the media canister is 400 L. Capacity will vary widely with raw water turbidity. The flowrate used during microbial pathogen studies was 0.476 L/min, far below the 1.25 L/min manufacturer stated flowrate during normal operation.

Cleaning, Replacement, and End of Life Indicator

When pumping becomes difficult or after 400 L of water have passed through the device the canister must be replaced. This device is not capable of being backwashed. Instructions recommend that the device be flushed with 1 pint of dilute bleach (0.25 tsp / gallon) or iodine solution before and after periods of extended storage. Device instructions state to conduct integrity testing prior to each trip, and if device freezes or is subject to shock loads. Integrity testing consists of adding provided blue food dye to water then pumping it through the device. If even the faintest of blue color is present in the processed water, the canister must be replaced.

Weight and Size

The dry weight of the device is 630 grams including the 0.65 L canteen. Dimensions are 16.8 cm x 11.2 cm x 8.4 cm (length x width x height).

Cost

Trav-L-Pure	$156.00
Replacement canister	$42.00

Device Evaluation

No data was received specific to challenging the General Ecology, Inc., First Need Trav-L-Pure against reference 3. Based upon independent published data (reference 1) reviewed for the General Ecology First Need Deluxe, utilizing the same treatment technology, the First Need Trav-L-Pure should be capable of meeting the requirements of reference 3. Bacteria and cyst reduction based on size exclusion by microfiltration is a proven technology and an intact membrane will effectively reject these microbes (reference 4). Virus removal by the "structured matrix" is based on electrochemical attraction, and although shown to be effective under laboratory conditions, is not considered as consistent of a reduction mechanism as size exclusion. Virus attraction to solid surfaces is highly affected by virus type, charge, and water pH, and therefore, removal efficacy is highly variable (reference 5). There also exists the possibility for release of previously attracted viruses from this media under certain water quality conditions. Since this device utilizes electrochemical adsorption, the flowrate through the device can have a dramatic effect on pathogen reduction. To ensure safe water production, the device should not be operated above the flowrate of 0.476 L/min or beyond the production capacity of 378 L, the flowrate and capacity shown to meet the above pathogen reductions (reference 1). Users cannot be expected to regulate flowrate during production, adding uncertainty to the expected virus reduction claims, and stressing the importance of laboratory testing at device recommended conditions. The filter media contains activated carbon that uses adsorption for virus removal. The carbon has a finite number of sites for virus adsorption and once exhausted the ability of the device to remove viruses is questionable. This device requires no chemical addition and no wait time prior to water consumption. There is no indicator of process failure on a real-time basis, and the end of device useful life is based on integrity testing, filter clogging, or by the user keeping track of the volume of water purified. Inherent to treatment devices utilizing small pore size membranes is the likelihood of clogging when processing highly turbid raw water. Depending on source water quality, device production capacity may vary widely. Although this device uses two pre-filters, this inherent disadvantage is still valid. Integrity testing of the device, recommended before expected use and after freezing of device, entails visual inspection of product water after placing blue dye in the raw source. The ability of the user to detect slight color change is uncertain, making this a questionable technique for determining device failure. Device instructions state not to allow device to freeze. Device temperature range stated at 33 - 145º F. No storage life is stated.

Advantages

- Independent testing for a device utilizing the same technology confirms bacteria, virus, and protozoan reduction in accordance with the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 3) at a reduced flowrate and production capacity.
- No chemicals required.
- No wait time prior to consumption.

Disadvantages

- No data supplied for this specific device that shows pathogen reduction in accordance with the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 3).
- Testing for pathogen reduction efficacy was not conducted at manufacturer stated flow conditions, making applicability of results to actual use questionable.
- Electrochemical virus attraction by proprietary media is not widely proven technology and efficacy may be affected by raw water quality.
- Mechanical sieving inherently prone to clogging with high turbidity waters.
- No ability to backwash device once filter clogs.
- No real-time indicator of process failure.

References

1. Gerba, C.P., and Naranjo, J.E., 2000. Microbiological Water Purification Without the Use of Chemical Disinfection. *Wilderness and Environmental Medicine*. 11:12-16.

2. Independent laboratory results of tests showing compliance with the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifier, 1995. Provided by General Ecology.

3. USEPA, 1989. Guide Standard and Protocol for Testing Microbiological Water Purifiers. *Federal Register*. 54:34067.

4. U.S. Army Center for Health Promotion and Preventive Medicine, 2005. *Technical Information Paper; Filtration in the Use of Individual Water Purification Devices*, Aberdeen Proving Ground, MD.

5. Gerba, C.P., 1984. Applied and Theoretical Aspects of Virus Adsorption to Surfaces. *Advances in Applied Microbiology*. 30:133-168.

ANNEX 14 TO APPENDIX E

DEVICE EVALUATION #14
HYDRATION TECHNOLOGIES, INC. – HYDROPACK

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Hydration Technologies, Inc. – HydroPack

www.hydrationtech.com

Device Information

The Hydration Technologies, Inc., HydroPack is a portable passive water treatment device utilizing an osmotic membrane for pathogen reduction. The device consists of a 2 L vinyl bag with a semi-permeable membrane on one side. According to the manufacturer, the membrane, although unlike conventional porous membranes, is equivalent to having a pore size of 0.0005 µm. This device uses no pumping to process the water, but rather uses osmotic potential across the membrane as a driving force. The bag is placed directly into the raw water source and a nutrient charge of sugar and electrolytes in the bag pulls water across the membrane by creating an osmotic potential. To reduce this potential and equilibrate the solute concentration across the membrane, water is drawn from the less concentrated to the more concentrated side of the membrane until equilibrium is reached. The finished product is a sports drink similar to Gatorade®. Water production rate is proportional to solute gradient. The following nutrition information was approximated based on the X Pack, the reusable version of the HydroPack (Table 1). This information is based per charge (single use), recommended for the production of 2 L of product at 3.6% solution.

Table 1. HydroPack Nutrient Charge Nutritional Information.

Parameter	Value/2L Product
Calories	293
Total Fat	0 g
Sodium	40 g
Potassium	166 g
Sugars	73 g
Protein	0 g

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Ingredients: fructose, water, citric acid, lime extract, sweetness enhancer, potassium citrate, sodium citrate, sodium benzoate, potassium sorbate.
Note: According to the manufacturer, the nutrient charge is undergoing reformulation.

Effectiveness Against Microbial Pathogens

Manufacturer in-house data showed virus reduction in excess of 4-log (reference 1). Results from an independent laboratory for a similar device (HTI, Inc., X Pack) show bacteria reduction in excess of 6-log (reference 2). No results were received that tested this device against the U.S. Environmental Protection Agency (USEPA) Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 3). Expert opinion states that this technology should be capable of meeting the log reduction requirements shown below when tested against the USEPA Standard for the manufacturer rated capacity of the device. The removal mechanism of osmotic membranes is complex, but can be considered to be based on size exclusion utilizing very small pores that reject even dissolved contaminants. Based on the absence of independent results challenged against reference 3, this device is assigned a rating of one √ for the reduction of each pathogen (click here for rating explanation), indicating that expert opinion expects this device to meet the requirements of reference 3 (Table 2).

Table 2. Expected Performance Against Microbial Pathogens.

Microbial Pathogen Type	Expected Disinfection Capability	Evaluation Rating	Primary Pathogen Reduction Mechanism
Bacteria	> 6-log	√	size exclusion
Viruses	> 4-log	√	size exclusion
Giardia cysts	> 3-log	√	size exclusion
Cryptosporidium oocysts	> 3-log	√	size exclusion

Production Rate and Capacity

Production rate and capacity of this device is dependant upon solute gradient across the membrane and temperature. Manufacturer stated production rate is 1 L/6 hrs at 68º F. This device is designed for one use and is capable of producing 2 L of drink. Unlike porous pressure driven filter devices, turbidity does not affect the production capacity or rate.

Cleaning, Replacement, and End of Life Indicator

The HydroPack is a single use, disposable device not designed to be cleaned or reused.

Weight and Size

The dry weight of the device is about 300 grams.
Dimensions are (H x W x L) 4 cm x 10 cm x 18 cm.

Cost

HydroPack device	$18.00

Device Evaluation

No laboratory data was received or the Hydration Technologies, Inc., HydroPack challenging the device against the standards in reference 3. Since the device utilizes the same membrane as the Hydration Technologies, Inc., X Pack, the results showing > 6-log reduction of bacteria for that device apply to the HydroPack. Based on the characteristics of osmotic membranes, reduction of viruses (> 4-log) and cysts (> 3-log) to the standards of reference 3 should be obtainable (reference 4). This device entails a single step with no chemicals required or residuals added. The device is placed into the raw water source and must remain in the source or the duration of production. When placing the device into the raw source care should be taken to maintain the drink port above the water surface to prevent possible contamination. The driving force for water purification consists of a gradient in sugar and electrolyte concentration. To create this gradient a powder or liquid nutrient charge is inside the device. Because if this, the liquid produced is not water, but a drink similar to commercial sports drinks. The concentration of the drink with respect to sugar content can be adjusted by the user by consuming the drink prior to production completion or by pouring out some of the charge prior to use. Since drink production is related to solute gradient, producing a drink that is more dilute will require increased production time. Therefore, the already extremely slow production rate of 1 L every 6 - 8 hours increases. Conversely, creating a more concentrated drink will take less time, but will lower the overall amount of drink produced per device. Two other conditions that affect drink production, but to a lesser extent, are water temperature (increase in temperature will increase production rate) and the movement of the bag (slight movement or shaking periodically will increase production rate). The device is designed for single use with a capacity of 2 L. Care must be taken during storage and transport not to puncture or excessively abuse the bag by folding or creasing. Prior to consumption, the liquid in the bag should be observed to confirm that it is not similar in characteristics (color, cloudiness) to the raw water source. If the liquid in

the bag resembles that of the raw source then the membrane may be defective and device and liquid should be discarded without consumption. This device has no real-time indicator of process failure. Small defects in the membrane may allow pathogens to enter the product bag and be consumed without notice. The manufacturer states a storage life of 3 years when kept below 90º F.

Advantages

- Technology is capable of reducing microbial pathogens in accordance with the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 3).
- Osmotic membrane capable of rejecting microbial pathogens and most all other environmental contaminants.
- No chemicals required.
- Unaffected by raw water turbidity.

Disadvantages

- No test results showing compliance with the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 3).
- Extremely slow production rate.
- Single use, able to process only 2 L of product.
- Device must remain in raw water source for duration of product drink production.
- No real-time indicator of process failure.
- Does not produce water; product is similar to a sports drink.

References

1. Manufacturer in-house laboratory test results showing > 4-log reduction of virus, 2003. Provided by HTI.

2. Independent laboratory results of tests showing >6 log reduction of bacteria, 2001. Provided by HTI.

3. USEPA, 1989. Guide Standard and Protocol for Testing Microbiological Water Purifiers. *Federal Register*. 54:34067.

4. U.S. Army Center for Health Promotion and Preventive Medicine, 2005. *Technical Information Paper; Filtration in the Use of Individual Water Purification Devices,* Aberdeen Proving Ground, MD.

ANNEX 15 TO APPENDIX E

DEVICE EVALUATION #15
HYDRATION TECHNOLOGIES, INC. – HYDROWELL 24

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Hydration Technologies, Inc. – HydroWell 24

www.hydrationtech.com

Device Information

The Hydration Technologies, Inc., (HTI) HydroWell 24 is a portable passive water treatment device utilizing an osmotic membrane for pathogen reduction. This device is designed for group use, to be left stationary during operation. The device consists of a plastic bucket with enclosed osmotic membrane cartridge, 5 vinyl 1.6 L nutrient charge syrup bags, and cleaning supplies (metabisulfite solution). The device requires the user to supply the collection vessel for product drink. The membrane cartridge utilizes the same semi-permeable membrane as other HTI products (Hydropack, X Pack), with greater surface area for increased production rate. According to the manufacturer, the membrane, although unlike conventional porous membranes, is equivalent to having a pore size of 0.0005 µm. This device uses no pumping to process the water, but rather uses osmotic potential across the membrane as a driving force. A nutrient charge of sugar and electrolytes pulls water across the membrane by creating an osmotic potential. To reduce this potential and equilibrate the solute concentration across the membrane, water is drawn from the less concentrated to the more concentrated side of the membrane until equilibrium is reached. The finished product is a sports drink similar to Gatorade®. Water production rate is proportional to solute gradient. The following nutrition information was approximated based on data from the HTI X Pack device, but substituting a 3% solution for the HydroWell 24 drink produced (Table 1). This information is based per 1 L drink produced.

Table 1. HydroWell 24 Nutrient Charge Nutritional Information.

Parameter	Value/L Product
Calories	122
Total Fat	0 g
Sodium	17 g
Potassium	69 g
Sugars	30 g
Protein	0 g

® Gatorade is a registered trademark of the Quaker Oats Co., Chicago, IL. Use of trademarked products does not imply endorsement by the U.S. Army, but is intended only in identification of a specific product.

Ingredients: fructose, water, citric acid, lime extract, sweetness enhancer, potassium citrate, sodium citrate, sodium benzoate, potassium sorbate.
Note: According to the manufacturer, the nutrient charge is undergoing reformulation.

Effectiveness Against Microbial Pathogens

Manufacturer in-house data showed virus reduction in excess of 4-log (reference 1). Results from an independent laboratory for a similar device (HTI, Inc., X Pack) show bacteria reduction in excess of 6-log (reference 2). No results were received that tested this device against the U.S. Environmental Protection Agency (USEPA) Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 3). Expert opinion states that this technology should be capable of meeting the log reduction requirements shown below when tested against the USEPA Standard for the manufacturer rated capacity of the device. The removal mechanism of osmotic membranes is complex but can be considered to be based on size exclusion utilizing very small pores that reject even dissolved contaminants. Based on the absence of independent results challenged against reference 3, this device is assigned a rating of one √ for the reduction of each pathogen (click here for rating explanation), indicating that expert opinion expects this device to meet the requirements of reference 3 (Table 2).

Table 2. Expected Performance Against Microbial Pathogens.

Microbial Pathogen Type	Expected Disinfection Capability	Evaluation Rating	Primary Pathogen Reduction Mechanism
Bacteria	> 6-log	√	size exclusion
Viruses	> 4-log	√	size exclusion
Giardia cysts	> 3-log	√	size exclusion
Cryptosporidium oocysts	> 3-log	√	size exclusion

Production Rate and Capacity

Production rate and capacity of this device is dependant upon solute gradient across the membrane and temperature. Manufacturer stated production rate is 1 L/hr at 68º F (0.017 L/min). The production capacity is 24 L per day with a useful life of 30 days. Unlike porous pressure driven filter devices, turbidity does not affect the production capacity or rate.

Cleaning, Replacement, and End of Life Indicator

The HydroWell 24 is designed for 30 days of use with flushing every 3 - 7 days. The device has no real-time end of life indicator. This device is purchased with 5 1.6 L nutrient charges, capable of producing water continuously for about 13 days. Additional nutrient charges can be purchased for water production of up to 30 days. At the end of 30 days from first use the device should be discarded.

Weight and Size

The dry weight of the device is 16,300 grams.
Dimensions are (H x W x L) 40 cm x 33 cm x 34 cm.

Cost

HydroWell 24 (nutrient charges for 320 L)	$294.00
Resupply Kit (nutrient charges for 320 L)	$57.00

Device Evaluation

No laboratory data was received for the Hydration Technologies, Inc., HydroWell 24 challenging the device against the standards in reference 3. Since the device utilizes the same membrane, but in a different configuration, as the Hydration Technologies, Inc., X Pack, the results showing > 6-log reduction of bacteria for that device apply to the HydroWell 24. Based on the characteristics of osmotic membranes, reduction of viruses (> 4-log) and cysts (> 3-log) should be obtainable (reference 4). Since nutrient charge is necessary to create the osmotic potential, the liquid produced is not water, but a drink similar to commercial sports drinks. The device is designed to be used for 30 days with cleaning every 3 - 7 days for a total capacity of 720 L. This is a large device, designed for multiple users and once set-up to process water should remain in a stable environment. This device has no real-time indicator of process failure. Small defects in the membrane may allow pathogens across the membrane and be consumed without notice. No information was received as to the cleaning process for this device. Cleaning should be assumed to follow that for the HTI, Inc., Hydrowell Expedition. The manufacturer states a storage life of 3 years when kept below 90º F.

Advantages

- Technology is capable of reducing microbial pathogens in accordance with the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 3).

- Osmotic membrane capable of rejecting microbial pathogens and most all other environmental contaminants.
- No chemicals required.
- Unaffected by raw water turbidity.

Disadvantages

- No test results showing compliance with the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 3).
- Slow production rate.
- Not portable once water processing is initiated.
- Large size, not for individual use.
- No real-time indicator of process failure.
- Does not produce water; product is similar to a sports drink.

References

1. Manufacturer in-house laboratory test results showing >4 log reduction of virus, 2003. Provided by HTI.

2. Independent laboratory results of tests showing >6 log reduction of bacteria, 2001. Provided by HTI.

3. USEPA, 1989. Guide Standard and Protocol for Testing Microbiological Water Purifiers. *Federal Register*. 54:34067.

4. U.S. Army Center for Health Promotion and Preventive Medicine, 2005. *Technical Information Paper; Filtration in the Use of Individual Water Purification Devices,* Aberdeen Proving Ground, MD.

ANNEX 16 TO APPENDIX E

DEVICE EVALUATION #16
HYDRATION TECHNOLOGIES, INC. – HYDROWELL EXPEDITION

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Hydration Technologies, Inc. – HydroWell Expedition

www.hydrationtech.com

Device Information

The Hydration Technologies, Inc., (HTI) HydroWell Expedition is a portable passive water treatment device utilizing an osmotic membrane for pathogen reduction. The device consists of a vinyl hydration pack bladder with enclosed osmotic membrane cartridge, ten 4-ounce nutrient charge syrup containers, 1 bottle Potable Aqua™ iodine tablets (50 count), 1 bottle Campden Tablets (10 count, 100-mg sodium metabisulfite, 150 mg dextrose), 1 bottle test dye tablets (10 count), 2 bottles preservative solution (10 ml 14% sodium metabisulfite in water), collapsible cup, and hand pump bulb. The device requires the user to supply a hydration pack backpack capable of holding a 100 ounce bladder. The membrane cartridge utilizes the same semi-permeable membrane as other HTI products (Hydropack, X Pack), in a spiral wound configuration for greater surface area and increased production rate. According to the manufacturer, the membrane, although unlike conventional porous membranes, is equivalent to having a pore size of 0.0005 µm. This device uses no pumping to process the water, but rather uses osmotic potential across the membrane as a driving force. The raw water bag and nutrient charge bag are connected to the membrane cartridge. Through suction on the bite tube, the user pulls nutrient charge into the membrane cartridge which pulls the water across the membrane by creating an osmotic potential. To reduce this potential and equilibrate the solute concentration across the membrane, water is drawn from the less concentrated to the more concentrated side of the membrane until equilibrium is reached. The finished product is a sports drink similar to Gatorade®. Water production rate is proportional to solute gradient. The following nutrition information (Table 1) was approximated based on values from the HTI Expedition syrup containers, assuming a 3.6% finished product sugar concentration. This information is based per 1 L drink produced.

™ Potable Aqua is a trademark of Wisconsin Pharmacal Company, Jackson, WI.
® Gatorade is a registered trademark of the Quaker Oats Co., Chicago, IL. Use of trademarked products does not imply endorsement by the U.S. Army, but is intended only in identification of a specific product.

Table 1. HydroWell Expedition Nutrient Charge Nutritional Information.

Parameter	Value/L Product
Calories	147
Total Fat	0 g
Sodium	20 g
Potassium	83 g
Sugars	36 g
Protein	0 g

Ingredients: fructose, water, citric acid, lime extract, sweetness enhancer, potassium citrate, sodium citrate, sodium benzoate, potassium sorbate.
Note: According to the manufacturer, the nutrient charge is undergoing reformulation.

Effectiveness Against Microbial Pathogens

Manufacturer in-house data showed virus reduction in excess of 4-log (reference 1). Results from an independent laboratory for a similar device (HTI, Inc., X Pack) show bacteria reduction in excess of 6-log (reference 2). No results were received that tested this device against the U.S. Environmental Protection Agency (USEPA) Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 3). Expert opinion states that this technology should be capable of meeting the log reduction requirements shown below when tested against the USEPA Standard for the manufacturer rated capacity of the device. The removal mechanism of osmotic membranes is complex but can be considered to be based on size exclusion utilizing very small pores that reject even dissolved contaminants. Based on the absence of independent results challenged against reference 3, this device is assigned a rating of one √ for the reduction of each pathogen (click here for rating explanation), indicating that expert opinion expects this device to meet the requirements of reference 3 (Table 2).

Table 2. Expected Performance Against Microbial Pathogens.

Microbial Pathogen Type	Expected Disinfection Capability	Evaluation Rating	Primary Pathogen Reduction Mechanism
Bacteria	> 6-log	√	size exclusion
Viruses	> 4-log	√	size exclusion
Giardia cysts	> 3-log	√	size exclusion
Cryptosporidium oocysts	> 3-log	√	size exclusion

Production Rate and Capacity

Production rate and capacity of this device is dependent upon solute gradient across the membrane and temperature. Manufacturer stated production rate is 0.5 L/hr at 68º F (0.008 L/min). This device is demand driven. The user draws nutrient syrup into the membrane cartridge by creating suction in the drink tube. The production capacity is 12 L per day with a useful life of 30 days for a total production of about 360 L. Nutrient charges supplied with the device provide for about 30 L of drink. Unlike porous pressure driven filter devices, turbidity does not affect the production capacity or rate.

Cleaning, Replacement, and End of Life Indicator

The HydroWell Expedition is designed for 30 days of use with flushing every 7 days. Cleaning can be accomplished with or without access to potable water. With access to potable water, the user should empty both bags, fill and rinse with potable water, then empty both bags. Refill the product bag with potable water, add one bottle of preservative sodium metabisulfite solution, close and shake. Then, remove the bite valve and attach the hand pump. Squeeze the bulb to pump the solution through the device and out of the drink tube. Open the product bag port to relieve suction then close. Close all ports, reattach the bite valve then the device can be stored for up to 7 days. Prior to next use, add water to both bags, then pump all water out using the hand pump as explained above. If potable water is not available for cleaning, empty the dirty water bag, but leave about 2 cups of drink in the product bag. Add the preservative solution and pump out as explained above. The device can now be stored for up to 4 days. Prior to next use, fill the dirty water side with water, then pump out of the drink tube as explained above. The device can now be used to produce drink. This device is supplied with indicator dye to allow the user to determine visually if the membrane has been compromised. Due to user subjectivity, this is not considered a real time indicator of process failure. This device is purchased with 10 nutrient charges, capable of producing drink continuously for about 2 days. Additional nutrient charges can be purchased for water production of up to 30 days. At the end of 30 days from first use the device should be discarded regardless of volume of drink produced.

Weight and Size

The dry weight of the device is about 2800 grams.
Dimensions are (H x W x L) 8 cm x 16 cm x 40 cm.

Cost

HydroWell Expedition (nutrient charges for 30 L)	$129.00
Resupply Kit (nutrient charges for 30 L)	$29.00

Device Evaluation

No laboratory data was received for the HTI HydroWell Expedition challenging the device against the standards in reference 3. Since the device utilizes the same membrane, but in a different configuration, as the HTI X Pack, the results showing > 6-log reduction of bacteria for that device apply to the HydroWell Expedition. Based on the characteristics of osmotic membranes, reduction of viruses (> 4-log) and cysts (> 3-log) should be obtainable (reference 4). This device, although expected to meet the required pathogen reductions based on membrane exclusion alone, requires detailed chemical addition steps to limit bacterial growth on the membrane and promote adequate production rate. Prior to each bladder filling, the user must add 2 tablets of Potable Aqua™ iodine tablets and one test dye tablet to the dirty water bag, then one tablet of Campden sodium metabisulfite and one nutrient syrup bottle to the product bag. This device is demand driven. As the user pulls nutrient charge into the membrane cartridge, osmotic potential pulls water through the membrane. Since this device is demand driven, creating more suction will make the product drink more concentrated by reducing the time for water to pass through the membrane. Therefore, creating the 4% sugar solution recommended by the manufacturer is subject to the user's interpretation, affecting the production capacity of each nutrient charge. Additionally, users may be inclined to drink more concentrated solution rather then wait for proper solution concentration to be produced. Because nutrient charge is necessary to create the osmotic potential, the liquid produced is not water, but a drink similar to commercial sports drinks. The device is designed to be used for 30 days with cleaning every 3 - 7 days for a total capacity of 180 L. Cleaning is a somewhat complicated procedure that can be accomplished with or without access to potable water, however the procedure differs slightly as explained above. Since highly concentrated sugar solution is used to produce drink, bacterial growth is possible inside the bags, and therefore, cleaning is critical to prevent contamination. Care must be taken during storage and transport not to puncture or excessively abuse the bag by folding or creasing. Small defects in the membrane may allow pathogens across the membrane and be consumed without notice. This device is supplied with indicator dye to allow the user to determine visually if the membrane has been compromised. If the user detects a brown tint to the product drink then the device and product should be discarded without consumption. Since the user's ability to detect slight color change in the bite tube is uncertain, this is a questionable technique for determining device failure. Due to changing product components, instructions, product specifications, and price may vary between manufacturer website and product received. This device requires the addition of sodium metabisulfite. The bottle states that the user should not ingest this chemical, yet it is added directly to the product drink as well as used during cleaning. Persons allergic to sulfites should consult a physician prior to consumption. The manufacturer states a storage life of 3 years when kept below 90º F.

Advantages

- Technology is capable of reducing microbial pathogens in accordance with the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 3).
- Osmotic membrane capable of rejecting microbial pathogens and most all other environmental contaminants.
- Unaffected by raw water turbidity.
- Incorporated into hydration pack, allowing hands free operation.

Disadvantages

- No test results showing compliance with the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 3).
- Slow production rate.
- Drink sugar concentration subject to user operation enabling consumption of highly concentrated drink and reduced capacity.
- No real-time indicator of process failure.
- Chemical addition required.
- Complicated cleaning procedures.
- Does not produce water; product is similar to a sports drink.

References

1. Manufacturer in-house laboratory test results showing > 4-log reduction of virus, 2003. Provided by HTI.

2. Independent laboratory results of tests showing > 6-log reduction of bacteria. 2001. Provided by HTI.

3. USEPA, 1989. Guide Standard and Protocol for Testing Microbiological Water Purifiers. *Federal Register*. 54:34067.

4. U.S. Army Center for Health Promotion and Preventive Medicine, 2005. *Technical Information Paper; Filtration in the Use of Individual Water Purification Devices*, Aberdeen Proving Ground, MD.

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ANNEX 17 TO APPENDIX E

DEVICE EVALUATION #17
HYDRATION TECHNOLOGIES, INC. – X PACK

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Hydration Technologies, Inc. – X Pack

www.hydrationtech.com

Device Information

The Hydration Technologies, Inc., (HTI) X Pack is a portable, passive water treatment device utilizing an osmotic membrane for pathogen reduction. The device consists of an inner 1.5 L vinyl bag for processed fluid, surrounded by an outer 1.5 L vinyl bag for raw water. The two bags are separated by a semi-permeable membrane. According to the manufacturer, the membrane, although unlike conventional porous membranes, is equivalent to having a pore size of 0.0005 µm. This device uses no pumping to process the water, but rather uses osmotic potential across the membrane as a driving force. A nutrient charge of sugar and electrolytes is poured into the inner bag, which pulls water across the membrane by creating an osmotic potential. To reduce this potential and to equilibrate the solute concentration across the membrane, water is drawn from the less concentrated to the more concentrated side of the membrane until equilibrium is reached. The finished product is a sports drink similar to Gatorade®. Water production rate is proportional to solute gradient. The following nutrition information is per charge, recommended for the production of 1.5 L product at 3.6% solution (Table 1). Nutrition information for a lime flavor nutrient charge is as follows:

Table 1. X Pack Nutrient Charge Nutritional Information.

Parameter	Value/1.5 L Product
Calories	220
Total Fat	0 g
Sodium	30 g
Potassium	125 g
Sugars	55 g
Protein	0 g

Ingredients: fructose, water, citric acid, lime extract, sweetness enhancer, potassium citrate, sodium citrate, sodium benzoate, potassium sorbate.
Note: According to the manufacturer, the nutrient charge is undergoing reformulation.

® Gatorade is a registered trademark of the Quaker Oats Co., Chicago, IL. Use of trademarked products does not imply endorsement by the U.S. Army, but is intended only in identification of a specific product.

Effectiveness Against Microbial Pathogens

Results from an independent laboratory (reference 1) indicate that the X Pack is capable of reducing bacterial contamination by > 6-log. Additionally, manufacturer in-house laboratory data showed virus reduction in excess of 4-log (reference 2). No results were received that tested this device against the U.S. Environmental Protection Agency (USEPA) Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 3). Expert opinion states that osmotic membrane technology should be capable of meeting the log reduction requirements shown below when tested against the USEPA Standard for the manufacturer rated capacity of the device. The removal mechanism of osmotic membranes is complex, but can be considered to be based on size exclusion utilizing very small pores that reject even dissolved contaminants. Based on the absence of independent results challenged against reference 3, this device is assigned a rating of one √ for the reduction of each pathogen (click here for rating explanation), indicating that expert opinion expects this device to meet the requirements of reference 3 (Table 2).

Table 2. Expected Performance Against Microbial Pathogens.

Microbial Pathogen Type	Expected Disinfection Capability	Evaluation Rating	Primary Pathogen Reduction Mechanism
Bacteria	> 6-log	√	size exclusion
Viruses	> 4-log	√	size exclusion
Giardia cysts	> 3-log	√	size exclusion
Cryptosporidium oocysts	> 3-log	√	size exclusion

Production Rate and Capacity

Production rate and capacity of this device is dependant upon solute gradient across the membrane and temperature. Manufacturer stated production rate is 1.1 L/6 hrs at 68º F (0.003 L/min). Instructions state to allow device 6-12 hours and up to 24 hours to produce drink. Based on a manufacturer stated device life of 10 days from initial use, the production capacity is about 40 L. Unlike porous pressure driven filter devices, turbidity does not affect the production capacity or rate.

Cleaning, Replacement, and End of Life Indicator

The X Pack is a not designed to be cleaned. The device can be operated for 10 days from initial use and has no real-time process failure indicator or end of life indicator. This device is purchased with 10 nutrient charges, capable of producing drink continuously for about 2.5 days. Additional nutrient charges can be purchased for drink production of up to 10 days. At the end of 10 days from first use the device should be discarded regardless of the amount of drink produced.

Weight and Size

The dry weight of the device is about 1250 grams including the 10 nutrient charges. Dimensions are as follows:

X Pack with charges (H x W x L)	2.5 cm x 17.8 cm x 30.5 cm

Cost

X Pack (nutrient charges for 10 L)	$64.00
Resupply Kit (nutrient charges for 10 L)	$21.00

Device Evaluation

The HTI X Pack has been tested by an independent laboratory and shown to be able to reduce bacterial contamination by > 6-log (reference 1). Based on the characteristics of osmotic membranes, reduction of viruses (> 4-log) and cysts (> 3-log) to the standards of reference 3 should be obtainable (reference 4). The driving force for water purification consists of a gradient in sugar and electrolyte concentration. To create this gradient a powder or liquid nutrient charge must be added to the product drink bag. Because if this, the liquid produced is not water, but a drink similar to commercial sports drinks. The concentration of the drink with respect to sugar content can be adjusted by the user by placing more or less charge into the bag, or by consuming the drink prior to complete exhaustion of the raw water source. Since drink production is related to solute gradient, producing a drink that is more dilute will require increased production time. Therefore, the already extremely slow production rate of 1 L every 6 - 8 hours will increase. Conversely, creating a more concentrated drink will take less time, but will lower the overall amount of drink produced per nutrient charge. Two other conditions that affect drink production, but to a lesser extent, are water temperature (increase in temperature will increase production rate) and the movement of the bag (slight movement or shaking periodically will increase production rate). At the production rate stated by the manufacturer, one device is unable to produce the volume of liquid required for hydration (5-15 L/day depending on environment and

work conditions) as stated in Technical Bulletin Medical (TB MED) 577 (reference 5). The bag should not be allowed to freeze at any time after first use, and care must be taken during storage and transport not to puncture or excessively abuse the bag by folding or creasing. Before consumption, both the raw water and product drink bags should be checked to confirm that liquid is not freely flowing between the two and that the raw water bag is empty or at a minimum, less full than the product bag. If the liquid in the bags appears similar in characteristics (color, cloudiness) then the membrane may be defective and the device and liquid should be discarded without consumption. The device is designed to be used for 10 continuous days after first use then discarded. Likelihood of bacterial growth in the product bag increases with increasing time from first use. Continued use after 10 days should only occur during emergencies when no other means of purification are available. Use in warm environments increases the probability of bacterial growth in the product bag. This device has no real-time indicator of process failure. Small defects in the membrane may allow pathogens to enter the product bag and be consumed without notice. The manufacturer states a storage life of 3 years when kept below 90º F.

Advantages

- Technology is capable of reducing microbial pathogens in accordance with the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 3).
- Osmotic membrane capable of rejecting microbial pathogens and most all other environmental contaminants.
- No chemicals required.
- Unaffected by raw water turbidity.

Disadvantages

- No test results showing compliance with the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 3).
- Extremely slow production.
- Unable to produce recommended volume of daily liquid intake of 5-15L/day.
- No real-time indicator of process failure.
- Disposable, useful life of 10 days.
- Does not produce water; product is similar to a sports drink.

References

1. Independent laboratory results of tests showing > 6-log reduction of bacteria, 2003. Provided to U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM) by HTI.

2. Manufacturer laboratory results of tests showing >4 log reduction of virus. 2001. Provided by HTI.

3. USEPA, 1989. Guide Standard and Protocol for Testing Microbiological Water Purifiers. *Federal Register*. 54:34067.

4. USACHPPM, 2005. *Technical Information Paper; Filtration in the Use of Individual Water Purification Devices,* Aberdeen Proving Ground, MD.

5. U.S. Army, 1986. TB MED 577 – *Sanitary Control and Surveillance of Field Water Supplies*.

Device Evaluation Update – March 2006

Independent laboratory results were received that tested the Hydration Technologies X-Pack against a modified USEPA Guide Standard. Testing targeted polio- and rota-virus and *Cryptosporidium* parvum reduction at the following three conditions: end of device useful life (after 10 days of production), end of device useful life after device subject to a 5 foot drop, and end of device useful life after device subject to vibration. These environmental stress conditions were designed to expose the device to operational use conditions. No bacterial challenge was conducted during this testing. Since these devices produce fluid through passive forward osmosis, flow rates are dependent upon ambient conditions and solute concentration and therefore cannot be set by the user. All devices were conditioned with 5 days use with general test water 1 (GTW 1) followed by 5 days use with GTW 3. Conditioning did not contain challenge organisms. After conditioning, GTW 3 was spiked with test organisms and the devices were allowed to produce for 12 hours. Results for all devices, regardless of environmental stress, showed > 4 log virus and > 3 log *Cryptosporidium* reduction. A total of 32 devices were tested. During testing one bag developed a pin-hole leak as well as a water entry point which would not seal, preventing the device from being evaluated. This testing does not conform to the requirements of the USEPA Guide Standard, but gives an indication of the virus and *Cryptosporidium* reduction efficacy of this device. Prior to this testing, this device was assigned pathogen reduction ratings of √ bacteria, √ virus, √ *Giardia*, and √ *Cryptosporidium* based on device technology. This new data supports the original ratings.

Updated Table 2. Expected Performance Against Microbial Pathogens.

Microbial Pathogen Type	Expected Disinfection Capability	Evaluation Rating	Primary Pathogen Reduction Mechanism
Bacteria	> 6-log	√	size exclusion
Viruses	> 4-log	√	size exclusion
Giardia cysts	> 3-log	√	size exclusion
Cryptosporidium oocysts	> 3-log	√	size exclusion

Reference:

Independent laboratory testing conducted October - December 2005. Testing sponsored by the U.S. Army Research, Development, and Engineering Command, Natick, MA.

ANNEX 18 TO APPENDIX E

DEVICE #18
INGRAM WATER AND AIR EQUIPMENT – SURVIVAL STRAW

NOT EVALUATED

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ANNEX 19 TO APPENDIX E

DEVICE EVALUATION #19
INNOVA PURE WATER, INC. – BIOLOGICAL FILTER BOTTLE

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Innova Pure Water, Inc. – Biological Filter Bottle

www.innovapurewater.com

Device Information

The Innova Pure Water, Inc., Biological Filter Bottle is a handheld sports type squeeze bottle. The bottle has a capacity of 0.8 L (27 oz.). Use requires the user to simply fill with water to the recommended fill line. The bottle contains an activated carbon block prefilter and a 0.2 µm polysulfone hollow-fiber primary filter. The prefilter sits near the bottom of the bottle and is connected to the primary filter's plastic housing. The prefilter is removable. The hollow fibers of the primary filter are packed into a plastic housing and the open ends are oriented at the effluent side of the housing. The top of the hollow fiber filter cartridge is sealed with a hard epoxy with the open end of the hollow fibers flush with the epoxy surface; this forces water to flow into the hollow fibers for purification. There is a plastic housing enclosing both the primary and prefilter. This housing has two holes near its connection with the bottle cap. This requires the user to tilt the bottle to purify water. No manufacturer directions were received with this device explaining use, cleaning, or storage.

Effectiveness Against Microbial Pathogens

No testing data, independent or otherwise, was received testing this device strict to the U.S. Environmental Protection Agency (USEPA) Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1). Independent testing data was obtained from the manufacturer website showing bacteria reduction using a modified version of reference 1. The results, to the testing volume of 38 L, showed bacterial reduction of > 6-log. Laboratory results were obtained for cyst reduction using microspheres following the National Sanitation Foundation (NSF) International Standard 53 (reference 2). Results showed > 4-log reduction with testing volume based on percent flow drop. No indication is given as to the total volume of water tested. Additionally, no elevated turbidity water was used during testing, as required in reference 1. No data was received for virus reduction by this device. The data received and general knowledge of membrane filtration (references 3 and 4) indicate that this device should be capable of consistently meeting the minimum 6-log bacteria reduction and 3-log reduction for *Giardia* cysts and *Cryptosporidium* oocysts stated in the USEPA Protocol. It is not expected to consistently reduce viruses (4-log reduction). Based on general knowledge of size exclusion by membrane filtration, the Innova Pure Water, Inc., Biological Filter Bottle is assigned one √ for

bacteria reduction, one √ each for the reduction of *Giardia* cysts and *Cryptosporidium* oocysts. The device receives an X for virus reduction (for an explanation of the rating checks click here).

Table. Expected Performance Against Microbial Pathogens.

Microbial Pathogen Type	Expected Disinfection Capability	Evaluation Rating	Primary Pathogen Reduction Mechanism
Bacteria	> 6-log	√	size exclusion
Viruses	> 4-log	X	-
Giardia cysts	> 3-log	√	size exclusion
Cryptosporidium oocysts	> 3-log	√	size exclusion

Production Rate and Capacity

Inherent to the production rate and capacity of filtration devices is the quality of the raw water source. Because it is a squeeze bottle, the actual production rate is dependent on the user. The production capacity stated on this device is up to 300 L. However, production capacity will vary widely with raw water quality (e.g., turbidity).

Cleaning, Replacement, and End of Life Indicator

This device cannot be backwashed to remove sediment from the filters (prefilter and primary). When the prefilter becomes clogged it must be replaced. For practical purposes, the filter cartridges are not cleanable. The manufacturer recommends replacing the filter cartridge every 3 months regardless of water volume filtered. The device contains no end of life indicator short of filter clogging.

Weight and Size

Dry weight (no accessories or tubing)	160 grams (estimated)
Size (height x diameter)	27 cm x 7 cm

Cost

Filter Bottle	$35.00
Replacement primary filter with two prefilters	$18.00

Device Evaluation

No data was received that challenged the Innova Pure Water, Inc., Biological Filter Bottle against the USEPA Protocol (reference 1). The limited data obtained from the manufacturer website, as well as general knowledge of size exclusion by membrane filtration, indicate that the device should be capable of consistently reducing bacteria, *Giardia* cysts and *Cryptosporidium* oocysts to the required minimum log reductions stated in reference 1. Since no testing was performed out to the manufacturer recommended production capacity there is no indication of the long term efficacy of this filter against pathogens or turbid water. This device is not expected to consistently reduce viruses (4-log). Additional treatment is necessary to remove viruses such as adding a disinfectant (e.g., chlorine, iodine, chlorine dioxide) to the water after filtration. The actual usable capacity of the bottle is less than the manufacturer stated volume of 0.8 L due to displacement by the filter cartridge and housing. This device contains a carbon block prefilter to reduce particulate matter and reduce source water taste and odor. Since the device is not able to be backwashed to remove accumulated particles, once clogged, the filter must be replaced. There is no indicator of process failure or end of device useful life.

Advantages

- Expected to consistently provide adequate protection from bacteria, *Giardia* cysts and *Cryptosporidium* oocysts, although device-specific testing data using the USEPA Protocol is not available.
- No wait time prior to consumption.
- Simple and effective.

Disadvantages

- No data testing this device against the USEPA Protocol (reference 1).
- Not expected to be consistently effective against viruses.
- Reduced production capacity when using high turbidity water.
- Not backwashable.
- No real-time indicator of process failure.

References

1. USEPA, 1989. Guide Standard and Protocol for Testing Microbiological Water Purifiers. *Federal Register*. 54:34067.

2. NSF International, 2004. Drinking Water Treatment Units – Health Effects (NSF/ANSI 53). NSF International, Ann Arbor, Michigan.
3. Laboratory challenge data obtained from the manufacturer website.

4. U.S. Army Center for Health Promotion and Preventive Medicine, 2005. *Technical Information Paper; Filtration in the Use of Individual Water Purification Devices,* Aberdeen Proving Ground, MD.

ANNEX 20 TO APPENDIX E

DEVICE EVALUATION #20
INNOVA PURE WATER, INC. – INLINE FILTER

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Innova Pure Water, Inc. – Inline Filter

www.innovapurewater.com

Device Information

The Innova Pure Water, Inc., Inline filter is designed for use with commercial hydration packs or for purification of water during transfer from two containers. The inline filter contains a 0.2 µm hollow fiber polysulfone membrane bundle primary filter and a carbon block prefilter identical to that in the Innova Biological Filter Bottle. The hollow fibers are packed into a plastic housing and the open ends are oriented at the effluent side of the housing. The filter cartridge is contained in a sturdy plastic housing with separate inlet and outlet for connecting to the drink tube of a hydration pack or other tubing for fluid transfer. Water flows into the filter housing, through the carbon prefilter, then from the outside of the hollow fibers to the inside, and out of the open ends of the hollow fibers. The top of the hollow fiber filter cartridge is sealed with a hard epoxy with the open end of the hollow fibers flush with the epoxy surface; this forces water to flow into the hollow fibers for purification. No manufacturer directions were received with this device explaining use, cleaning, storage, or expected production capacity. Since the filter cartridge is identical to that in the Innova Bottle, information for that device will be assumed.

Effectiveness Against Microbial Pathogens

No testing data, independent or otherwise, was received testing this device strict to the U.S. Environmental Protection Agency (USEPA) Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1). Independent testing data was obtained from the manufacturer website showing bacteria reduction using a modified version of reference 1. The results, to the testing volume of 38 L, showed bacterial reduction of > 6-log. Laboratory results were obtained for cyst reduction using microspheres following the National Sanitation Foundation (NSF) International Standard 53 (reference 2). Results showed > 4-log reduction with testing volume based on percent flow drop. No indication is given as to the total volume of water tested. Additionally, no elevated turbidity water was used during testing, as required in reference 1. No data was received for virus reduction by this device. The data received and general knowledge of membrane filtration (references 3 and 4) indicate that this device should be capable of consistently meeting the minimum 6-log bacteria reduction and 3-log reduction for *Giardia* cysts and *Cryptosporidium* oocysts stated in the USEPA Protocol. It is not expected to

consistently reduce viruses (4-log reduction). Based on general knowledge of size exclusion by membrane filtration, the Innova Pure Water, Inc., Inline filter is assigned one √ for bacteria reduction, one √ each for the reduction of *Giardia* cysts and *Cryptosporidium* oocysts. The device receives an X for virus reduction (for an explanation of the rating checks click here).

Table. Expected Performance Against Microbial Pathogens.

Microbial Pathogen Type	Expected Disinfection Capability	Evaluation Rating	Primary Pathogen Reduction Mechanism
Bacteria	> 6-log	√	size exclusion
Viruses	> 4-log	X	-
Giardia cysts	> 3-log	√	size exclusion
Cryptosporidium oocysts	> 3-log	√	size exclusion

Production Rate and Capacity

Inherent to the production rate and capacity of filtration devices is the quality of the raw water source. Because it is an inline filter, the actual production rate is dependent on the user. No production capacity is stated by the manufacturer for this device. The production capacity of the Innova Filter Bottle using the identical filter cartridge is stated to be up to 300 L. However, production capacity will vary widely with raw water quality (e.g., turbidity).

Cleaning, Replacement, and End of Life Indicator

This device cannot be backwashed to remove sediment from the filters (prefilter and primary). When the prefilter becomes clogged it must be replaced. For practical purposes, the filter cartridges are not cleanable. The device contains no end of life indicator short of filter clogging.

Weight and Size

Dry weight (no accessories or tubing)	160 grams (estimated)
Size (height x diameter)	23 cm x 4 cm

Cost

Inline filter	$42.00
Replacement primary filter with two prefilters	$18.00

Device Evaluation

No data was received that challenged the Innova Pure Water, Inc., Inline filter against the USEPA Protocol (reference 1). The limited data obtained from the manufacturer website, as well as general knowledge of size exclusion by membrane filtration, indicate that the device should be capable of consistently reducing bacteria, *Giardia* cysts, and *Cryptosporidium* oocysts to the required minimum log reductions stated in reference 1. Since no testing was performed out to the manufacturer recommended production capacity there is no indication of the long term efficacy of this filter against pathogens or turbid water. This device is not expected to consistently reduce viruses (4-log). Additional treatment is necessary to remove viruses such as adding a disinfectant (e.g., chlorine, iodine, chlorine dioxide) to the water after filtration. This device contains a carbon block prefilter to reduce particulate matter and reduce source water taste and odor. Since the device is not able to be backwashed to remove accumulated particles, once clogged, the filter must be replaced. Once the device has been used, flow direction should not be reversed or cross contamination may occur. There is no indicator of process failure or end of device useful life.

Advantages

- Expected to consistently provide adequate protection from bacteria, *Giardia* cysts and *Cryptosporidium* oocysts, although device-specific testing data using the USEPA Protocol is not available.
- No wait time prior to consumption.
- Simple and effective.

Disadvantages

- No data testing this device against the USEPA Protocol (reference 1).
- Not expected to be consistently effective against viruses.
- Reduced production capacity when using high turbidity water.
- Not backwashable.
- No real-time indicator of process failure.

References

1. USEPA, 1989. Guide Standard and Protocol for Testing Microbiological Water Purifiers. *Federal Register*. 54:34067.

2. NSF International, 2004. Drinking Water Treatment Units – Health Effects (NSF/ANSI 53). NSF International, Ann Arbor, Michigan.
3. Laboratory challenge data obtained from the manufacturer website.

4. U.S. Army Center for Health Promotion and Preventive Medicine, 2005. *Technical Information Paper; Filtration in the Use of Individual Water Purification Devices,* Aberdeen Proving Ground, MD.

ANNEX 21 TO APPENDIX E

DEVICE EVALUATION #21
KATADYN – BASE CAMP

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Katadyn – Base Camp

www.katadyn.com

Device Information

The Katadyn Base Camp is a gravity feed water treatment device utilizing glass fiber microfiltration. This device is identical to the Katadyn Camp except for the type of filtration element used. Containing what the manufacturer terms "AntiClog Technology", the device consists of 129 square inches of pleated 0.3 µm glass fiber media, with an activated carbon core. This device creates an absolute barrier to contaminants greater than the pore size and may remove taste and odor through carbon filtration. This device is designed for bacteria and cyst reduction, but contains no reduction mechanism for virus. The manufacturer recommends a chemical disinfectant be added if virus is suspected in the water source. The device consists of a 10 L water bag, glass fiber filter element, outlet tubing, and tubing clamp. The filter element used in this device is identical to the Katadyn Hiker Pro, and contains a washable filter cover to reduce the clogging effect when filtering turbid waters. No chemicals and no wait time are required for use. To use, water is poured or scooped into the bag, then the bag is hung above the ground surface and allowed to produce by gravity flow. The greater the distance in elevation between the water surface in the bag and the end of the outlet tubing, the greater the production rate. Prior to first use, and after prolonged storage, the manufacturer recommends discarding a small amount of water to reduce stale taste. This device is field serviceable, and can be disassembled without tools. The filter protector can be removed and cleaned as often as necessary, but the filter element cannot be cleaned and must be discarded once clogged. The filter protector supplies an extra barrier to extend the microfilter life by reducing particulate matter, but it is unlikely to increase microbial pathogen reduction.

Effectiveness Against Microbial Pathogens

Independent laboratory results were received challenging a similar device, the Katadyn Hiker (tested under a previously brand name), against a modified version of the U.S. Environmental Protection Agency (USEPA) Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1). Since the Base Camp device utilizes the same filter element as the Hiker, results for the Hiker are considered representative of those expected for the Base Camp. Results for bacteria challenge showed reduction of > 6-log or just under 6-log based on geometric

averages of samples collected (references 2, 3). Data collected for *Cryptosporidium* reduction met the > 3-log reduction requirement of reference 1 (references 2, 3). Since the primary reduction mechanism is size exclusion, and because *Giardia* cysts are larger in size than C*ryptosporidium* oocysts, similar results for *Giardia* reduction can be assumed. This device is not designed for virus reduction and therefore, no data was reviewed for reduction of this pathogen. This device is assigned one √ for bacteria and cyst reduction (for an explanation of the rating checks click here) based on size exclusion by the glass microfilter. Since the device is not designed, and has no mechanism, for virus reduction, the device is assigned one X for this pathogen.

Table. Expected Performance Against Microbial Pathogens.

Microbial Pathogen Type	Expected Disinfection Capability	Evaluation Rating	Pathogen Reduction Mechanism
Bacteria	> 6-log	√	size exclusion
Viruses	not effective*	X	none
Giardia cysts	> 3-log	√	size exclusion
Cryptosporidium oocysts	> 3-log	√	size exclusion

* additional treatment required for virus reduction.

Production Rate and Capacity

Inherent to the production rate and capacity of filtration devices is the quality of the raw water source. The manufacturer stated production capacity of the device is 750 L at a rate of 0.5 L/min. This device utilizes a glass depth microfilter. The filter cannot be backwashed, and once clogged must be replaced. If clogged, a small amount of water may be produced if the filter is removed and swished in water (raw water acceptable). The filter protector is expected to extend the life of the microfilter, but clogging will likely still occur, dependent upon the raw water quality. The filter protector is a removable coarse material that can be scraped clean and swished in water to remove particulates. The capacity of this device will vary widely with raw water turbidity.

Cleaning, Replacement, and End of Life Indicator

This device cannot be backwashed to remove sediment from the filter. When the device becomes unusable due to decreased production rate, the clogged filter must be replaced. The filter protector can be removed, cleaned and reused. The device contains no end of life indicator short of filter clogging. Since the device works solely on size exclusion, as long as the device will process water, stated pathogen reductions should be valid. The carbon core will eventually become exhausted. Since little or no pathogen reduction is attributed to the carbon core, if it were to be exhausted prior to clogging of the microfilter, microbial reduction should be unchanged. No data was presented to determine the capacity of the carbon core.

Weight and Size

Katadyn Base Camp	370 grams
Size (height x diameter)	19 cm x 10 cm
Tubing	91 cm

Cost

Katadyn Camp	$60.00
Replacement glass fiber element	$35.00

Device Evaluation

The Katadyn Base Camp utilizes a 0.3 µm glass microfilter and carbon core for the reduction of bacteria, and cysts, as well as taste and odor. Independent data for the Katadyn Hiker utilizing the same filter element, showed reduction of bacteria and cysts to within the requirements of reference 1, or by > 6-log and > 3-log, respectively, based on a modified version of the protocol. Inconsistent reduction of bacteria, with one test not meeting the required > 6-log reduction, as well as testing procedures not strict to the USEPA protocol, warrants the assignment of one check each for reduction of cysts and bacteria. This rating states that, due to the device technology, expert opinion believes that the device should be able to meet the bacteria and cyst reduction requirements of reference 1 (reference 4). More independent laboratory data is necessary to confirm these reductions. Since the device reduction mechanism is size exclusion by means of a 0.3 µm microfilter, no virus reduction is claimed by the manufacturer. Additional treatment is required to fully meet the requirements of reference 1 and ensure adequate reduction of all three classes of microorganism. This device, like all filters with small pore sizes, is highly affected by turbid (cloudy) waters. This device utilizes no chemicals and requires no wait time prior to water consumption. There is no indicator of process failure or end of device useful life

except filter clogging or the user keeping track of the volume of water produced. Since this device operates off of gravity, use is restricted to stationary scenarios, or when able to hang device during movement, such as inside a vehicle. Flowrate of the device will change with the amount of water in the bag (head) as well as with the elevation change from water surface in bag compared to outlet tubing elevation. No manufacturing information or quality control data was received for this device. The manufacturer states ISO 9000 certification. No information was received on the storage life or required storage conditions for this device.

Advantages

- Based on treatment technology and limited independent data reviewed, this device should be capable of reducing bacteria and cysts to within the requirements of the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1).
- No wait time prior to water consumption.
- Activated carbon core should reduce taste and odors.
- Passive device requiring no user input.
- Simple and lightweight.

Disadvantages

- Device is not designed for virus reduction and therefore unable to fully meet the pathogen reduction requirements of the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1).
- Additional treatment required.
- Small pore size of filter makes device inherently susceptible to clogging by waters with elevated turbidities.
- Device unable to be backwashed.
- No real-time indicator of process failure.
- Device requires hanging and cannot be used on the move on foot.

References

1. USEPA, 1989. Guide Standard and Protocol for Testing Microbiological Water Purifiers. *Federal Register*. 54:34067.

2. Independent laboratory results of tests showing bacteria and cyst reduction, 1996. Provided by Katadyn.

3. Independent laboratory results of tests showing bacteria and cyst reduction, 1995. Provided by Katadyn.

4. U.S. Army Center for Health Promotion and Preventive Medicine, 2005. *Technical Information Paper; Filtration in the Use of Individual Water Purification Devices*, Aberdeen Proving Ground, MD.

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ANNEX 22 TO APPENDIX E

DEVICE EVALUATION #22
KATADYN – CAMP

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Katadyn – Camp

www.katadyn.com

Device Information

The Katadyn Camp is a gravity feed water treatment device utilizing ceramic microfiltration. This device is identical to the Katadyn Base Camp except for the type of filtration element used. The ceramic element is a field cleanable 0.2 µm depth filter with silver impregnation. This device is designed for bacteria and cyst reduction, but contains no reduction mechanism for virus. The manufacturer recommends a chemical disinfectant be added if virus is suspected in water source. The device consists of a 10 L water bag, ceramic filter element, outlet tubing, and tubing clamp. Additionally, the device comes with a filter element scrubbing pad, ceramic element measuring gauge, and plastic storage container. The ceramic element silver impregnation is designed to limit bacterial growth on the element. This device creates an absolute barrier to contaminants greater than the pore size. No chemicals and no wait time are required for use. To use, water is poured or scooped into the bag, then the bag is hung above the ground surface and allowed to produce by gravity flow. The greater the distance in elevation between the water surface in the bag and the end of the outlet tubing, the greater the production rate. Prior to first use, and after prolonged storage, the manufacturer recommends discarding a small amount of water to reduce stale taste. This device is fully field-serviceable, and can be disassembled without tools.

Effectiveness Against Microbial Pathogens

No results were obtained that challenged this device strict to the requirements of the U.S. Environmental Protection Agency (USEPA) Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1). Results from an independent laboratory study (reference 2) were reviewed that challenged the Katadyn Mini (a filtration device manufactured by Katadyn, utilizing a ceramic filter cartridge identical to the Camp, except smaller in size) against a modified version of reference 1. No information was supplied as to the flow rate used during testing, and total production during testing was 200 L. Under these modified protocol conditions, data showed that the Mini was capable of meeting the log reduction requirements for bacteria and *Cryptosporidium* oocysts. This testing did not challenge the device against *Giardia* cysts or virus. Since the primary reduction mechanism is size exclusion, and because *Giardia*

cysts are larger in size than C*ryptosporidium* oocysts, similar results for *Giardia* reduction can be assumed. Viruses are too small to be removed by the ceramic element used in these filtration devices. Very little information was received on the testing procedure. It was noted that during testing, the Mini required cleaning with the supplied scouring pad at every test point, stating also that the device tended to clog very easily. Results stated that flow improved considerably after cleaning but that as more water was passed through the device, cleaning was required more often. Due to the testing modifications with respect to reference 1 and lack of data specific to the Camp, this evaluation based reduction capabilities on treatment technology. Therefore, this device is assigned one √ for bacteria and cyst reduction (for an explanation of the rating checks click here) based on size exclusion by the ceramic microfilter. Since the device is not designed, and has no mechanism, for virus reduction, the device is assigned one X for this pathogen. Additional treatment is required for virus reduction.

Table. Expected Performance Against Microbial Pathogens.

Microbial Pathogen Type	Expected Disinfection Capability	Evaluation Rating	Pathogen Reduction Mechanism
Bacteria	> 6-log	√	size exclusion
Viruses	not effective*	X	none
Giardia cysts	> 3-log	√	size exclusion
Cryptosporidium oocysts	> 3-log	√	size exclusion

* additional treatment required for virus reduction.

Production Rate and Capacity

Inherent to the production rate and capacity of filtration devices is the quality of the raw water source. The manufacturer stated production capacity of the device is up to 20,000 L at a average flowrate of 5 L/hr or 0.084 L/min. Since cleaning irreversibly decreases the size of the element, the overall capacity of this device will vary widely with raw water turbidity. No data was received showing the number of times this device can be cleaned before ceramic element replacement is required. Additionally, since the available data only processed 200 L, and with no indication of challenge water turbidity, no estimation of actual production capacity can be made.

Cleaning, Replacement, and End of Life Indicator

This device utilizes a ceramic depth microfilter which can be cleaned by scrubbing the surface of the filter element to remove accumulated debris. Given the small pore size of the ceramic element, it is expected to clog frequently during use with turbid waters and is therefore designed to be cleaned multiple times throughout its useful life. As stated above, the Katadyn Mini underwent multiple cleanings during the 200 L microbial challenge testing. Since the ceramic element used during testing was smaller than this device, production volume prior to required cleaning is expected to increase but cannot be quantified. The report (reference 2) states that cleaning restored the production rate considerably and did not affect pathogen reductions. Supplied with the device is a gauge that is placed over the ceramic element. If the gauge fits around the element then the filter has been cleaned to its capacity and must be replaced. Since the device works solely on size exclusion, as long as the device will process water and the element is not determined to be too thin, stated pathogen reductions should be valid. When the filter begins to clog and flowrate decreases, the user should discontinue use and clean the ceramic element.

Weight and Size

Katadyn Camp	620 grams
Size (height x diameter)	19 cm x 10 cm
Tubing	140 cm

Cost

Katadyn Camp	$70.00
Replacement ceramic element	$60.00

Device Evaluation

The Katadyn Camp utilizes a 0.2 µm silver impregnated ceramic element for the reduction of bacteria and cysts. The silver impregnation is designed to limit microbial growth on the ceramic element. No data was received regarding the efficacy of this bacteriostatic design. Microbial reduction data reviewed for a similar device manufactured by Katadyn (reference 2), tested against an abbreviated version of the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1), showed that this device is capable of reducing bacteria by > 6-log, and cysts by > 3-log. No information was given as to the exact testing conditions and the volume of water treated during testing was far less than the stated capacity of the device. This device contains no virus reduction mechanism and therefore no testing was

performed for this pathogen. Additional treatment is required to fully meet the requirements of reference 1 and ensure adequate reduction of all three classes of microorganism. Since size exclusion by ceramic microfilter elements is a generally accepted mechanism for pathogen reduction, we expect this device to adequately reduce bacteria and cysts in accordance with reference 1 and recommend additional treatment for virus reduction (reference 3). The testing results received note the requirement for multiple cleanings. Due to the small pore size, ceramic element cleaning is expected, increasing in frequency with increasing raw water turbidity. Results showed consistent pathogen reductions after cleaning (reference 2). It is expected that pathogen reductions will remain consistent throughout the useful life of the device. This device utilizes no chemicals and requires no wait time prior to water consumption. Since this device operates off of gravity, use is restricted to stationary scenarios, or when able to hang device during movement, such as inside a vehicle. Flowrate of the device will change with the amount of water in the bag (head) as well as with the elevation change from water surface in bag compared to outlet tubing elevation. There is no indicator of process failure. A plastic gauge acts as an end of device useful life indicator. Since during cleaning of the ceramic element the filter reduces size, when the gauge fits around the filter it must be replaced. This device, like all containing ceramic elements, must not be frozen while wet. Expansion of the water during freezing may crack the element. Additionally, the user should avoid shocking the device due to the brittle nature of ceramic elements and possible fracturing during shock loads. No manufacturing information or quality control data was received for this device. The manufacturer states ISO 9000 certification. No information was received on the storage life or required storage conditions for this device

Advantages

- Based on treatment technology and independent data reviewed, this device should be capable of reducing bacteria and cysts to within the requirements of the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1).
- No wait time prior to water consumption.
- Field-serviceable.
- Passive device requiring no user input.
- End of device useful life indicator.

Disadvantages

- Device is not designed for virus reduction and therefore unable to fully meet the pathogen reduction requirements of the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1).
- Additional treatment required.

- Small pore size of filter makes device inherently susceptible to clogging by waters with elevated turbidities.
- Ceramic element fragile to shock loads and freezing.
- No real-time indicator of process failure.
- Device requires hanging and cannot be used on the move on foot.

References

1. USEPA, 1989. Guide Standard and Protocol for Testing Microbiological Water Purifiers. *Federal Register*. 54:34067.

2. Independent laboratory results of tests showing bacteria and cyst reduction, 1995. Provided by Katadyn.

3. U.S. Army Center for Health Promotion and Preventive Medicine, 2005. *Technical Information Paper; Filtration in the Use of Individual Water Purification Devices*, Aberdeen Proving Ground, MD.

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ANNEX 23 TO APPENDIX E

DEVICE EVALUATION #23
KATADYN – COMBI MICROFILTER

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Katadyn – Combi Microfilter

www.katadyn.com

Device Information

The Katadyn Combi Microfilter is a handheld pump water treatment device utilizing ceramic microfiltration. The ceramic element is a field cleanable 0.2 µm depth filter with silver impregnation. This device is designed for bacteria and cyst reduction, but contains no reduction mechanism for virus. The manufacturer recommends a chemical disinfectant be added if viruses are suspected in the water source. The device, as purchased, contains two packs of granular activated carbon designed to reduce taste and odor, as well as reduce chemicals possibly found in the raw water source. The use of carbon is optional, and is not considered a primary mechanism for the reduction of microbial pathogens. The carbon is stated to last about 200 L or 6 months, depending on raw water quality. The device consists of a plastic housing and pump, ceramic filter element, activated carbon, inlet and outlet tubing, tubing weight and float, and 130 µm pre-filter. Additionally, the device comes with a filter element scrubbing pad, ceramic element measuring gauge, pump lubricant, bottle adaptor, extra o-rings, and a storage bag. The weight and float work together to keep the inlet tubing submerged, yet off of the bottom of the raw water source, to limit the introduction of sediment. The ceramic element silver impregnation is designed to limit bacterial growth on the element. This device creates an absolute barrier to contaminants greater than the pore size. No chemicals and no wait time are required for use. Prior to first use, and after prolonged storage, the manufacturer recommends discarding a small amount of water to reduce stale taste. This device is fully field serviceable, and can be disassembled without tools. Additionally, Katadyn offers a carbon cartridge bottle attachment that can be added to the effluent tubing for taste and odor reduction. This device is capable of being attached to a pressurized source (e.g., municipal tap), utilizing system pressure to process water (device termed Katadyn Combi Plus with this accessory). Device flow rate, etc., using this optional accessory, will depend on characteristics of pressurized source and are not addressed in this evaluation.

Effectiveness Against Microbial Pathogens

No results were obtained that challenged this device strict to the requirements of the U.S. Environmental Protection Agency (USEPA) Guide Standard and Protocol for Testing

Microbiological Water Purifiers (reference 1). Results from an independent laboratory study (reference 2) were reviewed that challenged the Katadyn Mini (a filtration device manufactured by Katadyn, utilizing a ceramic filter cartridge identical to the Combi, except smaller in size) against a modified version of reference 1. No information was supplied as to the flow rate used during testing, and total production during testing was 200 L. Under these modified protocol conditions, data showed that the Mini was capable of meeting the log reduction requirements for bacteria and *Cryptosporidium* oocysts. This testing did not challenge the device against *Giardia* cysts or viruses. Since the primary reduction mechanism is size exclusion, and because *Giardia* cysts are larger in size than C*ryptosporidium* oocysts, similar results for *Giardia* reduction can be assumed. Viruses are too small to be removed by the ceramic element used in these filtration devices. Very little information was received on the testing procedure. It was noted that during testing, the Mini required cleaning with the supplied scouring pad at every test point, stating also that the device tended to clog very easily. Results state that flow improved considerably after cleaning, but that as more water was passed through the device, cleaning was required more often. Due to the testing modifications with respect to reference 1, and the lack of data specific to the Combi, this evaluation based reduction capabilities on treatment technology. Therefore, this device is assigned one √ for bacteria and cyst reduction (for an explanation of the rating checks click here) based on size exclusion by the ceramic microfilter. Since the device is not designed, and has no mechanism, for virus reduction, the device is assigned one X for this pathogen. Additional treatment is required for virus reduction.

Table. Expected Performance Against Microbial Pathogens.

Microbial Pathogen Type	Expected Disinfection Capability	Evaluation Rating	Pathogen Reduction Mechanism
Bacteria	>6 log	√	size exclusion
Viruses	not effective*	X	none
Giardia cysts	>3 log	√	size exclusion
Cryptosporidium oocysts	>3 log	√	size exclusion

* additional treatment required for virus reduction.

Production Rate and Capacity

Inherent to the production rate and capacity of filtration devices is the quality of the raw water source. The manufacturer stated production capacity of the device is up to 50,000 L at a rate of

1.0 L/min. Since cleaning irreversibly decreases the size of the element, the overall capacity of this device will vary widely with raw water turbidity. No data was received showing the number of times this device can be cleaned before ceramic element replacement is required. Additionally, since the available data only processed 200 L, and with no indication of challenge water turbidity, no estimation of actual production capacity can be made.

Cleaning, Replacement, and End of Life Indicator

This device utilizes a ceramic depth microfilter which can be cleaned by scrubbing the surface of the filter element to remove accumulated debris. Given the small pore size of the ceramic element, it is expected to clog frequently during use with turbid waters and is therefore designed to be cleaned multiple times throughout its useful life. As stated above, the Katadyn Mini underwent multiple cleanings during the 200 L microbial challenge testing. Since the ceramic element used during testing was smaller than this device, production volume prior to required cleaning is expected to be greater but cannot be quantified. The report (reference 2) states that cleaning restored the production rate considerably and did not affect pathogen reductions. Supplied with the device is a gauge that is placed over the ceramic element. If the gauge fits around the element then the filter has been cleaned to its capacity and must be replaced. Since the device works solely on size exclusion, as long as the device will process water and the element is not determined to be too thin, stated pathogen reductions should be valid. When the filter begins to clog and pumping difficulty increases, the user should discontinue use and clean the ceramic element. This device does not contain a pressure relief valve, allowing for the possibility of the user over pressurizing the filter and damaging the seals. Since activated carbon is not considered a primary pathogen reduction mechanism, continuing use after the carbon capacity is exhausted, or using the device without carbon, should not affect microbial water quality.

Weight and Size

Katadyn Combi Microfilter	600 grams
Size (height x diameter)	27 cm x 8 cm
Tubing	107 cm

Cost

Katadyn Combi Microfilter	$140.00
Replacement ceramic element	$75.00
Replacement activated carbon	$9.00

Device Evaluation

The Katadyn Mini Microfilter utilizes a 0.2 µm silver impregnated ceramic element for the reduction of bacteria and cysts. The silver impregnation is designed to limit microbial growth on the ceramic element. No data was received regarding the efficacy of this bacteriostatic design. Microbial reduction data reviewed for a similar device manufactured by Katadyn (reference 2), tested against an abbreviated version of the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1), showed that this device should be capable of reducing bacteria by > 6-log, and cysts by > 3-log. No information was given as to the exact testing conditions and the volume of water treated during testing was far less than the stated capacity of the device. This device contains no virus reduction mechanism and, therefore, no testing was performed for this pathogen. Additional treatment is required to fully meet the requirements of reference 1 and ensure adequate reduction of all three classes of microorganism. Since size exclusion by ceramic microfilter elements is a generally accepted mechanism for pathogen reduction, we expect this device to adequately reduce bacteria and cysts in accordance with reference 1 and recommend additional treatment for virus reduction (reference 3). Activated carbon use is optional for this device and is expected to reduce taste and odor, but have no appreciable impact on microbial reduction. The testing results received note the requirement for multiple cleanings. Due to the small pore size, ceramic element cleaning is expected, increasing in frequency with increasing raw water turbidity. Results showed consistent pathogen reductions after cleaning (reference 2). It is expected that pathogen reductions will remain consistent throughout the useful life of the device. This device utilizes no chemicals and requires no wait time prior to water consumption. There is no indicator of process failure. A plastic gauge acts as an end of device useful life indicator. Since, during cleaning of the ceramic element the filter reduces size, when the gauge fits around the filter it must be replaced. This device, like all containing ceramic elements, must not be frozen while wet. Expansion of the water during freezing may crack the element. Additionally, the user should avoid shocking the device due to the brittle nature of ceramic elements and possible fracturing during shock loads. No manufacturing information or quality control data was received for this device. The manufacturer states ISO 9000 certification. No information was received on the storage life or required storage conditions for this device.

Advantages

- Based on treatment technology and independent data reviewed, this device should be capable of reducing bacteria and cysts to within the requirements of the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1).
- No wait time prior to water consumption.
- Field-serviceable.
- End of device useful life indicator.

Disadvantages

- Device is not designed for virus reduction and, therefore, unable to fully meet the pathogen reduction requirements of the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1).
- Additional treatment required.
- Small pore size of filter makes device inherently susceptible to clogging by waters with elevated turbidities.
- Ceramic element fragile to shock loads and freezing.
- No real-time indicator of process failure.

References

1. USEPA, 1989. Guide Standard and Protocol for Testing Microbiological Water Purifiers. *Federal Register*. 54:34067.

2. Independent laboratory results of tests showing bacteria and cyst reduction, 1995. Provided by Katadyn.

3. U.S. Army Center for Health Promotion and Preventive Medicine, 2005. *Technical Information Paper; Filtration in the Use of Individual Water Purification Devices,* Aberdeen Proving Ground, MD.

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ANNEX 24 TO APPENDIX E

DEVICE EVALUATION #24
KATADYN – EXSTREAM WATER BOTTLE PURIFIER

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Katadyn – Exstream Water Bottle Purifier

www.katadyn.com

Device Information

The Katadyn Exstream / Exstream XR Water Bottle Purifiers are handheld sports type squeeze bottles. These devices are available in both 0.62 L (21 oz) Exstream and the 0.83 L (28 oz) Exstream XR versions. Each bottle contains a modular filter cartridge system consisting of a carbon prefilter for sediment and odor reduction, a 1 µm protozoan cyst filter, and Virustat® cartridge for bacteria and virus reduction. The Virustat cartridge is a U.S. Environmental Protection Agency (USEPA) registered pesticide containing a PentaPure® penta-iodide resin followed by a layer of coconut-carbon to remove residual iodine prior to consumption. If desired, the Virustat cartridge and the carbon pre-filter can both be used alone, but due to design of mating joints the cyst filter can only be used in conjunction with the Virustat cartridge. Microbial reduction will be lessened if parts of the filter are not used. The filters are designed to ensure the correct order (pre-filter, cyst filter, then Virustat cartridge) to prevent user error. Before first use and after periods of storage, the bottle must be pre-conditioned by processing two volumes of water through the bottle then by filling a third time and allowing this water to remain for 2 hours prior to use. Subsequent to this conditioning normal use can begin, entailing simply filling the bottle with the cleanest water available, opening the bite valve, and squeezing the bottle to process water. Each of the three filters can be replaced separately as necessary.

Effectiveness Against Microbial Pathogens

Results from an independent study (references 1, 2) showed that when challenged against the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 3), this device (under brand name of company producing this device at the time of testing) met the pathogen log reduction, shown below, based on geometric averages of three identical devices for a production capacity of 100 L per device at a minimum flowrate of 0.125 L/min. This device is assigned three √s for the reduction of bacteria, virus, and Giardia, since independent results demonstrated effectiveness against these pathogens when challenged to reference 3 (for an

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explanation of the rating checks click here). In the absence of data, one √ is assigned to *Cryptosporidium* since excellent reductions are expected based on size exclusion by the cyst filter.

Table. Expected Performance Against Microbial Pathogens.

Microbial Pathogen Type	Expected Disinfection Capability	Evaluation Rating	Primary Pathogen Reduction Mechanism
Bacteria	> 6-log	√√√	iodinated resin
Viruses	> 4-log	√√√	iodinated resin
Giardia cysts	> 3-log	√√√	size exclusion
Cryptosporidium oocysts	> 3-log	√	size exclusion

Production Rate and Capacity

Inherent to the production rate and capacity of filtration devices is the quality of the raw water source. This device underwent microbiological reduction tests at a production rate of 0.125 – 0.200 L/min. Given the design, the actual rate is dependent on the user. In accordance with laboratory testing, the device should be operated at no more than 0.125 L/min to ensure pathogen removal. The production capacity of the device is stated to be 100 L based on the useful life of the Virustat® cartridge. Capacities of the pre-filter and cyst filter will vary widely with raw water turbidity.

Cleaning, Replacement, and End of Life Indicator

This device cannot be backwashed to remove sediment from the filter. When the device becomes unusable due to decreased production rate, the clogged filter must be replaced. Most often this will require replacement of the pre-filter, although the cyst filter may need replacement periodically. The bottle is dishwasher safe or can be hand washed with mild detergent and clean water. For practical purposes, the filter cartridges are not cleanable. The device contains no end of life indicator short of filter clogging. Independent data showed that the iodine resin was still effective at the rated capacity of the device (reference 1). After the rated capacity of 100 L has been processed, the Virustat® cartridge must be replaced to ensure pathogen reduction.

Weight and Size

Exstream dry weight	200 grams
Exstream XR dry weight	230 grams
Size (height x diameter)	28 cm x 8 cm

Cost

Exstream	$45.00
Exstream XR	$50.00
Replacement Virustat® cartridge, cyst, and prefilter	$33.00
Replacement Cyst filter (2 pack)	$16.95
Replacement Prefilter (2 pack)	$16.95

Device Evaluation

The pathogen reduction technology of the Katadyn Exstream / Exstream XR Water Bottle Purifiers has been shown, based on independent data (references 1, 2), to be capable of meeting the requirements of reference 3. Bacteria and virus reduction is based on iodine disinfection and cyst reduction is due to size exclusion by microfiltration (reference 4). Although the 1 µm cyst filter should adequately reduce *Cryptosporidium* oocysts, no data was presented for review. The device consists of three stages of filtration, utilizing carbon, microfiltration, and iodinated resin disinfection. Taste, odor, and sediment will likely be reduced by the carbon elements. Results from reference 1 indicate considerable iodine residual (3-7 mg/L) in the processed water despite the use of carbon as a last stage process. Persons with sensitivity to iodine, thyroid problems, and pregnant women should avoid this device due to residual iodine. The iodine residual should pose no medical threat to healthy users. If taste from residual iodine is objectionable, the pre-filter, containing carbon, can be placed as the last filter to polish the iodine from the treated water. In this case, the cyst filter will likely clog sooner, due to particulate build-up. This device, like all filters with small pore sizes, is highly affected by turbid (cloudy) waters. During the microbial pathogen reduction testing following reference 3, the pre-filter and cyst filter each required replacement 14 times due to clogging during the 50 L of elevated turbidity testing. These results indicate that this device is not practical if turbid waters are expected. Since the device is not able to be backwashed to remove accumulated particulates, once clogged, the pre- and/or cyst filters must be replaced. In an emergency and if replacement filters are unavailable, the user should remove the clogged filter(s), leaving only the Virustat cartridge. This will allow the user to process a limited amount of water prior to this filter also clogging if used with highly turbid waters. Microbial reduction will be lessened, with little or no cyst removal capabilities (reference 5). The iodinated resin in the Virustat cartridge will provide

some bacteria and virus reduction, but efficacy may be lessened due to water turbidity. This option should only be used if no other means of purifying water is available. This device requires a 2-hour pre-conditioning prior to first use, after periods of storage, and when replacing the Virustat cartridge. After this step, no wait time is required during normal use. There is no indicator of process failure or end of device useful life. The manufacturer states ISO 9000 certification. No information was received on the storage life or required storage conditions for this device.

Advantages

- Independent testing confirms bacteria, virus, and protozoan reduction in accordance with the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 3).
- No wait time prior to consumption, after 2-hour pre-conditioning step.
- Simple and effective.

Disadvantages

- Independent tests indicate device is highly affected by turbid waters, requiring frequent filter replacements.
- No data showing reduction efficacy of *Cryptosporidium* oocysts.
- Device unable to be backwashed.
- No real-time indicator of process failure.

References

1. Independent laboratory results of tests showing compliance with the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers, 1995. Provided by Katadyn.

2. Independent laboratory results of tests showing compliance with the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (bacteria and virus only), 2000. Provided by Katadyn.

3. USEPA, 1989. Guide Standard and Protocol for Testing Microbiological Water Purifiers. *Federal Register*. 54:34067.

4. U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM), 2005. *Technical Information Paper; Filtration in the Use of Individual Water Purification Devices,* Aberdeen Proving Ground, MD.

5. USACHPPM, 2005. *Technical Information Paper; Iodine Disinfection in the Use of Individual Water Purification Devices,* Aberdeen Proving Ground, MD.

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ANNEX 25 TO APPENDIX E

DEVICE EVALUATION #25
KATADYN – EXSTREAM XR WATER BOTTLE PURIFIER

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Katadyn –Exstream XR Water Bottle Purifier

www.katadyn.com

Device Information

The Katadyn Exstream / Exstream XR Water Bottle Purifiers are handheld sports type squeeze bottles. These devices are available in both 0.62 L (21 oz) Exstream and the 0.83 L (28 oz) Exstream XR versions. Each bottle contains a modular filter cartridge system consisting of a carbon prefilter for sediment and odor reduction, a 1 µm protozoan cyst filter, and Virustat® cartridge for bacteria and virus reduction. The Virustat cartridge is a U.S. Environmental Protection Agency (USEPA) registered pesticide containing a PentaPure® penta-iodide resin followed by a layer of coconut-carbon to remove residual iodine prior to consumption. If desired, the Virustat cartridge and the carbon pre-filter can both be used alone, but due to design of mating joints the cyst filter can only be used in conjunction with the Virustat cartridge. Microbial reduction will be lessened if parts of the filter are not used. The filters are designed to ensure the correct order (pre-filter, cyst filter, then Virustat cartridge) to prevent user error. Before first use and after periods of storage, the bottle must be pre-conditioned by processing two volumes of water through the bottle then by filling a third time and allowing this water to remain for 2 hours prior to use. Subsequent to this conditioning normal use can begin, entailing simply filling the bottle with the cleanest water available, opening the bite valve, and squeezing the bottle to process water. Each of the three filters can be replaced separately as necessary.

Effectiveness Against Microbial Pathogens

Results from an independent study (references 1, 2) showed that when challenged against the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 3), this device (under brand name of company producing this device at the time of testing) met the pathogen log reduction, shown below, based on geometric averages of three identical devices for a production capacity of 100 L per device at a minimum flowrate of 0.125 L/min. This device is assigned three √s for the reduction of bacteria, virus, and Giardia, since independent results

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® PentaPure is a registered trademark of Katadyn Products, Inc., Birkenweg 4, Switzerland. Use of trademarked products does not imply endorsement by the U.S. Army, but is intended only in identification of a specific product.

demonstrated effectiveness against these pathogens when challenged to reference 3 (for an explanation of the rating checks click here). In the absence of data, one √ is assigned to *Cryptosporidium* since excellent reductions are expected based on size exclusion by the cyst filter.

Table. Expected Performance Against Microbial Pathogens.

Microbial Pathogen Type	Expected Disinfection Capability	Evaluation Rating	Primary Pathogen Reduction Mechanism
Bacteria	> 6-log	√√√	iodinated resin
Viruses	> 4-log	√√√	iodinated resin
Giardia cysts	> 3-log	√√√	size exclusion
Cryptosporidium oocysts	> 3-log	√	size exclusion

Production Rate and Capacity

Inherent to the production rate and capacity of filtration devices is the quality of the raw water source. This device underwent microbiological reduction tests at a production rate of 0.125 – 0.200 L/min. Given the design, the actual rate is dependent on the user. In accordance with laboratory testing, the device should be operated at no more than 0.125 L/min to ensure pathogen removal. The production capacity of the device is stated to be 100 L based on the useful life of the Virustat cartridge. Capacities of the pre-filter and cyst filter will vary widely with raw water turbidity.

Cleaning, Replacement, and End of Life Indicator

This device cannot be backwashed to remove sediment from the filter. When the device becomes unusable due to decreased production rate, the clogged filter must be replaced. Most often this will require replacement of the pre-filter, although the cyst filter may need replacement periodically. The bottle is dishwasher safe or can be hand washed with mild detergent and clean water. For practical purposes, the filter cartridges are not cleanable. The device contains no end of life indicator short of filter clogging. Independent data showed that the iodine resin was still effective at the rated capacity of the device (reference 1). After the rated capacity of 100 L has been processed, the Virustat cartridge must be replaced to ensure pathogen reduction.

Weight and Size

Exstream dry weight	200 grams
Exstream XR dry weight	230 grams
Size (height x diameter)	28 cm x 8 cm

Cost

Exstream	$45.00
Exstream XR	$50.00
Replacement Virustat® cartridge, cyst, and prefilter	$33.00
Replacement Cyst filter (2 pack)	$16.95
Replacement Prefilter (2 pack)	$16.95

Device Evaluation

The pathogen reduction technology of the Katadyn Exstream / Exstream XR Water Bottle Purifiers has been shown, based on independent data (references 1, 2), to be capable of meeting the requirements of reference 3. Bacteria and virus reduction is based on iodine disinfection and cyst reduction is due to size exclusion by microfiltration (reference 4). Although the 1 µm cyst filter should adequately reduce *Cryptosporidium* oocysts, no data was presented for review. The device consists of three stages of filtration, utilizing carbon, microfiltration, and iodinated resin disinfection. Taste, odor, and sediment will likely be reduced by the carbon elements. Results from reference 1 indicate considerable iodine residual (3-7 mg/L) in the processed water despite the use of carbon as a last stage process. Persons with sensitivity to iodine, thyroid problems, and pregnant women should avoid this device due to residual iodine. The iodine residual should pose no medical threat to healthy users. If taste from residual iodine is objectionable, the pre-filter, containing carbon, can be placed as the last filter to polish the iodine from the treated water. In this case, the cyst filter will likely clog sooner, due to particulate build-up. This device, like all filters with small pore sizes, is highly affected by turbid (cloudy) waters. During the microbial pathogen reduction testing following reference 3, the pre-filter and cyst filter each required replacement 14 times due to clogging during the 50 L of elevated turbidity testing. These results indicate that this device is not practical if turbid waters are expected. Since the device is not able to be backwashed to remove accumulated particulates, once clogged, the pre- and/or cyst filters must be replaced. In an emergency and if replacement filters are unavailable, the user should remove the clogged filter(s), leaving only the Virustat cartridge. This will allow the user to process a limited amount of water prior to this filter also clogging if used with highly turbid waters. Microbial reduction will be lessened, with little or no cyst removal capabilities (reference 5). The iodinated resin in the Virustat cartridge will provide

some bacteria and virus reduction, but efficacy may be lessened due to water turbidity. This option should only be used if no other means of purifying water is available. This device requires a 2-hour pre-conditioning prior to first use, after periods of storage, and when replacing the Virustat cartridge. After this step, no wait time is required during normal use. There is no indicator of process failure or end of device useful life. The manufacturer states ISO 9000 certification. No information was received on the storage life or required storage conditions for this device.

Advantages

- Independent testing confirms bacteria, virus, and protozoan reduction in accordance with the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 3).
- No wait time prior to consumption, after 2-hour pre-conditioning step.
- Simple and effective.

Disadvantages

- Independent tests indicate device is highly affected by turbid waters, requiring frequent filter replacements.
- No data showing reduction efficacy of *Cryptosporidium* oocysts.
- Device unable to be backwashed.
- No real-time indicator of process failure.

References

1. Independent laboratory results of tests showing compliance with the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers, 1995. Provided by Katadyn.

2. Independent laboratory results of tests showing compliance with the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (bacteria and virus only), 2000. Provided by Katadyn.

3. USEPA, 1989. Guide Standard and Protocol for Testing Microbiological Water Purifiers. *Federal Register*. 54:34067.

4. U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM), 2005. *Technical Information Paper; Filtration in the Use of Individual Water Purification Devices,* Aberdeen Proving Ground, MD.

5. USACHPPM, 2005. *Technical Information Paper; Iodine Disinfection in the Use of Individual Water Purification Devices,* Aberdeen Proving Ground, MD.

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ANNEX 26 TO APPENDIX E

DEVICE EVALUATION #26

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Katadyn – Guide

www.katadyn.com

Device Information

The Katadyn Guide is a handheld pump water treatment device with microfilter treatment technology. Containing what the manufacturer terms "AntiClog Technology", the device consists of 143 square inches of pleated 0.3 µm glass fiber media, with an activated carbon core. This device creates an absolute barrier to contaminants greater than the pore size and may remove taste and odor through carbon filtration. This device contains no chemicals and requires no wait time. It is recommended that the initial liter of water be discarded due to carbon fines. During subsequent use, it is recommended that the first 5 - 10 strokes worth of water be discarded to remove stale water from the device. The device consists of a plastic housing, 130 µm pre-filter, glass fiber microfilter with activated carbon core, universal bottle adaptor for product water, and tubing. The pre-filter is fitted with a weight and adjustable float to keep it submerged, yet off of the bottom of the water source to limit the introduction of sediment to the filter. Additionally, pump lubricant and a carry bag are included with the device. Newer versions of this device may include a removable filter protector, and a hydration pack quick connect fitting. The filter protector supplies an extra barrier to extend the microfilter life by reducing particulate matter, but it is unlikely to increase microbial pathogen reduction. The quick connect fittings allow for easy filling of a hydration pack. This device is designed for bacteria and cyst reduction. The manufacturer makes no virus reduction claims.

Effectiveness Against Microbial Pathogens

No laboratory results were obtained that challenged this device to demonstrate pathogen reduction. This device utilizes identical pathogen reduction mechanisms as the Katadyn Hiker and therefore the results reviewed for that device were deemed applicable to the Katadyn Guide. Independent laboratory results were received challenging the Katadyn Hiker (tested under a previously brand name) against a modified version of the U.S. Environmental Protection Agency (USEPA) Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1). Results for bacteria challenge showed reduction of > 6-log based on geometric averages of samples collected (references 2, 3). Data collected for *Cryptosporidium* reduction met the > 3-log reduction requirement of reference 1 (references 2, 3). Since the primary

reduction mechanism is size exclusion, and because *Giardia* cysts are larger in size than C*ryptosporidium* oocysts, similar results for *Giardia* reduction can be assumed. This device is not designed for virus reduction and therefore, no data was reviewed for reduction of this pathogen. This device is assigned one √ for bacteria and cyst reduction (for an explanation of the rating checks click here) based on size exclusion by the glass microfilter. Since the device is not designed, and has no mechanism, for virus reduction, the device is assigned one X for this pathogen.

Table. Expected Performance Against Microbial Pathogens.

Microbial Pathogen Type	Expected Disinfection Capability	Evaluation Rating	Pathogen Reduction Mechanism
Bacteria	> 6-log	√	size exclusion
Viruses	not effective*	X	none
Giardia cysts	> 3-log	√	size exclusion
Cryptosporidium oocysts	> 3-log	√	size exclusion

* additional treatment required for virus reduction.

Production Rate and Capacity

Inherent to the production rate and capacity of filtration devices is the quality of the raw water source. The manufacturer stated production capacity of the device is 750 L at a rate of 1.5 L/min. User effort is stated to be 36 strokes/L. This device utilizes a glass depth microfilter. The filter cannot be backwashed, and once clogged must be replaced. If clogged, a small amount of water may be produced if the filter is removed and swished in water (raw water acceptable). The filter protector should extend the life of the microfilter, but clogging may still occur, dependent upon the raw water quality. The filter protector is a removable coarse material that can be scraped clean and swished in water to remove particulates. The capacity of this device will vary widely with raw water turbidity.

Cleaning, Replacement, and End of Life Indicator

This device cannot be backwashed to remove sediment from the filter. When the device becomes unusable due to decreased production rate, the clogged filter must be replaced. The filter protector can be removed, cleaned and reused. The device contains no end of life indicator

short of filter clogging. Since the device works solely on size exclusion, as long as the device will process water, stated pathogen reductions should be valid. The carbon core will eventually become exhausted. Since little or no pathogen reduction is attributed to the carbon core, if it were to be exhausted prior to clogging of the microfilter, microbial quality should be unchanged. No data was presented to determine the capacity of the carbon core.

Weight and Size

Guide	400 grams
Size (height x diameter)	25 cm x 7 cm
Tubing, 2 pieces (length, each)	92 cm

Cost

Guide	$85.00
Guide replacement filter (glass microfilter, carbon, filter protector)	$35.00

Device Evaluation

The Katadyn Guide utilizes a 0.3 µm glass microfilter and granular activated carbon core for the reduction of bacteria, and cysts, as well as taste and odor. The Katadyn Guide utilizes the same reduction mechanisms as the Katadyn Hiker and, therefore, in the absence of data specific to the Guide, results for the Hiker were reviewed for this analysis. Independent data for the Katadyn Hiker showed reduction of bacteria and cysts by > 6-log and > 3-log, respectively. Due to data not specific to this device, one check each for reduction of cysts and bacteria is assigned. This rating states that, due to the device technology, expert opinion believes that the device should be able to meet the bacteria and cyst reduction requirements of reference 1 (reference 4). More independent laboratory data specific to this device is necessary to confirm these reductions. Since the device reduction mechanism is size exclusion by means of a 0.3 µm microfilter, no virus reduction is claimed by the manufacturer. Additional treatment is required to fully meet the requirements of reference 1 and ensure adequate reduction of all three classes of microorganism. This device, like all filters with small pore sizes, is highly affected by turbid (cloudy) waters. This device utilizes no chemicals and requires no wait time prior to water consumption. There is no indicator of process failure or end of device useful life except filter clogging or the user keeping track of the volume of water produced. No manufacturing information or quality control data was received for this device. The manufacturer states ISO 9000 certification. No information was received on the storage life or required storage conditions for this device.

Advantages

- Based on treatment technology and limited independent data reviewed, this device should be capable of reducing bacteria and cysts to within the requirements of the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1).
- No wait time prior to water consumption.
- Activated carbon core should reduce taste and odors.
- Simple and lightweight.

Disadvantages

- Device is not designed for virus reduction and, therefore, unable to fully meet the pathogen reduction requirements of the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1).
- Additional treatment required.
- Small pore size of filter makes device inherently susceptible to clogging by waters with elevated turbidities.
- Device unable to be backwashed.
- No real-time indicator of process failure.

References

1. USEPA, 1989. Guide Standard and Protocol for Testing Microbiological Water Purifiers. *Federal Register*. 54:34067.

2. Independent laboratory results of tests showing bacteria and cyst reduction, 1996. Provided by Katadyn.

3. Independent laboratory results of tests showing bacteria and cyst reduction, 1995. Provided by Katadyn.

4. U.S. Army Center for Health Promotion and Preventive Medicine, 2005. *Technical Information Paper; Filtration in the Use of Individual Water Purification Devices,* Aberdeen Proving Ground, MD.

ANNEX 27 TO APPENDIX E

DEVICE EVALUATION #27
KATADYN – HIKER

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Katadyn – Hiker

www.katadyn.com

Device Information

The Katadyn Hiker is a handheld pump water treatment device containing microfilter treatment technology. Containing what the manufacturer terms "AntiClog Technology", the device consists of 129 square inches of pleated 0.3 µm glass fiber media, with an activated carbon core. This device creates an absolute barrier to contaminants greater than the pore size and may remove taste and odor through carbon filtration. This device contains no chemicals and requires no wait time. It is recommended that the initial liter of water be discarded due to carbon fines. During subsequent use, it is recommended that the first 5 - 10 strokes worth of water be discarded to remove stale water from the device. The device consists of a plastic housing, 130 µm pre-filter, glass microfilter, activated carbon core, universal bottle adaptor for product water, and tubing. The pre-filter is fitted with a weight and adjustable float to keep it submerged, yet off of the bottom of the water source to limit the introduction of sediment to the filter. Additionally, pump lubricant and a carry bag are included with the device. The Katadyn Hiker Pro is an identical device with the addition of a removable filter protector, quick connect tubing fittings, and a hydration pack connector. The filter protector supplies an extra barrier to extend the microfilter life by removing particulate matter, but it is unlikely to increase microbial pathogen reduction. The quick connect fittings allow for easy removal of the tubing as well as the filling of a hydration pack without having to open the pack bladder. This device is designed for bacteria and cyst reduction. The manufacturer makes no virus reduction claims.

Effectiveness Against Microbial Pathogens

Independent laboratory results were received challenging the Katadyn Hiker (tested under a previous brand name) against a modified version of the U.S. Environmental Protection Agency (USEPA) Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1). Results for bacteria challenge showed reduction of > 6-log based on geometric averages of samples collected (references 2, 3). Data collected for *Cryptosporidium* reduction met the > 3-log reduction requirement of reference 1 (references 2, 3). Since the primary reduction mechanism is size exclusion, and because *Giardia* cysts are larger in size than C*ryptosporidium* oocysts, similar results for *Giardia* cyst reduction can be assumed. This device is not designed for virus reduction and, therefore no data was reviewed for reduction of this

pathogen. Due to unclear testing conditions and modifications of testing water quality as compared to the requirements of reference 1, this device is assigned one √ each for bacteria and cyst reduction (for an explanation of the rating checks click here) based on size exclusion by the glass microfilter. Since the device is not designed, and has no mechanism for virus reduction, the device is assigned one X for this pathogen.

Table. Expected Performance Against Microbial Pathogens.

Microbial Pathogen Type	Expected Disinfection Capability	Evaluation Rating	Pathogen Reduction Mechanism
Bacteria	> 6-log	√	size exclusion
Viruses	not effective*	X	none
Giardia cysts	> 3-log	√	size exclusion
Cryptosporidium oocysts	> 3-log	√	size exclusion

* Additional treatment required for virus reduction.

Production Rate and Capacity

Inherent to the production rate and capacity of filtration devices is the quality of the raw water source. The manufacturer stated production capacity of the device is 750 L at a rate of 1 L/min. User effort is stated to be 48 strokes/min, resulting in 1 L of product. This device utilizes a glass depth microfilter. The filter cannot be backwashed, and once clogged must be replaced. If clogged, a small amount of water may be produced if the filter is removed and swished in water (raw water acceptable). The Katadyn Hiker Pro contains a filter protector which will extend the life of the microfilter, but clogging may still occur, dependent upon the raw water quality. The filter protector is a removable coarse material that can be scraped clean and swished in water to remove particulates. The capacity of this device will vary widely with raw water turbidity.

Cleaning, Replacement, and End of Life Indicator

This device cannot be backwashed to remove sediment from the filter. When the device becomes unusable due to decreased production rate, the clogged filter must be replaced. The filter protector of the Hiker Pro can be removed, cleaned, and reused. The device contains no end of life indicator short of filter clogging. Since the device works solely on size exclusion, as long as the device will process water, stated pathogen reductions should be valid. The carbon

core will eventually become exhausted. Since little or no pathogen reduction is attributed to the carbon core, if it were to be exhausted prior to clogging of the microfilter, microbial quality should be unchanged. No data was presented to determine the capacity of the carbon core.

Weight and Size

Hiker / Hiker Pro	310 grams
Size (height x diameter)	16.5 cm x 8 cm
Tubing, 2 pieces (length, each)	92 cm

Cost

Hiker	$60.00
Hiker Pro	$70.00
Hiker and Hiker Pro replacement filter (glass microfilter, carbon, filter protector)	$35.00

Device Evaluation

The Katadyn Hiker utilizes a glass microfilter and carbon core for the reduction of bacteria, and cysts, as well as taste and odor. Independent data collected under a modified USEPA protocol (reference 1) showed reduction of bacteria and cysts by > 6-log and > 3-log, respectively. Laboratory results are unclear on flow rate used during testing and the challenge water quality was not strict to reference 1. Pathogen reduction by size exclusion with a 0.3 µm microfilter is a proven mechanism and, therefore, this device is assigned one check each for bacteria and cyst reduction, indicating pathogen reduction to the requirements of reference 1 are expected (reference 4). No virus reduction is claimed by the manufacturer or expected using this device. Additional treatment is required to fully meet the requirements of reference 1 and ensure adequate reduction of all three classes of microorganism. No information was given as to any maintenance required during testing. This device, like all filters with small pore sizes, is highly affected by turbid (cloudy) waters. This device utilizes no chemicals and requires no wait time prior to water consumption. There is no indicator of process failure or end of device useful life except filter clogging or by the user keeping track of the volume of water produced. This device contains no pressure reducing valve. The user should be careful not to over pressurize the filter as the device clogs, potentially damaging the integrity of the filter element and reducing the pathogen reduction effectiveness. No manufacturing information or quality control data was received for this device. The manufacturer states ISO 9000 certification. No information was received on the storage life or required storage conditions for this device.

Advantages

- Based on treatment technology and independent data reviewed, this device should be capable of reducing bacteria and cysts to within the requirements of the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1).
- No wait time prior to water consumption.
- Activated carbon core should reduce taste and odors.
- Simple and lightweight.

Disadvantages

- Device is not designed for virus reduction and, therefore, unable to fully meet the pathogen reduction requirements of the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1).
- Additional treatment required.
- Small pore size of filter makes device inherently susceptible to clogging by waters with elevated turbidities.
- Device unable to be backwashed.
- No real-time indicator of process failure.

References

1. USEPA, 1989. Guide Standard and Protocol for Testing Microbiological Water Purifiers. *Federal Register*. 54:34067.

2. Independent laboratory results of tests showing bacteria and cyst reduction, 1996. Provided by Katadyn.

3. Independent laboratory results of tests showing bacteria and cyst reduction, 1995. Provided by Katadyn.

4. U.S. Army Center for Health Promotion and Preventive Medicine, 2005. *Technical Information Paper; Filtration in the Use of Individual Water Purification Devices,* Aberdeen Proving Ground, MD.

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DEVICE EVALUATION #28
KATADYN – HIKER PRO

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Katadyn – Hiker Pro

www.katadyn.com

Device Information

The Katadyn Hiker is a handheld pump water treatment device containing microfilter treatment technology. Containing what the manufacturer terms "AntiClog Technology", the device consists of 129 square inches of pleated 0.3 µm glass fiber media, with an activated carbon core. This device creates an absolute barrier to contaminants greater than the pore size and may remove taste and odor through carbon filtration. This device contains no chemicals and requires no wait time. It is recommended that the initial liter of water be discarded due to carbon fines. During subsequent use, it is recommended that the first 5 - 10 strokes worth of water be discarded to remove stale water from the device. The device consists of a plastic housing, 130 µm pre-filter, glass microfilter, activated carbon core, universal bottle adaptor for product water, and tubing. The pre-filter is fitted with a weight and adjustable float to keep it submerged, yet off of the bottom of the water source to limit the introduction of sediment to the filter. Additionally, pump lubricant and a carry bag are included with the device. The Katadyn Hiker Pro is an identical device with the addition of a removable filter protector, quick connect tubing fittings, and a hydration pack connector. The filter protector supplies an extra barrier to extend the microfilter life by removing particulate matter, but it is unlikely to increase microbial pathogen reduction. The quick connect fittings allow for easy removal of the tubing as well as the filling of a hydration pack without having to open the pack bladder. This device is designed for bacteria and cyst reduction. The manufacturer makes no virus reduction claims.

Effectiveness Against Microbial Pathogens

Independent laboratory results were received challenging the Katadyn Hiker (tested under a previous brand name) against a modified version of the U.S. Environmental Protection Agency (USEPA) Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1). Results for bacteria challenge showed reduction of > 6-log based on geometric averages of samples collected (references 2, 3). Data collected for *Cryptosporidium* reduction met the > 3-log reduction requirement of reference 1 (references 2, 3). Since the primary reduction mechanism is size exclusion, and because *Giardia* cysts are larger in size than C*ryptosporidium* oocysts, similar results for *Giardia* cyst reduction can be assumed. This device is not designed for virus reduction and, therefore no data was reviewed for reduction of this

pathogen. Due to unclear testing conditions and modifications of testing water quality as compared to the requirements of reference 1, this device is assigned one √ each for bacteria and cyst reduction (for an explanation of the rating checks click here) based on size exclusion by the glass microfilter. Since the device is not designed, and has no mechanism for virus reduction, the device is assigned one X for this pathogen.

Table. Expected Performance Against Microbial Pathogens.

Microbial Pathogen Type	Expected Disinfection Capability	Evaluation Rating	Pathogen Reduction Mechanism
Bacteria	> 6-log	√	size exclusion
Viruses	not effective*	X	none
Giardia cysts	> 3-log	√	size exclusion
Cryptosporidium oocysts	> 3-log	√	size exclusion

* Additional treatment required for virus reduction.

Production Rate and Capacity

Inherent to the production rate and capacity of filtration devices is the quality of the raw water source. The manufacturer stated production capacity of the device is 750 L at a rate of 1 L/min. User effort is stated to be 48 strokes/min, resulting in 1 L of product. This device utilizes a glass depth microfilter. The filter cannot be backwashed, and once clogged must be replaced. If clogged, a small amount of water may be produced if the filter is removed and swished in water (raw water acceptable). The Katadyn Hiker Pro contains a filter protector which will extend the life of the microfilter, but clogging may still occur, dependent upon the raw water quality. The filter protector is a removable coarse material that can be scraped clean and swished in water to remove particulates. The capacity of this device will vary widely with raw water turbidity.

Cleaning, Replacement, and End of Life Indicator

This device cannot be backwashed to remove sediment from the filter. When the device becomes unusable due to decreased production rate, the clogged filter must be replaced. The filter protector of the Hiker Pro can be removed, cleaned, and reused. The device contains no end of life indicator short of filter clogging. Since the device works solely on size exclusion, as long as the device will process water, stated pathogen reductions should be valid. The carbon

core will eventually become exhausted. Since little or no pathogen reduction is attributed to the carbon core, if it were to be exhausted prior to clogging of the microfilter, microbial quality should be unchanged. No data was presented to determine the capacity of the carbon core.

Weight and Size

Hiker / Hiker Pro	310 grams
Size (height x diameter)	16.5 cm x 8 cm
Tubing, 2 pieces (length, each)	92 cm

Cost

Hiker	$60.00
Hiker Pro	$70.00
Hiker and Hiker Pro replacement filter (glass microfilter, carbon, filter protector)	$35.00

Device Evaluation

The Katadyn Hiker utilizes a glass microfilter and carbon core for the reduction of bacteria, and cysts, as well as taste and odor. Independent data collected under a modified USEPA protocol (reference 1) showed reduction of bacteria and cysts by > 6-log and > 3-log, respectively. Laboratory results are unclear on flow rate used during testing and the challenge water quality was not strict to reference 1. Pathogen reduction by size exclusion with a 0.3 µm microfilter is a proven mechanism and, therefore, this device is assigned one check each for bacteria and cyst reduction, indicating pathogen reduction to the requirements of reference 1 are expected (reference 4). No virus reduction is claimed by the manufacturer or expected using this device. Additional treatment is required to fully meet the requirements of reference 1 and ensure adequate reduction of all three classes of microorganism. No information was given as to any maintenance required during testing. This device, like all filters with small pore sizes, is highly affected by turbid (cloudy) waters. This device utilizes no chemicals and requires no wait time prior to water consumption. There is no indicator of process failure or end of device useful life except filter clogging or by the user keeping track of the volume of water produced. This device contains no pressure reducing valve. The user should be careful not to over pressurize the filter as the device clogs, potentially damaging the integrity of the filter element and reducing the pathogen reduction effectiveness. No manufacturing information or quality control data was received for this device. The manufacturer states ISO 9000 certification. No information was received on the storage life or required storage conditions for this device.

Advantages

- Based on treatment technology and independent data reviewed, this device should be capable of reducing bacteria and cysts to within the requirements of the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1).
- No wait time prior to water consumption.
- Activated carbon core should reduce taste and odors.
- Simple and lightweight.

Disadvantages

- Device is not designed for virus reduction and, therefore, unable to fully meet the pathogen reduction requirements of the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1).
- Additional treatment required.
- Small pore size of filter makes device inherently susceptible to clogging by waters with elevated turbidities.
- Device unable to be backwashed.
- No real-time indicator of process failure.

References

1. USEPA, 1989. Guide Standard and Protocol for Testing Microbiological Water Purifiers. *Federal Register*. 54:34067.

2. Independent laboratory results of tests showing bacteria and cyst reduction, 1996. Provided by Katadyn.

3. Independent laboratory results of tests showing bacteria and cyst reduction, 1995. Provided by Katadyn.

4. U.S. Army Center for Health Promotion and Preventive Medicine, 2005. *Technical Information Paper; Filtration in the Use of Individual Water Purification Devices*, Aberdeen Proving Ground, MD.

ANNEX 29 TO APPENDIX E

DEVICE EVALUATION #29
KATADYN – MICRO WATER BOTTLE

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Katadyn – Micro Water Bottle

www.katadyn.com

Device Information

The Katadyn Micro Water Bottle is a handheld sports type squeeze bottle. This device is a 0.62 L (21 oz.) plastic bottle containing a modular filter cartridge system consisting of a 0.3 micron pleated glass microfilter for bacteria and cyst reduction, and carbon filter for taste and odor control. This device is not designed for virus reduction. Normal use entails simply filling the bottle with the cleanest water available, opening the bite valve, and squeezing the bottle to process water. No wait time or conditioning steps are necessary prior to using the device beyond expelling a small amount of water before first use to remove carbon fines. The filters can be replaced as necessary and if desired the device can be upgraded to the Katadyn Exstream Water Bottle Purifier to enable reduction of bacteria, cysts, and viruses by purchasing different filter cartridges.

Effectiveness Against Microbial Pathogens

No results were received that tested the device against the U.S. Environmental Protection Agency (USEPA) Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1). Independent laboratory results (reference 2) were reviewed that tested the device against an abbreviated version of the protocol found in reference 1, entailing less sampling events, and omitting virus challenge. Results indicated that this device is capable of reducing bacteria and cysts by the values stated below by means of size exclusion through the glass microfilter. This device was assigned one √ for bacteria and cyst reduction, indicating that based on treatment technology, the device should be able to meet the requirements of reference 1 for these pathogens (click here for rating explanation) (reference 3). The device is assigned one X for virus reduction since there is no reduction mechanism or manufacturer claim for reducing this pathogen. Testing indicated that this device is highly affected by turbidity and, therefore, underwent minimal pathogen challenging with the high turbidity waters required in reference 1.

Table. Expected Performance Against Microbial Pathogens.

Microbial Pathogen Type	Expected Disinfection Capability	Evaluation Rating	Primary Pathogen Reduction Mechanism
Bacteria	> 6-log	√	size exclusion
Viruses	not effective*	X	none
Giardia cysts	> 3-log	√	size exclusion
Cryptosporidium oocysts	> 3-log	√	size exclusion

* Additional treatment required.

Production Rate and Capacity

Inherent to the production rate and capacity of filtration devices is the quality of the raw water source. The manufacturer stated production capacity of the device is 100 L. As shown during independent laboratory pathogen reduction testing (reference 2), turbid water negatively affects production capacity. Due to clogging after processing less than 5 liters of the high turbidity water specified in reference 1, the testing was stopped, resulting in a total production capacity of about 62 L. The majority of this production capacity was tested with clear water. The capacity of this device will vary widely with raw water turbidity. Given the design, the actual production rate is dependent on the user. Testing of a similar device, the Katadyn Exstream Water Bottle Purifier, indicated a production rate of 0.125 L/min as a minimum acceptable rate. In the absence of data, that production rate will be assumed for this device.

Cleaning, Replacement, and End of Life Indicator

This device cannot be backwashed to remove sediment from the filter. When the device becomes unusable due to decreased production rate, the clogged filter must be replaced. The bottle is dishwasher safe or can be hand washed with mild detergent and clean water. For practical purposes, the filter cartridges are not cleanable. The device contains no end of life indicator short of filter clogging. Since the device works solely on size exclusion, as long as the device will process water, stated pathogen reductions should be valid.

Weight and Size

Micro device	200 grams
Size (height x diameter)	28 cm x 8 cm

Cost

Micro device	$30.00
Replacement filter cartridges (microfilter and carbon)	$20.00

Device Evaluation

No data was received that tested this device against the protocol of reference 1. Independent laboratory results (reference 2) indicate that this device is capable of reducing bacteria and cysts by > 6-log and > 3-log, respectively. Bacteria and cyst reduction are accomplished by the 0.3 µm microfilter, followed by a carbon filter for taste and odor reduction. This device is not designed for virus reduction and therefore requires additional treatment to reduce health risk due to viral contamination. This device, like all filters with small pore sizes, is highly affected by turbid (cloudy) waters. During testing, turbid water quickly clogged the filter, making the device inoperable. These results indicate that this device is not practical if highly turbid waters are expected. Since the device is not able to be backwashed to remove accumulated particulates, once clogged, the filters must be replaced. No wait time is required prior to water consumption. There is no indicator of process failure or end of device useful life except filter clogging. No information was received on the storage life or required storage conditions for this device.

Advantages

- Independent testing (reference 2) confirmed bacteria and cyst reduction of > 6-log and > 3-log, respectively.
- No wait time prior to water consumption.
- Simple and lightweight.

Disadvantages

- Device is not designed for virus reduction and, therefore, unable to meet the pathogen reduction requirements of the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1).
- No independent laboratory data to indicate bacteria and cyst reduction in accordance with reference 1.
- Additional treatment required.
- Independent tests (reference 2) indicate device is highly affected by turbid waters.
- Device unable to be backwashed.
- No real-time indicator of process failure.

References

1. USEPA, 1989. Guide Standard and Protocol for Testing Microbiological Water Purifiers. *Federal Register*. 54:34067.

2. Independent laboratory results of tests showing bacteria and cyst reduction, 2005. Provided by Katadyn.

3. U.S. Army Center for Health Promotion and Preventive Medicine, 2005. *Technical Information Paper; Filtration in the Use of Individual Water Purification Devices,* Aberdeen Proving Ground, MD.

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DEVICE #30
KATADYN – DRIP CERADYN

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ANNEX 31 TO APPENDIX E

DEVICE #31
KATADYN – DRIP GRAVIDYN

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ANNEX 32 TO APPENDIX E

DEVICE EVALUATION #32
KATADYN – MINI MICROFILTER

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Katadyn – Mini Microfilter

www.katadyn.com

Device Information

The Katadyn Mini Microfilter is a handheld pump water treatment device utilizing ceramic microfiltration. The ceramic element is a field cleanable 0.2 µm depth filter with silver impregnation. This device is designed for bacteria and cyst reduction, but contains no reduction mechanism for virus. The manufacturer recommends a chemical disinfectant be added if viruses are suspected in the water source. The device consists of a plastic housing and pump, ceramic filter element, inlet and outlet tubing, tubing float, and pre-filter. Additionally, the device comes with a filter element scrubbing pad, ceramic element measuring gauge, pump lubricant, and storage bag. The weighted pre-filter and float work to keep the inlet tubing submerged, yet off of the bottom of the raw water source to limit the introduction of sediment. The ceramic element silver impregnation is designed to limit bacterial growth on the element. This device creates an absolute barrier to contaminants greater than the pore size. No chemicals and no wait time are required for use. Prior to first use, and after prolonged storage, the manufacturer recommends discarding a small amount of water to reduce stale taste. This device is fully field-serviceable, and can be disassembled without tools. Additionally, Katadyn offers a carbon cartridge bottle attachment that can be added to the effluent tubing for taste and odor reduction.

Effectiveness Against Microbial Pathogens

No results were obtained that challenged this device strict to the requirements of the U.S. Environmental Protection Agency (USEPA) Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1). Results from an independent laboratory study (reference 2) were reviewed that challenged the Katadyn Mini against a modified version of reference 1. No information was supplied as to the flow rate used during testing, and total production during testing was 200 L. Under these modified protocol conditions, data showed that this device is capable of meeting the log reduction requirements for bacteria and *Cryptosporidium* oocysts. This testing did not challenge the device against *Giardia* cysts or virus. Since the primary reduction mechanism is size exclusion, and because *Giardia* cysts are larger in size than C*ryptosporidium* oocysts, similar results for *Giardia* reduction can be assumed. Viruses are too small to be removed by this filtration device. Very little information was received on the testing procedure. It was noted that during testing, this device required

cleaning with the supplied scouring pad at every test point, stating also that the device tended to clog very easily. Results state that flow improved considerably after cleaning but that as more water was passed through the device, cleaning was required more often. Due to the testing modifications with respect to reference 1, this evaluation based reduction capabilities on treatment technology. Therefore, this device is assigned one √ for bacteria and cyst reduction (for an explanation of the rating checks click here) based on size exclusion by the ceramic microfilter. Since the device is not designed, and has no mechanism for virus reduction, the device is assigned one X for this pathogen. Additional treatment is required for virus reduction.

Table. Expected Performance Against Microbial Pathogens.

Microbial Pathogen Type	Expected Disinfection Capability	Evaluation Rating	Pathogen Reduction Mechanism
Bacteria	>6 log	√	size exclusion
Viruses	not effective*	X	none
Giardia cysts	>3 log	√	size exclusion
Cryptosporidium oocysts	>3 log	√	size exclusion

* Additional treatment required for virus reduction.

Production Rate and Capacity

Inherent to the production rate and capacity of filtration devices is the quality of the raw water source. The manufacturer stated production capacity of the device is up to 2,000 L at a rate of 0.5 L/min. Since cleaning irreversibly decreases the size of the element, the overall capacity of this device will vary widely with raw water turbidity. No data was received showing the number of times this device can be cleaned before ceramic element replacement is required. Additionally, since the available data only processed 200 L, and with no indication of challenge water turbidity, no estimation of actual production capacity can be made.

Cleaning, Replacement, and End of Life Indicator

This device utilizes a ceramic depth microfilter which can be cleaned by scrubbing the surface of the filter element to remove accumulated debris. Given the small pore size of the ceramic element, it is expected to clog frequently during use with turbid waters and is therefore designed to be cleaned multiple times throughout its useful life. As stated above, the device underwent

multiple cleanings during the 200 L microbial challenge testing. The report (reference 2) states that cleaning restored the production rate considerably and did not affect pathogen reductions. Supplied with the device is a gauge that is placed over the ceramic element. If the gauge fits around the element then the filter has been cleaned to its capacity and must be replaced. Since the device works solely on size exclusion, as long as the device will process water and the element is not determined to be too thin, stated pathogen reductions should be valid. When the filter begins to clog and pumping difficulty increases the user should discontinue use and clean the ceramic element. This device does not contain a pressure relief valve, allowing for the possibility of the user over pressurizing the filter and damaging the seals.

Weight and Size

Katadyn Mini Microfilter	230 grams
Size (height x width x length)	4 cm x 8 cm x 18 cm
Tubing	74 cm

Cost

Katadyn Mini Microfilter	$90.00
Replacement Ceramic Element	$50.00

Device Evaluation

The Katadyn Mini Microfilter utilizes a 0.2 µm silver impregnated ceramic element for the reduction of bacteria and cysts. The silver impregnation is designed to limit microbial growth on the ceramic element. No data was received regarding the efficacy of this bacteriostatic design. Microbial reduction data reviewed for this device (reference 2), tested against an abbreviated version of the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1), showed that this device is capable of reducing bacteria by >6 log, and cysts by >3 log. No information was given as to the exact testing conditions and the volume of water treated during testing was far less than the stated capacity of the device. This device contains no virus reduction mechanism and therefore no testing was performed for this pathogen. Additional treatment is required to fully meet the requirements of reference 1 and ensure adequate reduction of all three classes of micro-organism. Since size exclusion by ceramic microfilter elements is a generally accepted mechanism for pathogen reduction, we expect this device to adequately reduce bacteria and cysts in accordance with reference 1 and recommend additional treatment for virus reduction (reference 3). The testing results received note the requirement for multiple cleanings. Due to the small pore size, ceramic element cleaning is expected, increasing in frequency with increasing raw water turbidity. Results showed consistent

pathogen reductions after cleaning (reference 2). It is expected that pathogen reductions will remain consistent throughout the useful life of the device. This device utilizes no chemicals and requires no wait time prior to water consumption. There is no indicator of process failure. A plastic gauge acts as an end of device useful life indicator. Since, during cleaning of the ceramic element the filter reduces size, when the gauge fits around the filter it must be replaced. This device, like all containing ceramic elements, must not be frozen while wet. Expansion of the water during freezing may crack the element. Additionally, the user should avoid shocking the device due to the brittle nature of ceramic elements and possible fracturing during shock loads. No manufacturing information or quality control data was received for this device. The manufacturer states ISO 9000 certification. No information was received on the storage life or required storage conditions for this device.

Advantages

- Based on treatment technology and independent data reviewed, this device should be capable of reducing bacteria and cysts to within the requirements of the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1).
- No wait time prior to water consumption.
- Field-serviceable.
- Simple and lightweight.
- End of device useful life indicator.

Disadvantages

- Device is not designed for virus reduction and therefore unable to fully meet the pathogen reduction requirements of the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1).
- Additional treatment required.
- Small pore size of filter makes device inherently susceptible to clogging by waters with elevated turbidities.
- Ceramic element fragile to shock loads and freezing.
- No real-time indicator of process failure.

References

1. USEPA, 1989. Guide Standard and Protocol for Testing Microbiological Water Purifiers. *Federal Register*. 54:34067.

2. Independent laboratory results of tests showing bacteria and cyst reduction. 1995. Provided by Katadyn.

3. U.S. Army Center for Health Promotion and Preventive Medicine, 2005. *Technical Information Paper; Filtration in the Use of Individual Water Purification Devices,* Aberdeen Proving Ground, MD.

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ANNEX 33 TO APPENDIX E

DEVICE EVALUATION #33
KATADYN – POCKET MICROFILTER

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Katadyn – Pocket Microfilter

www.katadyn.com

Device Information

The Katadyn Pocket Microfilter is a handheld pump water treatment device utilizing ceramic microfiltration. The ceramic element is a field cleanable 0.2 µm depth filter with silver impregnation. This device is designed for bacteria and cyst reduction, but contains no reduction mechanism for virus. The manufacturer recommends a chemical disinfectant be added if viruses are suspected in the water source. The device consists of a plastic housing with metal pump handle and end caps, ceramic filter element, inlet and outlet tubing, tubing weight and float, bottle clip, and 130 µm pre-filter. Additionally, the device comes with a ceramic filter element scrubbing pad and measuring gauge, pump lubricant, and storage bag. The tubing weight and float work to keep the inlet tubing submerged, yet off of the bottom of the raw water source to limit the introduction of sediment. The ceramic element silver impregnation is designed to limit bacterial growth on the element. This device creates an absolute barrier to contaminants greater than the pore size. No chemicals and no wait time are required for use. Prior to first use, and after prolonged storage, the manufacturer recommends discarding a small amount of water to reduce stale taste. This device is fully field-serviceable, and can be disassembled without tools. Additionally, Katadyn offers a carbon cartridge bottle attachment that can be added to the effluent tubing for taste and odor reduction.

Effectiveness Against Microbial Pathogens

No results were obtained that challenged this device strict to the requirements of the U.S. Environmental Protection Agency (USEPA) Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1). Results from an independent laboratory study (reference 2) were reviewed that challenged the Katadyn Mini (a filtration device manufactured by Katadyn, utilizing a ceramic filter cartridge identical to the Pocket, except smaller in size) against a modified version of reference 1. No information was supplied as to the flow rate used during testing, and total production during testing was 200 L. Under these modified protocol conditions, data showed that the Mini was capable of meeting the log reduction requirements for bacteria and *Cryptosproidium* oocysts. This testing did not challenge the device against *Giardia* cysts or viruses. Since the primary reduction mechanism is size exclusion, and because *Giardia* cysts are larger in size than C*ryptosporidium* oocysts, similar results for *Giardia* reduction can

be assumed. Viruses are too small to be removed by this filtration device. Very little information was received on the testing procedure. It was noted that during testing, the Mini required cleaning with the supplied scouring pad at every test point, stating also that the device tended to clog very easily. Results state that flow improved considerably after cleaning, but that as more water was passed through the device, cleaning was required more often. Due to the testing modifications with respect to reference 1 and the lack of data specific to the Pocket, this evaluation based reduction capabilities on treatment technology. Therefore, this device is assigned one √ each for bacteria and cyst reduction (for an explanation of the rating checks click here) based on size exclusion by the ceramic microfilter. Since the device is not designed, and has no mechanism for virus reduction, the device is assigned one X for this pathogen. Additional treatment is required for virus reduction.

Table. Expected Performance Against Microbial Pathogens.

Microbial Pathogen Type	Expected Disinfection Capability	Evaluation Rating	Pathogen Reduction Mechanism
Bacteria	> 6-log	√	size exclusion
Viruses	not effective*	X	none
Giardia cysts	> 3-log	√	size exclusion
Cryptosporidium oocysts	> 3-log	√	size exclusion

* Additional treatment required for virus reduction.

Production Rate and Capacity

Inherent to the production rate and capacity of filtration devices is the quality of the raw water source. The manufacturer stated production capacity of the device is up to 50,000 L at a rate of 1.0 L/min. Since cleaning irreversibly decreases the size of the element, the overall capacity of this device will vary widely with raw water turbidity. No data was received showing the number of times this device can be cleaned before ceramic element replacement is required. Additionally, since the available data only processed 200 L, and with no indication of challenge water turbidity, no estimation of actual production capacity can be made.

Cleaning, Replacement, and End of Life Indicator

This device utilizes a ceramic depth microfilter which can be cleaned by scrubbing the surface of the filter element to remove accumulated debris. Given the small pore size of the ceramic element, it is expected to clog frequently during use with turbid waters and is therefore designed to be cleaned multiple times throughout its useful life. As stated above, the Katadyn Mini underwent multiple cleanings during the 200 L microbial challenge testing. Since the ceramic element used during testing was smaller than used in this device, production volume prior to required cleaning is expected to be greater but cannot be quantified. The report (reference 2) states that cleaning restored the production rate considerably and did not affect pathogen reductions. Supplied with the device is a gauge that is placed over the ceramic element. If the gauge fits around the element then the filter has been cleaned to its capacity and must be replaced. Since the device works solely on size exclusion, as long as the device will process water and the element is not determined to be too thin, stated pathogen reductions should be valid. When the filter begins to clog and pumping difficulty increases the user should discontinue use and clean the ceramic element. This device does not contain a pressure relief valve, allowing for the possibility of the user over pressurizing the filter and damaging the seals.

Weight and Size

Katadyn Pocket Microfilter	570 grams
Size (height x diameter)	25 cm x 8 cm
Tubing	96 cm

Cost

Katadyn Pocket Microfilter	$200.00
Replacement Ceramic Element	$140.00

Device Evaluation

The Katadyn Pocket Microfilter utilizes a 0.2 µm silver impregnated ceramic element for the reduction of bacteria and cysts. The silver impregnation is designed to limit microbial growth on the ceramic element. No data was received regarding the efficacy of this bacteriostatic design. Microbial reduction data reviewed for a similar device manufactured by Katadyn (reference 2), tested against an abbreviated version of the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1), showed that this device should be capable of reducing bacteria by > 6-log, and cysts by > 3-log. No information was given as to the exact testing conditions and the volume of water treated during testing was far less than the stated

capacity of the device. This device contains no virus reduction mechanism and therefore no testing was performed for this pathogen. Additional treatment is required to fully meet the requirements of reference 1 and ensure adequate reduction of all three classes of microorganism. Since size exclusion by ceramic microfilter elements is a generally accepted mechanism for pathogen reduction, we expect this device to adequately reduce bacteria and cysts in accordance with reference 1 and recommend additional treatment for virus reduction (reference 3). The testing results received noted the requirement for multiple cleanings. Due to the small pore size, ceramic element cleaning is expected, increasing in frequency with increasing raw water turbidity. Results showed consistent pathogen reductions after cleaning (reference 2). It is expected that pathogen reductions will remain consistent throughout the useful life of the device. This device utilizes no chemicals and requires no wait time prior to water consumption. There is no indicator of process failure. A plastic gauge acts as an end of device useful life indicator. Since, during cleaning of the ceramic element the filter reduces size, when the gauge fits around the filter it must be replaced. This device, like all containing ceramic elements, must not be frozen while wet, as expansion of the water during freezing may crack the element. Additionally, the user should avoid shocking the device due to the brittle nature of ceramic elements and possible fracturing during shock loads. No manufacturing information or quality control data was received for this device. The manufacturer states ISO 9000 certification. No information was received on the storage life or required storage conditions for this device.

Advantages

- Based on treatment technology and independent data reviewed, this device should be capable of reducing bacteria and cysts to within the requirements of the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1).
- No wait time prior to water consumption.
- Field-serviceable.
- End of device useful life indicator.

Disadvantages

- Device is not designed for virus reduction and therefore unable to fully meet the pathogen reduction requirements of the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1).
- Additional treatment required.
- Small pore size of filter makes device inherently susceptible to clogging by waters with elevated turbidities.
- Ceramic element fragile to shock loads and freezing.
- No real-time indicator of process failure.

References

1. USEPA, 1989. Guide Standard and Protocol for Testing Microbiological Water Purifiers. *Federal Register*. 54:34067.

2. Independent laboratory results of tests showing bacteria and cyst reduction. 1995. Provided by Katadyn.

3. U.S. Army Center for Health Promotion and Preventive Medicine, 2005. *Technical Information Paper; Filtration in the Use of Individual Water Purification Devices,* Aberdeen Proving Ground, MD.

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ANNEX 34 TO APPENDIX E

DEVICE EVALUATION #34
MCNETT – AQUAMIRA™ WATER BOTTLE AND FILTER

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McNett – Aquamira™ Water Bottle and Filter

www.mcnett.com

Device Information

The Aquamira™ water bottle and filter is a handheld sports type squeeze bottle. The bottle has a capacity of 0.65 L (22 oz). The bottle contains a filter cartridge using an activated carbon block depth filter that sits inside the top of the sports bottle between the bottle and the drink spout. The activated carbon filter is a 6 cm long hollow-core cylinder with a 0.8 cm thick wall. Water flows from outside through the filter wall into the hollow inside and out the drink spout. The filter reportedly has an approximate pore size of 2 µm. Information provided on the bottle and packaging claims this device removes sediment, organic debris, and chlorine taste as well as 99.9% (3-log) *Cryptosporidium* oocysts and *Giardia* cysts. Directions for use require the user to fill the bottle with water to within 4 cm from the top, insert the activated carbon filter, replace the cap and squeeze to produce water. Prior to the first use the filter must be flushed with one bottle of water to remove filter particle fines. For storage, the manufacturer recommends the bottle and filter to air dry completely and store dry filter in a plastic bag.

Effectiveness Against Microbial Pathogens

No data was received showing the effectiveness of this product with respect to the U.S. Environmental Protection Agency (USEPA) Guide Standard Protocol for Testing Microbiological Water Purifiers (reference 1). The theory and practice of depth filtration has been widely studied and there has been significant research conducted on activated carbon block filtration (reference 2). In the absence of data specific to this device tested using reference 1, and based on general knowledge of depth and carbon block filtration, this device should be capable of consistently reducing *Giardia* cysts and *Cryptosporidium* oocysts to the required minimum log reductions stated in reference 1 (i.e., 3-log) when used as directed. It is not expected to consistently reduce bacteria (6-log) and viruses (4-log). Based on general depth and carbon block filtration information, the Aquamira water bottle and filter is assigned one √ for the reduction of *Giardia* cysts and *Cryptosporidium* oocysts and an X for bacteria and virus reduction (for an explanation of the rating checks click here).

™ Aquamira is a registered trademark of McNETT Corporation, Bellingham, WA. Use of trademarked names does not imply endorsement by the U.S. Army, but is intended only in identification of a specific product.

Table. Expected Performance Against Microbial Pathogens.

Microbial Pathogen Type	Expected Disinfection Capability	Evaluation Rating	Primary Pathogen Reduction Mechanism
Bacteria	> 6-log	X	-
Viruses	> 4-log	X	-
Giardia cysts	> 3-log	√	size exclusion
Cryptosporidium oocysts	> 3-log	√	size exclusion

Production Rate and Capacity

Inherent to the production rate and capacity of filtration devices is the quality of the raw water source. Because it is a squeeze bottle, the actual production rate is dependent on the user. The production capacity of the device is stated to be approximately 130 L. However, production capacity will vary widely with raw water quality (i.e., turbidity).

Cleaning, Replacement, and End of Life Indicator

This device cannot be backwashed to remove sediment from the filter. When the device becomes unusable due to decreased production rate, the clogged filter must be replaced. The bottle is dishwasher safe or can be hand washed. For practical purposes, the filter cartridges are not cleanable. The device contains no end of life indicator short of filter clogging.

Weight and Size

Dry weight	150 grams
Size (height x diameter)	24 cm x 7 cm

Cost

Bottle with filter	$20.00
Replacement filter	$11.00

Device Evaluation

No data was received that challenged the Aquamira water bottle and filter against reference 1. General research on depth filtration indicates that this device should be capable of consistently reducing *Giardia* cysts and *Cryptosporidium* oocysts. This device is not likely capable of consistently reducing bacteria and viruses. Additional treatment is necessary to remove bacteria and viruses such as adding a disinfectant (e.g., chlorine, iodine, chlorine dioxide) to the bottle prior to filtering. The activated carbon should remove tastes and odors. This device, like all filters with small pore sizes, is highly affected by turbid (cloudy) waters. Since the device is not able to be backwashed to remove accumulated particulates, once clogged, the filter must be replaced. There is no indicator of process failure or end of device useful life.

Advantages

- Expected to consistently provide adequate protection from *Giardia* cysts and *Cryptosporidium* oocysts, although device-specific testing data using the USEPA protocol is not available.
- No wait time prior to consumption.
- Simple and effective.
- Provides taste and odor reduction.

Disadvantages

- Not expected to be consistently effective against bacteria and viruses.
- Reduced production capacity when using high turbidity water.
- Not backwashable.
- No real-time indicator of process failure.

References

1. USEPA, 1989. Guide Standard and Protocol for Testing Microbiological Water Purifiers. *Federal Register*. 54:34067.

2. U.S. Army Center for Health Promotion and Preventive Medicine. (2005). *Technical Information Paper; Filtration in the Use of Individual Water Purification Devices,* Aberdeen Proving Ground, MD.

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ANNEX 35 TO APPENDIX E

DEVICE EVALUATION #34
MCNETT – FRONTIER™ EMERGENCY WATER FILTER SYSTEM

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McNett – Frontier™ Emergency Water Filter System

www.mcnett.com

Device Information

The Frontier Emergency Water Filter System is a filtering straw. The straw is attached to a filtering cartridge that uses an activated carbon block depth filter. The activated carbon filter is a 9 cm long hollow-core cylinder with a 0.5 cm thick wall. Water flows from outside through the filter wall into the hollow inside and out the straw. The filter has a pore size of 2 µm. Directions call for the user to attach the straw to the filter cartridge, fill container with source water, insert filter and drink from straw. Do not submerge or contaminate the drinking end of the straw. Prior to use, carbon particle fines must be removed by drawing water half way up the straw, removing the straw and discarding the water. For storage, the filter should be air-dried for 48 hours before storing.

Effectiveness Against Microbial Pathogens

No data was received showing the effectiveness of this product with respect to the U.S. Environmental Protection Agency (USEPA) Guide Standard Protocol for Testing Microbiological Water Purifiers (reference 1). The device packaging claims removal of *Giardia* cysts, *Cryptosporidium* oocysts, and *E. coli* bacteria. The theory and practice of depth filtration has been widely studied and there has been significant research conducted on activated carbon block filtration (reference 2). In the absence of data specific to this device tested using reference 1, and based on general knowledge of depth and carbon block filtration, this device should be capable of consistently reducing *Giardia* cysts and *Cryptosporidium* oocysts to the required minimum log reductions stated in reference 1 (i.e., 3-log) when used as directed. It is not expected to consistently reduce bacteria (6-log) and viruses (4-log). Based on general depth and carbon block filtration information, the Frontier Emergency Water Filter System is assigned one √ for the reduction of *Giardia* cysts and *Cryptosporidium* oocysts and an X for bacteria and virus reduction (for an explanation of the rating checks click here).

™ Frontier is a registered trademark of McNETT Corporation, Bellingham, WA. Use of trademarked names does not imply endorsement by the U.S. Army, but is intended only in identification of a specific product.

Table. Expected Performance Against Microbial Pathogens.

Microbial Pathogen Type	Expected Disinfection Capability	Evaluation Rating	Primary Pathogen Reduction Mechanism
Bacteria	Not Effective	X	-
Viruses	Not Effective	X	-
Giardia cysts	> 3-log	√	size exclusion
Cryptosporidium oocysts	> 3-log	√	size exclusion

Production Rate and Capacity

Inherent to the production rate and capacity of filtration devices is the quality of the raw water source. Because the device operates on human suction, the actual production rate is dependent on the user. The production capacity of the device is stated to be up to 76 L. However, production capacity will vary widely with raw water quality (i.e., turbidity).

Cleaning, Replacement, and End of Life Indicator

This device cannot be cleaned to remove sediment from the filter. When the device becomes unusable due to decreased production rate, the clogged device must be disposed. For practical purposes, the filter cartridge is not cleanable. The device contains no end of life indicator short of filter clogging.

Weight and Size

Dry weight	20 grams
Size (height x diameter)	9.5 cm x 2 cm

Cost

Bottle with filter	$10.00

Device Evaluation

No data was received that challenged the Frontier Emergency Water Filter System against reference 1. General research on depth filtration indicates that this device should be capable of consistently reducing *Giardia* cysts and *Cryptosporidium* oocysts. This device is not likely capable of consistently reducing bacteria and viruses. Additional treatment is necessary to remove bacteria and viruses such as adding a disinfectant (e.g., chlorine, iodine, chlorine dioxide) to the water to be treated prior to filtering. The activated carbon should remove tastes and odors. This device, like all filters with small pore sizes, is highly affected by turbid (cloudy) waters. Since the device is not able to be backwashed or cleaned to remove accumulated particulates, once clogged, the filter must be replaced. There is no indicator of process failure or end of device useful life.

Advantages

- Expected to consistently provide adequate protection from *Giardia* cysts and *Cryptosporidium* oocysts, although device-specific testing data using the USEPA protocol is not available.
- No wait time prior to consumption.
- Very simple to use.
- Provides taste and odor reduction.

Disadvantages

- Not expected to be consistently effective against bacteria and viruses.
- Reduced production capacity when using high turbidity water.
- Not backwashable or cleanable.
- No real-time indicator of process failure.

References

1. USEPA, 1989. Guide Standard and Protocol for Testing Microbiological Water Purifiers. *Federal Register*. 54:34067.

2. U.S. Army Center for Health Promotion and Preventive Medicine. (2005). *Technical Information Paper; Filtration in the Use of Individual Water Purification Devices,* Aberdeen Proving Ground, MD.

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ANNEX 36 TO APPENDIX E

DEVICE EVALUATION #36
MOUNTAIN SAFETY RESEARCH – MINIWORKS™ EX MICROFILTER

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Mountain Safety Research – MiniWorks™ EX Microfilter

www.msrcorp.com

Device Information

The Mountain Safety Research (MSR) MiniWorks EX Microfilter is a handheld pump water treatment device utilizing ceramic microfiltration. At the heart of the device is what the manufacturer calls the "Marathon EX Ceramic Element", a 0.3 µm nominal ceramic depth filter with carbon block core. This device is designed for bacteria, cyst, and taste and odor reduction, but contains no reduction mechanism for viruses. The manufacturer recommends a chemical disinfectant be added for treating viruses. The device consists of a plastic housing, ceramic and carbon filter element, inlet tubing, tubing weight and float, and foam pre-filter. Additionally, the device comes with a filter element scrubbing pad, ceramic element measuring gauge, and storage bag. The tubing weight and float work to keep the inlet tubing submerged, yet off of the bottom of the raw water source to limit the introduction of sediment. The bottom of the pump housing contains threads for direct connection to MSR Dromedary™ bags and wide mouth (e.g., Nalgene®) bottles. The device can also be held above any collection container to collect product water. The device utilizes what the manufacturer calls an "airspring accumulator", which traps an air bubble in the filter housing. The air bubble compresses on the down stroke then expands on the up stoke, pushing water through the cartridge without additional operator input. This device creates an absolute barrier to contaminants greater than the pore size and may remove taste and odor through carbon filtration. This device contains no chemicals and requires no wait time. No discarding of initial product water is recommended by the manufacturer. Before initial use, and after extended non-use, the airspring accumulator must be primed by pumping a small amount of water then air through the filter to trap the air bubble. This device is fully field-serviceable, and can be disassembled without tools. For optimal use the manufacturer recommends a pumping rate of 70-80 strokes per minute.

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Effectiveness Against Microbial Pathogens

No results were obtained that challenged this device strict to the requirements of the U.S. Environmental Protection Agency (USEPA) Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1). Results from independent laboratory studies (references 2 and 3) were reviewed that challenged the MSR MiniWorks against modified versions of reference 1. Under this modified protocol, data showed that this device is capable of meeting the log reduction requirements for bacteria and *Cryptosproidium* oocysts as stated in reference 3 and shown in the table below. Since size exclusion is the reduction mechanism, observed virus reduction (reference 2) was minimal and did not meet the requirements of reference 1. Due to *Giardia* being larger in size it was assumed that the device would meet the reduction requirements of reference 1. During the testing of reference 2 the flowrate was set at 0.7 L/min and the device was tested to a capacity of 400 L. The ceramic cartridge was cleaned four times during testing, with the fourth cleaning intentionally reducing the filter diameter to the manufacturer stated minimum size based on the supplied filter gauge. Testing then resumed to demonstrate the reduction capabilities during a pseudo end of filter life condition. The testing conducted in reference 3 was run to 378 L with no information on flowrate stated. Neither testing demonstrated device pathogen reduction capabilities to the manufacturer stated 2,000 L. Due to the testing modifications with respect to reference 1, this evaluation based reduction capabilities on treatment technology. Therefore, this device is assigned one √ for bacteria and cyst reduction (for an explanation of the rating checks click here) based on size exclusion by the ceramic microfilter. Since the device is not designed, and has no mechanism for virus reduction, the device is assigned one X for this pathogen. Additional treatment is required for virus reduction.

Table. Expected Performance Against Microbial Pathogens.

Microbial Pathogen Type	Expected Disinfection Capability	Evaluation Rating	Pathogen Reduction Mechanism
Bacteria	> 6-log	√	Size exclusion
Viruses	not effective*	X	none
Giardia cysts	> 3-log	√	Size exclusion
Cryptosporidium oocysts	> 3-log	√	Size exclusion

* Additional treatment required for virus reduction.

Production Rate and Capacity

Inherent to the production rate and capacity of filtration devices is the quality of the raw water source. The manufacturer stated production capacity of the device is 2000 L at a rate of 1.0 L/min. User effort is stated to be 70-80 strokes/L. This device utilizes a ceramic depth microfilter which can be cleaned when production rate decreases due to filter clogging. Since cleaning irreversibly decreases the size of the element, the overall capacity of this device will vary widely with raw water turbidity. Illustrating the ability of this device to be cleaned multiple times and continue to process water are results from a study conducted on reducing water turbidity (reference 4). In this study, water with a turbidity of 60-70 NTU was processed and tested for effluent turbidity. The device produced over 300 L of water and underwent 34 cleanings without a reduction in turbidity removal capability and without reducing the ceramic element to its end life diameter. No testing on microbial reduction was conducted during these tests. No data was presented on the capacity of the carbon core within the ceramic element. Since no appreciable pathogen reduction is attributed to the carbon, microbial reduction should remain consistent even if the carbon adsorption capacity is exhausted.

Cleaning, Replacement, and End of Life Indicator

This device utilizes a ceramic depth microfilter, which can be cleaned by scrubbing the surface of the filter element to remove accumulated debris. Given the small pore size of the ceramic element, it is expected to clog frequently during use with turbid waters and is therefore designed to be cleaned multiple times throughout its useful life. Supplied with the device is a gauge that is placed over the ceramic element. If the gauge fits around the element then the filter has been cleaned to its capacity and must be replaced. Since the device works solely on size exclusion, as long as the device will process water and the element is not determined to be too thin, stated pathogen reductions should be valid. When the filter begins to clog, and pumping difficulty increases, a pressure relief valve prohibits the user from over pressurizing the filter and damaging the seals.

Weight and Size

MiniWorks™ EX	460 grams
Size (height x width x length)	20 cm x 7 cm x 10 cm
Tubing	122 cm

Cost

MiniWorks™ EX	$80.00
Replacement Marthon EX Ceramic Element	$38.00

Device Evaluation

The MSR MiniWorks EX utilizes a ceramic 0.3 µm microfilter with carbon core for the reduction of bacteria and cysts, as well as taste and odor. Data reviewed for this device showed that it is effective at reducing bacteria and cysts by > 6-log, and > 3-log respectively. Since pathogen reduction is by size exclusion, no virus reduction is expected by this device. Additional treatment is required to fully meet the requirements of reference 1 and ensure adequate reduction of all three classes of microorganism. Testing was not conducted in accordance with reference 1 since the device was tested to 400 L and not the manufacturer stated 2000 L. Additionally, it is unclear whether the device was tested at the stated production rate of 1 L/min. Due to this, we rate the device as expected to meet the requirements of reference 1, but base this on treatment technology since data specific to this protocol was not received (reference 5). The device required multiple cleanings during testing. Pathogen reductions remained consistent after cleanings, even when tested at the minimum recommended thickness of the ceramic filter cartridge. This device, like all filters with small pore sizes, is highly affected by turbid (cloudy) waters. A study conducted to determine the ability of the device to filter turbid water showed that when challenged with highly turbid water, the device was able to reduce this turbidity, but required frequent cleaning due to particulate build-up. During this testing the device was cleaned 34 times while processing 300 L. Although this indicates a high maintenance effort, it displays the ability of the device to be cleaned and returned to full performance. This device utilizes no chemicals and requires no wait time prior to water consumption. There is no indicator of process failure. A plastic gauge acts as an end of device useful life indicator. Since during cleaning of the ceramic element the filter reduces size, when the gauge fits around the filter, it must be replaced. No manufacturing information or quality control data was received for this device. This device, like all containing ceramic elements, must not be frozen while wet. Expansion of the water during freezing may crack the element. Additionally, the user should avoid shocking the device due to the brittle nature of the ceramic element and possible fracturing during shock loads. No information was received on the storage life or required storage conditions for this device.

Advantages

- Based on treatment technology and independent data reviewed, this device should be capable of reducing bacteria and cysts to within the requirements of the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1).
- No wait time prior to water consumption.
- Activated carbon core should reduce taste and odors.
- Field-serviceable.
- End of device useful life indicator.

Disadvantages

- Device is not designed for virus reduction and therefore, unable to fully meet the pathogen reduction requirements of the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1).
- Additional treatment required.
- Small pore size of filter makes device inherently susceptible to clogging by waters with elevated turbidities.
- Ceramic element fragile to shock loads and freezing.
- No real-time indicator of process failure.

References

1. USEPA, 1989. Guide Standard and Protocol for Testing Microbiological Water Purifiers. *Federal Register*. 54:34067.

2. Independent laboratory results of tests showing bacteria and cyst reduction. 1997. Provided by MSR.

3. Independent laboratory results of tests showing bacteria and cyst reduction. 1996. Provided by MSR.

4. Naval Facilities Engineering Service Center, 1993. Team Water Purifier Test Report. Technical Memorandum TM-2003-AMP.

5. U.S. Army Center for Health Promotion and Preventive Medicine, 2005. *Technical Information Paper; Filtration in the Use of Individual Water Purification Devices,* Aberdeen Proving Ground, MD.

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ANNEX 37 TO APPENDIX E

DEVICE EVALUATION #37
MOUNTAIN SAFETY RESEARCH – SWEETWATER® MICROFILTER

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Mountain Safety Research – SweetWater® Microfilter

www.msrcorp.com

Device Information

The Mountain Safety Research (MSR) SweetWater Microfilter is a handheld pump water treatment device utilizing glass fiber microfiltration. The 0.2 µm borosilicate glass fiber labyrinth depth filter surrounds a granular activated carbon core. This device is designed for bacteria, cyst, and taste and odor reduction, but contains no reduction mechanism for virus. The manufacturer recommends a chemical disinfectant be added for treating virus. The device consists of a one-piece Lexan® polycarbonate housing with microfilter and granular activated carbon core, inlet and outlet tubing, tubing weight and float, and 80 µm stainless steel pre-filter. Additionally, the device comes with a filter element cleaning brush, water bottle adaptor, and storage bag. The tubing weight and float work to keep the inlet tubing submerged, yet off of the bottom of the raw water source to limit the introduction of sediment. The pump handle detaches from one of the two attachment points and folds flat against the filter body, allowing for compact storage. This device creates an absolute barrier to contaminants greater than the pore size and may remove taste and odor through carbon filtration. This device contains no chemicals and requires no wait time. Before first use the filter must be brushed and rinsed, then the manufacturer recommends discarding the first few liters produced to remove carbon dust. This device is fully field-serviceable, and can be disassembled without tools. A pressure relief valve prevents over pressurization of the filter, limiting damage to the glass fiber, and giving the user an indication that the unit requires cleaning.

Effectiveness Against Microbial Pathogens

Independent laboratory results were received (reference 1) testing the MSR SweetWater Microfilter (tested under a previous brand name) against the requirements of the U.S. Environmental Protection Agency (USEPA) Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 2). Data showed that this device is able to meet the requirements of reference 2, for bacteria and *Cryptosporidium* oocysts at the manufacturer designed flowrate and throughout the stated production capacity. Since size exclusion is the reduction mechanism, observed virus reduction (reference 2) was minimal and did not meet the requirements of reference 1. Independent laboratory results for an abbreviated USEPA Protocol

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using the MSR SweetWater Purifier System (tested under a previous brand name) that incorporates post filtration chlorine disinfectant addition was reviewed (reference 3). Results showed *Giardia* and *Cryptosporidium* reduction by greater than the requirements of reference 2. These reductions can be attributed to size exclusion by the microfilter since chlorine is not effective at reducing *Giardia* and *Cryptosporidium* at the concentrations and times used. No information was stated as to the number of times the device was cleaned during testing. This device is assigned three checks for bacteria and *Cryptosporidium* (for an explanation of the rating checks click here), one √ for *Giardia* based on size exclusion by the glass microfilter. Since the device is not designed, and has no mechanism for virus reduction, the device is assigned one X for this pathogen. Additional treatment is required for virus reduction.

Table. Expected Performance Against Microbial Pathogens.

Microbial Pathogen Type	Expected Disinfection Capability	Evaluation Rating	Pathogen Reduction Mechanism
Bacteria	> 6-log	√√√	size exclusion
Viruses	not effective*	X	none
Giardia cysts	> 3-log	√	size exclusion
Cryptosporidium oocysts	> 3-log	√√√	size exclusion

* Additional treatment required for virus reduction.

Production Rate and Capacity

Inherent to the production rate and capacity of filtration devices is the quality of the raw water source. The manufacturer stated production capacity of the device is 750L at a rate of 1.0 L/min. The pump design allows for production during both up and down strokes. This device utilizes a glass fiber depth microfilter, which can be cleaned when production rate decreases due to filter clogging. No data was presented on the capacity of the carbon core within the ceramic element. Since no appreciable pathogen reduction is attributed to the carbon, microbial reduction should remain consistent even if the carbon adsorption capacity is exhausted.

Cleaning, Replacement, and End of Life Indicator

This device utilizes a glass fiber depth microfilter, which can be cleaned by brushing the surface of the filter element to remove accumulated debris. Given the small pore size of the filter

element, it is expected to clog frequently during use with turbid waters and is therefore designed to be cleaned multiple times throughout its useful life. If production rate does not increase adequately after cleaning, the user can process a bleach solution (1 ounce to 1 liter) through the device and allow it to sit for 24 hours. Since brushing the filter element removes glass fiber and thins the cartridge, once a black mesh (manufacturer termed Filter Replacement Safety Indicator) is visible on the inside surface of the element, the filter must be replaced. Since the device works solely on size exclusion, as long as the device will process water and the element is not determined to be too thin, stated pathogen reductions should be valid. When the filter begins to clog and pumping difficulty increases a pressure relief valve prohibits the user from over pressurizing the filter and damaging the seals.

Weight and Size

SweetWater Microfilter	320 grams
Size (height x width x length)	20 cm x 7 cm x 9 cm
Tubing	76 cm

Cost

SweetWater Microfilter	$60.00
Replacement filter element	$35.00

Device Evaluation

The MSR SweetWater Microfilter utilizes a glass fiber 0.2 µm labyrinth depth microfilter with carbon core for the reduction of bacteria, and cysts, as well as taste and odor. Data reviewed for this device showed that it is effective at reducing bacteria and *Cryptosporidium* by > 6-log, and > 4-log respectively. *Giardia* reduction was not shown in strict adherence to the protocol of reference 2, but is expected to equal or exceed that of *Cryptosporidium*. Since pathogen reduction is by size exclusion, no virus reduction is expected by this device (reference 4). Additional treatment is required to fully meet the requirements of reference 2 and ensure adequate reduction of all three classes of microorganism. No information was received on cleaning the device during testing and no data was shown as to the ability of this device to process highly turbid water. Since the filter is not pleated, the surface area is less than similar devices on the market, but the ability to brush the filter surface clean is advantageous. As a means of device life indicator, after brushing the filter, the user observes the filter surface for visible black mesh. One visible, the appearance of this mesh indicates that the filter needs replacement. Cleaning is simple, entailing simply unscrewing the pump head, brushing the filter, and then rinsing with water. No information was received as to the approximate number of times

the device can be cleaned. Additionally, as the filter clogs and pressures build, a pressure relief valve in the pumping chamber prevents damage to the filter due to excessive pressure. Device design allows for water processing on both up and down strokes, decreasing user effort while increasing water output. The manufacturer claims a 4 to 1 mechanical advantage pump handle and 1-2 pounds of force to operate. This device utilizes no chemicals and requires no wait time prior to water consumption. There is no indicator of process failure. No manufacturing information or quality control data was received for this device. No information was received on the storage life or required storage conditions for this device.

Advantages

- Independent testing confirms bacteria, and cyst reduction in accordance with the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 2).
- No wait time prior to water consumption.
- Activated carbon core should reduce taste and odors.
- Field-serviceable.
- Simple and lightweight.
- End of device useful life indicator.

Disadvantages

- Device is not designed for virus reduction and therefore unable to fully meet the pathogen reduction requirements of the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 2).
- Additional treatment required for virus reduction.
- Small pore size of filter makes device inherently susceptible to clogging by waters with elevated turbidities.
- No real-time indicator of process failure.

References

1. Independent laboratory results of tests showing bacteria and cyst reduction. 1995. Provided by MSR.

2. USEPA, 1989. Guide Standard and Protocol for Testing Microbiological Water Purifiers. *Federal Register*. 54:34067.

3. Independent laboratory results of tests showing bacteria, cyst, and virus reduction. 2000. Provided by MSR.

4. U.S. Army Center for Health Promotion and Preventive Medicine, 2005. *Technical Information Paper; Filtration in the Use of Individual Water Purification Devices,* Aberdeen Proving Ground, MD.

Device Evaluation Update – February 2006

Independent laboratory results for testing conducted by NSF International was received that tested the MSR SweetWater Microfilter against the USEPA Guide Standard. Testing was conducted using the ceramic candle portion of the protocol with a production volume of 4 L/day for 10.5 days. The flow rate was 1.25 L/min as per manufacturer instructions. Results indicate that this device is capable of >6-log reduction of bacteria, and >3-log reduction of *Cryptosporidium parvum*. According to the USEPA Guide standard, geometric averages may be used to determine compliance with the protocol, yet no sample may exceed the ½ log tolerance stated for cyst reduction. During testing, one sample did exceed this tolerance. Inadequate reduction of virus (<1-log) was observed during testing. This testing was conducted for specific user scenarios, and therefore not to the manufacturer stated production volume. Based on this new data, there is no change to the pathogen reduction ratings previously stated (√√√ bacteria, X virus, √ *Giardia*, √√√ *Cryptosporidium*).

Updated Table. Expected Performance Against Microbial Pathogens.

Microbial Pathogen Type	Expected Disinfection Capability	Evaluation Rating	Pathogen Reduction Mechanism
Bacteria	> 6-log	√√√	size exclusion
Viruses	not effective*	X	none
Giardia cysts	> 3-log	√	size exclusion
Cryptosporidium oocysts	> 3-log	√√√	size exclusion

* Additional treatment required for virus reduction.

Reference:

Independent laboratory testing conducted November 2005. Testing sponsored by the Department of the Air Force, Air Force Materiel Command.

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ANNEX 38 TO APPENDIX E

DEVICE EVALUATION #38
MOUNTAIN SAFETY RESEARCH – SWEETWATER® PURIFIER SYSTEM

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Mountain Safety Research – SweetWater® Purifier System

www.msrcorp.com

Device Information

The Mountain Safety Research (MSR) SweetWater Purifier System is a handheld pump water treatment device utilizing microfiltration, carbon adsorption, and chlorine disinfection. The 0.2 µm borosilicate glass fiber labyrinth depth filter surrounds a granular activated carbon core. The microfilter and carbon within this device are designed for bacteria, cyst, and taste and odor reduction. The filter portion of the device is the MSR SweetWater Microfilter and contains no reduction mechanism for viruses. To enable this device to effectively reduce viruses that are much smaller than filter pore size, a 3.5% sodium hypochlorite disinfectant solution (manufacturer termed purifier solution) is added to the treated water. Manufacturer recommended dose is 5 drops (0.25 mL) per liter, resulting in an initial concentration of about 8.75 mg/L free chlorine. The user adds the disinfectant after filtering the water then must wait 5 minutes before consumption. The device consists of a one-piece Lexan® polycarbonate housing with microfilter and carbon core, inlet and outlet tubing, tubing weight and float, 80 µm stainless steel pre-filter, and 75 mL purifier solution. Additionally, the device comes with a 2 L Platypus® Hydration Reservoir for treated water, filter element cleaning brush, water bottle adaptor, and storage bag. The tubing weight and float work to keep the inlet tubing submerged, yet off of the bottom of the raw water source to limit the introduction of sediment. The pump handle detaches from one of the two attachment points and folds flat against the filter body, allowing for compact storage. This device creates an absolute barrier to contaminants greater than the pore size and may remove taste and odor through carbon filtration. Before first use the filter must be brushed and rinsed, then the manufacturer recommends discarding the first few liters produced to remove carbon dust. This device is fully field-serviceable, and can be disassembled without tools. A pressure relief valve prevents over pressurization of the filter, limiting damage to the glass fiber, and giving the user an indication that the unit requires cleaning.

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Effectiveness Against Microbial Pathogens

Independent laboratory results were received (reference 1) testing the MSR SweetWater Purifier System (tested under a previous brand name) against the requirements of the U.S. Environmental Protection Agency (USEPA) Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 2). Data showed that this device is able to meet the requirements of reference 2 for bacteria, virus, *Giardia* cysts, and *Cryptosporidium* oocysts at the manufacturer designed flowrate and to a production capacity of 378 L. Based on results from a study (reference 3) using the MSR SweetWater Microfilter (tested under a previous brand name), the primary reduction mechanism for all pathogens tested, except viruses, is size exclusion (reference 4). Virus reduction is attributed to disinfection by the purifier solution. The manufacturer recommended dose of 8.75 mg/L for a contact time of 5 minutes results in a CT (concentration x time) value of 44 mg-min/L. USEPA-recommended CT for 4-log inactivation of viruses by free chlorine at pH 6-9 and temperature of 0.5º C (worst case) is 12 mg-min/L (reference 5). Since the manufacturer-recommended CT is higher than that recommended by the USEPA, virus reduction should be considered adequate at all natural water conditions (temperature 0.5 – 25º C, pH 6-9). Utilizing the recommended CT, it is possible that any *Giardia* not removed through the filter may be inactivated by the purifier solution, depending on water conditions. The recommended CT will likely inactivate all remaining bacteria, but will have no effect on *Cryptosporidium* oocysts. No information was stated as to the number of times the device required cleaning during testing, especially important when challenging with highly turbid waters. This device is assigned three √s for bacteria, *Giardia* cysts, *Cryptosporidium* oocysts, and virus reduction (for an explanation of the rating checks click here) based on size exclusion and chlorine disinfection, respectively.

Table. Expected Performance Against Microbial Pathogens.

Microbial Pathogen Type	Expected Disinfection Capability	Evaluation Rating	Pathogen Reduction Mechanism
Bacteria	> 6-log	√√√	size exclusion
Viruses	> 4-log	√√√	disinfection
Giardia cysts	> 3-log	√√√	size exclusion
Cryptosporidium oocysts	> 3-log	√√√	size exclusion

Production Rate and Capacity

Inherent to the production rate and capacity of filtration devices is the quality of the raw water source. The manufacturer stated production capacity of the filter portion of this device is 750 L at a rate of 1.0 L/min. The included purifier solution will treat 300 L based on the recommended dosage. Since the purifier solution is integral to the inactivation of viruses, the production capacity of the device as a whole should be considered 300 L. Utilizing the device without the purifier solution does not protect against viruses and will increase the possibility of illness due to viral pathogens. In addition to the 1.0 L/min production rate is the required 5-minute wait time for disinfection. The pump design allows for production during both up and down strokes. This device utilizes a glass fiber depth microfilter, which can be cleaned when production rate decreases due to filter clogging. Since cleaning the filter removes material, there is a finite number of times the device can be cleaned. Therefore, use in highly turbid waters requiring more frequent cleaning will reduce the device production capacity. No data was presented on the capacity of the carbon core within the ceramic element. Since no appreciable pathogen reduction is attributed to the carbon, microbial reduction should remain consistent even if the carbon adsorption capacity is exhausted.

Cleaning, Replacement, and End of Life Indicator

This device utilizes a glass fiber depth microfilter, which can be cleaned by brushing the surface of the filter element to remove accumulated debris. Given the small pore size of the filter element, it is expected to clog frequently during use with turbid waters and is therefore designed to be cleaned multiple times throughout its useful life. If production rate does not increase adequately after cleaning, the user can process a bleach solution (1 ounce bleach to 1 liter water) through the device and allow it to sit for 24 hours. Since brushing the filter element removes glass fiber and thins the cartridge, once a black mesh (manufacturer termed Filter Replacement Safety Indicator) is visible on the inside surface of the element, the filter must be replaced. Since the filter works solely on size exclusion, as long as the device will process water and the element is not determined to be too thin, stated pathogen reductions should be valid (when accompanied with the purifier solution). When the filter begins to clog and pumping difficulty increases, a pressure relief valve prohibits the user from over pressurizing the filter and damaging the seals. Release of water from the pressure relief valve indicates to the user that the device should be cleaned.

Weight and Size

SweetWater Purifier System	400 grams
Filter size (height x width x length)	20 cm x 7 cm x 10 cm

Tubing	76 cm
Purifier solution (height x diameter)	11 cm x 4 cm

Cost

SweetWater Purifier System	$75.00
Replacement filter element	$35.00
Replacement purifier solution	$9.00

Device Evaluation

The MSR SweetWater Purifier System utilizes a glass fiber 0.2 µm labyrinth depth microfilter with carbon core for the reduction of bacteria, cysts, and taste and odor, and a chlorine disinfectant solution for the inactivation of virus. Independent laboratory data reviewed for this device (tested under a previous brand name) showed that it is effective at reducing bacteria, virus, *Giardia*, and *Cryptosporidium* to within the requirements of reference 2. No information was received on cleaning the device during testing and no data was shown as to the ability of this device to process highly turbid water. Since the filter is not pleated, the surface area is less than similar devices on the market, but the ability to easily disassemble and brush the filter surface clean is advantageous. As a means of device life indicator, after brushing the filter, the user observes the filter surface for visible black mesh. Once visible, the appearance of this mesh indicates that the filter needs replacement. Cleaning is simple, entailing unscrewing the pump head, brushing the filter, and then rinsing with water. No information was received as to the approximate number of times the device can be cleaned. Additionally, as the filter clogs and pressures build, a pressure relief valve in the pumping chamber prevents damage to the filter due to excessive pressure. Device design allows for water processing on both up and down strokes, decreasing user effort while increasing water output. The manufacturer claims a 4 to 1 mechanical advantage pump handle and 1-2 pounds of force to operate. The purifier solution contains 3.5% sodium hypochlorite and is dosed at 5 drops per liter of filtered water. After adding the solution, the user must mix, then wait 5 minutes for disinfection to occur prior to consumption. The somewhat high concentration of about 8.75 mg/L free chlorine results in a CT of 44 mg-min/L. This CT exceeds the USEPA requirement of 12 mg-min/L based on expected natural water conditions (pH 6-9, 0.5 – 25º C) and is therefore expected to sufficiently inactivate viruses (reference 6). Utilizing the recommended dose, it is likely that any remaining bacteria, and depending on pH and temperature, *Giardia*, will be inactivated during disinfection. It is possible that using the recommended chlorine dose will add an unpleasant taste to the water. There are no regulations set for short term use of chlorine for water disinfection. The USEPA sets a maximum residual disinfectant level of 4.0 mg/L for chlorine based on long term use. No health effects are expected for short term use at the recommended dose. If desired, the dose can

be decreased and the wait time increased proportionally, without affecting disinfection capability. For example, adding 2 drops of purifier solution instead of 5 drops, and waiting for 13 minutes instead of 5 minutes will result in the same disinfection capability (CT). In this case the chlorine dose would be 3.5 mg/L. The purifier solution loses potency over time and should not be used past the expiration date stamped on the bottle. This device has no indicator of process failure. No manufacturing information or quality control data was received for this device. The manufacturer recommends storing the purifier solution in a cool, dry area away from direct sunlight, and to refrigerate when not in use. No information was received on the storage life of the microfilter or required storage conditions for this device.

Advantages

- Independent testing confirms bacteria, virus, and cyst reduction in accordance with the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 2).
- Activated carbon core should reduce taste and odors.
- Field-serviceable.
- Simple and lightweight.
- End of device useful life indicator.

Disadvantages

- Small pore size of filter makes device inherently susceptible to clogging by waters with elevated turbidities.
- Chlorine disinfectant may add objectionable taste to water.
- Two step process.
- No real-time indicator of process failure.

References

1. Independent laboratory results of tests showing bacteria, cyst, and virus reduction. 2000. Provided by MSR.

2. USEPA, 1989. Guide Standard and Protocol for Testing Microbiological Water Purifiers. *Federal Register*. 54:34067.

3. Independent laboratory results of tests showing bacteria and cyst reduction. 1995. Provided by MSR.

4. U.S. Army Center for Health Promotion and Preventive Medicine, 2005. *Technical Information Paper; Filtration in the Use of Individual Water Purification Devices,* Aberdeen Proving Ground, MD.

5. Federal Register (2003). *National Primary Drinking Water Regulations: Long Term 2 Enhanced Surface Water Treatment Rule; Proposed Rule.* 68(154), 47640-47795.

6. U.S. Army Center for Health Promotion and Preventive Medicine, 2005. *Technical Information Paper; Chlorine Disinfection in the Use of Individual Water Purification Devices,* Aberdeen Proving Ground, MD.

ANNEX 39 TO APPENDIX E

DEVICE EVALUATION #39
MOUNTAIN SAFETY RESEARCH – WATERWORKS™ EX MICROFILTER

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Mountain Safety Research – WaterWorks™ EX Microfilter

www.msrcorp.com

Device Information

The Mountain Safety Research (MSR) WaterWorks EX Microfilter is a handheld pump water treatment device utilizing ceramic microfiltration and second stage membrane microfiltration. This device is identical to the MSR MiniWorks™ EX except for the second stage filter, making the device slightly larger and heavier. At the heart of the device is what the manufacturer calls the "Marathon EX Ceramic Element", a 0.3 µm nominal ceramic depth filter with carbon block core. The second stage manufacturer termed "PES" filter cartridge consists of a pleated polyethersulfone membrane microfilter rated at 0.2 µm absolute. This device is designed for bacteria, cyst, and taste and odor reduction, but contains no reduction mechanism for virus. The manufacturer recommends a chemical disinfectant be added for treating virus. The device consists of a plastic housing, ceramic and carbon filter element, membrane microfilter, inlet tubing, tubing weight and float, and foam pre-filter. Additionally, the device comes with a filter element scrubbing pad, ceramic element measuring gauge, and storage bag. The tubing weight and float work to keep the inlet tubing submerged, yet off of the bottom of the raw water source to limit the introduction of sediment. The bottom of the pump housing contains threads for direct connection to MSR Dromedary™ bags and wide mouth (e.g., Nalgene®) bottles. The device can also be held above any collection container to collect product water. The device utilizes what the manufacturer calls an "airspring accumulator", which traps an air bubble in the filter housing. The air bubble compresses on the down stroke then expands on the up stoke, pushing water through the cartridge without additional operator input. This device creates an absolute barrier to contaminants greater than the pore size and may remove taste and odor through carbon filtration. This device contains no chemicals and requires no wait time. No discarding of initial product water is recommended by the manufacturer. Before initial use, and after extended non-use, the airspring accumulator must be primed by pumping a small amount of

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™ MiniWorks is a registered trademark of Mountain Safety Research, Inc., Seattle, WA.
™ Dromedary is a registered trademark of Mountain Safety Research, Inc., Seattle, WA.
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water then air through the filter to trap the air bubble. This device is fully field-serviceable, and can be disassembled without tools. For optimal use the manufacturer recommends a pumping rate of 70-80 strokes per minute.

Effectiveness Against Microbial Pathogens

No results were received specific to testing the MSR WaterWorks EX. Since this device is identical to the MSR MiniWork EX except for an additional second stage microfilter, testing results for the MiniWorks can be assumed to apply to this device. Pathogen reductions are expected to meet or exceed those shown for the MiniWorks. No results were obtained that challenged either device strict to the requirements of the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1). Results from independent laboratory studies (references 2 and 3) were reviewed that challenged the MSR MiniWorks against modified versions of reference 1. Under this modified protocol, data showed that this device is capable of meeting the log reduction requirements for bacteria and *Cryptosporidium* oocysts as stated in reference 3 and shown in the table below. Since size exclusion is the reduction mechanism, observed virus reduction (reference 2) was minimal and did not meet the requirements of reference 1. Due to the larger size of *Giardia* in comparison to *Cryptosporidium*, adequate log reduction is assumed. During the testing of reference 2 the flowrate was set at 0.7 L/min and the device was tested to a capacity of 400 L. The ceramic cartridge was cleaned four times during testing, with the fourth cleaning intentionally reducing the filter diameter to the manufacturer stated minimum size based on the supplied filter gauge. Testing then resumed to demonstrate the reduction capabilities during a pseudo end of filter life condition. The testing conducted in reference 3 was run to 378 L with no information on flowrate stated. Neither testing demonstrated device pathogen reduction capabilities to the manufacturer stated 2,000 L. Due to the testing modifications with respect to reference 1, this evaluation based reduction capabilities on treatment technology. Therefore, this device is assigned one √ for bacteria and cyst reduction (for an explanation of the rating checks click here) based on size exclusion by the ceramic microfilter. Since the device is not designed, and has no mechanism for virus reduction, the device is assigned one X for this pathogen. Additional treatment is required for virus reduction.

Table. Expected Performance Against Microbial Pathogens.

Microbial Pathogen Type	Expected Disinfection Capability	Evaluation Rating	Pathogen Reduction Mechanism
Bacteria	> 6-log	√	size exclusion
Viruses	not effective*	X	none
Giardia cysts	> 3-log	√	size exclusion
Cryptosporidium oocysts	> 3-log	√	size exclusion

* Additional treatment required for virus reduction.

Production Rate and Capacity

Inherent to the production rate and capacity of filtration devices is the quality of the raw water source. The manufacturer stated production capacity of the device is 2000 L at a rate of 1.0 L/min. User effort is stated to be 70-80 strokes/L. This device utilizes a ceramic depth microfilter, which can be cleaned when production rate decreases due to filter clogging. Since cleaning irreversibly decreases the size of the element, the overall capacity of this device will vary widely with raw water turbidity. Illustrating the ability of the similar MSR MiniWork EX device to be cleaned multiple times and continue to process water are results from a study conducted on reducing water turbidity (reference 4). In this study, water with a turbidity of 60-70 NTU was processed and tested for effluent turbidity. The device produced over 300 L of water and underwent 34 cleanings without a reduction in turbidity removal capability and without reducing the ceramic element to its end life diameter. No testing on microbial reduction was conducted during these tests. No data was presented on the capacity of the carbon core within the ceramic element. Since no appreciable pathogen reduction is attributed to the carbon, microbial reduction should remain consistent even if the carbon adsorption capacity is exhausted. No data was presented on the PES microfilter. Since water entering this stage has been processed through the ceramic cartridge it should not be exposed to particulate matter and therefore, is not expected to clog frequently. Capacity of this second stage filter is dependent upon water quality.

Cleaning, Replacement, and End of Life Indicator

This device utilizes a ceramic depth microfilter, which can be cleaned by scrubbing the surface of the filter element to remove accumulated debris. Given the small pore size of the ceramic element, it is expected to clog frequently during use with turbid waters and is therefore designed

to be cleaned multiple times throughout its useful life. Supplied with the device is a gauge that is placed over the ceramic element. If the gauge fits around the element then the filter has been cleaned to its capacity and must be replaced. Since the device works solely on size exclusion, as long as the device will process water and the element is not determined to be too thin, stated pathogen reductions should be valid. When the filter begins to clog and pumping difficulty increases a pressure relief valve prohibits the user from over pressurizing the filter and damaging the seals. The second stage PES filter is not capable of being cleaned. Once clogged, this filter must be replaced.

Weight and Size

WaterWorks EX	540 grams
Size (height x width x length)	23 cm x 7 cm x 11 cm
Tubing	122 cm

Cost

WaterWorks EX	$140.00
Replacement Marthon EX Ceramic Element	$38.00
Replacement PES Element	$50.00

Device Evaluation

The MSR WaterWorks EX utilizes a ceramic 0.3 µm microfilter with carbon core and a 0.2 µm poly membrane microfilter for the reduction of bacteria and cysts, as well as taste and odor. Data reviewed for the MSR MiniWorks, utilizing similar treatment technology minus the membrane microfilter, showed that it is effective at reducing bacteria and cysts by > 6-log, and > 3-log respectively. Since pathogen reduction is by size exclusion, no virus reduction is expected by this device. Additional treatment is required to fully meet the requirements of reference 1 and ensure adequate reduction of all three classes of microorganism. Since this device utilizes an additional microfilter, pathogen reductions are expected to meet or exceed those of the MiniWorks. Testing was not conducted in accordance with reference 1 since the device was tested to 400 L and not the manufacturer stated 2000 L. Additionally, it is unclear whether the device was tested at the stated production rate of 1 L/min. Due to this, we rate the device as expected to meet the requirements of reference 1, but base this on treatment technology since data specific to this protocol was not received (reference 5). During testing, the device required multiple cleanings. Pathogen reductions remained consistent after cleanings, even when tested at the minimum recommended thickness of the ceramic filter cartridge. This device, like all filters with small pore sizes, is highly affected by turbid (cloudy) waters. A study conducted

to determine the ability of the similar MSR MiniWorks EX to filter turbid water showed that when challenged with highly turbid water, the device was able to reduce this turbidity but required frequent cleaning due to particulate build-up. During this testing, the device was cleaned 34 times while processing 300 L. Although this indicates a high maintenance effort, it displays the ability of the device to be cleaned and returned to full performance. This device utilizes no chemicals and requires no wait time prior to water consumption. There is no indicator of process failure. A plastic gauge acts as an end of device useful life indicator. Since during cleaning of the ceramic element the filter reduces size, when the gauge fits around the filter, it must be replaced. No manufacturing information or quality control data was received for this device. This device, like all containing ceramic elements, must not be frozen while wet. Expansion of the water during freezing may crack the element. Additionally, the user should avoid shocking the device due to the brittle nature of the ceramic element and possible fracturing during shock loads. No information was received on the storage life or required storage conditions for this device.

Advantages

- Based on treatment technology and independent data reviewed, this device should be capable of reducing bacteria and cysts to within the requirements of the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1).
- Second stage microfilter for redundancy in pathogen reduction.
- No wait time prior to water consumption.
- Activated carbon core should reduce taste and odors.
- Field-serviceable.
- End of device useful life indicator.

Disadvantages

- Device is not designed for virus reduction and therefore, unable to fully meet the pathogen reduction requirements of the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1).
- Additional treatment required.
- Small pore size of filter makes device inherently susceptible to clogging by waters with elevated turbidities.
- Ceramic element fragile to shock loads and freezing.
- No real-time indicator of process failure.

References

1. USEPA, 1989. Guide Standard and Protocol for Testing Microbiological Water Purifiers. *Federal Register*. 54:34067.

2. Independent laboratory results of tests showing bacteria and cyst reduction. 1997. Provided by MSR.

3. Independent laboratory results of tests showing bacteria and cyst reduction. 1996. Provided by MSR.

4. Naval Facilities Engineering Service Center, 1993. Team Water Purifier Test Report. Technical Memorandum TM-2003-AMP.

5. U.S. Army Center for Health Promotion and Preventive Medicine, 2005. *Technical Information Paper; Filtration in the Use of Individual Water Purification Devices*, Aberdeen Proving Ground, MD.

ANNEX 40 TO APPENDIX E

DEVICE EVALUATION #40
PRE-MAC – MODEL SWP WATER PURIFIER

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Pre-Mac – Model SWP Water Purifier

www.pre-mac.com

Device Information

The Pre-Mac model SWP water purifier is a portable hand-pump water treatment device. According to the manufacturer, microbiological treatment consists of filtration and disinfection. The device consists of flexible inlet tubing containing a fine mesh screen which provides coarse filtration, outlet tubing, a hand pump, all connected to a disposable plastic cartridge containing activated carbon cloth and iodine resin. The activated carbon cloth provides filtration and adsorption the iodine resin provides disinfection. Operation of the hand pump draws water through the fine mesh screen on the inlet tubing and sends the water through the activated charcoal cloth and then the iodine resin in the cartridge. The resin is designed to impart an iodine residual (typically 2-4 mg/L) in treated water that provides additional disinfection. The manufacturer directs users to provide a minimum of 2 minutes contact time before drinking. A 4-minute contact time is directed when treating water at temperatures of 5° C or less. The manufacturer also offers an optional field test kit for measuring iodine residual in treated water.

Effectiveness Against Microbial Pathogens

No test data is available for the model SWP water purifier using the U.S. Environmental Protection Agency (USEPA) Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1). However, an independent laboratory conducted testing using the USEPA Protocol on an earlier Pre-Mac model water purifier that is very similar in operation and treatment technology (reference 2). Therefore, these results are considered applicable to the model SWP water purifier. The results showed the earlier model consistently met the 6-log and 4-log bacteria and virus removal/inactivation minimum requirements. The device did not consistently meet the minimum 3-log protozoan cyst removal/inactivation requirement when challenged with *Cryptosporidium* oocysts. These test results suggest the Pre-Mac SWP would meet the minimum 6-log bacteria and 4-log virus removal/inactivation requirements when used according to directions. The results also suggest the Pre-Mac SWP would not meet the required minimum 3-log cyst removal/inactivation for *Cryptosporidium* oocysts. Other independent testing using protocols other than the USEPA Protocol verify the ability of the Pre-Mac SWP to provide at least a 6-log bacteria and 4-log virus removal/inactivation. Available testing data did

not include *Giardia* cysts as a test organism. Based on general knowledge of the treatment technologies used in the SWP water purifier (activated carbon and iodine resin), the device would not consistently provide a 3-log removal or inactivation of *Giardia* cysts when used as directed. If the iodine resin is a pentaiodide (I_5) resin, the device would be capable of reducing *Giardia* cysts if contact time after passage through the device were extended to at least 40 minutes (reference 3). However, since there is no device-specific testing data available using *Giardia* cysts and we do not know the exact composition of the iodine resin, we must consider the device ineffective against *Giardia* cysts. Additional treatment is, therefore, necessary to remove or inactivate cysts. Based on evaluation of available data and considering the data did not include device-specific testing using the USEPA Protocol, the Pre-Mac model SWP water purifier receives one √ for bacteria, and viruses, and one X for *Giardia* cysts and *Cryptosporidium* oocysts (for an explanation of the rating checks click here). The following table summarizes the device's expected effectiveness against microbial pathogens, evaluation rating, and the mechanism by which pathogens are removed or inactivated:

Table. Expected Performance Against Microbial Pathogens.

Microbial Pathogen Type	Expected Performance	Evaluation Rating	Inactivation/removal Mechanism
Bacteria	> 6-log	√	Iodine disinfection with some size exclusion and adsorption
Viruses	> 4-log	√	Iodine disinfection with some adsorption
Giardia cysts	Not Effective	**X**	Some size exclusion, adsorption and iodine disinfection
Cryptosporidium oocysts	Not Effective	**X**	Some size exclusion and adsorption

Production Rate and Capacity

Inherent to the production rate and capacity of filtration devices is the quality of the raw water source. The actual production rate and capacity is dependent on the user and raw water quality. The manufacturer's stated production rate is 200 ml/min. The stated capacity is 50-100L.

Cleaning, Replacement, End of Life Indicator

When pumping becomes difficult or 50L of water has passed through the device, the device must be disposed. The device is not capable of being cleaned or backwashed. Instructions recommend discarding the first 0.05L of treated water if the SWP water purifier is new.

Weight and Size

The dry weight of the device is 60 grams. Dimensions are 2 cm diameter x 13 cm length.

Cost

The Pre-Mac SWP water purifier is not sold at stores in the United States. The device is available through online ordering and at stores outside of the United States. The device costs approximately $40.

Device Evaluation

Based on evaluation of available data, the Pre-Mac model SWP water purifier is expected to provide 6-log bacteria and 4-log virus removal or inactivation under most water quality conditions expected. The SWP water purifier will not consistently provide a 3-log *Giardia* cyst and *Cryptosporidium* oocyst removal or inactivation. Additional treatment such as filtration with a 1 µm absolute filter will be necessary to remove these protozoan cysts. Iodine resin disinfection is the primary mechanism of bacteria and virus inactivation. The iodine resin inactivates bacteria, viruses, and some *Giardia* cysts through direct contact with the resin as well as through the iodine residual the resin imparts to the water. The device will also provide some filtration and adsorption of bacteria, viruses, *Giardia* cysts, and *Cryptosporidium* oocysts due to the activated charcoal cloth. There is no indicator of process failure on a real-time basis and end of device useful life is based on filter clogging, or by the user keeping track of the volume of water purified. The iodine resin releases decreasing amounts of iodine as usage continues, but there are no instructions on when to dispose of the device based on iodine residuals if measured using the optional field test kit. Inherent to treatment devices using filtration is the likelihood of clogging and reduced device capacity when treating highly turbid water. The iodine resin and residual are not expected to cause any adverse health effects to healthy adults who have no pre-existing thyroid conditions or sensitivity to iodine. This device is not recommended for use by pregnant women (concern for fetus), people with known hypersensitivity to iodine, people with a history (or family history) of thyroid disease, and people from areas with chronic iodine deficiency (reference 3). The iodine residual imparted by the resin can cause a medicinal taste and color the water. Iodine can be neutralized by adding ascorbic acid (Vitamin C) or sodium

thiosulfate, which will improve the taste and color. Flavored drink mixes can mask the flavor. However, neutralizers and flavor aids should not be added until after recommend contact times are achieved.

Advantages

- Independent testing using the USEPA Protocol with a similar Pre-Mac device suggests the SWP water purifier will provide 6-log bacteria and 4-log virus removal or inactivation when treating most water quality conditions expected.
- Very small and lightweight.
- Very easy to use.
- No adverse health effects expected in healthy adults with no iodine sensitivity.

Disadvantages

- Not effective against *Giardia* and *Cryptosporidium*. Additional treatment is necessary.
- Not recommended for use by pregnant women or people with iodine sensitivity
- Can impart color and medicinal taste.

References

1. USEPA, Registration Division Office of Pesticide Program, Criteria and Standards Division Office of Drinking Water. (1987). *Guide Standard and Protocol for Testing Microbiological Water Purifiers.* Washington, D.C.

2. U.S. Army Biomedical Research & Development Laboratory. (1993). *Evaluation of the Medical Efficacy of the Pre-Mac Model FWP Individual Water Purifier for Treating Microbiological Contaminants in Water.* (USABRDL Technical Report 9204). Frederick, MD. Prepared by Shaub, S.A., Hargett, H.T., Sterling, C.R., and Marshall, M.M.

3. U.S. Army Center for Health Promotion and Preventive Medicine. (2005). *Technical Information Paper; Iodine Disinfection in the Use of Individual Water Purification Devices,* Aberdeen Proving Ground, MD.

ANNEX 41 TO APPENDIX E

DEVICE EVALUATION #41
PRE-MAC – MODEL MWP WATER PURIFIER

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Pre-Mac – Model MWP Water Purifier

www.pre-mac.com

Device Information

The Pre-Mac model MWP water purifier is a portable hand-pump water treatment device. According to the manufacturer, microbiological treatment consists of filtration and disinfection. The device consists of flexible inlet tubing containing a fine mesh screen which provides coarse filtration, outlet tubing, a hand pump, and two replaceable cartridges. One cartridge contains an activated carbon cloth which provides filtration and adsorption, and the other cartridge contains an iodine resin which provides disinfection. When treating cloudy, turbid water, the manufacturer recommends using a 0.2 µm pre-filter. Operation of the hand pump draws water through the fine mesh screen on the inlet tubing and sends the water first through the activated charcoal cloth cartridge and then through the iodine resin cartridge. The resin is designed to impart an iodine residual (typically 2-4 mg/L) in treated water that provides additional disinfection. The manufacturer directs users to provide a minimum of 3 minutes contact time before drinking. A 5-minute contact time is directed when treating water at temperatures of 5° C or less. The manufacturer also offers an optional field test kit for measuring iodine residual in treated water.

Effectiveness Against Microbial Pathogens

No test data is available for the model MWP water purifier using the U.S. Environmental Protection Agency (USEPA) Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1). However, an independent laboratory conducted testing using the USEPA Protocol on an earlier Pre-Mac model water purifier that is very similar in operation and treatment technology (reference 2). Therefore, these results are considered applicable to the model MWP water purifier. The results showed the earlier model consistently met the 6-log and 4-log bacteria and virus removal/inactivation minimum requirements. The device did not consistently meet the minimum 3-log protozoan cyst removal/inactivation requirement when challenged with *Cryptosporidium* oocysts. These test results suggest the Pre-Mac MWP would meet the minimum 6-log bacteria and 4-log virus removal/inactivation requirements when used according to directions. The results also suggest the Pre-Mac MWP would not meet the required minimum 3-log cyst removal/inactivation for *Cryptosporidium* oocysts. Other independent

testing using protocols other than the USEPA Protocol verify the ability of the Pre-Mac MWP to provide at least a 6-log bacteria and 4-log virus removal/inactivation. Available testing data did not include *Giardia* cysts as a test organism. Based on general knowledge of the treatment technologies used in the MWP water purifier (activated carbon and iodine resin) and the intermittent use of the 2 µm pre-filter with high turbidity waters, the MWP water purifier would not consistently provide a 3-log removal or inactivation of *Giardia* cysts when used as directed. If the iodine resin is a pentaiodide (I_5) resin, the device would be capable of reducing *Giardia* cysts if contact time after passage through the device were extended to at least 40 minutes (reference 3). However, since there are no device-specific testing data available using *Giardia* cysts and we do not know the exact composition of the iodine resin, we must consider the device ineffective against *Giardia* cysts. Additional treatment is, therefore, necessary to remove or inactivate cysts. Based on evaluation of available data and considering the data did not include device-specific testing using the USEPA protocol, the Pre-Mac model MWP water purifier receives one √ for bacteria, and viruses, and an X for *Giardia* cysts and *Cryptosporidium* oocysts (for an explanation of the rating checks click here). The following table summarizes the device's expected effectiveness against microbial pathogens, evaluation rating, and the mechanism by which pathogens are removed or inactivated:

Table. Expected Performance Against Microbial Pathogens when Used as Directed.

Microbial Pathogen Type	Expected Performance	Evaluation Rating	Inactivation/removal Mechanism
Bacteria	> 6-log	√	Iodine disinfection with some size exclusion and adsorption
Viruses	> 4-log	√	Iodine disinfection with some adsorption
Giardia cysts	Not Effective	**X**	Some size exclusion, adsorption and iodine disinfection
Cryptosporidium oocysts	Not Effective	**X**	Some size exclusion and adsorption

Production Rate and Capacity

Inherent to the production rate and capacity of filtration devices is the quality of the raw water source. The actual production rate and capacity is dependent on the user and raw water quality. The manufacturer's stated production rate is 400 ml/min. The stated capacity is 200-500 L.

Cleaning, Replacement, End of Life Indicator

When pumping becomes difficult or 200 L of water has passed through the device the cartridges must be replaced. The device is not capable of being cleaned or backwashed. Instructions recommend discarding the first 0.25L of treated water if the MWP water purifier is new.

Weight and Size

The dry weight of the device is 180 grams. Dimensions are 4.5 cm diameter x 14 cm length.

Cost

The Pre-Mac MWP water purifier is not sold at stores in the United States. The device is available through online ordering and at stores outside of the United States. The device costs approximately $100. Replacement cartridges cost approximately $45.

Device Evaluation

Based on evaluation of available data, the Pre-Mac model MWP water purifier is expected to provide 6-log bacteria and 4-log virus removal or inactivation under most water quality conditions expected. The MWP water purifier will not consistently provide a 3-log *Giardia* cyst and *Cryptosporidium* oocyst removal or inactivation. Additional treatment such as filtration with a 1 µm absolute filter will be necessary to remove these protozoan cysts. Iodine resin disinfection is the primary mechanism of bacteria and virus inactivation. The iodine resin inactivates bacteria, viruses, and some *Giardia* cysts through direct contact with the resin as well as through the iodine residual the resin imparts to the water. The device will also provide some filtration and adsorption of bacteria, viruses, *Giardia* cysts, and *Cryptosporidium* oocysts due to the activated charcoal cloth and the 2 µm pre-filter when used in high turbidity waters. There is no indicator of process failure on a real-time basis and end of device useful life is based on filter clogging, or by the user keeping track of the volume of water purified. The iodine resin releases decreasing amounts of iodine as usage continues, but there are no instructions on when to replace cartridges based on iodine residuals if measured using the optional field test kit. Inherent to treatment devices using filtration is the likelihood of clogging when processing highly turbid raw water. The optional 2 µm pre-filter should be used in highly turbid water. This will clog the pre-filter and necessitate the need for additional pre-filters but will extend the life of the purifier. The iodine resin and residual are not expected to cause any adverse health effects to healthy adults with no pre-existing thyroid conditions or sensitivity to iodine. This device is not recommended for use by pregnant women (concern for fetus), people with known hypersensitivity to iodine, people with a history (or family history) of thyroid disease, and people

from areas with chronic iodine deficiency (reference 3). The iodine residual imparted by the resin can cause a medicinal taste and color the water. Iodine can be neutralized by adding ascorbic acid (Vitamin C) or sodium thiosulfate, which will improve the taste and color. Flavored drink mixes can mask the flavor. However, neutralizers and flavor aids should not be added until after directed contact times are achieved.

Advantages

- Independent testing using the USEPA protocol with a similar Pre-Mac device suggests the MWP water purifier will provide 6-log bacteria and 4-log virus removal or inactivation when treating most water quality conditions expected.
- Small and lightweight.
- Simple to use.
- No adverse health effects expected in healthy adults with no iodine sensitivity.

Disadvantages

- Not effective against *Giardia* and *Cryptosporidium*. Additional treatment is necessary.
- Not recommended for use by pregnant women or people with iodine sensitivity
- Can impart color and medicinal taste.

References

1. U.S. Environmental Protection Agency, Registration Division Office of Pesticide Program, Criteria and Standards Division Office of Drinking Water. (1987). *Guide Standard and Protocol for Testing Microbiological Water Purifiers.* Washington, D.C.

2. U.S. Army Biomedical Research & Development Laboratory. (1993). *Evaluation of the Medical Efficacy of the Pre-Mac Model FWP Individual Water Purifier for Treating Microbiological Contaminants in Water.* (USABRDL Technical Report 9204). Frederick, MD. Prepared by Shaub, S.A., Hargett, H.T., Sterling, C.R., and Marshall, M.M.

3. U.S. Army Center for Health Promotion and Preventive Medicine. (2005). *Technical Information Paper; Iodine Disinfection in the Use of Individual Water Purification Devices,* Aberdeen Proving Ground, MD.

ANNEX 42 TO APPENDIX E

DEVICE EVALUATION #42
PRE-MAC – MODEL PWP WATER PURIFIER

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Pre-Mac – Model PWP Water Purifier

www.pre-mac.com

Device Information

The Pre-Mac model PWP water purifier is a pour-through portable water treatment device operating by gravity flow. According to the manufacturer, microbiological treatment consists of filtration and disinfection. The device consists of a cap to use for collecting untreated water, a pre-filter chamber to pour the untreated water into, the flow-through treatment chamber containing activated charcoal cloth and iodine resin, and a water bottle adaptor to connect the PWP directly to a bottle for receiving treated water. Untreated water collected with the top cap is poured into the pre-filter chamber where coarse filtration is provided by a cleanable filter pad and a fine mesh screen. The water then flows through the treatment chamber where the activated charcoal cloth provides filtration and adsorption, followed by disinfection provided by the iodine resin. The resin is designed to impart an iodine residual (typically 3-5 mg/L) in treated water that provides additional disinfection. The manufacturer directs users to provide a minimum of 2 minutes contact time before drinking. An optional outlet filter can be used to remove residual iodine, but specifics of this filter are not known. The manufacturer also offers an optional field test kit for measuring iodine residual in treated water. The device should be stored in an upright position at normal room temperature. Avoid repeated freeze-thaw cycles.

Effectiveness Against Microbial Pathogens

No test data is available for the model PWP water purifier using the U.S. Environmental Protection Agency (USEPA) Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1). However, an independent laboratory conducted testing using the USEPA Protocol on an earlier Pre-Mac model water purifier that is very similar in treatment technology (reference 2). Therefore, these results are considered applicable to the model PWP water purifier. The results showed the earlier model consistently met the 6-log and 4-log bacteria and virus removal/inactivation minimum requirements. The device did not consistently meet the minimum 3-log protozoan cyst removal/inactivation requirement when challenged with *Cryptosporidium* oocysts. These test results suggest the Pre-Mac PWP would meet the minimum 6-log bacteria and 4-log virus removal/inactivation requirements when used according to directions. The results also suggest the Pre-Mac PWP would not meet the required minimum

3-log cyst removal/inactivation for *Cryptosporidium* oocysts. Independent testing using a protocol other than the USEPA Protocol verifies the ability of the Pre-Mac PWP to consistently provide at least a 6-log bacteria removal/inactivation. Independent testing of other Pre-Mac models (SWP and MWP) using a non-USEPA protocol suggest the PWP will consistently provide a 4-log virus removal/inactivation. Available testing data did not include *Giardia* cysts as a test organism. Based on general knowledge of the treatment technologies used in the PWP water purifier (activated carbon and iodine resin), the device would not consistently provide a 3-log removal or inactivation of *Giardia* cysts when used as directed. If the iodine resin is a pentaiodide (I_5) resin, the device would be capable of reducing *Giardia* cysts if contact time after passage through the device were extended to at least 40 minutes (reference 3). However, since there is no device-specific testing data available using *Giardia* cysts and we do not know the exact composition of the iodine resin, we must consider the device ineffective against *Giardia* cysts. Additional treatment is, therefore, necessary to remove or inactivate cysts. Based on evaluation of available data and considering the data did not include device-specific testing using the USEPA protocol, the Pre-Mac model PWP water purifier receives one √ for bacteria, and viruses, and one X for *Giardia* cysts and *Cryptosporidium* oocysts (for an explanation of the rating checks click here). The following table summarizes the device's expected effectiveness against microbial pathogens, evaluation rating, and the mechanism by which pathogens are removed or inactivated:

Table. Expected Performance Against Microbial Pathogens.

Microbial Pathogen Type	Expected Performance	Evaluation Rating	Inactivation/removal Mechanism
Bacteria	> 6-log	√	Iodine disinfection with some size exclusion and adsorption
Viruses	> 4-log	√	Iodine disinfection with some adsorption
Giardia cysts	Not Effective	**X**	Some size exclusion, adsorption and iodine disinfection
Cryptosporidium oocysts	Not Effective	**X**	Some size exclusion and adsorption

Production Rate and Capacity

The stated capacity is 1000L. Inherent to the production rate and capacity of filtration devices is the quality of the raw water source. The actual production rate and capacity is dependent on the raw water quality. The manufacturer's stated production rate is 200 ml/min.

Cleaning, Replacement, End of Life Indicator

When flow through the device becomes very slow, stops, or 1000L of water has been treated, the device must be disposed. The device is not capable of being cleaned or backwashed. Instructions recommend discarding the first 0.5L of treated water if the PWP water purifier is new.

Weight and Size

The dry weight of the device is 500 grams. Dimensions are 9.5 cm diameter x 14 cm length.

Cost

The Pre-Mac PWP water purifier is not sold at stores in the United States. The device is available through online ordering and at stores outside of the United States. The device costs approximately $100.

Device Evaluation

Based on evaluation of available data, the Pre-Mac model PWP water purifier is expected to consistently provide 6-log bacteria and 4-log virus removal or inactivation under most water quality conditions expected. The PWP water purifier will not consistently provide a 3-log *Giardia* cyst and *Cryptosporidium* oocyst removal or inactivation. Additional treatment such as filtration with a 1 µm absolute filter will be necessary to remove these protozoan cysts. Iodine resin disinfection is the primary mechanism of bacteria and virus inactivation. The iodine resin inactivates bacteria, viruses, and some *Giardia* cysts through direct contact with the resin as well as through the iodine residual the resin imparts to the water. The device will also provide some filtration and adsorption of bacteria, viruses, *Giardia* cysts, and *Cryptosporidium* oocysts due to the activated charcoal cloth. There is no indicator of process failure on a real-time basis and end of device useful life is based on filter clogging, or by the user keeping track of the volume of water purified. The iodine resin releases decreasing amounts of iodine as usage continues, but there are no instructions on when to dispose of the device based on iodine residuals if measured using the optional field test kit. Inherent to treatment devices using filtration is the likelihood of clogging and reduced device capacity when treating highly turbid water. The iodine resin and residual are not expected to cause any adverse health effects to healthy adults who have no pre-existing thyroid conditions or sensitivity to iodine. This device is not recommended for use by pregnant women (concern for fetus), people with known hypersensitivity to iodine, people with a history (or family history) of thyroid disease, and people from areas with chronic iodine deficiency (reference 3). The iodine residual imparted by the resin can cause a medicinal taste

and color the water. Iodine can be neutralized by adding ascorbic acid (Vitamin C) or sodium thiosulfate, which will improve the taste and color. Flavored drink mixes can mask the flavor. However, neutralizers and flavor aids should not be added until after achieving the manufacturer-directed contact time. The manufacturer also provides an optional post filter to remove residual iodine after achieving directed contact time.

Advantages

- Independent testing using the USEPA protocol with a similar Pre-Mac device suggests the PWP water purifier will provide 6-log bacteria and 4-log virus removal or inactivation when treating most water quality conditions expected.
- Small and lightweight.
- Very easy to use.
- No adverse health effects expected in healthy adults with no iodine sensitivity.

Disadvantages

- Not effective against *Giardia* and *Cryptosporidium*. Additional treatment is necessary.
- Not recommended for use by pregnant women or people with iodine sensitivity
- Can impart color and medicinal taste.

References

1. U.S. Environmental Protection Agency, Registration Division Office of Pesticide Program, Criteria and Standards Division Office of Drinking Water. (1987). *Guide Standard and Protocol for Testing Microbiological Water Purifiers.* Washington, D.C.

2. U.S. Army Biomedical Research & Development Laboratory. (1993). *Evaluation of the Medical Efficacy of the Pre-Mac Model FWP Individual Water Purifier for Treating Microbiological Contaminants in Water.* (USABRDL Technical Report 9204). Frederick, MD. Prepared by Shaub, S.A., Hargett, H.T., Sterling, C.R., and Marshall, M.M.

3. U.S. Army Center for Health Promotion and Preventive Medicine. (2005). *Technical Information Paper; Iodine Disinfection in the Use of Individual Water Purification Devices,* Aberdeen Proving Ground, MD.

ANNEX 43 TO APPENDIX E

DEVICE #43
PRE-MAC – TRAVEL WELL

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ANNEX 44 TO APPENDIX E

DEVICE EVALUATION #44
PRISMEDICAL CORPORATION – TRITON™ PERSONAL WATER PURIFICATION UNIT

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Prismedical Corporation – Triton™ Personal Water Purification Unit

www.prismedical.com

Device Information

The Prismedical Triton Personal Water Purification Unit is a passive, handheld water treatment device consisting of a plastic purification pack (canister about the size of an aluminum drink can), two vinyl bags, and rubber tubing for connections. The device is operated by connecting the raw water bag to the influent side (top) of the purification pack with supplied tubing, and similarly the product water bag to the effluent or bottom of the purification pack. The connections on the pack and the tubing are designed to prevent connecting the bags in the reverse order. Untreated water is then poured into the raw water bag and the device is hung several feet off of the ground to allow for gravity water flow through the device. The raw water bag holds about 3 L of water and contains a 15 µm asymmetric depth filter. The pre-filter is charged to increase pathogen removal and, according to the manufacturer, has characteristics of membranes with much smaller pore sizes. The treatment unit consists of carbon, proprietary strong anion/ cation ion exchange resin, a 2 µm (nominal) glass macrofilter, and 0.2 µm (absolute) microfilter. The product water bag is vinyl, holds about 3 L, and is distinctly different in appearance from the raw water bag. The manufacturer claims multiple barriers for pathogens throughout the device due to chemically modified components, where no one step mitigates a single category of contaminant. Although the device will operate on gravity alone, pressurizing the system by means of pressing or sitting on the raw water bag will dramatically increase the flow rate. This device uses no chemicals for pathogen reduction and therefore imparts no taste and presents no health concerns. The Triton Personal Water Purification Unit evolved from another device that Prismedical produces called the Mainstream™ Water Purification Device. The Mainstream device targets the production of sterile water from a purified drinking water source and is a U.S. Food and Drug Administration-approved device for medical use. The Mainstream contains slightly different pathogen reduction mechanisms, excluding the prefilter, in comparison to the Triton™. Due to limited data received on the Triton' where applicable, data for the more thoroughly studied Mainstream will be substituted and noted.

™ Triton is a registered trademark of Prismedical Corporation, Napa, CA.

™ Mainstream is a registered trademark of Prismedical Corporation, Napa, CA. Use of trademarked products does not imply endorsement by the U.S. Army, but is intended only in identification of a specific product.

Effectiveness Against Microbial Pathogens

No data was received showing the pathogen reduction capabilities of this device when challenged against the U.S. Environmental Protection Agency (USEPA) Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1). The protocol used in microbial challenge studies for the Triton was based on that used for the Mainstream device, and is different than testing protocols commonly used for drinking water purification. Testing data received for both devices followed the Health Industry Manufacturers Association (HIMA) Microbiological Evaluation of Filters for Sterilizing Liquids protocol (reference 2). This protocol, designed to test devices used to create sterile water for medical purposes, contains stringent bacterial reduction requirements, but lacks worst-case challenge water incorporating elevated turbidities and changes in pH and water temperature. Based on the pathogen reduction mechanism of the Triton and the data received that was conducted independently using the Mainstream, bacteria reduction is expected to exceed the 6-log requirement of the USEPA Guide Standard (reference 1). The HIMA protocol does not require cyst reduction challenges due to their size being many times larger than bacteria. Given the reduction mechanisms, cyst reduction should exceed the requirement of reference 1. No data was reviewed for virus reduction. Based on the reduction mechanism, data received by the manufacturer for the Mainstream, and conversations with the manufacturer, virus reduction to the requirements of reference 1 is expected. Since the primary mechanism of virus reduction is adsorption, and this process can be affected by turbidity (particulates) and pH, testing for virus, as well as bacteria and cysts, against reference 1 is critical to confirm expected reductions. Additionally, published data (reference 3) was received for the Mainstream that showed bacteria and virus reduction capabilities. Excellent reductions were shown using USEPA-grade drinking water spiked with each pathogen. Since the Mainstream is similar to the Triton, these results support the assumptions made on pathogen reduction, but confirmation is needed incorporating worst-case water quality. This device is assigned one √ for each pathogen (for an explanation of the rating checks click here) based on treatment technology.

Table. Expected Performance Against Microbial Pathogens.

Microbial Pathogen Type	Expected Disinfection Capability	Evaluation Rating	Pathogen Reduction Mechanism
Bacteria	> 6-log	√	size exclusion
Viruses	> 4-log	√	adsorption, ion exchange
Giardia cysts	> 3-log	√	size exclusion
Cryptosporidium oocysts	> 3-log	√	size exclusion

Production Rate and Capacity

Inherent to the production rate and capacity of filtration devices is the quality of the raw water source. Manufacturer stated production rate is 0.075 L/min for gravity production at 1.1 psi, and 0.2 L/min when pressurized to 5 psi. Independent laboratory data reviewed for flow rate with the Mainstream, using gravity flow and no appreciable turbidity, showed the production of 3 L of water in about 60 minutes (0.050 L/min). Pressurizing the system to about 5 psi, decreased the time to produce 3 L to about 20 minutes, corresponding to a flow rate of 0.150 L/min. The addition of particulates decreased production rate. Prismedical in-house data using the Triton with water having a relatively low turbidity of about 1 NTU and no microbial challenge, showed flow rates of 0.060 – 0.090 L/min for the first 100 L produced and dropping down to about 0.004 L/min by the device capacity limit of 200 L. Device capacity is stated to be 200 L but will vary widely with raw water turbidity.

Cleaning, Replacement, and End of Life Indicator

When production rate decreases, the raw water bag can be turned inside out and the pre-filter can be cleaned by scraping particulates off and rinsing the membrane with water. Raw water is acceptable to use for cleaning the pre-filter. The treatment unit is not designed to be backwashed and once clogged must be replaced. If production cannot be restored to a practical rate, or after 200 L of water have been processed, the device must be discarded. After the device has processed 200 L of water the unit should be discarded regardless of production rate since the ion exchange resin may be exhausted. This device does not contain an indicator of process failure or end of useful life indicator besides clogging. There are no replaceable parts for this device.

Weight and Size

The dry weight of the device is 500 grams. Dimensions are as follows:

Overall Device (H x diameter)	16 cm x 12 cm
Purification pack (H x diameter)	11.5 cm x 7 cm
Raw and treated water bags (foldable, each) (L x W)	43 cm x 18 cm
Tubing (2 pieces, each)	43 cm

Cost

Triton (GSA price)	$57.82

Device Evaluation

The Prismedical Triton Personal Water Purification Unit has not been challenged against the requirements of the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1). Data received for bacteria reduction by an independent laboratory (reference 4) followed the HIMA protocol, and although pathogen reduction requirements were met, water characteristics used during testing are not considered worst-case challenge in accordance with reference 1. Based on treatment technology, bacteria reduction to the requirements of reference 1 is expected. No data was received for cyst and virus reduction. Based on membrane pore size, excellent cyst reduction is expected. Based on treatment technology, published data for the Mainstream device, and discussions with the manufacturer, virus reduction is expected to exceed the 4-log requirement of reference 1 (reference 5). Pathogen reductions need to be confirmed by testing the device against the full USEPA Guide Standard and Protocol (reference 1). Since virus reduction is by adsorption, water quality will affect efficiency. Additionally, the device has a finite capacity for virus adsorption. Therefore, it must be demonstrated that this device can not only meet the reduction requirements for viruses as well as for bacteria and cysts, but do so to the stated capacity of 200 L. This device requires no chemical addition and no wait time prior to water consumption. There is no indicator of process failure on a real-time basis, and end of device useful life is based on filter clogging, or by the user keeping track of the volume of water purified. Inherent to treatment devices utilizing small pore size membranes is the likelihood of clogging when processing highly turbid raw water. Although this device uses a pre-filter that is able to be mechanically cleaned, this inherent disadvantage is still valid. The large surface area of the pre-filter is advantageous when used with turbid waters. Throughout the use of the device, water production rate is expected to decrease considerably and will be affected by water quality. Since this device requires gravity flow or the application of pressure, such as by sitting on the raw water bag, using the device on the move may not be feasible. The manufacturer states that the canister can be used as an in-line filter when accompanied by a hydration pack, but no information was received as to the effort on the user's part to pull water through the device. The manufacturer states full accountability by Prismedical employees during the manufacturing process, but no manufacturing specific information or quality control data was received for this device. No information was received on the storage life or required storage conditions for this device.

Advantages

- Independent and published data using a similar device showed excellent bacteria and virus reduction. Excellent cyst reduction is expected based on treatment technology. [No results were received using worst case (e.g., elevated turbidity) challenge water.]
- No chemicals required.
- No wait time prior to consumption.
- Large surface area pre-filter with cleaning capability.

Disadvantages

- No data showing pathogen reduction capabilities in accordance with the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1).
- Slow water production rate.
- No real-time indicator of process failure.
- Device unable to be backwashed.

References

1. USEPA, 1989. Guide Standard and Protocol for Testing Microbiological Water Purifiers. *Federal Register*. 54:34067.

2. HIMA, 1982. Microbiological Evaluation of Filters for Sterilizing Liquids. HIMA Document No. 3, Vol. 4.

3. Taylor, M.A., et. al., 2004. Remote Site Production of Sterile Purified Water from Available Surface Water. *Prehospital and Disaster Medicine*. 3:266-277.

4. Independent laboratory data supplied by Prismedical showing bacteria and virus reduction.

5. U.S. Army Center for Health Promotion and Preventive Medicine, 2005. *Technical Information Paper; Filtration in the Use of Individual Water Purification Devices,* Aberdeen Proving Ground, MD.

Device Evaluation Update – February 2006

Independent laboratory results for testing conducted by NSF International was received that tested the Prismedical Triton Personal Water Purification Unit against the USEPA Guide Standard. Testing was conducted using the ceramic candle portion of the protocol with a

production volume of 4 L/day for 10.5 days. The flow rate was 0.075 L/min. Results indicate that this device is capable of > 6-log reduction of bacteria, and > 3-log reduction of *Cryptosporidium parvum*. This device met the > 4-log reduction of both rotavirus and poliovirus during initial testing. On day six virus reduction decreased to below the 4-log requirement. By day 7 the device was well under the 4-log requirement. During this time, bacteria and cyst reduction remained constant. On day 8, after 24 L of relatively clear type 1 water and 4 L of turbid type 2 water, the units clogged, ending testing for this device. During testing on day 7 the turbidity of the water was about 290 NTU, well above the ≥ 30 NTU requirement. It is unclear if this device would have clogged prior to day 10 using the lower NTU water. The device showed decreased virus reduction prior to this increased turbidity water. Our original pathogen reduction ratings for this device were √ bacteria, √ virus, √ *Giardia*, and √ *Cryptosporidium* based on device technology. Based on this new data, it is questionable whether adequate virus reduction is likely. Furthermore, it appears that this device may have trouble meeting the 200 L manufacturer stated capacity using elevated turbidity waters. Until additional data becomes available indicating otherwise, it should be assumed that this device is incapable of meeting the virus reduction requirements and the new pathogen reduction ratings should be √ bacteria, X virus, √ *Giardia*, and √ *Cryptosporidium*.

Updated Table. Expected Performance Against Microbial Pathogens.

Microbial Pathogen Type	Expected Disinfection Capability	Evaluation Rating	Pathogen Reduction Mechanism
Bacteria	> 6-log	√	size exclusion
Viruses	> 4-log	X	adsorption, ion exchange
Giardia cysts	> 3-log	√	size exclusion
Cryptosporidium oocysts	> 3-log	√	size exclusion

Reference:

Independent laboratory testing conducted November 2005. Testing sponsored by the Department of the Air Force, Air Force Materiel Command.

ANNEX 45 TO APPENDIX E

DEVICE EVALUATION #45
SAWYER PRODUCTS – IN-LINE FILTER

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Sawyer Products – In-line Filter

www.sawyerproducts.com

Device Information

The Sawyer In-line filter is designed for use with commercial hydration packs. The In-line filter contains a filter cartridge similar to the primary filter in Sawyer's water bottle, a 0.2 µm hollow fiber filter. The filter cartridge is contained in a sturdy plastic housing with separate inlet and outlet for connecting to the drink tube of a hydration pack or other tubing for fluid transfer. The hollow fiber filter is a 0.2 µm polysulfone hollow fiber filter. The hollow fibers are packed into a plastic housing and the open ends are oriented at the effluent side of the housing. Water flows into the filter housing, from the outside of the hollow fibers to the inside, then out the open ends into the drink spout. The top of the hollow fiber filter cartridge is sealed with a hard epoxy with the open end of the hollow fibers flush with the epoxy surface; this forces water to flow into the hollow fibers. Cleaning and storage directions are also provided. Cleaning the filter prior to long term storage or after extended use consists of adding 4 drops of chlorine bleach to 1 quart of clean water, flushing it through the filter, waiting 20 minutes, then draining. Storage directions require the user to dry the filter after cleaning. Directions indicate this device does not reduce viruses. Additional treatment such as the use of a disinfectant is necessary. Directions also indicate the filter should not be used in the reverse flow direction, and cross contamination may occur. The manufacturer states not to allow the device to freeze as this may damage the filter.

Effectiveness Against Microbial Pathogens

No testing data, independent or otherwise, using the U.S. Environmental Protection Agency (USEPA) Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1) was received for this device. Independent testing data was obtained from the manufacturer website showing bacteria, *Giardia*, and *Cryptosporidium* reduction (reference 2). Results showed > 6-log reduction in bacteria and > 5-log reduction in cysts using 100 mL of pathogen spiked "stream" water. The data received and general knowledge of membrane filtration (references 2 and 3) indicate that this device should be capable of consistently meeting the minimum 6-log bacteria reduction and 3-log reduction for *Giardia* cysts and *Cryptosporidium* oocysts stated in the USEPA Protocol. It is not expected to consistently reduce viruses (4-log reduction). Based on general knowledge of size exclusion by membrane filtration, the Sawyer

In-line filter is assigned one √ for bacteria reduction, one √ each for the reduction of *Giardia* cysts and *Cryptosporidium* oocysts. The device receives an X for virus reduction (for an explanation of the rating checks click here).

Table. Expected Performance Against Microbial Pathogens.

Microbial Pathogen Type	Expected Disinfection Capability	Evaluation Rating	Primary Pathogen Reduction Mechanism
Bacteria	>6 log	√	size exclusion
Viruses	>4 log	X	-
Giardia cysts	>3 log	√	size exclusion
Cryptosporidium oocysts	>3 log	√	size exclusion

Production Rate and Capacity

Inherent to the production rate and capacity of filtration devices is the quality of the raw water source. Because it is an in-line filter, the actual production rate is dependent on the user. The manufacturer states a flow rate of 1.8 L/min using a hydration pack and 0.63 L/min using gravity flow. The production capacity of the device is stated to be up to 950 L. However, production capacity will vary widely with raw water quality (e.g., turbidity).

Cleaning, Replacement, and End of Life Indicator

This device cannot be backwashed to remove sediment from the filter. When the device becomes unusable due to decreased production rate, the clogged filter must be replaced. For practical purposes, the filter cartridge is not cleanable. The device contains no end of life indicator short of filter clogging.

Weight and Size

Dry weight (filter cartridge only, no tubing)	100 g. (estimated)
Size (height x diameter)	13 cm x 5 cm

Cost

In-line filter	$35.00

Device Evaluation

No data was received that challenged the Sawyer In-line filter against the USEPA Protocol (reference 1). The limited data obtained from the manufacturer website, as well as general knowledge of size exclusion by membrane filtration, indicate that the device should be capable of consistently reducing bacteria, *Giardia* cysts and *Cryptosporidium* oocysts to the required minimum log reductions stated in reference 1. The testing data received was for challenging the device against 100 mL of pathogen spiked water. This data gives no indication of the long term efficacy of this filter against pathogens or turbid water. This device is not expected to consistently reduce viruses (4-log). Additional treatment is necessary to remove viruses such as adding a disinfectant (e.g., chlorine, iodine, chlorine dioxide) to the water after filtration. This device contains no prefilter and therefore, is highly susceptible to clogging when used with turbid water. Since the device is not able to be backwashed to remove accumulated particles, once clogged, the filter must be replaced. There is no indicator of process failure or end of device useful life.

Advantages

- Expected to consistently provide adequate protection from bacteria, *Giardia* cysts and *Cryptosporidium* oocysts, although device-specific testing data using the USEPA Protocol is not available.
- No wait time prior to consumption.
- Simple and effective.

Disadvantages

- No data testing this device against the USEPA Protocol (reference 1).
- Not expected to be consistently effective against viruses.
- No prefilter. Reduced production capacity when using high turbidity water.
- Not backwashable.
- No real-time indicator of process failure.

References

1. USEPA, 1989. Guide Standard and Protocol for Testing Microbiological Water Purifiers. *Federal Register*. 54:34067.

2. Laboratory challenge data obtained from the manufacturer website.

3. U.S. Army Center for Health Promotion and Preventive Medicine, 2005. *Technical Information Paper; Filtration in the Use of Individual Water Purification Devices,* Aberdeen Proving Ground, MD.

ANNEX 46 TO APPENDIX E

DEVICE EVALUATION #46
SAWYER PRODUCTS – WATER BOTTLE FILTER

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Sawyer Products – Water Bottle Filter

www.sawyerproducts.com

Device Information

The Sawyer water bottle filter is a handheld sports type squeeze bottle. The bottle has a capacity of 0.65 L (22 oz.). The bottle contains an activated carbon pre-filter and a 0.2 µm hollow-fiber primary filter. The pre-filter sits near the bottom of the bottle and is connected to the primary filter's plastic housing. The pre-filter is removable. The primary filter is connected to the drink spout by flexible tubing. The activated carbon pre-filter is an 8 cm (L) x 3 cm (Dia) hollow-core cylinder with a 0.6 cm thick wall. The pre-filter is enclosed in plastic housing. There are openings in the plastic housing in the bottom 1.5 cm and water flows from outside through the filter wall into the hollow inside and out to the primary filter. The primary filter is a 0.2 µm polysulfone hollow fiber filter. The hollow-fibers are packed into a plastic housing and the open ends are oriented at the top of the housing. Water from the pre-filter flows into the primary filter housing, and then from the outside of the hollow fibers to the inside, out the open ends into the drink spout. The top of the primary filter cartridge is sealed with a hard plastic with openings for the hollow fiber ends. This forces water to flow through the hollow fibers. Directions for use require the user to simply fill with water to the recommended fill line. The Sawyer water bottle filter comes with three pre-filters and extra tubing.

Effectiveness Against Microbial Pathogens

No testing data, independent or otherwise, using the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1) was received for this device. Independent testing data was obtained from the manufacturer website showing bacteria, *Giardia*, and *Cryptosporidium* reduction (reference 2). Results showed >6-log reduction in bacteria and >5-log reduction in cysts using 100 mL of pathogen spiked "stream" water. The data received and general knowledge of membrane filtration (references 2, 3) indicate that this device should be capable of consistently meeting the minimum 6-log bacteria reduction and 3-log reduction for *Giardia* cysts and *Cryptosporidium* oocysts stated in the USEPA Protocol. It is not expected to consistently reduce viruses (4-log reduction). Based on general knowledge of size exclusion by membrane filtration, the Sawyer Water Bottle is assigned one √ for bacteria reduction, one √ each for the reduction of *Giardia* cysts and *Cryptosporidium* oocysts. The device receives an X for virus reduction (for an explanation of the rating checks click here).

Table. Expected Performance Against Microbial Pathogens.

Microbial Pathogen Type	Expected Disinfection Capability	Evaluation Rating	Primary Pathogen Reduction Mechanism
Bacteria	> 6-log	√	size exclusion
Viruses	> 4-log	X	-
Giardia cysts	> 3-log	√	size exclusion
Cryptosporidium oocysts	> 3-log	√	size exclusion

Production Rate and Capacity

Inherent to the production rate and capacity of filtration devices is the quality of the raw water source. Because it is a squeeze bottle, the actual production rate is dependent on the user. The production capacity of the device is stated to be approximately 300 L. However, production capacity will vary widely with raw water quality (e.g., turbidity).

Cleaning, Replacement, and End of Life Indicator

This device cannot be backwashed to remove sediment from the filters (pre-filter and primary). When the pre-filter becomes clogged they can be replaced (up to two times). However, replacement primary filters are not sold separately and therefore, the entire device must be replaced. For practical purposes, the filter cartridges are not cleanable. The device contains no end of life indicator short of filter clogging.

Weight and Size

Dry weight (including extra pre-filters and tubing)	160 grams
Size (height x diameter)	27 cm x 7 cm

Cost

Bottle with extra pre-filters and tubing	$36.00

Device Evaluation

No data was received that challenged the Sawyer Water Bottle against the USEPA Protocol (reference 1). The limited data obtained from the manufacturer website, as well as general knowledge of size exclusion by membrane filtration, indicate that the device should be capable of consistently reducing bacteria, *Giardia* cysts and *Cryptosporidium* oocysts to the required minimum log reductions stated in reference 1. The testing data received was for challenging the device against 100 mL of pathogen spiked water. This data gives no indication of the long term efficacy of this filter against pathogens or turbid water. This device is not expected to consistently reduce viruses (4-log). Additional treatment is necessary to remove viruses such as adding a disinfectant (e.g., chlorine, iodine, chlorine dioxide) to the water after filtration. The activated carbon prefilter should reduce source water taste and odor. This device, like all filters with small pore sizes, is highly affected by turbid (cloudy) waters. Since the device is not able to be backwashed to remove accumulated particles, once clogged, the filter must be replaced. There is no indicator of process failure or end of device useful life.

Advantages

- Expected to consistently provide adequate protection from bacteria, *Giardia* cysts, and *Cryptosporidium* oocysts, although device-specific testing data using the USEPA protocol is not available.
- No wait time prior to consumption.
- Simple and effective.
- Provides taste and odor reduction.

Disadvantages

- No data testing this device against the USEPA Protocol (reference 1).
- Not expected to be consistently effective against viruses.
- Reduced production capacity when using high turbidity water.
- Not backwashable.
- No real-time indicator of process failure.

References

1. USEPA, 1989. Guide Standard and Protocol for Testing Microbiological Water Purifiers. *Federal Register*. 54:34067.

2. Laboratory challenge data obtained from the manufacturer website.

3. U.S. Army Center for Health Promotion and Preventive Medicine, 2005. *Technical Information Paper; Filtration in the Use of Individual Water Purification Devices,* Aberdeen Proving Ground, MD.

ANNEX 47 TO APPENDIX E

DEVICE EVALUATION #47
SEYCHELLE – FLIP-TOP™ STRAW FILTER BOTTLE

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Seychelle – Flip-Top™ Straw Filter Bottle

www.seychelle.com

Device Information

The Flip-Top Straw Filter Bottle is a handheld sports type squeeze bottle. The bottle has a capacity of 0.65 L (22 oz.). The bottle contains a filter cartridge consisting of an activated carbon block depth filter that is connected to the drink spout by flexible tubing and sits near the bottom of the sports bottle. The activated carbon filter is a 6 cm long hollow-core filter with a 0.6 cm thick wall. There is a final coarse filter inside the hollow core where water exits the filter cartridge to the flexible tubing. Seychelle also offers a silver-impregnated carbon block filter for use with this device. Water flows from outside through the activated carbon block filter wall into the hollow inside, through the coarse filter and into the flexible tubing connected to the drink spout. The carbon block filter has a 2 µm pore size rating. Information provided by Seychelle claims this device removes or reduces 99.9% (3-log) *Cryptosporidium* oocysts and 99.99% (4-log) *Giardia* cysts, as well as various inorganic and organic chemical contaminants. Directions for use require the user to fill the bottle with water and squeeze to produce water. Prior to the first use the filter must be flushed with two full bottles of water to remove filter particle fines. When storing the device, Seychelle recommends the filter be flushed with a chlorine solution (2 drops chlorine to one bottle water) and allowed to dry.

Effectiveness Against Microbial Pathogens

No data was received showing the effectiveness of this product with respect to the U.S. Environmental Protection Agency (USEPA) Guide Standard Protocol for Testing Microbiological Water Purifiers (reference 1). The theory and practice of depth filtration has been widely studied and there has been significant research conducted on activated carbon block filtration (reference 2). In the absence of data specific to this device tested using reference 1, and based on general knowledge of depth and carbon block filtration, this device should be capable of consistently reducing *Giardia* cysts and *Cryptosporidium* oocysts to the required minimum log reductions stated in reference 1 (i.e., 3-log) when used as directed. It is not expected to

™ Flip-Top Straw Filter Bottle is a registered trademark of Seychelle Environmental Technologies, Inc. Use of trademarked products does not imply endorsement by the U.S. Army, but is intended only in identification of a specific product.

consistently reduce bacteria (6-log) and viruses (4-log). The silver impregnated into the filter is not designed to reduce microbial pathogens in water being treated. Rather, its purpose is to inhibit bacterial growth on the filter throughout the filter's useful life. Based on general depth and carbon block filtration information, the Flip-Top Straw Filter Bottle is assigned one √ for the reduction of *Giardia* cysts and *Cryptosporidium* oocysts and an X for bacteria and virus reduction (for an explanation of the rating checks click here).

Table. Expected Performance Against Microbial Pathogens.

Microbial Pathogen Type	Expected Disinfection Capability	Evaluation Rating	Primary Pathogen Reduction Mechanism
Bacteria	> 6-log	X	-
Viruses	> 4-log	X	-
Giardia cysts	> 3-log	√	size exclusion
Cryptosporidium oocysts	> 3-log	√	size exclusion

Production Rate and Capacity

Inherent to the production rate and capacity of filtration devices is the quality of the raw water source. Because it is a squeeze bottle, the actual production rate is dependent on the user. The production capacity is stated at up to 380 L. However, production capacity will vary widely with raw water quality (i.e., turbidity).

Cleaning, Replacement, and End of Life Indicator

This device cannot be backwashed to remove sediment from the filter. When the device becomes unusable due to decreased production rate, the clogged filter must be replaced. The bottle can be hand washed. For practical purposes, the filter cartridges are not cleanable. The device contains no end of life indicator short of filter clogging.

Weight and Size

Dry weight	200 grams
Size (height x diameter)	25 cm x 7 cm

Cost

Flip-Top Bottle with standard filter (no silver)	$30.00
Flip-Top Bottle with silver-impregnated filter	$32.00
Replacement filter (no silver)	$15.00
Replacement silver-impregnated filter	$17.00

Device Evaluation

No data was received that challenged the Flip-Top Straw Filter Bottle against reference 1. General research on depth and carbon block filtration indicates that this device should be capable of consistently reducing *Giardia* cysts and *Cryptosporidium* oocysts. This device is not likely capable of consistently reducing bacteria and viruses. Additional treatment is necessary to remove bacteria and viruses such as adding a disinfectant (e.g., chlorine, iodine, chlorine dioxide) to the bottle prior to filtering. There is a possibility that silver can leach from the silver-impregnated cartridge filter and be consumed. Although no data was received evaluating the potential for silver leaching, it is not likely that using this device for short periods would cause any adverse health effects due to silver ingestion (reference 2). The activated carbon should remove tastes and odors. This device, like all filters with small pore sizes, is highly affected by turbid (cloudy) waters. Since the device is not able to be backwashed to remove accumulated particulates, once clogged, the filter must be replaced. There is no indicator of process failure or end of device useful life.

Advantages

- Expected to consistently provide adequate protection from *Giardia* cysts and *Cryptosporidium* oocysts, although device-specific testing data using the USEPA protocol is not available.
- No wait time prior to consumption.
- Simple and effective.
- Provides taste and odor reduction.

Disadvantages

- Not expected to be consistently effective against bacteria and viruses.
- Reduced production capacity when using high turbidity water.
- Not backwashable.
- No real-time indicator of process failure.

References

1. USEPA, 1989. Guide Standard and Protocol for Testing Microbiological Water Purifiers. *Federal Register*. 54:34067.

2. U.S. Army Center for Health Promotion and Preventive Medicine, 2005. *Technical Information Paper; Filtration in the Use of Individual Water Purification Devices,* Aberdeen Proving Ground, MD.

ANNEX 48 TO APPENDIX E

DEVICE EVALUATION #48
SEYCHELLE – FLIP-TOP™ STRAW FILTER BOTTLE WITH SILVERATOR

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Seychelle – Flip-Top™ Straw Filter Bottle w/Silverator

www.seychelle.com

Device Information

The Flip-Top Straw Filter Bottle is a handheld sports type squeeze bottle. The bottle has a capacity of 0.65 L (22 oz.). The bottle contains a filter cartridge consisting of an activated carbon block depth filter that is connected to the drink spout by flexible tubing and sits near the bottom of the sports bottle. The activated carbon filter is a 6 cm long hollow-core filter with a 0.6 cm thick wall. There is a final coarse filter inside the hollow core where water exits the filter cartridge to the flexible tubing. Seychelle also offers a silver-impregnated carbon block filter for use with this device. Water flows from outside through the activated carbon block filter wall into the hollow inside, through the coarse filter and into the flexible tubing connected to the drink spout. The carbon block filter has a 2 µm pore size rating. Information provided by Seychelle claims this device removes or reduces 99.9% (3-log) *Cryptosporidium* oocysts and 99.99% (4-log) *Giardia* cysts, as well as various inorganic and organic chemical contaminants. Directions for use require the user to fill the bottle with water and squeeze to produce water. Prior to the first use the filter must be flushed with two full bottles of water to remove filter particle fines. When storing the device, Seychelle recommends the filter be flushed with a chlorine solution (2 drops chlorine to one bottle water) and allowed to dry.

Effectiveness Against Microbial Pathogens

No data was received showing the effectiveness of this product with respect to the U.S. Environmental Protection Agency (USEPA) Guide Standard Protocol for Testing Microbiological Water Purifiers (reference 1). The theory and practice of depth filtration has been widely studied and there has been significant research conducted on activated carbon block filtration (reference 2). In the absence of data specific to this device tested using reference 1, and based on general knowledge of depth and carbon block filtration, this device should be capable of consistently reducing *Giardia* cysts and *Cryptosporidium* oocysts to the required minimum log reductions stated in reference 1 (i.e., 3-log) when used as directed. It is not expected to

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consistently reduce bacteria (6-log) and viruses (4-log). The silver impregnated into the filter is not designed to reduce microbial pathogens in water being treated. Rather, its purpose is to inhibit bacterial growth on the filter throughout the filter's useful life. Based on general depth and carbon block filtration information, the Flip-Top Straw Filter Bottle is assigned one √ for the reduction of *Giardia* cysts and *Cryptosporidium* oocysts and an X for bacteria and virus reduction (for an explanation of the rating checks click here).

Table. Expected Performance Against Microbial Pathogens.

Microbial Pathogen Type	Expected Disinfection Capability	Evaluation Rating	Primary Pathogen Reduction Mechanism
Bacteria	> 6-log	X	-
Viruses	> 4-log	X	-
Giardia cysts	> 3-log	√	size exclusion
Cryptosporidium oocysts	> 3-log	√	size exclusion

Production Rate and Capacity

Inherent to the production rate and capacity of filtration devices is the quality of the raw water source. Because it is a squeeze bottle, the actual production rate is dependent on the user. The production capacity is stated at up to 380 L. However, production capacity will vary widely with raw water quality (i.e., turbidity).

Cleaning, Replacement, and End of Life Indicator

This device cannot be backwashed to remove sediment from the filter. When the device becomes unusable due to decreased production rate, the clogged filter must be replaced. The bottle can be hand washed. For practical purposes, the filter cartridges are not cleanable. The device contains no end of life indicator short of filter clogging.

Weight and Size

Dry weight	200 grams
Size (height x diameter)	25 cm x 7 cm

Cost

Flip-Top Bottle with standard filter (no silver)	$30.00
Flip-Top Bottle with silver-impregnated filter	$32.00
Replacement filter (no silver)	$15.00
Replacement silver-impregnated filter	$17.00

Device Evaluation

No data was received that challenged the Flip-Top Straw Filter Bottle against reference 1. General research on depth and carbon block filtration indicates that this device should be capable of consistently reducing *Giardia* cysts and *Cryptosporidium* oocysts. This device is not likely capable of consistently reducing bacteria and viruses. Additional treatment is necessary to remove bacteria and viruses such as adding a disinfectant (e.g., chlorine, iodine, chlorine dioxide) to the bottle prior to filtering. There is a possibility that silver can leach from the silver-impregnated cartridge filter and be consumed. Although no data was received evaluating the potential for silver leaching, it is not likely that using this device for short periods would cause any adverse health effects due to silver ingestion (reference 2). The activated carbon should remove tastes and odors. This device, like all filters with small pore sizes, is highly affected by turbid (cloudy) waters. Since the device is not able to be backwashed to remove accumulated particulates, once clogged, the filter must be replaced. There is no indicator of process failure or end of device useful life.

Advantages

- Expected to consistently provide adequate protection from *Giardia* cysts and *Cryptosporidium* oocysts, although device-specific testing data using the USEPA protocol is not available.
- No wait time prior to consumption.
- Simple and effective.
- Provides taste and odor reduction.

Disadvantages

- Not expected to be consistently effective against bacteria and viruses.
- Reduced production capacity when using high turbidity water.
- Not backwashable.
- No real-time indicator of process failure.

References

1. USEPA, 1989. Guide Standard and Protocol for Testing Microbiological Water Purifiers. *Federal Register*. 54:34067.

2. U.S. Army Center for Health Promotion and Preventive Medicine, 2005. *Technical Information Paper; Filtration in the Use of Individual Water Purification Devices,* Aberdeen Proving Ground, MD.

ANNEX 49 TO APPENDIX E

DEVICE EVALUATION #49
SEYCHELLE – PRES 2 PURE™ FIELD CANTEEN

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Seychelle – Pres 2 Pure™ Field Canteen

www.seychelle.com

Device Information

The Pres 2 Pure field canteen is a handheld squeeze bottle in the shape of a canteen. The canteen has a capacity of 0.89 L (30 oz). The canteen contains a filter cartridge consisting of an activated carbon block depth filter that is connected directly to the drink spout. The activated carbon filter is a 6 cm long hollow-core cylinder with a 1.0 cm thick wall. Seychelle also offers a silver-impregnated carbon block filter for use with this device. Water flows from outside through the filter wall into the hollow inside and out the drink spout. The carbon block filter has a 2 µm absolute pore size rating. Information provided by Seychelle claims this device removes or reduces 99.9% (3-log) *Cryptosporidium* oocysts and 99.99% (4-log) *Giardia* cysts, as well as various inorganic and organic chemical contaminants. The canteen was not designed to remove viruses. Seychelle recommends using a disinfectant such as chlorine or iodine for virus removal. Directions for use require the user to fill the bottle with water and squeeze to produce water. Prior to the first use the filter must be flushed to remove filter particle fines. When storing the device, Seychelle recommends the filter be flushed with a chlorine solution (½ tsp per gallon of water) and allowed to dry. The filter cartridge can be periodically cleaned by brushing it lightly with a clean toothbrush.

Effectiveness Against Microbial Pathogens

No data was received showing the effectiveness of this product with respect to the U.S. Environmental Protection Agency (USEPA) Guide Standard Protocol for Testing Microbiological Water Purifiers (reference 1). The theory and practice of depth filtration has been widely studied and there has been significant research conducted on activated carbon block filtration (reference 2). In the absence of data specific to this device tested using reference 1, and based on general knowledge of depth and carbon block filtration, this device should be capable of consistently reducing *Giardia* cysts and *Cryptosporidium* oocysts to the required minimum log reductions stated in reference 1 (i.e., 3-log) when used as directed. It is not expected to consistently reduce bacteria (6-log) and viruses (4-log). The silver impregnated into the filter is

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not designed to reduce microbial pathogens in water being treated. Rather, its purpose is to inhibit bacterial growth on the filter throughout the filter's useful life. Based on general depth and carbon block filtration information, the Pres 2 Pure™ canteen is assigned one √ for the reduction of *Giardia* cysts and *Cryptosporidium* oocysts and an X for bacteria and virus reduction (for an explanation of the rating checks click here).

Table. Expected Performance Against Microbial Pathogens.

Microbial Pathogen Type	Expected Disinfection Capability	Evaluation Rating	Primary Pathogen Reduction Mechanism
Bacteria	> 6-log	X	-
Viruses	> 4-log	X	-
Giardia cysts	> 3-log	√	size exclusion
Cryptosporidium oocysts	> 3-log	√	size exclusion

Production Rate and Capacity

Inherent to the production rate and capacity of filtration devices is the quality of the raw water source. Because it is a squeeze bottle, the actual production rate is dependent on the user. The production capacity is stated at up to 760 L. However, production capacity will vary widely with raw water quality (i.e., turbidity).

Cleaning, Replacement, and End of Life Indicator

This device cannot be backwashed to remove sediment from the filter. Seychelle recommends periodic cleaning of the carbon block filter with a toothbrush. This will clean the surface of the filter and can prolong its use. When the device becomes unusable due to decreased production rate, the clogged filter must be replaced. The bottle can be hand washed. The device contains no end of life indicator short of filter clogging.

Weight and Size

Dry weight	140 grams
Size (height x width x depth)	21 cm x 11 cm x 6 cm

Cost

Pres 2 Pure canteen with standard filter (no silver)	$25.00
Pres 2 Pure canteen with silver-impregnated filter	$27.00
Replacement filter (no silver)	$15.00
Replacement silver-impregnated filter	$17.00

Device Evaluation

No data was received that challenged the Pres 2 Pure field canteen against reference 1. General research on depth and carbon block filtration indicates that this device should be capable of consistently reducing *Giardia* cysts and *Cryptosporidium* oocysts. This device is not likely capable of consistently reducing bacteria and viruses. Additional treatment is necessary to remove bacteria and viruses such as adding a disinfectant (e.g., chlorine, iodine, chlorine dioxide) to the canteen prior to filtering. There is a possibility that silver can leach from the silver-impregnated cartridge filter and be consumed. Although no data was received evaluating the potential for silver leaching, it is not likely that using this device for short periods would cause any adverse health effects due to silver ingestion (reference 2). The activated carbon should remove tastes and odors. This device, like all filters with small pore sizes, is highly affected by turbid (cloudy) waters. Since the device is not able to be backwashed to remove accumulated particulates, once clogged, the filter must be replaced. There is no indicator of process failure or end of device useful life.

Advantages

- Expected to consistently provide adequate protection from *Giardia* cysts and *Cryptosporidium* oocysts, although device-specific testing data using the USEPA protocol is not available.
- No wait time prior to consumption.
- Simple and effective.
- Provide taste and odor reduction.

Disadvantages

- Not expected to be consistently effective against bacteria and viruses.
- Reduced production capacity when using high turbidity water.
- Not backwashable.
- No real-time indicator of process failure.

References

1. USEPA, 1989. Guide Standard and Protocol for Testing Microbiological Water Purifiers. *Federal Register*. 54:34067.

2. U.S. Army Center for Health Promotion and Preventive Medicine. (2005). *Technical Information Paper; Filtration in the Use of Individual Water Purification Devices,* Aberdeen Proving Ground, MD.

ANNEX 50 TO APPENDIX E

DEVICE EVALUATION #50
SEYCHELLE – PRES 2 PURE™ FIELD CANTEEN WITH SILVERATOR

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Seychelle – Pres 2 Pure™ Field Canteen w/Silverator

www.seychelle.com

Device Information

The Pres 2 Pure field canteen is a handheld squeeze bottle in the shape of a canteen. The canteen has a capacity of 0.89 L (30 oz). The canteen contains a filter cartridge consisting of an activated carbon block depth filter that is connected directly to the drink spout. The activated carbon filter is a 6 cm long hollow-core cylinder with a 1.0 cm thick wall. Seychelle also offers a silver-impregnated carbon block filter for use with this device. Water flows from outside through the filter wall into the hollow inside and out the drink spout. The carbon block filter has a 2 µm absolute pore size rating. Information provided by Seychelle claims this device removes or reduces 99.9% (3-log) *Cryptosporidium* oocysts and 99.99% (4-log) *Giardia* cysts, as well as various inorganic and organic chemical contaminants. The canteen was not designed to remove viruses. Seychelle recommends using a disinfectant such as chlorine or iodine for virus removal. Directions for use require the user to fill the bottle with water and squeeze to produce water. Prior to the first use the filter must be flushed to remove filter particle fines. When storing the device, Seychelle recommends the filter be flushed with a chlorine solution (½ tsp per gallon of water) and allowed to dry. The filter cartridge can be periodically cleaned by brushing it lightly with a clean toothbrush.

Effectiveness Against Microbial Pathogens

No data was received showing the effectiveness of this product with respect to the U.S. Environmental Protection Agency (USEPA) Guide Standard Protocol for Testing Microbiological Water Purifiers (reference 1). The theory and practice of depth filtration has been widely studied and there has been significant research conducted on activated carbon block filtration (reference 2). In the absence of data specific to this device tested using reference 1, and based on general knowledge of depth and carbon block filtration, this device should be capable of consistently reducing *Giardia* cysts and *Cryptosporidium* oocysts to the required minimum log reductions stated in reference 1 (i.e., 3-log) when used as directed. It is not expected to consistently reduce bacteria (6-log) and viruses (4-log). The silver impregnated into the filter is

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not designed to reduce microbial pathogens in water being treated. Rather, its purpose is to inhibit bacterial growth on the filter throughout the filter's useful life. Based on general depth and carbon block filtration information, the Pres 2 Pure canteen is assigned one √ for the reduction of *Giardia* cysts and *Cryptosporidium* oocysts and an X for bacteria and virus reduction (for an explanation of the rating checks click here).

Table. Expected Performance Against Microbial Pathogens.

Microbial Pathogen Type	Expected Disinfection Capability	Evaluation Rating	Primary Pathogen Reduction Mechanism
Bacteria	> 6-log	X	-
Viruses	> 4-log	X	-
Giardia cysts	> 3-log	√	size exclusion
Cryptosporidium oocysts	> 3-log	√	size exclusion

Production Rate and Capacity

Inherent to the production rate and capacity of filtration devices is the quality of the raw water source. Because it is a squeeze bottle, the actual production rate is dependent on the user. The production capacity is stated at up to 760 L. However, production capacity will vary widely with raw water quality (i.e., turbidity).

Cleaning, Replacement, and End of Life Indicator

This device cannot be backwashed to remove sediment from the filter. Seychelle recommends periodic cleaning of the carbon block filter with a toothbrush. This will clean the surface of the filter and can prolong its use. When the device becomes unusable due to decreased production rate, the clogged filter must be replaced. The bottle can be hand washed. The device contains no end of life indicator short of filter clogging.

Weight and Size

Dry weight	140 grams
Size (height x width x depth)	21 cm x 11 cm x 6 cm

Cost

Pres 2 Pure™ canteen with standard filter (no silver)	$25.00
Pres 2 Pure™ canteen with silver-impregnated filter	$27.00
Replacement filter (no silver)	$15.00
Replacement silver-impregnated filter	$17.00

Device Evaluation

No data was received that challenged the Pres 2 Pure field canteen against reference 1. General research on depth and carbon block filtration indicates that this device should be capable of consistently reducing *Giardia* cysts and *Cryptosporidium* oocysts. This device is not likely capable of consistently reducing bacteria and viruses. Additional treatment is necessary to remove bacteria and viruses such as adding a disinfectant (e.g., chlorine, iodine, chlorine dioxide) to the canteen prior to filtering. There is a possibility that silver can leach from the silver-impregnated cartridge filter and be consumed. Although no data was received evaluating the potential for silver leaching, it is not likely that using this device for short periods would cause any adverse health effects due to silver ingestion (reference 2). The activated carbon should remove tastes and odors. This device, like all filters with small pore sizes, is highly affected by turbid (cloudy) waters. Since the device is not able to be backwashed to remove accumulated particulates, once clogged, the filter must be replaced. There is no indicator of process failure or end of device useful life.

Advantages

- Expected to consistently provide adequate protection from *Giardia* cysts and *Cryptosporidium* oocysts, although device-specific testing data using the USEPA protocol is not available.
- No wait time prior to consumption.
- Simple and effective.
- Provide taste and odor reduction.

Disadvantages

- Not expected to be consistently effective against bacteria and viruses.
- Reduced production capacity when using high turbidity water.
- Not backwashable.
- No real-time indicator of process failure.

References

1. USEPA, 1989. Guide Standard and Protocol for Testing Microbiological Water Purifiers. *Federal Register*. 54:34067.

2. U.S. Army Center for Health Promotion and Preventive Medicine. (2005). *Technical Information Paper; Filtration in the Use of Individual Water Purification Devices*, Aberdeen Proving Ground, MD.

ANNEX 51 TO APPENDIX E

DEVICE EVALUATION #51
SEYCHELLE – BOTTOMS-UP WATER BOTTLE

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Seychelle – Bottoms-Up Water Bottle

www.seychelle.com

Device Information

The Bottoms-Up water bottle is a handheld sports type squeeze bottle. The bottle has a capacity of 0.89 L (30 oz). The bottle contains a filter cartridge consisting of an activated carbon block depth filter that is connected directly to the drink spout. The activated carbon filter is a 6 cm long hollow-core cylinder with a 0.6 cm thick wall. The bottle is filled from the bottom. The drink spout and filter cartridge are not removable from the bottle. During use water flows from outside through the filter wall into the hollow inside and out the drink spout. The carbon block filter has a 2 µm absolute pore size rating. Information provided by Seychelle claims this device removes or reduces 99.9% (3-log) *Cryptosporidium* oocysts and 99.99% (4-log) *Giardia* cysts, as well as various inorganic and organic chemical contaminants including tastes and odors. The bottle is not designed for virus removal and Seychelle recommends adding a disinfectant such as iodine or chlorine to remove viruses. Directions for use require the user to fill the bottle with water and squeeze to produce water. Prior to the first use the filter must be flushed with two bottles of water to remove filter particle fines. When storing the device, Seychelle recommends the filter be flushed with a chlorine solution (¼ tsp. per half-gallon of water) and allowed to dry. Replacement filters are not available.

Effectiveness Against Microbial Pathogens

No data was received showing the effectiveness of this product with respect to the U.S. Environmental Protection Agency (USEPA) Guide Standard Protocol for Testing Microbiological Water Purifiers (reference 1). The theory and practice of depth filtration has been widely studied and there has been significant research conducted on activated carbon block filtration (reference 2). In the absence of data specific to this device tested using reference 1, and based on general knowledge of depth and carbon block filtration, this device should be capable of consistently reducing *Giardia* cysts and *Cryptosporidium* oocysts to the required minimum log reductions stated in reference 1 (i.e., 3-log) when used as directed. It is not expected to consistently reduce bacteria (6-log) and viruses (4-log). Based on general depth and carbon block filtration information, the Bottoms-Up bottle is assigned one √ for the reduction of *Giardia* cysts and *Cryptosporidium* oocysts and an X for bacteria and virus reduction (for an explanation of the rating checks click here).

Table. Expected Performance Against Microbial Pathogens.

Microbial Pathogen Type	Expected Disinfection Capability	Evaluation Rating	Primary Pathogen Reduction Mechanism
Bacteria	> 6-log	X	-
Viruses	> 4-log	X	-
Giardia cysts	> 3-log	√	size exclusion
Cryptosporidium oocysts	> 3-log	√	size exclusion

Production Rate and Capacity

Inherent to the production rate and capacity of filtration devices is the quality of the raw water source. Because it is a squeeze bottle, the actual production rate is dependent on the user. The production capacity is stated at up to 760 L. However, production capacity will vary widely with raw water quality (i.e., turbidity).

Cleaning, Replacement, and End of Life Indicator

This device cannot be backwashed to remove sediment from the filter. When the device becomes unusable due to decreased production rate, the clogged filter must be replaced. The device contains no end of life indicator short of filter clogging.

Weight and Size

Dry weight	150 grams
Size (height x diameter)	26 cm x 8 cm

Cost

Bottoms-Up Bottle	$25.00

Device Evaluation

No data was received that challenged the Bottoms-Up bottle against reference 1. General research on depth and carbon block filtration indicates that this device should be capable of consistently reducing *Giardia* cysts and *Cryptosporidium* oocysts. This device is not likely

capable of consistently reducing bacteria and viruses. Additional treatment is necessary to remove bacteria and viruses such as adding a disinfectant (e.g., chlorine, iodine, chlorine dioxide) to the bottle prior to filtering. This device, like all filters with small pore sizes, is highly affected by turbid (cloudy) waters. Since the device is not able to be backwashed to remove accumulated particulates, once clogged, the filter must be replaced. There is no indicator of process failure or end of device useful life.

Advantages

- Expected to consistently provide adequate protection from *Giardia* cysts and *Cryptosporidium* oocysts, although device-specific testing data using the USEPA protocol is not available.
- No wait time prior to consumption.
- Simple and effective.
- Provide taste and odor reduction.

Disadvantages

- Not expected to be consistently effective against bacteria and viruses.
- Reduced production capacity when using high turbidity water.
- Not backwashable.
- No real-time indicator of process failure.

References

1. USEPA, 1989. Guide Standard and Protocol for Testing Microbiological Water Purifiers. *Federal Register*. 54:34067.

2. U.S. Army Center for Health Promotion and Preventive Medicine. (2005). *Technical Information Paper; Filtration in the Use of Individual Water Purification Devices*, Aberdeen Proving Ground, MD.

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ANNEX 52 TO APPENDIX E

DEVICE EVALUATION #52
SEYCHELLE – IN-LINE ELIMINATOR™ WATER FILTRATION SYSTEM

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Seychelle – In-Line Eliminator™ Water Filtration System

www.seychelle.com

Device Information

The In-Line Eliminator water filtration system is an in-line filter device designed for use with commercial hydration packs. The in-line filter contains a filter cartridge similar to Seychelle's Flip-Top's silver-impregnated filter. The filter cartridge is contained in a sturdy plastic housing with separate inlet and outlet for connecting to the drink tube of a hydration pack. The silver-impregnated activated carbon filter is a 6 cm long hollow-core filter with a 0.6 cm thick wall. The carbon block filter is rated a 2 µm pore size. There is a final coarse filter inside the hollow core where water exits the filter cartridge. Information provided on Seychelle's website indicates the device removes or reduces 99.9% (3-log) *Cryptosporidium* oocysts, and 99.99% (4-log) *Giardia* cysts, as well as various removals of certain inorganic and organic chemicals, including tastes and odors. The information also notes that when using water where viruses could be present, it is strongly recommended to add a disinfectant to the hydration pack before filtering. After installing the in-line filter on the drink tube line (fittings are included with the in-line filter) water flows from the hydration pack into the in-line filter housing where it will flow from the outside of the carbon block filter into the inside hollow core and through the final coarse filter before exiting the filter housing. Prior to use the filter cartridge must be flushed to remove particle fines. The flush process recommended is essentially a backflush process. Also, it is recommended that after extended use the filter be backflushed to prolong the useful life. No directions are provided on how to store the filter.

Effectiveness Against Microbial Pathogens

No data was received showing the effectiveness of this product with respect to the U.S. Environmental Protection Agency (USEPA) Guide Standard Protocol for Testing Microbiological Water Purifiers (reference 1). The theory and practice of depth filtration has been widely studied and there has been significant research conducted on activated carbon block filtration (reference 2). In the absence of data specific to this device tested using reference 1, and based on general knowledge of depth and carbon block filtration, this device should be capable

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of consistently reducing *Giardia* cysts and *Cryptosporidium* oocysts to the required minimum log reductions stated in reference 1 (i.e., 3-log) when used as directed. It is not expected to consistently reduce bacteria (6-log) and viruses (4-log). The silver impregnated into the filter is not designed to reduce microbial pathogens in water being treated. Rather, its purpose is to inhibit bacterial growth on the filter throughout the filter's useful life. Based on general depth and carbon block filtration information, the In-Line Eliminator filter is assigned one √ for the reduction of *Giardia* cysts and *Cryptosporidium* oocysts and an X for bacteria and virus reduction (for an explanation of the rating checks click here).

Table. Expected Performance Against Microbial Pathogens When Used as Directed.

Microbial Pathogen Type	Expected Disinfection Capability	Evaluation Rating	Primary Pathogen Reduction Mechanism
Bacteria	> 6-log	X	-
Viruses	> 4-log	X	-
Giardia cysts	> 3-log	√	size exclusion
Cryptosporidium oocysts	> 3-log	√	size exclusion

Production Rate and Capacity

Inherent to the production rate and capacity of filtration devices is the quality of the raw water source. Because it is an in-line filter designed to be used with a hydration pack, the actual production rate is dependent on the user. The production capacity is stated at up to 380 L. However, production capacity will vary widely with raw water quality (i.e., turbidity).

Cleaning, Replacement, and End of Life Indicator

Based on directions and supplies provided, this device can be backwashed to remove sediment from the filter that could prolong the life of the filter. When the device becomes unusable due to decreased production rate after backwashing, the clogged filter must be replaced. For practical purposes, the filter cartridges are not cleanable. The device contains no end of life indicator short of filter clogging.

Weight and Size

Dry weight	110 grams
Size (height x diameter)	13 cm x 5 cm

Cost

In-Line Eliminator with silver-impregnated filter	$23.00

No replacement filter information provided.

Device Evaluation

No data was received that challenged the Flip-Top Straw Filter Bottle against reference 1. General research on depth and carbon block filtration indicates that this device should be capable of consistently reducing *Giardia* cysts and *Cryptosporidium* oocysts. This device is not likely capable of consistently reducing bacteria and viruses. Additional treatment is necessary to remove bacteria and viruses such as adding a disinfectant (e.g., chlorine, iodine, chlorine dioxide) to the hydration pack prior to filtering. There is a possibility that silver can leach from the silver-impregnated cartridge filter and be consumed. Although no data was received evaluating the potential for silver leaching, it is not likely that using this device for short periods would cause any adverse health effects due to silver ingestion (reference 2). This device, like all filters with small pore sizes, is highly affected by turbid (cloudy) waters. The device can be backwashed to remove accumulated particulates, effectively prolonging the useful life of the filter. Once the filter remains clogged after backwashing, it must be replaced. There is no indicator of process failure or end of device useful life.

Advantages

- Expected to consistently provide adequate protection from *Giardia* cysts and *Cryptosporidium* oocysts, although device-specific testing data using the USEPA protocol is not available.
- No wait time prior to consumption.
- Simple and effective.
- Backwashable.
- Provides taste and odor reduction.

Disadvantages

- Not expected to be consistently effective against bacteria and viruses. Additional treatment necessary.
- Reduced production capacity when using high turbidity water.
- No real-time indicator of process failure.

References

1. USEPA, 1989. Guide Standard and Protocol for Testing Microbiological Water Purifiers. *Federal Register*. 54:34067.

2. U.S. Army Center for Health Promotion and Preventive Medicine. (2005). *Technical Information Paper; Filtration in the Use of Individual Water Purification Devices,* Aberdeen Proving Ground, MD.

ANNEX 53 TO APPENDIX E

DEVICE EVALUATION #53
SEYCHELLE ENVIRONMENTAL TECHNOLOGIES, INC. – SURVIVOR™
PORTABLE WATER PURIFICATION BOTTLE

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Seychelle Environmental Technologies, Inc. – Survivor™ Portable Water Purification Bottle

www.seychelle.com

Device Information

The Seychelle Environmental Technologies, Inc., Survivor Portable Water Purification Bottle is a handheld sports type squeeze bottle. The bottle has a capacity of 0.71 L (24 oz.). The bottle contains a filter cartridge consisting of an activated carbon block depth filter that is connected to the drink spout by flexible tubing and sits near the bottom of the sports bottle. The activated carbon filter is a 6 cm long hollow-core filter with a 0.6 cm thick wall. There is a final coarse filter inside the hollow core where water exits the filter cartridge to the flexible tubing. Water flows from outside through the activated carbon block filter wall into the hollow inside, through the coarse filter and into the flexible tubing connected to the drink spout. The carbon block filter has a 2 µm pore size rating. Information provided by Seychelle claims this device removes or reduces 99.9% (3-log) *Cryptosporidium* oocysts and 99.99% (4-log) *Giardia* cysts, as well as various inorganic and organic chemical contaminants. Seychelle offers a silver-impregnated carbon block filter for use with its water bottles. It is unclear whether the carbon block filter with this device is silver impregnated and should be assumed not to be. The silver impregnation is designed to limit microbial growth on the filter and is not expected to increase reduction of contaminants from the bulk water. Directions for use require the user to fill the bottle with water and squeeze to produce water. Prior to the first use the filter must be flushed with two full bottles of water to remove filter particle fines. When storing the device, Seychelle recommends the filter be flushed with a chlorine solution (2 drops chlorine to 1 bottle water) and allowed to dry. The above mentioned treatment and device is identical to the Seychelle Flip-Top Water Bottle. What makes the Seychelle Survivor Purification Bottle different is the additional chlorine tablets [U.S. Environmental Protection Agency (USEPA) Reg. No. 55304-4-71426, Est. No. 76762-PA-1] included to be used if viruses are suspected in the source water. Instructions state to take 1 of 5 included tablets that are scored in quarters, break off 1 quarter and place it in 1 full bottle of water (24 oz). The user should then wait 15 minutes prior to

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consumption. The manufacturer markets this device with a filter capacity of 560 L and enough chorine tablets to treat 94 L. The 5 chlorine tablets included will treat, as directed, 20 bottles full of water equaling 14 L (0.71 L/bottle x 5 tablets x 4 doses per tablet), not the 94 L stated by the manufacturer. Instruction state to not allow bottle to freeze, as that may damage the bottle and/or filter. Additional items included with this device are an emergency thermal blanket, compass, and whistle, all of which fit into, or attached to, the water bottle insulated jacket.

Effectiveness Against Microbial Pathogens

No data was received showing the effectiveness of this product with respect to the USEPA Guide Standard Protocol for Testing Microbiological Water Purifiers (reference 1). The theory and practice of depth filtration has been widely studied and there has been significant research conducted on activated carbon block filtration (reference 2). In the absence of data specific to this device tested using reference 1, and based on general knowledge of depth and carbon block filtration, this device should be capable of consistently reducing *Giardia* cysts and *Cryptosporidium* oocysts to the required minimum log reductions stated in reference 1 (e.g., 3-log) when used as directed. It is not expected to consistently reduce bacteria (6-log). No information is given on the chemical composition or the disinfectant concentration received from each dose when using the included chlorine tablets. Because of this, it is unclear whether the dose is adequate to reduce viruses to the requirements of reference 1. Based on general depth and carbon block filtration information, the Survivor Purification Bottle is assigned one √ each for the reduction of *Giardia* cysts and *Cryptosporidium* oocysts and one X each for bacteria and virus reduction (for an explanation of the rating checks click here).

Table. Expected Performance Against Microbial Pathogens.

Microbial Pathogen Type	Expected Disinfection Capability	Evaluation Rating	Primary Pathogen Reduction Mechanism
Bacteria	> 6-log	X	-
Viruses	> 4-log	X	-
Giardia cysts	> 3-log	√	size exclusion
Cryptosporidium oocysts	> 3-log	√	size exclusion

Production Rate and Capacity

Inherent to the production rate and capacity of filtration devices is the quality of the raw water source. Because it is a squeeze bottle, the actual production rate is dependent on the user. The production capacity is stated by the manufacturer to be up to 560 L for the filter and 94 L for the chlorine tablets. As explained above, based on the instructions, the chlorine tablets will only dose 14 L. Since the chlorine tablets are a critical component of the device, the overall capacity should be considered 14 L. As stated in the device instructions, production capacity will vary widely with raw water quality (e.g., turbidity). There is a 15 minute wait time prior to consumption when using the chlorine tablets.

Cleaning, Replacement, and End of Life Indicator

This device cannot be backwashed to remove sediment from the filter. When the device becomes unusable due to decreased production rate, the clogged filter must be replaced. The bottle can be hand washed. For practical purposes, the filter cartridges are not cleanable. The device contains no end of life indicator short of filter clogging or after using all of the chlorine tablets.

Weight and Size

Dry weight	300 grams
Size (height x diameter)	25 cm x 7 cm

Cost

Survivor Bottle (with chlorine tablets and accessories)	$35.00
Replacement filter	$15.00
Replacement chlorine tablets (5 count)	$ 1.50

Device Evaluation

No data was received that challenged the Survivor Portable Water Purification Bottle against reference 1. General research on depth and carbon block filtration indicates that this device should be capable of consistently reducing *Giardia* cysts and *Cryptosporidium* oocysts. Since no information is given regarding the chlorine tablet composition or concentration of the instructed dose, adequate reduction/inactivation of bacteria and viruses cannot be assumed. Additional treatment or clarification of the manufacturer recommended treatment is necessary to reduce bacteria and viruses, such as adding a disinfectant (e.g., chlorine, iodine, chlorine dioxide) to the

bottle prior to filtering. The chlorine tablet packaging contains an expiration date, after which the tablets should not be used. Care must be taken when unpackaging the chlorine tablets from the blister-pack, so as not to break them into the wrong size. Care also should be taken after handling the tablets to avoid chlorine exposure to the skin and eyes. It is unclear whether the carbon block filter is silver impregnated. If it is, then there is a possibility that silver can leach from the silver-impregnated cartridge filter and be consumed. Although no data was received evaluating the potential for silver leaching, it is not likely that using this device for short periods would cause any adverse health effects due to silver ingestion. The activated carbon should remove tastes and odors from the source water as well as from any disinfectant used prior to filtration. This device, like all filters with small pore sizes, is highly affected by turbid (cloudy) waters. Since the device is not able to be backwashed to remove accumulated particulates, once clogged, the filter must be replaced. There is no indicator of process failure or end of device useful life.

Advantages

- Expected to consistently provide adequate protection from *Giardia* cysts and *Cryptosporidium* oocysts, although device-specific testing data using the USEPA Protocol is not available.
- Simple and effective for cysts.
- Provides taste and odor reduction.

Disadvantages

- Not expected to be consistently effective against bacteria and viruses.
- Reduced production capacity when using high turbidity water.
- Not backwashable.
- No real-time indicator of process failure.

References

1. USEPA, 1989. Guide Standard and Protocol for Testing Microbiological Water Purifiers. *Federal Register*. 54:34067.

2. U.S. Army Center for Health Promotion and Preventive Medicine, 2005. *Technical Information Paper; Filtration in the Use of Individual Water Purification Devices,* Aberdeen Proving Ground, MD.

ANNEX 54 TO APPENDIX E

DEVICE EVALUATION #54
DEATRICK & ASSOCIATES – CHLOR-FLOC® WATER PURIFICATION TABLETS

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Deatrick & Associates – Chlor-Floc® Water Purification Tablets

NSN 6850-01-352-6129

Device Information

Military issue Chlor-Floc water purification tablets are used for treating individual water supplies. Chlor-Floc tablets contain flocculating agents (e.g., aluminum sulfate) to clarify the water and sodium dichloroisocyanurate, a form of chlorine, to provide disinfection. Chlor-Floc is manufactured by the Control Chemical Company in South Africa and distributed in the United States by Deatrick and Associates. This device comes with 30 tablets, 1 plastic bag, and 3 filter pouches. Directions call for the user to fill the plastic bag with 1L of water, add 1 tablet, close and shake bag until tablet dissolves, then swirl the bag for 10 seconds. Let the bag sit for 4 minutes, swirl again for 10 seconds, then let the bag sit an additional 15 minutes. After 15 minutes pour the water through one of the filter pouches and into a separate container (i.e., a canteen) taking care not to pour the sediment into the filter pouch. Rinse the sediment from the plastic bag and save bag for future treatment. Depending on the temperature of the water being treated 1 or 2 tablets are added. Waters warmer than 5° C require only 1 tablet while waters 5° C or colder require 2 tablets. In all cases the wait time is approximately 20 minutes (4-minute and 15-minute wait times), except when treating warmer waters (25° C) when only a total of approximately 12 minutes is required (4-minute and 7-minute wait times). The filter pouches can be reused if cleaned thoroughly with treated water. The user should always be sure to use the same side of the filter pouch for straining. The tablets should be stored in their sealed tablet wrappers away from excessive heat or direct sunlight.

Effectiveness Against Microbial Pathogens

Independent testing using the U.S. Environmental Protection Agency (USEPA) Guide Standard and Protocol for Testing Microbiological Water Purifiers confirms this product met the minimum 6-, 4-, and 3-log reduction requirements for bacteria, viruses and *Giardia* cysts (respectively) when used according to directions (references 1-3). This testing also showed that Chlor-Floc

® Chlor-Floc is a registered trademark of Control Chemical, D/B/A Deatrick and Associates Inc., Alexandria, VA. Use of a trademarked product does not imply endorsement by the U.S. Army, but is intended only in identification of a specific product.

did not adequately provide a minimum 3-log *Cryptosporidium* oocysts reduction. Using Chlor-Floc according to directions results in a disinfectant concentration times contact time (CT) of 96 mg-min/L for 25° C waters and warmer, 160 mg-min/L for 6-24° C waters, and 320 mg-min/L for 5° C and colder waters. Additional treatment such as filtration through a 1 micron absolute filter is necessary for the adequate removal of *Cryptosporidium* oocysts. Providing additional wait time when using Chlor-Floc for chlorine disinfection will not likely provide adequate *Cryptosporidium* reduction in a reasonable amount of time. Although test data showed 0.7 – 2.7-log reduction of *Cryptosporidium*, the reduction was due to the physical removal of the oocysts by the flocculation and sedimentation process. Chlorine disinfection provided negligible *Cryptosporidium* reduction at the prescribed wait time of 20 minutes. Based on independent data testing the device under sever conditions required by the USEPA protocol, Chlor-Floc is given three √s for effectiveness against bacteria, viruses, and *Giardia* cysts, and an X for effectiveness against *Cryptosporidium* oocysts (for an explanation of the rating checks click here). The following table summarizes Chlor-Floc's expected performance, evaluation rating, and the mechanism by which pathogens are inactivated:

Table. Expected Performance Against Microbial Pathogens When Used As Directed.

Microbial Pathogen Type	Expected Performance	Evaluation Rating	Reduction Mechanism
Bacteria	6-log	√√√	Flocculation/sedimentation & disinfection
Viruses	4-log	√√√	Flocculation/sedimentation & disinfection
Giardia cysts	3-log	√√√	Flocculation/sedimentation & disinfection
Cryptosporidium oocysts	Not Effective	X	-

Production Capacity

One package of Chlor-Floc treats 15-30 liters depending on water temperature.

Cleaning, Replacement, End of Life Indicator, Shelf Life

The shelf life of Chlor-Floc is 3 years from the date of manufacture.

Weight and Size

The weight of the entire Chlor-Floc package (plastic bag, tablets, and filter pouches) is approximately 80 grams. The approximate dimensions of the Chlor-Floc package are 18 cm (L) x 8 cm (W) x 2 cm (H).

Cost

The National Stock Number (NSN) for Chlor-Floc is NSN 6850-01-352-6129. The cost is $12.79 per package (30 tablets, 1 plastic bag, and 3 filter pouches).

Device Evaluation

Independent testing using the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers confirms Chlor-Floc met the minimum 6-log, 4-log, and 3-log reduction requirements for bacteria, viruses, and *Giardia* cysts, respectively (references 1-3). The testing also showed that Chlor-Floc did not meet the minimum 3-log *Cryptosporidium* oocysts reduction requirement when used as directed. Additional treatment to reduce *Cryptosporidium* is necessary, such as using a 1-micron absolute pore size filter. Water temperature can't often be measured in the field and requires user subjectivity. In situations where temperature cannot be determined, the user should take a conservative approach and treat water according to the directions for treating 5° C or colder waters. Chlor-Floc, when used as directed, will reduce the cloudiness/turbidity of the water. Test data indicate turbidity reduction increases with increasing water temperature and increasing turbidity of the water being treated due to the physical and chemical properties of the flocculating agents. Compared to disinfectant only devices, Chlor-Floc is more complicated to use. When used as directed, Chlor-Floc will expose the user to chlorine and cyanuric acid (due to the use of sodium dichloroisocyanurate) and may expose the user to disinfection byproducts such as trihalomethanes and haloacetic acids when chlorine reacts with naturally present organic matter. However, when used as directed for short periods of time, exposure to these compounds is not expected to cause adverse health effects in healthy adults (reference 4). Use of this device may impart a chlorine taste or smell to the water.

Advantages

- Expect consistent protection from bacteria, viruses, and *Giardia* cysts when used as directed.
- Small and lightweight.
- Reduces cloudiness/turbidity.
- Fairly simple to use.
- No adverse health effects expected in healthy adults.

Disadvantages

- Not effective against *Cryptosporidium*. Additional treatment is necessary.
- Can impart taste and odor.
- Requires user subjectivity with respect to evaluating water temperature.

References

1. USEPA, Registration Division Office of Pesticide Program, Criteria and Standards Division Office of Drinking Water, 1987. *Guide Standard and Protocol for Testing Microbiological Water Purifiers.* Washington, D.C.

2. U.S. Army Natick Research, Development, and Engineering Center, 1993. *Efficacy of Flocculating and Other Emergency Water Purification Tablets.* (NATICK/TR-93/033). Natick, MA. Prepared by Powers, E.M.

3. U.S. Army Biomedical Research & Development Laboratory, 1992. *Evaluation of the Military Effectiveness of Chlor-Floc Water Purification Tablets for Treatment of Waterborne Micro-Organisms.* (Technical Report 9205). Fort Detrick, MD. Prepared by Schaub, S.A. et al.

4. U.S. Army Center for Health Promotion and Preventive Medicine, 2005. *Technical Information Paper; Chlorine Disinfection in the Use of Individual Water Purification Devices,* Aberdeen Proving Ground, MD.

ANNEX 55 TO APPENDIX E

DEVICE EVALUATION #55
COGHLAN'S, LTD. – COGHLAN'S EMERGENCY DRINKING WATER GERMCIDAL TABLETS™

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Coghlan's, Ltd. – Coghlan's Emergency Drinking Water Germcidal Tablets™

www.coghlans.com

Device Information

Coghlan's emergency drinking water germicidal tablets contain iodine. The manufacturer that produces these tablets, Wisconsin Pharmacal, also produces Globaline™ for the U.S. Military, and Potable Aqua™, which are identical to Coghlan's iodine tablets. Coghlan's, Ltd., sells two products with Coghlan's iodine tablets, one product consists of iodine tablets only; the other product consists of iodine tablets and neutralizing tablets (ascorbic acid) that remove iodine taste, color, and odor. Fifty iodine tablets are packaged in a small bottle with a vinyl lined screw cap. The cap also has an adhesive seal that allows it to be reused to keep moisture from getting into the bottle. Directions for use require the addition of two tablets to 1 liter of water and cap the water container loosely to allow a small amount of leakage. Wait 5 minutes. Shake the container to allow screw threads on the closure to be moistened then tighten cap. Wait 30 more minutes before drinking. If using neutralizing tablets, add two tablets to 1 liter only after the required wait time for the iodine tablets. Two iodine tablets result in a 16 mg/L iodine concentration in 1 liter. Coghlan's iodine tablets are composed of tetraglycine hydroperiodide, sodium acid pyrophosphate and talc. The disinfection capabilities of iodine have long been recognized and it is widely used as an antiseptic and as an emergency drinking water disinfectant. The device should be stored in a cool dry place and the tablets should be kept dry.

Effectiveness Against Microbial Pathogens

Independent testing using the U.S. Environmental Protection Agency (USEPA) Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1) has been conducted with Globaline (references 2 and 3). Because Globaline and Coghlan's iodine tablets are identical products, the results can be applied to Coghlan's iodine tablets. Independent testing using the reference 1 protocol confirms Coghlan's iodine tablets consistently provide a 6-log bacteria and 4-log virus reduction when used as directed. This testing also confirms that Coghlan's iodine

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tablets do not consistently provide 3-log *Giardia* cyst and *Cryptosporidium* oocyst reduction when used as directed. Coghlan's iodine tablets, when used according to directions, provide a 16 mg/L iodine dosage and a 35 minute contact time resulting in a disinfectant concentration times contact time (CT) of 560 mg-min/L. Coghlan's iodine tablets can provide a 3-log *Giarida* cyst inactivation when treating most water quality conditions if contact time is increased beyond the directed 35 minutes. Independent testing data using reference 1 indicated contact times of at least 60 minutes (CT = 960 mg-min/L) achieved a 3-log *Giardia* cyst inactivation (reference 2). Other iodine disinfection studies recommend a CT of at least 720 mg-min/L for a 3-log *Giardia* cyst inactivation (reference 4). To ensure a 3-log *Giardia* cyst inactivation when using Coghlan's iodine tablets, provide at least a 45-60 minute contact time. A 3-log *Cryptosporidium* oocyst inactivation is not realistically achieveable when using Coghlan's iodine tablets. Additional treatment is necessary to remove or inactivate *Cryptosporidium* oocysts. Based on independent data that tested the a product identical to Coghlan's iodine tablets under severe conditions required by the USEPA protocol, Coghlan's iodine tablets are given three √s for effectiveness against bacteria and viruses, and an X for effectiveness against *Giardia* cysts and *Cryptosporidium* oocysts (for an explanation of the rating checks click here). The following table summarizes Coghlan's iodine tablets expected performance, evaluation rating, and the mechanism by which the pathogens are reduced:

Table. Expected Performance Against Microbial Pathogens When Used As Directed.

Microbial Pathogen Type	Expected Performance	Evaluation Rating	Inactivation/removal Mechanism
Bacteria	> 6-log	√√√	disinfection
Viruses	> 4-log	√√√	disinfection
Giardia cysts	Not Effective*	X*	-
Cryptosporidium oocysts	Not Effective	X	-

* Recommend at least 45-60 minutes contact time to ensure 3-log *Giardia* cyst inactivation.

Production Capacity

One bottle of Coghlan's iodine tablets treats 25 liters (two tablets per liter of water).

Cleaning, Replacement, End of Life Indicator, Shelf Life

The manufacturer does not provide shelf life recommendations. Once the bottle is opened, the iodine tablets will begin to deteriorate. The tablets can last several months if the bottle is kept tightly closed between use. In general, the potency of the tablets can be determined by their color. As the tablet deteriorates, the color changes. A fully effective tablet is steel gray. A 50% deteriorated tablet is white to yellowish brown. And a completely deteriorated tablet is deep brown.

Weight and Size

The weight of the Coghlan's iodine tablets bottle is approximately 30 grams. The weight of the neutralizer bottle is approximately 30 grams. The approximate dimensions of each bottle are 5 cm x 2.5 cm (H x Dia).

Cost

Coghlan's iodine tablets alone cost approximately $5.00. Coghlan's iodine tablets and neutralizer tablets cost approximately $10.00.

Device Evaluation

Independent testing using the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1) has been conducted with Globaline (references 2 and 3). Because Globaline and Coghlan's iodine tablets are identical products, the results can be applied to Coghlan's iodine tablets. Independent testing using the reference 1 protocol confirms Coghlan's iodine tablets consistently provide a 6-log bacteria and 4-log virus reduction when used as directed. This testing also confirms that Coghlan's iodine tablets do not consistently provide 3-log *Giardia* cyst and *Cryptosporidium* oocyst reduction when used as directed. Coghlan's iodine tablets can provide a 3-log Giarida cyst inactivation when more than 60 minutes of wait time is provided. Coghlan's iodine tablets are not effective against *Cryptosporidium* oocysts. Additional treatment such as filtration with a 1 µm absolute filter to reduce *Cryptosporidium* oocysts is necessary. Coghlans' iodine tablets are not expected to cause any adverse health effects when used by healthy adults with no pre-existing thyroid conditions or sensitivity to iodine. Coghlan's iodine tablets are not recommended for use by pregnant women (concern for fetus), people with known hypersensitivity to iodine, people with a history (or family history) of thyroid disease, and people from areas with chronic iodine deficiency (reference 4). Iodine in Coghlans' iodine tablets can cause a medicinal taste and odor, and color the water. The iodine can be neutralized by adding ascorbic acid (available with Coghlan's iodine tablets) or sodium thiosulfate, which will improve the taste, odor, and color. Flavored drink mixes can mask the

flavor. Neutralizers and flavor aids should not be added until after recommended contact times are achieved. Use of Coghlan's iodine tablets will not remove or reduce particulate matter.

Advantages

- Independent testing using the USEPA protocol confirms 6-log bacteria and 4-log virus reduction when used as directed.
- Very small and lightweight.
- Simple and inexpensive to use.
- No adverse health effects expected in healthy adults with no iodine sensitivity.

Disadvantages

- Not effective against *Cryptosporidium*. Additional treatment is necessary.
- Not consistently effective against *Giardia* cysts when used as directed. Recommend at least 45-60 minute contact time for adequate *Giardia* cyst reduction.
- Not recommended for use by pregnant women or people with iodine sensitivity.
- Does not reduce or remove particulate matter.
- Can impart color, medicinal taste, and odor.

References

1. USEPA, Registration Division Office of Pesticide Program, Criteria and Standards Division Office of Drinking Water, 1987. *Guide Standard and Protocol for Testing Microbiological Water Purifiers.* Washington, D.C.

2. U.S. Army Natick Research, Development, and Engineering Center, 1993. *Efficacy of Flocculating and Other Emergency Water Purification Tablets.* (NATICK/TR-93/033). Natick, MA. Prepared by Powers, E.M.

3. Gerba, C.P., Johnson, D.C., & Hasan, M.N, 1997. Efficacy of iodine water purification tablets against *Cryptosporidium* oocysts and *Giardia* cysts. *Wilderness and Environmental Medicine*, 8, 96-100.

4. U.S. Army Center for Health Promotion and Preventive Medicine, 2005. *Technical Information Paper; Iodine Disinfection in the Use of Individual Water Purification Devices,* Aberdeen Proving Ground, MD.

ANNEX 56 TO APPENDIX E

DEVICE EVALUATION #56
COGHLAN'S, LTD. – COGHLAN'S EMERGENCY DRINKING WATER GERMCIDAL TABLETS™ WITH NEUTRALIZER

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Coghlan's, Ltd. – Coghlan's Emergency Drinking Water Germcidal Tablets™ w/Neutralizer

www.coghlans.com

Device Information

Coghlan's emergency drinking water germicidal tablets contain iodine. The manufacturer that produces these tablets, Wisconsin Pharmacal, also produces Globaline™ for the U.S. Military, and Potable Aqua™, which are identical to Coghlan's iodine tablets. Coghlan's, Ltd., sells two products with Coghlan's iodine tablets, one product consists of iodine tablets only; the other product consists of iodine tablets and neutralizing tablets (ascorbic acid) that remove iodine taste, color, and odor. Fifty iodine tablets are packaged in a small bottle with a vinyl lined screw cap. The cap also has an adhesive seal that allows it to be reused to keep moisture from getting into the bottle. Directions for use require the addition of two tablets to 1 liter of water and cap the water container loosely to allow a small amount of leakage. Wait 5 minutes. Shake the container to allow screw threads on the closure to be moistened then tighten cap. Wait 30 more minutes before drinking. If using neutralizing tablets, add two tablets to 1 liter only after the required wait time for the iodine tablets. Two iodine tablets result in a 16 mg/L iodine concentration in 1 liter. Coghlan's iodine tablets are composed of tetraglycine hydroperiodide, sodium acid pyrophosphate and talc. The disinfection capabilities of iodine have long been recognized and it is widely used as an antiseptic and as an emergency drinking water disinfectant. The device should be stored in a cool dry place and the tablets should be kept dry.

Effectiveness Against Microbial Pathogens

Independent testing using the U.S. Environmental Protection Agency (USEPA) Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1) has been conducted with Globaline (references 2 and 3). Because Globaline and Coghlan's iodine tablets are identical products, the results can be applied to Coghlan's iodine tablets. Independent testing using the

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reference 1 protocol confirms Coghlan's iodine tablets consistently provide a 6-log bacteria and 4-log virus reduction when used as directed. This testing also confirms that Coghlan's iodine tablets do not consistently provide 3-log *Giardia* cyst and *Cryptosporidium* oocyst reduction when used as directed. Coghlan's iodine tablets, when used according to directions, provide a 16 mg/L iodine dosage and a 35 minute contact time resulting in a disinfectant concentration times contact time (CT) of 560 mg-min/L. Coghlan's iodine tablets can provide a 3-log *Giarida* cyst inactivation when treating most water quality conditions if contact time is increased beyond the directed 35 minutes. Independent testing data using reference 1 indicated contact times of at least 60 minutes (CT = 960 mg-min/L) achieved a 3-log *Giardia* cyst inactivation (reference 2). Other iodine disinfection studies recommend a CT of at least 720 mg-min/L for a 3-log *Giardia* cyst inactivation (reference 4). To ensure a 3-log *Giardia* cyst inactivation when using Coghlan's iodine tablets, provide at least a 45-60 minute contact time. A 3-log *Cryptosporidium* oocyst inactivation is not realistically achieveable when using Coghlan's iodine tablets. Additional treatment is necessary to remove or inactivate *Cryptosporidium* oocysts. Based on independent data that tested the a product identical to Coghlan's iodine tablets under severe conditions required by the USEPA protocol, Coghlan's iodine tablets are given three √s for effectiveness against bacteria and viruses, and an X for effectiveness against *Giardia* cysts and *Cryptosporidium* oocysts (for an explanation of the rating checks click here). The following table summarizes Coghlan's iodine tablets expected performance, evaluation rating, and the mechanism by which the pathogens are reduced:

Table. Expected Performance Against Microbial Pathogens When Used As Directed.

Microbial Pathogen Type	Expected Performance	Evaluation Rating	Inactivation/removal Mechanism
Bacteria	> 6-log	√√√	disinfection
Viruses	> 4-log	√√√	disinfection
Giardia cysts	Not Effective*	X*	-
Cryptosporidium oocysts	Not Effective	X	-

* Recommend at least 45-60 minutes contact time to ensure 3-log *Giardia* cyst inactivation.

Production Capacity

One bottle of Coghlan's iodine tablets treats 25 liters (two tablets per liter of water).

Cleaning, Replacement, End of Life Indicator, Shelf Life

The manufacturer does not provide shelf life recommendations. Once the bottle is opened, the iodine tablets will begin to deteriorate. The tablets can last several months if the bottle is kept tightly closed between use. In general, the potency of the tablets can be determined by their color. As the tablet deteriorates, the color changes. A fully effective tablet is steel gray. A 50% deteriorated tablet is white to yellowish brown. And a completely deteriorated tablet is deep brown.

Weight and Size

The weight of the Coghlan's iodine tablets bottle is approximately 30 grams. The weight of the neutralizer bottle is approximately 30 grams. The approximate dimensions of each bottle are 5 cm x 2.5 cm (H x Dia).

Cost

Coghlan's iodine tablets alone cost approximately $5.00. Coghlan's iodine tablets and neutralizer tablets cost approximately $10.00.

Device Evaluation

Independent testing using the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1) has been conducted with Globaline (references 2 and 3). Because Globaline and Coghlan's iodine tablets are identical products, the results can be applied to Coghlan's iodine tablets. Independent testing using the reference 1 protocol confirms Coghlan's iodine tablets consistently provide a 6-log bacteria and 4-log virus reduction when used as directed. This testing also confirms that Coghlan's iodine tablets do not consistently provide 3-log *Giardia* cyst and *Cryptosporidium* oocyst reduction when used as directed. Coghlan's iodine tablets can provide a 3-log Giarida cyst inactivation when more than 60 minutes of wait time is provided. Coghlan's iodine tablets are not effective against *Cryptosporidium* oocysts. Additional treatment such as filtration with a 1 µm absolute filter to reduce *Cryptosporidium* oocysts is necessary. Coghlans' iodine tablets are not expected to cause any adverse health effects when used by healthy adults with no pre-existing thyroid conditions or sensitivity to iodine. Coghlan's iodine tablets are not recommended for use by pregnant women (concern for fetus), people with known hypersensitivity to iodine, people with a history (or family history) of thyroid disease, and people from areas with chronic iodine deficiency (reference 4). Iodine in Coghlans' iodine tablets can cause a medicinal taste and odor, and color the water. The iodine can be neutralized by adding ascorbic acid (available with Coghlan's iodine tablets) or sodium thiosulfate, which will improve the taste, odor, and color. Flavored drink mixes can mask the

flavor. Neutralizers and flavor aids should not be added until after recommended contact times are achieved. Use of Coghlan's iodine tablets will not remove or reduce particulate matter.

Advantages

- Independent testing using the USEPA protocol confirms 6-log bacteria and 4-log virus reduction when used as directed.
- Very small and lightweight.
- Simple and inexpensive to use.
- No adverse health effects expected in healthy adults with no iodine sensitivity.

Disadvantages

- Not effective against *Cryptosporidium*. Additional treatment is necessary.
- Not consistently effective against *Giardia* cysts when used as directed. Recommend at least 45-60 minute contact time for adequate *Giardia* cyst reduction.
- Not recommended for use by pregnant women or people with iodine sensitivity.
- Does not reduce or remove particulate matter.
- Can impart color, medicinal taste, and odor.

References

1. USEPA, Registration Division Office of Pesticide Program, Criteria and Standards Division Office of Drinking Water, 1987. *Guide Standard and Protocol for Testing Microbiological Water Purifiers.* Washington, D.C.

2. U.S. Army Natick Research, Development, and Engineering Center, 1993. *Efficacy of Flocculating and Other Emergency Water Purification Tablets.* (NATICK/TR-93/033). Natick, MA. Prepared by Powers, E.M.

3. Gerba, C.P., Johnson, D.C., & Hasan, M.N, 1997. Efficacy of iodine water purification tablets against *Cryptosporidium* oocysts and *Giardia* cysts. *Wilderness and Environmental Medicine*, 8, 96-100.

4. U.S. Army Center for Health Promotion and Preventive Medicine, 2005. *Technical Information Paper; Iodine Disinfection in the Use of Individual Water Purification Devices,* Aberdeen Proving Ground, MD.

ANNEX 57 TO APPENDIX E

DEVICE #57
CONTINENTAL TECHNOLOGIES, INC. – REDICLEAN

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ANNEX 58 TO APPENDIX E

DEVICE EVALUATION #58
HYDRO-PHOTON, INC. – STERIPEN™

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Hydro-Photon, Inc. – SteriPEN™

www.steripen.com

Device Information

The SteriPEN is a device that generates ultraviolet (UV) light for disinfection. The battery-powered device is designed to treat 0.5 L and 1 L volumes of water. The manufacturer states the device is intended for use with clear water only. Discolored or dirty water should be prefiltered until clear prior to treatment with the device. To treat water the user pushes the on/off button to warm up the UV lamp. Once warmed, the UV lamp is dipped into the 0.5 L or 1 L water volume. Once the UV lamp is immersed it turns on. For a 0.5 L water volume, the UV lamp stays on for 48 seconds. For a 1 L water volume, the UV lamp stays on for 90 seconds. While the UV lamp is on, the user is instructed to stir the water to achieve better treatment. Treatment is complete once the lamp turns off. The device provides a UV dose in the range of 35 - 50 mJ/cm^2. There are several safety precautions designed into the device to ensure it is used only when immersed in water. The device should not be exposed to ambient temperatures above 60^o C (140^o F) or below -20^o C (-4^o F). The manufacturer also offers a coarse prefilter to reduce particulates prior to treatment with the device.

Effectiveness Against Microbial Pathogens

Independent testing using the U.S. Environmental Protection Agency (USEPA) Guide Standard and Protocol for Testing Microbiological Water Purifiers has been conducted with the SteriPEN (references 1 and 2). Only bacteria and viruses were used in this testing. This testing indicated the device did not consistently provide adequate bacteria (6-log) and virus (4-log) reduction[1]. Although the testing confirms the SteriPEN provides a 6-log bacteria and 4-log virus removal in clear (low turbidity) water only, it did not confirm the SteriPEN provides similar bacteria and virus log removals in more challenging (higher turbidity) water. It is important to note that the more difficult challenge water #2 (i.e., higher turbidity) was passed through another COTS device, the General Ecology First Need Deluxe, prior to the water being treated by the SteriPEN. The First Need Deluxe has already been shown to pass the USEPA Protocol and adequately

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™ SteriPEN is a registered trademark of Hydro-Photon, Inc., Blue Hill, ME. Use of a trademarked product does not imply endorsement by the U.S. Army, but is intended only in identification of a specific product.

[1] The term reduction is used here to provide consistency of language with other device evaluation papers. UV light does not reduce microbial pathogens by killing or damaging cells like chemical disinfectants. Rather, UV light prevents the cell from reproducing, thereby preventing it from infecting a host. A more suitable term is inactivation.

reduce protozoan cysts (3-log), bacteria (6-log), and viruses (4-log) (reference 3). This test data does not accurately represent the SteriPEN's effectiveness in more turbid water. Other independent test data not using the USEPA Protocol indicate the device is able to adequately reduce viruses in clear water only. One independent study tested the SteriPEN and its optional prefilter using natural stream water. However, the turbidity of that water was not reported. Therefore, the device's effectiveness in more turbid water could not be determined. General research on turbidity's effect on UV disinfection is not conclusive (reference 4). Some studies show turbidity has no adverse effect on UV disinfection while other studies indicate turbidity has a significant effect on UV disinfection. General research also indicates viruses are the most resistant to UV disinfection, typically requiring significantly higher UV doses compared to protozoan cysts and bacteria (reference 4). Protozoan cysts (*Giardia* and *Cryptosporidium*) on the other hand are the least resistant, requiring very low UV doses. The assumption can then be made that data showing adequate virus reduction would also result in at least adequate protozoan cyst (*Giardia* and *Cryptosporidium*) reduction. Because protozoan cysts typically require very low UV doses (i.e., < 12 mJ/cm^2) and because the SteriPEN provides a UV dose much higher in the range of 35-50 mJ/cm^2, the SteriPEN is expected to consistently provide a 3-log reduction even in clear, low turbidity (reference 4). In regards to determining effectiveness against microbiological pathogens a conservative approach is taken. Based on the manufacturer's statement that this device is intended to treat clear water, independent testing challenging the device in clear water only (and a natural water of unknown turbidity), and the inconclusive effect of turbidity on UV disinfection, the SteriPEN is not expected to consistently provide adequate reduction of bacteria, viruses, and cysts even when using the optional prefilter when treating more turbid waters. Based on device specific test data and general UV disinfection research, the SteriPEN is given an X for effectiveness against bacteria, viruses, *Giardia* cysts, and *Cryptosporidium* oocysts (for an explanation of the rating checks click here). The following table summarizes SteriPEN's expected performance, evaluation rating, and the mechanism by which the pathogens are reduced:

Table. Expected Performance Against Microbial Pathogens.

Microbial Pathogen Type	Expected Performance	Evaluation Rating	Inactivation/removal Mechanism
Bacteria	Not Effective	X	-
Viruses	Not Effective	X	-
Giardia cysts	Not Effective	X	-
Cryptosporidium oocysts	Not Effective	X	-

Production Capacity

The manufacturer recommends replacing the UV lamp after 5,000 treatments for a 16 oz. (~ 0.5 L) water volume, which corresponds to a 2,500 L capacity. When using alkaline batteries, the manufacturer expects 20-30 treatments for a 16 oz. (~ 0.5 L) water volume corresponding to a 10-15 L capacity. Water production (disinfection) occurs during a manufacturer preset lamp-on duration of 48 seconds for 0.5 L and 90 seconds for 1 L.

Cleaning, Replacement, End of Life Indicator, Shelf Life

Clean the device with a mild soap solution. Batteries will need replacement as needed. There is a low battery indicator. There is also a dose counter which will indicate when the UV lamp should be replaced. Both the low battery and dose counter indicators can be considered end of life indicators.

Weight and Size

The weight of the SteriPEN with batteries is approximately 250 grams with 4 AA alkaline batteries. The approximate dimensions are 19 cm long x 5 cm max. dia.

Cost

SteriPEN	$150.00
Optional PreFilter	$ 10.00
Alkaline batteries (4 AA)	$ 3.00

Device Evaluation

Independent testing using the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers indicates the device met the minimum log reduction requirements for bacteria and viruses in clear water only. Based on the manufacturer's statement that this device is only intended to treat clear water, independent testing challenging the device in clear water only (and a natural water of unknown turbidity), and the inconclusive effect of turbidity on UV disinfection, the SteriPEN is not expected to consistently provide adequate reduction of bacteria, viruses, and cysts even when using the optional prefilter. Additional treatment is necessary to ensure adequate pathogen reduction such as prefiltering using a smaller pore size filter (e.g., 0.2-micron pore size) to produce clear (low turbidity) water prior to treatment. The SteriPEN is not likely to cause any adverse health effects when used as directed. Exposure to UV light, which can be harmful, is prevented by treating water held in any type of container except quartz (e.g., plastic, glass, metal). The SteriPEN produces little to no disinfection byproducts. And, the risk of adverse health effects from mercury exposure via ingestion due to lamp breakage is

minimal since the device would not be operable. Use of this device will not impart any taste or odor to the water being treated. The device may reduce particulate matter when used with the optional prefilter. Without the prefilter, the SteriPEN will not reduce particulate matter. For the purpose of this study, device production capacity is based on the limiting device component. For size, weight, and cost purposes, this evaluation included one set of four AA alkaline batteries, corresponding to a production capacity of 10 - 15 L. The price per liter of about $10.00 will decrease with increasing production volume since only battery replacement will be required. The UV lamp is stated to treat 2500 L.

Advantages

- Small and lightweight.
- Very simple to use.
- No adverse health effects expected when used as directed.

Disadvantages

- Intended for treating clear waters only.
- Not expected to be consistently effective against viruses, bacteria, and cysts when treating more turbid waters.
- Does not reduce or remove particulate matter.

References

1. USEPA, Registration Division Office of Pesticide Program, Criteria and Standards Division Office of Drinking Water, 1987. *Guide Standard and Protocol for Testing Microbiological Water Purifiers.* Washington, D.C.

2. Independent testing data provided by Hydro-Photon, Inc. Available on the Hydro-Photon website: http://www.hydro-photon.com/pgs/tests_info.html.

3. Independent laboratory results of tests showing compliance with the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers, 1995. Provided by General Ecology.

4. U.S. Army Center for Health Promotion and Preventive Medicine, 2005. *Technical Information Paper; Ultraviolet Light Disinfection in the Use of Individual Water Purification Devices,* Aberdeen Proving Ground, MD.

Device Evaluation Update – February 2006

Independent laboratory results for testing conducted by NSF International was received that tested the Hydro-Photon, Inc. SteriPEN against the USEPA Guide Standard. Testing was conducted using the UV portion of the protocol with a production volume of 4 L/day for 10.5 days. Testing was conducted in 16-32 oz. batches. Testing followed the dosimetry method described in NSF Standard 55 that measures UV dose and correlates it with MS-2 kill. Based on the MS-2 stock used, a kill of 2-log or greater was determined to be adequate to be considered a water purifier, and therefore effective at reducing pathogens. Collimated beam testing indicated that this reduction equated to a dose of 40 mJ/cm^2. Results indicated that this device did not meet the minimum log reduction requirements based on MS-2 kill. Initially, this device did meet the 2 log required reduction, but this reduction decreased by day 6. On the following days, under higher turbidity water, the device performed poorly, with less than 1-log kill. This performance is expected in turbid waters where UV transmittance is limited. The turbidity levels during this testing were 100-470 NTU, well above the ≥30 NTU requirement, however this device did not meet the required log reductions in relatively clear type 1 water. Based on this testing, it is not likely that this device will consistently meet the log reduction requirements under any water conditions. There is no change to the pathogen reduction ratings previously stated (X bacteria, X virus, X *Giardia*, X *Cryptosporidium*).

Updated Table. Expected Performance Against Microbial Pathogens.

Microbial Pathogen Type	Expected Performance	Evaluation Rating	Inactivation/removal Mechanism
Bacteria	Not Effective	X	-
Viruses	Not Effective	X	-
Giardia cysts	Not Effective	X	-
Cryptosporidium oocysts	Not Effective	X	-

References:

Independent laboratory testing conducted November 2005. Testing sponsored by the Department of the Air Force, Air Force Materiel Command.

NSF International, 2004. *Ultraviolet Microbiological Water Treatment Systems*.

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ANNEX 59 TO APPENDIX E

DEVICE EVALUATION #59
KATADYN – MICROPUR® MP 1 EMERGENCY DRINKING WATER TABLETS

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Katadyn – MICROPUR® MP 1 Emergency Drinking Water Tablets

www.katadyn.com

Device Information

The Katadyn Micropur MP 1 Emergency Drinking Water Tablets produce chlorine dioxide disinfectant upon addition to water. The tablets come in a package of 30, individually wrapped in foil pouches in 3 sheets of 10 foil pouches. The manufacturer's user directions involve removing one tablet from its foil pouch and quickly adding to 1 liter (1 quart) of untreated water. Allow a 4-hour contact time away from sunlight to generate a 4 mg/L chlorine dioxide solution. The active ingredients are sodium chlorite and sodium dichloroisocyanurate dihydrate. The tablets generate chlorine dioxide by reacting the sodium chlorite with an acid, sodium bisulfite, and chlorine, sodium dichloroisocyanurate dihydrate, to form chlorine dioxide. The device should be stored in a cool, dry area away from sunlight and heat.

Effectiveness Against Microbial Pathogens

Independent testing using the U.S. Environmental Protection Agency (USEPA) Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1) confirms this product met the minimum 6-, 4-, and 3-log inactivations for bacteria, viruses, and protozoan cysts (both *Giardia* and *Cryptosporidium*) when used according to directions (reference 2). Using the Micropur tablets according to the manufacturer's directions results in a disinfectant concentration times contact time (CT) of 960 mg-min/L. This CT is more than adequate for bacteria, viruses, and *Giardia* cysts. However, there is concern for this product being able to routinely provide a 3-log *Cryptosporidium* oocysts inactivation in colder waters (e.g., < 10º C) when used according to directions. For a 3-log *Cryptosporidium* oocyst inactivation, the USEPA proposed CTs higher than that provided by this product when treating colder waters (reference 3). For 5º C water, the USEPA recommends a CT of 1286 mg-min/L. These higher CT values are based on other chlorine dioxide disinfection experiments and take into account the variability and uncertainty of the data (reference 3). To be sure the Micropur tablets provide a 3-log *Cryptosporidium* oocyst inactivation when treating cold water (< 10° C), we recommend increasing the contact time beyond the 4-hour contact time listed in the directions. Based on

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independent data testing the device under severe conditions required by the USEPA protocol, the Micropur MP1 tablets are given three √s for effectiveness against bacteria, viruses, *Giardia* cysts, and *Cryptosporidium* oocysts (for an explanation of the rating checks click here). The following table summarizes Katadyn's Micropur MP1 emergency drinking water tablets expected performance, evaluation rating, and the mechanism by which pathogens are inactivated.

Table. Expected Performance Against Microbial Pathogens When Used as Directed.

Microbial Pathogen Type	Expected Disinfection Capability	Evaluation Rating	Inactivation/removal Mechanism
Bacteria	> 6-log	√√√	disinfection
Viruses	> 4-log	√√√	disinfection
Giardia cysts	> 3-log	√√√	disinfection
Cryptosporidium oocysts	> 3-log*	√√√*	disinfection

* Recommend additional contact time for waters < 10° C.

Production Capacity

One package of Katadyn's Micropur MP 1 Emergency Drinking Water Tablets treats 30 liters (one tablet per liter of water).

Cleaning, Replacement, End of Life Indicator, Shelf Life.

The device has an expiration date. However, the date of production is not indicated, therefore shelf life cannot be determined. Based on the device's expiration date and the date of purchase, it can be assumed that the minimum shelf life is 3 years.

Weight and Size

The total weight of the entire package (30 tablets) is approximately 20 grams. The tablets come in 3 sheets of 10 tablets. Each sheet measures approximately 17 cm long x 6.5 cm wide. Three sheets are approximately 1 cm deep.

Cost

The tablets cost about $20.00 per package.

Device Evaluation

Independent testing using the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1) confirms the Micropur MP 1 tablets met the minimum 6-, 4-, and 3-log inactivations for bacteria, viruses, and protozoan cysts (both *Giardia* and *Cryptosporidium*) (reference2). Due to variability and uncertainty in other *Cryptosporidium* oocyst inactivation studies with chlorine dioxide, we recommend additional contact time beyond the manufacturer directed 4-hour contact time to be sure of achieving a 3-log *Cryptosporidium* oocyst inactivation when treating colder waters (< l0° C). Turbidity will reduce chlorine dioxide concentrations and subsequently its disinfection capability, although to a lesser extent than water temperature (reference 4). Under most water quality conditions expected to be encountered, turbidity should not adversely affect the disinfection capability of the tablets. However, in very cloudy or turbid water, additional contact time beyond the 4-hour manufacturer contact time is recommended. Both water temperature and turbidity (cloudiness) can't often be measured accurately in the field and will require user subjectivity. In these situations, a conservative approach is recommended and additional contact time should be provided to protect the Soldier's health. These tablets generate chlorine dioxide and will produce chlorite, a byproduct of chlorine dioxide, when treating water containing organic matter (reference 4). Chlorine dioxide and chlorite can have serious adverse health effects for children, infants, and fetuses as a result of short-term exposure. But, no adverse health effects are expected for healthy adult individuals using this product for short periods of time and at manufacturer recommended dosages.

Advantages

- Independent testing using the USEPA Protocol confirms the device consistently provides 6-log bacteria, 4-log virus, and 3-log *Giardia* and *Cryptosporidium* inactivation under most water quality conditions expected.
- Very small and lightweight.
- Simple and inexpensive to use.
- No adverse health effects expected in healthy adults from short-term use.

Disadvantages

- Minimum 4-hour wait time required for adequate treatment. Recommend longer wait time for treating colder waters (< 10º C) to ensure adequate *Cryptosporidium* inactivation.
- Does not reduce or remove particulate matter.

- Requires user subjectivity with respect to water temperature and cloudiness.
- May cause adverse health effects in children, infants, and fetuses from short-term use.

References

1. USEPA, Registration Division Office of Pesticide Program, Criteria and Standards Division Office of Drinking Water, 1987. *Guide Standard and Protocol for Testing Microbiological Water Purifiers.* Washington, D.C.

2. Independent testing data provided by Katadyn, 2001.

3. Federal Register, 2003. *National Primary Drinking Water Regulations: Long Term 2 Enhanced Surface Water Treatment Rule; Proposed Rule,* 68(154), 47640-47795.

4. U.S. Army Center for Health Promotion and Preventive Medicine, 2005. *Technical Information Paper; Chlorine Dioxide Disinfection in the Use of Individual Water Purification Devices,* Aberdeen Proving Ground, MD.

ANNEX 60 TO APPENDIX E

DEVICE EVALUATION #60
MCNETT CORP. – AQUA MIRA WATER TREATMENT

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McNett Corp. – Aqua Mira Water Treatment

www.mcnett.com

Device Information

The McNett Aqua Mira water treatment drops produce chlorine dioxide, a disinfectant. The drops are marketed as a treatment to kill odor-causing bacteria and enhance the taste of stored potable water. The device comes in two separate 30 mL bottles. One bottle, labeled Part A, contains a 2% sodium chlorite solution. The second bottle, labeled Part B, contains a 5% phosphoric acid solution. Chlorine dioxide is generated when these two solutions are mixed together. The manufacturer's directions require the user to place 7 drops of Part A (sodium chlorite) and 7 drops of Part B (phosphoric acid) in the provided mixing cap. Fifteen drops should be added if water is cloudy or tinted. Allow 5 minutes for the mixture to react (generate chlorine dioxide). Then add the mixture to 1 L of water, shake to mix, and let stand 15 minutes. If water is very cold, cloudy, or tinted let stand 30 minutes. Based on the assumption that 1 drop equals 0.05 ml, 7 drops of Part A and Part B added to 1 L of water results in an approximate chlorine dioxide dose of 3.5 mg/L. Fifteen drops of each part added to 1 L of water results in an approximate chlorine dioxide dose of 7.5 mg/L. The drops generate chlorine dioxide by reacting the sodium chlorite with phosphoric acid. The manufacturer recommends storing Aqua Mira away from heat and sunlight to prevent reduced effectiveness. For long periods of storage, Aqua Mira should be refrigerated, but do not freeze.

Effectiveness Against Microbial Pathogens

No test data is available for the Aqua Mira drops using the U.S. Environmental Protection Agency (USEPA) Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1). There is a significant amount of research on chlorine dioxide water disinfection and is summarized in reference 2. In the absence of testing data specific to this device and based on available research the McNett Aqua Mira drops should be capable of consistently reducing bacteria, viruses, and *Giardia* cysts to the required minimum log reductions stated in reference 1 (i.e., 6-log bacteria, 4-log virus, and 3-log *Giardia* cyst reduction). When used as directed, the dose and wait time correspond to a disinfectant concentration times contact time (CT) of approximately 60 mg-min/L for clear, warm waters. For cloudy or cold waters, the directions require higher dose and longer wait time resulting in a CT of approximately 225 mg-min/L. When used as directed, the resulting CTs should be more than adequate to consistently provide a

6-log bacteria, 4-log virus, and 3-log *Giardia* cyst reduction. When used as directed, this device will not consistently provide a 3-log reduction of *Cryptosporidium* oocysts. The USEPA proposed significantly higher CTs for a 3-log reduction of *Cryptosporidium* oocysts using chlorine dioxide. For 5° C water, the USEPA recommends a CT of 1286 mg-min/L. These higher CT values are based on numerous chlorine dioxide disinfection experiments and take into account the variability and uncertainty of the data (reference 3). Using the instructed dosage for cloudy or cold waters and extending the wait time to a minimum of 3 hours, resulting in an approximate CT of 1350 mg-min/L, would help ensure adequate reduction of *Cryptosporidium* oocysts. Waters less than 5° C would require even longer wait times, up to 4.5 hours. Based on general chlorine dioxide disinfection studies, the McNett Aqua Mira drops are given one √ each for bacteria, viruses, and *Giardia* cysts, and an X for *Cryptosporidium* oocysts (for an explanation of the rating checks click here). The following table summarizes McNett's Aqua Mira drops expected performance, evaluation rating, and the mechanism by which pathogens are inactivated:

Table. Expected Performance Against Microbial Pathogens When Used as Directed.

Microbial Pathogen Type	Expected Disinfection Capability	Evaluation Rating	Inactivation/removal Mechanism
Bacteria	> 6-log	√	Disinfection
Viruses	> 4-log	√	Disinfection
Giardia cysts	> 3-log	√	Disinfection
Cryptosporidium oocysts	Not Effective	X*	-

* Recommend using the instructed dosage for cloudy or cold waters and extending the wait time to a minimum of 3 hours to help ensure adequate *Cryptosporidium* oocyst reduction. Waters less than 5° C would need an even longer wait time, up to 4.5 hours.

Production Capacity

One package of McNett's Aqua Mira drops reportedly treats up to 120 liters. However, based on a volume of 30 ml per bottle and a dose of 7-15 drops (assuming 1 drop = 0.05 ml) per bottle for each liter of water treated, this corresponds to a production capacity of 40-90 liters.

Cleaning, Replacement, End of Life Indicator, Shelf Life

The device has an expiration date. The manufacturer recommends using Aqua Mira before the expiration date. However, the date of production is not indicated, therefore, storage life cannot be determined. Based on the device's expiration date and the date of purchase, it can be assumed that the minimum shelf life is 4 years.

Weight and Size

The total weight of both bottles is approximately 90 grams. The approximate dimensions of both bottles combined are 8 cm x 5.5 cm x 2.5 cm (H x L x W).

Cost

The device cost about $15.00.

Device Evaluation

No data testing the McNett Aqua Mira drops was available. Research conducted on chlorine dioxide disinfection indicates that this device should be capable of consistently reducing bacteria, viruses, and Giardia cysts when used as directed. This device is not capable of consistently reducing *Cryptosporidium* oocysts when used as directed. Using the directed dose for cloudy or cold waters and extending the wait time to a minimum of 3 hours should ensure adequate *Cryptosporidium* oocyst reduction. Waters colder than 5° C would require even longer wait time. Also, additional treatment such as a 1 µm absolute filter can adequately reduce *Cryptosporidium* oocysts. Both water temperature and cloudiness (turbidity) can't often be measured in the field and requires user subjectivity. In these situations, a conservative approach is recommended and treating water according to directions for cloudy or cold water should adequately protect the soldier from bacteria, viruses, and *Giardia* cysts. These drops generate chlorine dioxide and will also produce chlorite, a byproduct of chlorine dioxide. Chlorite is present as a result of incomplete generation of chlorine dioxide as well as the conversion of chlorine dioxide to chlorite when reacting with organic matter in water (reference 2). Chlorine dioxide and chlorite can have serious adverse health effects for children, infants, and fetuses as a result of short-term exposure. But, no adverse health effects are expected for healthy adult individuals using this product for short periods of time and at manufacturer recommended dosages.

Advantages

- Expect consistent protection from bacteria, viruses, and *Giardia* cysts when used as directed.
- Very small and lightweight.
- Simple and inexpensive to use.
- No adverse health effects expected in healthy adults from short-term use.

Disadvantages

- Not consistently effective against *Cryptosporidium* oocysts when used as directed. Extending wait time up to 4.5 hours will help ensure adequate *Cryptosporidium* oocyst reduction.
- Does not reduce or remove particulate matter.
- Requires user subjectivity with respect to water temperature and cloudiness.
- May cause adverse health effects in children, infants, and fetuses from short-term use.

References

1. USEPA, Registration Division Office of Pesticide Program, Criteria and Standards Division Office of Drinking Water. (1987). *Guide Standard and Protocol for Testing Microbiological Water Purifiers.* Washington, D.C.

2. U.S. Army Center for Health Promotion and Preventive Medicine. (2005). *Technical Information Paper; Chlorine Dioxide Disinfection in the Use of Individual Water Purification Devices*, Aberdeen Proving Ground, MD.

3. Federal Register (2003). *National Primary Drinking Water Regulations: Long Term 2 Enhanced Surface Water Treatment Rule; Proposed Rule.* 68(154), 47640-47795.

ANNEX 61 TO APPENDIX E

DEVICE EVALUATION #61
MEDENTECH, LTD. – AQUATABS™

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Medentech, Ltd. – Aquatabs™

www.medentech.com

Device Information

Aquatabs™ contain sodium dichloroisocyanurate, a form of chlorine. Fifty chlorine tablets are individually packaged in foil pouches in sheets of 10 tablets. Directions for use require the addition of 1 tablet to 1 liter of water and wait 30 minutes before consuming. If sediment is in the water, the user is directed to allow the water to settle or filter the water through a fine cloth. The decanted or filtered water should then be treated with Aquatabs. One chlorine tablet added to 1 liter results in a 5 mg/L chlorine concentration. Sodium dichloroisocyanurate is a stabilized form of chlorine that slows the degradation of chlorine in the presence of sunlight.

Effectiveness Against Microbial Pathogens

No test data is available for the Aquatabs using the U.S. Environmental Protection Agency (USEPA) Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1). There is a significant amount of research on chlorine disinfection and is summarized in reference 2. Without testing data specific to this device, it must be evaluated using available general research on chlorine disinfection. In the absence of testing data specific to this device and based on available research, the Aquatabs should be capable of consistently reducing bacteria and viruses to the required minimum log reductions stated in reference 1 (i.e., 6-log bacteria and 4-log virus reduction). When used as directed, the dose and wait time correspond to a disinfectant concentration times contact time (CT) of approximately 150 mg-min/L. When used as directed, the resulting CTs should be more than adequate to consistently provide a 6-log bacteria and 4-log virus reduction. When used as directed, this device will not consistently provide a 3-log reduction of *Giardia* cysts and *Cryptosporidium* oocysts. Based on the USEPA's Surface Water Treatment Rule CT tables for *Giardia* cyst inactivation, CT levels up to 382 mg-min/L at colder temperatures (0.5° C) and higher pH levels (8.0) are recommended for a 3-log *Giardia* cyst reduction using chlorine. When used as

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directed, Aquatabs would not consistently provide a 3-log reduction at colder temperatures and higher pH levels. Increasing the wait time beyond the directed 30 minutes to approximately 1.5 hours results in a CT of 450 mg-min/L and would likely ensure a 3-log *Giardia* cyst reduction at colder temperatures and higher pH levels. Numerous studies have shown that chlorine is not effective against *Cryptosporidium* oocysts for typical drinking water applications (reference 2). Tremendous doses and wait times are necessary for adequate *Cryptosporidium* oocyst reduction, making Aquatabs an unrealistic choice. Based on general chlorine disinfection studies, the Aquatabs are given one √ each for bacteria and viruses, and an X for *Giardia* cysts and *Cryptosporidium* oocysts (for an explanation of the rating checks click here). The following table summarizes Aquatabs expected performance, evaluation rating, and the mechanism by which pathogens are reduced:

Table. Expected Performance Against Microbial Pathogens When Used As Directed.

Microbial Pathogen Type	Expected Performance	Evaluation Rating	Reduction Mechanism
Bacteria	6-log	√	disinfection
Viruses	4-log	√	disinfection
Giardia cysts	Not Effective*	X*	-
Cryptosporidium oocysts	Not Effective	X	-

*Recommend at least 90 minutes contact time to ensure 3-log *Giardia* cyst reduction.

Production Capacity

One package of Medentech Aquatabs treats 50 liters.

Cleaning, Replacement, End of Life Indicator, Shelf Life

The shelf life of Aquatabs is 5 years from the date of manufacture.

Weight and Size

The weight of the Aquatabs package is approximately 10 grams. The approximate dimensions of a sheet of 10 tablets are 10 cm x 4 cm. Five sheets are approximately 1 cm deep.

Cost

Aquatabs are not sold at stores in the United States. The device is available through online ordering and at stores outside of the United States. The device costs approximately $10.00.

Device Evaluation

No data testing the Aquatabs was available. General research conducted on chlorine disinfection indicates that this device should be capable of consistently reducing bacteria and viruses when used as directed. This device is not capable of consistently reducing *Giardia* cysts and *Cryptosporidium* oocysts when used as directed. Extending the wait time from 30 minutes to at least 1.5 hours will likely ensure adequate reduction of *Giardia* cysts in colder waters and higher pH levels. Aquatabs are not effective against *Cryptosporidium* oocysts. Additional treatment, such as a 1 µm absolute filter, is necessary to adequately reduce *Cryptosporidium* oocysts. When used as directed, Aquatabs will expose the user to chlorine and cyanuric acid and may expose the user to disinfection byproducts such as trihalomethanes and haloacetic acids when chlorine reacts with naturally present organic matter. However, when used as directed for short periods of time, exposure to these compounds is not expected to cause adverse health effects in healthy adults (reference 2).

Advantages

- Expect consistent protection from bacteria and viruses when used as directed.
- Very small and lightweight.
- Simple and inexpensive to use.
- No adverse health effects expected in healthy adults.

Disadvantages

- Not consistently effective against *Giardia* cysts when used as directed. Recommend at least 1.5 hours wait time for adequate *Giardia* cyst reduction.
- Not effective against *Cryptosporidium*. Additional treatment is necessary.
- Does not reduce or remove particulate matter.
- Can impart taste and odor.

References

1. USEPA, Registration Division Office of Pesticide Program, Criteria and Standards Division Office of Drinking Water. (1987). *Guide Standard and Protocol for Testing Microbiological Water Purifiers.* Washington, D.C.

2. U.S. Army Center for Health Promotion and Preventive Medicine. (2005). *Technical Information Paper; Chlorine Disinfection in the Use of Individual Water Purification Devices,* Aberdeen Proving Ground, MD.

ANNEX 62 TO APPENDIX E

DEVICE EVALUATION #62
MOUNTAIN SAFETY RESEARCH – MIOX® PURIFIER

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Mountain Safety Research – MIOX® Purifier

www.msrgear.com

Device Information

The Mountain Safety Research (MSR®) MIOX® Purifier is a device that produces a disinfectant through the electrolysis of a brine solution. The device is similar to a large magic marker (it is commonly referred to as the MIOX Pen). The device uses electricity provided by batteries and a brine solution provided by wetted rock salt to produce a disinfectant. The disinfectant produced by this process is chlorine. There is speculation that other short-lived oxidants may be produced by this process, however, the most current scientific information indicates that only chlorine is produced (reference 1). The chlorine produced by the device is then added to the water to be treated. There is a military and civilian version of this device. Device operation of both versions is identical. The only difference is the packaging and appearance. The military version is black and tan colored and comes in a nylon carrying case. The civilian version is black and red and comes with a mesh/nylon drawstring bag. Both devices come with two batteries, a packet of rock salt, and a container with 50 chlorine residual test strips. Prior to use the batteries must be installed and rock salt added to the device's salt chamber. Directions call for addition of water to the device's reaction cell and mixing that water with the salt in the salt chamber to produce a brine solution in the reaction cell. The device is activated, passing a current through the brine solution in the reaction cell (which contains an anode and cathode). This causes electrolysis of the brine solution and production of chlorine. This chlorine solution is then added to the water to be treated. The user then tests the water being treated with a chlorine residual test strip to ensure the minimum dose of 4 mg/L is achieved. If the minimum dose is not achieved, the user is directed to continue adding additional chlorine doses and checking the chlorine residual until a minimum 4 mg/L chlorine dose is obtained. Ten minutes after adding the chlorine to the water, the user is directed to check chlorine residual again. If not adequate (i.e., at least 4 mg/L) the water must be dosed again. Once the adequate dose of chlorine is added to the water, the user is required to wait a total of 30 minutes for adequate bacteria, virus, and *Giardia* cyst reduction. The manufacturer also recommends an "overkill option" – if test strips are unavailable or the

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situation dose not allow for the test procedure, the user may overdose the water 8X instead. To do so, use two 4 L doses per 1 L of water and wait 30 minutes, after which even the "worst case" water will be ready to drink. The manufacturer also makes a special note regarding *Cryptosporidium* treatment – in all cases, using test strips or overkill, treating water contaminated with *Cryptosporidium* requires a 4-hour wait time. The manufacturer does not provide any storage requirements.

Effectiveness Against Microbial Pathogens

Independent testing using the U.S. Environmental Protection Agency (USEPA) Guide Standard and Protocol for Testing Microbiological Water Purifiers confirms this product met the minimum 6-, 4-, and 3-log inactivations for bacteria, viruses, and *Giardia* cysts when used according to directions (i.e., at least a 4 mg/L chlorine dose and 30 minute wait time) (references 2,3). Using the MIOX Purifier according to directions results in a minimum disinfectant concentration times contact time (CT) of 120 mg-min/L. The directions also describe an overkill option and special treatment instructions for *Cryptosporidium*. The overkill option results in a dose of at least 32 mg/L (8X normal 4 mg/L dose) and a wait time of 30 minutes. This corresponds to a CT of 960 mg-min/L. The special treatment instructions for *Cryptosporidium* result in two different doses; one being at least 4 mg/L (when using test strips) and the other dose being at least 32 mg/L (using overkill option). Regardless of dose, the wait time is the same 4 hours for both. These doses and wait times correspond to CTs of 960 mg-min/L and 7,680 mg-min/L, respectively. There is independent testing using the USEPA Protocol challenging the MIOX Purifier with *Cryptosporidium* oocysts (reference 3). That data shows the MIOX Purifier consistently provided a 3-log *Cryptosporidium* reduction at only the higher, overkill dose and 4-hour wait time (i.e., CT of 7,680 mg-min/L). Other device specific test data (that was uncertain if the USEPA Protocol was used) indicated the MIOX Purifier was not able to consistently provide a 3-log *Cryptosporidium* reduction when using the lower dose (4 mg/L when using the test strips) and 4-hour wait time. Since the directions imply that the MIOX Purifier can provide adequate *Cryptosporidium* reduction when using the test strips (i.e., a 4mg/L dose) and waiting 4 hours when the device-specific test data does not support this, the MIOX Purifier must be considered to not be able to consistently provide a 3-log *Cryptosporidium* reduction when used as directed. When using this device, always using the overkill option dose (8X normal dose) and waiting 4 hours will ensure adequate *Cryptosporidium* reduction. Based on independent data, testing the device under severe conditions required by the USEPA protocol and other device-specific testing data, the MSR MIOX Purifier is given three √s for effectiveness against bacteria, viruses, and *Giardia* cysts, and an X for effectiveness against *Cryptosporidium* oocysts (for an explanation of the rating checks click here). The following table summarizes the device's expected performance, evaluation rating, and the mechanism by which pathogens are inactivated:

Table. Expected Performance Against Microbial Pathogens When Used as Directed.

Microbial Pathogen Type	Expected Disinfection Capability	Evaluation Rating	Inactivation/removal Mechanism
Bacteria	> 6-log	√√√	disinfection
Viruses	> 4-log	√√√	disinfection
Giardia cysts	> 3-log	√√√	disinfection
Cryptosporidium oocysts	Not Effective*	X*	-

* Using the overkill option dose (8X the normal dose) and waiting 4 hours will ensure adequate *Cryptosporidium* reduction.

Production Capacity

As purchased, the manufacturer states the production capacity is approximately 200 L. This capacity is based on the amount of salt provided.

Cleaning, Replacement, End of Life Indicator, Shelf life

No device cleaning is required. Batteries, rock salt, and chlorine residual test strips will need replacement. The chlorine residual test strips have an expiration date, although shelf life could not be determined. A low battery indicator acts as an end of life indicator. The chlorine test strips serve as a device failure indicator.

Weight and Size

The total weight of the device, rock salt, batteries, and chlorine residual test strips is approximately 230 grams. The dimensions of the device and components in the provided carrying case are approximately 17 cm x 9.5 cm x 3.5 cm (H x L x W).

Cost

Civilian version	$130.00
Chlorine test strips and salt (sodium chloride)	$ 18.00
Lithium Batteries, 2 pack	$ 13.00

Military version (NSN 4610-01-513-8498)	$107.00
Sodium chloride (NSN 6810-01-513-8737)	$ 3.00
Replacement MIOX® Purifier (NSN 4460-01-518-5095)	$ 72.00
Replacement carrying case (NSN 4460-01-518-5099)	$ 17.00
Chlorine test strips (NSN 6550-01-516-4933)	$ 9.00
Battery, 12 pack (NSN 6135-01-351-1131)	$ 28.00

Device Evaluation

Independent testing using the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers confirms the MSR MIOX Purifier met the minimum 6-, 4-, and 3-log inactivations for bacteria, viruses, and *Giardia* cysts when used as directed (at least a 4 mg/L chlorine dose and 30-minute wait time) (references 2 and 3). The MSR MIOX Purifier is not considered to consistently provide a 3-log *Cryptosporidium* reduction when used as directed due to discrepancies with the special *Cryptosporidium* treatment instructions and device-specific testing confirming the device meets a 3-log *Cryptosporidium* reduction for only the overkill dose and 4-hour wait time. The use of the chlorine test strips is critical to proper device operation and water treatment. The device-specific test data indicated significant variability in production of chlorine doses. For example, one test using three separate devices required in the range of 4-5 initial chlorine doses to achieve at least a 4 mg/L chlorine dose in a clean (low oxidant demand) water. Compared to other disinfectants, this device is more complicated and requires more effort to use. However, a limited military assessment was conducted in which soldiers indicated the device was easy to use and required minimal training. The assessment also indicated the device is durable. When used as directed, the device will expose the user to chlorine and may expose the user to disinfection byproducts such as trihalomethanes and haloacetic acids when chlorine reacts with naturally present organic matter. However, when used as directed for short periods of time, exposure to these compounds is not expected to cause adverse health effects in healthy adults (reference 1). The device can impart a chlorine taste and odor to the water being treated. The device will not remove or reduce particulate matter.

Advantages

- Independent testing using the USEPA Protocol confirms the device consistently provides 6-log bacteria, 4-log virus, and 3-log *Giardia* cyst reduction when used as directed.
- Small and lightweight.
- Inexpensive to use.
- No adverse health effects expected in healthy adults from short-term use.

Disadvantages

- Does not consistently provide adequate *Cryptosporidium* reduction when used as directed. Using the overkill option dose (8X normal dose) and waiting 4 hours will ensure adequate *Cryptosporidium* reduction.
- Does not reduce or remove particulate matter.
- Can impart chlorine taste and odor.

References

1. U.S. Army Center for Health Promotion and Preventive Medicine. (2005). *Technical Information Paper; Chlorine Disinfection in the Use of Individual Water Purification Devices,* Aberdeen Proving Ground, MD.

2. U.S. Environmental Protection Agency, Registration Division Office of Pesticide Program, Criteria and Standards Division Office of Drinking Water. (1987). *Guide Standard and Protocol for Testing Microbiological Water Purifiers.* Washington, D.C.

3. Independent testing data provided by MSR and MIOX.

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ANNEX 63 TO APPENDIX E

DEVICE EVALUATION #63
POLAR EQUIPMENT, INC. – POLAR PURE WATER DISINFECTANT

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Polar Equipment, Inc. – Polar Pure Water Disinfectant

www.polarequipment.com

Device Information

The Polar Equipment, Inc., Polar Pure Water Disinfectant is a small specially designed glass bottle containing crystalline iodine. The bottle contains a trap in the neck to prevent iodine crystal loss during use. The user fills the bottle with water (raw, untreated water is acceptable), which dissolves a small amount of crystals, creating a 300 mg/L iodine solution at room temperature (20º C). Iodine solubility, and therefore solution concentration, increases with increasing temperature and this affects dose (e.g., 3º C = 200 mg/L, 40º C = 400 mg/L). After the required 1-hour wait time for the solution inside the bottle to equilibrate, the user observes the thermometer on the outside of the bottle, and based on the location of the green dot, the corresponding dose, in bottle capfuls, is poured from the bottle into a user supplied 1 L vessel containing untreated water. This creates a 4 mg/L iodine residual concentration. The manufacturer recommends that the dose be doubled if the untreated water is cloudy. Directions indicate that a 20-minute wait time is required prior to consumption. For effectiveness against *Giardia* cysts, the directions indicate the water being treated must be warmed to 20º C by warming in the sun or adding hot water. The bottle containing the iodine crystals should be refilled with water so that the solution is ready for next use after a minimum wait of 1 hour. The device should not be frozen.

Effectiveness Against Microbial Pathogens

No data was received showing the effectiveness of this product with respect to the U.S. Environmental Protection Agency (USEPA) Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1). Extensive research on iodine water disinfection can be found in literature and is summarized in reference 2. There is also some device-specific data that did not use the reference 1 protocol (reference 3). In the absence of data specific to this device tested using reference 1, and in accordance with other device-specific test data and available research, this device should be capable of consistently reducing bacteria (6-log) and viruses (4-log) to the required minimum log reductions stated in reference 1 under most water quality conditions when used as directed. It is not expected to consistently reduce *Giardia* cysts to the required 3-log reduction when used as directed. When used as directed, Polar Pure provides a disinfectant concentration times contact time (CT) of 80 mg-min/L for clear, warm

waters and 160 mg-min/L for cloudy, warm waters. Polar Pure is capable of consistently achieving adequate *Giardia* cyst log reductions if increased dosages and/or longer contact time (wait time) beyond manufacturer's directions are used. To ensure adequate reduction of *Giardia* cysts in all water quality conditions, it is recommended that wait time be increased to at least 90-120 minutes and dosage doubled to provide a dose of 8 mg/L. This results in CT of 720-960 mg-min/L. Iodine has not been shown to be effective against *Cryptosporidium* oocysts. Based on general iodine disinfection studies and the limited device-specific testing data, the Polar Pure Water Disinfectant is given one √ each for bacteria and viruses, and an X for *Giardia* cysts and *Cryptosporidium* oocysts (for an explanation of the rating checks click here). The following table summarizes Polar Pure's expected performance, evaluation rating, and the mechanism by which pathogens are reduced:

Table. Expected Performance Against Microbial Pathogens When Used as Directed.

Microbial Pathogen Type	Expected Performance	Evaluation Rating	Inactivation/removal Mechanism
Bacteria	> 6-log	√	disinfection
Viruses	> 4-log	√	disinfection
Giardia cysts	Not Effective*	X*	-
Cryptosporidium oocysts	Not Effective	X	-

* Recommend doubling dosage (8 mg/L) and increasing wait time to 90-120 minutes to ensure adequate *Giardia* cyst reduction.

Production Capacity

According to manufacturer instructions, this device is capable of treating up to 2000 liters of water depending on water quality. After a 1-hour wait to allow the solution to saturate with iodine, plus the required wait time once dosed, one full bottle of saturated iodine solution can treat 2 - 6 L depending on water conditions.

Cleaning, Replacement, and End of Life Indicator, Shelf Life

No cleaning is required. If iodine crystals are visible in the bottle, the iodine solution will be produced in accordance with the manufacturer instructions. Once the iodine crystals are no longer visible, the bottle should be discarded. The manufacturer states an indefinite shelf life.

Weight and Size

The dry weight of the device is 90 grams. The bottle is about 8 cm in height and 5 cm in diameter.

Cost

This device costs about $10.00.

Device Evaluation

No data was received that challenged the Polar Equipment, Inc., Polar Pure Water Disinfectant against reference 1. Research conducted on iodine disinfection indicates that this device should be capable of consistently reducing bacteria and viruses when used as directed. This device is not capable of consistently reducing *Giardia* cysts and *Cryptosporidium* oocysts when used as directed. Increasing dosage to 8 mg/L and increasing wait time to at least 90-120 minutes should ensure adequate reduction of *Giardia* cysts for most water quality conditions expected. Additional treatment such as a 1 µm absolute filter is necessary to reduce *Cryptosporidium* oocysts. Both water temperature and cloudiness (turbidity) can't often be measured in the field and requires user subjectivity. In these situations, a conservative approach is recommended and treating water using recommended increased wait time and dosage should adequately protect the soldier from bacteria, viruses, and *Giardia* cysts. Polar Pure is not expected to cause any adverse health effects when used as directed by healthy adults with no pre-existing thyroid conditions or sensitivity to iodine. There is concern to healthy individuals if the iodine crystals are poured into the water being treated. Consuming treated water containing iodine crystals could potentially expose the user to extremely high iodine concentrations that may be harmful to healthy adults. Polar Pure is not recommended for use by pregnant women (concern for fetus), people with known hypersensitivity to iodine, people with a history (or family history) of thyroid disease, and people from areas with chronic iodine deficiency (reference 2). Use of this device may impart a medicinal taste and color the water. The iodine can be neutralized by adding ascorbic acid (Vitamin C) or sodium thiosulfate, which will improve the taste and color. Flavored drink mixes can mask the flavor. Neutralizers and flavor aids should only be added after the recommended wait times are reached. Use of this device will not reduce or remove particulate matter.

Advantages

- Although device-specific testing data using the USEPA protocol is not available, Polar Pure is expected to consistently provide adequate protection from bacteria and viruses when used as directed.
- Very small and lightweight device capable of treating up to 2000 L.

- Simple and inexpensive to use.
- No adverse health effects expected in healthy adults with no iodine sensitivity.

Disadvantages

- Not effective against *Cryptosporidium* oocysts. Additional treatment is necessary.
- Not consistently effective against *Giardia* cysts. Recommend increased wait times (90-120 minutes) and dosage (8 mg/L) to provide adequate protection from *Giardia* cysts.
- Not recommended for use by pregnant women or people with iodine sensitivity.
- Does not remove or reduce particulate matter and can impart color and medicinal taste.
- Requires user subjectivity with respect to evaluating cloudiness (turbidity) and temperature.

References

1. USEPA, 1989. Guide Standard and Protocol for Testing Microbiological Water Purifiers. *Federal Register*. 54:34067.

2. U.S. Army Center for Health Promotion and Preventive Medicine. (2005). *Technical Information Paper; Iodine Disinfection in the Use of Individual Water Purification Devices,* Aberdeen Proving Ground, MD.

3. Ongerth, J.E. et. al. (1989). Backcountry Water Treatment to Prevent Giardiasis. *American Journal of Public Health*, 79(12), 1633-1637.

ANNEX 64 TO APPENDIX E

DEVICE EVALUATION #64
ADVANCE CHEMICALS LTD. – PRISTINE® WATER PURIFICATION SYSTEM

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Advance Chemicals Ltd. – Pristine® Water Purification System

www.pristine.ca

Device Information

The Pristine Water Purification System produces the water disinfectant chlorine dioxide. The device comes in two separate 30 mL bottles. One bottle, labeled A, contains a 2% sodium chlorite solution. The second bottle, labeled B, contains a 5% phosphoric acid solution. Chlorine dioxide is generated when these two solutions are mixed together. The manufacturer's directions require the user to place 5 drops of A (sodium chlorite) and 5 drops of B (phosphoric acid) in the provided mixing cap and allow to react for 5 minutes. Add the solution to 1 L of water and wait 15 minutes before drinking. Based on the assumption that 1 drop equals 0.05 ml, 5 drops of A and B added to 1 L of water results in an approximate chlorine dioxide dose of 2.5 mg/L. For very cold or cloudy water, or if *Cryptosporidium* is suspected, the instructions require a triple dose (15 drops) and a wait time of 30 minutes. This results in an approximate chlorine dioxide dose of 7.5 mg/L. Additional instructions provided with the device packaging give varying wait times and dosages based on water temperature. The drops generate chlorine dioxide by reacting the sodium chlorite with phosphoric acid. The device should be stored in a cool, dry location.

Effectiveness Against Microbial Pathogens

No test data is available for this device using the U.S. Environmental Protection Agency (USEPA) Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1). There is a significant amount of research on chlorine dioxide water disinfection and is summarized in reference 2. In the absence of testing data specific to this device and based on available research, the device should be capable of consistently reducing bacteria, viruses, and *Giardia* cysts to the required minimum log reductions stated in reference 1 (i.e., 6-log bacteria, 4-log virus, and 3-log *Giardia* cyst reduction). When used as directed, the dose and wait time correspond to a disinfectant concentration times contact time (CT) of approximately 38 mg-min/L for clear, warm waters. For cloudy, cold waters, or if *Cryptosporidium* contamination is suspected, the directions require higher dose and longer wait time resulting

® Pristine is a registered trademark of Advance Chemical, Ltd., Langely, BC, Canada. Use of a trademarked product does not imply endorsement by the U.S. Army, but is intended only in identification of a specific product.

in a CT of approximately 225 mg-min/L. Additional instructions for treating water when *Cryptosporidium* contamination is suspected results in ranges of CT depending on water temperature. For example, instructions for treating 4° C water result in a CT ranging from approximately 900 – 1125 mg-min/L based on dosage and wait time. When used as directed, the resulting CTs should be adequate to consistently provide a 6-log bacteria, 4-log virus, and 3-log *Giardia* cyst reduction. When used as directed, this device will not consistently provide a 3-log reduction of *Cryptosporidium* oocysts. The USEPA proposed significantly higher CTs for a 3-log reduction of *Cryptosporidium* oocysts. For 5° C water, the USEPA recommends a CT of 1286 mg-min/L. These higher CT values are based on numerous chlorine dioxide disinfection experiments and take into account the variability and uncertainty of the data (reference 3). Using the manufacturer provided chart for treating water when Crypto contamination is suspected results in lower CTs than those recommended by the USEPA. Therefore, this device is not expected to consistently provide a 3-log *Cryptosporidium* oocyst reduction when used as directed. Using the instructed dosage for cloudy, cold, or *Cryptosporidium* contaminated waters and extending the wait time to a minimum of 3 hours, resulting in an approximate CT of 1350 mg-min/L, would help ensure adequate reduction of *Cryptosporidium* oocysts. Waters less than 5° C would require even longer wait times, up to 4.5 hours. Based on general chlorine dioxide disinfection studies, the Pristine Water Purification System is given one √ each for bacteria, viruses, and *Giardia* cysts, and an X for *Cryptosporidium* oocysts (for an explanation of the rating checks click here). The following table summarizes the device's expected performance, evaluation rating, and the mechanism by which pathogens are inactivated:

Table. Expected Performance Against Microbial Pathogens When Used as Directed.

Microbial Pathogen Type	Expected Disinfection Capability	Evaluation Rating	Inactivation/removal Mechanism
Bacteria	> 6-log	√	disinfection
Viruses	> 4-log	√	disinfection
Giardia cysts	> 3-log	√	disinfection
Cryptosporidium oocysts	Not Effective	X*	-

* Recommend using the instructed dosage for cloudy, cold, or *Cryptosporidium* contaminated waters and extending the wait time to a minimum of 3 hours to help ensure adequate *Cryptosporidium* oocyst reduction. Waters less than 5° C would need an even longer wait time, up to 4.5 hours.

Production Capacity

One package of Pristine Water Purification System treats up to 120 liters. However, based on a volume of 30 ml per bottle and a dose of 7-15 drops (assuming 1 drop = 0.05 ml) per bottle for each liter of water treated, this corresponds to a production capacity of 40-90 liters.

Cleaning, Replacement, End of Life Indicator, Shelf life

The device has an expiration date. However, the date of production is not indicated, therefore, shelf life cannot be determined. Based on the device's expiration date and the date of purchase, it can be assumed that the minimum shelf life is 4 years.

Weight and Size

The total weight of both bottles is approximately 90 grams. The dimensions of both bottles are 8 cm x 5.5 cm x 2.5 cm (H x L x W).

Cost

The Pristine Water Purification System is not sold at stores in the United States. The device is available through online ordering and at stores outside of the United States. The device costs approximately $15.00

Device Evaluation

No data testing the Pristine Water Purification System was available. Research conducted on chlorine dioxide disinfection indicates that this device should be capable of consistently reducing bacteria, viruses, and *Giardia* cysts when used as directed. This device is not capable of consistently reducing *Cryptosporidium* oocysts when used as directed. Using the directed dose for cloudy or cold waters and extending the wait time to a minimum of 3 hours should ensure adequate *Cryptosporidium* oocyst reduction. Waters colder than 5° C would require even longer wait time, up to 4.5 hours. Also, additional treatment such as a 1 µm absolute filter can adequately reduce *Cryptosporidium* oocysts. Both water temperature and cloudiness (turbidity) can't often be measured in the field and requires user subjectivity. In these situations, a conservative approach is recommended and treating water according to directions for cloudy or cold water should adequately protect the soldier from bacteria, viruses, and *Giardia* cysts. These drops generate chlorine dioxide and will also produce chlorite, a byproduct of chlorine dioxide. Chlorite is present as a result of incomplete generation of chlorine dioxide as well as the conversion of chlorine dioxide to chlorite when reacting with organic matter in water

(reference 2). Chlorine dioxide and chlorite can have serious adverse health effects for children, infants, and fetuses as a result of short-term exposure. But, no adverse health effects are expected for healthy adult individuals using this product for short periods of time and at manufacturer recommended dosages.

Advantages

- Expect consistent protection from bacteria, viruses, and *Giardia* cysts when used as directed.
- Very small and lightweight.
- Simple and inexpensive to use.
- No adverse health effects expected in healthy adults from short-term use.

Disadvantages

- Not consistently effective against *Cryptosporidium* oocysts when used as directed. Extending wait time up to 4.5 hours will help ensure adequate *Cryptosporidium* oocyst reduction.
- Does not reduce or remove particulate matter.
- Requires user subjectivity with respect to water temperature and cloudiness.
- May cause adverse health effects in children, infants, and fetuses from short-term use.

References

1. USEPA, Registration Division Office of Pesticide Program, Criteria and Standards Division Office of Drinking Water. (1987). *Guide Standard and Protocol for Testing Microbiological Water Purifiers.* Washington, D.C.

2. U.S. Army Center for Health Promotion and Preventive Medicine. (2005). *Technical Information Paper; Chlorine Dioxide Disinfection in the Use of Individual Water Purification Devices,* Aberdeen Proving Ground, MD.

3. Federal Register (2003). *National Primary Drinking Water Regulations: Long Term 2 Enhanced Surface Water Treatment Rule; Proposed Rule.* 68(154), 47640-47795.

ANNEX 65 TO APPENDIX E

DEVICE EVALUATION #65
MILITARY ISSUE IODINE TABLETS – GLOBALINE™

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Military Issue Iodine Tablets – Globaline™

NSN 6850-00-985-7166

Device Information

Military issue iodine tablets, known as Globaline, are used for treating individual water supplies. One manufacturer, Wisconsin Pharmacal markets Globaline as Potable Aqua for civilian use and also manufactures Coghlan's Emergency Drinking Water Germicidal Tablets™ for Coghlan's Ltd. All these products are identical. The Globaline tablets are packaged in a small bottle (50 tablets per bottle) with a vinyl lined screw cap. The cap and bottle come from the manufacturer sealed with wax to prevent moisture from getting into the bottle. Directions for use tell the Soldier to add two tablets to a 1-quart (1 liter) canteen, wait 5 minutes, shake the canteen, loosen the cap and let water cover the neck of the canteen, then wait 30 more minutes before drinking. Two tablets result in a 16 mg/L iodine concentration in a 1-quart canteen. Globaline is composed of tetraglycine hdroperiodide, sodium acid pyrophosphate and talc. The disinfection capabilities of iodine have long been recognized and it is widely used as an antiseptic and as an emergency drinking water disinfectant. The U.S. Army's Field Manual (FM) No. 4-25.12 also provides the same directions for use of Globaline™ (reference 1).

Effectiveness Against Microbial Pathogens

Independent testing using the U.S. Environmental Protection Agency (USEPA) Guide Standard Protocol for Testing Microbiological Water Purifiers (reference 2) indicate Globaline met the minimum 6-log reduction for bacteria and 4-log reduction for viruses (references 3, 4). The data also indicate Globaline did not meet the minimum 3-log *Giardia* cyst inactivation requirement when used as directed. Additionally, data indicate Globaline did not provide a 3-log *Cryptosporidium* oocyst inactivation (reference 4). Globaline, when used according to directions, provides a 16 mg/L iodine dosage and a 35 minute contact time resulting in a disinfectant concentration times contact time (CT) of 560 mg-min/L. Globaline can provide a

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™ Coghlan's Emergency Drinking Water Germicidal Tablets is a trademark of Coghlan's Ltd., Winnipeg, Canada. Use of trademarked products does not imply endorsement by the U.S. Army, but is intended only in identification of a specific product

3-log *Giarida* cyst inactivation when treating most water quality conditions if contact time is increased beyond the directed 35 minutes. Independent testing data using reference 2 protocol indicated contact times of at least 60 minutes (CT = 960 mg-min/L) achieved a 3-log *Giardia* cyst inactivation (reference 3). Other iodine disinfection studies recommend a CT of at least 720 mg-min/L for a 3-log *Giardia* cyst inactivation (reference 5). To ensure a 3-log *Giardia* cyst inactivation when using Globaline, provide at least a 45-60 minute contact time. A 3-log *Cryptosporidium* oocyst inactivation is not realistically achieveable when using Globaline. Additional treatment is necessary to remove or inactivate *Cryptosporidium* oocysts. Based on independent data testing the device under severe conditions required by the USEPA protocol, the Globaline tablets are given three √s for effectiveness against bacteria and viruses, and an X for effectiveness against *Giardia* cysts and *Cryptosporidium* oocysts (for an explanation of the rating checks click here). The following table summarizes Globaline's expected performance, evaluation rating, and the mechanism by which the pathogens are reduced:

Table. Expected Performance Against Microbial Pathogens When Used As Directed.

Microbial Pathogen Type	Expected Performance	Evaluation Rating	Inactivation/removal Mechanism
Bacteria	> 6-log	√√√	disinfection
Viruses	> 4-log	√√√	disinfection
Giardia cysts	Not Effective*	X*	-
Cryptosporidium oocysts	Not Effective	X	-

* Recommend at least 45-60 minutes contact time to ensure 3-log *Giardia* cyst inactivation.

Production Capacity

One bottle of Globaline™ iodine tablets treats 25 liters (2 tablets per liter of water).

Cleaning, Replacement, End of Life Indicator

The manufacturer does not provide shelf life recommendations. Once the wax seal on the bottle is broken and the bottle is opened, the iodine tablets will begin to deteriorate. The tablets can last several months if the bottle is kept tightly closed between use. In general, the potency of the tablets can be determined by their color. As the tablet deteriorates, the color changes. A fully effective tablet is steel gray. A 50 % deteriorated tablet is white to yellowish brown, and a completely deteriorated tablet is deep brown. The Field Manual (FM) 4-25.12 notes that iodine

tablets should be a uniform gray in color with a smooth even surface. Tablets that are yellowish brown or crumbling should be turned in and replaced with new iodine tablets (reference 1).

Weight and Size

The weight of the bottle is approximately 50 grams. The approximate dimensions of the bottle are 5 cm x 2.5 cm (H x Dia).

Cost

The National Stock Number (NSN) for Globaline is NSN 6850-00-985-7166. The cost is $1.54 per bottle.

Device Evaluation

Independent testing using the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 2) confirms the Globaline tablets met the minimum 6-log and 4-log reduction for bacteria and viruses, respectively. The Globaline tablets did not meet the minimum 3-log *Giardia* cyst and *Cryptosporidium* oocyst inactivation requirements when used as directed. Globaline can provide a 3-log *Giarida* cyst inactivation when more than 60 minutes contact time is provided. Globaline tablets are not effective against *Cryptosporidium* oocysts. Additional treatment such as filtration with a 1 µm absolute filter to reduce *Cryptosporidium* oocysts is necessary. Globaline tablets are not expected to cause any adverse health effects when used by healthy adults with no pre-existing thyroid conditions or sensitivity to iodine. Globaline tablets are not recommended for use by pregnant women (concern for fetus), people with known hypersensitivity to iodine, people with a history (or family history) of thyroid disease, and people from areas with chronic iodine deficiency (reference 5). Iodine in the Globaline tablets can cause a medicinal taste and color the water. The iodine can be neutralized by adding ascorbic acid (Vitamin C) or sodium thiosulfate, which will improve the taste and color. Flavored drink mixes can mask the flavor. Neutralizers and flavor aids should not be added until after recommend contact times are achieved. Use of the tablets will not remove or reduce particulate matter.

Advantages

- Independent testing using the USEPA protocol confirms 6-log bacteria and 4-log virus reduction when treating most water quality conditions expected when used as directed.
- Very small and lightweight.
- Simple and inexpensive to use.
- No adverse health effects expected in healthy adults with no iodine sensitivity.

Disadvantages

- Not effective against *Cryptosporidium*. Additional treatment is necessary.
- Not consistently effective against *Giardia* cysts when used as directed. Recommend at least 45-60 minute contact time for adequate *Giardia* cyst reduction.
- Not recommended for use by pregnant women or people with iodine sensitivity.
- Does not reduce or remove particulate matter.
- Can impart color and medicinal taste.

References

1. U.S. Army FM No. 4-25.12, Unit Field Sanitation Team, Washington, DC, 25 January 2002.

2. USEPA, Registration Division Office of Pesticide Program, Criteria and Standards Division Office of Drinking Water, 1987. *Guide Standard and Protocol for Testing Microbiological Water Purifiers.* Washington, D.C.

3. U.S. Army Natick Research, Development, and Engineering Center, 1993. *Efficacy of Flocculating and Other Emergency Water Purification Tablets.* (NATICK/TR-93/033). Natick, MA. Prepared by Powers, E.M.

4. Gerba, C.P., Johnson, D.C., & Hasan, M.N, 1997. Efficacy of iodine water purification tablets against *Cryptosporidium* oocysts and *Giardia* cysts. *Wilderness and Environmental Medicine*, 8, 96-100.

5. U.S. Army Center for Health Promotion and Preventive Medicine, 2005. *Technical Information Paper; Iodine Disinfection in the Use of Individual Water Purification Devices,* Aberdeen Proving Ground, MD.

ANNEX 66 TO APPENDIX E

DEVICE EVALUATION #66
WISCONSIN PHARMACAL CO., LLC – POTABLE AQUA™ WITH NEUTRALIZER

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Wisconsin Pharmacal Co., LLC – Potable Aqua™ w/Neutralizer

www.pharmacalway.com

Device Information

Potable Aqua emergency drinking water germicidal tablets contain iodine. The manufacturer markets two products with Potable Aqua, one product consists of iodine tablets only; the other consists of iodine tablets and neutralizing tablets (ascorbic acid) that remove iodine taste, odor, and color. The manufacturer, Wisconsin Pharmacal, also produces Globaline™ for the U.S. Military, and Coghlan's Emergency Drinking Water Tablets™ for Coghlan's Ltd., which are identical to Potable Aqua. Fifty iodine tablets are packaged in a small bottle with a vinyl lined screw cap. The cap also has an adhesive seal that allows it to be reused to keep moisture from getting into the bottle. Directions for use require the addition of 2 tablets to 1 liter of water and cap loosely to allow a small amount of leakage. Wait 5 minutes. Shake the container to allow screw threads on the closure to be moistened then tighten cap. Wait 30 more minutes before drinking. If using neutralizing tablets, add 2 tablets to 1 liter only after the required wait time for the iodine tablets. Two iodine tablets result in a 16 mg/L iodine concentration in 1 liter. Potable Aqua is composed of tetraglycine hydroperiodide, sodium acid pyrophosphate and talc. The disinfection capabilities of iodine have long been recognized and it is widely used as an antiseptic and as an emergency drinking water disinfectant. The device should be stored in a cool dry place and tablets should be kept dry.

Effectiveness Against Microbial Pathogens

Independent testing using the U.S. Environmental Protection Agency (USEPA) Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1) has been conducted with Globaline (references 2 and 3). Because Globaline and Potable Aqua are identical products, the results can be applied to Potable Aqua. Independent testing using the reference 1 protocol confirms Potable Aqua consistently provides a 6-log bacteria and 4-log virus reduction when used as directed. This testing also confirms that Potable Aqua does not consistently provide

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™ Potable Aqua and Globaline are trademarks of Wisconsin Pharmacal Company, LLC, Jackson, WI.
™ Coghlan's Emergency Drinking Water Germicidal Tablets is a trademark of Coghlan's Ltd., Winnipeg, Canada. Use of a trademarked product does not imply endorsement by the U.S. Army, but is intended only in identification of a specific product

3-log *Giardia* cyst and *Cryptosporidium* oocyst reduction when used as directed. Potable Aqua, when used according to directions, provides a 16 mg/L iodine dosage and a 35-minute contact time resulting in a disinfectant concentration times contact time (CT) of 560 mg-min/L. Potable Aqua can provide a 3-log *Giarida* cyst inactivation when treating most water quality conditions if contact time is increased beyond the directed 35 minutes. Independent testing data using reference 1 indicated contact times of at least 60 minutes (CT = 960 mg-min/L) achieved a 3-log *Giardia* cyst inactivation (reference 2). Other iodine disinfection studies recommend a CT of at least 720 mg-min/L for a 3-log *Giardia* cyst inactivation (reference 4). To ensure a 3-log *Giardia* cyst inactivation when using Potable Aqua, provide at least a 45-60-minute contact time. A 3-log *Cryptosporidium* oocyst inactivation is not realistically achievable when using Potable Aqua. Additional treatment is necessary to remove or inactivate *Cryptosporidium* oocysts. Based on independent data testing the device under severe conditions required by the USEPA protocol, Potable Aqua is given three √s for effectiveness against bacteria and viruses, and an X for effectiveness against *Giardia* cysts and *Cryptosporidium* oocysts (for an explanation of the rating checks click here). The following table summarizes Potable Aqua's expected performance, evaluation rating, and the mechanism by which the pathogens are reduced:

Table. Expected Performance Against Microbial Pathogens When Used As Directed.

Microbial Pathogen Type	Expected Performance	Evaluation Rating	Inactivation/removal Mechanism
Bacteria	> 6-log	√√√	disinfection
Viruses	> 4-log	√√√	disinfection
Giardia cysts	Not Effective*	X*	-
Cryptosporidium oocysts	Not Effective	X	-

* Recommend at least 45-60 minutes contact time to ensure 3-log *Giardia* cyst inactivation.

Production Rate and Capacity

One bottle of Potable Aqua iodine tablets treats 25 liters (2 tablets per 1 liter of water).

Cleaning, Replacement, End of Life Indicator, Shelf Life

The manufacturer recommends a shelf life of 1 year if the bottle has been opened. A shelf life of up to 4 years is recommended for an unopened bottle. In general, the potency of the tablets can

be determined by their color. As the tablet deteriorates, the color changes. A fully effective tablet is steel gray. A 50% deteriorated tablet is white to yellowish brown, and a completely deteriorated tablet is deep brown.

Weight and Size

The weight of the Potable Aqua bottle is approximately 30 grams. The weight of the neutralizer bottle is approximately 30 grams. The approximate dimensions of each bottle are 5 cm x 2.5 cm.

Cost

Potable Aqua tablets alone cost approximately $5.00. Potable Aqua tablets and neutralizer tablets cost approximately $7.00.

Device Evaluation

Independent testing using the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1) has been conducted with Globaline (references 2 and 3). Because these are identical products, the results can be applied to Potable Aqua. Independent testing using the reference 1 protocol confirms Potable Aqua consistently provides a 6-log bacteria and 4-log virus reduction when used as directed. This testing also confirms that Potable Aqua does not consistently provide 3-log *Giardia* cyst and *Cryptosporidium* oocyst reduction when used as directed. Potable Aqua can provide a 3-log *Giarida* cyst inactivation when more than 60 minutes of wait time is provided. Potable Aqua™ tablets are not effective against *Cryptosporidium* oocysts. Additional treatment such as filtration with a 1 µm absolute filter to reduce *Cryptosporidium* oocysts is necessary. Potable Aqua is not expected to cause any adverse health effects when used by healthy adults with no pre-existing thyroid conditions or sensitivity to iodine. Potable Aqua is not recommended for use by pregnant women (concern for fetus), people with known hypersensitivity to iodine, people with a history (or family history) of thyroid disease, and people from areas with chronic iodine deficiency (reference 4). Iodine in Potable Aqua™ can cause a medicinal taste and color the water. The iodine can be neutralized by adding ascorbic acid (available with Potable Aqua) or sodium thiosulfate, which will improve the taste, odor, and color. Flavored drink mixes can mask the flavor. Neutralizers and flavor aids should not be added until after recommend contact times are achieved. Use of the Potable Aqua™ will not remove or reduce particulate matter.

Advantages

- Independent testing using the USEPA protocol confirms 6-log bacteria and 4-log virus reduction when used as directed.
- Very small and lightweight.
- Simple and inexpensive to use.
- No adverse health effects expected in healthy adults with no iodine sensitivity.

Disadvantages

- Not effective against *Cryptosporidium*. Additional treatment is necessary.
- Not consistently effective against *Giardia* cysts when used as directed. Recommend at least 45-60-minute contact time for adequate *Giardia* cyst reduction.
- Not recommended for use by pregnant women or people with iodine sensitivity.
- Does not reduce or remove particulate matter.
- Can impart color, medicinal taste, and odor.

References

1. U.S. Environmental Protection Agency, Registration Division Office of Pesticide Program, Criteria and Standards Division Office of Drinking Water. (1987). *Guide Standard and Protocol for Testing Microbiological Water Purifiers.* Washington, D.C.

2. U.S. Army Natick Research, Development, and Engineering Center. (1993). *Efficacy of Flocculating and Other Emergency Water Purification Tablets.* (NATICK/TR-93/033). Natick, MA. Prepared by Powers, E.M.

3. Gerba, C.P., Johnson, D.C., & Hasan, M.N. (1997). Efficacy of iodine water purification tablets against *Cryptosporidium* oocysts and *Giardia* cysts. *Wilderness and Environmental Medicine,* 8, 96-100.

4. U.S. Army Center for Health Promotion and Preventive Medicine. (2005). *Technical Information Paper; Iodine Disinfection in the Use of Individual Water Purification Devices,* Aberdeen Proving Ground, MD.

ANNEX 67 TO APPENDIX E

DEVICE EVALUATION #67
WISCONSIN PHARMACAL CO., LLC – POTABLE AQUA™

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Wisconsin Pharmacal Co., LLC – Potable Aqua™

www.pharmacalway.com

Device Information

Potable Aqua emergency drinking water germicidal tablets contain iodine. The manufacturer markets two products with Potable Aqua, one product consists of iodine tablets only; the other consists of iodine tablets and neutralizing tablets (ascorbic acid) that remove iodine taste, odor, and color. The manufacturer, Wisconsin Pharmacal, also produces Globaline™ for the U.S. Military, and Coghlan's Emergency Drinking Water Tablets™ for Coghlan's Ltd., which are identical to Potable Aqua. Fifty iodine tablets are packaged in a small bottle with a vinyl lined screw cap. The cap also has an adhesive seal that allows it to be reused to keep moisture from getting into the bottle. Directions for use require the addition of 2 tablets to 1 liter of water and cap loosely to allow a small amount of leakage. Wait 5 minutes. Shake the container to allow screw threads on the closure to be moistened then tighten cap. Wait 30 more minutes before drinking. If using neutralizing tablets, add 2 tablets to 1 liter only after the required wait time for the iodine tablets. Two iodine tablets result in a 16 mg/L iodine concentration in 1 liter. Potable Aqua is composed of tetraglycine hydroperiodide, sodium acid pyrophosphate and talc. The disinfection capabilities of iodine have long been recognized and it is widely used as an antiseptic and as an emergency drinking water disinfectant. The device should be stored in a cool dry place and tablets should be kept dry.

Effectiveness Against Microbial Pathogens

Independent testing using the U.S. Environmental Protection Agency (USEPA) Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1) has been conducted with Globaline (references 2 and 3). Because Globaline and Potable Aqua are identical products, the results can be applied to Potable Aqua. Independent testing using the reference 1 protocol confirms Potable Aqua consistently provides a 6-log bacteria and 4-log virus reduction when used as directed. This testing also confirms that Potable Aqua does not consistently provide

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™ Potable Aqua and Globaline are trademarks of Wisconsin Pharmacal Company, LLC, Jackson, WI.
™ Coghlan's Emergency Drinking Water Germicidal Tablets is a trademark of Coghlan's Ltd., Winnipeg, Canada. Use of a trademarked product does not imply endorsement by the U.S. Army, but is intended only in identification of a specific product

3-log *Giardia* cyst and *Cryptosporidium* oocyst reduction when used as directed. Potable Aqua, when used according to directions, provides a 16 mg/L iodine dosage and a 35-minute contact time resulting in a disinfectant concentration times contact time (CT) of 560 mg-min/L. Potable Aqua can provide a 3-log *Giarida* cyst inactivation when treating most water quality conditions if contact time is increased beyond the directed 35 minutes. Independent testing data using reference 1 indicated contact times of at least 60 minutes (CT = 960 mg-min/L) achieved a 3-log *Giardia* cyst inactivation (reference 2). Other iodine disinfection studies recommend a CT of at least 720 mg-min/L for a 3-log *Giardia* cyst inactivation (reference 4). To ensure a 3-log *Giardia* cyst inactivation when using Potable Aqua, provide at least a 45-60-minute contact time. A 3-log *Cryptosporidium* oocyst inactivation is not realistically achievable when using Potable Aqua. Additional treatment is necessary to remove or inactivate *Cryptosporidium* oocysts. Based on independent data testing the device under severe conditions required by the USEPA protocol, Potable Aqua is given three √s for effectiveness against bacteria and viruses, and an X for effectiveness against *Giardia* cysts and *Cryptosporidium* oocysts (for an explanation of the rating checks click here). The following table summarizes Potable Aqua's expected performance, evaluation rating, and the mechanism by which the pathogens are reduced:

Table. Expected Performance Against Microbial Pathogens When Used As Directed.

Microbial Pathogen Type	Expected Performance	Evaluation Rating	Inactivation/removal Mechanism
Bacteria	> 6-log	√√√	disinfection
Viruses	> 4-log	√√√	disinfection
Giardia cysts	Not Effective*	X*	-
Cryptosporidium oocysts	Not Effective	X	-

* Recommend at least 45-60 minutes contact time to ensure 3-log *Giardia* cyst inactivation.

Production Rate and Capacity

One bottle of Potable Aqua iodine tablets treats 25 liters (2 tablets per 1 liter of water).

Cleaning, Replacement, End of Life Indicator, Shelf Life

The manufacturer recommends a shelf life of 1 year if the bottle has been opened. A shelf life of up to 4 years is recommended for an unopened bottle. In general, the potency of the tablets can

be determined by their color. As the tablet deteriorates, the color changes. A fully effective tablet is steel gray. A 50% deteriorated tablet is white to yellowish brown, and a completely deteriorated tablet is deep brown.

Weight and Size

The weight of the Potable Aqua bottle is approximately 30 grams. The weight of the neutralizer bottle is approximately 30 grams. The approximate dimensions of each bottle are 5 cm x 2.5 cm.

Cost

Potable Aqua tablets alone cost approximately $5.00. Potable Aqua tablets and neutralizer tablets cost approximately $7.00.

Device Evaluation

Independent testing using the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1) has been conducted with Globaline (references 2 and 3). Because these are identical products, the results can be applied to Potable Aqua. Independent testing using the reference 1 protocol confirms Potable Aqua consistently provides a 6-log bacteria and 4-log virus reduction when used as directed. This testing also confirms that Potable Aqua does not consistently provide 3-log *Giardia* cyst and *Cryptosporidium* oocyst reduction when used as directed. Potable Aqua can provide a 3-log *Giarida* cyst inactivation when more than 60 minutes of wait time is provided. Potable Aqua™ tablets are not effective against *Cryptosporidium* oocysts. Additional treatment such as filtration with a 1 µm absolute filter to reduce *Cryptosporidium* oocysts is necessary. Potable Aqua is not expected to cause any adverse health effects when used by healthy adults with no pre-existing thyroid conditions or sensitivity to iodine. Potable Aqua is not recommended for use by pregnant women (concern for fetus), people with known hypersensitivity to iodine, people with a history (or family history) of thyroid disease, and people from areas with chronic iodine deficiency (reference 4). Iodine in Potable Aqua™ can cause a medicinal taste and color the water. The iodine can be neutralized by adding ascorbic acid (available with Potable Aqua) or sodium thiosulfate, which will improve the taste, odor, and color. Flavored drink mixes can mask the flavor. Neutralizers and flavor aids should not be added until after recommend contact times are achieved. Use of the Potable Aqua™ will not remove or reduce particulate matter.

Advantages

- Independent testing using the USEPA protocol confirms 6-log bacteria and 4-log virus reduction when used as directed.
- Very small and lightweight.
- Simple and inexpensive to use.
- No adverse health effects expected in healthy adults with no iodine sensitivity.

Disadvantages

- Not effective against *Cryptosporidium*. Additional treatment is necessary.
- Not consistently effective against *Giardia* cysts when used as directed. Recommend at least 45-60-minute contact time for adequate *Giardia* cyst reduction.
- Not recommended for use by pregnant women or people with iodine sensitivity.
- Does not reduce or remove particulate matter.
- Can impart color, medicinal taste, and odor.

References

1. U.S. Environmental Protection Agency, Registration Division Office of Pesticide Program, Criteria and Standards Division Office of Drinking Water. (1987). *Guide Standard and Protocol for Testing Microbiological Water Purifiers.* Washington, D.C.

2. U.S. Army Natick Research, Development, and Engineering Center. (1993). *Efficacy of Flocculating and Other Emergency Water Purification Tablets.* (NATICK/TR-93/033). Natick, MA. Prepared by Powers, E.M.

3. Gerba, C.P., Johnson, D.C., & Hasan, M.N. (1997). Efficacy of iodine water purification tablets against *Cryptosporidium* oocysts and *Giardia* cysts. *Wilderness and Environmental Medicine,* 8, 96-100.

4. U.S. Army Center for Health Promotion and Preventive Medicine. (2005). *Technical Information Paper; Iodine Disinfection in the Use of Individual Water Purification Devices,* Aberdeen Proving Ground, MD.

ANNEX 68 TO APPENDIX E

DEVICE EVALUATION #68
XINIX – XTREME WATER PURIFIER

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Xinix – Xtreme Water Purifier

www.xinix.com

Device Information

The Xinix Xtreme Water Purifier is a dilute chlorine dioxide solution. The device is marketed as a drinking water treatment, wound cleanser, and general sanitary hygiene practices (e.g., washing hands and utensils). The device is a single 5 mL bottle containing a 0.15% chlorine dioxide solution. The device is designed to treat 3 L of water, the size of a typical commercially available individual use water bladder (i.e., hydration system). The manufacturer's directions require the user to add the entire 5 mL bottle into 3 L of water to be treated. This results in an approximate chlorine dioxide dose of 2.5 mg/L. Mix and wait 15 minutes before drinking. Directions also state the water to be treated can be turbid but not dark.

Effectiveness Against Microbial Pathogens

Independent testing using the U.S. Environmental Protection Agency (USEPA) Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1) confirms this device's ability to consistently provide a 6-log bacteria, 4-log virus, and 3-log *Giardia* cyst reduction when used as directed (reference 2). When used as directed a corresponding disinfectant concentration times contact time (CT) of approximately 38 mg-min/L is provided. Based on the independent testing data using the reference 1 protocol and other chlorine dioxide disinfection studies, the CT provided should consistently provide adequate bacteria, virus, and *Giardia* cyst protection under most any water quality condition expected. The device will not consistently provide 3-log *Cryptosporidium* oocyst reduction when used as directed. Other device-specific testing data that did not use the reference 1 protocol showed the device was not capable of providing a 3-log *Cryptosporidium* oocyst reduction (reference 2). The USEPA proposed significantly higher CTs for a 3-log reduction of *Cryptosporidium* oocysts. For 5° C water, the USEPA recommends a CT of 1286 mg-min/L. These higher CT values are based on numerous chlorine dioxide disinfection experiments and take into account the variability and uncertainty of the data (reference 3). The device can provide protection against *Cryptosporidium* by greatly extending the wait time from 15 minutes to approximately 9 hours or by treating 1 L of water instead of 3 L and extending the wait time from 15 minutes to approximately 3 hours. This results in a CT of 1350 mg-min/L which, according to the USEPA, would ensure a 3-log *Cryptosporidium* reduction at 5° C and above. Waters less than 5° C would require even longer

wait times. Based on independent data testing the device under severe conditions required by the USEPA Protocol, the Xinix Xtreme Water Purifier is given three √s for effectiveness against bacteria, viruses, and *Giardia* cysts, and an X for *Cryptosporidium* oocysts (for an explanation of the rating checks click here). The following table summarizes Xinix's Xtreme Water Purifier expected performance, evaluation rating, and the mechanism by which pathogens are reduced:

Table. Expected Performance Against Microbial Pathogens When Used as Directed.

Microbial Pathogen Type	Expected Disinfection Capability	Evaluation Rating	Pathogen Reduction Mechanism
Bacteria	> 6-log	√√√	disinfection
Viruses	> 4-log	√√√	disinfection
Giardia cysts	> 3-log	√√√	disinfection
Cryptosporidium oocysts	Not Effective	X*	-

* Recommend extending the wait time to a minimum of 9 hours to help ensure adequate *Cryptosporidium* oocyst reduction. Or, treat 1 L of water with a minimum wait time of 3 hours. Waters less than 5° C would need an even longer wait time.

Production Capacity

One bottle of Xinix's Xtreme Water Purifier treats 3 liters.

Cleaning, Replacement, End of Life Indicator, Shelf Life

There is no expiration date or production date on the bottle. Based on discussions with the manufacturer, it is recommended that the product be used within 1 year of purchase (i.e., a shelf life of 1 year after), although that information is not provided on the bottle. Information on the bottle indicates the product is active when yellow. This means that the solution is effective when it is colored yellow. When the solution turns clear, there is no longer chlorine dioxide present, thus acting as an end of life indicator.

Weight and Size

The weight of the bottle is approximately 40 grams. The approximate dimensions of the bottle are 5.5 cm long x 2 cm diameter.

Cost

The device cost about $2.00.

Device Evaluation

Independent testing using the USEPA Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1) confirms the Xinix Xtreme Water Purifier met the minimum 6-, 4-, and 3-log reductions for bacteria, viruses, and *Giardia* cysts when used as directed (reference 2). This device is not capable of consistently reducing *Cryptosporidium* oocysts when used as directed. Extending the wait time to a minimum of 9 hours or treating 1 L of water with a minimum wait time of 3 hours should ensure adequate *Cryptosporidium* oocyst reduction. Waters colder than 5° C would require even longer wait time. Also, additional treatment such as a 1 µm absolute filter can adequately reduce *Cryptosporidium* oocysts. Since the directions that water to be treated can be turbid but not dark, some user subjectivity is required in the field to make this judgment. The use of chlorine dioxide in water treatment will produce chlorite, a byproduct of chlorine dioxide formed when chlorine dioxide reacts with organic matter in water (reference 4). Chlorine dioxide and chlorite can have serious adverse health effects for children, infants, and fetuses as a result of short-term exposure. But, no adverse health effects are expected for healthy adult individuals using this product for short periods of time and at manufacturer recommended dosages.

Advantages

- Independent testing confirms 6-log bacteria, 4-log virus, and 3-log *Giardia* cyst reduction when used as directed.
- Very small and lightweight.
- Simple and inexpensive to use.
- No adverse health effects expected in healthy adults from short-term use.

Disadvantages

- Not consistently effective against *Cryptosporidium* oocysts when used as directed. Extending wait time up to 9 hours will help ensure adequate *Cryptosporidium* reduction.
- Does not reduce or remove particulate matter.
- Some user subjectivity required.
- May cause adverse health effects in children, infants, and fetuses from short-term use.

References

1. USEPA, Registration Division Office of Pesticide Program, Criteria and Standards Division Office of Drinking Water. (1987). *Guide Standard and Protocol for Testing Microbiological Water Purifiers.* Washington, D.C.

2. Independent testing data provided by Xinix (2001, 2002).

3. Federal Register (2003). *National Primary Drinking Water Regulations: Long Term 2 Enhanced Surface Water Treatment Rule; Proposed Rule.* 68(154), 47640-47795.

4. U.S. Army Center for Health Promotion and Preventive Medicine. (2005). *Technical Information Paper; Chlorine Dioxide Disinfection in the Use of Individual Water Purification Devices,* Aberdeen Proving Ground, MD.

APPENDIX F

TIPs ON TREATMENT TECHNOLOGY USED IN IWPs

TIP #31-002-0306 – Chlorine Disinfection
TIP #31-003-0306 – Electrochemically Generated Oxidant Disinfection
TIP #31-004-0306 – Filtration
TIP #31-005-0306 – Iodine Disinfection
TIP #31-006-0306 – Ultraviolet Light Disinfection
TIP #31-007-0306 – Chlorine Dioxide Disinfection

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ANNEX 1 TO APPENDIX F

TIP #31-002-0306
CHLORINE DISINFECTION IN THE USE OF INDIVIDUAL WATER PURIFICATION DEVICES

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CHLORINE DISINFECTION IN THE USE OF INDIVIDUAL WATER PURIFICATION DEVICES

Technical Information Paper #31-002-0306

PURPOSE

This information paper provides an in-depth review of chlorine as a disinfectant in potable water supplies. This paper is intended to assist the reader in evaluating the disinfection capabilities of Individual Water Purification Devices (IWPDs) using chlorine to kill or inactivate disease-causing bacteria, viruses, and protozoan cysts.

REFERENCES

Appendix A contains a list of references.

INTRODUCTION

Background

Understanding the disinfection capabilities of chlorine to kill or inactivate disease-causing microorganisms is important in protecting Soldiers, who are considering using this technology, from acute health threats posed by these microorganisms. Soldiers deployed beyond traditional field drinking water supplies must have access to potable water. Using IWPDs is one way to provide potable water in these situations. These IWPDs must protect the Soldier from acute microbial health threats. The U.S. Environmental Protection Agency (USEPA) Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1) provides performance standards by which an IWPD using chlorine can be evaluated. The performance standards are a minimum 6-log reduction/inactivation of bacteria, 4-log reduction/inactivation of viruses, and 3-log reduction/inactivation of protozoan cysts. Chlorine-using IWPDs meeting these standards are considered effective against disease causing bacteria, viruses, and protozoan cysts. Some IWPD manufacturers test their devices using this protocol. This is the best way to evaluate the IWPDs disinfection capabilities. In the absence of that testing data, this information paper can be used to gain an understanding of chlorine disinfection capabilities and help determine if an IWPD using chlorine could successfully meet the EPA Guide's minimum performance standards.

General

Chlorine has long been identified as an effective and efficient disinfection agent. One-time, emergency chlorination of water supplies has been practiced for over 100 years, with the first continuous use of chlorine for water supply disinfection occurring in Boonton, New Jersey, in

1908 (references 2 and 3). Chlorine and its derivatives represent the most widespread compound used for disinfection in the United States. There are several Commercial-Off-The-Shelf (COTS) IWPDs that use chlorine for disinfection, including Chlor-Floc™, which was tested by an Army agency and found to be a safe alternative to iodine tablets (reference 4). These IWPDs may either rely on chlorine disinfection alone or combine chlorine disinfection with filtration to remove pathogenic organisms from water.

CHLORINE CHEMISTRY IN WATER.

General

Chlorine is added to water in one of three forms: elemental chlorine (chlorine gas), sodium hypochlorite solution or calcium hypochlorite powder, also called high-test hypochlorite (HTH). Chlorine gas reacts rapidly with water to form two compounds - hypochlorous acid (HOCl) and hydrochloric acid (HCl) as follows (reference 5):

Equation 1. $Cl_2 + H_2O \leftrightarrow HOCl + HCl \qquad K = 3.9 \times 10^4$ at 25˚C

The forward hydrolosis reaction is virtually complete at pH greater than 4 and chlorine solutions up to 100 mg/L (dilute solutions), as expected with the magnitude of the equilibrium constant (K) (reference 6). Hypochlorous acid, the active chlorine form in disinfection reactions, is a weak acid that further dissociates into two components, the hydrogen ion (H^+) and the hypochlorite ion (OCl^-), as follows (reference 5):

Equation 2. $HOCl \leftrightarrow H^+ + OCl^- \qquad K_a = 3.5 \times 10^{-8}$ at 25˚C

$pK_a = 7.5$

As shown in Figure 1, both HOCL and OCl^- species are present to some extent at pH values between 6.5 to 8.5 (reference 3), with equal distribution at pH 7.5 (reference 6). The dissociated hypochlorite ion (OCl^-) predominates at higher pH values, while the undissociated hypochlorous acid (HOCl) predominates at lower pH values. Hypochlorous acid is more reactive than the hypochlorite ion, and a much stronger disinfectant (reference 2). Thus, a lower water pH promotes more efficient disinfection. In general, a water pH of less than 8 is recommended for chlorine disinfection (reference 6). Chlorine will react with many naturally occurring organic compounds in water to produce undesirable disinfectant by-products (DBPs), which may have adverse effects generally associated with long-term exposure (reference 5). Two groups of DBP compounds, trihalomethanes (THMs) and haloacetic acids (HAAs), are currently regulated by the EPA.

™ Chlor-Floc is a trademark of Control Chemical, D/B/A Deatrick and Associates Inc., Alexandria, VA. Use of trademarked products does not imply endorsement by the U.S. Army, but is intended only in identification of a specific product.

Chlorine Demand

As a strong oxidant, chlorine will combine with many other substances, including ferrous iron, manganese, ammonia and other inorganic and organic material, in water (reference 7). In aqueous solutions with pH 7.0 to 8.5, HOCl reacts rapidly with ammonia to form inorganic chloramines (termed combined chlorine) in a series of competing reactions (reference 5). These reactions are instantaneous, with no appreciable disinfection occurring until this initial "chlorine demand" is met. Subsequent addition of chlorine will results in establishment of a free available chlorine [(FAC), which includes HOCl and OCl^-] residual. Figure 2 shows the "breakpoint chlorination" curve, which is unique for each water source. Thus, the chlorine dosage should be adequate to satisfy the chlorine demand of the source water, but not excessive beyond the breakpoint, as taste and odor problems may occur.

Figure 1. Distribution of Hypochlorous Acid/Hypochlorite versus pH

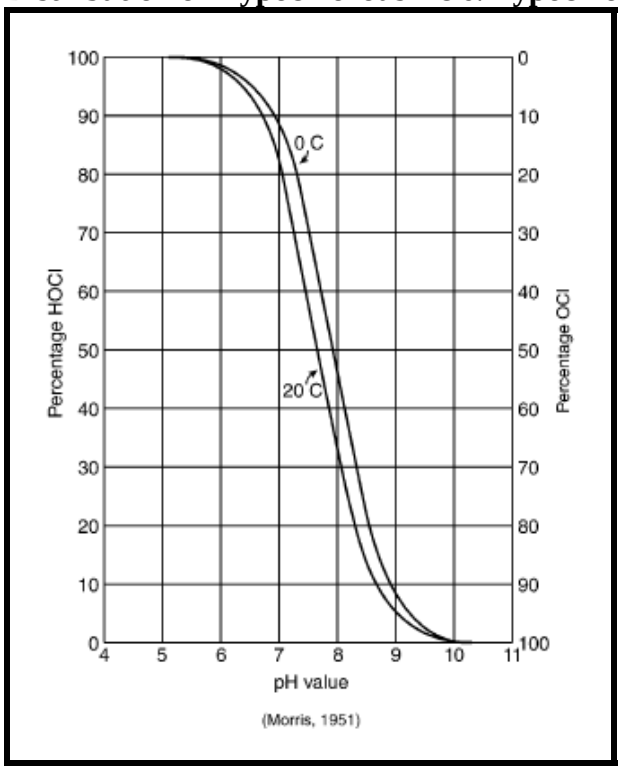
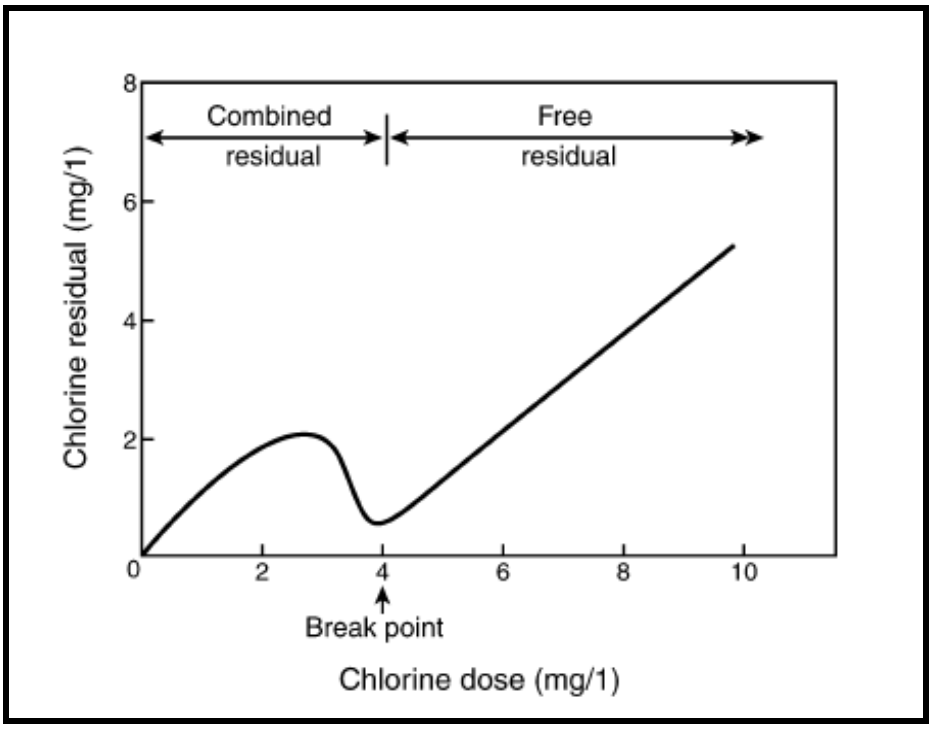


Figure 2. Breakpoint Chlorination Curve



IWPD Forms

General

Chlorine is available in various forms, including calcium hypochlorite (solid), sodium hypochlorite (solution) and as pure chlorine gas. For hand-held IWPDs, chlorine takes the form of either calcium hypochlorite tablets or sodium hypochlorite (including household bleaches). Calcium hypochlorite (chlorinated lime, tropical bleach, bleaching powder, 'HTH') is a powder containing between 30 and 70% available chlorine. It must be stored carefully to prevent deterioration, and although it can cause burns, is generally safe to handle and transport (reference 8). Sodium hypochlorite solutions contain about 1 to 18% chlorine and are thus mostly water. Sodium hypochlorite solution must be stored carefully to prevent deterioration and can cause burns (reference 8).

Chlorine Stabilizers

Ultraviolet rays in sunlight degrade free chlorine compounds in water and significantly decrease disinfection efficacy over time. Chlorine concentrations may be reduced by one-half when exposed to sunlight for only 1 hour (reference 9). To mitigate these effects, chlorinated

derivatives of cyanuric acid, termed isocyanurates, are used to prolong the lifetime of free chlorine in water that is exposed to sunlight. The isocyanurate compound, originally introduced for swimming pool chlorine sanitation in 1960, dissociates in water to form both cyanuric acid, which "stabilizes" free chlorine compounds, and hypochlorous acid, the active disinfectant (reference 9). Chlorine concentrations may be prolonged 3 to 10 times longer in water when cyanuric acid is present in sufficient quantities (reference 9). Studies have shown that cyanuric acid does not interfere with disinfection conditions (reference 10) at concentrations used in drinking water. Some chlorine-using IWPDs may use isocyanurates to prolong chlorine residual in the treated water.

DISINFECTION CAPABILITIES.

General

Chlorine is effective at inactivating bacteria and viruses, and under certain circumstances, *Giardia* (reference 5). However, chlorine has little impact on *Cryptosporidium* oocysts at typical water treatment concentrations (up to 5 mg/L) (reference 5). Chlorine's general disinfection capability with respect to microorganisms can be illustrated in the following way from most effective to least effective:

bacteria > viruses > *Giardia* cysts > *Cryptosporidium* oocysts

The rate of disinfection, or destruction, of microorganisms in water is generally described by the Chick-Watson law (Equation 3, references 11 and 12), which is the basis for the CT values widely used today to determine disinfectant germicidal efficiency. The CT factor is defined as the product of the residual disinfectant concentration (C, in mg/L) and the contact time (T, in minutes) that the residual disinfectant is in contact with the water.

Equation 3. $$\ln \frac{N}{N_0} = -\alpha C^n t$$

Where: N = number of microorganisms at time t
N_0 = initial number of microorganisms
α = inactivation constant
C = disinfectant concentration, moles/L
n = constant of dilution, usually close to 1.0
t = time, min

Chlorine's disinfection capability decreases with decreasing temperature and increasing pH. The EPA has published extensive CT tables for virus and *Giardia* inactivation, for different temperature, pH, and chlorine residual conditions (reference 13). Turbidity can also have

negative effects on chlorine disinfection because particles can shield microorganisms from chlorine. Turbidity particles also typically increase organic content, resulting in higher source water chlorine demand (reference 6).

Environmental Effects on Disinfection Capability

Effect of pH on Disinfection Capability

Since the germicidal efficiency of HOCl is much higher than that of OCl^-, as pH increases, the CT requirement for a given log-reduction increases. Most research has confirmed that chlorine is more biocidal at low, rather than high pH, and the pH effect is more profound for chlorine than other disinfectants, such as chlorine dioxide, ozone, and even combined chlorine (chloramines) (reference 5). Virus inactivation studies have shown that 50% more contact time is required at pH 7.0 than at pH 6.0 to achieve comparable inactivation, and that raising the pH from 7.0 to 9.0 requires a six-fold increase in contact time for comparable viral inactivation (references 5 and 14). However, some viruses have been shown to be more sensitive to chlorine at high, rather than low, pH (references 5 and 15). In these cases, the increased disinfection efficiency may be due to OCl^- forming neutral ion pairs with sodium, potassium, and lithium.

Effect of Temperature on Disinfection Capability

Temperature, over the range appropriate for drinking water, affects the rate of disinfection reactions according to the Arrhenius equation, with colder water slowing inactivation rates. For chlorine, and all other disinfectants, pathogen inactivation effectiveness increases as water temperature rises (reference 5). Additionally, for a given CT value, a low C and a high T is more effective than the reverse (i.e., a high C and a low T), underscoring the importance of temperature in disinfection efficacy (reference 5). Virus studies showed that the contact time must be increased by two to three times when the temperature is lowered by 10˚ C to achieve similar inactivation levels (reference 16).

Effect of Turbidity on Disinfection Capability

Particles responsible for turbidity can surround and shield pathogenic microorganisms from free chlorine, thus decreasing inactivation efficiency. One study investigated indigenous coliform bacteria associated with particulate matter and the protective effects that the particles may have in shielding disinfection. Using sieve and nylon screens to separate particle fractions, coliform bacteria associated with the < 7-µm fraction were inactivated more rapidly than the > 7-µm fraction when exposed to 0.5 mg/L free chlorine at pH 7.0 and 5˚ C (reference 17). The results showed the significance that particle agglomeration and clumping may have on chemical oxidation efficiency. Another study suggested that turbidity impacts on free chlorine disinfection efficiency are magnified at lower temperatures (reference 18). Free chlorine will rapidly oxidize organic matter associated with turbidity; reducing disinfection efficiency since a

free chlorine residual will only appear after all organic matter is oxidized. Thus, higher chlorine dosages may be necessary when using IWPDs to overcome organic matter oxidation and still provide disinfection when treating raw, unfiltered water supplies.

Bactericidal Efficiency

Chlorine is an extremely effective disinfectant for inactivating bacteria under normal conditions. A chlorine inactivation study of pathogenic *Escherichia coli* O157:H7E and wild-type *E. Coli* strains was conducted by the EPA (reference 19). The study showed that at a typical water treatment dosage of 1.1 mg/L FAC, pH 7.0, and 5˚ C, both pathogenic and wild-type *E. Coli* strains were inactivated by over 4½ orders of magnitude within 2 minutes (reference 19). The findings indicated that these bacteria were sensitive to chlorine. Certain spore-forming bacteria, such as *Bacillus* or *Clostridium*, may show higher resistance to free chlorine when disseminated as spores (reference 20). Early research in the 1940s involving *E. Coli, Pseudomonas aeruginosa, Salmonella typhi,* and *Shigella dysenteriae* showed that HOCl is more effective than OCl^- for inactivation of these bacteria (reference 21). Further research showed HOCl to be 70 to 80 times more effective than OCl^- for inactivating bacteria (references 5, 22). Highly turbid water may require higher CT (i.e., longer contact time and/or higher dose) to assure adequate bacteriological disinfection.

Virucidal Efficiency

Chlorine has been shown to be a highly effective viricide. One of the most comprehensive virus studies was conducted in 1971 using treated Potomac estuary water (references 5, 23). The tests were performed to determine the resistance of 20 different enteric viruses to free chlorine under constant conditions of 0.5 mg/L free chlorine residual, pH 7.8, and a temperature of 2° C. The study showed the least resistant virus to be reovirus, requiring only 2.7 minutes to achieve 99.99% inactivation (4-log removal). The most resistant virus was a poliovirus, requiring more than 60 minutes for 4-log removal. The CT range required for 4-log removal was 1.4 to 30 mg·min/L, indicating that adequate disinfection should occur with typical chlorine doses of up to 5 mg/L, depending on the chlorine demand of the source water (reference 23). Other viral survival studies were conducted in the 1970's on 20 cultures, including both laboratory and field poliovirus strains (references 5, 24) under constant conditions of 0.4 mg/L free chlorine residual, pH 7.0, and a temperature of 5˚ C. Test results showed that only two poliovirus strains required 10 minutes to achieve 4-log inactivation (CT = 4 mg·min/L), six poliovirus strains required 100 minutes to reached 4-log inactivation (CT = 40 mg·min/L), and 12 polioviruses strains required 1,000 minutes to reach 4-log inactivation (CT = 400 mg·min/L). Thus, higher FAC levels (> 0.4 mg/L) may be needed for shorter contact times to ensure 4-log viral inactivation. The SWTR provides the CT values for 4-log inactivation at various source water temperatures with a typical source water pH range of 6-9 (reference 13). Because of chlorine's

high efficiency in viral inactivation, CT values are typically governed by *Giardia* (protozoan) CT criteria. Highly turbid water may require higher CT (i.e., longer contact time and/or higher dose) to assure adequate viral disinfection.

Table 1. USEPA SWTR Required CT Values for 4-Log Inactivation of Viruses By Free Chlorine for pH 6-9

Temperature (deg C)					
0.5	**5**	**10**	**15**	**20**	**25**
12	8	6	4	3	2

Cysticidal Efficiency

Giardia cysts

Chlorine has been shown to have limited success inactivating protozoa. Protozoan cysts such as *Entamoeba histolytica* and *Giardia lamblia* are highly resistant to chlorine disinfection and may require prolonged contact times at high chlorine residuals (2-3 mg/l) to achieve 99.9% (3-log) inactivation (reference 20). Past studies have shown that, at 2.5 mg/L free chlorine at 5˚ C and pH 6, a contact time of 30 minutes was needed to achieve a 2-log reduction; 60 minutes was needed when the pH was increased to 7 (reference 25). Comparative studies have shown the resistance of *Giardia* cysts to chlorine inactivation to be two orders of magnitude higher than that of enteroviruses and more than 3 orders of magnitude higher than enteric bacteria (references 5, 26). Extensive CT requirements for *Giardia* cyst inactivation when using free chlorine have been determined for various pH and temperature conditions (reference 13), and are included in Appendix B. A mathematical model for 99.9% (3-log) *Giardia* inactivation was also developed based infectivity data (reference 27):

Equation 4. $CT = 0.75 (0.9847\ C^{0.1758}\ pH^{2.7519}\ temp^{-0.1467})$

where:
C = the disinfectant residual concentration
temp = the reaction temperature in degrees Celsius

Equation 4 should generally be used under the conditions it was derived: C between 0.44 and 4.23 mg/L; pH between 6 and 8; and temperature between 0.5 and 5˚ C. However, the CT result would be conservative (more protective) for lower pH values and higher temperatures. The CT result from Equation 4 may be adjusted for higher temperatures by assuming that for each 10˚C increase in temperature, the CT decreases by 0.5 (reference 27).

Cryptosporidium Oocysts

Chlorine is not effective for the inactivation of *Cryptosporidium* oocysts at typical water treatment doses (e.g., 5 mg/L). One *Cryptosporidium* study reported that 80 mg/l of free chlorine required 90 minutes to achieve only a 1-log (90%) inactivation of oocysts, and further indicated that conventional disinfection practices would do little to inactivate waterborne *Cryptosporidium* (references 28, 20). Another study showed a 40% (0.2-log) inactivation of *Cryptosporidium* at CT values of both 30 and 3,600 mg·min/L (references 29 and 5). A 1996 study showed no significant *Cryptosporidium* inactivation with free chlorine concentrations ranging from 5 to 80 mg/L at pH 8, a temperature of 22° C, and contact times of 48 to 245 minutes (references 30, 5). The study also reported that, at pH 6.0 and temperature of 22° C, a 1-log *Cryptosporidium* inactivation required a CT of between 3,000 and 4,000 mg·min/L, and a 3-log *Cryptosporidium* inactivation required exposure to 80 mg/L of free chlorine for 120 minutes (references 30 and 5). Therefore, IWPDs using only chlorine disinfection for treatment (i.e., without filtration) should not be relied upon for protection from *Cryptosporidium* contamination. The EPA has not adopted CT tables for *Cryptosporidium* in the proposed Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR), choosing instead to concentrate on tighter source protection and more effective *Cryptosporidium* disinfectants, such as chlorine dioxide and ozone (reference 31).

CHLORINE TOXICITY

When added to water, chlorine reacts with natural organic matter in water to form disinfection by-products. Ingestion of chlorine and its halogenated by-products, including THMs and HAAs, can result in adverse health effects when consumed in large enough quantities for long periods of time. The EPA regulates chlorine, total trihalomethane (TTHMs) and (the sum of) five HAAs (HAA5) in drinking water systems that use chlorine for disinfection. The EPA established a maximum residual disinfectant level (MRDL) of 4.0 mg/L for chlorine and maximum contaminant levels (MCLs) of 0.80 and 0.60 mg/L for TTHM and HAA5 compounds, respectively (reference 32). Potential health effects from ingestion of water containing free chlorine above 4.0 mg/L include eye, nose and throat irritation, stomach discomfort, nausea and vomiting. Evidence from animal and human studies suggests that chlorine and hypochlorite solutions themselves probably do not contribute to the development of cancer or any toxic effects (reference 33). Potential health effects from ingestion of water with elevated levels of TTHMs over a long period of time include liver, kidney or central nervous system problems, as well as the increased risk of cancer. Some studies also show an association between high levels of TTHMs and an increased risk of early term miscarriage (references 31 and 33). Potential health effects from ingestion of water with elevated levels of HAA5 compounds over a long period of time include the increased risk of cancer (reference 31). Generally, short-term exposure to elevated levels of THMs and HAAs for healthy adults does not result in adverse health effects (reference 34). For IWPD use, the risk of illness and death resulting from exposure to pathogens in drinking water is very much greater than the risks from chlorine and its DBPs (reference 34).

However, manufacturer recommended chlorine dosages should be followed to minimize the potential for DBP formation and exposure. Toxicity studies of cyanuric acid, the stabilizing compound in isocyanurates, have shown no carcinogenic, mutagenic or teratogenic effects, even at levels considerably above those typically found in drinking water (reference 35).

CONCLUSIONS

Chlorine as an IWPD is effective at inactivating bacteria and viruses, and under certain circumstances, *Giardia*. However, chlorine has little impact on *Cryptosporidium* oocysts at typical water treatment concentrations. Individual Water Purification Devices using only chlorine disinfection for treatment (i.e., without filtration) should not be relied upon for protection from *Cryptosporidium* contamination. Colder temperatures, higher pHs, and higher turbidities all tend to have an adverse effect on disinfection capability. Generally, short-term exposure to chlorine DBPs at IWPD manufacturer-recommended chlorine dosages of up to 5 mg/L should not result in adverse health effects. To avoid potential adverse health effects, longer contact times should be used in place of higher chlorine dosages, provided sufficient free available chlorine remains after oxidizing organic matter. Some chlorine-using IWPDs may use isocyanurates to prolong chlorine residual in the treated water. Toxicity studies involving isocyanurate compounds have not shown any adverse human health effects at typical drinking water concentrations. Table 2 provides a summary of the disinfection capabilities of chlorine.

Table 2. Chlorine Disinfection Capabilities

Parameter	Chlorine Disinfection
General Disinfection Capability	Cysts most resistant. Achieving cyst inactivation will ensure adequate bacteria and virus inactivation. Disinfection capability generally follows: Bacteria > Viruses > *Giardia* > *Cryptosporidium*
Bacteria	Effective at reasonable CT values for IWPD use.
Viruses	Effective at reasonable CT values for IWPD use. Use EPA SWTR CT table for recommended CT values (Table 1).
Giardia Cysts	Effective at reasonable CT values for IWPD use. Use EPA SWTR CT tables for recommended CT values (Appendix B).
Cryptosporidium Oocysts	Ineffective, even at high CT values. Not practical for IWPD use.
Effect of Temperature	Colder water temperatures require higher CT values. Use a two-fold increase in CT for every 10˚C decrease. Use longer contact time instead of higher dosages to achieve higher CT values.
Effect of pH	Disinfection efficiency increases with decreasing pH. Recommend pH less than 8.0 to ensure presence of hypochlorous acid (HOCl)
Effect of Turbidity	Higher turbidity generally reduces disinfection capability. Higher dosages may be necessary to ensure the presence of free chlorine after oxidation of organic matter.
Health Effects	Chlorine, THMs and HAAs have potential health concerns at elevated levels. IWPD manufacturer-recommended dosages are not likely to cause adverse health effects for healthy adults.

PREPARED BY: Brian C. Pickard, Environmental Engineer

DATED: March 2006

APPENDIX A
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APPENDIX B
CT VALUES FOR INACTIVATION OF *GIARDIA* CYSTS BY FREE CHLORINE

Table B-1. EPA SWTR Required CT Values for 3-Log Inactivation of *Giardia* By Free Chlorine at 0.5 degrees Celsius of Lower

pH	Chlorine Concentration (mg/L)													
	≤ 0.4	**0.6**	**0.8**	**1**	**1.2**	**1.4**	**1.6**	**1.8**	**2**	**2.2**	**2.4**	**2.6**	**2.8**	**3**
≤ 6	137	141	145	148	152	155	157	162	165	169	172	175	178	181
6.5	163	168	172	176	180	184	189	193	197	201	205	209	213	217
7.0	195	200	205	210	215	221	226	231	236	242	247	252	257	261
7.5	237	239	246	253	259	266	273	279	286	297	298	304	310	316
8.0	277	286	295	304	313	321	329	338	346	353	361	368	375	382
8.5	329	342	354	365	376	387	397	407	417	426	435	444	452	460
≤ 9.0	390	407	422	437	451	464	477	489	500	511	522	533	543	552

Table B-2. EPA SWTR Required CT Values for 3-Log Inactivation of *Giardia* By Free Chlorine at 5 degrees Celsius

pH	Chlorine Concentration (mg/L)													
	≤ 0.4	**0.6**	**0.8**	**1**	**1.2**	**1.4**	**1.6**	**1.8**	**2**	**2.2**	**2.4**	**2.6**	**2.8**	**3**
≤ 6	97	100	103	105	107	109	111	114	116	118	120	122	124	126
6.5	117	120	122	125	127	130	132	135	138	140	143	146	148	151
7.0	139	143	146	149	152	155	158	162	165	169	172	175	178	182
7.5	166	171	175	179	183	187	192	196	200	204	209	213	217	221
8.0	198	204	210	216	221	227	232	238	243	248	253	258	263	268
8.5	236	244	252	260	267	274	281	287	294	300	306	312	318	324
≤ 9.0	279	291	301	312	320	329	337	345	353	361	368	375	382	389

Table B-3. EPA SWTR Required CT Values for 3-Log Inactivation of *Giardia* By Free Chlorine at 10 degrees Celsius

pH	Chlorine Concentration (mg/L)													
	≤ 0.4	**0.6**	**0.8**	**1**	**1.2**	**1.4**	**1.6**	**1.8**	**2**	**2.2**	**2.4**	**2.6**	**2.8**	**3**
≤ 6	73	75	78	79	80	82	83	86	87	89	90	92	93	95
6.5	88	90	92	94	95	98	99	101	104	105	107	110	111	113
7.0	104	107	110	112	114	116	119	122	124	127	129	131	134	137
7.5	125	128	131	134	137	140	144	147	150	153	157	160	163	166
8.0	149	153	158	162	166	170	174	179	182	186	190	194	197	201
8.5	177	183	189	195	200	206	211	215	221	225	230	234	239	243
≤ 9.0	209	218	226	234	240	247	253	259	265	271	276	281	287	292

Table B-4. EPA SWTR Required CT Values for 3-Log Inactivation of *Giardia* By Free Chlorine at 15 degrees Celsius

pH	Chlorine Concentration (mg/L)													
	≤ 0.4	**0.6**	**0.8**	**1**	**1.2**	**1.4**	**1.6**	**1.8**	**2**	**2.2**	**2.4**	**2.6**	**2.8**	**3**
≤ 6	49	50	52	53	54	55	56	57	58	59	60	61	62	63
6.5	59	60	61	63	64	65	66	68	69	70	72	73	74	76
7.0	70	72	73	75	76	78	79	81	83	85	86	88	89	91
7.5	83	86	88	90	92	94	96	98	100	102	105	107	109	111
8.0	99	102	105	108	111	114	116	119	122	124	127	129	132	134
8.5	118	122	126	130	134	137	141	144	147	150	153	156	159	162
≤ 9.0	140	146	151	156	160	165	169	173	177	181	184	188	191	195

Table B-5. EPA SWTR Required CT Values for 3-Log Inactivation of *Giardia* By Free Chlorine at 20 degrees Celsius

pH	Chlorine Concentration (mg/L)													
	≤ 0.4	0.6	0.8	1	1.2	1.4	1.6	1.8	2	2.2	2.4	2.6	2.8	3
≤ 6	36	38	39	39	40	41	42	43	44	44	45	46	47	47
6.5	44	45	46	47	48	49	50	51	52	53	54	55	56	57
7.0	52	54	55	56	57	58	59	61	62	63	65	66	67	68
7.5	62	64	66	67	69	70	72	74	75	77	78	80	81	83
8.0	74	77	79	81	83	85	87	89	91	93	95	97	99	101
8.5	89	92	95	98	100	103	105	108	110	113	115	117	119	122
≤ 9.0	105	109	113	117	120	123	126	129	132	135	138	141	143	146

Table B-6. EPA SWTR Required CT Values for 3-Log Inactivation of *Giardia* By Free Chlorine at 25 degrees Celsius

pH	Chlorine Concentration (mg/L)													
	≤ 0.4	**0.6**	**0.8**	**1**	**1.2**	**1.4**	**1.6**	**1.8**	**2**	**2.2**	**2.4**	**2.6**	**2.8**	**3**
≤ 6	24	25	26	26	27	27	28	29	29	30	30	31	31	32
6.5	29	30	31	31	32	33	33	34	35	35	36	37	37	38
7.0	35	36	37	37	38	39	40	41	41	42	43	44	45	46
7.5	42	43	44	45	46	47	48	49	50	51	52	53	54	55
8.0	50	51	53	54	55	57	58	60	61	62	63	65	66	67
8.5	59	61	63	65	67	69	70	72	74	75	77	78	80	81
9.0	70	73	75	78	80	82	84	86	88	90	92	94	96	97

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ANNEX 2 TO APPENDIX F

TIP #31-003-0306
ELECTROCHEMICALLY GENERATED OXIDANT DISINFECTION IN THE USE OF INDIVIDUAL WATER PURIFICATION DEVICES

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Electrochemically Generated Oxidant Disinfection in the Use of Individual Water Purification Devices

Technical Information Paper #31-003-0306

PURPOSE

This information paper provides an in-depth review of on-site electrochemically generated oxidants (EGO) as a disinfectant in potable water supplies. This paper is intended to assist the reader in evaluating the disinfection capabilities of Individual Water Purification Devices (IWPDs) using EGO to kill or inactivate disease-causing bacteria, viruses, and protozoan cysts.

REFERENCES

Appendix A contains a list of references.

INTRODUCTION

Background

Understanding the disinfection capabilities of EGO to kill or inactivate disease-causing microorganisms is important in protecting Soldiers, who are considering using this technology, from acute health threats posed by these microorganisms. Soldiers deployed beyond traditional field drinking water supplies must have access to microbiologically safe water. Using IWPDs is one way to provide microbiologically safe water in these situations. These IWPDs must protect the Soldier from acute microbial health threats. The U.S. Environmental Protection Agency (EPA) Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1) provides performance standards by which an IWPD using EGO can be evaluated. The performance standards are a minimum 6-log reduction/inactivation of bacteria, 4-log reduction/inactivation of viruses, and 3-log reduction/inactivation of protozoan cysts (typically *Giardia* or *Cryptosporidium*). EGO-using IWPDs meeting these standards are considered effective against disease causing bacteria, viruses, and protozoan cysts. Some IWPD manufacturers test their devices using this protocol. This is the best way to evaluate the IWPDs disinfection capabilities. In the absence of that testing data, this information paper can be used to gain an understanding of EGO disinfection capabilities and help determine if an IWPD using EGO technology could successfully meet the EPA Guide's minimum performance standards.

General

Electrochemically generated oxidant technology is well established. The technology dates back to the 1930's when it was primarily used for the disinfection of swimming pools (reference 2). Additionally, it is also extensively used in the wastewater and drinking water industries and has

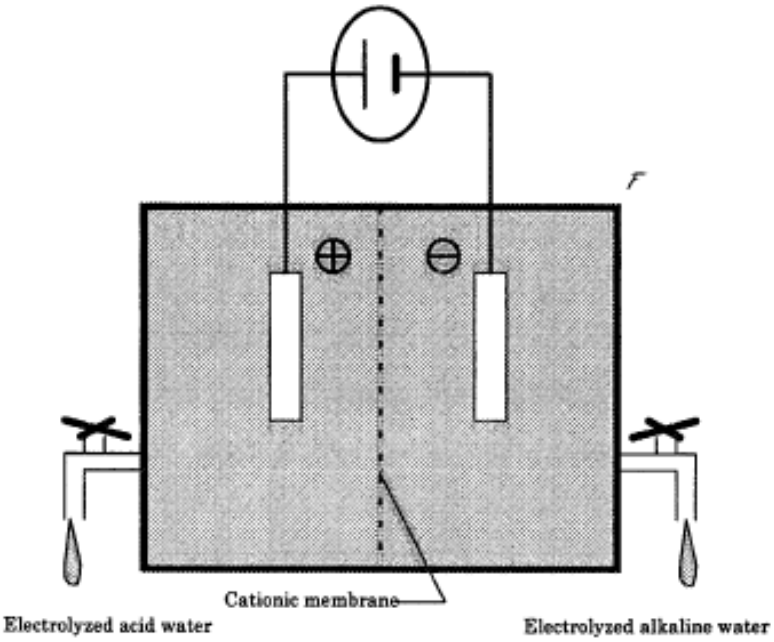
more recently been utilized in the food and agricultural industry (reference 3). Currently, there is only one Commercial-Off-The-Shelf (COTS) IWPD product using EGO technology.

ELECTROCHEMICALLY GENERATED OXIDANT CHEMISTRY

Electrochemically Generated Oxidant Production

In the simplest sense, EGO is formed by passing an electric current through a brine (NaCl) solution to produce oxidants to be used for disinfection. A reaction cell (also called an electrolytic cell) is where oxidant production occurs. In this cell, filled with a brine solution, are two electrodes (an anode and a cathode). When a voltage is applied between the electrodes, oxidant is produced. There are two basic types of EGO generators (reference 4). The most frequently employed is a two-cell EGO generator in which the anode and cathode are separated by a cationic membrane. A schematic of a two-cell EGO generator is shown in Figure 1. This type of EGO generator produces two solutions, one a low pH, high oxidant concentration solution from the cell containing the anode and a high pH, low oxidant solution from the cell containing the cathode. The second type of EGO generator contains both the anode and cathode in a single reaction cell without a cationic membrane. The current COTS IWPD device uses the single cell EGO generator technology. The oxidant concentration is a function of the voltage applied between the electrodes and the salt (brine) concentration and quality. Higher currents and voltage will produce a stronger oxidant solution and food grade salt is preferred to optimize oxidant generation (references 2 and 5). There are several different EGO generator manufacturers and their reaction cells and operation requirements all differ. However, in general a wide range of salt solution and voltages are capable of producing adequate oxidants.

Figure 1. Schematic of a Two-Cell EGO Generator.



Source: Reference 4.

Oxidant Composition

The primary oxidant formed using EGO technology is chlorine in the form of hypochlorous acid, HOCl. It has been suggested that oxidants other than chlorine are produced by this technology such as ozone, chlorine dioxide, hydrogen peroxide, and hydroxyl radicals (reference 6). However, it has been clearly demonstrated in several studies that chlorine is the primary oxidant produced and other oxidants have not been measured at detectable levels (references 7-9).

DISINFECTION CAPABILITIES

General

Because the primary oxidant formed is chlorine, disinfection capabilities are similar, if not identical, to traditional chlorine solutions (i.e., solutions made from sodium hypochlorite, calcium hypochlorite, and chlorine gas). In the majority of research conducted on EGO disinfection effectiveness, the impacts of pH, turbidity, and temperature on disinfection effectiveness are similar to chlorine solutions. The disinfection capabilities of chlorine and the environmental effects on chlorine are well documented in the U.S. Army Center for Health Promotion and Preventive Medicine's (USACHPPM) Chlorine Disinfection Technical

Information Paper and are summarized in Table 1 (reference 10). Because chlorine is the primary oxidant produced in EGO technology, this reference will provide the reader with a general understanding of the disinfection effectiveness of the EGO solutions. However, there are also studies suggesting that EGO technology produces a more effective disinfectant than typical chlorine solutions under the same conditions. The following discussion provides information from studies indicating EGO is more effective than typical chlorine solutions.

Disinfection Effectiveness Compared to Chlorine Solutions

Several studies were conducted comparing the disinfection effectiveness of EGO solutions to typical chlorine solutions. Results were variable. In all cases EGO solutions were as effective or more effective than a chlorine solution as a biocide. One study showed a sodium hypochlorite solution was less effective than EGO when tested at the same chlorine concentration and water quality characteristics (reference 12). This study showed that a sodium hypochlorite solution needed 2-3 times greater CTs (disinfectant concentration times contact time) to achieve the same log inactivations as an EGO solution for various bacteria. The CT is the product of disinfectant concentration (C in mg/L) and contact time (T in min). The CT product is a useful way for comparing alternative disinfectants and the resistance of various pathogens (reference 21). Another study showed an EGO solution provided a 3-log *Cryptosporidium* reduction with CTs of 75 mg-min/L, while a chlorine solution under the same conditions showed no *Cryptosporidium* reduction with a CT of 225 mg-min/L (reference 13). In contrast, other studies showed EGO solutions to be similar in disinfection effectiveness as chlorine. One study showed that chlorine solutions matched to the properties of EGO solutions were generally as effective as the EGO solutions in inactivating various pathogenic bacteria (reference 14). Another study showed similar inactivation results of pathogenic bacteria between chlorine solutions and EGO solutions (reference 15). There is also contrasting research between the EGO solutions. In disinfection studies, the general assumption is that greater CTs result in greater disinfection efficacy (i.e., greater log inactivation). However, available research shows EGO solutions with lower chlorine concentrations (i.e., lower CTs) have resulted in greater log inactivations than EGO solutions with higher chlorine concentrations (i.e., higher CTs) (references 12 and 13). Available research indicates variability in effectiveness of EGO solutions compared to chlorine solutions as well as variability in the effectiveness of similar EGO solutions. Therefore, it is difficult to predict the disinfection effectiveness of EGO solutions.

Cryptosporidium Oocyst Disinfection

Some manufacturers and vendors market EGO technology's ability to inactivate *Cryptosporidium* as a significant advantage over using typical chlorine solutions. It is well established that chlorine, as it is used in drinking water treatment, is not effective at inactivating *Cryptosporidium* oocysts (reference 10). As previously discussed, some research has shown that EGO technology can inactivate *Cryptosporidium* oocysts more effectively (i.e., at lower CTs) than chlorine solutions. However, due to contrasting research, the variable and unpredictable

Table 1. Chlorine Disinfection Capabilities (reference 10)

Parameter	Chlorine Disinfection
General Disinfection Capability	Cysts most resistant. Achieving cyst inactivation will ensure adequate bacteria and virus inactivation. Disinfection capability generally follows: Bacteria > Viruses > *Giardia* > *Cryptosporidium*
Bacteria	Effective at reasonable CT values for IWPD use.
Viruses	Effective at reasonable CT values for IWPD use. Use EPA SWTR CT table for recommended CT values (reference 11).
Giardia Cysts	Effective at reasonable CT values for IWPD use. Use EPA SWTR CT tables for recommended CT values (reference 11).
Cryptosporidium Oocysts	Ineffective, even at high CT values. Not practical for IWPD use.
Effect of Temperature	Colder water temperatures require higher CT values. Use a two-fold increase in CT for every 10˚ C decrease. Use longer contact time instead of higher dosages to achieve higher CT values.
Effect of pH	Disinfection efficiency increases with decreasing pH. Recommend pH less than 8.0 to ensure presence of hypochlorous acid (HOCl)
Effect of Turbidity	Higher turbidity generally reduces disinfection capability. Higher dosages may be necessary to ensure the presence of free chlorine after oxidation of organic matter.
Health Effects	Chlorine, THMs and HAAs have potential health concerns at elevated levels. IWPD manufacturer-recommended dosages are not likely to cause adverse health effects for healthy adults.

disinfection effectiveness of EGO technology suggests that EGO technology should not be relied upon to consistently provide adequate *Cryptosporidium* inactivation. Using EGO technology as an IWPD should be considered to be as effective as chlorine and, therefore, can be effective against bacteria, viruses, and *Giardia* cysts. Based on available research, EGO technology has the potential to be effective against *Cryptosporidium* oocysts, but because of the disinfection variability shown by the research, EGO technology should not be considered consistently effective against *Cryptosporidium*.

Explanation for Variable Disinfection Effectiveness

Currently, there are no proven explanations for the variable and unpredictable disinfection effectiveness of EGO technology. The most common hypothesis by authors of studies showing EGO technology's variability and unpredictability is that oxidants other than chlorine (e.g., ozone, chlorine dioxide, etc.) are generated at variable concentrations and are short-lived (references 12, 13, and 16). However, it has been thoroughly demonstrated in other studies that there is no appreciable formation of oxidants other than chlorine (references 7-9).

EGO SOLUTION TOXICITY

Because the primary oxidant generated by EGO technology is chlorine, toxicity concerns are similar to those for typical chlorine solutions. When added to water, the chlorine in the EGO solution reacts with natural organic matter to primarily form trihalomethane (THM) and haloacetic acid (HAA) disinfection by-products (DBPs). Ingestion of chlorine and its halogenated by-products, including THMs and HAAs, can result in adverse health effects when consumed in large enough quantities for long periods of time. The EPA regulates chlorine, total trihalomethanes (TTHMs) and (the sum of) five HAAs (HAA5) in drinking water systems that use chlorine for disinfection. The EPA established a maximum residual disinfectant level of 4.0 mg/L for chlorine and maximum contaminant levels of 0.80 and 0.60 mg/L for TTHM and HAA5 compounds, respectively (reference 17). Potential health effects from ingestion of water containing free chlorine above 4.0 mg/L include eye, nose and throat irritation, stomach discomfort, nausea and vomiting. Evidence from animal and human studies suggests that chlorine and hypochlorite solutions themselves probably do not contribute to the development of cancer or any toxic effects (reference 18). Potential health effects from ingestion of water with elevated levels of TTHMs over a long period of time include liver, kidney or central nervous system problems, as well as the increased risk of cancer. Some studies also show an association between high levels of TTHMs and an increased risk of early term miscarriage (references 17-19). Potential health effects from ingestion of water with elevated levels of HAA5 compounds over a long period of time include the increased risk of cancer (reference 19). Generally, short term exposure to elevated levels THMs and HAAs for healthy adults does not result in adverse health effects (reference 20). For IWPD use, the risk of illness and death resulting from

exposure to pathogens in drinking water is very much greater than the risks from chlorine and its DBPs (reference 20). However, manufacturer recommended EGO dosages should be followed to minimize the potential for DBP formation and exposure.

CONCLUSIONS

The use of EGO technology results in the production of primarily a chlorine disinfectant. For this reason an EGO solution, in general, has the same disinfection effectiveness and experiences the same impact of environmental effects on disinfection effectiveness as typical chlorine solutions. Research shows the disinfection effectiveness of EGO solutions to be variable and unpredictable. In general, the disinfection effectiveness of EGO solutions is as effective, or can be more effective, than typical chlorine solutions. Using EGO technology as an IWPD should be considered to be as effective as chlorine and, therefore, can be effective against bacteria, viruses, and *Giardia* cysts. Based on available research EGO technology has the potential to be effective against *Cryptosporidium* oocysts, but because of the disinfection variability shown by the research, EGO technology should not be considered consistently effective against *Cryptosporidium*. Generally, short term exposure to elevated levels of THMs and HAAs for healthy adults does not result in adverse health effects. For IWPD use, the risk of illness and death resulting from exposure to pathogens in drinking water is very much greater than the risks from exposure to chlorine and its DBPs. However, manufacturer recommended EGO dosages should be followed to minimize the potential for DBP formation and exposure. Table 2 provides a summary of the disinfection capabilities of EGO Solutions.

Table 2. Summary of Disinfection Capabilities of EGO Solutions.

Parameter	EGO Solutions
General	As effective or can be more effective than chlorine. Disinfection capability generally follows: Bacteria > Viruses > *Giardia* > *Cryptosporidium*
Bacteria	Effective
Viruses	Effective
Giardia Cysts	Like chlorine, consider providing additional contact time beyond IWPD manufacturer recommended CTs.
Cryptosporidium Oocysts	Effectiveness is variable and unpredictable. Considered not consistently effective...
Effect of Temperature	Like chlorine, colder temperatures can reduce effectiveness. Higher CTs will ensure for colder temperatures increases effectiveness.
Effect of pH	Like chlorine, higher pH decreases effectiveness. pH less than 8.0 ensures presence of the most effective chlorine species, hypochlorous acid (HOCl).
Effect of Turbidity	Like chlorine, higher turbidity reduces effectiveness. Higher dosages may be necessary to ensure effectiveness.

PREPARED BY: Steven H. Clarke, Environmental Engineer

DATED: March 2006

APPENDIX A
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ANNEX 3 TO APPENDIX F

TIP #31-004-0306
FILTRATION IN THE USE OF INDIVIDUAL WATER PURIFICATION DEVICES

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Filtration in the Use of Individual Water Purification Devices

Technical Information Paper #31-004-0306

PURPOSE

This information paper provides an in-depth review of filtration (including adsorption and ion exchange) as a pathogen and particulate reduction mechanism when treating natural waters. This paper is intended to assist the reader in evaluating the capabilities of Individual Water Purification Devices (IWPDs) using size exclusion, adsorption, and/or ion exchange to reduce disease-causing bacteria, virus, and protozoan cyst populations, as well as turbidity causing particulate matter.

REFERENCES

Appendix A contains a list of references.

INTRODUCTION

Background

Understanding the ability of filtration to reduce disease-causing microorganisms is important in protecting Soldiers, who are considering using this technology, from acute health threats posed by these microorganisms. Soldiers deployed beyond traditional field drinking water supplies must have access to potable water. Using IWPDs is one way to provide microbiologically safe water in these situations. These IWPDs must protect the Soldier from acute microbial health threats. The U.S. Environmental Protection Agency (EPA) Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1) provides performance standards by which an IWPD using filtration can be evaluated. The performance standards are a minimum 6-log reduction/inactivation of bacteria, 4-log reduction/inactivation of viruses, and 3-log reduction/ inactivation of protozoan cysts (typically *Giardia* or *Cryptosporidium*). IWPDs meeting these standards are considered effective at reducing disease causing bacteria, viruses, and protozoan cysts. Some IWPD manufacturers test their devices using this protocol. This is considered the best way to evaluate the IWPDs pathogen reduction capabilities. In the absence of that testing data, this information paper can be used to gain an understanding of the advantages as well as limitations of filtration and help determine if an IWPD using filtration could successfully meet the EPA Guide's minimum performance standards.

Origin of Filtration for Water Treatment

For the purpose of this paper, filtration will be used broadly to incorporate separation by (1) granular media, (2) size exclusion (e.g., membranes), (3) electrochemical adsorption (e.g., activated carbon), and (4) ion exchange (e.g., anion, cation exchange). Filtration is a well-studied process for drinking water treatment. Naturally, as groundwater migrates in the subsurface, contaminants are removed from the water due to ionic attraction as well as sieving based on size. Concurrently, contaminants such as iron and manganese may be dissolved into the groundwater and often remain in the dissolved form until pumped to the surface. Similarly, microorganisms are imparted to and extracted from the groundwater during subsurface movement. Surface water (e.g., ponds, lakes, rivers), like groundwater, has ever-changing quality with respect to microorganisms, particulates, chemistry, etc., but is more exposed to human activity, often degrading water quality. To reduce water contaminants and create potable water safe for human consumption, water treatment has included filtration to mimic and better the natural removal of water contaminants. Filtration for water treatment dates back to 2000 b.c.e., where crude sand and charcoal filters were used to provide better tasting water (reference 2). Centuries later Hippocrates designed a cloth bag known as the Hippocrates Sleeve, used to remove sediments from water after boiling. By the end of the Middle Ages water quality began to be linked with disease. In the mid 19th century the spread of Cholera was noticeably decreased where sand filtration was utilized (reference 2). The benefits of water filtration for not only increasing water aesthetics, but decreasing the spread of disease, lead to the widespread use of filtration seen today when purifying water for potable use.

Current Use of Filtration for Water Treatment

The original slow sand filtration developed centuries ago has now been replaced with rapid sand filtration using multi-media beds, adsorption, utilizing electrochemical forces to attract contaminants to the media surface, natural and synthetic membranes engineered with distinct pore sizes, and ion exchange, where one ion is removed from the water and replaced with a less offensive ion. Current U.S. Army field water treatment includes several filtration devices such as the Reverse Osmosis Water Purification Unit, Tactical Water Purification System, and Lightweight Water Purifier, designed for large volume water purification. An industry challenge has been to reduce the size of full-scale filtration processes down to individual units, while maintaining treatment efficacy against pathogens and particulate matter, but without excessive maintenance. To date, there have been no IWPDs fielded to the Soldier that have used filtration as the primary mechanism of water purification. Currently fielded emergency drinking water products include an iodine-based disinfection tablet (Globaline™) and a flocculant-chlorine

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disinfectant based product (Chlor-Floc™). Today, there are several Commercial-Off-The-Shelf (COTS) IWPDs that use filtration as the primary pathogen reduction mechanism.

SEPARATION MECHANISMS

The mechanisms of separation during filtration vary depending on material and design. Overall, several mechanisms may be simultaneously rejecting contaminants. For example, during filtration primarily incorporating size exclusion, adsorption and depth filtration mechanisms are likely aiding in particle retention.

Straining

Straining entails the removal of particles by size exclusion when particles are larger than the void spaces in the filter. Straining is a removal mechanism for virtually all filtration technologies with the importance of this mechanism related to raw water quality and size of particulate matter in reference to pore size.

Straining by Granular Media

For spherical granular media, close-packed arrangement will remove particles when the ratio of particle diameter to grain diameter is greater than 0.15 (reference 3). For typical slow sand filters, this equates to the removal of particles down to about 15 µm, increasing to 30-80 µm for rapid sand filtration. It should be noted that other mechanisms aid in the removal of smaller particles for these filtration techniques. Specifically, for slow sand filtration a thin slimy layer of particulate sludge forms, termed smutzdecke, effective in trapping particulates and microorganisms at the surface. When particulates form a layer during granular media filtration it may also be termed a cake. Cake filtration is often used to describe straining out particles, often smaller than the media pore size, by this top layer, or build-up, when evaluating granular carbon filtration.

Straining by Membrane Filtration

Porous membranes contain varying size pores and are rated by their pore size based on nominal, average, and absolute size. Absolute pore size is the size of the largest particle (e.g., glass bead) that will pass through a membrane under specific testing conditions. For membranes with uniform cylindrical pores this rating has meaning, but only under the low pressure conditions tested during pore size determination. Membranes with cylindrical pore structures are called capillary-pore membranes. Conversely, some membranes are manufactured to create a tortuous path (sponge-like appearance, termed tortuous-pore membranes) where pores of varying size

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create a path by which depth filtration mechanisms arise as well as size exclusion. In this case, the term absolute pore size has little meaning, and nominal ratings are used. Nominal pore ratings specify the percentage of particles removed of a certain size particle, again usually tested with glass beads (e.g., 80% of 1 µm particles retained). Lastly, membrane pore size can be rated as the average size of all pores. Different pore size testing techniques, as well as varying definitions, create a questionable pore rating system unless proper information on the membrane is noted. For example, it has been noted that certain manufacturers state absolute pore sizes when a membrane can remove 85% of a certain size particle, contrasting the historical definition of an absolute pore rating. Caution, therefore, must be used when evaluating membrane efficacy based solely on stated pore size.

Depth Filtration Theory

Particle removal and retention within depth filters involves Van der Waals forces where two surfaces have attractive forces, in this case between the particle and the media surface. Van der Waals forces are short-ranged, and only become effective when the two surfaces are in close proximity. For particle-media surfaces to come close enough together for these forces to become effective, transport mechanisms must be present. These mechanisms are represented by three different processes, which include interception, inertia and sedimentation, and diffusion. These processes are attributed with most particle removal. As a particle is transported through a filter, if the streamline is within one half or less of the diameter of the particle from the media surface, the particle will be intercepted. Second, as streamlines curve around the media, particles can deviate from the streamline and continue towards the media due to inertia forces. Particles may also deviate from streamlines due to gravitational forces and settle onto the media surface. In both cases, particle will be retained at the media surface. Lastly, particles may deviate from streamlines due to Brownian motion and diffuse to the media surface. The following diagram, Figure 1 (borrowed from reference 3), illustrates the different filtration mechanisms described. Depth filtration is not limited to granular media, but can be applied to microfilters, membranes and carbon filtration as well.

Figure 1. Filtration Mechanisms.

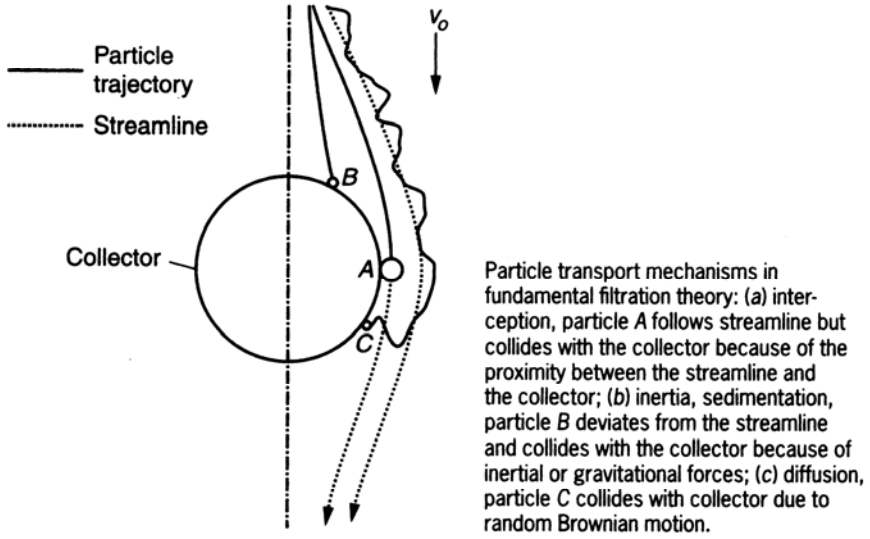

Diagram borrowed from reference 3.

Rejection by Osmotic Membranes

Two solutions in contact with one another with varying solute concentrations naturally try to equilibrate. In water treatment we can use this driving force to equilibrate, by placing a semi-permeable membrane between the two solutions. By engineering the membrane to allow passage of the water molecules through the membrane, yet reject the solutes, the two solutions will naturally equilibrate as the water dilutes the more concentrated side. Flux through the membrane will vary based on solute gradient, temperature, and membrane properties. Common practice in water treatment is to reverse the natural osmotic tendency by pressurizing the influent side, forcing water molecules through the membrane and rejecting the solutes, termed reverse osmosis (RO). Despite use in water treatment for many years, the exact mechanism of water transport and solute rejection is still debated. The underlying question is whether these membranes are non-porous and diffusion driven, or whether they contain very small pores for preferential (size exclusion) convective transport of the solvent. There are several theories, or models, on the rejection mechanisms of osmotic membranes of which three are most commonly accepted.

Solution-Diffusion Model

The solution-diffusion model describes permeation through a dense membrane that is permeable but non-porous. Water and solutes dissolve into the membrane, diffuse through the solid material, and re-liquefy on the permeate side. In this model, separation occurs due to the different flux of solutes.

Pore Flow Model

This model considers convective flow through a porous membrane. Water and solute flux is coupled with separation occurring due to sieving. Since many solutes, namely salt, are similar in size to water molecules, physical sieving would not be efficient. An apparent limitation of this model is the small pore size required, less than 0.1 nm, for separation to occur.

Preferential Sorption-Capillary Flow Model

This model describes a porous membrane where water is preferentially sorbed to the surface and transported through the membrane due to concentration gradient. Membranes with low dielectric constants prefer water molecules, creating a layer of low solute concentration, in essence blocking the solutes from contact with the membrane surface and therefore preventing passage. Osmotic potential, to pull water across a membrane from a less to more solute concentrated side, has also been applied to IWPDs in a passive form. By using a non-offensive solute on the membrane product side, water will naturally pass across the membrane to the higher solute concentration. Sometimes termed forward osmosis, this process, simply termed osmosis (O) for this paper, utilizes the same pathogen reduction mechanisms as that of conventional RO.

Adsorption

Adsorption is a mass transfer operation in which contaminants present in a liquid phase are accumulated on a solid phase, thereby being removed from the liquid. The constituent being adsorbed is referred to as the adsorbate and the solid onto which the constituent adsorbs is the adsorbent. The degree of adsorption is affected by attraction of the three following interfaces: adsorbate/adsorbent, adsorbate/water, water/adsorbent. The strength of the adsorbate/adsorbent interface as compared to the others will determine adsorption efficacy. Dissolved species are concentrated onto the surface by physical attraction or chemical reaction. Physical adsorption is by nonspecific binding mechanisms such as Van der Waals forces. This binding is reversible, where adsorbates may desorb in response to a decrease in solution concentration. Chemisorption entails specific attraction where chemical binding transfers electrons between the adsorbent and adsorbate. Physical adsorption has weaker forces and bonding energies, operates over longer distances, and is more reversible than chemical adsorption. Chemical adsorbates, which can only form a layer one molecule thick due to specific bonding, may have several different attractive forces. Polar compounds having a slightly positive and negative end and molecules orient themselves to lower their combined free energy, creating a dipole attraction. The negative end attracts the positive end of another molecule forming a dipole-dipole bond. More important to water treatment is the dipole-dipole bond with water, termed hydrogen bonding. These bonds are very strong and are responsible for water being a liquid at room temperature. Hydrogen bonding between the water molecule and adsorbate competes with adsorbate/adsorbent attraction. By maximizing physical attraction, covalent bonding and Coulombic forces, all of which are not involved in adsorbate/water, water/adsorbent interaction, we can increase

adsorption efficacy. Water pH, molecule size, and adsorbate solubility all play roles in adsorption and affect species (polar, neutral, ionic) differently. Since adsorption is not a primary mechanism for pathogen reduction these interactions will not be further discussed but can be found elsewhere (references 3-5). During the adsorption process, dissolved species are transported into the porous structure of the adsorbent material by diffusion, then adsorbed onto the interior surface of the grain. Porous adsorbent materials have very large internal surface areas (400 – 1500 m^2/g), and pore volume (0.1 – 0.8 mL/g) (reference 3) creating many sites for adsorption to occur. Three commonly used commercial adsorbents include zeolites (aluminosilicates), synthetic polymeric adsorbents, and activated carbon. A notable affect on adsorption with the most common adsorbent, activated carbon, is water pH. In order for electrostatic interactions to contribute to removal by adsorption, particle-media charges must attract the particle to the media surface. Since most particles in natural waters posses a negative charge, media should posses a positive charge. As pH increases, activated carbon becomes less positive until a point of zero charge (PZC) is reached (reference 4). At a pH above this point, electrostatic interactions repel particles from the surface, inhibiting adsorption. Depending on the carbon used the PZC may range from a pH of less than 4 up to greater than 10 (reference 4).

Ion Exchange

Ion exchange for drinking water is a process in which ions within the water stream are adsorbed to the surface of resins and exchanged for a less offensive ion that is then imparted into the finished water. A generic representation of softening using a sodium resin is shown below, with R representing the exchange resin.

$$R\text{-}(Na^{+})_4 + Ca^{+2} \longleftrightarrow R\text{-}(Ca^{+2}) + (Na^{+})_4$$

Similar to adsorption, ion exchange is powered by electrostatic/electrochemical attraction in which ions of opposite charge attract, however, with ion exchange, the presaturant ions on the resin are released into the water. For ion exchange to occur, the presaturant ions cannot be present in the bulk fluid. Natural tendency to equilibrate will favor ions both in the bulk fluid as well as on the resin surface, therefore equilibrium will occur if given enough time (reference 6). Resin beads are usually 0.04 to 1.0 mm in diameter and made by materials such as polystyrene divinylbenzene. Favorable ion exchange resins are reversible, and once all exchange sites are exhausted they can be restored through regeneration, although eventually irreversible fouling will occur. Regeneration usually consists of several bed volumes of highly concentrated regenerant followed by rinse water. To date, the most common use of ion exchange has been for softening, although heavy metal reduction and resins designed for specific ion reduction are also becoming more commonplace. There are four common ion exchange resins, classified as either strong-acid cation, weak-acid cation, strong-base anion, or weak-base anion. The cation exchange resins are negatively charged resins often used for calcium and magnesium removal, while the less common anion resins are positively charged for the removal of nitrate and other anions. Both strong-acid and strong-base resins are effective throughout all pH ranges, with the

weak-acid and base resins effective only within narrow alkaline and acidic pH regions, respectively. The preference of the ion exchange resin to attract one ion over another is termed its selectivity sequence. Ions are ranked based on separation factors, or the ratio of the affinity of the resin to favor the ion compared to the presaturant ions already attached to the resin. In general, with dilute solutions, ion exchange resins prefer ions with the highest charge and lowest degree of hydration. If both anion and cation removal is required, different resins can be run in series or mixed bed resin columns can be used to produce deionized water. In this case, strong-acid resin of the H^+ form and strong-base resin of the OH^- form are mixed with the resultant presaturant ions released forming water. In this case no ions are imparted to the finished water. A major drawback of mixed bed resins is that the resin must be separated before regeneration can occur. Since IWPDs are not designed to be regenerated, these drawbacks are not applicable.

ROLE OF PATHOGEN IN FILTRATION SEPARATION MECHANISMS

The primary difference between pathogens for reduction during filtration is size. Approximate sizes are as follow: viruses 0.005 – 0.3 µm, bacteria 0.1 -10 µm, *Cryptosporidium* oocysts 4 – 6 µm, *Giardia* cysts 8 – 12 µm. Common filters used in IWPDs have pore sizes between 0.2 and 2 µm, although some exist outside of this range. Primary reduction mechanisms for each pathogen vary with purification technology, with generalizations based on pathogen morphology as follows. (1) Based on size exclusion alone, filter retention of *Cryptosporidium* oocysts and *Giardia* cysts is likely for properly functioning devices. It is generally assumed that if a filter can reduce *Cryptosporidium* oocysts then *Giardia* cyst reduction is likely (reference 7). Utilizing filters where the primary means of reduction is by size exclusion, latex microspheres have been used as surrogates, demonstrating the lack of importance of other mechanisms for cyst reduction (references 1, 8). (2) Bacterial reduction by filters is based on adsorption as well as size exclusion (reference 9). Reduction by microporous media with pore sizes of 0.45 µm or less will likely provide adequate bacterial reduction based on size exclusion alone. Clean bed filtration, utilizing larger pore sizes will likely not meet the bacterial reduction requirements of references 1 and 10. (3) Due to the extremely small size of viruses, reduction by size exclusion to the levels required in references 1 and 10 is unlikely, unless utilizing very tight membranes such as for osmosis. Extensive literature exists demonstrating viral adsorption onto microporous filters as well as how water quality affects viral reduction (references 9 and 11-24). Particles immersed in aqueous solutions, including viruses, develop a surface charge by adsorbing ions on its surface (reference 11). The charge of viruses has been shown to play a significant role in adsorption onto surfaces and this charge changes with pH. Similar to the ZPC of activated carbon, the pH at which viruses have no net charge is called the isoelectric point (pI). Below this pH, viruses are positively charged, and above this point they are negatively charged. Coupling filters that are positively charged at a pH where the viruses are negatively charged, with the difference in charge minimized (e.g., near both pI) promotes the most efficient adsorption (reference 12). From this, it is apparent that no single combination of adsorbent/adsorption conditions exists to give optimum reduction of all viruses for all water qualities (reference 12). Increasing electrostatic and or hydrophobic interactions by the addition of chemicals such as

magnesium sulfate (reference 13) or by specially treating the filter to promote a positive charge at natural water pH will increase virus retention (references 14-17). One study investigating coliphage reduction by a 0.2 µm microporous filter, showed reduction based on adsorption as well as size exclusion (reference 9). Initial retention on clean bed filters was based on inertial impaction due to adsorptive forces, resulting in low to moderate reduction and highly affected by flow rates, water quality, and membrane material. As cake formed on the surface the primary reduction mechanism changed to direct interception at the surface due to reduction in pore size (reference 9). Reduction efficacy was less affected by water quality but still showed some susceptibility to changes in flow rate. Virus reduction by adsorption or size exclusion on capillary formed membranes is unlikely to consistently meet the requirements of reference 1.

IWPDs USING MEMBRANE FILTRATION

Membrane Filtration

A membrane is a thin layer of semi-permeable material that is capable of separating materials when a driving force is applied across the surface. This separation into two phases (concentrations) creates a chemical potential between the two sides of the membrane that is based on the physical and chemical properties of the materials being separated. Membranes are not considered to be passive materials but are termed functional materials whose performance characteristics are based on the nature of the elements to be separated and the driving force. Membranes are classified based on the size or molecular weight cutoff (MWCO) of the solutes they are capable of rejecting. Membranes used in water treatment, in order of decreasing pore size/MWCO, are microfilters, ultrafilters, nanofilters, and osmotic membranes. In addition to the pore size, membranes are also classified based on their structure, either symmetric or asymmetric. Symmetric membranes contain consistent pores, porosity, and transport properties. Asymmetric membranes contain complex pore structure with pore size, porosity, and transport properties changing with depth. Asymmetric membranes contain a thin active layer where separation occurs, supported by a thicker, more porous support structure to provide membrane integrity. Currently available IWPDs utilize micro and osmotic membrane filters. Membranes are complex materials and are often difficult to classify due to minor differences in materials and structure. The following information gives general information on the most common types of membranes used in IWPDs. Membrane configurations within IWPDs are commonly oriented as flat sheet, pleated sheet, or hollow fiber. With respect to pathogen reduction efficacy, membrane orientation is not a factor. Due to lack of information provided by manufacturers, and the proprietary nature of IWPDs, not all types of membranes found in IWPDs will be discussed.

Polymer Microfilter Membranes

Polymer microfilter membranes used in IWPDs are thin sheets up to about 200 µm thick or hollow fiber microporous membranes having diameters of 70 to 600 µm and thicknesses similar to thin sheet membranes. These membranes are engineered with specific

properties for different applications and can be made of many materials. Common materials may be polycarbonate (PC), cellulose acetate (CA), or polyethersulfone (PES). Each material contains properties that affect membrane performance. In general, increasing hydrophilicity (contact angle less than 90 degrees, e.g., does not repel water molecules) will decrease fouling potential and increase flux. Membranes that are biologically inert, operate over a wide pH and temperature range, and are chemically resistant are the most desirable for water treatment. Detailed descriptions on the production of these membranes can be found in reference 25.

Microbial pathogen reduction mechanism by polymer microfiltration membranes is based on pore structure. Capillary-pore membranes, often made of PC, are thin (about 10 µm) and consist of uniform cylindrical pores, reject microbes based on size exclusion alone, and are generally given an absolute pore size rating. In theory, these membranes should reject all microbes greater than the pore size, but in practice, defects in pore size manufacturing as well as seams and seals within the device will prevent total rejection of larger organisms. During use, capillary-pore membranes will build-up rejected solids on the surface of the membrane. This build-up will decrease the effective pore size of the membrane and increase headloss. As this clogging increases, so does the ability of the membrane to reject microorganisms. Clean capillary-pore membrane microfilters have pore sizes down to 0.1 µm, which can be expected to reject bacteria and protozoan cysts, but have minimal effect on virus reduction. In contrast to capillary-pore membranes, tortuous-pore membranes are thick (about 150 µm), consist of sponge-like structure where sieving as well as depth filtration mechanisms dominate, and have increased flux over capillary-pore membranes. These are often made of CA or PES. Pore sizes vary with depth and spatially with direction. In addition to sieving, microbes are adsorbed onto the media as described in the above sections on depth filtration theory and adsorption. Due to more efficient separation mechanisms, these membranes have been shown to retain particles orders of magnitude smaller than the nominal pore size (reference 25). Tortuous-pore membranes, like capillary-pore membranes, have pore sizes down to about 0.1 µm, making these efficient at retaining bacteria and protozoan cysts, but not effective at sieving viruses. Due to the adsorptive nature of these membranes, it has been shown that several log virus reduction can be achieved but results are inconsistent and drop with continued production (references 3 and 25). Polymer microfilter membranes are very effective at reducing particulate matter and based on pore size should be able to reduce water turbidity to below 1 nephelometric turbidity unit (NTU). Due to the small pore size of these membranes they are prone to fouling, especially with the dead-end configurations used in IWPDs. Pre-filtering and a cleanable or backwashable configuration will reduce fouling.

Osmotic Membranes

Osmosis uses pressure, RO or solute gradient osmosis, to drive the solvent through a dense, nonporous membrane (some models consider a porous membrane) that will retain salts and solutes down to very low molecular weights. Natural osmotic pressure induces travel from a less to a more concentrated solution. A pressure, in excess of the osmotic potential, must be

applied to reverse this flow (RO). Osmotic potential is a function of the molar concentration of the solute. In essence, smaller molecules create higher osmotic potentials. Pressures to reverse this natural tendency can be high. Twice the osmotic pressure is common in design with seawater separations, with pressures of 5 to 8 MP are typically used. The mechanism of separation for RO is solution/diffusion + exclusion as explained above. Separation is based on the solubility and diffusivity of materials in the membrane. RO membranes are usually made of hydrophilic cellulose acetate materials, cellulose ester plastics, or composites such as a cross-linked polyamide on a polysulfone and fabric base. CA membranes along with other non-composite membranes are termed asymmetric. The entire membrane is composed of the same material with the pore size decreasing as you approach the surface. In nonporous asymmetric membranes, the surface skin is dense with a porous support membrane underneath of the same material. Composite membranes are anisotropic where the top layer and sublayer originate from different material. The top dense layer sits on top of a porous material, usually an asymmetric membrane. Composites can be designed for certain selectivities, but presently are less common than CA. CA membranes can resist a low level chlorine residual, but are very susceptible to biological degradation. RO membranes are very thin ranging from 0.25 to 4 μm to increase flux through the membrane as flux is inversely proportional to membrane thickness. They operate ideally at pH 4 to 6.5 and at temperatures below 30° C. Water flux increases with temperature as long as temperature remains within the ideal range of the membrane material. Membrane configuration may be plate and frame, spiral-wound, tubular, or hollow fine fiber. The most common configuration, spiral-wound, contains sheets of membranes separated by spacer sheets then rolled together around a feedwater spacer. The hollow fine fiber configuration is similar to that used for microfiltration but incorporating tighter membranes. Increased surface area, resulting in higher flux, and less fouling are benefits of the hollow fine fiber design.

Osmotic membranes are classified based on MWCO with mechanisms of removal described in an above section. Measured in dalton, these membranes are capable of rejecting molecules with a mass of > 100 dalton regardless of charge. Generally speaking rejection efficacy favors multivalent ions, branched isomers, and increasing molecular mass. Based on size exclusion alone, osmotic membranes are capable of retaining species as small as 0.0001 μm (reference 26). These membranes can remove most all natural water contaminants known, although no treatment can universally remove everything. Microorganisms, salts, hardness, and organic chemicals, among many others can be removed, whereas most dissolved gases such as hydrogen sulfide and carbon dioxide will not be removed (reference 26). IWPDs utilizing osmotic membranes are historically designed for salt water desalination. With the introduction of IWPDs using osmosis, application to fresh water has been considered. Currently, IWPDs using RO or O should be capable of reducing waterborne pathogens (bacteria, cysts, and viruses) to levels considered acceptable for human consumption, as recommended by the EPA (reference 1). Devices using osmotic membranes will produce the lowest NTU water of all membrane materials. IWPDs using RO are historically not designed for natural water purification where turbid water may quickly foul the membrane. RO units will perform most efficient for desalination were particulate matter is not a concern. RO use in IWPDs for natural waters would

require very efficient pre-filtering, as by another membrane process such as microfiltration, and is therefore not considered a viable technology. IWPDs using O will also produce extremely low NTU water and will not be affected by particulate matter regardless of natural water turbidity. Since O devices do not use pressure to force water through the membrane, no cake is formed at the media surface and no pre-filtering is required.

IWPDs USING CERAMIC MICROFILTRATION

Ceramic microfilters are made from inorganic ceramic pastes derived from powders of alumina (Al_2O_3), zirconia (ZrO_2), and titanium (TiO_2). These pastes are extruded and sintered at high temperature to form membrane supports with macro pores. Subsequently, submicronic powders are laid on the supports to create smaller pore diameters. This process creates a symmetric material with high chemical, mechanic, and thermal resistance that can be formed in a variety of shapes including candles, discs, and tubes (reference 27). Pore structure is tortuous path depth filtration with symmetric pores throughout the depth of the filter. With pore sizes down to 0.1 µm, ceramic microfilters are efficient at retaining bacteria and cysts through adsorption and depth filtration mechanisms. At the household level utilizing untreated water sources, ceramic filter use has been shown to reduce coliform bacteria resulting in greater than 70% reduction in cases of diarrhea (reference 28). As with other microfilters, no mechanism exists to adequately reduce virus concentrations. Commercially available ceramic microfilters are often impregnated with silver to discourage microbial growth on the media surface. This is intended solely to limit growth on the media and will have no effect on bulk water pathogen reduction. Ceramic microfilters are very effective at reducing particulate matter and based on pore size should be able to reduce water turbidity to below 1 NTU. Due to the small pore size of these filters they are prone to fouling, especially in dead-end configurations used in IWPDs. For IWPD use, ceramic filters are designed to be mechanically cleaned by scraping particulate build-up from the media surface. The ability to clean this media multiple times makes these filters a very effective, but high maintenance, technology for use with turbid waters. Due to the small pore size of these membranes, pre-filtering is required.

IWPDs USING FIBER AND FABRIC FILTRATION

Fiber and fabric microfilters can be made of compressed or cast fibers such as cellulose papers, woven fabrics, and glass, in addition to numerous other materials (reference 29). The most common to IWPDs are fiber microfilters made of material such as borosilicate glass. These filters are symmetric depth filters with pores sizes down to about 0.2 µm. Pathogen reduction follows depth filtration, adsorption, and straining mechanisms. Clean bed pathogen reduction may entail Van der Waals interaction and electrostatic interactions as well as straining based on size exclusion. After continued use, cake formation will likely make straining the predominant rejection mechanism. Consistent reduction of bacteria and cysts based on size exclusion is expected. No mechanisms exist to consistently reduce virus to the standards of reference 1. Fiber and fabric microfilters are very effective at reducing particulate matter and based on pore

size should be able to reduce water turbidity to below 1 NTU. Due to the small pore size of these filters they are prone to fouling, especially in the dead end configurations used in IWPDs. With proper design, such as allowing for mechanical cleaning by way of scraping the surface, these filters can be highly effective at treating turbid waters. Non-cleanable filters, requiring replacement once clogged are not as desirable for turbid waters. Due to the small pore size of these membranes, pre-filtering is required.

IWPs USING CARBON FILTRATION

Carbon Filtration

Carbon used for water treatment can be of three different forms; granular, powdered, block. Granular activated carbon (GAC) for water treatment is often made from wood, peat, lignite, coal, or coconut shells. Manufacturing consists of carbonization and activation. Carbonization is conducted in the absence of air at temperatures up to 700º C, while activation, or oxidation, is accomplished at temperatures of 800 – 900º C in the presence of oxidizing gases such as steam or CO_2. Activation burns off anything volatile, leaving highly porous grains with large surface areas. Grain size varies with typical values between 0.4 mm and 2.5 mm. Powdered activated carbon (PAC) is made of the same materials as the granular form, but activation can entail either gas or chemical processes. The final product is powder with typical particle sizes ranging from 10 to 100 µm. Carbon block is produced by sintering powdered carbon, thermoplastic binders, and other additives. Material is extruded or molded under heat and pressure to form a hollow filter block of just about any shape or size. Absolute control over pore size is possible as well as engineering for specific contaminant reduction. Carbon blocks, unlike GAC, contain increased surface area, do not exhibit channeling, and contain an order of magnitude smaller pore size resulting in increased adsorption capacity (reference 30). Commercially available carbon block is often impregnated with silver to discourage microbial growth on the media surface. This is intended solely to limit growth on the media and will have no effect on bulk water pathogen reduction. When carbon adsorption capacity becomes exhausted, regeneration, involving the desorption of solutes from the media without affecting the media surface, and reactivation, entailing partial regeneration affecting the media surface, are conducted to restore the media for future use.

Pathogen Reduction

GAC has no specific mechanism for pathogen reduction beyond that typical of other granular media (reference 31). Typically larger in size than most filter media, pathogen and particulate removal by GAC is poorly accomplished by the straining and depth filtration mechanisms described in an above section. PAC, like GAC, is used for taste and odor reduction, and is not considered an effective barrier to pathogens. Carbon blocks have been shown to effectively reduce pathogens from water (references 32-34). Pathogen reduction by carbon blocks can follow any of the three generally accepted particle reduction mechanisms for porous media; cake

filtration (surface retention), depth filtration, or adsorptive filtration. Depending on pore size, pathogens may be retained based on size exclusion alone. As cake forms on the media surface, exclusion of smaller particles due to decreased pore size is considered a predominant reduction mechanism (reference 33, 34). Carbon block surface charge may play an important role in clean bed filtration. The surface charge of carbon block is based on the pH at which the surface is not charged, called the PZC (reference 4). At pH below this point the surface is positively charged and above this point negatively charged. Since pathogens generally possess a negative charge, as pH decreases, reduction should increase due to electrostatic interactions. It has been shown that initial reduction due to electrostatic or Van der Waals attraction is followed by straining, as the negatively charged particles neutralize the surface of the carbon block (reference 32). When pH was above the PZC, pathogen reduction based on adsorption was ineffective. Proprietary chemically treated carbon blocks are available that have been shown to be capable of reducing bacteria, cysts, and viruses by the requirements of reference 1 (reference 32). Little is known about the proprietary chemical treatment and the exact pathogen kill mechanism is unclear. With respect to available IWPDs, carbon blocks with pore sizes of 1 µm or greater are common. Based on this, cyst reduction would be likely, and except for specially treated carbon blocks, consistent bacterial and viral reduction would not be expected to the reduction requirements of reference 1. Granular carbon filtration will retain some particulate matter based on particle size. As a cake forms on the surface, increased removal will occur. Clean bed granular carbon alone will not likely reduce water to less than 1 NTU. Carbon block filtration will reduce particulate matter with efficacy based on block pore size. Again, particulate size will be a factor in retention within carbon blocks which, as used currently in IWPDs, have a pore size of about 1-2 µm. Granular carbon will not likely be the limiting treatment technology requiring pre-filtering for IWPDs, as an additional pathogen reduction mechanism will be present that will dictate required pre-filtration. To reduce clogging, pre-filtering is beneficial when using carbon block, but not required as shown by current device configurations.

IWPs USING ION EXCHANGE

Ion exchange is not a proven technology for pathogen reduction. IWPDs utilizing ion exchange must employ an additional mechanism to adequately reduce microbial contamination. Microbial growth can occur within ion exchange beds, possibly resulting in increased contamination due to microbial growth sloughing into the effluent stream. One non-conventional ion exchange process has shown much promise at inactivating pathogens. Iodine ion exchange resins, primarily of the tri-iodide or penta-iodide form, have been extensively studied and are considered effective at pathogen inactivation through disinfection mechanisms (references 29, 35). Ion exchange is not designed for, and will not be effective at, reducing particulate matter. Pre-filtering is necessary to avoid fouling of the resin.

CONCLUSION

The effectiveness of filtration as the primary mechanism to reduce pathogens in IWPDs is based on the technology used as well as the raw water quality. Filtration utilizing microporous filters primarily reduces pathogens by size exclusion due to surface or depth filtration mechanisms. Adsorptive interactions contribute to pathogen reduction during the initial filtration until cake formation occurs where charge neutralization limits the effectiveness of this mechanism. For IWPDs using size exclusion as the reduction mechanism, bacteria and cyst reduction is possible dependant on pore size. The small size of viruses prevents retention by size exclusion to the reduction requirements for purifying natural water. Adsorption of viruses has also been shown to be inadequate to consistently meet requirements for producing microbiologically safe water. Carbon filtration performs similar to granular or microporous filters with equivalent pore sizes. Proprietary chemically treated carbon surfaces have been shown to meet reduction requirements for microbiologically safe water but may be sensitive to water characteristics such as pH. IWPDs using osmotic membranes are the most effective at reducing pathogens although pressure driven osmotic devices will quickly foul when used with fresh water sources. For IWPDs, filtration will decrease the particulate matter present in turbid water with efficacy based on pore size. The ability of the IWPD to perform properly with turbid water sources is dictated by the pre-filter configuration and ability to clean the media surface.

Table. Summary of the Pathogen Reduction Efficacy and the Effect of Particulate Matter on IWP Filtration Technologies.

Technology	Summary
Membrane Microfilter	Expected effectiveness at reducing bacteria and cysts. Microfilter pore size too large to adequately reduce viruses, requiring additional treatment. Common configurations limit the effectiveness of membrane surface cleaning making this technology susceptible to fouling from particulate matter. Degree of fouling directly related to efficacy of pre-filter. Straining as well as depth filtration mechanisms may be involved in microbial and particulate rejection based on membrane structure.
Ceramic Microfilter	Expected effectiveness at reducing bacteria and cysts. Microfilter pore size too large to adequately reduce viruses, requiring additional treatment. Ability to scrape rejected material from the microfilter surface enables flow to be restored after fouling. Frequency of cleaning, and length of filter useful life directly related to efficacy of pre-filter. Straining as well as depth filtration mechanisms can be involved in microbial and particulate rejection.
Fiber/Fabric Microfilter	Expected effectiveness at reducing bacteria and cysts. Microfilter pore size too large to adequately reduce viruses, requiring additional treatment. Filters designed to be cleanable should provide some ability to restore

	flow after fouling. Frequency of cleaning, and length of filter useful life directly related to efficacy of pre-filter. Non-cleanable filters highly susceptible to fouling. Straining as well as depth filtration mechanisms may be involved in microbial and particulate rejection.
Reverse Osmosis	Effective at reducing bacteria, viruses, and cysts. Technology is not designed to treat fresh water sources and, therefore, requires very effective pre-filtering to prevent membrane fouling. Not a feasible IWP technology for microbial or particulate reduction of fresh water.
Osmosis	Effective at reducing bacteria, viruses, and cysts. Technology is passive, eliminating the fouling effects of turbid water, and eliminating the need for pre-filtration. Slow production of fluid, exacerbated by cold temperatures.
Granular/Powdered Carbon	Not considered effective at reducing bacteria, viruses, or cysts. Granular media is often too large to effectively reduce pathogens based on size exclusion and is not considered effective at depth filtration mechanisms. Powdered carbon is used solely for taste and odor reduction and is not effective at pathogen reduction. Particulate matter affects these technologies similar to conventional granular media.
Carbon Block	Expected effectiveness at reducing cysts. Consistent reduction of bacteria is not expected due to the pore size of carbon blocks commonly used in IWPs. Not effective at adequately reducing viruses, although proprietary media has shown some promise. Pathogen reduction based on size exclusion and depth filtration mechanisms. Effects of particulate matter similar to other technologies of similar pore size. Pre-filtration and cleanable filters will decrease fouling from particulate matter.
Ion Exchange	Not considered effective at reducing bacteria, viruses, or cysts. Iodine ion exchange resins have been proven effective at pathogen inactivation through disinfection mechanisms. Particulate matter fouls ion exchange resin and therefore prefiltration is necessary.

PREPARED BY: Arthur H. Lundquist, Environmental Engineer

DATED: March 2006

APPENDIX A
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ANNEX 4 TO APPENDIX F

TIP #31-005-0306
IODINE DISINFECTION IN THE USE OF INDIVIDUAL WATER PURIFICATION DEVICES

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Iodine Disinfection in the Use of Individual Water Purification Devices

Technical Information Paper #31-005-0306

PURPOSE

This information paper provides an in-depth review of iodine as a disinfectant in potable water supplies. This paper is intended to assist the reader in evaluating the disinfection capabilities of Individual Water Purification Devices (IWPDs) using iodine to kill or inactivate disease-causing bacteria, viruses, and protozoan cysts.

REFERENCES

Appendix A contains a list of references.

INTRODUCTION

Background

Understanding the disinfection capabilities of iodine to kill or inactivate disease-causing microorganisms is important in protecting Soldiers, who are considering using this technology, from acute health threats posed by these microorganisms. Soldiers deployed beyond traditional field drinking water supplies must have access to microbiologically safe water. Using IWPDs is one way to provide microbiologically safe water in these situations. These IWPDs must protect the Soldier from acute microbial health threats. The U.S. Environmental Protection Agency (EPA) Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1) provides performance standards by which an IWPD using iodine can be evaluated. The performance standards are a minimum 6-log reduction/inactivation of bacteria, 4-log reduction/inactivation of viruses, and 3-log reduction/inactivation of protozoan cysts (typically *Giardia* or *Cryptosporidium*). Iodine-using IWPDs meeting these standards are considered effective against disease causing bacteria, viruses, and protozoan cysts. Some IWPD manufacturers test their devices using this protocol. This is the best way to evaluate the IWPDs disinfection capabilities. In the absence of that testing data, this information paper can be used to gain an understanding of iodine disinfection capabilities and help determine if an IWPD using iodine could successfully meet the EPA Guide's minimum performance standards.

General

Iodine (I_2) has long been recognized for its anti-microbial properties. It has been used extensively in the health care industry as an antiseptic and disinfectant (references 2 and 3). The U.S. Army also realized the benefits of iodine as a drinking water disinfectant, issuing iodine-based tablets (Globaline™) to American Soldiers in 1952 (references 4 and 5). The Army continues to provide iodine-based tablets in addition to other emergency field drinking water products (i.e., Chlor-Floc™) (reference 6). Today, there are several Commercial-Off-The-Shelf (COTS) IWPD products that use iodine for disinfection.

Types of Iodine-based Disinfectants

Iodine-based disinfection products available today can be divided into two categories; iodine solutions and iodine resins. Iodine solutions are made by adding iodine (e.g., tincture of iodine, a 2% iodine solution), or by adding a tablet containing iodine along with carrier and stabilizing agents to enhance dissolvability (e.g., Globaline, composed of tetraglycine hydroperiodide, sodium acid pyrophosphate and talc, reference 4). Iodine resins are solid-phase iodine disinfectants. Iodine resins are used by passing water through the iodine resin where disinfection occurs through direct contact of the microorganism and the iodine sorbed onto the resin. Iodine resins are generally considered demand-release disinfectants (reference 7). Demand-release iodine resins release iodine to the microorganism after coming into contact with the resin and generally produce a dilute iodine residual (reference 7).

IODINE CHEMISTRY

Chemistry of Iodine in Water

When iodine is added to water, it may remain unchanged or it may hydrolyze into five different species depending on pH and the initial iodine concentration (references 4 and 8). In general, the following reaction occurs when iodine is added to water (reference 9):

$$I_2 + H_2O \leftrightarrow HOI + I^- + H^+ \qquad K_{eq} = 3 \times 10^{-12} \text{ at } 25 \text{ deg C}$$

In addition to the formation of hypoiodous acid (HOI) and iodide ion (I^-), hypoiodite ion (OI-), triiodide ion (I3-), and iodate (HIO3) may be formed. However, under typical concentrations used in drinking water disinfection, and at typical pH ranges for natural water sources, hypoiodite ion, triiodide ion, and iodate are not considered to be formed at any appreciable concentrations (reference 12). The small equilibrium constant indicates a higher concentration

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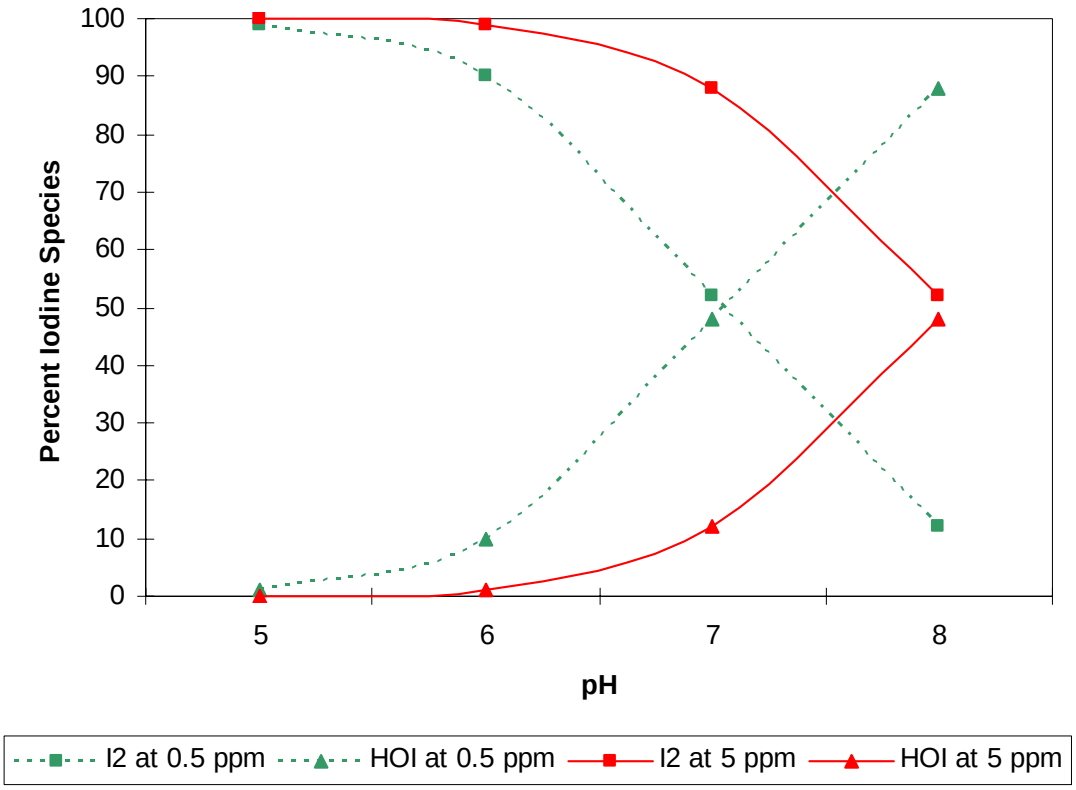
™ Chlor-Floc is a trademark of Control Chemical Co., D/B/A Deatrick and Associates, Inc., Alexandria, VA. Use of trademarked products does not imply endorsement by the U.S. Army, but is intended only in identification of a specific product.

of reactants (iodine) compared to the products (hypoiodous acid and iodide ion) present at equilibrium. In other words, this equation suggests that in natural waters with typical pH ranges from 5 -8, iodine is present and can be present in significant amounts depending on initial iodine concentration (reference 10). The figure shows the distribution of iodine species at various pH levels and initial iodine concentrations at 25 degrees C (adapted from references 9 and 11).

Figure. Distribution Diagram of Iodine Species at 25 Degrees Celsius



From the figure, we can see that at near neutral to alkaline pH levels (~7+), depending on initial iodine concentration there can be significant concentrations of both iodine and hypoiodous acid present. Lower initial iodine doses result in significant concentrations of both iodine and hypoiodous acid at near neutral pH levels. At higher pH levels above 8, hypoiodous acid dissociates by the following reaction (reference 9):

$$HOI \leftrightarrow H^+ + OI^- \quad pK_a = 12.3 \text{ at } 20 \text{ deg. C}$$

The production of hypoiodite ion (OI^-) is considered negligible since it would only be present in significant concentrations at pH levels not typically seen in natural waters (i.e., above pH 10)

(reference 10). Further limiting production of hypoiodite ion is the fact that hypoiodous acid is unstable at pH levels above 8 and decomposes to iodate and iodide according to the following reaction (reference 10):

$$3HOI + 2(OH^-) \leftrightarrow HIO_3 + 2H_2O + 2I^-$$

Iodine Resin Preparation

Preparation of iodine resins involves binding polyiodide ions to a strong-base anion resin. This creates a positively charged resin. Most microorganisms are negatively charged at typical pH levels (i.e., 5 – 8) encountered in natural waters (references 13 and 14). These opposite charges produce an electrostatic attraction that helps bring the microorganism into direct contact with the iodine resin (reference 15). There are generally two types of iodine resins produced for drinking water treatment, a triiodide (I_3^-) and a pentaiodide (I_5^-) resin.

DISINFECTION CAPABILITIES

General

Iodine Solutions

Iodine is an effective disinfectant for viruses, bacteria, and many cysts at IWPD manufacturer-recommended iodine dosages and contact times. In general, iodine is most effective against bacteria, followed by viruses. Iodine is least effective against cysts. Iodine is not an effective disinfectant against *Cryptosporidium parvum* oocysts (references 2, 3, 15 and16). Most manufacturers of iodine solution IWPDs recommend dosages between 4 and 16 mg/L with contact times ranging from 20 – 35 minutes, resulting in CTs of 80 – 560 mg-min/L. CT is the product of disinfectant concentration (C in mg/L) and contact time (T in min). The CT product is a useful way for comparing alternative disinfectants and the resistance of various pathogens (reference 26). Because cysts are most resistant, dosages and contact times will be based on inactivation of cysts and CTs will be in the high-end of the 80 – 560 mg-min/L CT range. Compared to other disinfectants such as chlorine and chloramines, iodine reacts less with organic compounds, is less soluble, is least hydrolyzed in water, and is effective over the pH range likely encountered in natural water sources likely to be treated with an IWPD (references 2, 3 and 17). Together, these characteristics mean that low iodine residuals will persist longer, be more stable, and exert less of a demand in the presence of organic matter compared to chlorine and chloramines (reference 12). It has been established that only iodine and hypoiodous acid are capable of biocidal activity. The other iodine species are not effective biocides (references 3, 11, 12 and 16). For these reasons only iodine and hypoiodous acid are the iodine species considered in this paper.

Iodine Resins

Like iodine solutions, iodine resins are effective disinfectants against bacteria, viruses, and many cysts. However, the resins have not been proven effective against *Cryptosporidium* oocysts (references 3, 15, 18, 19 and 20). Iodine resins used in IWPDs are generally combined with other treatment processes such as filtration and are not usually used as stand-alone IWPDs. Iodine resin disinfection operates on the theory that iodine binds to the microbe, penetrating and inactivating it. Contact between the microbe and the resin is necessary and is assisted by electrostatic forces (reference 3). Microbes are exposed to high iodine concentrations when passing through the resins, which allow for reduced contact time compared with iodine solutions (reference 16). Iodine resins typically produce a residual of 0.02 - 2 mg/L in water passed through the resin (reference 15). However, the iodine residual is not considered to provide additional disinfection. In most cases, bacteria and viruses are immediately killed or inactivated after coming into direct contact with the iodine sorbed to the resin. For cysts, additional contact time is sometimes necessary after passing through the resin to allow sufficient time for the iodine picked up from the resin to penetrate the cysts and kill or inactivate it. In theory, the iodine residual produced by the resin is not used for disinfection. However, the iodine residual may provide a measure of microbial protection when storing water to prevent microbial growth in the storage container, similar to the maintenance of a disinfectant residual in a distribution system. Of the two types of resins used in drinking water, pentaiodide resin has been shown to have better biocidal capabilities than triiodide resin (reference 7).

Environmental Effects on Disinfection Capability

Effect of pH on Disinfection Capability

In general, the pH of most natural water sources is neutral to mildly acidic, which is within the effective range for chemical disinfectants used for drinking water, including iodine solutions (reference 3). Iodine and hypoiodous acid have varying degrees of biocidal effectiveness against various pathogens. Iodine is up to three times more cysticidal and 6 times more sporocidal than hypoiodous acid (reference 3). Hypoiodous acid, on the other hand, is 40 times more virucidal and up to 4 times more bactericidal than iodine (reference 3). Because the concentration of these iodine species is dependent upon pH and initial iodine dose (see Figure), the following generalizations can be made. Iodine solutions are more effective cysticides and poorer virucides and bactericides at mildly acidic pH levels (< pH 7). Iodine solutions are more effective virucides and bactericides and poorer cysticides at alkaline pH levels (> pH 7). And, because it generally takes much longer to inactivate cysts than bacteria and viruses, iodine solutions used as IWPDs would be most effective at near neutral to mildly alkaline pH levels. However, at pH levels above 8, biocidal capability may drop sharply because HOI becomes unstable and decomposes to iodate and iodide, which are not effective biocides (see iodine chemistry above). To use iodine most effectively as a disinfectant, the pH should be near neutral to mildly alkaline to allow adequate levels of both iodine and hypoiodous acid (reference 4).

Resins do not appear to be significantly affected by pH levels typically encountered in natural waters. One study using both triiodide and pentaiodide resins showed less than 4-log virus inactivation at extremely low pH levels (pH 2.5 and 3.0) (reference 15). At these low pH levels, it was believed that the viruses lost their negative charge, becoming neutral or positively charged, effectively reducing the electrostatic attraction and subsequently preventing direct contact with the iodine on the positively charged resins. Greater than 4-log virus inactivation was achieved at all higher pH levels (pH 4.0 – 7.0).

Effect of Temperature on Disinfection Capability

In general, colder water temperatures reduce the disinfection capability of iodine solutions and other chemical disinfectants (references 9, 17 and 21). Cold water temperatures slow disinfection and must be compensated for by longer contact time or higher concentration to achieve comparable disinfection at warmer water temperatures (reference 3). A 2 to 3-fold increase in inactivation rates per 10° C water temperature increase seems a generally accepted rule (reference 3). Studies have shown a significant impact on iodine disinfection capability by temperature. One study showed CT's to provide 2-log inactivation of the *E. Coli* bacteria were 2-9 times higher in colder waters (2-5° C) than in warmer waters of 20-25° C (references 9 and 22). Another study showed a CT 3 times higher was necessary at a 3° C water temperature (CT = 200 mg-min/L) compared to 23° C water temperature (CT = 65 mg-min/L) for a 2-log inactivation of *E. histolytica* cysts (references 9 and 10). Another study using *Giardia* cysts showed CT's up to 3 times higher in 3° C water resulted in only a 1.5-log inactivation compared to CT's at 20° C which resulted in > 2.7-log inactivation (references 7 and 21). These studies show temperature has a significant effect on iodine disinfection capability. Longer contact times and/or higher iodine doses (i.e., increased CT's) are necessary in colder waters. Using a 2-fold CT increase for every 10° C decrease in water temperature is a good estimate to use when determining CT requirements for iodine disinfection capability.

There is limited information on the effect of water temperature on the disinfection capability of iodine resins. Water temperatures do not appear to affect bacteria and virus inactivation when using iodine resins. However, cysts may require additional contact time after passing through a resin to ensure inactivation. One study evaluated water temperature's effect on *Giardia* cyst inactivation by pentaiodide resin (references 7 and 23). The data suggested that additional contact time was necessary to provide a 3-log inactivation after passing through the resin (reference 23). Three minutes additional contact time was necessary at 25° C while more than 40 minutes additional contact time was necessary at 4° C. Although an iodine residual was present in the water after passing through the column, the inactivation of the *Giardia* cysts is likely due to the iodine bound to the cysts after coming into contact with the resin (reference 23). Additional contact time of water passed through an iodine resin is recommended to ensure adequate *Giardia* cyst inactivation (3-log).

Effect of Turbidity on Disinfection Capability

In general, disinfection capability of iodine solutions is reduced since microorganisms can be protected from the iodine by adsorption to or enmeshment in solid particles in water (references 16 and 24). There is limited information discussing the effects of turbidity on the disinfection capability of iodine. Most iodine disinfection studies involving varying turbidities also include other variables that affect iodine disinfection (e.g., pH and temperature). However, some limited information can be extracted. One study indicated turbidity from clays measuring 50-500 mg/L total suspended solids had no measurable effect on iodine disinfection capability, but high concentrations of fine loess (165 – 245 mg/L) interfered with bactericidal capability of iodine (reference 25). This study would indicate that turbidity does have an affect on iodine disinfection capability but not as significant compared to temperature.

Available information on fouling of iodine resins focuses more on the impact of dissolved organic matter and not on turbidity (i.e., solid or particulate matter). Resins will act as filter media and can physically remove particulate matter from water (reference 26). The particulate matter could interfere with the disinfecting capability of the iodine resin by preventing direct contact between the organism and the resin. Dissolved organic matter can have a large impact on iodine resin disinfection. One study indicated dissolved organic matter (measured as total organic carbon) at concentrations of 6 mg/ml (6,000 mg/L) reduced the disinfection capability of a triiodide (I_3) resin against viruses. The organic matter competed for sites on the resin beads and prevented direct contact between the resin and the virus (reference 20). However, a 10-fold reduction in dissolved organic matter (600 mg/L) did not appear to adversely affect the triiodide's disinfection capability of viruses. Heavy organic matter loading could reduce the disinfection capability of an iodine resin. A pretreatment process to remove/reduce organic matter (particulate and dissolved) will provide better resin disinfection capability in highly turbid waters.

Bactericidal Capability

Iodine Solutions

Numerous studies indicate iodine is an effective bactericide over the range of temperature and pH expected in natural water sources (references 9, 10, 22 and 27). Very low CT levels, ranging from 0.4 – 2.4 mg-min/L are required to inactivate 2-logs of *E. Coli* over a wide pH range (6 – 9) and temperature range (2 – 37° C) (reference 9). CT's of less than 10 mg-min/L resulted in a 4-log inactivation of *E. Coli* at a near neutral pH (6 – 7) and extreme temperatures (~ 0 – 37° C) (references 9 and 27). These low CT's translate into low iodine residuals and/or short contact times. For example, assuming a contact time of 20 minutes, a 0.5 mg/L iodine residual would be necessary to provide 4-log inactivation of *E. Coli* at near neutral pH at any temperature encountered in natural waters (20 min x 0.5 mg/L = 10 mg-min/L). When iodine solutions are

used at typical doses for emergency drinking water disinfection (4 – 16 mg/L) and typical recommended contact times (20 – 35 minutes), the resulting CT's of 80 – 560 mg-min/L would likely ensure a 6-log inactivation of bacteria.

Iodine Resins

Data indicate iodine resins may achieve a 6-log inactivation of bacteria. One study showed at least a 4-log inactivation of *Staphylococcus aureus* over a wide pH range of 2.5 – 7.0 using triiodide (I3) and pentaiodide (I5) resins (reference 15). Other studies showed 4 – 9-log removal/inactivation for various pathogenic bacteria including *E. Coli* and *Salmonella typhimurium* using a triiodide resin (references 15 and 19). No significant removal of bacteria by filtration was reported. The effectiveness of resins against bacteria is due to its disinfecting ability and not for the ability to filter, or physically remove bacteria (reference 19). Iodine resins will likely provide a 6-log inactivation of bacteria under most situations.

Virucidal Capability

Iodine Solutions

Several studies also show that iodine solutions are effective virucides (references 9, 10 and 27). Viruses are more resistant to iodine disinfection than bacteria, typically requiring higher CT's than bacteria and in some cases much higher CT's at low pH levels (e.g., 4 – 5), where hypoiodous acid (HOI) is not present, and at cold water temperatures (e.g., 5° C) (reference 9). Most studies evaluated the virucidal efficacy of iodine solutions against f_2 virus and Poliovirus. Data indicate 2-log inactivation at near neutral to alkaline pH levels (6 – 10) and various water temperatures (5 – 30° C) occurred at CT's of 15 – 75 mg-min/L with the higher CTs occurring at lower pH levels and colder water temperatures. One study showed a CT of less than 10 mg-min/L resulted in a 4-log inactivation of f_2 virus at a pH of 7 and a very warm water temperature of 37° C (reference 9). Iodine solutions will likely provide a 4-log inactivation of viruses under most natural water conditions expected. Because IWPD dosages and contact times will be based on cyst inactivation, and resulting CTs will be large (80 – 560 mg-min/L), it is likely an IWPD will achieve 4-log virus inactivation under most water quality conditions.

Iodine Resins

Data reviewed indicates iodine resins can likely achieve 4-log virus inactivation levels. Several studies show at least 4-log inactivation of various viruses at pH levels above 3.0 with low turbidity water for both triiodide (I3) and pentaiodide (I5) resins (references 15 and 20). One study showed a reduced virucidal capability of a triiodide resin when water containing significant amounts of organic matter (6 mg/ml or 6,000 mg/L organic matter) was tested (reference 20). However, a 10-fold reduction in organic matter (0.6 mg/ml or 600 mg/L) did not

appear to affect the triiodide resin's disinfection capability (reference 20). Triiodide and pentaiodide resins will likely provide a 4-log virus inactivation under most natural water quality conditions.

Cysticidal Capability

Iodine Solutions

Most cysts, in particular *Giardia* cysts and *Cryptosporidium* oocysts, appear to be more resistant to iodine disinfection than bacteria or viruses. Achieving adequate cyst inactivation should ensure adequate bacteria and virus inactivation.

There are several studies evaluating the iodine disinfection capability against *Giardia* cysts (references 6, 8, 21 and 28). Overall, the data from these studies indicate that iodine is capable of providing a 3-log *Giardia* cyst inactivation, but additional contact time or higher doses (i.e., higher CT's) are necessary at colder water temperatures and more turbid waters (references 6, 8 and 28). Warmer waters (> 20° C), both clear and cloudy, with pH levels ranging from 6 – 9, resulted in > 2.7 log (~3 log) *Giardia* cyst inactivation with CT's ranging from 45 – 241 mg-min/L. As water temperatures decreased (< 20° C) CT values for > 2.7 log *Giardia* cyst inactivation increased, ranging from 123 – 600 mg-min/L (clear and cloudy waters, pH ranged from 6 – 9). One study recommended CT's ranging from 240 – 720 mg-min/L for colder waters (5 – 15° C) to ensure a 100% inactivation of *Giardia* cysts (reference 17). At colder water temperatures (clear and turbid) achieving a 3-log inactivation of *Giardia* cysts is not likely when using iodine according to recommended instructions (CT's ranging from 80 – 560 mg-min/L). Additional contact time and/or higher iodine dosages, beyond those recommended by IWPD manufacturers, are likely necessary to ensure 3-log *Giardia* cyst inactivation.

There is limited data on *Cryptosporidium* oocyst inactivation by iodine (references 8 and 29). These data indicate iodine solutions are ineffective at inactivating *Cryptosporidium* oocysts. One study indicated a CT of 1,015 mg-min/L is required to achieve a 2-log *Cryptosporidium* oocyst inactivation (reference 29). This CT is far beyond IWPD CT's resulting from using iodine solutions according to manufacturer recommended instructions (CT's ranging from 80 – 560 mg-min/L). This indicates iodine would not be an effective disinfectant against *Cryptosporidium* due to the extremely high iodine dose and long contact times necessary to provide a 3-log inactivation.

Iodine Resins

Pentaiodide resins are much more effective at inactivating *Giardia* cysts than triiodide resins (reference 23). A pentaiodide resin achieved a 3-log *Giardia* cyst inactivation compared to

0.2 – 0.4-log inactivation achieved by triiodide resin under identical experimental conditions (temperatures of 4 and 25° C) (reference 23). Additional contact time after passing through the pentaiodide resin column was necessary to achieve the 3-log inactivation. The 3-log inactivation was achieved within 3 minutes of passing through the column at 25° C (reference 23). More than 40 minutes of additional contact time was necessary at 4° C water temperature to achieve similar inactivation rates (reference 23). Other literature indicates that for adequate cyst inactivation (with the exception of *Cryptosporidium* oocysts) that additional contact time is necessary after passing through the resin (references 3, 7, 15, 16 and 28). Although an iodine residual was present in the water after passing through the column, the inactivation of the *Giardia* cysts is likely due to the iodine bound to the cysts after coming into contact with the resin and not due to the iodine residual (reference 23). The additional contact time indicates *Giardia* cysts are more resistant to iodine resin inactivation compared to bacteria and viruses. There is evidence that *Giardia* cysts can be filtered by the resin. Approximately 65% of *Giardia* cysts passing through a pentaiodide column temporarily adhered to the resin bead surface (reference 23). However, these cysts were subsequently washed off the resin beads after continued use and passed through the pentaiodide resin column. These cysts were inactivated (reference 23). A 3-log inactivation of *Giardia* cysts can be achieved if a pentaiodide resin bed is used and additional contact time is provided after passing through the resin bed. In colder waters, longer contact time is necessary to ensure *Giardia* cyst inactivation. Ensuring adequate *Giardia* cyst inactivation (3-log) will ensure adequate bacteria (6-log) and virus (4-log) inactivation.

Iodine resins are not effective at inactivating *Cryptosporidium* oocysts. One study showed no inactivation of *Cryptosporidium* oocysts that passed through a pentaiodide resin (reference 18). Similar to *Giardia* cysts, there is evidence that *Cryptosporidium* oocysts are filtered by the resin bed (reference 18). This is likely due to electrostatic interactions. Therefore, resins could provide a measure of physical removal of *Cryptosporidium* oocysts. However, like *Giardia* cysts, subsequent use of resins might cause the release or washing off of oocysts from the resin and the oocysts could remain viable. Iodine resins cannot be considered effective for inactivating *Cryptosporidium* oocysts. Additional treatment such as filtration would be necessary to control *Cryptosporidium.*

IODINE TOXICITY

Iodine is not widely used as a disinfectant in typical municipal drinking water systems due to potential adverse health effects caused from excessive iodine intake (reference 30). It's been suggested that chronic (long term) intake of 2 mg/day should be regarded as excessive and potentially harmful (reference 30). When ingested, iodine is converted to iodide and efficiently absorbed into the body. Most iodide resides in the thyroid gland (reference 30). Excessive amounts of iodine can cause an enlarged thyroid, a condition known as goiter (reference 30). For healthy individuals without pre-existing thyroid conditions or sensitivity to iodine, ingesting iodine concentrations associated with using IWPDs for short periods of time (i.e., 3 months or

less) are not likely to experience adverse health effects (reference 31). It is recommended that pregnant women, people with known hypersensitivity to iodine, people with a history (or family history) of thyroid disease, and people from countries or localities with chronic iodine deficiency should not use iodine as a means of water treatment (reference 31).

CONCLUSIONS

Iodine Solutions

Iodine solutions are effective disinfectants against bacteria, viruses, and *Giardia* cysts. They are not effective against *Cryptosporidium* oocysts. Temperature appears to have the greatest effect on iodine disinfection capability. *Giardia* cysts are more resistant to iodine disinfection than bacteria or viruses. Achieving adequate *Giardia* cyst inactivation should ensure adequate bacteria and virus inactivation. At colder water temperatures (both clear and turbid), and turbid water at any temperature, additional contact time and/or higher iodine dosages than recommended by IWPD manufacturers are likely necessary to achieve a 3-log inactivation of *Giardia* cysts (and 6-log bacteria and 4-log virus inactivation). CT's up to 720 mg-min/L are recommended for cold waters (5° C) to ensure *Giardia* cyst inactivation. Using iodine solutions to inactivate *Cryptosporidium* oocysts is not practical.

Iodine Resins

Pentaiodide resins are effective disinfectants against bacteria, viruses, and *Giardia* cysts. Triiodide resins are less effective than pentaiodide resins. Both resins are not effective for inactivating or removing *Cryptosporidium* oocysts. Turbidity and organic matter can reduce the disinfection capability of iodine resins. Similar to iodine solutions, *Giardia* cysts appear to be more resistant to inactivation by iodine resins than bacteria and viruses. Achieving adequate *Giardia* cyst (3-log) inactivation should ensure adequate bacteria (6-log) and virus (4-log) inactivation. Additional contact time is necessary after passing through a pentaiodide resin to ensure *Giardia* cyst inactivation. Provide at least 3 minutes additional contact time for warmer waters (> 20° C). Provide at least 40 minutes additional contact time for colder waters (< 5° C). The table provides a summary of the disinfection capability of iodine resins and solutions.

Table. Summary of Disinfection Capabilities of Iodine Solutions and Resins.

Parameter	Iodine Solutions	Iodine Resins
General	Cysts most resistant. Achieving *Giardia* cyst inactivation will ensure adequate bacteria and virus inactivation.	Cysts most resistant. Achieving *Giardia* cyst inactivation will ensure adequate bacteria and virus inactivation
Bacteria	Effective	Effective
Viruses	Effective	Effective
Giardia Cysts	Provide additional contact time beyond IWPD manufacturer recommended CTs.	Pentaiodide resin effective. Triiodide resin not effective. Provide additional contact time after passing through resin.
Cryptosporidium Oocysts	Not effective.	Not effective.
Effect of Temperature	Major effect. Increase contact time and/or dose at colder temperatures. CT's up to 720 mg-min/L recommended for *Giardia* cyst inactivation in colder waters.	Major effect. Increase contact time after passing through pentaiodide resin at colder temperatures. Allow up to 40 minutes additional contact time for *Giardia* cysts inactivation in colder waters (< 5° C)
Effect of pH	Minor effect. Generally effective over typical pH levels for natural waters	Minor effect. Generally effective over pH range typical for natural waters
Effect of Turbidity	Affects disinfection capability. Provide additional contact time and/or increase iodine dose in more turbid waters.	Affects disinfection capability. Heavy organic matter loading can significantly reduce disinfection capability.

PREPARED BY: Steven H. Clarke, Environmental Engineer

DATED: March 2006

APPENDIX A
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ANNEX 5 TO APPENDIX F

TIP #31-006-0306
ULTRAVIOLET LIGHT DISINFECTION IN THE USE OF INDIVIDUAL WATER PURIFICATION DEVICES

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Ultraviolet Light Disinfection in the Use of Individual Water Purification Devices

Technical Information Paper #31-006-0306

PURPOSE

This information paper provides an in-depth review of ultraviolet (UV) light for use as a disinfection technology in potable water supplies. This paper is intended to assist the reader in evaluating the disinfection capabilities of UV light-using Individual Water Purification Devices (IWPDs) to inactivate disease-causing bacteria, viruses, and cysts.

REFERENCES

Appendix A contains a list of references.

INTRODUCTION

Background

Understanding the disinfection capabilities of UV light to inactivate disease-causing microorganisms is important in protecting Soldiers, who are considering using this technology, from acute health threats posed by these microorganisms. Soldiers deployed beyond traditional field drinking water supplies must have access to microbiologically safe water. Using IWPDs is one way to provide microbiologically safe water in these situations. These IWPDs must protect the Soldier from acute microbial health threats. The U.S. Environmental Protection Agency (EPA) Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1) provides performance standards by which an IWPD that uses UV light can be evaluated. The performance standards are a minimum 6-log reduction/inactivation of bacteria, 4-log reduction/inactivation of viruses, and 3-log reduction/inactivation of protozoan cysts. UV-using IWPDs meeting these standards are considered effective against disease causing bacteria, viruses, and protozoan cysts. Some IWPD manufacturers test their devices using this protocol. This is the best way to evaluate the IWPDs disinfection capabilities. In the absence of that testing data, this information paper can be used to gain an understanding of UV light disinfection capabilities and help determine if an IWPD using UV light could successfully meet the EPA Guide's minimum performance standards. This information paper was developed primarily using information obtained from the EPA's Draft Ultraviolet Disinfection Guidance Manual (reference 2). The manual provides a comprehensive review of available scientific literature concerning UV disinfection in drinking water systems.

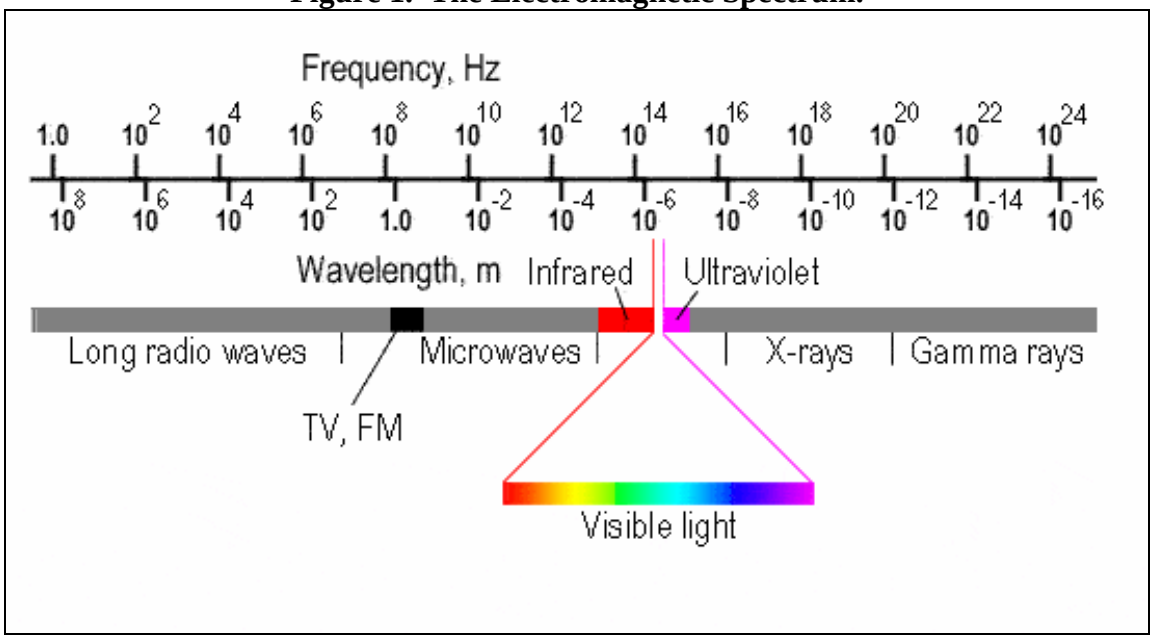
b. History of UV Light in Potable Water Applications. The germicidal properties of UV light were discovered in 1887. The first application of UV light in drinking water occurred in 1910 at Marselles, France. Since then, UV light is used in drinking water systems worldwide primarily for disinfection. Currently there is only one Commercial-Off-The-Shelf (COTS) IWPD using UV light for disinfection. However, as UV research continues, more COTS IWPDs incorporating UV technology may be developed.

ULTRAVIOLET DISINFECTION

UV Light Description

In drinking water, UV light is used for disinfection. The use of UV for disinfection involves: (1) the generation of UV light with the desired germicidal properties, and (2) the delivery (or transmission) of that light to microbial pathogens. As Figure 1 shows, UV light lies between x-rays and visible light in the electromagnetic spectrum. The UV spectrum covers the wavelength range from 100-400 nm. UV light at certain wavelengths can inactivate microorganisms. UV light with wavelengths from 200-300 nm inactivates most microorganisms, with the greatest amount of inactivation occurring around 260 nm.

Figure 1. The Electromagnetic Spectrum.



Source: http://www.sentinelarchiving.com/ARTICLES/electromag.htm

UV Light Generation

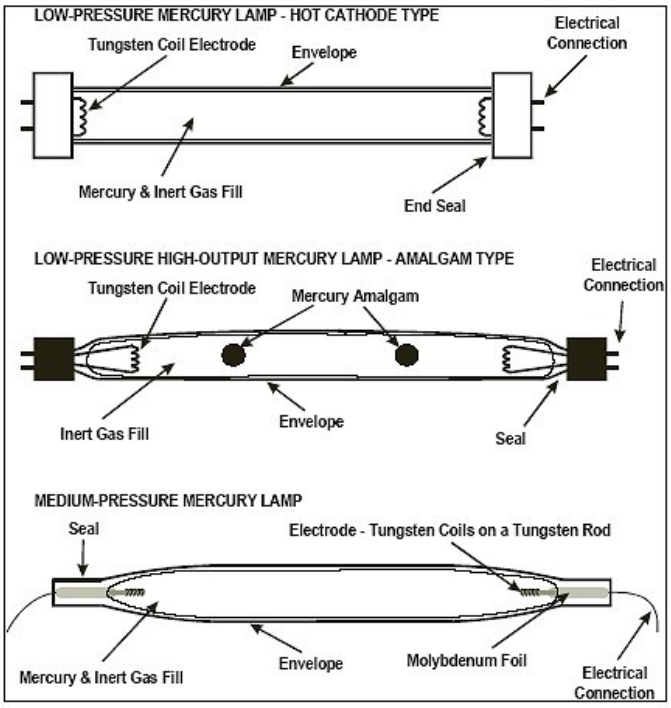
Generation of UV light is similar to the generation of light in a fluorescent lamp. In general, a UV lamp contains an inert gas (e.g., argon) and a small amount of liquid mercury. When a voltage is applied to the lamp, some of the liquid mercury vaporizes. Free electrons and ions then collide with the gaseous mercury atoms, "exciting" the mercury atoms into a higher energy state. Excited mercury atoms have a tendency to return to their ground, or normal, energy state by discharging energy. The energy discharged is in the form of UV light. Mercury is advantageous for UV disinfection applications because it emits light in the germicidal wavelength range (200 – 300 nm). The UV light produced depends on the concentration of mercury atoms in the UV lamp, which is directly related to the mercury vapor pressure. Low pressure mercury vapor produces monochromatic (light at primarily one wavelength) UV light at a wavelength of 253.7 nm. Higher pressure mercury vapor produces UV light at several wavelengths (polychromatic).

UV Lamps

UV Lamp Types

For water treatment systems, there are three general types of UV lamps typically used; low-pressure (LP), low-pressure high-output (LPHO), and medium-pressure (MP). These terms are based on the vapor pressure of mercury when the lamps are operating. LP and LPHO lamps operate at mercury vapor pressures of $2x10^{-3}$ – $2x10^{-5}$ pounds per square inch (psi), thereby producing monochromatic UV light at 253.7 nm. MP lamps operate at much higher mercury vapor pressures of 2 – 200 psi and produce polychromatic UV light at a higher intensity. LP and LPHO lamps operate at temperatures of 40 – 200° C, while MP lamps operate at a much higher temperature range of 600-900° C. LP lamps have the lowest power requirements, while LPHO and MP lamps have higher power requirements. Subsequently, LP lamps have the lowest germicidal output (0.2 W/cm), while LPHO and MP lamps have higher germicidal outputs (0.5 – 3.5 W/cm and 5 – 30 W/cm, respectively). Figure 2 shows drawings of LP, LPHO, and MP lamps. There is generally no difference in disinfection capability between these lamps. But there are advantages and disadvantages to each. For example, compared to LP lamps, MP lamps have a higher germicidal output, typically require fewer lamps for a given applications, and would likely be a smaller reactor. There are other types of lamps that can produce UV light such as metal halide lamps, electrode-less mercury vapor lamps, and eximer lams. However, because these lamps are not commonly used for drinking water UV disinfection application, they are not discussed here. Most UV-using IWPDs will likely use LP lamps due to lower operating temperatures and lower power requirements.

Figure 2. LP, LPHO, and MP Lamp Drawings.



Source: Reference 2

UV Lamp Breakage

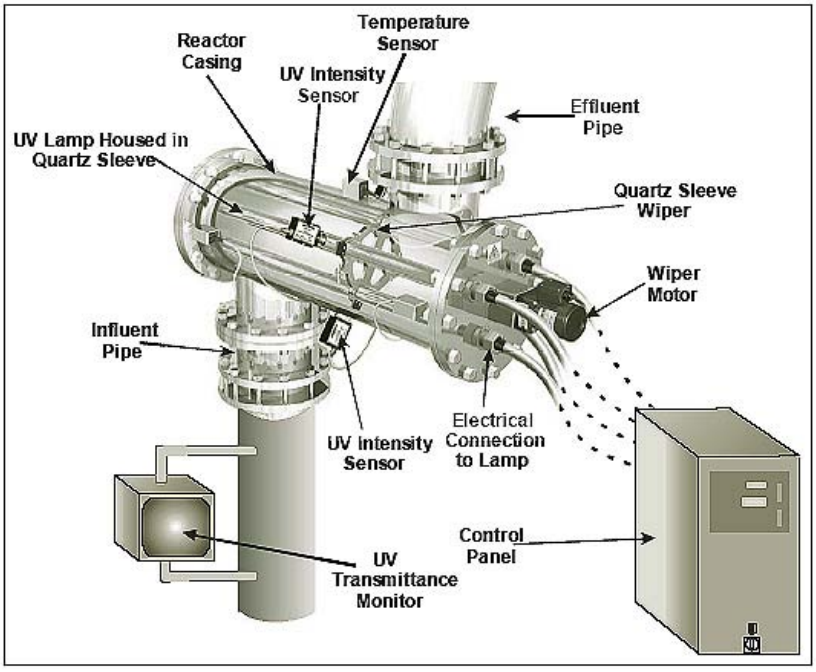
Lamp sleeves can break. Breakage is a concern due to potential for mercury release. UV lamps contain mercury or an amalgam composed of mercury and another element, such as indium or gallium. LP and MP lamps generally contain elemental mercury, while LHPO lamps generally contain a mercury amalgam. The mercury contained within a UV lamp is isolated from exposure by a lamp envelope and surrounding lamp sleeve. For the mercury to be released, both the lamp and lamp sleeve must break. Breakage can occur when lamps are in operation as well as when not operating but during maintenance. The mercury content in a single UV lamp used for water treatment typically ranges from 0.005 to 0.4 grams (5-400 mg). LP lamps have less mercury (5-50 mg/lamp) compared to LPHO (26-150 mg/lamp) and MP lamps (200-400 mg/lamp). Depending on the state mercury is in (gas, solid, or liquid) when a lamp breaks can be important when determining potential health risks. Mercury in the vapor phase may be released as very fine particles, which may readily dissolve in water, as opposed to solid or liquid mercury that will tend to settle. There is very little information on determining the amount of mercury released relative to the amount of mercury in the lamp prior to breakage. One study involving the breakage of a UV lamp containing 150 mg mercury in a 50 L batch reactor resulted in a concentration of 2.5 ug/L of mercury in the reactor. However, it was not reported whether all

150 mg of mercury was recovered. For IWPD use, since it is assumed that LP lamps are used, breakage of the lamp during operation may result in contamination of water being treated with 5-50 mg of mercury.

UV Reactors

In drinking water systems, UV lamps are contained in a UV reactor. UV reactors operate as either batch or continuous flow reactors. Several characteristics must be taken into account when designing, installing, and operating a UV reactor. Among them are water quality characteristics, distance between the lamp and the reactor wall, and the distribution of UV light. Additionally, continuous flow reactors must take into account hydraulic characteristics of water flowing through the reactor. Due to all these characteristics, microorganisms will not all receive the same UV dose. For example, UV lamp placement in a reactor influences UV dose delivery. If the distance between the lamp and the reactor wall is too large (i.e., a large amount of water between the lamp and the reactor wall), microorganisms furthest from the lamp will receive less UV intensity and subsequently a lower UV dose. Figure 3 is a schematic of a continuous flow UV reactor. Most UV-using IWPDs will likely utilize a batch reactor system.

Figure 3. Continuous Flow UV Reactor Schematic.



Source: Reference 2.

UV Dose

Definition of UV Dose

In drinking water applications, disinfection using UV light follows the familiar CT concept (disinfectant concentration times contact time). However, instead of using CT to describe UV disinfection, UV dose is used instead. UV dose is defined as the measurement of the energy per unit area that falls upon a surface. UV dose is the product of UV intensity, I, and exposure time, T (IT), similar to the CT concept. UV intensity is usually expressed as mW/cm^2 and exposure time is measured in seconds (s). So UV dose is reported as mWs/cm^2. However, UV dose is commonly expressed as millijoules per square centimeter (mJ/cm^2), because 1 mWs = 1 mJ.

Estimating UV Dose

When disinfection test data is not available models can be used to gain an understanding of disinfection capabilities of UV-using IWPDs. Several complex models have been developed to estimate UV intensity delivered to a microorganism. With the estimated UV intensity, the UV dose can calculated based on various exposure times and compared to UV doses determined in scientific literature. The simplest model used to estimate UV intensity is the radial model:

$$I(r) = (P_L / 2\pi r) \times (e^{-aer})$$

Where: P_L = UV power emitted per unit arc length of the lamp (mW/cm)
r = Radial distance from the lamp (cm)
ae = Base e absorption coefficient of the water (1/cm). $ae = 2.303 * A_{254}$
I(r) = UV intensity (mW/cm^2) at a distance r from the lamp

Using data provided by the manufacturer on UV power emitted (P_L), dimensions of the IWPD UV reactor, and assuming water quality variables to develop an absorption coefficient (ae), UV intensity can be calculated. In the absence of good quality IWPD specific testing data, this model can be used to provide a rough evaluation of disinfection capability.

Mechanism of UV Disinfection

Inactivating Versus Killing Microorganisms

When discussing UV light disinfection capabilities, a distinction must be made between inactivating and killing microorganisms. For chemical disinfectants (e.g., chlorine, chlorine dioxide, iodine), inactivating and killing can be considered synonymous terms since chemical disinfectants destroy and damage cellular structures which interferes with metabolism, biosynthesis, and growth. In contrast, UV light does not destroy or damage cellular structures. Rather, UV light prevents microorganisms from reproducing. Microorganisms that cannot

reproduce cannot infect and are thereby inactivated. Subsequently, when evaluating UV disinfection capability, *Giardia* cyst and *Cryptosporidium* oocyst assays that measure infectivity, not viability must be used. Excystation assays measuring viability are not accurate indicators of UV disinfection capability.

Inactivation Mechanism

UV light inactivates microorganisms by damaging deoxyribonucleic acid (DNA) and ribonucleic acid (RNA). When DNA and RNA absorb UV light, damage results from the formation of dimers (covalent bonds between the same nucleic acids). Dimers cause faults in the transcription of information from DNA to RNA, which in turn results in disruption of microorganism replication. The microorganism continues to live, but it can't reproduce and therefore is not infective. A microorganism that cannot replicate cannot infect a host. Microorganisms developed two mechanisms to repair damage caused by UV light. These mechanisms are termed light and dark repair. It is possible for microorganisms to repair themselves to the extent where they will become infective again after exposure to UV light. Fortunately, however, most data indicates UV doses typically used in water treatment prevent most repairs. In general, microorganism inactivation by UV light follows first order reaction rates. However, inactivation rates can vary depending on microorganism type, and water quality conditions (e.g., turbidity, particulate matter, and clumping of microorganisms). Lastly, similar to chemical disinfectants and the CT approach to disinfection evaluation, data has shown that UV disinfection follows the law of reciprocity over an intensity range of 1-200mW/cm^2. For example, a UV dose of 1 mW/cm^2 for 200 sec (i.e., 200 mJ/cm^2) achieves the same level of inactivation as a UV dose of 200mW/cm^2 for 1 sec (i.e., 200 mJ/cm^2).

Environmental Effects

Introduction

UV light can interact with materials potentially reducing disinfection capability. Interactions include absorption, reflection, refraction, and scattering. Absorption is the transformation of light to other forms of energy. When UV light is absorbed, it is no longer available for disinfecting microorganisms. The remaining interactions, reflection, refraction, and scattering, change the direction of UV light and the light is still available for disinfection. UV transmittance and UV absorbance are two related common water quality parameters used to measure these interactions. UV transmittance (UVT), particle content, and constituents that foul lamp sleeves are the most significant water quality factors impacting UV disinfection capability. Water temperature and pH do not generally have an impact on UV disinfection capability.

Effect of UVT

Both UVT and UV absorbance describe the amount of UV light passing through water. They are related by the following equation:

$$\% \text{ UVT} = 100 \times 10^{-A254 * d}$$

Where: UVT = UV transmittance at a 254 nm and a 1 cm pathlength
A_{254} = UV absorbance at 254 nm based on a 1 cm pathlength (unitless)
d = distance from UV lamp (cm). When measuring UV absorbance, d = 1cm

UVT is affected by turbidity, particulate matter, and natural organic matter (NOM). UVT directly affects dose-delivery, and subsequently disinfection capability. As turbidity increases, UVT decreases and UV absorbance increases. Decreased UVT decreases UV intensity delivered to the microorganism, thereby decreasing disinfection capability. Table 1 illustrates the effect of turbidity on UVT, UV absorbance, UV intensity, and the required exposure time necessary to achieve a UV dose of 5 mJ/cm^2 (reference 3). Notice as turbidity increases, UVT decreases, UV Absorbance increases, and UV intensity decreases. Therefore, to maintain a consistent 5 mJ/cm^2 dose, exposure time must be increased. UV absorbers in typical source waters include humic and fulvic acids, other organics, metals (e.g., iron), and anions (e.g., nitrates, sulfites). Both soluble and particulate forms of these compounds will absorb UV light, subsequently reducing UVT. UVT and UV absorbance will vary over time due to changing concentrations of these compounds. UVT and UV absorbance are more variable in rivers and small lakes and will also vary seasonally. Water systems using coagulation/flocculation, filtration, and oxidation treatment processes will increase UVT by reducing UV absorbing compounds, thereby increasing UV disinfection capability. For water systems considering the use of UV disinfection, UV should be installed after filtration. Installing UV prior to filtration will require higher UV doses to achieve the same level of inactivation due to higher levels of NOM, turbidity, and particulate matter. Particles can reduce UV disinfection capability by absorbing UV light and shielding microbes from UV light. No clear correlations have been observed between the amount of turbidity, its characteristics, and the impact on UV disinfection capability (reference 4). Some studies have demonstrated that turbidities above 10 nephelometric turbidity unit (NTU) and even up to 100 NTU have no impact on UV disinfection (references 1 and 5). While other studies observed reduced UV disinfection capability at turbidities in the 5 NTU range (reference 4). In general, increasing turbidities result in decreasing UV disinfection capability. One study showed increasing turbidities from 0.25 to 20 NTU resulted in a 0.8-log and 0.5-log decrease in inactivation of *Cryptosporidium* and *Giardia*, respectively (reference 3). The type of particle present in water can affect UV disinfection. Particles with higher organic content were observed to protect particle-associated viruses from UV light compared to particles of the same size with no organic content (reference 6).

Table 1. Effect of Turbidity on UVT, UV Absorbance, UV Intensity, and Exposure Time.

Turbidity (NTU)	% UVT	UV Absorbance	UV Intensity (mW/cm^2)	Exposure time necessary to achieve 5 mJ/cm^2 dose (s)
0.25	86	0.07	0.40	12.4
5.0	78	0.11	0.39	12.8
10.0	71	0.15	0.36	13.9
20.1	59	0.23	0.33	15.0

Effect of Water Temperature and pH

An advantage of UV disinfection over chemical disinfectants is that inactivation is generally independent of water temperature and pH. Overall, effect of water temperature is insignificant on UV disinfection capability. Temperature can affect the activity of repair enzymes and nucleic acid configuration, which may result in a very slight increase in UV dose necessary with decreasing temperatures to achieve the same log inactivation. Compared to turbidity, particulate matter, and NOM, the effect of water temperature is insignificant. The water pH has an insignificant effect on UV disinfection capability. Repair and nucleic acid configuration are affected by pH. However, pH within a cell is relatively constant and does not vary with water pH. Studies using MS2 virus showed pH over 6-9 range had no effect on inactivation.

Effect of Fouling Contaminants

Fouling of UV lamps will reduce UV disinfection capability. Hardness, alkalinity, temperature, iron concentration, and pH all influence fouling. Compounds exhibiting decreasing solubility with increasing temperatures (e.g., $CaCO_3$, $CaSO_4$, $FeCO_3$) are prime contributors to lamp fouling. One study showed at total and calcium hardness levels less than 140 mg/L and iron less than 0.1 mg/L, mechanical cleaning (wiper sweeping) every 15 min to 1 hour during operation of a continuous flow UV reactor was sufficient to overcome impact of sleeve fouling. The Langelier Saturation Index and Calcium Carbonate Precipitation Potential can be used to help indicate fouling potential by indicating the tendency of the water to form a calcium carbonate precipitate. For UV-using IWPDs, fouling of the UV lamp is not expected to be significant. Although groundwaters are primarily associated with high hardness and dissolved solids, there are also surface waters containing high levels of hardness and dissolved solids (reference 7). Most IWPDs would likely be used with surface waters. However, since IWPD use would be intermittent, not continuous, and the same source would likely not be used consistently, UV lamp fouling is not expected to be a significant factor reducing UV disinfection capability.

Bacteria, Virus, and Protozoa Inactivation Capability

Microorganism Inactivation Capability

The effectiveness of UV light on microorganism inactivation varies with different types of microorganisms. Generally, UV light is most effective at inactivating *Cryptosporidium* and *Giardia*, followed by bacteria and then viruses:

Cryptosporidium and *Giardia* > Bacteria > Viruses

Interestingly, UV resistance appears to follow microorganism size, with the smallest microorganisms being most resistant. The reason for this may be due to the amount of UV light absorption per cell. With microorganisms larger than 1 micron, the absorption of UV light by the cell can be significant, effectively reducing resistance to UV disinfection. Table 2 is a summary of numerous UV disinfection studies and shows UV doses and corresponding log inactivation for various microorganisms. The most UV resistant viruses of concern in drinking water are adenovirus Type 40 and 41. Because viruses are the most resistant to UV disinfection, dosing is controlled by log inactivation requirements for viruses, not protozoan cysts (reference 4). As Table 2 shows, *Cryptosporidium* and *Giardia* are very sensitive to inactivation by low doses of UV light (reference 8).

Table 2. UV Dose and Corresponding Log Inactivation by Microorganism.

Microorganism Type	Microorganism	UV Dose for 3-log inactivation (mJ/cm^2)	UV dose for 4-log inactivation (mJ/cm^2)
Virus	Adenovirus Type 40	90	120
Virus	MS2	52	71
Virus	Poliovirus Type 1	23	30
Virus	Hepatitis A	15	21
Spore	*Bacillus subtilis*	61	78
Bacteria	*Salmonella enteriditis*	9	10
Bacteria	*Salmonella typhi*	5	9
Bacteria	*Escherichia coli*	6.7	8.4
Bacteria	*Vibrio cholerae*	2.2	2.9
Protozoa	*Cryptosporidium parvum*	<6	-
Protozoa	*Giardia lamblia*	<6	-

Adapted from reference 2.

Development of UV Dose Tables

Pursuant to the Long Term 2 Enhanced Surface Water Treatment Rule, the EPA proposed UV dose tables for various log inactivation of viruses, *Cryptosporidium*, and *Giardia* (reference 9). The proposed UV doses for 3-log *Giardia* and *Cryptosporidium*, and 4-log virus inactivation are shown in Table 3. Comparing these doses to those in Table 2 shows that the EPA proposed UV doses are higher. These doses are more conservative and were developed to account for uncertainty associated with the inactivation studies of microorganisms in controlled conditions using low turbidity water (less than or equal to 1 NTU). These uncertainties are addressed by applying a safety factor to experimentally determined UV doses. The EPA collected UV inactivation research data conducted over the past 50 years for adenovirus, *Giardia lamblia, Giardia muris, and Cryptosporidium parvum.* Adenovirus was evaluated because it is considered the most resistant to inactivation by UV light of the pathogenic waterborne viruses. The EPA evaluated 19 studies for these microorganisms. When evaluating UV-using IWPDs that are treating raw, unfiltered waters, higher UV doses than those shown in Table 3 may be necessary to achieve the same level of inactivation. Higher UV doses can be achieved by longer exposure time, removing UV absorbing components (e.g., particulate matter, NOM) from the water prior to UV exposure (e.g., filtration or carbon absorption), or, if possible, increasing UV lamp intensity. Even at higher UV doses, it appears that a UV-using IWPD can reasonably achieve minimum 6-log bacteria, 4-log virus, and 3-log *Giardia* and *Cryptosporidium* inactivation. For example, treating a turbid water (e.g., 30 NTU) may require a doubling of the EPA proposed UV dose of 186 mJ/cm^2 required for 4-log virus inactivation shown in Table 3 (i.e., a UV dose of 372 mJ/cm^2) to assure adequate inactivation. Assuming the UV-using IWPD delivers an average UV intensity of 0.5 mW/cm^2, an exposure time of 744 seconds (~12 min) is necessary to achieve the required dose.

Table 3. Proposed UV Dose Requirements for 3-log *Cryptosporidium* and *Giardia* Inactivation and 4-log Virus Inactivation (mJ/cm^2)

3-log *Cryptosporidium* inactivation	3-log *Giardia* inactivation	4-log virus inactivation
12	11	186

UV TOXICITY

Disinfection Byproduct Formation

A main chronic health concern with chemical disinfectants is the formation of disinfection byproducts (DBPs). Trihalomethanes and haloacetic acids, the only regulated DBPs are not formed during UV disinfection. However, there are studies that show low-level (i.e., ug/L)

formation of non-regulated DBPs (e.g., aldehydes). The health effects of non-regulated DBPs at the levels formed during UV disinfection has not been widely researched. Use of UV-using IWPDs may result in higher levels of non-regulated DBPs formed since raw, unfiltered waters would contain higher amounts of DBP precursors (e.g., NOM). However, the IWPDs would be used on a short-term basis (i.e., < 3-4 weeks) by healthy adult soldiers. Therefore, exposure to UV-produced DBPs would likely have negligible adverse health effects.

Mercury Exposure

There is a health concern for the potential of mercury exposure due to lamp breakage. As discussed earlier, all UV lamps contain some amount of mercury. Lamps used in water treatment systems reportedly have between 5-400 mg of mercury. The risk associated with a mercury release to the water due to lamp breakage during operation depends on many factors. Little information exists regarding the fate of mercury released to the water as a result of UV lamp breakage. This adds to the uncertainty of the risk of adverse health effects. UV lamp breakage during operation can result in potential ingestion of mercury. The EPA established a maximum contaminant level (MCL) for mercury at 0.002 mg/L. The EPA has found mercury to potentially cause kidney damage from short-term exposures at levels above the 0.002 mg/L MCL (reference 10). UV lamps in IWPDs will contain mercury. Since these IWPDs will most likely utilize LP lamps due to lower power requirements and lower operating temperatures, breaking a UV lamp during operation could result in 5-50 mg of mercury being released into the water being treated. Therefore, there is cause for concern, even for short-term exposure of mercury to healthy soldiers if a UV lamp breaks during operation.

CONCLUSIONS

UV Disinfection Capability

UV disinfection is effective against protozoan cysts, bacteria, and viruses. UV light does not kill microorganisms. Rather, it damages the DNA and RNA and prevents the microorganism from reproducing. When a microorganism cannot reproduce it cannot infect. UV light is most effective against *Cryptosporidium* and *Giardia* followed by bacteria. UV light is least effective against viruses. Turbidity, particulate matter, and NOM are the most significant water quality parameters having the greatest effect on UV disinfection capability. Water temperature and pH have an insignificant effect on UV disinfection capability. Increasing levels of turbidity, particulate matter, and NOM absorb more UV light, making less UV light available for disinfection. Similar to the CT concept, the IT concept [UV intensity (mW/cm^2) times exposure time (s)], commonly referred to as UV dose (mJ/cm^2), is used to describe UV disinfection capability. Increasing concentrations of turbidity, particulate matter, and NOM require higher UV doses in the form of increased UV intensity and/or longer exposure times to achieve the same amount of inactivation. Studies evaluating UV disinfection capability indicate UV doses of 120 mJ/cm^2 are adequate to achieve 4-log virus inactivation of the most resistant viruses. The

EPA adds a safety factor and proposes a UV dose of 186 mJ/cm^2 for a 4-log inactivation of viruses. These UV doses will ensure a 3-log *Giardia* and *Cryptosporidium* inactivation and likely ensure a 6-log bacteria inactivation. Most UV lamps used in drinking water applications contain mercury. There is concern of adverse health effects to the consumer as a result of mercury exposure from UV lamp breakage during operation.

Evaluating UV-Using IWPDs

UV-using IWPDs can be effective against *Cryptosporidium*, *Giardia*, bacteria, and viruses. Since raw, unfiltered waters will be treated, UV doses higher than those proposed by the EPA will likely be required to achieve the same level of inactivation. For example, treating a highly turbid water (e.g., 30 NTU) may require a doubling of the EPA proposed UV dose of 186 mJ/cm^2 required for 4-log virus inactivation (i.e., a UV dose of 372 mJ/cm^2). Assuming the UV-using IWPD delivers an average UV intensity of 0.5 mW/cm^2, an exposure time of 744 seconds (~12 min) is necessary to achieve the required dose. This seems reasonable and practical for field use. Models can be used to help understand UV disinfection capabilities of UV-using IWPDs under various water quality conditions likely to be encountered. There is cause for concern for adverse health effects from exposure to mercury if the UV lamp is broken during operation. Since all UV lamps contain mercury and UV-using IWPDs most likely utilize LP lamps due to lower power requirements and lower operating temperatures, breaking IWPD UV lamp during operation may result in up to 5-50 mg of mercury being released into the water being treated. The risk of adverse health effects from UV lamp breakage during operation is uncertain, however, there is cause for concern, even for short-term exposure of mercury to healthy soldiers. Table 4 summarizes UV disinfection capabilities, environmental effects, and potential health concerns with using UV light.

Table 4. UV Disinfection Capabilities.

Parameter	UV Disinfection
General Disinfection Capability	Viruses most resistant. *Giardia* and *Cryptosporidium* least resistant. UV dose will be based on virus inactivation.
Bacteria	Effective at reasonable UV doses for IWPD use.
Viruses	Effective at reasonable UV doses for IWPD use. Use proposed EPA UV dose table for recommended doses (Table 3). UV doses higher than those recommended may be necessary based on turbidity, particulate matter, and NOM.
Giardia Cysts	Effective at reasonable UV doses for IWPD use.
Cryptosporidium Oocysts	Effective at reasonable UV doses for IWPD use.
Effect of Temperature	Negligible effect.
Effect of pH	Negligible effect.
Effect of Turbidity/Particulate Matter/NOM	Significant effect. Higher concentrations require higher UV doses to achieve same levels of inactivation.
Health Effects	UV lamp breakage during operation may exposure user to unsafe levels of mercury.

PREPARED BY: Steven H. Clarke, Environmental Engineer

DATED: March 2006

APPENDIX A
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ANNEX 6 TO APPENDIX F

TIP #31-007-0306
CHLORINE DIOXIDE DISINFECTION IN THE USE OF INDIVIDUAL WATER PURIFICATION DEVICES

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Chlorine Dioxide Disinfection in the Use of Individual Water Purification Devices

Technical Information Paper #31-007-0306

PURPOSE

This information paper provides an in-depth review of chlorine dioxide as a disinfectant in potable water supplies. This paper is intended to assist the reader in evaluating the disinfection capabilities of Individual Water Purification Devices (IWPDs) using chlorine dioxide to kill or inactivate disease-causing bacteria, viruses, and protozoan cysts.

REFERENCES

Appendix A contains a list of references.

INTRODUCTION

Background

Understanding the disinfection capabilities of chlorine dioxide to kill or inactivate disease-causing microorganisms is important in protecting soldiers, who are considering using this technology, from acute health threats posed by these microorganisms. Soldiers deployed beyond traditional field drinking water supplies must have access to microbiologically safe water. Using IWPDs is one way to provide microbiologically safe water in these situations. These IWPDs must protect the Soldier from acute microbial health threats. The U.S. Environmental Protection Agency (EPA) Guide Standard and Protocol for Testing Microbiological Water Purifiers (reference 1) provides performance standards by which an IWPD using chlorine dioxide can be evaluated. The performance standards are a minimum 6-log reduction/inactivation of bacteria, 4-log reduction/inactivation of viruses, and 3-log reduction/inactivation of protozoan cysts. Chlorine dioxide-using IWPDs meeting these standards are considered effective against disease causing bacteria, viruses, and protozoan cysts. Some IWPD manufacturers test their devices using this protocol. This is the best way to evaluate the IWPDs disinfection capabilities. In the absence of that testing data, this information paper can be used to gain an understanding of chlorine dioxide disinfection capabilities and help determine if an IWPD using chlorine dioxide could successfully meet the EPA Guide's minimum performance standards.

General

Chlorine dioxide (ClO_2) was discovered in 1811 (reference 2). It's widely used in numerous industries including wood pulp processes, wastewater treatment, and food processing. Water treatment plants in the United States first used chlorine dioxide in the 1940s for taste and odor control (reference 3). In addition to taste and odor control, many drinking water systems throughout the world today use chlorine dioxide for disinfection, control of organic disinfection byproducts (e.g., trihalomethanes), and oxidation of iron and manganese. Currently, there are only a few Commercial-Off-The-Shelf (COTS) IWPDs using chlorine dioxide for disinfection.

CHLORINE DIOXIDE CHEMISTRY IN WATER

General

Chlorine dioxide exists as an undissociated gas dissolved in water at a near neutral pH range (pH 6-9) (reference 4). Because chlorine dioxide exists as a gas it is vulnerable to volatilization; it can be easily removed from water by turbulent aeration, and is destroyed by ultraviolet light when exposed to sunlight (reference 5). Chlorine dioxide is stable in dilute solution in a closed container in the absence of light (reference 5). One of the advantages of using chlorine dioxide over chlorine for disinfection is the decreased formation of organic disinfection byproducts (DBPs), such as trihalomethanes (reference 3). However, chlorine dioxide is an oxidant and reactions with organic matter form inorganic DBPs including primarily chlorite ion (ClO_2^-) and to a lesser extent chlorate ion (ClO_3^-). Chloride (Cl^-) is also formed to a lesser extent. The reaction of chlorine dioxide in water at pH 6-8 containing organic matter is suggested to be (reference 6):

$$ClO_2 + e^- \rightarrow ClO_2^-$$

$$ClO_2^- + H^+ \leftrightarrow HClO_2 \text{ (chlorous acid)}$$

$$4HClO_2 \rightarrow 2ClO_2 + H^+ + Cl^- + HClO_3 + H_2O$$

Chlorine dioxide reacts rapidly. In drinking water, where typical dosages are 0.07 – 2.0 mg/L, chlorite is the predominant reaction product with approximately 50-70% of chlorine dioxide converted to chlorite, and 30% converted to chlorate and chloride (reference 3). Manufacturer recommended dosages for IWPD use may be similar to those used in water systems or may be much higher. Chlorine dioxide IWPD manufacturers recommend dosages from 0.7 – 4 mg/L for most waters and up to 7.5 mg/L when treating cold and/or cloudy waters (references 7 and 8).

Generation

Chlorine Dioxide Generation for Water Systems

Chlorine dioxide can't be stored commercially or compressed since it is explosive under pressure. Therefore, it must be generated on-site (reference 5). Although there are emerging technologies for chlorine dioxide generation, the two most common methods are (references 2 and 5):

(1) sodium chlorite – acid generation

$$5NaClO_2 + 4HCl \leftrightarrow 4ClO_2 + 5NaCl + 2H_2O$$

(2) sodium chlorite – chlorine generation

$$NaClO_2 + Cl_2 \leftrightarrow 2ClO_2 + 2NaCl$$

Chlorine Dioxide Generation for IWPDs

Chlorine dioxide must also be generated on-site on a much smaller scale or provided in dilute chlorine dioxide solutions for IWPD use. Currently, generating chlorine dioxide on-site for use as an IWPD uses buffered sodium chlorite, generally referred to as "stabilized chlorine dioxide" (references 9 and 10). The sodium chlorite must be "activated" by adding an acid, usually phosphoric or citric acid, resulting in the formation of chlorine dioxide in a reaction similar to the sodium chlorite – acid generation reaction used by water systems (shown earlier). There are health concerns associated with the use of "stabilized chlorine dioxide." "Stabilized chlorine dioxide" can potentially result in little formation of chlorine dioxide, thereby reducing disinfection capability, and can also potentially result in high concentrations of chlorite, which may cause adverse health effects when ingested and also has no disinfection capability (references 3 and 11). Dilute solutions of chlorine dioxide are also used as IWPDs. These solutions lose chlorine dioxide over time, but can be stable for several months and possibly longer. One study showed dilute chlorine dioxide concentrations (approximately 35 mg/L) exhibited variable losses based on the type of container used for storage (reference 12). For example, a 35 mg/L chlorine dioxide solution stored in a high-density Polyethylene Terephthalate (PETE) container for 45 days resulted in a 3% loss of chlorine dioxide (34 mg/L). In contrast, the same study stored chlorine dioxide in a clear glass container for 31 days which resulted in a 12% gain of chlorine dioxide (39 mg/L) possibly due to continuing formation of chlorine dioxide from chlorite. Another study showed a 6.2% overall gain in chlorine dioxide concentration after 252 days of storage in a PETE container (reference 12).

DISINFECTION CAPABILITIES

General

Chlorine dioxide is an effective disinfectant against bacteria, viruses, and many cysts including the capability to disinfect *Cryptosporidium* with realistic (typical to slightly higher water system) dosages (reference 3). A comparison of CTs required for a 2-log inactivation for *E. Coli* bacteria, Poliovirus 1, and *Giardia* cysts showed *Giardia* cysts were 2-5 times more resistant than Poliovirus 1 and 16-22 times more resistant than *E. Coli* bacteria (reference 13). The CT is the product of disinfectant concentration (C in mg/L) and contact time (T in min). The CT product is a useful way for comparing alternative disinfectants and the resistance of various pathogens (reference 28). Poliovirus was 4-11 times more resistant than *E. Coli* bacteria (reference 13). *Cryptosporidium* oocysts are the most resistant, being 8-16 times more resistant than *Giardia* cysts (reference 5). Chlorine dioxide's general disinfection capability with respect to microorganisms can be illustrated in the following way from most effective to least effective:

bacteria > viruses > *Giardia* cysts > *Cryptosporidium* oocysts

Chlorine dioxide is similar to other chemical disinfectants in that its disinfection capability decreases with decreasing temperature, its disinfection capability generally decreases with increasing turbidity, and its disinfection capability is affected by pH (references 3, 4 and 13). Since chlorine dioxide exists as an undissociated gas in water, volatilization and loss of chlorine dioxide and subsequent disinfecting capability is a concern (reference 3). Because chlorine dioxide is an oxidant it will react with organic matter in the water forming primarily chlorite and to a lesser extent chlorate and chloride. Both chlorite and chlorate show no disinfection capabilities and may cause adverse health effects in children, infants, and fetuses (reference 11). Drinking water systems using chlorine dioxide for disinfection are not generally able to provide adequate disinfection per regulations in raw water with high organic carbon (i.e., organic matter) when adding chlorine dioxide in the raw water. This is because the chlorine dioxide is used up by reacting with organic matter, being reduced to primarily chlorite and leaving no chlorine dioxide residual (reference 3). This can be a concern for IWPDs when treating raw, unfiltered water supplies. Higher dosages may be necessary to react with organic matter and provide disinfection.

Environmental Effects on Disinfection Capability

Effect of pH on Disinfection Capability

Compared to chlorine, chlorine dioxide is a more effective disinfectant across a broader pH range (roughly between 5 and 10) than free chlorine (reference 3). Several studies have shown the effect of pH on chlorine dioxide disinfection capability, with most results indicating disinfection capability generally increases with increasing pH (reference 14). Numerous studies

with viruses (e.g., poliovirus, hepatitis A virus) showed CTs required for a 2-log virus inactivation were 13 – 20 times higher at a pH of approximately 6 compared to a pH of 9 and 10 (references 13 and 15). Another study showed CTs up to 90-100 times higher were required for a 4-log virus inactivation at a pH of 6 compared to a pH of 10 (reference 16). Although these studies showed much higher CTs necessary at lower pHs, CTs were still low at the lower pHs (ranging from approximately 3 – 13 mg-min/L). This indicates chlorine dioxide is a highly effective disinfectant over a broad pH range. In contrast to the previous studies, a study on chlorine dioxide disinfection capability against *Cryptosporidium* oocysts indicated pH does not appear to have a significant effect on *Cryptosporidium* inactivation (reference 17). The degree of pH effect may be dependent on the targeted organism and in general chlorine dioxide shows an increase in disinfection capability with increasing pH. Chlorine dioxide would likely be effective over the pH range (pH 6-9) for natural, untreated water sources likely to be encountered when using IWPDs.

Effect of Temperature on Disinfection Capability

Like most chemical disinfectants, chlorine dioxide disinfection capability decreases with decreasing temperatures (reference 5). Cold water temperatures slow disinfection and must be compensated for by longer contact times or higher dosages to achieve comparable disinfection at warmer water temperatures (reference 18). A two to three-fold increase in inactivation rates per 10° C water temperature increase seems a generally accepted rule (reference 18). When considering chlorine dioxide, the U.S. Environmental Protection Agency (EPA) developed CT tables for the Surface Water Treatment Rule (SWTR) by assuming a twofold decrease in CT for every 10° increase (reference 19). Research shows a 2-log inactivation of *E. Coli* required four times higher CT at 5° C compared to 20° C (reference 13). A study using *Naegleria* cysts showed at 5° C a CT twice as high than at 20° C was required to provide a 2-log inactivation (reference 5). Using a two-fold CT increase for every 10° decrease in water temperature is a good estimate to use when determining CT requirements for chlorine dioxide disinfection capability.

Effect of Turbidity on Disinfection Capability

Turbidity also has an effect on chlorine dioxide disinfection capability. Turbidity in the form of particulate matter, aggregated or clumped microorganisms, and dissolved organic matter can reduce the effectiveness of chlorine dioxide. One study determined that bentonite clay added to produce turbidity levels up to 2.3 nephelometric turbidity units (NTUs) had no adverse effect on chlorine dioxide disinfection of poliovirus. However, at turbidity levels of 3.2 and 14.1 NTU, poliovirus inactivation was noticeably decreased (references 13 and 20). The study suggested that bentonite appeared to offer protection or shield the viruses from chlorine dioxide disinfection. Another study using bentonite reduced chlorine dioxide disinfection capability against *Naegleria* cysts by 11% at turbidities less than or equal to 5 NTU and 25% at turbidities between 5 and 17 NTUs (reference 5). Clumped or aggregated microorganisms are also shown

to be more resistant to chlorine dioxide disinfection (reference 5). In the presence of organic matter chlorine dioxide rapidly oxidizes the organic matter and is converted to primarily chlorite, and to a lesser extent chlorate and chloride ion (reference 3). This results in loss of chlorine dioxide residual and an increase in chlorite ion leading to reduced disinfection capability. Turbidity does have an effect on chlorine dioxide disinfection capability. Chlorine dioxide disinfection capability decreases in more turbid waters since microorganisms are protected by solid particles in water, protected by aggregation or clumping, and protected by loss of chlorine dioxide residual from oxidation of organic matter. Higher chlorine dioxide dosages may be necessary when using IWPDs to overcome organic matter oxidation and still provide disinfection when treating raw, unfiltered water supplies.

Bactericidal Capability

Chlorine dioxide is an effective bactericide. Research on chlorine dioxide bactericidal capability shows bacteria are less resistant than viruses and cysts (reference 13). Studies using *E. Coli* showed 2-log inactivation occurred very quickly in demand-free waters (i.e., no organic matter present) with CT's all less than 1.0 mg-min/L, ranging from 0.25 – 0.48 mg-min/L, at the coldest water temperatures (5° C) and lowest pH levels (6.5 - 7.0) (i.e., worst case conditions, references 13, 21). Another study estimated CTs of 1 or less at 5° C necessary for a 4-log *E. Coli* inactivation (reference 22). Chlorine dioxide should easily achieve a 6-log bacteria inactivation at low temperatures and low pHs if chlorine dioxide is used for disinfection of more resistant viruses and cysts. Highly turbid water may require higher CT (i.e., longer contact time and/or higher dose).

Virucidal Capability

Chlorine dioxide is an effective virucide. Research shows viruses are more resistant than bacteria but less resistant than cysts (reference 13). Similar to bactericidal capability, viruses are rapidly inactivated (reference 13). Experiments conducted under worst case conditions (5° C water temperature in the 6 – 7 pH range) resulted in CT's of 5.5 mg-min/L for a 2-log Poliovirus 1 inactivation and 12.6 mg-min/L for a 4-log Hepatitis A virus inactivation (references 13 and 16). The SWTR provides the following CT values for 4-log virus inactivation at various water temperatures with pH 6-9 (reference 19):

Table 1. EPA Surface Water Treatment Rule (SWTR) Required CT Values for 4-Log Inactivation of Viruses by Chlorine Dioxide for pH 6-9

Temperature (deg C)					
<= 1	**5**	**10**	**15**	**20**	**25**
50.1	33.4	25.1	16.7	12.5	8.4

The data used to develop Table 1 were based on experiments conducted in low turbidity waters under otherwise worst case conditions, 5° C water temperature and pH 6. These CT values are based on low turbidity waters since it is assumed water systems provide disinfection after filtration, as the last treatment step prior to distribution. Higher turbidity waters may require higher CT to achieve the same log inactivation. Separate CT values for different pHs were not developed since chlorine dioxide is generally a more effective disinfectant at higher pHs. Therefore, these CT values are more conservative at the higher pHs (reference 19). A safety factor of 2 was applied to the data to determine CT values in Table 1 (reference 19). The CT values at temperatures other than 5° C in the Table were determined by using a two-fold increase in CT for every 10° C decrease (reference 19). Even at cold water temperatures, low pHs, and low turbidity waters, CTs appear realistic and achievable. Based on a typical chlorine dioxide dosage of 2.0 mg/L for a water system, contact times of 4-25 minutes are necessary to achieve CT values in Table 1. A chlorine dioxide dose of 0.8 mg/L [EPA's Maximum Residual Disinfectant Level (MRDL) for chlorine dioxide] results in contact times of 11-63 minutes which are still reasonable for IWPD use. Highly turbid water may require higher CT (i.e., longer contact time and/or higher dose).

Cysticidal Capability

Giardia Cysts

Chlorine dioxide is effective against *Giardia* cysts. One study showed CTs ranging from 1.7-17.6 mg-min/L necessary for 2-log *Giardia muris* cyst inactivation (reference 23). The SWTR provides the following CT values for 3-log inactivation of *Giardia* cysts at various water temperatures with pH 6-9 (reference 19):

Table 2. EPA SWTR Required CT Values for 3-Log Inactivation of *Giardia* Cysts by Chlorine Dioxide for pH 6-9

	Temperature (deg C)				
<= 1	**5**	**10**	**15**	**20**	**25**
63	26	23	19	15	11

Data used to develop Table 2 were based on experiments conducted in low turbidity waters at pH 7 and water temperatures ranging from 1 - 25° C for 2-log *Giardia* cyst inactivation (reference 19). Determining 3-log inactivation at all temperatures listed in Table 2 required extrapolation using first order kinetics and applying a safety factor of 1.5 (reference 19). Based on Table 2 it appears chlorine dioxide is effective against *Giardia* cysts at realistic and achievable CT values. Based on a typical chlorine dioxide dosage of 2.0 mg/L for a water

system, contact times of 6 - 32 minutes, depending on temperature, are necessary to achieve the CT values in Table 2. These contact times are also reasonable for IWPDs. A chlorine dioxide dose of 0.8 mg/L (EPA's MRDL for chlorine dioxide) results in contact times of 14 - 79 minutes which are still reasonable for IWPD use. Highly turbid water may require higher CT (i.e., longer contact time and/or higher dose).

Cryptosporidium Oocysts

Chlorine dioxide appears effective against *Cryptosporidium* oocysts at CT values achievable by water systems. Studies show 3-log *Cryptosporidium* inactivation varied from a CT of 70 mg-min/L to 400 mg-min/L under various water quality conditions (reference 5). *Cryptosporidium* is more resistant than *Giardia* cysts; up to 8-16 times more resistant (reference 5). Similar to bacteria, viruses, and other cysts, chlorine dioxide, in general, is more effective against *Cryptosporidium* oocysts at higher pHs and higher temperatures (reference 5). However, there is data suggesting pH has a negligible effect on inactivation of *Cryptosporidium* (reference 17). Pursuant to the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR), the EPA proposed chlorine dioxide CT tables for various log inactivations of *Cryptosporidium* (reference 24) based on studies conducted using low turbidity waters. The proposed CT values for 3-log *Cryptosporidium* inactivation are shown in Table 3. These doses are conservative and were developed using a safety margin to account for variability and uncertainty in the experimental data (reference 24).

Table 3. EPA Proposed CT Values for 3-Log Inactivation of *Cryptosporidium* Oocysts by Chlorine Dioxide for pH 6-9

Temperature (deg C)					
1	**5**	**10**	**15**	**20**	**25**
1830	1286	830	536	347	226

Based on a typical chlorine dioxide dosage of 2.0 mg/L for a water system, contact times of 115 - 915 minutes (2 - 15 hours), depending on temperature, are necessary to achieve the CT values in Table 3. For water systems, these CT values are realistic and achievable at warmer water temperatures. Higher than typical chlorine dioxide dosages would be necessary for a water system to achieve the proposed CTs in colder waters (i.e., less than 10° C). Based on this Table, use of an IWPD would be practical in only warmer waters (i.e., above 10° C). Highly turbid water may require even higher CT values (i.e., longer contact time and/or higher dose). Chlorine dioxide is effective against Cryptosporidium oocysts in warmer, low turbidity waters.

CHLORINE DIOXIDE TOXICITY

Health Effects of Chlorine Dioxide and Chlorite

Chlorine dioxide and its byproducts, chlorite and chlorate ion can result in adverse health effects when consumed at large enough quantities. The EPA regulates chlorine dioxide and chlorite ion in drinking water for systems using chlorine dioxide for disinfection. The EPA established a MRDL of 0.8 mg/L for chlorine dioxide and a maximum contaminant level (MCL) of 1.0 mg/L for chlorite (reference 25). The most common adverse health effects of chlorine dioxide and chlorite ion are oxidizing effects seen in the blood, either as methemoglobinemia or hemolytic anemia (reference 3). Children, infants, and fetuses, a more susceptible subpopulation may experience adverse neurotoxic effects (reference 26). When a regulated water system using chlorine dioxide is out of compliance with the chlorine dioxide MRDL or chlorite MCL, the EPA considers this to have a significant potential to have serious adverse health effects as a result of short-term exposure (reference 27). However, the short-term adverse health effects are limited to children, infants, and fetuses. It is these groups that may be susceptible to adverse nervous system effects from short-term exposure (reference 27). Health effect data for healthy adults appear to indicate that short-term exposure does not result in adverse health effects. Several clinical studies assessing the acute and subchronic effects of chlorine dioxide, chlorite, and chlorate have been conducted (reference 3). Healthy adults consuming 2.5 mg daily of either chlorine dioxide, chlorite, or chlorate for 12 weeks showed no clinically significant adverse health effects (reference 3). Another study had healthy adults consuming 0.1 to 24 mg/L concentrations of either chlorine dioxide, chlorite, or chlorate daily for 3 weeks, again resulting in no clinically significant adverse health effects. Based on this information, it is not likely that healthy adults consuming water containing chlorine dioxide concentrations recommended by IWPD manufacturers (0.7 – 7.5 mg/L) for a short duration (e.g., < 3 weeks) would experience any adverse health effects from ingestion of chlorine dioxide, chlorite, or chlorate. However, adverse health effects could occur if higher chlorine dioxide dosages are used for treating highly turbid and/or colder water to kill *Cryptosporidium*. To avoid potential adverse health effects, longer contact times should be used in place of higher chlorine dioxide dosages, provided sufficient chlorine dioxide remains after oxidizing organic matter.

Health Concerns of Stabilized Chlorine Dioxide

The use of “stabilized chlorine dioxide” products for IWPD use may expose the user to significant chlorite concentrations. The “activation” of stabilized chlorine dioxide (i.e., sodium chlorite) with an acid can result in high levels of chlorite remaining after activation and relatively low chlorine dioxide concentrations compared to typical chlorine dioxide generating systems (reference 3). Use of these products may result in the direct application of several hundred mg/L of chlorite to the water, much higher than typical drinking water chlorite levels (reference 3).

CONCLUSIONS

Chlorine dioxide as an IWPD can be effective against bacteria, viruses, *Giardia* cysts, and to a limited extent, *Cryptosporidium* oocysts. Very high CT values are estimated for a 3-log *Cryptosporidium* inactivation in colder waters, requiring very high chlorine dioxide dosages and/or very long contact times. Colder temperatures, lower pHs, and higher turbidity all tend to have an adverse effect on disinfection capability. Health concerns of ingesting chlorine dioxide and chlorite ion are likely minimal for healthy adults over a short-term duration (e.g., < 3 weeks) for IWPD manufacturer-recommended chlorine dioxide dosages of 0.7 – 7.5 mg/L. However, adverse health effects could occur if higher chlorine dioxide dosages are used for treating highly turbid and/or colder water to kill *Cryptosporidium*. To avoid potential adverse health effects, longer contact times should be used in place of higher chlorine dioxide dosages, provided sufficient chlorine dioxide remains after oxidizing organic matter. IWPDs using "stabilized chlorine dioxide" may result in exposure to high levels of chlorite. Table 4 provides a summary of chlorine dioxide's disinfection capabilities.

Table 4. Chlorine Dioxide Disinfection Capabilities

Parameter	Chlorine Dioxide Disinfection
General Disinfection Capability	Cysts most resistant. Achieving cyst inactivation will ensure adequate bacteria and virus inactivation. Disinfection capability generally follows: Bacteria > viruses > *Giardia* > *Cryptosporidium*
Bacteria	Effective at reasonable CT values for IWPD use
Viruses	Effective at reasonable CT values for IWPD use. Use EPA SWTR CT table for recommended CT values (Table 1).
Giardia Cysts	Effective at reasonable CT values for IWPD use. Use EPA SWTR CT table for recommended CT values (Table 2).
Cryptosporidium Oocysts	Effective at high CT values. Use Table 3 as guide for CT values. If possible, use longer contact times instead of higher dosages to achieve adequate CT values.
Effect of Temperature	Colder water temperatures require higher CT values. Use a two-fold increase in CT for every 10° C decrease. Use longer contact time instead of higher dosages to achieve higher CT values.

Effect of pH	Effective over typical pH levels for raw, untreated natural waters. Disinfection capability generally increases with increasing pH.
Effect of Turbidity	Higher turbidity generally reduces disinfection capability. Use longer contact time instead of higher dosages in more turbid waters to achieve CT values. Higher dosages may be necessary to ensure chlorine dioxide remains after oxidation of organic matter.
Health Effects	Chlorine dioxide and chlorite are potential health concerns. IWPD manufacturer-recommended dosages are not likely to cause adverse health effects for healthy adults. Exposure to much higher chlorite concentrations may occur when using stabilized chlorine dioxide products.

PREPARED BY: Steven H. Clarke, Environmental Engineer

DATED: March 2006

APPENDIX A
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APPENDIX G

IWP PATHOGEN REDUCTION RATINGS

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IWP Pathogen Reduction Ratings

Protection of soldier health is the paramount objective when evaluating individual water purifiers (IWPs) for use in field environments. Acute illness caused by waterborne pathogens can quickly render a Soldier combat-ineffective and therefore, must be addressed when choosing an IWP. For comparison purposes across IWPs incorporating many different technologies, common challenge conditions must be employed to gain data for meaningful comparisons of the ability of each device to reduce the risk of pathogen ingestion. Prior to this study, the only industry standard for testing IWPs was the 1987 U.S. Environmental Protection Agency (EPA) *Guide Standard and Protocol for Testing Microbiological Water Purifiers* (NSF International Protocol P231 *Microbiological Water Purifiers* is also an industry standard but adopts the pathogen reduction requirements of the USEPA Guide Standard). The EPA Guide Standard requires log reductions of pathogens (> 6-log bacteria, > 4-log virus, > 3-log *Giardia*) under specific water quality conditions. Challenge testing incorporates pathogen challenge under two water quality conditions. First, relatively clear, neutral pH water is used (termed type 1 water), followed by a more challenging water quality (type 2 water) specific to each technology, incorporating increased turbidity (particulate matter, cloudiness), as well as changes in temperature, pH, and dissolved solids. In order to be considered compliant with the EPA Guide Standard, IWPs must meet the required pathogen log reductions under both water types. We used the requirements of this protocol as the standard under which we evaluated each IWP's ability to protect soldier health. When we state adequate or inadequate reduction or inactivation of a pathogen the basis for that determination is the requirement for that pathogen in the EPA Guide Standard. In reviewing the information and data, or lack thereof, supplied by the manufacturers it quickly became apparent that many of the devices had not been tested against this protocol, or testing that was conducted did not strictly follow the protocol. Despite this lack of adequate challenge testing, many devices are marketed as having passed the protocol. For our evaluation we devised a hierarchy of √s (checks) to relay to the user our confidence in the ability of the IWP to adequately reduce the risk of illness from waterborne pathogens. In general, we took a conservative approach, assigning our highest confidence rating (√√√) only when data followed strict to the EPA Guide Standard and clearly showed the ability of the device to adequately reduce pathogens under manufacturer specified conditions. If any doubt existed on the testing data, professional judgment on the ability of the device technology to reduce the pathogen was relied upon for ratings. Additionally, we added a rating based on the reduction of *Cryptosporidium* oocysts. The EPA Guide Standard does not specifically require testing against this pathogen, but mentions that future protocol updates may include this organism. The emergence of this pathogen as one with the ability to infect and debilitate its host demands its inclusion as a microorganism requiring treatment.

√. One check means we expect the device to consistently provide adequate protection from specific pathogen groups by achieving at least a 6-log bacteria, 4-log virus, 3-log *Giardia* cyst,

and 3-log *Cryptosporidium* oocyst reduction. There is a level uncertainty in the effectiveness of the device because there is no device-specific testing data using the EPA test protocol in which the device was tested at the manufacturer's recommended operating conditions (e.g., production rate, capacity). One check is based on evaluation of general scientific knowledge of treatment technology (e.g., filtration theory), disinfection/removal studies conducted using general technology (e.g., disinfection study using an iodine solution), device-specific testing not using the EPA test protocol, or device-specific testing (in-house or independent) using the EPA test protocol but not under manufacturer-specified device operating conditions. Although we expect the device to consistently provide microbial pathogen protection, the device still poses some level of health risk to the Soldier.

√√. Two checks means we expect the device to consistently provide adequate protection from microbial pathogen groups by achieving at least a 6-log bacteria, 4-log virus, 3-log *Giardia* cyst, or 3-log *Cryptosporidium* oocyst reduction. Two checks is based on in-house/manufacturer testing using the EPA test protocol under manufacturer-specified device operating conditions (e.g., production rate, capacity). This data is more robust and more adequately challenges the device. However, there is still some uncertainty in the effectiveness of the device because of the concern for the potential lack of impartiality and objectivity of the testing data. Two checks means the device poses less risk to the Soldier from getting sick.

√√√. Three checks means we expect the device to consistently provide adequate protection from microbial pathogen groups by achieving at least a 6-log bacteria, 4-log virus, 3-*log Giardia* cyst, or 3-log *Cryptosporidium* oocyst reduction. Three checks is based on independent testing using the EPA test protocol under manufacturer-specified device operating conditions. Independent testing is considered neutral and impartial. This data is the most robust and challenging data and, subsequently, means there is very little uncertainty in the effectiveness of this device. Three checks means the device poses the lowest risk to the Soldier from getting sick.

X. Means we do not expect the device to consistently provide adequate protection from microbial pathogen groups. This is based on available data, lack of data, or general scientific knowledge of the treatment technology. Using a device with one or more X's poses the greatest risk to the soldier for getting sick.

EXAMPLE 1.

Scenario. A filtration device is independently tested against the EPA test protocol and meets minimum log removal requirements for bacteria, viruses, and cysts. But, the device was not tested under manufacturer-specified device operating conditions. It was tested at half the manufacturer-specified flow rate.

Our Effectiveness Determination. We choose ONE CHECK for all pathogens since the device met the EPA protocol but the device was not tested at the specified flow rate. The data isn't as robust and the test did not provide as severe a challenge.

EXAMPLE 2.

Scenario. A filtration and disinfection device is independently tested against the EPA test protocol and meets minimum log removal requirements for bacteria and viruses, but not cysts. However, the information provided to us does not provide details describing testing conditions such as flow rates.

Our Effectiveness Determination. We choose ONE CHECK for bacteria and viruses and an X for *Cryptosporidium* and *Giardia*. One check is chosen since not enough data was provided to adequately evaluate the device. We don't know if the device was challenged to a degree intended by the EPA protocol. This device poses some level of risk because we don't have adequate data to determine if the device was tested under manufacturer-specified operating conditions.

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APPENDIX H

WEB-BASED IWP INFORMATION TOOL

This Project's web-based information tool functions as a shareable, searchable, single repository of project information. It is located at http://usachppm.apgea.army.mil/WPD. This website presents the Project report, the Project-developed testing protocol, and IWP information and data. The data is presented in a searchable format so that the user can apply it to best suit their needs. Users can download data search results and other Project information, to include the individual treatment device evaluation papers that present a review of device use, testing data, and advantages/disadvantages.

The web-based IWP information tool is intended primarily for military personnel who have missions in which traditional field water drinking supplies, such as Reverse Osmosis Water Purification Units (ROWPUs), are not available or may not be consistently available and, therefore, may be considering purchasing an individual handheld water purifier. In addition, this database is also useful to anyone in situations where microbiologically safe drinking water is not available. Such situations may include: camping, backpacking, natural disasters, foreign travel, contaminated individual sources (wells or springs), and motor homes and trailers.

One of the Project's goals was to collect and share information on all COTS IWPs obtainable by Soldiers stationed within the continental United States (CONUS). A survey was performed to identify and include all devices available at retailers within the CONUS or available worldwide on the Internet. It did not matter where the device originated; only that it was available. The objective of the survey was to identify all devices that were designed for individual use and marketed for pathogen reduction or inactivation. Devices that were designed solely for reduction of chlorine, lead, and/or taste and odor, etc., were not included in this survey. This database does not cover or provide assessment of any IWP's ability to remove or reduce chemical contaminants.

Once you have reviewed the website, please send any comments to water.supply@apg.amedd.army.mil. We will strive to update the website as new information or devices become available. Also, be sure to sign up on our homepage for email updates.