

**IMPACT OF RELATIVE HUMIDITY AND AIRBORNE BENZENE
CONCENTRATIONS ON CONDENSATION WATER FROM AIR PRODUCT
WATER**

by

CPT Karim Elyamani

Environmental Science and Engineering Officer

United States Army

Thesis submitted to the Faculty of the
Preventive Medicine and Biostatistics Graduate Program
Uniformed Services University of the Health Sciences
In partial fulfillment of the requirements for the degree of Master of Science in Public

Health 2017



UNIFORMED SERVICES UNIVERSITY, SCHOOL OF MEDICINE GRADUATE PROGRAMS
Graduate Education Office (A 1045), 4301 Jones Bridge Road, Bethesda, MD 20814



DISSERTATION APPROVAL FOR THE MASTER IN SCIENCE IN PUBLIC HEALTH DISSERTATION
IN THE DEPARTMENT OF PREVENTIVE MEDICINE AND BIOSTATISTICS

Title of Thesis: "Impact of Relative Humidity and Airborne Benzene Concentrations on Condensation Water from Air Product Water"

Name of Candidate: Karim Elyamani
Master of Science in Public Health Degree
March 23, 2017

THESIS AND ABSTRACT APPROVED:

DATE:

Maria K. Majar, MS, CIH, CSP, CAPT
DEPARTMENT OF PREVENTIVE MEDICINE & BIOSTATISTICS
Committee Chair

23 MAR 17

Christopher A. Gellasch, PhD, LTC
DEPARTMENT OF PREVENTIVE MEDICINE & BIOSTATISTICS
Thesis Advisor

23 MAR 2017

James S. Dusenbury, PhD
TARDEC FORCE PROJECTION TECHNOLOGY
Committee Member

23 MAR 17

Carlis W. Brown, MSPH, LCDR
NAVAL MEDICAL RESEARCH UNIT DAYTON
Committee Member

23 MAR 17

ACKNOWLEDGMENTS

I thank the U.S. Army Tank Automotive Research, Development and Engineering Center's (TARDEC) Mr. Bob Shalewitz and Dr. James Dusenbury from the Water Treatment Team for funding and supporting this research. Without their assistance, this study would not have been possible.

I would like also to thank the Naval Medical Research Unit Dayton (NAMRU-D) for supporting me with the equipment, tools, and training necessary to complete this research.

I also thank the following members of my committee for their trust and confidence in my abilities: CAPT Maria Majar (Chairperson), Dr. James Dusenbury, LTC Christopher Gellasch, and LCDR Carlis Brown. I am particularly grateful and thankful to my research advisor (LTC Gellasch) and all the instructors here at the Uniform Services University of the Health Sciences (USUHS) who provided me with the necessary tools and knowledge to conduct and complete my research.

Many thanks to Dr. Cara Olsen, Dr. Theodore Juarez, MAJ Katherine Kinder, and Mr. James Richard for their guidance, recommendations, and technical support.

Lastly, I would like to thank all of my MSPH classmates (especially Major Ryan Jung) for their inputs and feedbacks at the end of each brief.

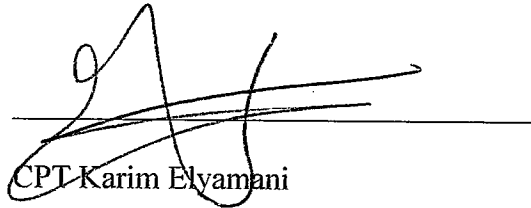
DEDICATION

I dedicate this Master of Science in Public Health thesis to my wife, Fadoua and my son Sammy. Also, to my parents for their guidance and love. Thank you all for your selfless support and sacrifices. –Karim

COPYRIGHT STATEMENT

The author hereby certifies that the use of any copyrighted material in the thesis manuscript entitled: IMPACT OF RELATIVE HUMIDITY AND AIRBORNE BENZENE CONCENTRATIONS ON CONDENSATION WATER FROM AIR PRODUCT WATER is appropriately acknowledged and, beyond brief excerpts, is with the permission of the copyright owner.

[Signature]

A handwritten signature in black ink, consisting of a large, stylized 'K' followed by a horizontal line and a vertical stroke, all enclosed within a circular loop.

CPT Karim Elyamani

April 5th, 2017

DISCLAIMER

The views presented here are those of the author and are not to be construed as official or reflecting the views of the Uniformed Services University of the Health Sciences, the Department of Defense or the U.S. Government.

Distribution Statement

Distribution A: Public Release.

The views presented here are those of the author and are not to be construed as official or reflecting the views of the Uniformed Services University of the Health Sciences, the Department of Defense or the U.S. Government.

ABSTRACT

Impact of Relative Humidity and Airborne Benzene Concentrations on Condensation
Water from Air Product Water:

CPT Karim Elyamani, Master of Science in Public Health, 2017

Thesis directed by: Lieutenant Colonel Christopher A. Gellasch, Assistant Professor,
Department of Preventive Medicine and Biostatistics, Occupational and Environmental
Health Sciences Division.

Finding sources of safe drinking water poses a challenge in remote areas without access to a reliable natural water source. Condensation Water from Air (CWFA) technology can help alleviate the worldwide water crisis by harnessing water vapor from air and producing potable water in diverse environments. This technology produces water by passing air over a surface cooled below the dew point of the ambient air, similar to a home dehumidifier. Previous studies have shown that water produced by CWFA systems is within drinking water standards for basic parameters such as metals, turbidity, pH, conductivity, alkalinity, total hardness, and total dissolved solids. However, a recent study evaluating the impact of air temperature and ambient benzene vapor concentrations on the CWFA product water found that benzene vapor concentrations representing an indoor industrial environment resulted in benzene product water concentrations up to twice the EPA drinking water standard of 5 µg/L.

The purpose of this research is to understand the effects of humidity on the transfer of benzene from ambient air to the CWFA product water. A CWFA machine was placed inside a 1 m³ volume exposure chamber with a low airflow rate (11 air changes per hour). A pressure vessel generated and maintained six different benzene vapor concentrations at steady state representing a range of polluted outdoor and industrial indoor environments. The conditions of the experiment consisted of two relative humidity conditions: 45% and 65%, and an air temperature of 25 °C. Both CWFA product and control water were analyzed for benzene using U.S. EPA Method 524.2. The results of this study indicate that benzene vapor concentrations typical to a highly polluted outdoor environment resulted in benzene product water concentrations below the USEPA drinking water standard of 5 µg/L. On the other hand, benzene vapor concentrations typical to highly polluted indoor industrial environment resulted in benzene product water concentrations exceeding the maximum contaminant limit of 5 µg/L. Also, the CWFA product water will have a higher benzene concentration at the lower RH if exposed to the same benzene air concentration; at 45% and 65 % relative humidity. The concentrations of benzene in the CWFA product water exceeded the MCL when benzene concentrations in the chamber's air exceeded 367 µg/m³ and 412 µg/m³ respectively (Medium to highly polluted industrial indoor environment). Finally, the exposure to a medium or highly polluted indoor environment at 45% RH resulted in benzene concentrations in the CWFA product water higher than the MCL and the calculated values. Other enrichment factors could be involved in the increase in benzene concentrations such as direct condensation on the coil of benzene from the chamber's air and the CWFA's processed air, wet deposition, adsorption of benzene on the air-water

interface of the formed film on the coil, and solubility of the benzene vapor in the chamber into the CWFA product water.

These findings indicate that both relative humidity and air quality could impact the quality of the CWFA product water which could be mitigated by choosing the right water treatment modules, the best operating environment, and the appropriate maintenance schedule.

TABLE OF CONTENTS

LIST OF TABLES	xi
LIST OF FIGURES	xii
CHAPTER 1: INTRODUCTION	1
BACKGROUND AND SIGNIFICANCE	1
CWFAS THEORY OF OPERATION	3
LITERATURE REVIEW	4
SELECTION OF THE CONTAMINANT OF CONCERN AND AIR	
CONCENTRATION LEVELS	5
BENZENE WORLDWIDE.....	6
PHYSICAL PROPERTIES OF BENZENE.....	8
TRANSFER OF BENZENE INTO THE WATER SAMPLES.....	9
HENRY’S LAW AND INFLUENCING FACTORS	10
CONCEPTUAL SITE MODEL (CSM).....	12
TOXICOLOGY OF BENZENE	13
MECHANISTIC TOXICOLOGY- ABSORPTION	13
MECHANISTIC TOXICOLOGY- DISTRIBUTION	14
MECHANISTIC TOXICOLOGY- BIOTRANSFORMATION/METABOLISM.....	14
MECHANISTIC TOXICOLOGY- EXCRETION/ELIMINATION	15
HEALTH EFFECTS OF BENZENE INGESTION	16
MAXIMUM CONTAMINANT LEVEL	17
PURPOSE OF THE STUDY	17
RESEARCH QUESTION	18
PURPOSES AND HYPOTHESIS	18
CHAPTER 2: METHODOLOGY	20
STUDY DESIGN.....	20
PREPARATORY PHASE	21
TEMPERATURE CONTROL	24
HUMIDITY CONTROL	25
HUMIDITY GENERATION WHEN THE CWFA MACHINE IS ON	25
HUMIDITY GENERATION WHEN THE CWFA MACHINE IS OFF	26
LIMITATIONS OF THE CWFA SYSTEM	26
THE FULL SCALE PHASE	27
CONDITIONS OF THE EXPERIMENTS.....	29
TEST MATERIAL	30
GENERATION SYSTEM.....	30
EXPOSURE SYSTEM	31
ENVIRONMENTAL CHAMBER SYSTEM	32
SAMPLING PLAN AND PROCEDURE	35

DATA COLLECTION	37
AIR DATA COLLECTION	37
CHAMBER DISTRIBUTION	38
HUMIDITY AND FTIR RESPONSE.....	39
WATER DATA COLLECTION.....	40
CHAPTER 3: RESULTS AND DISCUSSION.....	42
DIRECT READING INSTRUMENT RESULTS	42
FTIR RESULTS	42
PID RESULTS	43
POST-STUDY VERIFICATION OF AIR BENZENE CONCENTRATIONS	44
INFLUENCE OF BENZENE VAPOR CONCENTRATION AND HUMIDITY ON PRODUCT AND CONTROL WATER	46
45% RELATIVE HUMIDITY	46
65% RELATIVE HUMIDITY	51
ANALYSIS OF BENZENE EXPOSURE AT BOTH RELATIVE HUMIDITIES (45% AND 65%)	55
EQUILIBRIUM STUDY	61
PERCENT OF BENZENE IN THE CWFA PRODUCT WATER:	62
CHAPTER 4: CONCLUSION	66
ASSUMPTIONS/LIMITATIONS	68
FUTURE RESEARCH	70
REFERENCES	72
APPENDIX A- SPSS CALCULATIONS	76
APPENDIX B- FTIR SUPPLEMENTARY MATERIAL	81
APPENDIX C- PERCENT BENZENE CALCULATIONS FOR TABLE 15	82
APPENDIX D- DETERMINATION OF NOMINAL BENZENE HEAD SPACE CONCENTRATION INSIDE PRESSURE VESSEL	83
APPENDIX E- CALCULATION OF THE FLOW RATE FOR KNOWN AIR CHANGES PER HOUR.....	84
APPENDIX F- LABORATORY RESULTS.....	85

LIST OF TABLES

Table 1. Past water from air studies.....	5
Table 2. Summary of time weighed average (TWA) Benzene Ambient Air Levels in urbanized outdoor and industrialized indoor environments.....	7
Table 3. Classification of ambient outdoor and indoor benzene vapor concentration.....	8
Table 4. Physical Properties of Benzene (21).....	9
Table 5. Henry's Law constant corresponding to different coil and saturation temperatures.....	12
Table 6. Benzene Health Effects Associated with Oral Exposure.....	17
Table 7. Summary of the modeling experiment conducted at 25 °C	28
Table 8. Summary of the equilibrium experiment conducted at 25 °C.....	29
Table 9. Number and Type of Samples for the Full Scale Test.....	37
Table 10. Post-study verification of benzene concentrations in the air using Total Hydrocarbon Analyzer (THA) Flame Ionization Detector (FID).....	45
Table 11. Results of one hour-long exposure to six different benzene concentrations in the air at 45% RH and 25 °C (BDL or MDL=0.13 µg/L).....	46
Table 12. Results of one hour-long exposure to six different benzene concentrations in the air at 65% RH and 25 °C (BDL or MDL=0.13 µg/L).....	52
Table 13. Amounts of benzene in the air required to exceed the MCL at 45% and 65% RH.....	58
Table 14. Results of the equilibrium study using 650 µg/m ³ as target value at 45% and 65 % RH (BDL or MDL=0.13 µg/L).....	61
Table 15. Summary of the percent of benzene in the product water during the modeling study (Appendix A-Table A3)	63
Table A-1. SPSS Descriptive statistics at 65% RH	76
Table A-2. SPSS: Descriptive statistics at 45% RH	76
Table A-3. Temperatures of the coil at the following target benzene concentrations: 50, 200, 350, 500, 650, and 800 starting with 45% RH then 65% RH	77
Table A-4. SPSS calculations for the modeling at 45% RH.....	78
Table A-5. SPSS calculations for the modeling at 45% RH without the suspected outlier	78
Table A-6. SPSS calculations for the modeling at 65% RH.....	79
Table A-7. SPSS calculations for the modeling at 65% RH without the suspected outlier	79
Table A-8. SPSS calculations: multiple regression with dummy variables to compare 65 and 45% RH.....	80
Table B-1. FTIR results for benzene exposure at 45% relative humidity	81
Table B-2. FTIR results for benzene exposure at 65% relative humidity	81

LIST OF FIGURES

Figure 1. Example of the cooling-condensation process of CWFAS	3
Figure 2. Benzene (C ₆ H ₆) Structure (26)	8
Figure 3. CSM describing the sources, pathways, and receptor when using CWFA machine in presence of a contaminant in the air	13
Figure 4. Environmental monitoring instruments (from left to right: Magnehelic gage, Bapi instrument, Rotronic instrument, Air mass flow monitor, and Thermocouple)22	
Figure 5. LabVIEW program connected to the monitoring devices	22
Figure 6. Temperature control using an enclosure (front and back).....	25
Figure 7. Schematic diagram of the environmental chamber set-up for the study. 1. Enclosure, 2. Environmental chamber (H 1000), 3. Turbine blower supply air system, 4. Benzene gas cylinder, 5. Mass flow monitor, 6. Humidity controller, 7. Humidity sprayer, 8. CWFA system, 9. Water containers, 10. Static pressure probe, 11. Temperature and relative humidity probe, 12. Fourier Transform Infra-Red Spectrometer, 13. Photo Ionization Detector, 14. Room's temperature and relative humidity probe, 15. Signal converter, 16. NI Labview data logger, 17. Turbine blower exhaust system	33
Figure 8. The environmental chamber set-up	33
Figure 9. Revolving rectangular window used for water sampling	36
Figure 10. H1000 Sample port locations for chamber distribution testing.....	39
Figure 11. FTIR spectrum showing the absorption of Benzene and Water (33)	43
Figure 12. Benzene exposure at 45% RH	47
Figure 13. Exposure at 45% RH without suspected outlier	49
Figure 14. Six air benzene concentrations used to compare the transfer of benzene from air to the product and control water at 45% RH	51
Figure 15. Benzene exposure at 65% RH	53
Figure 16. Benzene exposure without the suspected outlier at 65% RH	55
Figure 17. Results of benzene exposure at 45% and 65% RH.....	57
Figure 18. General overview of the measured and calculated values at 45% RH	59
Figure 19. General overview of the measured and calculated values at 65% RH	60

CHAPTER 1: INTRODUCTION

BACKGROUND AND SIGNIFICANCE

Earth is a water-wealthy planet. More than 70 percent of the planet's surface is covered in water, however less than 3 percent is fresh water and the rest is undrinkable seawater. Over 68 percent of the fresh water on Earth is found in icecaps and glaciers, about 30 percent is found in ground water, and only 0.3 percent of our fresh water is found in the surface water of lakes, rivers, and swamps (18).

According to the United Nations, nearly one quarter of the world's population faces economic water shortage and almost one-fifth live in areas of water scarcity (28). Additionally, one in ten people lack access to drinking water, one third of all schools lack access to safe potable water and adequate sanitation, and one third of all healthcare facilities in low and middle-income countries lack a safe water source (33). Furthermore, the World Economic Forum classified water crisis as the number one global risk based on its impact on business and society (32). Finally, the urgency of water security keeps increasing as the world population continues to grow at a rapid pace and is estimated to reach more than 8 billion by 2030 (10).

According to Jenicek et al (10), the U.S. Army operates worldwide in a range of geographic and climate regimes and has long recognized water scarcity as an emerging issue. The military reacted to the water crisis by including water efficiency and management as one of the goals of the 2016 Army sustainability directives since deploying troops are often impacted by the quality and quantity of the water supplies, and the increased cost of production by unit volume of water. The same study also added that

the military modified their planning strategy for overseas moves by taking in consideration the following water scarcity factors: the increasing global demand on water, the impact of human activities on the quality and quantity of groundwater, the increasing water demands for energy with an estimated 8 percent of fresh water withdrawals globally are used for energy, the effects of global climate change on the water cycle resulting, and the current disputes among countries over water best known as the ‘the right to water’.

Condensation Water from Air (CWFA) technology can help alleviate the water scarcity problem by harnessing water vapor from air and producing potable water in diverse environments (urban, rural, and industrial). The Water From Air (WFA) technology uses two methods to produce water: condensation and desiccant technology. The condensation technology produces water either by cooling a surface below the dew point of the ambient air or through induction and control convection in a tower structure, while the desiccant technology consists of applying of a solid or liquid desiccant to concentrate water vapor (31). The WFA system for this study uses the condensation technology to exploit the moisture present in the air. Absolute humidity, defines the amount of water present in the air since it represents the mass of water vapor that exists within a given volume of air (8); the ranges of absolute humidity vary worldwide from 21.2 g/m³ in Djibouti (Republic of Djibouti) to 4.0 g/m³ of surface air in Las Vegas (Nevada, USA) to(31).

The new WFA systems are better at producing large quantities of water at minimal amounts of energy; these machines can produce one gallon of water for about 10 cents depending on the local electricity cost and humidity (1).

Military units operating in complex and decentralized combat environments may use WFA technology to continuously and quickly access water and succeed in their mission (2). The United States is among seven countries that purchased the water from air system and is currently field testing it (7).

CWFAS THEORY OF OPERATION

Similar to a dehumidifier, the CWFASs operate by condensing water vapor to form liquid droplets when air is passed over a cooled coil. As shown in Figure 1 below, the machine uses a fan to push filtered air over the coil, and a compressor to circulate a refrigerant through a condenser and an evaporator coil to lower the ambient air temperature to its dew point, causing water to condensate.

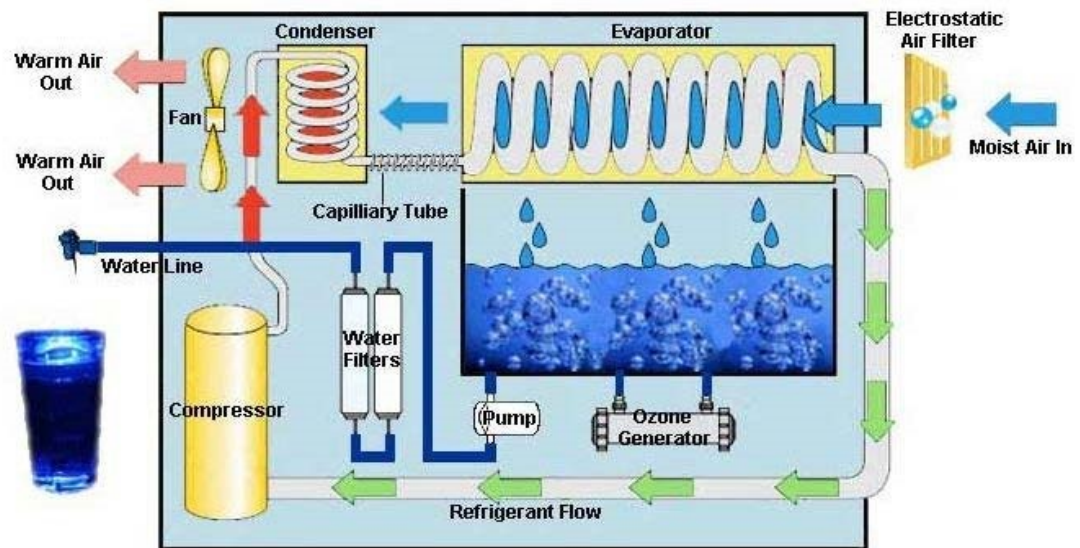


Figure 1. Example of the cooling-condensation process of CWFAS

The dew point or saturation temperature is defined as the temperature to which air must be cooled in order to reach saturation at a constant temperature and pressure, with higher dew points indicating the presence of more moisture in the air (20). Relative

humidity and ambient air temperature, and the size of the compressor affect the amount of water produced and the concentrations of benzenes transferred from ambient air to the water products.

LITERATURE REVIEW

Table 1 below summarizes several studies that have tested the quality of the water produced by condensation technology systems. Some studies examined basic water quality parameters such as turbidity pH, conductivity, alkalinity, total hardness, and total dissolved solids (14; 15). While, others tested for metals in addition to the same basic water quality parameters mentioned above (4; 9). A recent study by Kinder et al. (13) evaluated the impact of ambient benzene concentrations on CWFAS product water, and discovered that benzene concentrations in the produced water were within the EPA drinking water standards for polluted outdoor environment ($50 \mu\text{g}/\text{m}^3$) while they exceeded the standards for the indoor industrial environment ($640 \mu\text{g}/\text{m}^3$). However, that study concluded that more research is needed to fully understand the mechanism of transfer, roles of contributing factors (temperature and humidity), and relationship between contaminants in the air and contaminants in the CWFA product water (13).

Table 1. Past water from air studies

Author, Date	Environment	Water Quality Parameters	Water results	Air results
Gandhidasan & Abualhamayel, 2009	City of Dhahran in Saudi Arabia	Suspended solids, conductivity, appearance, pH, and metals	Within World Health Organization's (WHO) drinking water standards	No
Bautista-Olivas et al, 2014	Two Cities in Mexico	Electric conductivity (EC), pH, and metals	Within WHO's drinking water standards except for the Al, Fe, and Pb	No
Loveless, Farouq & Ghaffour, 2012	Cities in Saudi Arabia	Turbidity and conductivity	Within WHO's drinking water standards	No
Mahvi, Alipour & Rezaei, 2013	City of Bandar Abbas in Iran	Turbidity, alkalinity, total hardness, total dissolved solids, and electrical conductivity	Within WHO's drinking water standards	No
Kinder et al, 2017	Environmental Chamber, USA	Benzene	Within the EPA standards for polluted outdoor environment - Exceeded the drinking water standards for the indoor industrial environment	Yes

SELECTION OF THE CONTAMINANT OF CONCERN AND AIR CONCENTRATION LEVELS

The purpose of this study is to use modeling to predict the concentrations of benzene in the CWFA product water given specific environmental conditions. Since this research is a continuation of a previous research conducted by Kinder et al. (13) where

they proved the transfer of benzene from air to the CWFA product water, it was decided to use the same CWFA machine and contaminant of concern utilized in their study.

Benzene (C_6H_6), was selected because of its physical characteristics, likelihood of presence at deployment sites, presence of a maximum contamination level (MCL) for oral ingestion, and potential health effects. It is commonly found at low concentrations in the ambient air and is potentially hazardous to human health. The EPA, the International Agency for Research on Cancer (IARC), and the Department of Health and Human Services (DHHS) have classified benzene as human carcinogen. Also, benzene is ubiquitous in the atmosphere; it has been identified in outdoor air samples of both rural and urban environments and in indoor air. The sources of exposure to benzene in the air are: tobacco smoke, automobile service stations, exhaust from motor vehicles, industrial emissions, and vapors from products that contain benzene (glues, paints, furniture wax, and detergents). Finally, EPA established a maximum contaminant level (MCL) of 5 $\mu\text{g/L}$ for oral ingestion of benzene (3).

BENZENE WORLDWIDE

Air concentrations of benzene fluctuate worldwide and mean indoor industrial concentrations are typically higher than the outdoor air concentrations. An international literature review of ambient benzene concentrations in urban and industrialized areas was used to determine the appropriate test concentrations (Table 2). The worldwide review showed that ambient benzene concentrations outdoors is usually below $50 \mu\text{g/m}^3$ except for one city (Venice) where the measured air benzene concentration was $100 \mu\text{g/m}^3$. Also, the indoor ambient benzene concentrations could be as low as $144.7 \mu\text{g/m}^3$, which was measured inside a garage, range between $319 \mu\text{g/m}^3$ and $957 \mu\text{g/m}^3$ in most

industrial plants except for a petroleum plant in Norway where the measured air benzene concentration was as high as 3512 $\mu\text{g}/\text{m}^3$.

Table 2. Summary of time weighed average (TWA) Benzene Ambient Air Levels in urbanized outdoor and industrialized indoor environments

Author	Location	Type of outdoor environment	Benzene ambient concentrations ($\mu\text{g}/\text{m}^3$)
(38)	Mexico	Urban	0.5-47
(37)	Montreal and Toronto		2.8-40
	Houston, New York, and Pittsburgh		
	The Rhine area, Germany		
	Oslo, Norway		
(38)	London		
(38)	Bitthoven, Netherlands		1.7-42
(12)	Venice		100
Author	Location	Type of indoor environment	Benzene ambient concentrations ($\mu\text{g}/\text{m}^3$)
(6)	United Kingdom	Garage	144.7
(36)	Belgium	Industrial (Refineries and service stations)	319
	Norway	Industrial (Oil cargo tanks)	478
	Korea	Industrial (Shoe manufacturers)	510
	Europe and North America	Industrial (Coke industry)	957
	Norway	Industrial (Petroleum industries)	3512

Based on the literature (Table 2) and to simplify the analysis and interpretation of the study results, the level of air benzene pollution either indoors or outdoors was divided

into low, medium, and high ranges (Table 3 below). The new classification in Table 2 shows that the highest outdoor air pollution (75 - 100 $\mu\text{g}/\text{m}^3$) is still below the lowest industrial indoors pollution (144 - 367 $\mu\text{g}/\text{m}^3$) and that air benzene concentrations above 483 $\mu\text{g}/\text{m}^3$ are classified as high industrial indoors benzene contamination.

Table 3. Classification of ambient outdoor and indoor benzene vapor concentration

Environment	High ($\mu\text{g}/\text{m}^3$)	Median ($\mu\text{g}/\text{m}^3$)	Medium ($\mu\text{g}/\text{m}^3$)	Low ($\mu\text{g}/\text{m}^3$)
Polluted Outdoor	75-100	42	25-75	0.5-25
Indoor Industrial	483 and higher	494	367-483	144-367

PHYSICAL PROPERTIES OF BENZENE

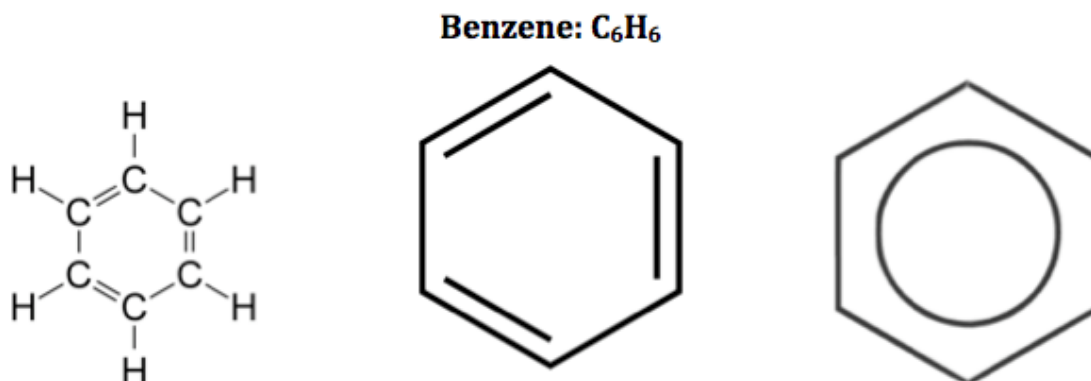


Figure 2. Benzene (C_6H_6) Structure (26)

Figure 2 above depicts benzene (C_6H_6) structure in three ways: The first version on the left shows the arrangement of atoms, the version in the center is used as a simplified diagrams of the benzene structure, and the last version on the right represents a benzene ring where three double bonds are not restricted to the positions shown but are

free to pass around the ring. Benzene is a clear, colorless, flammable liquid aromatic hydrocarbon that easily volatilizes (See Figure 2 above and table 4 below). It also evaporates very quickly in the air and dissolves slightly in water (21) . The low range of the taste threshold for benzene in water is reported as 0.5 parts per million (ppm). The odor threshold for detection in water is 2 ppm and approximately 60 ppm for odor detection in air (5).

Table 4. Physical Properties of Benzene (21)

Property	Information
Henry's Law Coefficient	0.0055 atm-m ³ /mol
Solubility	1790 mg/L at 25 °C
Molecular Weight	78.11 g/mol
Density	0.8756 g/cu cm at 20 °C
Surface Tension	28.22 mN/m at 25 °C
Vapor Pressure	94.8 mm Hg at 25 °C
Molar enthalpy of vaporization	33.83 kJ/mol

TRANSFER OF BENZENE INTO THE WATER SAMPLES

Volatile organic compounds (VOC) condensation is a separation method in which one or more volatile components of a vapor mixture are separated from the remaining vapors through saturation followed by a phase change. The transformation from gas to liquid is accomplished either by increasing the pressure at a given temperature or lowering the temperature at a constant pressure (24).

Cryogenic condensation is utilized by many industries to control organic solvent vapors and meet air pollution standards. This technology was developed in 1980 and has been widely used across Europe and the United States. It uses liquid nitrogen to capture volatile organic compounds by lowering the temperature of the gas mixture, thus

decreasing the saturation capacity of the carrier gas, and inducing the condensation of the VOCs into liquid droplets (27). This methodology works best with high vapor concentrations (greater than 5,000 ppm) and cryogenic temperatures (12).

The most common mechanism of water condensation is film condensation which covers the wall or surface of the condenser in a uniform manner, and less frequently is the dropwise condensation which coats the surface of the condenser irregularly. Once the drops are formed on the condenser, they grow on the surface, tend to join neighboring drops, and finally succumb to the gravitational forces and run off the surface (11).

In the case of the CWFA system, the vapor compression refrigeration cycle is used to condense air over a cooled surface forming water droplets by cooling air to the saturation temperature. The formed droplets coalesce and may form a semi-continuous film pending the amount of water vapor in the air. The thin film layer provides an increase in surface area on which benzene can adsorb.

HENRY'S LAW AND INFLUENCING FACTORS

Using the CWFAS machines in environments heavily contaminated by benzene will result in transfer of the contaminant from the ambient air to the product water (13). Henry's Law constant can be used to predict the amount of benzene that may be present in the product water given a certain concentration of benzene in the ambient air.

According to the English chemist William Henry: at a constant temperature, the quantity of gas absorbed by water is proportional to its partial pressure in the gas phase and the proportionality factor is called Henry's law constant (23). Each chemical has a Henry's constant that is indirectly derived from the relationship of the chemical's vapor pressure to the chemical's solubility(25).

This study will use the EPA equation (6) written below:

$$K_H = \frac{S}{1000 \times (VP) \times (M)} \quad [\text{EQ \#1}]$$

In which:

K_H = Henry's Law constant (mol/L*atm)

VP = vapor pressure (atm)

M = molecular weight (g/mol)

S = solubility (g/m³)

The calculated Henry's law constant will be used in the equation below written by Masters and Ela (17):

$$[gas] = K_H \times P_g \quad [\text{EQ \#2}]$$

Where:

K_H = Henry's Law constant (mol/L*atm)

P_g = Partial pressure of the gas in the air (atm)

$[gas]$ = Concentration of dissolved gas (mol/L)

Each gas-liquid system has its own Henry's Law constant. Temperature and dissolved material in the liquid will affect solubility. In general, the solubility of the gas decreases when temperature increases or when the amount of other dissolved gases or solids increases in the liquid. Therefore Henry's Law "constant" is more accurately referred to as a "coefficient" since the value may change with temperature (25). Often, Henry's Law coefficients are recorded at normal temperature and pressure (NTP): 25°C and 1 atmosphere (ATM). For temperature values other than NTP, Table 5 below shows

the Henry's law constants corresponding to the calculated saturation temperatures and measured coil temperatures at a steady state temperature (25 °C) and at two relative humidities (45 % and 65%).

Table 5. Henry's Law constant corresponding to different coil and saturation temperatures

	Temperature (°C)	Saturation temperature (°C)	Measured coil temperature (°C)
45 % RH	25	12.12	7.12
Henry's Law constant (atm*m³/mol)	5.56E-03	2.98E-03	2.28E-03
65 % RH	25	17.94	10.08
Henry's Law constant (atm*m³/mol)	5.56E-03	3.98E-03	2.67E-03

CONCEPTUAL SITE MODEL (CSM)

The conceptual model shown in Figure 3 below describes the effect of the concentrations of benzene in the ambient air on the concentrations of benzene in the WFA product water. The source in this CSM is either a polluted outdoors or industrial indoors, the first environmental media to carry contaminants from the source to the WFA machine is air followed by water which will transport the contaminant from the WFA system to the human receptor through the ingestion route.

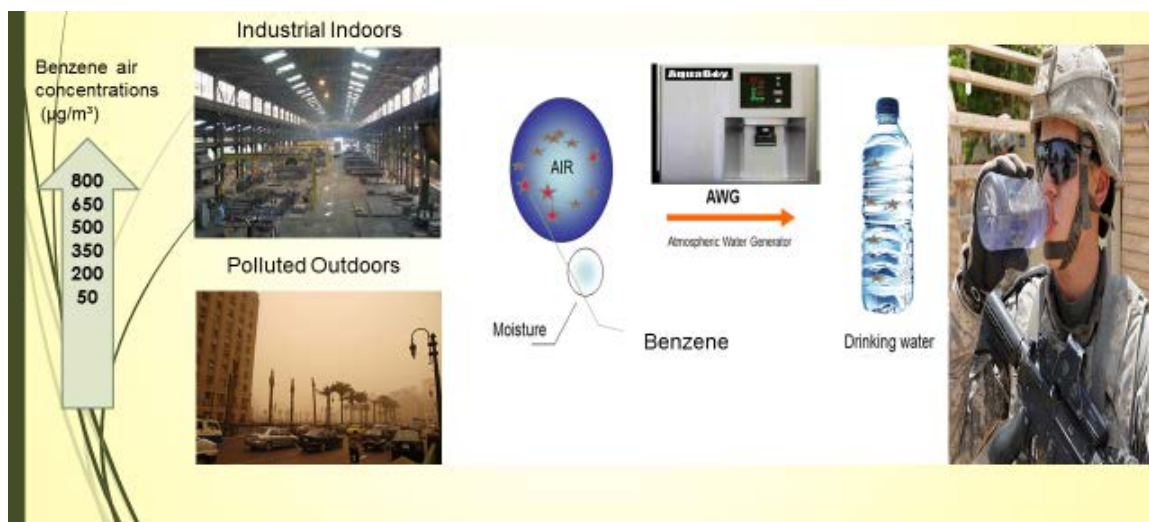


Figure 3. CSM describing the sources, pathways, and receptor when using CWFA machine in presence of a contaminant in the air

TOXICOLOGY OF BENZENE

Once benzene enters the bloodstream, it travels throughout the body and can be temporarily stored in the bone marrow and fat. The metabolism of benzene occurs either in the liver or bone marrow and results on benzene metabolites. Benzene metabolites are responsible for some harmful effects and most of them are eliminated within 24 hours of exposure.

MECHANISTIC TOXICOLOGY- ABSORPTION

Benzene can enter the body either through the lungs, gastrointestinal tract, or across the skin. Inhalation is the primary route of exposure to Benzene with a rapid absorption rate through the lining of the lungs before entering the bloodstream. The second mechanism of absorption is ingestion where 100 percent of Benzene is absorbed in the gastro-intestinal tract before entering the bloodstream based on data collected from accidental human poisoning and animal studies. The last mode of absorption is dermal after exposure to Benzene or benzene-containing products where both the rate and

percentage of absorption through skin are low: 0.4 g/cm²/hour and 0.05 percent respectively. The primary route of exposure examined in this study is the oral ingestion of benzene from drinking water (3).

MECHANISTIC TOXICOLOGY- DISTRIBUTION

Once inhaled, Benzene is distributed primarily to the liver for metabolism, but additionally transported to the blood, bone marrow, mammary glands, fat, and crosses the human placenta in amounts equal to or greater than the maternal blood. Since benzene is lipophilic, a high distribution to fatty tissue might be expected. Also, animal studies showed that benzene levels reached steady state concentration after exposure to an inhalation dose of 500 ppm in two hours in the bone marrow, four hours in the blood, and six hours in the fat.

The distribution of ingested Benzene has been studied only through animal research, no human studies were located. The tissue distribution of Benzene and its metabolites depended of the concentrations of the ingested dose and was detected in the following organs: liver, kidney, blood, Zymbal gland, nasal cavity tissue, and mammary gland. Dermal exposure was studied only trough animal studies and showed a distribution in the liver, kidneys, and skin (3).

MECHANISTIC TOXICOLOGY- BIOTRANSFORMATION/METABOLISM

The metabolism of Benzene is presumed to occur primarily at the liver while some secondary metabolism take place at the bone marrow. The mechanism of transport of hepatic metabolites to the bone marrow hasn't been elucidated at this time, but

suggestions point towards a covalent binding of reactive benzene metabolites to blood proteins. The bone marrow represents the site of toxicity for benzene.

The Primary metabolism of benzene in the liver starts with the cytochrome P-450 2E1 catalyzed oxidation reaction resulting in benzene oxide, which is then subjected to different metabolic enzymes to become one of the following Phenolic metabolites: phenol, hydroquinone, catechol, 1,2,4-benzenetriol, and 1,2- and 1,4-benzoquinone. The resulting phenolic metabolites can be metabolized at the bone marrow by myeloperoxidase (MPO) to form highly reactive semiquinone radicals and quinones that stimulate the production of reactive oxygen species (3).

MECHANISTIC TOXICOLOGY- EXCRETION/ELIMINATION

Major route of elimination of inhaled benzene is exhalation of unmetabolized benzene, while the absorbed benzene is excreted in humans via the metabolism to phenol and muconic acid followed by urinary excretion of conjugated derivatives (sulfates and glucuronides).

Ingested benzene is eliminated and excreted through exhalation and phenol metabolites in urine. Animal studies showed that the amount of benzene either exhaled or eliminated in the urine depends primarily of the amount ingested; lower doses result in higher output in urine whereas higher doses result in higher percentage of the dose getting exhaled (69%).

Limited human data on excretion of benzene after dermal exposure shows that approximately 30% of dermally absorbed benzene is eliminated in the form of phenol in the urine. Animal studies showed that the major routes of excretion in male rats exposed dermally to benzene were urine and, to a lesser extent, the expired air (3).

HEALTH EFFECTS OF BENZENE INGESTION

Oral exposure in humans to high levels of benzene concentrations can cause vomiting, irritation of the stomach, dizziness, sleepiness, convulsions, rapid heart rate, coma, and death. However, the health effects of ingesting foods or drinking liquids containing lower levels of benzene are not known. Both animal and human data showed that benzene is genotoxic since it could cause chromosomal aberrations in peripheral lymphocytes and bone marrow cells. Animal data showed that benzene can be a multiple site carcinogen and cause leukemia. Health effects of benzene result from acute, sub-chronic and chronic exposures. Oral exposure to benzene can affect the following organs: the gastrointestinal, hematopoietic, nervous, and immune systems. In animals, oral exposure to benzene can damage the blood and the immune system and can cause cancer due to benzene metabolite effects on the bone marrow(3).

The ATSDR describes the health effects associated with oral exposures to benzene as described below and summarized in Table 6.

Table 6. Benzene Health Effects Associated with Oral Exposure

Health Effect		Exposure Period	Type of Study	Symptoms
Genotoxic		Chronic	Animal and Human	Chromosomal aberrations in peripheral lymphocytes and bone marrow cells
Systemic	Hematological	Sub-chronic, Chronic	Animal	Decrease in erythrocytes and leukocytes
	Gastrointestinal	Acute	Human	Toxic gastritis and pyloric stenosis
Neurologic		Acute, Subchronic, and Chronic	Human	Memory loss, distal neuropathy and difficulty sleeping, peripheral nervous system effects
Immunological and Lymphoreticular Effects		Sub-chronic and Chronic	Animal and Human	Damage to antibody and leukocyte responses
Carcinogenic		Chronic	Animal	Leukemia and multiple site carcinogen (in animals)

MAXIMUM CONTAMINANT LEVEL

Given the wide range of potential health effects from the oral ingestion of benzene, the United States EPA has set the maximum contaminant level (MCL) for benzene in drinking water at 5 µg/L. The conservative MCL is calculated based on assumption that the average adult weighs 154 pounds and drinks approximately 2 quarts of water per day over a lifetime (70 years). Since benzene is carcinogen, the non-enforceable MCL goal (MCLG) is zero in drinking water (16).

PURPOSE OF THE STUDY

CWFA technology can be used in different civilian applications and by many nations, especially developing countries lacking residential drinking water such as India(22). The military could also use this technology to provide drinking water to small

units seeking logistical decentralization and deploying to remote areas without access to a reliable natural water source. However, insufficient information is available to determine the relationship between the quality of the ambient air and the product water of the CWFA technology; all the previous studies focused on testing the water for metals or basic water quality parameters such as turbidity pH, conductivity, alkalinity, total hardness, and total dissolved solids. Only Kinder et al. (13) in their recent study evaluated the impact of ambient benzene concentrations on CWFAS product water. Further research is needed to explain the mechanism of transfer of benzene from air to the CWFA products water to assess the quality of the CWFA product water and the appropriateness of the currently used CWFA water treatment filters. This research will assist in the modeling and prediction of product water benzene contamination based on ambient air data, selection of the appropriate CWFAS product water treatment technology, and the extrapolation of the results to other similar pollutants.

RESEARCH QUESTION

What is the mathematical relationship between the concentrations of benzene in the ambient air and the water samples (control and product) during the use of the “Water From Air” technology?

PURPOSES AND HYPOTHESIS

The purpose of this research is to use modeling to predict the concentrations of benzene in the CWFA product water given specific environmental conditions. The results of this study will be used to assess the need for CWFA product water treatment before consumption.

Hypothesis: the relationship between the concentrations of benzene in the ambient air and those transferred to the untreated CWFA product water will follow a linear model.

Specific aim #1 Identify the length of time required for the control water samples to reach the equilibrium by exposing six control water samples for six hours to 50 and 650 $\mu\text{g}/\text{m}^3$ ambient air target concentrations of benzene at two different relative humidity, and create a model that translates the transfer.

Specific aim #2 Measure benzene concentrations in the CWFA product water samples at 25 ($^{\circ}\text{C}$) and two different relative humidities (45% and 65%), and at the following benzene air target concentrations: 50, 200, 350, 500, 650, and 800 $\mu\text{g}/\text{m}^3$.

Specific aim #3 Create a model translating the relationship between the concentrations of benzene in the ambient air and the untreated water produced by the condensation “Water From Air” technology, and use simple linear regression to analyze the results of the data.

Specific aim #4 Compare the concentrations of benzene datasets in the control and product water samples, and compare the results of the simple linear regression between air and product water concentration at 45 and 65% relative humidities.

CHAPTER 2: METHODOLOGY

STUDY DESIGN

This quantitative research tested a CWFA system in a controlled environmental test chamber in order to model the mathematical relationship between the concentrations of benzene in the ambient air and the water samples during the use of the “Water From Air” technology (Aquaboy Atmospheric Water Generator, Atmospheric Water Solutions., Florida, USA). Testing was conducted at the Naval Medical Research Unit Dayton (NAMRU-D) located in Area B at Wright Patterson Air Force Base, Ohio. U.S. A range of benzene air concentrations including those representing outdoor polluted and indoor industrial environments were tested inside an inhalation exposure chamber at 25°C and at two relative humidities (45 and 65%). Two types of inhalation exposure chambers were available for testing at the NAMRU-D laboratory: H1000 and H2000 (H1000, Lab Products Inc., Seaford, DE). The H1000 was selected since it required less benzene to conduct the experiment and showed less variation in airflow volume, temperature, and relative humidity. Sampling consisted of collecting and analyzing benzene samples from the chamber’s air, CWFA product water, and control waters. This research was conducted in two phases: the preparatory and full scale phase.

PREPARATORY PHASE

The first step of the preparatory phase was to become familiar with the inhalation exposure chamber before installing the environmental monitoring equipment. The second step consisted of using the Laboratory Virtual Instrument Engineering Workbench (LabVIEW) program to monitor the environmental conditions inside and outside the chamber. The third step focused on finding the best method to reach and sustain the desired temperature and relative humidities with an altered CWFA machine. The final step involved learning about the limitations of both the chamber and the CWFA machine.

The preparatory phase started by installing the environmental data loggers and probes to continuously measure and record the environmental parameters in and around the environmental chamber such as: one temperature and relative humidity probe (Model HF532WB6XD1XX, Model HC2-S, Rotronics Instruments, Inc., Hauppauge, NY), two pressure probes (Magnehelic and BAPI pressure instruments), one air mass flow monitor (Model HFM-200, Teledyne-Hastings Instruments, Pittsburgh, PA) connected to a laminar flow element (Model HFM-200 LFE, Teledyne-Hastings Instruments, Pittsburgh, PA), and one thermocouple temperature data logger. The probes were inserted into the chamber through pre-made ports. Another temperature and relative humidity probe was placed outside the exposure chamber in the ambient room air. All the monitoring devices

were connected to a LabVIEW program (2012) which allowed live data monitoring and recording (See Figure 4 and 5 below).

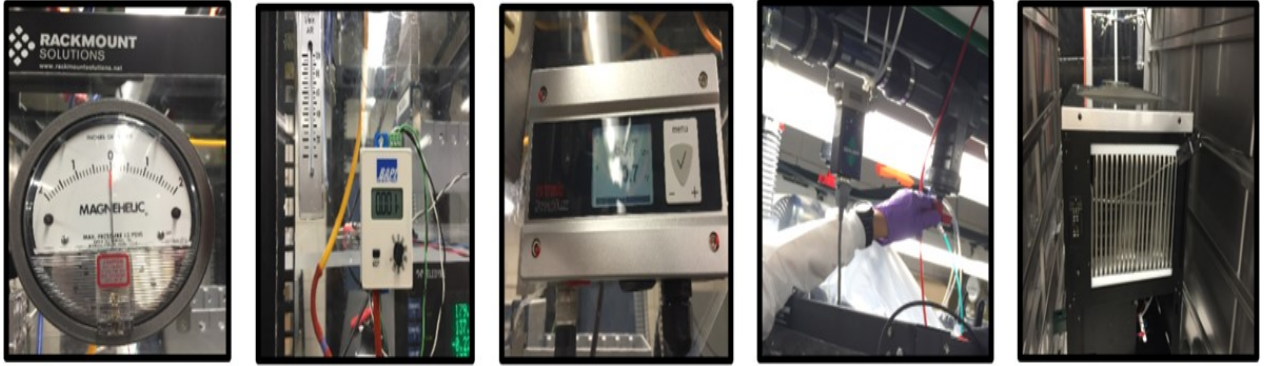


Figure 4. Environmental monitoring instruments (from left to right: Magnehelic gage, Bapi instrument, Rotronic instrument, Air mass flow monitor, and Thermocouple)



Figure 5. LabVIEW program connected to the monitoring devices

The airflow inside the H1000 was 180 L/Min to provide ~ 10.8 air changes/hour with a T90 equilibrium time of approximately 12.8 minutes (Equation 3) and T99 equilibrium time of approximately 25.6 minutes (Equation 4). T90 or T99 are the time

for the concentration of test substance in a chamber to respectively rise from background or zero to 90 or 99% of the equilibrium or target concentration.

$$T_{90} = 2.303 * \frac{X}{Y} \quad [\text{EQ \#3}]$$

$$T_{99} = 4.605 * \frac{X}{Y} \quad [\text{EQ \#4}]$$

The variables in both equations 3 and 4 are:

- X is the chamber volume (*L*)
- Y is the chamber flow rate (*L/min*)

Air leaving the chamber was pulled through a gate valve by a blower to the building exhaust flow system. The gate valve was used to control the static pressure inside the chamber relative to the ambient pressure. The chamber static pressure was set to a slightly negative pressure (approximately -0.05 inches of H₂O) to prevent the test chemical from entering the laboratory room air.

The preparatory phase was also used to prepare the CWFA machine for the experiment by stripping the CWFA machine from unneeded parts such as the system's pump, solenoid, the untreated water reservoir, and air filter. Removal of the product water treatment module allowed the evaluation of only untreated product water. The CWFA machine was centrally placed inside the H1000 chamber on the top of a stainless steel pan. Once the CWFA machine was turned on, it quickly consumed and decreased the humidity inside the chamber while increasing the temperature.

TEMPERATURE CONTROL

At the beginning of the preparatory phase, five unsuccessful trials were attempted to control the amount of heat generated by the CWFA machine. After these, the focus shifted from the CWFA machine to its surrounding environment. An enclosure measuring 2.13 meters (7 feet) Height x 2.13 meters (7 feet) Length x 1.83 meters (6 feet) Wide and made of 4 millimeter thick heavy duty plastic material (Polyethylene) was used to trap the heat or the cold inside. To warm the chamber when the CWFA machine was off, a technique combining a heater, settings of the heater, and distance was used to reach the desired temperature inside the environmental chamber. When the CWFA machine was on, three air conditioning units (two PAC A120E, De'Longhi America Inc, Upper Saddle River, NJ 07458 and one 416711, Idylis, Findlay, OH 45840) were used to decrease the heat generated by the machine and were set at temperatures ranging from 64 to 68 degrees Fahrenheit depending of the chamber's temperature. The number of air conditioning units on or off was determined by the displayed chamber temperature on the LABVIEW monitor (See Figure 6 below).

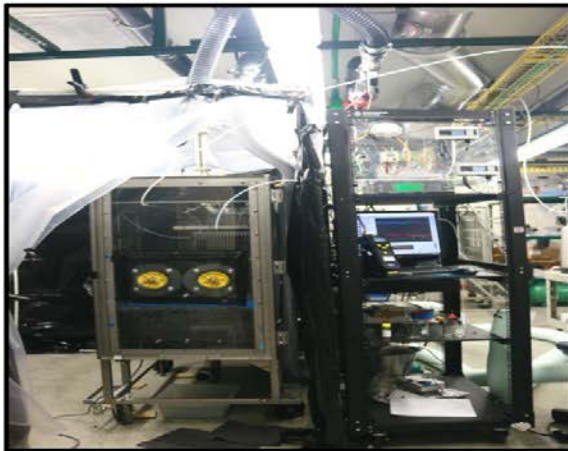


Figure 6. Temperature control using an enclosure (front and back)

HUMIDITY CONTROL

HUMIDITY GENERATION WHEN THE CWFA MACHINE IS ON

With the CWFA machine turned on, five experiments were tried to control the humidity inside the chamber before the final one could reach the desired relative humidity. The successful trial consisted of installing a manually-controlled stainless steel air atomizing nozzle (Model SUJ1A with fluid cap 1650 and air cap 64, Spraying Systems Co., Wheaton, IL) into one end of the H1000. The atomizer was supplied with house generated reverse-osmosis (RO) water and in-house filtered, instrument quality, compressed air at approximately 80 psi.

HUMIDITY GENERATION WHEN THE CWFA MACHINE IS OFF

To create and maintain the desired relative humidity inside the H1000 chamber when the CWFA machine is off, a program was created using LabVIEW (LabVIEW Software v.10.0, National Instruments, Austin, TX). The program controlled the opening and closing of the solenoid valves to provide as needed timed injections of RO water and air into the room main supply air flow to ensure that the target humidity is reached and maintained in the H1000 chamber.

LIMITATIONS OF THE CWFA SYSTEM

It was also observed during the preparatory phase that when the CWFA system went into standby mode the fan halted and water production was suspended. The operational cycle of the machine consisted of 94 minutes of continuous operations followed by a standby mode for about 30 minutes. While in standby mode the CWFA system was not exhausting hot air and as a result the temperature would drop while humidity would increase. Therefore, it was imperative to change the initial experimental design by turning off the CWFA during the six hour sampling period intended to find the equilibrium between benzene concentrations in the air and control water samples.

THE FULL SCALE PHASE

Six separate tests were used to measure the concentrations of benzene in the control and CWFA product waters. All tests for this experiment were run at 25 (°C) and at two different relative humidities (45% and 65 %) but for different lengths of time depending of the purpose of this study:

Modeling experiment: consisted of measuring benzene concentrations in the CWFA product water samples after one-hour long exposure to the following benzene air target concentrations: 50, 200, 350, 500, 650, and 800 ug /m³ (see Table 7 below). The goal was to create a model translating the relationship between the concentrations of benzene in the ambient air and the untreated water produced by the “Water From Air” technology.

Table 7. Summary of the modeling experiment conducted at 25 °C

Benzene air target concentrations (µg/m³)	Relative humidity (%)	Type of water samples	Discrete one hour sampling rounds
50	45	Product and control	1
	65		
200	45		
	65		
350	45		
	65		
500	45		
	65		
650	45		
	65		
800	45		
	65		

Equilibrium study: consisted of exposing six control water samples for six hours to 50 µg/m³ and 650 µg/m³ ambient air concentrations of benzene. At the end of each hour, one control water sample was collected until the end of the six hours long sampling period and benzene concentrations were measured (see table 8 below). The goal was to identify the length of time necessary for the control water samples to reach the equilibrium.

Table 8. Summary of the equilibrium experiment conducted at 25 °C

Benzene air target concentrations ($\mu\text{g}/\text{m}^3$)	Relative humidity (%)	Length of sampling period (hours)	Total number of control water samples	Number of control water samples collected each hour
50	45	6	6	1
	65	6	6	1
650	45	6	6	1
	65	6	6	1

CONDITIONS OF THE EXPERIMENTS

After a review of the literature, this study adopted the following benzene air target concentrations to represent the heavy polluted outdoor and the industrial indoor environments: 50, 200, 350, 500, 650, and 800 $\mu\text{g}/\text{m}^3$. These concentrations have been selected because they represent the levels of benzene concentrations observed in the air at various geographical locations throughout the world. In addition, having six evenly spaced concentrations would be sufficient for the development of a mathematical model.

Also, this study used two relative humidity conditions, a low 45% with a mean of 44.8 ± 0.9 % and high 65% with a mean of 64.6 ± 1.2 % value at a constant air temperature of 25 °C with a mean of 25.04 ± 0.2 °C to test the effects of humidity on the transfer of benzene from air to the water samples.

TEST MATERIAL

Benzene as a gas or a liquid was used to generate calibration bag standards or test atmospheres. Benzene gas cylinders, certified at 1 ppm (% purity) and 200 ppm (% purity) were obtained from Airgas USA, LLC, Dayton, OH. While liquid benzene, HPLC grade ($\geq 99.9\%$; Lot No. SHBG7317V) was obtained from Sigma-Aldrich St. Louis, MO. All benzene used for this study was stored at room temperature and undiluted.

The molecular weight and density for benzene are respectively 78.11 g/mole and 0.8765 g/mL @ 25° C, and both values were used to convert benzene concentrations from parts per million (ppm) to micrograms per cubic meter ($\mu\text{g}/\text{m}^3$).

GENERATION SYSTEM

Airborne benzene target concentrations in the chamber were 50, 200, 350, 500, 650 and 800 $\mu\text{g}/\text{m}^3$. The benzene test atmospheres were generated through a 10-gallon, stainless steel pressure vessel (McMaster-Carr, Aurora, OH). A small amount of benzene liquid (75 μL) was injected with a micropipetter (100 μL , Pipetman, Gilson, Inc., Middleton, WI) into the pressure vessel. The pressure vessel was sealed and pressurized to approximately 70 psi with house compressed air and the nominal concentration inside the pressure vessel was estimated at 94.4 ppm. The calculations to determine the nominal benzene head space concentration inside the pressure vessel are listed in Appendix D.

The house compressed air passed through the head space of the pressure vessel and delivered the concentrated benzene at different known flow rates through a mass flow controller (Model HFC-202, Teledyne-Hastings Instruments, Pittsburgh, PA) into the exposure chamber (H1000) air supply to create a concentration at or near the target concentrations.

EXPOSURE SYSTEM

Experiments were conducted in a glass and stainless steel exposure chamber (H1000, Lab Products Inc., Seaford, DE) with an internal volume of one cubic meter. The H1000 was situated inside a four millimeter thick plastic sheet enclosure 2.13 meters (7 feet) Height x 2.13 meters (7 feet) Length x 1.83 meters (6 feet) Wide using one half inch PVC tubing as the framework. The chamber was supplied with air that passed through a high efficiency particulate air filter (HEPA) (95% efficiency). The filtered room air was distributed by a blower to the H1000. The supply air flow was controlled by a manually operated inlet gate valve and monitored by a mass flow monitor (Model HFM-200, Teledyne-Hastings Instruments, Pittsburgh, PA) connected to a laminar flow element (Model HFM-200 LFE, Teledyne-Hastings Instruments, Pittsburgh, PA) placed in the supply air stream. Air leaving the chambers was pulled through an exhaust gate valve by a blower to the building exhaust flow system. The exhaust gate valve was used to control the static pressure inside the chamber relative to the ambient pressure.

The chamber static pressure was set to a slightly negative pressure (approximately -0.05 inches of H₂O) to prevent the test chemical from entering the room air. The H1000 was operated at a target total flow rate of approximately 180 L/min to provide 10.8 air changes/hour (See Appendix E for Calculation of the flow rate for known air changes per hour).

ENVIRONMENTAL CHAMBER SYSTEM

An environmental chamber system was set up to conduct the experiments. A schematic diagram and a picture of the set up are shown below in Figures 7 and 8.

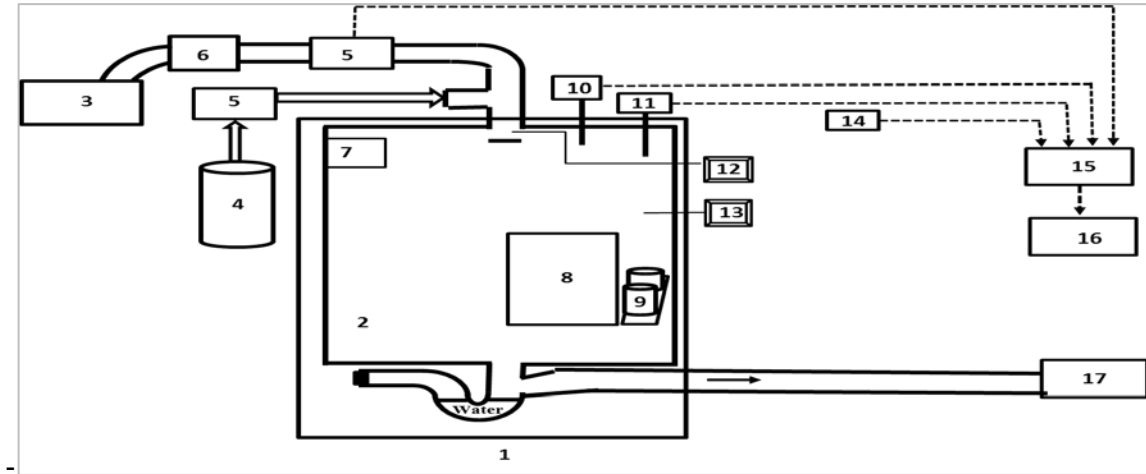


Figure 7. Schematic diagram of the environmental chamber set-up for the study. 1. Enclosure, 2. Environmental chamber (H 1000), 3. Turbine blower supply air system, 4. Benzene gas cylinder, 5. Mass flow monitor, 6. Humidity controller, 7. Humidity sprayer, 8. CWFA system, 9. Water containers, 10. Static pressure probe, 11. Temperature and relative humidity probe, 12. Fourier Transform Infra-Red Spectrometer, 13. Photo Ionization Detector, 14. Room's temperature and relative humidity probe, 15. Signal converter, 16. NI Labview data logger, 17. Turbine blower exhaust system



Figure 8. The environmental chamber set-up

Benzene concentrations were measured using a Fourier Infrared Transform Spectroscopy (FTIR) machine and a ppbRAE 3000 photoionization detector (PID) (Model PGM7340, RAE Systems, San Jose, California) with a 9.8 eV PID lamp as a real-time, direct-reading devices to indicate when the target benzene concentrations were reached as well as to maintain a steady state benzene concentration inside the chamber. The photoionization detector (PID) was calibrated using a benzene cylinder, and therefore eliminated the need for a benzene correction factor. Both the FTIR and PID air monitors were calibrated at the start of every new test condition. The high calibration point was executed using a certified 1.004 ppm benzene gas cylinder (Airgas, Laporte, TX) and low calibration was conducted using charcoal filtered pressurized room air.

The PID was placed next to the chamber with the probe connected to a half inch Teflon tube which ended nearby the air intake of the CWFA system.

At the end of each testing condition, benzene release ceased but the chamber's airflow continued for at least 25 minutes to allow time for the push/pull system to completely exhaust the chamber from any leftover benzene. Additionally, both the control and product water beakers were autoclaved at a temperature higher (121°C) than the boiling point of benzene (80.1 °C) and for an adequate length of time (15 mins) to ensure total removal of benzene before placing them into the environmental chamber. Below and nearby the evaporator coil of the CWFA system were respectively placed the

400 mL product and control water beakers containing 250 mL of deionized water. Upon experiment set-up, the chamber and enclosure were stabilized for at least 20 mins prior to the start of the test to permit temperature and relative humidity levels to stabilize at test conditions. Product water that had accumulated during chamber stabilization period was discarded outside the room so that only product water produced during the sampling period would be collected. At the end of each sampling round, product or control water beakers were collected and all the beakers were completely emptied and baked before the next sampling session. Only control water beakers were refilled with deionized water before the start of the next sampling period.

SAMPLING PLAN AND PROCEDURE

The concentrations of benzene in the air were measured using the FTIR and the PID as real-time and direct reading instruments, while water sampling was conducted at the end of each hour for all samples.

The full scale phase consisted of two RH conditions that each have 6 discrete one-hour sampling rounds at six airborne benzene concentrations and 2 six hour long continuous sampling at two airborne benzene concentrations (See Tables 8 and 9 under the full scale phase section).

Since the inhalation exposure chamber is not equipped with a sampling port or hand inserts to properly and safely perform the needed water sampling, it was decided to

cut and built a revolving rectangular window (43.2 centimeters (17 inches) long and 30.5 centimeters (12 inches) high) in the lower half of the Plexiglas door of the chamber to allow a quick retrieval of the 400 ml glass beakers while wearing polyvinyl alcohol chemical resistant gloves (See Figure 9 below).

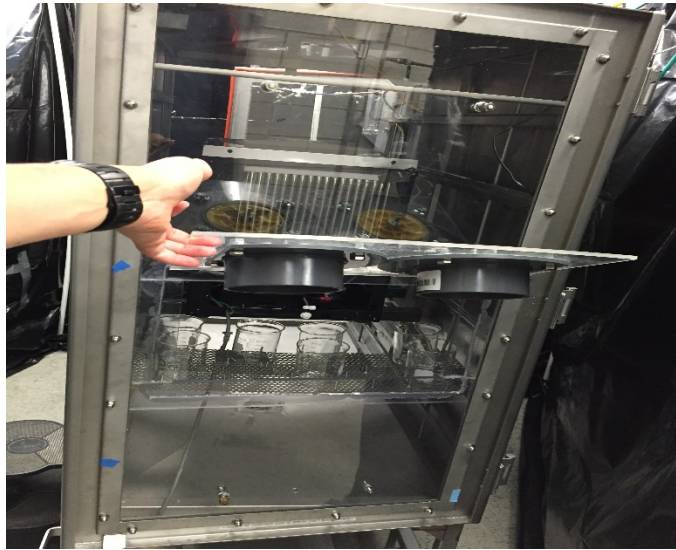


Figure 9. Revolving rectangular window used for water sampling

Three types of quality control samples were used during the water sampling: field blanks, duplicates, and trip blanks. Field blank samples, samples of uncontaminated reagent water which are free of benzene, were opened and exposed to the sampling environment while the sampling is performed then closed and returned to the laboratory for analysis. Duplicate water samples were taken for all the 12 discrete one hour long product water samples collected for modeling purposes and the 4 six hours long control

water samples collected to determine the amount of time necessary for benzene concentrations to reach equilibrium between the water samples and the chamber's air. Trip blanks, prepared by the laboratory with a reagent water that is free of benzene then shipped with the sampling containers to the sampling site, were not opened to the environment during the sampling process and were returned unopened to the laboratory for analysis (The full scale sampling scheme is detailed in Tables 7, 8 and 9).

Table 9. Number and Type of Samples for the Full Scale Test.

	Number of samples	Number of duplicates	Number of field blanks	Number of trip blanks	Number of samples
Product water samples	12	12	6	6	36
Control water samples	36	24			60
Total					96

DATA COLLECTION

AIR DATA COLLECTION

A Fourier Transform-Infrared (FTIR) spectrometer (Model iS10, Thermo Scientific Corp, Madison, WI) with a 2-meter, short path gas cell and barium fluoride (BaF₂) windows was used to analyze and monitor the concentration of benzene in the H1000.

A gas bag of 200 ppm benzene in air was created to identify benzene's wave numbers using the spectral library in OMNIC (OMNIC Series Thermo Scientific Corp, Madison, WI). The benzene peak was identified at a wave number of 3046.6 cm^{-1} bracketed in a range of 3010 to 3120 cm^{-1} .

The FTIR was calibrated by performing serial dilutions from a standard gas cylinder of 1 ppm benzene with room air to create gas bags at the following concentrations: 315, 629 and $1572\text{ }\mu\text{g/m}^3$.

CHAMBER DISTRIBUTION

The distribution of benzene in the H1000 chamber was evaluated prior to the start of exposures. The uniformity was checked using a FTIR that monitored the airborne benzene concentrations continuously and recorded 3 readings per minute. The FTIR sampled from 9 locations (center and 8 corner areas) in the H1000 after the generated benzene test atmosphere stabilized. Each position was sampled for at least 10 minutes in a sequential manner. The center position was sampled 4 times within the sequence. The measured concentration at the standard sampling location at the center of the chamber provided an indication of the temporal variability of benzene concentrations, while the measurements at the surrounding ports provided an indication of the spatial variability of benzene concentrations. Figure 10 is an illustration representing the sample port locations for the chamber distribution testing.

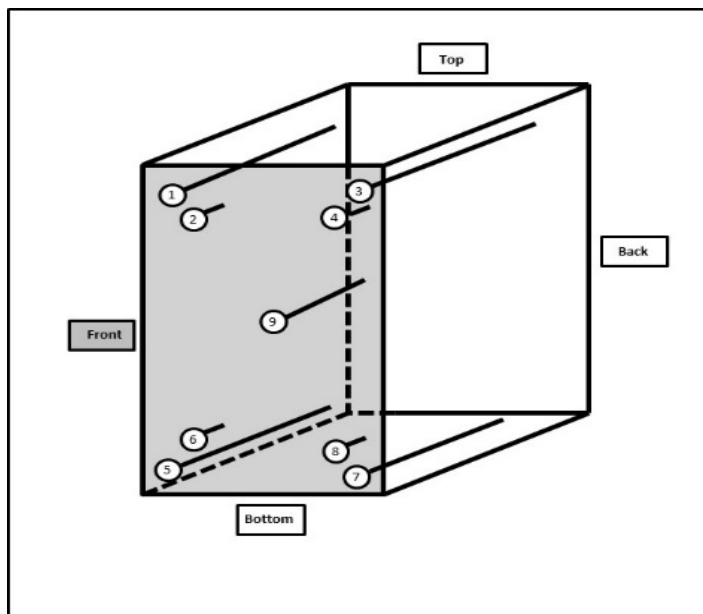


Figure 10. H1000 Sample port locations for chamber distribution testing.

The chamber distribution test results show that benzene was evenly distributed in the chamber.

HUMIDITY AND FTIR RESPONSE

The effect of humidity on the FTIR concentration was obvious during the trial runs. Perma Pure dryers (MD-110-12S-4, Model No. MD-110-24S-4, Perma Pure LLC, Toms River, NJ) were used in an attempt to separate the water vapor from the benzene test atmosphere prior to entry into the FTIR. A Perma Pure dryer uses a countercurrent nitrogen flow through an area between a stainless steel outer tube and a Nafion membrane inner tube wall to selectively and continuously remove water vapor from the

gas stream. A 12” or a 24” long Perma Pure dryer model were used to dry the benzene samples for some of the trial runs.

WATER DATA COLLECTION

400 mL glass beakers were used to collect product water samples and to hold control water during the experiment. The glass containers were rinsed with RO water and autoclaved at a temperature of 121°C for 15 mins before the start of every test day. The control beaker contained 250 mL of deionized water that stayed open to the atmosphere in the same manner as the product water beaker and remained in the chamber throughout the one hour sampling period or the six hours sampling period. At the end of the sampling period, product or control water beakers were collected through the chamber sampling window, and water was transferred from the beakers to the 40 ml amber glass vials with Teflon® septa. The 40 ml glass vials were filled in a manner to minimize agitation and completely filled to avoid any headspace. After the completion of the sampling, the 40 ml sample benzene vials were temporarily stored into a refrigerator kept between 0 – 4°C (1 to 2 days) before being transported to the laboratory using a portable cooler filled with ice.

A certified contracted laboratory (Pace Analytical Laboratory in Englewood, Ohio) completed the analytical procedure for the determination of benzene concentrations based on the U.S. EPA Method 524.2 (Measurement of Purgeable Organic Compounds in

Water by Capillary Column Gas Chromatography/Mass Spectrometry). The Method Detection Limit (MDL) and Practical Quantification Limit (PQL) used by the laboratory in their analysis for benzene were respectively 0.130 µg/L and 0.5 µg/L. No contaminants were detected in laboratory blank or trip samples.

CHAPTER 3: RESULTS AND DISCUSSION

DIRECT READING INSTRUMENT RESULTS

FTIR RESULTS

The FTIR results were impacted by both relative humidity and the low target concentrations of benzene used in this experiment. The results were inaccurate in determining the benzene concentrations in the air despite the use of a 12” or 24” long Perma Pure dryers (MD-110-12S-4, Model No. MD-110-24S-4, Perma Pure LLC, Toms River, NJ) to dry the air samples before the FTIR machine analyze them.

Benzene was expected just over $3,000\text{ cm}^{-1}$ in the FTIR spectrum due to the aromatic C-H bond in the chemical molecule. The benzene peak was identified at a wave number of $3,046.6\text{ cm}^{-1}$ bracketed in a range of $3,010$ to $3,120\text{ cm}^{-1}$. Figure 11 below shows the FTIR readings of benzene that may have been impacted by the presence of water due to a possible overlap between the wavenumbers of the water and benzene molecules. Water vapor inside the H1000 chamber masked the absorbance band of benzene and stopped the FTIR machine from accurately reading the spectral band specific to the benzene molecule during the exposure. The FTIR results were sometimes higher during the exposure to lower nominal concentrations and during the post-exposure to benzene rather than during the exposure (Appendix B: Tables B-1 and B-2). Due to

the erratic FTIR results, other means of verification of the nominal air concentrations of benzene inside the H1000 chamber were used.

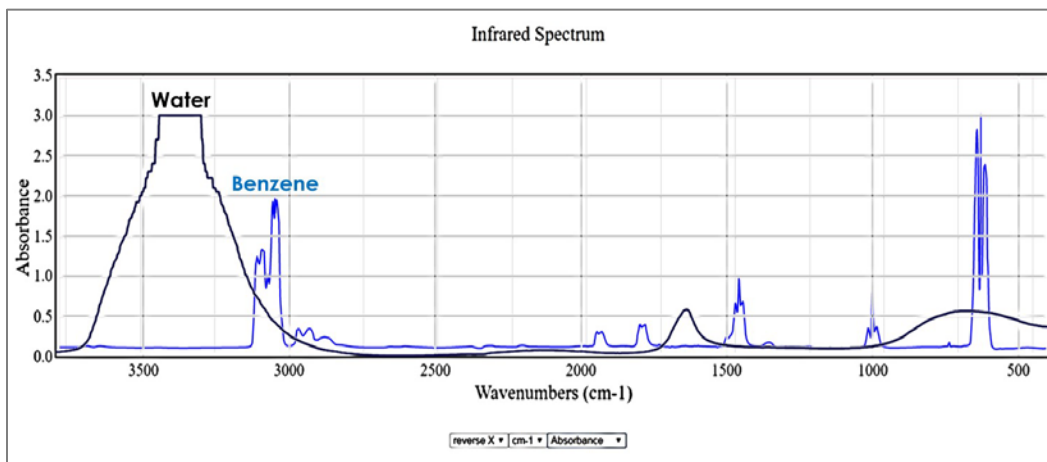


Figure 11. FTIR spectrum showing the absorption of Benzene and Water (33)

PID RESULTS

A malfunction of the PID stopped the instrument from providing accurate readings of the chamber benzene concentrations and showed inconsistent readouts for the test atmospheres. The PID readouts were either continuously lower than the expected nominal concentration or the readout continued to increase to unrealistic concentrations. The erroneous readings were probably due to a contamination of the lamp window and the chamber's humidity. The accumulation of organic deposits or buildup of film on the surface of the lamp and the quenching effect of the water vapor (non-ionizable gas) will result in a reduced sensitivity and inconsistent readings (29). Since both the PID and FTIR readings could not verify the concentrations of benzene in the air during the

experiment, a post-study was conducted to define the theoretical concentrations of benzene in the air inside the H1000 chamber.

POST-STUDY VERIFICATION OF AIR BENZENE CONCENTRATIONS

Total hydrocarbon analyzer (THA) flame ionization detector (FID) (Model 400A, Rosemount Analytical, Shakopee, Minnesota) was used as a post-study tool of verification of the air benzene concentrations inside the H1000 chamber. The measured air benzene concentrations were adopted as the theoretical air benzene concentrations for this study. The THA has a relative humidity limit of 95 % and an ambient temperature range from 0 ° to 43°C. Two trial runs were conducted inside the H1000 chamber to verify the nominal concentrations of benzene in the air using the same equipment setup and method of benzene generation utilized during full scale study. Both trials were performed at room temperature (20 °C) and two different relative humidities: 61% RH and 41% RH. The environmental conditions used in both post-study trials were five degrees Celsius and four percent relative humidity less than those used during the study which could have slightly impacted the concentration of benzene in the environmental chamber. Benzene was generated inside the H1000 chamber for 10 minutes to get a stable reading and an average THA reading was recorded every two minutes. The results of the post-study trials (Table 10) indicated that the generation method of benzene during the study produced a test atmosphere at or near expected concentrations, except for the

exposure at 45% RH where the percent difference between measured and target concentrations exceeded $\pm 20\%$ variation reaching -22% at 350 $\mu\text{g}/\text{m}^3$ and -39% at 200 $\mu\text{g}/\text{m}^3$. The high percent difference at 200 $\mu\text{g}/\text{m}^3$ and 350 $\mu\text{g}/\text{m}^3$ indicates that the target concentrations may not have been achieved as planned at those two values. The variance observed between the target concentrations and measured ones or among the measured concentrations could be attributed to the fact that the chamber never reached equilibrium during the post study which requires 27.6 minutes, partial interference of humidity with the THA readings, and the air sampling protocol.

Table 10. Post-study verification of benzene concentrations in the air using Total Hydrocarbon Analyzer (THA) Flame Ionization Detector (FID)

Target concentration ($\mu\text{g}/\text{m}^3$)	45% RH			65% RH		
	Actual average concentration ($\mu\text{g}/\text{m}^3$)	$\pm$ Standard deviation	% Difference from target concentration	Actual average concentration ($\mu\text{g}/\text{m}^3$)	$\pm$ Standard deviation	% Difference from target concentration
50	44	15	12	44	8	12
200	277	3	-39	193	6	4
350	426	12	-22	416	10	-19
500	531	15	-6	517	21	-3
650	732	12	-13	571	70	12
800	931	19	-16	833	48	-4

INFLUENCE OF BENZENE VAPOR CONCENTRATION AND HUMIDITY ON PRODUCT AND CONTROL WATER

45% RELATIVE HUMIDITY

The results of one hour long exposure to six different air benzene concentrations at steady state air temperature ($25^{\circ}\text{C} \pm 0.2$) and lower relative humidity ($45\% \pm 0.9$) are shown in Table 11 (SPSS descriptive statistical analysis of the air temperature and relative humidity throughout the experiment is shown Table A1 and A2 of Appendix A). All the control water results were below the detection limit except for the three highest air target concentrations: 500, 650, and 800 $\mu\text{g}/\text{m}^3$. The laboratory Method Detection Limit (MDL) is 0.13 ($\mu\text{g}/\text{L}$) and the Practical Quantification Limit (PQL) is 0.50 ($\mu\text{g}/\text{L}$).

Table 11. Results of one hour-long exposure to six different benzene concentrations in the air at 45% RH and 25°C (BDL or MDL=0.13 $\mu\text{g}/\text{L}$)

Benzene air concentrations ($\mu\text{g}/\text{m}^3$)		CWFA product waters concentration ($\mu\text{g}/\text{L}$)	Control water concentration ($\mu\text{g}/\text{L}$)
Target concentrations	Actual average concentrations		
50	44 ± 15	0.56	<0.13
200	277 ± 30	2.12	<0.13
350	426 ± 12	2.3	<0.13
500	531 ± 15	10.3	0.35
650	732 ± 12	12.8	0.45
800	931 ± 19	16.4	0.63

The relationship between the concentrations of benzene in the ambient air and those transferred to the untreated WFA product water at 45% RH is represented by a linear model in Figure 12 below. The linear regression relationship had the following R^2 of 0.8881 (Appendix A-Table A4) which indicates that the regression line approximates well the real data points.

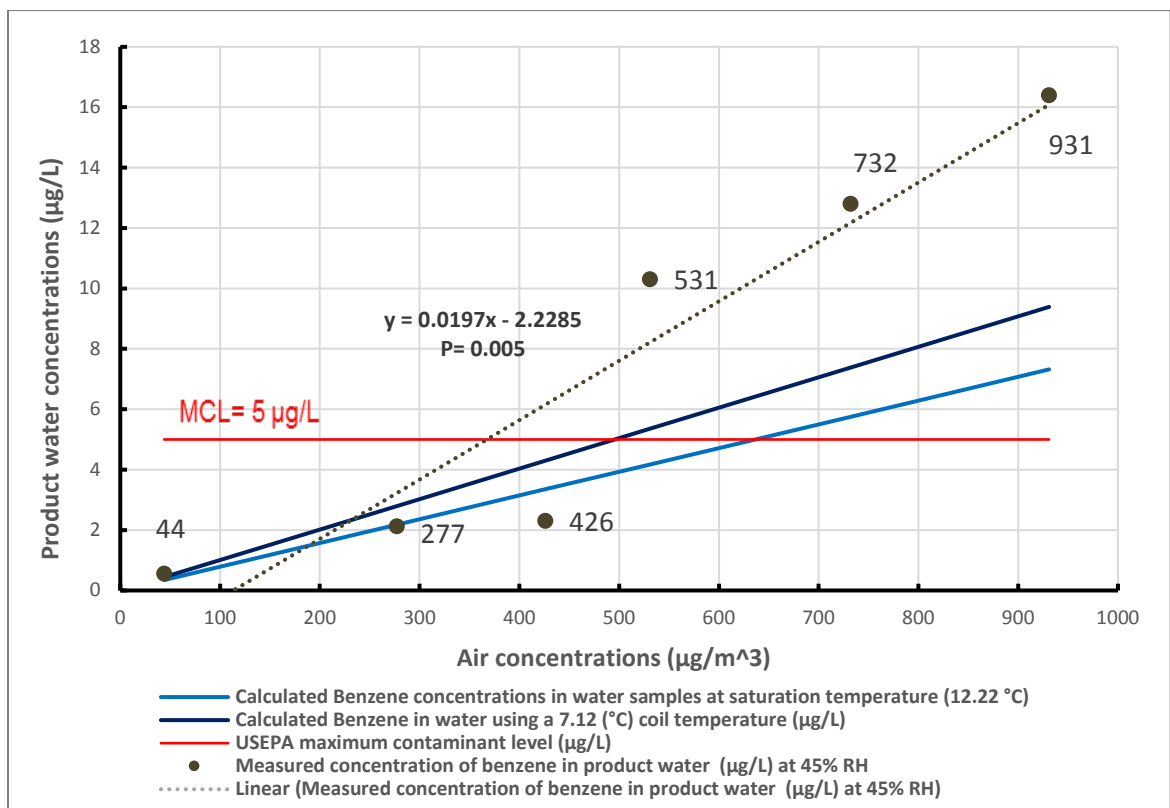


Figure 12. Benzene exposure at 45% RH

In addition, Henry's law was used to calculate and plot the predicted values of benzene concentrations in the product water using the saturation temperature (12.22 °C) and the recorded coil temperature (7.12 °C). As seen in a previous study, the calculated benzene concentrations in the product water using Henry's law increased when temperature decreased and the dataset of the calculated values remained below the dataset of the measured values at higher indoor benzene concentrations. Based on the linear regression equation in Figure 12, benzene concentrations in the product water are predicted to exceed the USEPA maximum contaminant limit (MCL) of 5 µg/L when benzene air concentrations in the chamber exceeded the threshold of 367 µg/m³ (industrial indoor environment).

The data point (426 µg/m³; 2.3 µg/L) is a suspected outlier since it did not follow the general trend of the rest of the data; the exposure to 426 µg/m³ of benzene in the air for one hour resulted in a benzene concentration in the CWFA product water almost equal to the exposure to 277 µg/m³ of benzene in the air (2.3 µg/L $\approx$ 2.12 µg/L). A Grubbs test was performed and the results indicated that the suspected outlier is the farthest from the rest of the data but it is not a significant outlier. Figure 13 below represents a linear regression relationship between the concentrations of benzene in the air and the concentrations of benzene in the product water without the suspected outlier value (416 µg/m³ target concentration and its corresponding product water value of 2.3

µg/L). The regression line has an R^2 equal to 0.96 (Appendix A-Table A5) which strongly validate the goodness of fit of the linear model. The suspected outlier is influential since the R^2 value has increased from 89% to 96%. Finally, benzene concentrations in the product water exceeded the USEPA maximum contaminant limit (MCL) of 5 µg/L when benzene air concentrations in the chamber exceeded the threshold of 322.5 µg/m³ at 45 % RH without the suspected outlier (industrial indoor environment) instead of 367 µg/m³ with the suspected outlier.

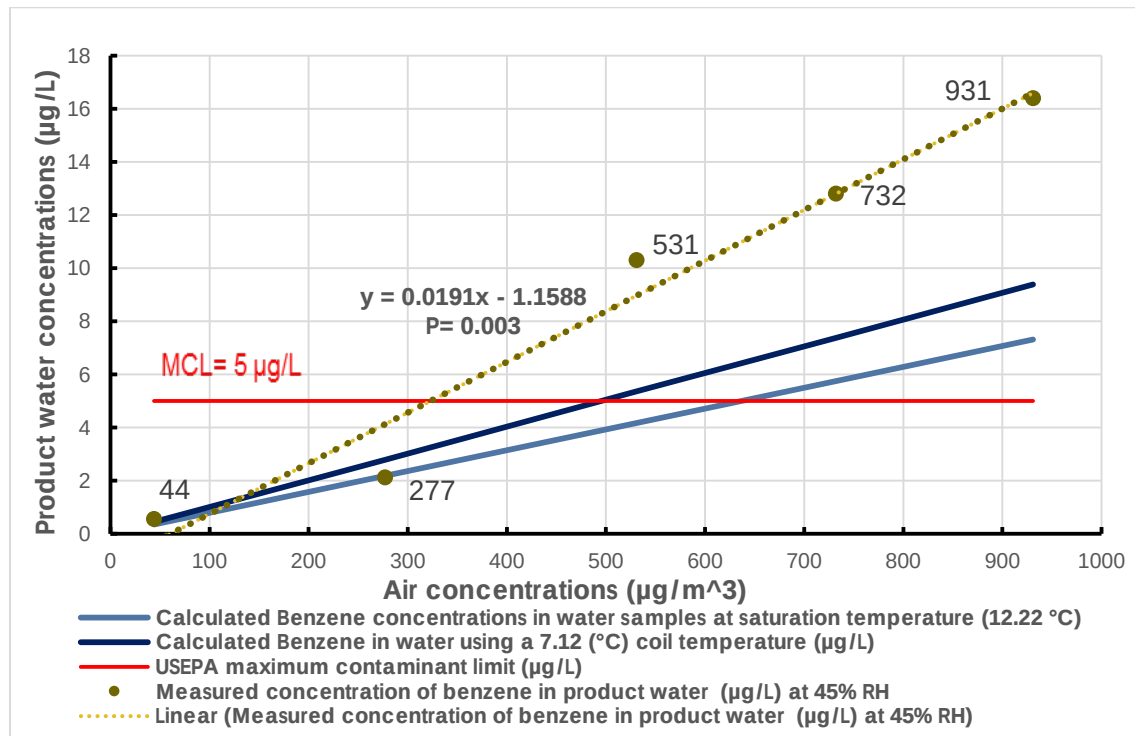


Figure 13. Exposure at 45% RH without suspected outlier

Figure 14 below shows the relationship between the CWFA product waters and the control water after one hour exposure to six different benzene concentrations in the air at 45% RH and 25°C. The graph shows that benzene concentrations in the CWFA product water were BDL ($<0.13 \mu\text{g/L}$) at the following benzene concentrations in the air: $44 \mu\text{g/m}^3$, $277 \mu\text{g/m}^3$, and $426 \mu\text{g/m}^3$. However, at concentrations representing a high industrial indoor environment (Please see Table 3 for air benzene classification), it was observed that an increase of benzene concentrations in the CWFA product water was associated with an increase in benzene concentrations in the control waters. The air concentrations $277 \mu\text{g/m}^3$ and $426 \mu\text{g/m}^3$ in Graph 13 are close to each other since their corresponding values are almost equal in the product water and below detection limits in the control water.

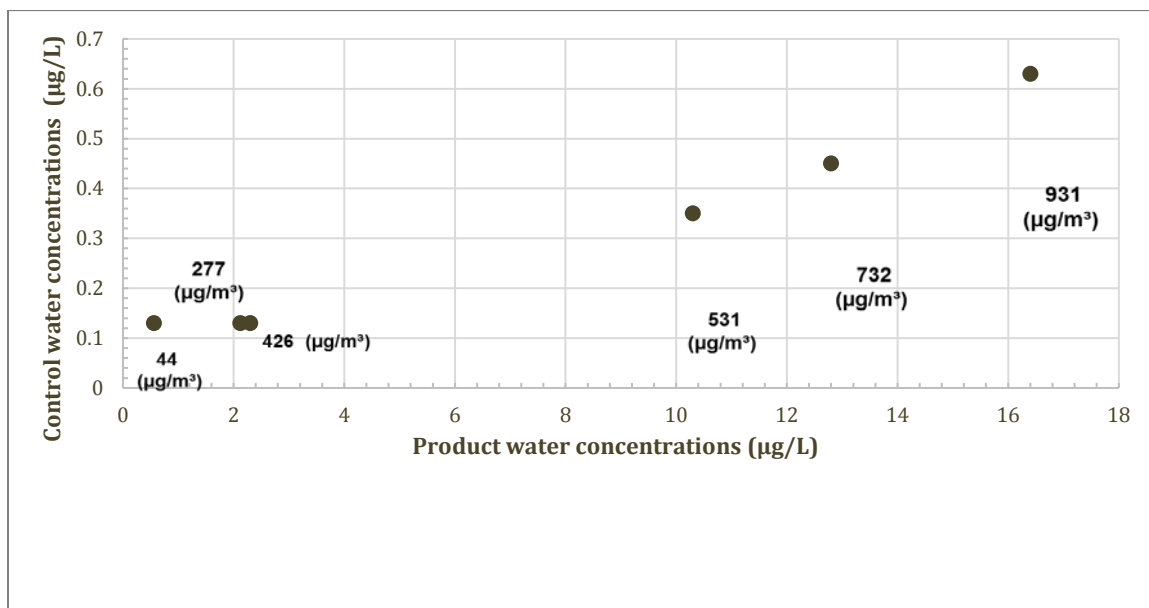


Figure 14. Six air benzene concentrations used to compare the transfer of benzene from air to the product and control water at 45% RH

65% RELATIVE HUMIDITY

The results of one hour long exposure to six different air benzene concentrations at steady state air temperature ($25^{\circ}\text{C} \pm 0.1$) and higher relative humidity ($65\% \pm 1$) are shown in Table 12 below (SPSS descriptive statistical analysis of the air temperature and relative humidity throughout the experiment is shown Table A1 and A2 of Appendix A). All the control water results were below the detection limit, the MDL is $0.13 \text{ } (\mu\text{g/L})$ and the PQL is $0.50 \text{ } (\mu\text{g/L})$. The data point ($416 \text{ } \mu\text{g/m}^3$; $7.24 \text{ } \mu\text{g/L}$) is a suspected outlier since it is not following the general trend of the rest of the data; the exposure to $416 \text{ } \mu\text{g/m}^3$ of benzene in the air for one hour resulted in a benzene concentration in the CWFA

product water almost equal to the exposure to 833 $\mu\text{g}/\text{m}^3$ of benzene in the air (7.24 $\mu\text{g}/\text{L}$ $\approx$ 7.30 $\mu\text{g}/\text{L}$). A Grubbs test was performed and the results indicated that the suspected outlier is the farthest from the rest of the data but it is not a significant outlier.

Table 12. Results of one hour-long exposure to six different benzene concentrations in the air at 65% RH and 25 °C (BDL or MDL=0.13 $\mu\text{g}/\text{L}$)

Benzene air concentrations ($\mu\text{g}/\text{m}^3$)		CWFA product waters concentration ($\mu\text{g}/\text{L}$)	Control water concentration ($\mu\text{g}/\text{L}$)
Target concentrations	Actual average concentrations at 65 % RH $\pm$ SD		
50	44 $\pm$ 8	1.05	<0.13
200	193 $\pm$ 6	4.14	<0.13
350	416 $\pm$ 10	7.24	<0.13
500	517 $\pm$ 21	4.89	<0.13
650	571 $\pm$ 70	5.88	<0.13
800	833 $\pm$ 48	7.30	<0.13

The relationship between the concentrations of benzene in the ambient air and those transferred to the untreated WFA product water at 65% RH is represented by a linear model in Figure 15 below. The linear regression was used to model the relationship between the concentrations of benzene in the water products (dependent

variable) and the concentrations of benzene in the air (explanatory variable). The linear regression relationship has an R^2 of 0.69 (Appendix A-Table A6) which shows that the data are moderately close to the fitted regression line.

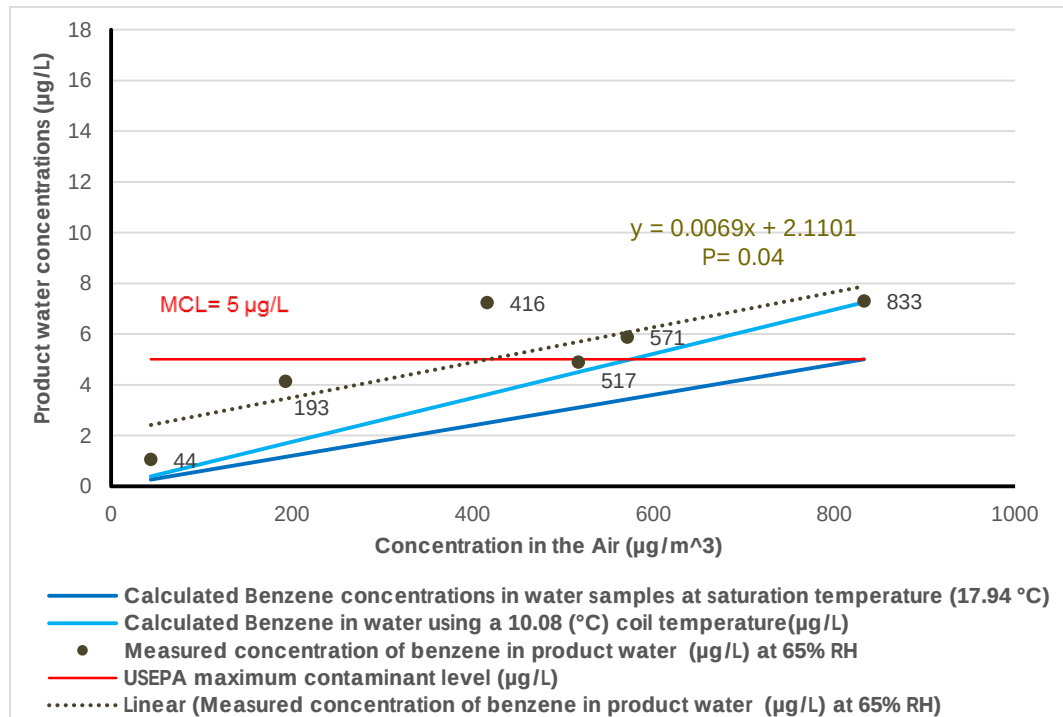


Figure 15. Benzene exposure at 65% RH

Henry's law coefficient was used to calculate and plot the predicted values of benzene concentrations in the product water using the saturation temperature (17.94°C) and the recorded coil temperature (10.08°C). Based on the linear regression equation and Figure 15, benzene concentrations in the product water are predicted to exceed the USEPA maximum contaminant limit (MCL) of 5 $\mu\text{g}/\text{L}$ when benzene air concentrations

in the chamber exceeded the threshold of $419 \mu\text{g}/\text{m}^3$ (industrial indoor environment) and were above their corresponding predicted values using both the coil and saturation temperatures. Additionally, the calculated benzene concentrations in the product water using Henry's law and either the coil or saturation temperature increased as temperature decreased.

Figure 16 below represents a linear regression relationship between the concentrations of benzene in the air and the concentrations of benzene in the product water without the suspected outlier value ($416 \mu\text{g}/\text{m}^3$ target concentration and its corresponding product water value of $7.24 \mu\text{g}/\text{L}$). The regression line has an R^2 equal to 0.89 (Appendix A-Table A7) which strongly validate the goodness of fit of the linear model. The suspected outlier is influential since the R^2 value has decreased substantially from 89% to 69%. If we include the outlier, we conclude that the relationship between y and x is only moderately strong, whereas if we exclude the red data point, we conclude that the relationship between y and x is strong. Finally, benzene concentrations in the product water exceeded the USEPA maximum contaminant limit (MCL) of $5 \mu\text{g}/\text{L}$ when benzene air concentrations in the chamber exceeded the threshold of $482 \mu\text{g}/\text{m}^3$ at 65 % RH in the absence of the suspected outlier (industrial indoor environment).

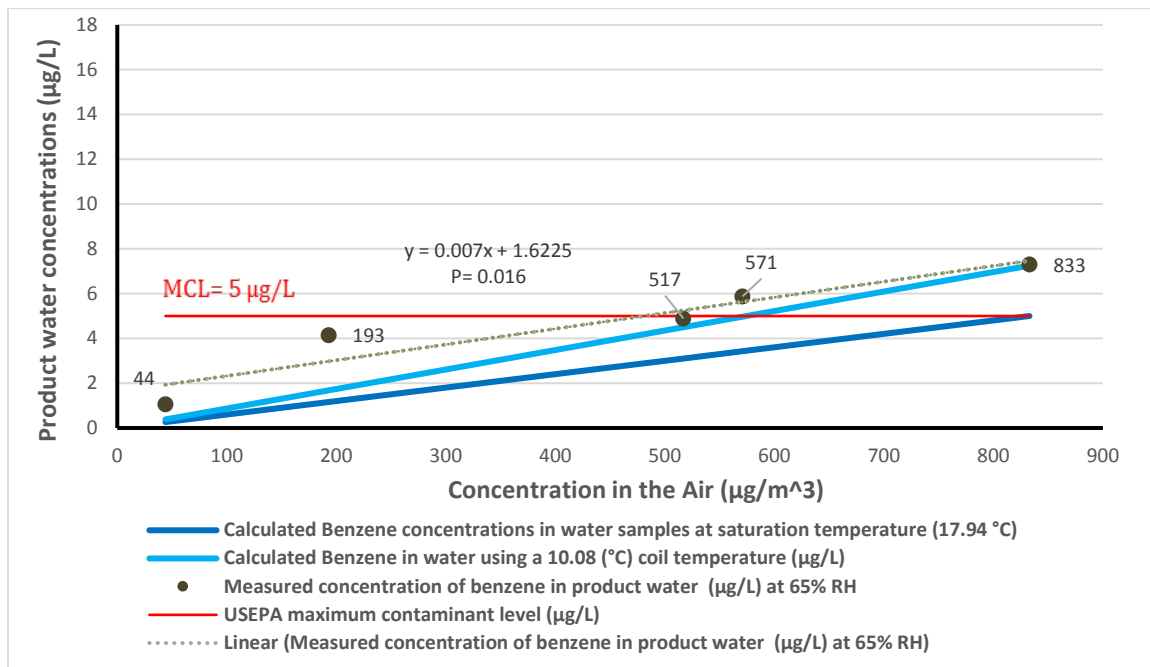


Figure 16. Benzene exposure without the suspected outlier at 65% RH

ANALYSIS OF BENZENE EXPOSURE AT BOTH RELATIVE HUMIDITIES (45% AND 65%)

Multiple linear regression with dummy variables was used to compare the concentrations of benzene in the water at 45 and 65% RH after one hour exposure to six different benzene concentrations in the air. The dependent variable consisted of the concentrations of benzene in the product water and the independent variables consisted of the relative humidity (45% and 65%), interaction between the concentrations of benzene in the air and relative humidity, and the concentrations of benzene in the air. The SPSS

results show that there is a relationship between the relative humidity and concentrations of benzene in the air and the concentrations of benzene in the product water (Appendix A-Table A8). Figure 17 below shows that at high concentrations of benzene in the air (indoor industrial environments), the measured benzene concentrations in the CWFA product water exceeded the MCL; also, exposure to low concentrations of benzene in the air (typical to outdoor environments) resulted in measured benzene concentrations in the CWFA product water below the MCL. Furthermore, Figure 12, 15, and 17 all show that the slope of the linear regression resulting from a benzene exposure at 45% RH is steeper than the one resulting from an exposure to benzene at 65% RH which indicates that the rate of transfer of benzene to the CWFA product water is higher at lower RH. In addition to enrichment factors such as direct condensation and wet deposition, lower relative humidity (45 % versus 65% RH) will result in lower coil temperature and an increased condensation of benzene on the coil. The resulting CWFA product water will have higher concentration of benzene, will be colder at 45% RH than at 65% RH, and will retain benzene longer before losing it to the ambient air due to the exposure to a warmer chamber's air temperature.

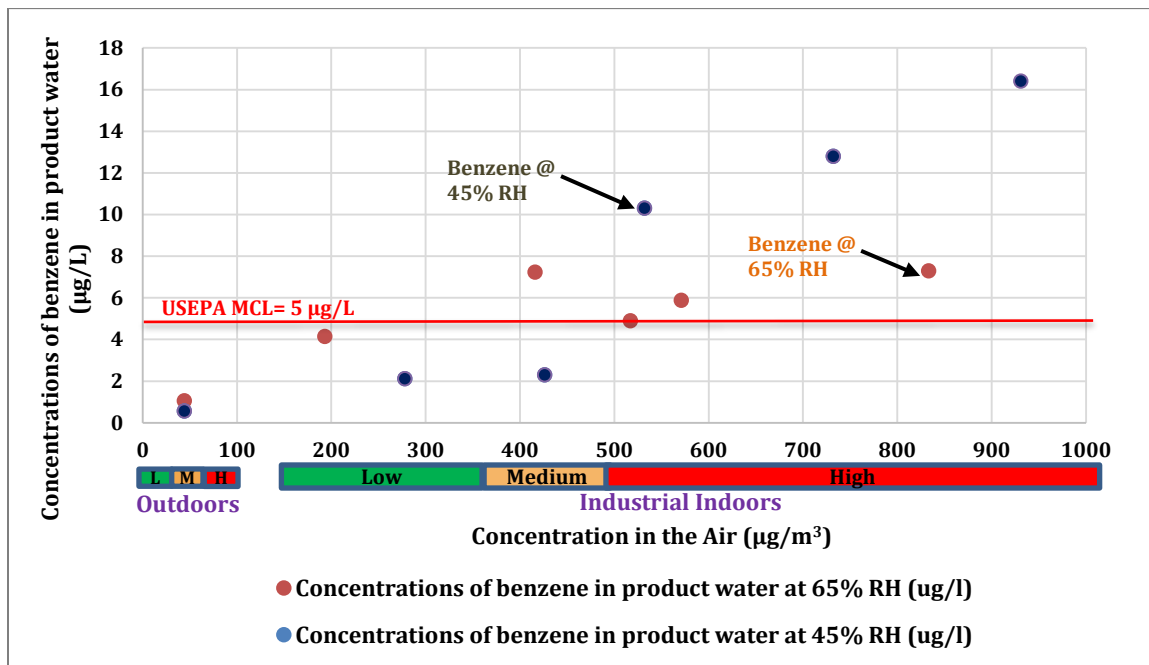


Figure 17. Results of benzene exposure at 45% and 65% RH

Table 13 below describes the amount of benzene in the air required to exceed the MCL at both relative humidities (45% and 65%). 322 ($\mu\text{g}/\text{m}^3$) and 419 ($\mu\text{g}/\text{m}^3$) are two conservative values chosen from Table 13 and adopted as the lowest air benzene concentrations necessary to exceed the MCL in the CWFA product water at 45% and 65% RH respectively. The table also shows that lower relative humidity (45%) requires less benzene in the air to exceed the MCL versus higher relative humidity (65%).

Table 13. Amounts of benzene in the air required to exceed the MCL at 45% and 65% RH

	Ambient of benzene concentration required to exceed the MCL ($\mu\text{g}/\text{m}^3$)	
	With the suspected outlier	Without the suspected outlier
45% Relative humidity	367	322
65% Relative humidity	419	482

Figure 18 below is a bar representation of the measured and calculated values of benzene in the CWFA product and control waters at 45% RH. The graph also shows a plus or minus 20% control limits value used by the testing laboratory for the U.S. EPA Method 524.2. A general analysis of the benzene in the CWFA product water in the figure reveals that exposure to low polluted outdoors environment resulted in low benzene concentrations in the CWFA product water while an exposure to high industrial indoors environment resulted in significantly higher amounts of benzene in the CWFA product water indicating the possibility of existence of a threshold benzene air concentration. The bar graph also shows that high industrial indoors benzene concentrations resulted in benzene concentrations in the CWFA product water above the MCL and almost double of the calculated concentrations. Additionally, at polluted

outdoors concentrations, the benzene concentrations in the CWFA product water were below the MCL and less than the calculated values. Finally, the results of the analysis of the control water samples were below detection limits except for those exposed to a high industrial indoors environment (the MDL is 0.13 ($\mu\text{g/L}$) and the PQL is 0.50 ($\mu\text{g/L}$)).

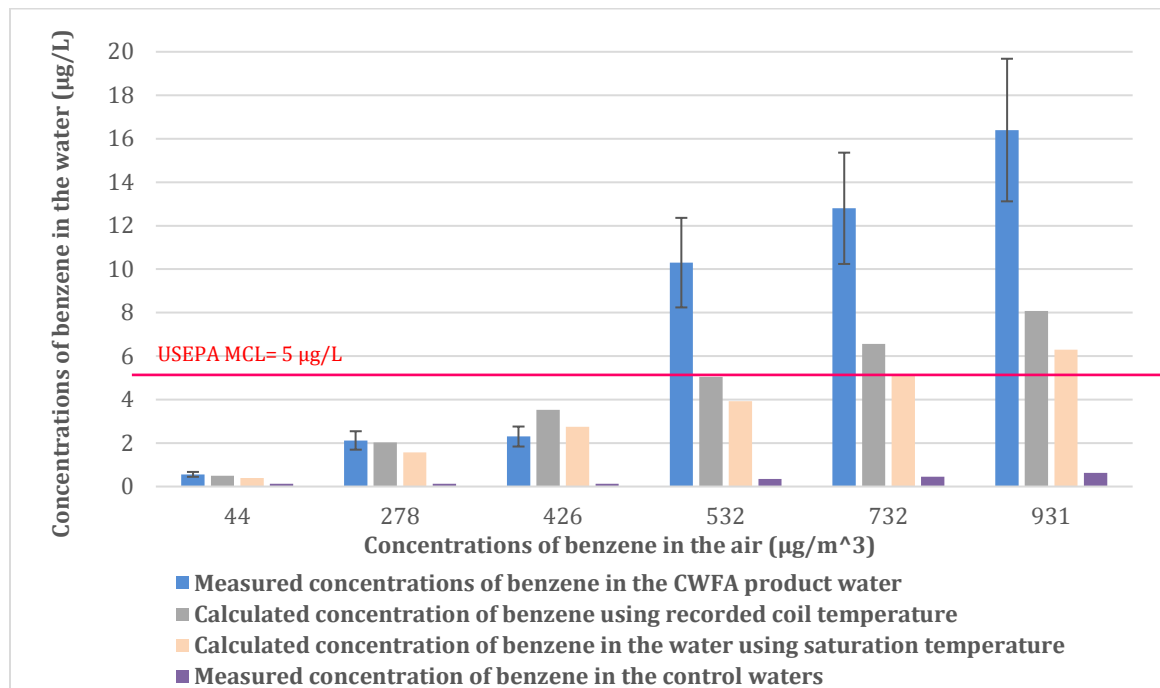


Figure 18. General overview of the measured and calculated values at 45% RH

Similarly to Figure 18, Figure 19 below is a bar representation of the measured and calculated values of benzene in the CWFA product and control waters at 65% RH and with a laboratory analysis error of 20%. The bar graph shows that exposure to a low polluted outdoors environment resulted in benzene concentrations in the CWFA product

water below the MCL but higher than those in the control water or the calculated values, while the exposure to a medium or high industrial indoors environment resulted in benzene concentrations in the CWFA product water above the MCL and almost equal to the calculated values using the coil temperature. Finally, all the results of the analysis of the control water samples were below detection limit (the MDL is 0.13 ($\mu\text{g/L}$) and the PQL is 0.50 ($\mu\text{g/L}$)).

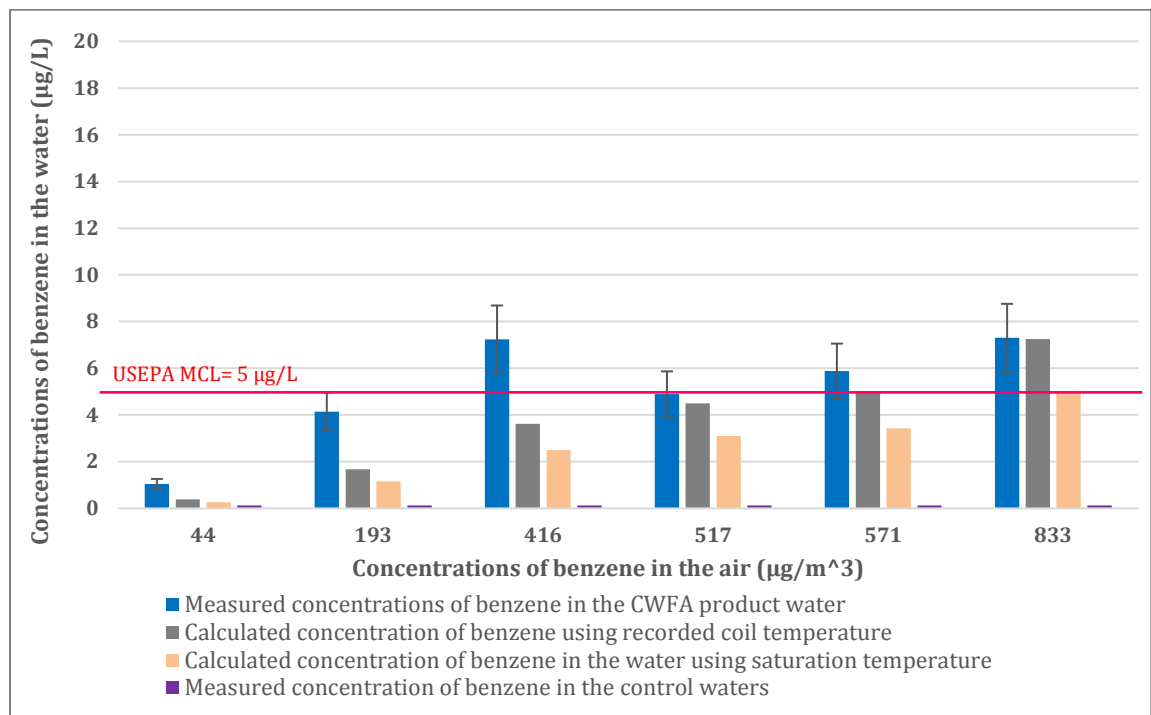


Figure 19. General overview of the measured and calculated values at 65% RH

EQUILIBRIUM STUDY

Henry's Law coefficient was used to estimate benzene concentrations in the control water at equilibrium since all that is required is air temperature, relative humidity and benzene vapor concentration. Table 14 below displays the calculated and measured concentrations of benzene in the control waters at 650 $\mu\text{g}/\text{m}^3$ and at both 45 and 65% RH. The time to equilibrium in this open system could not be estimated since the results were so far below the calculated values in a close system (3.43 $\mu\text{g}/\text{L}$ at 65 % RH and 5.75 $\mu\text{g}/\text{L}$ at 45% RH) and the distribution of the results showed a linear distribution which could be a part of any segment of the actual equilibrium curve.

Table 14. Results of the equilibrium study using 650 $\mu\text{g}/\text{m}^3$ as target value at 45% and 65 % RH (BDL or MDL=0.13 $\mu\text{g}/\text{L}$)

Six hour long experiment with samples collected at the end of:	Concentrations of benzene in the control water ($\mu\text{g}/\text{L}$)	
	45 % RH	65 % RH
First hour	<0.13 $\mu\text{g}/\text{L}$	<0.13 $\mu\text{g}/\text{L}$
Second hour	0.300	0.370
Third hour	0.400	0.510
Fourth hour	0.470	0.510
Fifth hour	0.680	0.670
Sixth hour	0.750	0.850

PERCENT OF BENZENE IN THE CWFA PRODUCT WATER:

At 25°C and after one hour-long sampling period, the CWFA system produces between 200 – 250 mL of water at 45 % RH and between 350 – 400 mL at 65% RH. The potential for benzene mass to transfer to the product water was calculated via the volume ratios between processed air and amount of condensed water, using equations from a previous study (13) (Appendix C). Table 15 below summarizes the percent of the total benzene mass passing through the CWFA system that was condensed from the air to product water.

Table 15. Summary of the percent of benzene in the product water during the modeling study (Appendix A-Table A3)

Relative humidity (%)	Coil Temperature (°C)	Air concentrations ($\mu\text{g}/\text{m}^3$)		Percent benzene in the product water (%)
		Target concentration	Actual average concentration	
45	7.19 ± 0.25	50	44	0.0023
	7.38 ± 0.22	200	277	0.0016
	7.28 ± 0.23	350	426	0.0011
	6.43 ± 0.40	500	531	0.0036
	7.69 ± 0.34	650	732	0.0036
	6.78 ± 0.42	800	931	0.0036
65	10.13 ± 0.15	50	44	0.0082
	10.11 ± 0.18	200	193	0.0079
	10.03 ± 0.15	350	416	0.0060
	10.47 ± 0.14	500	517	0.0035
	9.80 ± 0.12	650	571	0.0035
	9.96 ± 0.14	800	833	0.0032

The results of the percent benzene in the product water calculated in the Kinder et al. study (13) at the following air concentrations $106 \mu\text{g}/\text{m}^3$ and $768 \mu\text{g}/\text{m}^3$ are in the same order of magnitude (10^{-3}) as the results of the current study at 45% RH. Table 15 also indicates that high benzene vapor concentrations at 45% RH had a larger percentage of benzene condensed compared to the low benzene vapor concentration, which is

consistent with the fact that industrial direct condensation works best with high vapor concentrations (5,000 ppm) (12). Direct condensation consists of lowering the temperature of the coil to capture benzene by decreasing the temperature of the gas mixture, thus decreasing the saturation capacity of the air and inducing the condensation of benzene into liquid droplets either onto the coil or into the product water (11; 27). Another possible explanation could be the adsorption of benzene directly to the air-water interface made of water droplets formed by cooling air to the saturation temperature. After formation, the droplets will eventually coalesce, and form a semi continuous film with a free energy water-air interface favorable to the adsorption of the molecules of benzene (30). The large surface covered by the thin film layer of water accelerates the adsorption rate of benzene and decreases the amount of time necessary to reach equilibrium. If the adsorption of benzene to the thin film is coupled with a direct condensation of benzene on the coil, the resulting CWFA product water will be supersaturated. A cold CWFA product water with benzene concentrations exceeding saturation will eventually return to the equilibrium state once in the product water container as it warms. This will depend on the time of exposure, temperature of the produced water versus air temperature, and the volume of CWFA product water. One more potential explanation could be the occurrence of a wet deposition where benzene is dissolved into the water vapor before being pulled by the CWFA machine to undergo a

condensation on the coil (19). At the same air concentration of benzene in the chamber, the 65% RH would have a greater wet deposition when compared to 45 % RH due to the higher water content in the chamber and increased possibility for benzene molecules to dissolve in the water vapor.

Table 15 also shows that at lower air concentrations, the average percent of benzene condensing at 65 % RH was higher than the average percent at 45 % RH which could be explained by the fact that the mass of benzene in the water is higher at 65% RH than at 45% RH during an exposure to the same air benzene concentration. the contribution of a multitude of factors in addition to the already mentioned industrial condensation such as the increased adsorption of benzene to the water interface especially at 65% RH where droplets formation and coalescence is higher than at 45% RH, the increased wet deposition due to an elevated water vapor in the chamber at 65% RH resulting in higher dissolution of the benzene molecules in the water vapor, a direct wet deposition where water vapor with dissolved benzene is deposited directly into the product water without interacting with the CWFA machine.

CHAPTER 4: CONCLUSION

CWFA technology can be a useful source of drinking water, especially for small military units deploying to remote areas while seeking logistical decentralization.

However, insufficient information is available to determine the relationship between the quality of the ambient air and the CWFA product water to conduct an appropriate health risk assessment.

The purpose of this research is to study the impact of relative humidity and airborne benzene concentrations on Condensation Water from Air product water given specific conditions. Six benzene concentrations typical to industrial indoor and polluted outdoor environments were injected into an inhalation exposure chamber (1 m^3) at a steady temperature (25°C) and at two relative humidities (45 % and 65%). Air and water samples were collected and analyzed for benzene. The following Hypothesis: *“the relationship between the concentrations of benzene in the ambient air and those transferred to the untreated WFA product water will follow a linear model”* summarizes the methodology used to explore the relationship between untreated CWFA product water, benzene air concentration, and relative humidity. The results of the study supports the hypothesis of a linear regression model between the concentrations of benzene in the ambient air and the measured concentrations of benzene in the CWFA product water.

The results of this research indicate that the CWFA product water will have a higher benzene concentrations at the lower RH when exposed to high industrial indoors environment. Also, the exposure to a medium or highly polluted indoor environment (Table 3) at 45% RH resulted in benzene concentrations in the CWFA product water higher than the MCL and the calculated values. Other enrichment factors could be involved in the increase in benzene concentrations such as direct condensation of benzene on the coil, wet deposition, direct we deposition, and adsorption of benzene on the air-water interface of the formed film on the coil. This study also found that the exposure to benzene air concentrations typical to highly polluted industrial indoor environments (Table 3) at 65% RH resulted in benzene concentrations in the product water almost equal to the calculated concentrations using the coil temperature.

Furthermore, this research analyzed the combined results of both relative humidities (45 and 65% RH) and found that an exposure to benzene vapor concentrations typical to a highly polluted outdoor environment resulted in benzene concentrations in the product water below the MCL whereas an exposure to benzene vapor concentrations typical to highly polluted indoor industrial environment resulted in benzene concentrations in the product water exceeding the MCL (Table 3). In addition, the results of the study show that higher relative humidity (65%) requires more benzene in the air to exceed the MCL when compared to lower relative humidity (45%).

Based on the results of this study, it is predicted that benzene concentrations in the CWFA product water will exceed the MCL in the CWFA product water once air benzene concentrations exceed 322 ($\mu\text{g}/\text{m}^3$) and 419 ($\mu\text{g}/\text{m}^3$) at 45% and 65% RH respectively. The findings also indicate that both relative humidity and air quality could impact the quality of the CWFA product water which could be mitigated by choosing the right water treatment modules, the best operating environment, and the appropriate maintenance schedule. The results of this study will assist in assessing the untreated CWFA product water health risks and prevent potential health risk exposures subsequent to the ingestion of contaminated drinking water by service members.

ASSUMPTIONS/LIMITATIONS

Achieving and monitoring the target air concentrations of benzene inside the environmental chamber was one of the limitations of this study. The FTIR instrument was not functioning properly and did not provide accurate readings of benzene concentrations in the air due to both relative humidity and the low target concentrations of benzene used in this experiment. Water vapor masked the absorbance band of benzene and hindered the FTIR machine from accurately reading the spectral band specific to the benzene molecule during the exposure. The PID results were also inaccurate due to a malfunction of the instrument and showed inconsistent readings due to the accumulation of organic deposits or buildup of film on the surface of the lamp and

the quenching effect of the water vapor. The theoretical concentrations measured from the post study are representative of 10 minutes only of sampling time and cannot guarantee that benzene was generated and maintained during the experiment at the desired concentration at all times. Also, the post-study verification of the benzene concentrations inside the chamber was conducted at environmental conditions that were slightly lower than the study conditions (4% RH and 5 °C less) which could have impacted the readings of the Total Hydrocarbon Analyzer readings. In addition, the standard deviations of the THA results at 65% RH had a higher variation at three benzene air concentrations.

Another limitation of this study is the absence of sampling ports or hand inserts in the H1000 chamber to properly and safely perform the needed water sampling. The makeshift sampling window cut in the lower half of the Plexiglas door could have also compromised the seal of the chamber despite the slightly negative pressure maintained throughout the experiment. Also, during the preparatory phase of the experiment, it was noticed that the production cycle of the machine consisted of 94 minutes of continuous operation followed by a standby mode for about 30 minutes, therefore the initial sampling design to find the length of time required for the control waters to reach equilibrium was modified by turning off the CWFA machine. Finally, this study tested

only one CWFA machine with a specific coil design and work efficiency which is not representative of all the CWFA systems.

FUTURE RESEARCH

More studies are needed to investigate the enrichment factors, repeatability of this experiment with other CWFAs, and the behavior of other VOCs/SVOCs under the same conditions.

- Enrichment factors: the fact that benzene concentrations in the CWFA product water exceeded the calculated values using Henry's law suggest the existence of potential enrichment factors responsible for the significant increase such as direct condensation of benzene on the coil, wet deposition, direct we deposition, and adsorption of benzene on the air-water interface of the formed film on the coil. To better understand the mechanism of the enrichment factors, it would be valuable to isolate only the coil component of the CWFA machine inside a small controlled chamber and repeat the same experiment at the same environmental conditions.
- Behavior of other WFA systems: a similar study could be conducted using a desiccant WFA (DWFA) system to understand and compare the impact of the relative humidity and air benzene concentrations on the DWFA product water.
- Interaction of other VOCs/SVOCs with the CWFA machine: Both this study and Kinder et al.(13) were limited to benzene but further investigation is needed to

understand how other VOCs/SVOCs would transfer to the CWFA product water.

Another suitable VOC is toluene, which is commonly found in the environment, has an EPA chronic oral reference dose of 0.08 mg/kg/day, has a high vapor pressure and low to moderate water solubility, and is safer to use in laboratory experiments in comparison to benzene.

REFERENCES

1. AquaBoy Products. *FAQ*.
<http://www.atmosphericwatergenerator.net/faq/>. Accessed 04 October, 2016.
2. Army Capabilities Integration Center. 2014. Army Vision-Force 2025 White Paper.
http://www.arcic.army.mil/app_Documents/USArmy_WhitePaper_Army-Vision-Force-2025_23JAN2014.pdf
3. ATSDR. 2007. *Toxic Substances Portal-Benzene*.
<http://www.atsdr.cdc.gov/toxprofiles/tp.asp?id=40&tid=14>. Accessed 10 September, 2016.
4. Bautista-Olivas AL, Tovar-Salinas JL, Mancilla-Villa OR, Flores-Magdaleno H, Ramirez-Ayala C, et al. 2014. Trace metals concentration in condensed water from the atmospheric humidity in the valley of Mexico. *Interciencia* 39 (4): 234.
http://www.medsci.cn/Sci/show_paper.asp?id=62459244926
5. DES. 2013. *Benzene: Health Information Summary*.
<http://des.nh.gov/organization/commissioner/pip/factsheets/ard/documents/ard-ehp-3.pdf>.
6. EPA. 1996. Soil Screening Guidance: Technical Background Document.
<http://www.epa.gov/superfund/health/conmedia/soil/toc.htm#p1>.
7. Fast Company. 2016. World's 50 most innovative companies 2014.
<http://www.fastcompany.com/most-innovative-companies/2014/water-gen>
8. Gabler R, Petersen J, Trapasso L. 2006. *Essentials of Physical Geography*. Cengage Learning.
<https://books.google.com/books?id=cQBh93ibpscC>
9. Gandhidasan P, Abualhamayel HL. 2009. Investigation of humidity harvest as an alternative water source in the Kingdom of Saudi Arabia. *Water and Environment* 24:282-92.
<http://onlinelibrary.wiley.com.lrc1.usuhs.edu/doi/10.1111/j.1747-6593.2009.00189.x/full>
10. Jenicek EM, Myers NRD, Nemeth SB. 2011. Army Overseas Water Sustainability Study, US Army Corps of Engineers-Engineer Research and Development Center.

- http://www.aepi.army.mil/docs/whatsnew/ERDC-CERL_TR-11-15.pdf
11. Karl BS, Brown AC. 2001. Control of VOC and HAP by Condensation. In *Air Pollution Control Technology Handbook*:1-17: CRC Press. Number of 1-17 pp.
<http://www.crcnetbase.com/doi/abs/10.1201/9781420036435.ch14>
 12. Khan FI, Kr. Ghoshal A. 2000. Removal of Volatile Organic Compounds from polluted air. *Journal of Loss Prevention in the Process Industries* 13:527-45.
<http://www.sciencedirect.com/science/article/pii/S0950423000000073>
 13. Kinder KM, Gellasch CA, Dusenbury JS, Timmes TC, Hughes TM. 2017. Evaluating the impact of ambient benzene vapor concentrations on product water from Condensation Water From Air technology. *Sci Total Environ* 590-591:60-8.
<http://www.ncbi.nlm.nih.gov/pubmed/28288421>
 14. Loveless KJ, Farooq A, Ghaffour N. 2012. Collection of Condensate Water: Global Potential and Water Quality Impacts. *Water Resources Management* 27:1351-61.
<http://link.springer.com/article/10.1007%2Fs11269-012-0241-8>
 15. Mahvi A, Alipour V, Rezaei. 2013. Atmospheric moisture condensation to water recovery by home air conditioners. *American Journal of Applied Sciences*.
<http://thescipub.com/PDF/ajassp.2013.917.923.pdf>
 16. Maryland Department of the Environment. 2007. *BTEX*.
http://www.mde.state.md.us/assets/document/OilControl/Fact_Sheet_BTEX.pdf. Accessed 04 October 2016, 2016.
 17. Master GM, Ela WP. 2008. *Introduction to Environmental Engineering and Science*. Pearson.
 18. Mohan L, Posner A, Postel S, Treiber T, Covitt B, et al. 2012. *Earth's Freshwater*. <http://nationalgeographic.org/media/earths-fresh-water/>.
 19. National Oceanic and Atmospheric Administration. 2016. *Wet Deposition*.
http://ready.arl.noaa.gov/documents/Tutorial/html/chem_wet.html.
 20. NOAA. 2009. *National Weather Service*.
<http://w1.weather.gov/glossary/index.php?word=dew+point>.

21. PubChem Compound Database. 2016. *National Center for Biotechnology Information*.
<https://pubchem.ncbi.nlm.nih.gov/compound/241>.
22. Rajao G, Schwartz M. 2014. This machine makes drinking water from thin air. *CNN* Thu April 24, 2014 <http://www.cnn.com/2014/04/24/tech/innovation/machine-makes-drinking-water-from-air/>
23. Sander R. 2015. Compilation of Henry's law constants (version 4.0) for water as solvent. *Atmospheric Chemistry and Physics* 15:4399-981. <http://www.atmos-chem-phys.net/15/4399/2015/>
24. Shareef SG, Barbour JW, Lynch KS, Pelt WR. 1995. *Refrigerated Condensers*. <https://www3.epa.gov/ttnecat1/dir1/cs3-1ch2.pdf>. Accessed 04 Dec 16, 2016.
25. Smith LF, Harvey HA. 2007. Avoid Common Pitfalls When Using Henry's Law. *Environmental Management*
http://ws680.nist.gov/publication/get_pdf.cfm?pub_id=50449
26. Study.com. *What is Benzene?- Uses, Structure & Formula*.
<http://study.com/academy/lesson/what-is-benzene-uses-structure-formula.html>. Accessed 04 October 2016, 2016.
27. Trembley J, Beteta O. 2014. *Using Cryogenic Condensation*.
<http://www.airproducts.com/~media/downloads/article/U/using-cryogenic-condensation-to-control-organic-solvent-vapor-emissions.pdf>. Accessed 04 Dec 16, 2016.
28. United Nations. 2014. *International Decade for Action 'Water For Life' 2005-2015-Water Scarcity*.
<http://www.un.org/waterforlifedecade/scarcity.shtml>.
29. United States Department of Labor-Occupational Safety and Health Administration. 2017. *OSHA Technical Manual*.
https://www.osha.gov/dts/osta/otm/otm_ii/otm_ii_3.html#PIDs.
30. Valsaraj KT. 2009. Trace gas adsorption thermodynamics at the air-water interface: Implications in atmospheric chemistry. *Pure and Applied Chemistry* 81.
<https://www.degruyter.com/view/j/pac.2009.81.issue-10/pac-con-08-07-06/pac-con-08-07-06.xml>
31. Wahlgren RV. 2001. Atmospheric water vapour processor designs for potable water production: a review. *Water Res* 35:1-22.
<http://www.ncbi.nlm.nih.gov/pubmed/11257862>

32. Walton B. 2015. WaterNews-World Economic Forum Ranks Water Crises as Top Global Risk. *Circle of blue*.
<http://www.circleofblue.org/2015/world/world-economic-forum-ranks-water-crises-as-top-global-risk/>
33. Water.Org. 2016. *Global Water Crisis: Water And Sanitation Facts*. <http://water.org/water-crisis/water-sanitation-facts/>.

APPENDIX A- SPSS CALCULATIONS

Table A-1. SPSS Descriptive statistics at 65% RH

Descriptive Statistics

	N	Range	Minimum	Maximum	Mean		Std. Deviation	Variance
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic
Chamber Humidity (Mean)	551	6.145661379	61.28016346	67.42582484	64.56598789	.0498585900	1.170350087	1.370
Chamber Temp (Mean)	551	.7406559271	24.69850590	25.43916183	25.05433431	.0060175760	.1412529045	.020
Static Pressure (Mean)	551	.2504091857	-.246068526	.0043406596	-.037802059	.0012001914	.0281725596	.001
Room Relative Humidity (Mean)	551	23.05378341	39.48353724	62.53732065	46.66771384	.3303542468	7.754533805	60.133
Room Temperature (Mean)	551	5.229086060	18.64298108	23.87206714	22.15264328	.0694909935	1.631189136	2.661
Valid N (listwise)	551							

Table A-2. SPSS: Descriptive statistics at 45% RH

Descriptive Statistics

	N	Range	Minimum	Maximum	Mean		Std. Deviation	Variance
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic
Chamber Humidity (Mean)	554	6.393404767	42.00996412	48.40336889	44.78706099	.0380664968	.8959789238	.803
Chamber Temp (Mean)	554	1.021343560	24.47572917	25.49707273	25.03562040	.0074761027	.1759665595	.031
Static Pressure (Mean)	554	.1816410046	-.168471100	.0131699049	-.045983377	.0012222333	.0287679547	.001
Room Relative Humidity (Mean)	554	20.66987241	40.12691760	60.79679000	51.73796702	.3209298389	7.553791278	57.060
Room Temperature (Mean)	554	5.254154409	18.31636363	23.57051804	21.26054723	.0655781452	1.543526221	2.382
Valid N (listwise)	554							

Table A-3. Temperatures of the coil at the following target benzene concentrations: 50, 200, 350, 500, 650, and 800 starting with 45% RH then 65% RH

Descriptive Statistics

	N	Minimum	Maximum	Mean		Std. Deviation
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic
VAR00001-50-45	31	6.68	7.62	7.1979	.04549	.25329
VAR00002-200-45	31	6.86	7.80	7.3837	.03941	.21944
VAR00003-350-45	31	7.01	7.85	7.2885	.04080	.22714
VAR00004-500-45	31	5.90	7.29	6.4262	.07266	.40457
VAR00005-650-45	31	7.08	8.33	7.6923	.06034	.33597
VAR00006-800-45	31	6.24	7.64	6.7770	.07596	.42292
VAR00007	0					
VAR00008-50-65	31	9.81	10.41	10.1287	.02707	.15071
VAR00009-200-65	31	9.81	10.48	10.1158	.03220	.17930
VAR00010-350-65	31	9.61	10.33	10.0268	.02718	.15134
VAR00011-500-65	31	10.14	10.75	10.4739	.02560	.14254
VAR00012-650-65	31	9.57	10.02	9.8004	.02188	.12184
VAR00013-800-65	31	9.71	10.16	9.9587	.02460	.13699
Valid N (listwise)	0					

Table A-4. SPSS calculations for the modeling at 45% RH

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.942 ^a	.888	.860	2.479

Coefficients^a

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-2.228	1.990		-1.120	.325
	Benzene_in_air	.020	.003	.942	5.629	.005

Table A-5. SPSS calculations for the modeling at 45% RH without the suspected outlier

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.982 ^a	.965	.953	1.483

a. Predictors: (Constant), AIR_45_OUTLIER

Coefficients^a

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-1.159	1.248		-.928	.422
	AIR_45_OUTLIER	.019	.002	.982	9.075	.003

Table A-6. SPSS calculations for the modeling at 65% RH

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.832 ^a	.693	.616	1.45010

Coefficients^a

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.110	1.153		1.830	.141
	Concentrations_in_air_65	.007	.002	.832	3.005	.040

a. Dependent Variable: Concentrations_in_product_water_65

Table A-7. SPSS calculations for the modeling at 65% RH without the suspected outlier

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.945 ^a	.892	.856	.88515

Coefficients^a

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.622	.725		2.237	.111
	Concentraions_in_air_65_w ithout_outlier	.007	.001	.945	4.984	.016

a. Dependent Variable: Concentrations_in_product_water_65_without_outlier

Table A-8. SPSS calculations: multiple regression with dummy variables to compare 65 and 45% RH

Model	R		R Square	Adjusted R Square	Std. Error of the Estimate
1	.979 ^a		.959	.944	1.16091

Coefficients^a

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.481	.880		2.821	.022
	Concentrations_in_air_45_MR	.006	.002	.357	3.511	.008
	RH	-3.425	1.005	-.366	-3.407	.009
	Interaction	.726	.111	.878	6.568	.000

APPENDIX B- FTIR SUPPLEMENTARY MATERIAL

Table B-1. FTIR results for benzene exposure at 45% relative humidity

Target Concern ($\mu\text{g}/\text{m}^3$)	Exposure Duration (Hours)	PP Dryer (inch)	Benzene exposure readings ($\mu\text{g}/\text{m}^3$)	Post-exposure Readings (No benzene generation) ($\mu\text{g}/\text{m}^3$)
50	1	0	27	-101
200	-1	0	44	-82
350	1	12	147	227
500	1	12	164	293
650	1	12	143	214
800	1	12	157	265
50	6	0	77	-43
650	6	24	80	343

Table B-2. FTIR results for benzene exposure at 65% relative humidity

Target Concern	Exposure Duration	PP Dryer (inch)	Benzene exposure readings ($\mu\text{g}/\text{m}^3$)	Post-exposure Readings (No benzene generation)
50	1	24	84	398
200	1	24	109	739
350	1	24	108	730
500	1	24	119	876
650	1	24	37	-258
800	1	24	112	780
50	6	0	39	-86
650	6	0	192	90

APPENDIX C- PERCENT BENZENE CALCULATIONS FOR TABLE 15

The mass of air benzene (M_a) (μg) pulled through the CWFA system and the mass of benzene in the product water (M_w) (μg) at the end of each one-hour sampling period was calculated using equation 5 and 6 below respectively:

$$M_a = V_a \times C_a \quad (5)$$

$$M_w = V_w \times C_w \quad (6)$$

Where:

V_a = Volume of air (per sample period) processed through the CWFA system (m^3)
= 109 m^3 /Hour of sampling

C_a = Mean concentration of benzene in the air ($\mu\text{g}/\text{m}^3$).

V_w = Mean volume of water produced per test condition (L).

The percentage of benzene mass (P_b) in the air that transfers to the product water during each sampling period was calculated given equation 7.

$$P_b = \frac{M_w}{M_a} \times 100\% \quad (7)$$

APPENDIX D- DETERMINATION OF NOMINAL BENZENE HEAD SPACE CONCENTRATION INSIDE PRESSURE VESSEL

1. Determine the Volume of Benzene in PV (VBPV):

$$VBPV\ L = \frac{\text{Injection mL} \times \text{Density } \frac{g}{mL}}{\text{Gram Molecular Weight } \frac{g}{mol}} \times \text{Molar Volume } \frac{L}{mol}$$

2. Determine the Concentration of Benzene in PV (CBPV) under ambient conditions (14.7 psi):

$$CBPV\ ppm = \frac{VBPV\ L}{PV\ Volume\ L} \times 1,000,000$$

3. Add compressed air to increase the PV volume:

$$\text{New PV Volume } L = \left(\frac{\text{New PV Pressure psi} + 14.7\ psi}{14.7\ psi} \right) \times PV\ Volume\ L$$

4. Determine Final Concentration of Benzene in PV (FCBPV) under pressurized conditions:

$$FCBPV\ ppm = \frac{VBPV\ L}{\text{New PV Volume } L} \times 1,000,000$$

APPENDIX E- CALCULATION OF THE FLOW RATE FOR KNOWN AIR CHANGES PER HOUR

$$\text{Flow rate (L/min)} = \frac{\text{Target air changes}}{\text{Hour}} \times \frac{\text{Volume of H1000 (1000 liters)}}{\text{Sampling period (60 mns)}}$$

See example below:

$$\frac{10 \text{ AC}}{\text{Hour}} \times 1000 \text{ liters} / 60 \text{ min} = 167 (\text{L/min})$$

APPENDIX F- LABORATORY RESULTS (PAGES: 98-191)



Tuesday, January 24, 2017

Analytical Results

Karim Elyamani

Naval Medical Research Unit-Dayton
2729 R Street, Building 837, Area B
Wright-Patterson AFB, OH 45433

TEL: (937) 904-9460

FAX

RE: USUHS-WFA Project

Work Order: 16H0908

PACE Analytical received 38 sample(s) on 8/11/2016 for the analyses presented in the following report.

PACE Analytical attests that all analytical methods were performed using acceptable methods, and that the QA/QC procedures stipulated in these methods were followed. This report shall not be reproduced except in full. All samples are reported on a dry-weight basis unless otherwise stated.

If you have any questions regarding the test results, please feel free to call me at (937) 832-8242.

Respectfully submitted,

Alison Hudson

Client Services Manager

25 Holiday Drive * Englewood, Ohio 45322 * 1.937.832.8242 * 1.937.832.2868 Fax

Certifications: NELAP/NELAC - #04130 VAP - #CL0032 OEPA DW - #872 KDEP WW - #98039

931 Dudley Road * Edgewood, Kentucky 41017 * 1.859.341.9989 * 1.937.832.2868 Fax

Certifications: KDEP WW- #00053 KDEP DW- #00053

CLIENT: Naval Medical Research Unit-Dayton
 Project: USUHS-WFA Project

Lab Order: 16H0908

Work Order Sample Summary

The results of analyses performed on the following samples submitted to Pace Analytical Dayton are found in this report.

Field Sample ID	Lab ID	Matrix	Method Reference	Subcontract Lab
45-6-8-C1-50	16H0908-01	Water	EPA 524.2	
45-6-8-C2-50	16H0908-02	Water	EPA 524.2	
45-6-8-C3-50	16H0908-03	Water	EPA 524.2	
45-6-8-C4-50	16H0908-04	Water	EPA 524.2	
45-6-8-C5-50	16H0908-05	Water	EPA 524.2	
45-6-8-C6-50	16H0908-06	Water	EPA 524.2	
45-6-8-FB1-50	16H0908-07	Water	EPA 524.2	
65-7-8-C1-50	16H0908-08	Water	EPA 524.2	
65-7-8-C2-50	16H0908-09	Water	EPA 524.2	
65-7-8-C3-50	16H0908-10	Water	EPA 524.2	
65-7-8-C4-50	16H0908-11	Water	EPA 524.2	
65-7-8-C5-50	16H0908-12	Water	EPA 524.2	
65-7-8-C6-50	16H0908-13	Water	EPA 524.2	
65-7-8-FB1-50	16H0908-14	Water	EPA 524.2	
65-8-8-C1-650	16H0908-15	Water	EPA 524.2	
65-8-8-C2-650	16H0908-16	Water	EPA 524.2	
65-8-8-C3-650	16H0908-17	Water	EPA 524.2	
65-8-8-C4-650	16H0908-18	Water	EPA 524.2	
65-8-8-C5-650	16H0908-19	Water	EPA 524.2	
65-8-8-C6-650	16H0908-20	Water	EPA 524.2	
65-8-8-FB1-650	16H0908-21	Water	EPA 524.2	
45-9-8-P1-50-Aqua	16H0908-22	Water	EPA 524.2	
45-9-8-C1-50-Aqua	16H0908-23	Water	EPA 524.2	
45-9-8-P1-200-Aqua	16H0908-24	Water	EPA 524.2	
45-9-8-C1-200-Aqua	16H0908-25	Water	EPA 524.2	
45-9-8-P1-350-Aqua	16H0908-26	Water	EPA 524.2	
45-9-8-C1-350-Aqua	16H0908-27	Water	EPA 524.2	
45-9-8-P2-350-Aqua	16H0908-28	Water	EPA 524.2	
45-9-8-C2-350-Aqua	16H0908-29	Water	EPA 524.2	

CLIENT: Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project

Lab Order: 16H0908

Work Order Sample Summary

The results of analyses performed on the following samples submitted to Pace Analytical Dayton are found in this report.

Field Sample ID	Lab ID	Matrix	Method Reference	Subcontract Lab
45-9-8-FB-Aqua	16H0908-30	Water	EPA 524.2	
45-10-8-P1-500-Aqua	16H0908-31	Water	EPA 524.2	
45-10-8-C1-500-Aqua	16H0908-32	Water	EPA 524.2	
45-10-8-P1-650-Aqua	16H0908-33	Water	EPA 524.2	
45-10-8-C1-650-Aqua	16H0908-34	Water	EPA 524.2	
45-10-8-P1-800-Aqua	16H0908-35	Water	EPA 524.2	
45-10-8-C1-800-Aqua	16H0908-36	Water	EPA 524.2	
45-10-8-FB-Aqua	16H0908-37	Water	EPA 524.2	
Trip Blank [45-6-8-TB-50]	16H0908-38	Water	EPA 524.2	

CASE NARRATIVE:

This report is being revised to update analysis on samples 16H0908-07, -18, -20 and -31. The original data was not correctly uploaded into Element. In addition, This report is being revised to generate J-values, if applicable, for detections below the Practical Quantification Limit (PQL) and the Method Detection Limit (MDL). MDL values represent a statistical calculation of the point at which the analyte can be said to be present at an amount greater than zero for this analysis. While values between the MDL and the PQL should not generally be considered reliable enough for regulatory purposes they may provide useful information for experimental purposes.

PACE Analytical**Date:** 1/24/2017**CLIENT:** Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project**Lab Order:** 16H0908**Lab ID:** 16H0908-01
Client Sample ID: 45-6-8-C1-50**Collection Date:** 8/6/2016 1:31:00PM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
VOC 524.2		EPA 524.2						Analyst: NKK	
Benzene	BDL	0.130	0.500		ug/L	1	1634116	8/15/2016 8:56:00AM	8/15/2016 1:51:00PM

Date: 1/24/2017

Lab Order: 16H0908

Collection Date: 8/6/2016 2:30:00PM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
VOC 524.2		EPA 524.2						Analyst: NKK	
Benzene	BDL	0.130	0.500		ug/L	1	1634116	8/15/2016 8:56:00AM	8/15/2016 2:11:00PM

Date: 1/24/2017

Lab Order: 16H0908

Collection Date: 8/6/2016 3:24:00PM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
VOC 524.2		EPA 524.2						Analyst: NKK	
Benzene	BDL	0.130	0.500		ug/L	1	1634116	8/15/2016 8:56:00AM	8/15/2016 2:30:00PM

PACE Analytical**Date:** 1/24/2017**CLIENT:** Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project**Lab Order:** 16H0908**Lab ID:** 16H0908-04
Client Sample ID: 45-6-8-C4-50**Collection Date:** 8/6/2016 4:29:00PM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
VOC 524.2									
		EPA 524.2						Analyst: NKK	
Benzene	BDL	0.130	0.500		ug/L	1	1634116	8/15/2016 8:56:00AM	8/15/2016 2:50:00PM

PACE Analytical**Date:** 1/24/2017**CLIENT:** Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project**Lab Order:** 16H0908**Lab ID:** 16H0908-05
Client Sample ID: 45-6-8-C5-50**Collection Date:** 8/6/2016 5:29:00PM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
VOC 524.2		EPA 524.2						Analyst: NKK	
Benzene	BDL	0.130	0.500		ug/L	1	1634116	8/15/2016 8:56:00AM	8/15/2016 3:09:00PM

CLIENT: Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project

Lab Order: 16H0908

Lab ID: 16H0908-06
Client Sample ID: 45-6-8-C6-50

Collection Date: 8/6/2016 6:29:00PM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
VOC 524.2		EPA 524.2						Analyst: NKK	
Benzene	BDL	0.130	0.500		ug/L	1	1634116	8/15/2016 8:56:00AM	8/15/2016 3:28:00PM

PACE Analytical**Date:** 1/24/2017**CLIENT:** Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project**Lab Order:** 16H0908**Lab ID:** 16H0908-07
Client Sample ID: 45-6-8-FB1-50**Collection Date:** 8/6/2016 6:29:00PM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
VOC 524.2		EPA 524.2						Analyst: NKK	
Benzene	BDL	0.130	0.500	.	ug/L	1	1634032	8/12/2016 11:00:00AM	8/12/2016 11:18:00PM

PACE Analytical**Date:** 1/24/2017**CLIENT:** Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project**Lab Order:** 16H0908**Lab ID:** 16H0908-08
Client Sample ID: 65-7-8-C1-50**Collection Date:** 8/7/2016 2:20:00PM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
VOC 524.2			EPA 524.2						
Benzene	BDL	0.130	0.500		ug/L	1	1634116	8/15/2016 8:56:00AM	8/15/2016 3:48:00PM

Analyst: NKK

PACE Analytical**Date:** 1/24/2017**CLIENT:** Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project**Lab Order:** 16H0908**Lab ID:** 16H0908-09
Client Sample ID: 65-7-8-C2-50**Collection Date:** 8/7/2016 3:20:00PM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
VOC 524.2			EPA 524.2						
Benzene	BDL	0.130	0.500		ug/L	1	1634116	8/15/2016 8:56:00AM	8/15/2016 4:07:00PM

Analyst: NKK

PACE Analytical**Date:** 1/24/2017**CLIENT:** Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project**Lab Order:** 16H0908**Lab ID:** 16H0908-10
Client Sample ID: 65-7-8-C3-50**Collection Date:** 8/7/2016 4:20:00PM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
VOC 524.2		EPA 524.2						Analyst: NKK	
Benzene	BDL	0.130	0.500		ug/L	1	1634116	8/15/2016 8:56:00AM	8/15/2016 4:27:00PM

PACE Analytical**Date:** 1/24/2017**CLIENT:** Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project**Lab Order:** 16H0908**Lab ID:** 16H0908-11
Client Sample ID: 65-7-8-C4-50**Collection Date:** 8/7/2016 5:20:00PM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
VOC 524.2			EPA 524.2						
Benzene	BDL	0.130	0.500		ug/L	1	1634116	8/15/2016 8:56:00AM	8/15/2016 4:46:00PM

Analyst: NKK

PACE Analytical**Date:** 1/24/2017**CLIENT:** Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project**Lab Order:** 16H0908**Lab ID:** 16H0908-12
Client Sample ID: 65-7-8-C5-50**Collection Date:** 8/7/2016 6:20:00PM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
VOC 524.2		EPA 524.2						Analyst: NKK	
Benzene	BDL	0.130	0.500		ug/L	1	1634116	8/15/2016 8:56:00AM	8/15/2016 5:06:00PM

PACE Analytical**Date:** 1/24/2017**CLIENT:** Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project**Lab Order:** 16H0908**Lab ID:** 16H0908-13
Client Sample ID: 65-7-8-C6-50**Collection Date:** 8/7/2016 7:20:00PM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
VOC 524.2		EPA 524.2						Analyst: NKK	
Benzene	BDL	0.130	0.500		ug/L	1	1634116	8/15/2016 8:56:00AM	8/15/2016 5:25:00PM

PACE Analytical**Date:** 1/24/2017**CLIENT:** Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project**Lab Order:** 16H0908**Lab ID:** 16H0908-14
Client Sample ID: 65-7-8-FB1-50**Collection Date:** 8/7/2016 7:20:00PM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
VOC 524.2		EPA 524.2						Analyst: NKK	
Benzene	BDL	0.130	0.500		ug/L	1	1634032	8/12/2016 11:00:00AM	8/13/2016 1:36:00AM

PACE Analytical**Date:** 1/24/2017**CLIENT:** Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project**Lab Order:** 16H0908**Lab ID:** 16H0908-15
Client Sample ID: 65-8-8-C1-650**Collection Date:** 8/8/2016 11:17:00AM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
VOC 524.2		EPA 524.2						Analyst: NKK	
Benzene	BDL	0.130	0.500		ug/L	1	1634116	8/15/2016 8:56:00AM	8/15/2016 5:44:00PM

PACE Analytical**Date:** 1/24/2017**CLIENT:** Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project**Lab Order:** 16H0908**Lab ID:** 16H0908-16
Client Sample ID: 65-8-8-C2-650**Collection Date:** 8/8/2016 12:17:00PM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
VOC 524.2			EPA 524.2						
								Analyst: NKK	
Benzene	0.370	0.130	0.500	J	ug/L	1	1634116	8/15/2016 8:56:00AM	8/15/2016 6:04:00PM

PACE Analytical**Date:** 1/24/2017**CLIENT:** Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project**Lab Order:** 16H0908**Lab ID:** 16H0908-17
Client Sample ID: 65-8-8-C3-650**Collection Date:** 8/8/2016 1:17:00PM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
VOC 524.2			EPA 524.2						
Benzene	0.510	0.130	0.500		ug/L	1	1634116	8/15/2016 8:56:00AM	8/15/2016 6:23:00PM

Analyst: NKK

PACE Analytical

Date: 1/24/2017

CLIENT: Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project

Lab Order: 16H0908

Lab ID: 16H0908-18
Client Sample ID: 65-8-8-C4-650

Collection Date: 8/8/2016 2:17:00PM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
VOC 524.2									
			EPA 524.2						
Benzene	0.510	0.130	0.500		ug/L	1	1634032	8/12/2016 11:00:00AM	8/13/2016 2:54:00AM

Analyst: NKK

Date: 1/24/2017

Lab Order: 16H0908

Collection Date: 8/8/2016 3:17:00PM
Matrix: Water

Analyst: NKK

Date: 1/24/2017

Lab Order: 16H0908

Collection Date: 8/8/2016 4:17:00PM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
VOC 524.2	EPA 524.2				Analyst: NKK				
Benzene	0.850	0.130	0.500		ug/L	1	1634032	8/12/2016 11:00:00AM	8/13/2016 3:34:00AM

PACE Analytical

Date: 1/24/2017

CLIENT: Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project**Lab Order:** 16H0908**Lab ID:** 16H0908-21
Client Sample ID: 65-8-8-FB1-650**Collection Date:** 8/7/2016 4:18:00PM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
VOC 524.2		EPA 524.2						Analyst: NKK	
Benzene	BDL	0.130	0.500		ug/L	1	1634127	8/15/2016 8:11:00AM	8/15/2016 9:38:00PM

CLIENT: Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project

Lab Order: 16H0908

Lab ID: 16H0908-22
Client Sample ID: 45-9-8-P1-50-Aqua

Collection Date: 8/9/2016 12:30:00PM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
VOC 524.2		EPA 524.2						Analyst: NKK	
Benzene	0.560	0.130	0.500		ug/L	1	1634127	8/15/2016 8:11:00AM	8/15/2016 9:57:00PM

PACE Analytical**Date:** 1/24/2017**CLIENT:** Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project**Lab Order:** 16H0908**Lab ID:** 16H0908-23
Client Sample ID: 45-9-8-C1-50-Aqua**Collection Date:** 8/9/2016 12:30:00PM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
VOC 524.2		EPA 524.2						Analyst: NKK	
Benzene	BDL	0.130	0.500		ug/L	1	1634127	8/15/2016 8:11:00AM	8/15/2016 10:17:00PM

PACE Analytical**Date:** 1/24/2017**CLIENT:** Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project**Lab Order:** 16H0908**Lab ID:** 16H0908-24
Client Sample ID: 45-9-8-P1-200-Aqua**Collection Date:** 8/9/2016 2:45:00PM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
VOC 524.2		EPA 524.2							
Benzene	2.12	0.130	0.500		ug/L	1	1634127	8/15/2016 8:11:00AM	8/15/2016 10:36:00PM

Analyst: NKK

CLIENT: Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project

Lab Order: 16H0908

Lab ID: 16H0908-25
Client Sample ID: 45-9-8-C1-200-Aqua

Collection Date: 8/9/2016 12:45:00PM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
VOC 524.2		EPA 524.2						Analyst: NKK	
Benzene	BDL	0.130	0.500		ug/L	1	1634127	8/15/2016 8:11:00AM	8/15/2016 10:56:00PM

PACE Analytical**Date:** 1/24/2017**CLIENT:** Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project**Lab Order:** 16H0908**Lab ID:** 16H0908-26
Client Sample ID: 45-9-8-P1-350-Aqua**Collection Date:** 8/9/2016 5:51:00PM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
VOC 524.2			EPA 524.2						
Benzene	3.98	0.130	0.500		ug/L	1	1634127	8/15/2016 8:11:00AM	8/15/2016 11:15:00PM

Analyst: NKK

Date: 1/24/2017

Lab Order: 16H0908

Collection Date: 8/9/2016 5:51:00PM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
VOC 524.2	EPA 524.2			Analyst: NKK					
Benzene	BDL	0.130	0.500		ug/l.	1	1634127	8/15/2016 8:11:00AM	8/15/2016 11:35:00PM

PACE Analytical**Date:** 1/24/2017**CLIENT:** Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project**Lab Order:** 16H0908**Lab ID:** 16H0908-28
Client Sample ID: 45-9-8-P2-350-Aqua**Collection Date:** 8/9/2016 5:51:00PM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
VOC 524.2		EPA 524.2						Analyst: NKK	
Benzene	2.30	0.130	0.500		ug/L	1	1634127	8/15/2016 8:11:00AM	8/15/2016 11:55:00PM

PACE Analytical**Date:** 1/24/2017**CLIENT:** Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project**Lab Order:** 16H0908**Lab ID:** 16H0908-29
Client Sample ID: 45-9-8-C2-350-Aqua**Collection Date:** 8/9/2016 5:51:00PM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
VOC 524.2		EPA 524.2						Analyst: NKK	
Benzene	BDL	0.130	0.500		ug/L	1	1634127	8/15/2016 8:11:00AM	8/16/2016 12:14:00AM

CLIENT: Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project

Lab Order: 16H0908

Lab ID: 16H0908-30
Client Sample ID: 45-9-8-FB-Aqua

Collection Date: 8/9/2016 5:50:00PM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
VOC 524.2		EPA 524.2						Analyst: NKK	
Benzene	BDL	0.130	0.500		ug/L	1	1634127	8/15/2016 8:11:00AM	8/16/2016 12:34:00AM

PACE Analytical**Date:** 1/24/2017**CLIENT:** Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project**Lab Order:** 16H0908**Lab ID:** 16H0908-31
Client Sample ID: 45-10-8-P1-500-Aqua**Collection Date:** 8/10/2016 10:32:00AM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
VOC 524.2									
		EPA 524.2							
Benzene	10.3	0.130	0.500		ug/L	1	1634127	8/15/2016 8:11:00AM	8/31/2016 7:04:14PM

Analyst: NKK

PACE Analytical**Date:** 1/24/2017**CLIENT:** Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project**Lab Order:** 16H0908**Lab ID:** 16H0908-32
Client Sample ID: 45-10-8-C1-500-Aqua**Collection Date:** 8/10/2016 10:32:00AM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
VOC 524.2									
		EPA 524.2							
Benzene	0.350	0.130	0.500	J	ug/L	1	1634127	8/15/2016 8:11:00AM	8/16/2016 1:13:00AM

Analyst: NKK

CLIENT: Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project

Lab Order: 16H0908

Lab ID: 16H0908-33
Client Sample ID: 45-10-8-P1-650-Aqua

Collection Date: 8/10/2016 11:51:00AM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
VOC 524.2		EPA 524.2						Analyst: NKK	
Benzene	12.8	0.130	0.500		ug/L	1	1634127	8/15/2016 8:11:00AM	8/16/2016 1:32:00AM

PACE Analytical

Date: 1/24/2017

CLIENT: Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project

Lab Order: 16H0908

Lab ID: 16H0908-34
Client Sample ID: 45-10-8-C1-650-Aqua

Collection Date: 8/10/2016 11:51:00AM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
VOC 524.2		EPA 524.2						Analyst: NKK	
Benzene	0.450	0.130	0.500	J	ug/L	I	1634127	8/15/2016 8:11:00AM	8/16/2016 1:52:00AM

CLIENT: Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project

Lab Order: 16H0908

Lab ID: 16H0908-35
Client Sample ID: 45-10-8-P1-800-Aqua

Collection Date: 8/10/2016 1:22:00PM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
VOC 524.2		EPA 524.2						Analyst: NKK	
Benzene	16.4	0.130	0.500		ug/L	1	1634127	8/15/2016 8:11:00AM	8/16/2016 2:11:00AM

Date: 1/24/2017

Lab Order: 16H0908

Collection Date: 8/10/2016 1:22:00PM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
VOC 524.2	EPA 524.2			Analyst: NKK					
Benzene	0.630	0.130	0.500		ug/L	1	1634127	8/15/2016 8:11:00AM	8/16/2016 2:31:00AM

CLIENT: Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project

Lab Order: 16H0908

Lab ID: 16H0908-37
Client Sample ID: 45-10-8-FB-Aqua

Collection Date: 8/10/2016 1:22:00PM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
VOC 524.2	EPA 524.2							Analyst: NKK	
Benzene	BDL	0.130	0.500		ug/L	1	1634127	8/15/2016 8:11:00AM	8/16/2016 2:50:00AM

CLIENT: Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project

Lab Order: 16H0908

Lab ID: 16H0908-38
Client Sample ID: Trip Blank [45-6-8-TB-50]

Collection Date: 8/6/2016 6:29:00PM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
VOC 524.2_TB		EPA 524.2						Analyst: ACH	
1,1,1,2-Tetrachloroethane	BDL	0.133	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
1,1,1-Trichloroethane	BDL	0.158	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
1,1,2,2-Tetrachloroethane	BDL	0.113	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
1,1,2-Trichloroethane	BDL	0.162	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
1,1-Dichloroethane	BDL	0.127	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
1,1-Dichloroethene	BDL	0.245	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
1,1-Dichloropropene	BDL	0.123	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
1,2,3-Trichlorobenzene	BDL	0.119	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
1,2,3-Trichloropropane	BDL	0.162	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
1,2,4-Trichlorobenzene	BDL	0.0745	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
1,2,4-Trimethylbenzene	BDL	0.0832	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
1,2-Dibromoethane	BDL	0.160	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
1,2-Dichlorobenzene	BDL	0.129	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
1,2-Dichloroethane	BDL	0.127	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
1,2-Dichloropropane	BDL	0.101	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
1,3,5-Trimethylbenzene	BDL	0.0846	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
1,3-Dichlorobenzene	BDL	0.128	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
1,3-Dichloropropane	BDL	0.173	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
1,4-Dichlorobenzene	BDL	0.147	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
2,2-Dichloropropane	BDL	0.0905	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
2-Chlorotoluene	BDL	0.113	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
4-Chlorotoluene	BDL	0.0992	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
4-Isopropyltoluene	BDL	0.0905	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
Benzene	BDL	0.130	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	8/16/2016 1:01:00PM
Bromobenzene	BDL	0.120	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
Bromochloromethane	BDL	0.116	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
Bromodichloromethane	BDL	0.133	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
Bromoform	BDL	0.0884	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
Bromomethane	BDL	0.216	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
Carbon Tetrachloride	BDL	0.108	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
Chlorobenzene	BDL	0.137	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
Chloroethane	BDL	0.137	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
Chloroform	BDL	0.103	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
Chloromethane	BDL	0.150	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
cis-1,2-Dichloroethene	BDL	0.130	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
cis-1,3-Dichloropropene	BDL	0.115	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
Dibromochloromethane	BDL	0.0940	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
Dibromomethane	BDL	0.129	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
Dichlorodifluoromethane	BDL	0.133	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
Ethylbenzene	BDL	0.133	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
Xylenes (Total)	BDL	0.340	1.00		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
Hexachlorobutadiene	BDL	0.122	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM

CLIENT: Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project

Lab Order: 16H0908

Lab ID: 16H0908-38
Client Sample ID: Trip Blank [45-6-8-TB-50]

Collection Date: 8/6/2016 6:29:00PM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
Isopropylbenzene	BDL	0.133	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
Methylene Chloride	BDL	0.193	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
Methyl tert-Butyl Ether	BDL	0.0940	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
Naphthalene	BDL	0.126	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
n-Butylbenzene	BDL	0.100	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
n-Propylbenzene	BDL	0.0920	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
sec-Butylbenzene	BDL	0.120	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
Styrene	BDL	0.104	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
tert-Butylbenzene	BDL	0.121	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
Tetrachloroethene	BDL	0.155	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
Toluene	BDL	0.127	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
trans-1,2-Dichloroethene	BDL	0.101	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
trans-1,3-Dichloropropene	BDL	0.128	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
Trichloroethene	BDL	0.113	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
Trichlorofluoromethane	BDL	0.0745	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
Vinyl Chloride	BDL	0.143	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
Surrogate: 1,2-Dichlorobenzene-d4		%			70-130		1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM
Surrogate: 4-Bromofluorobenzene		%			70-130		1634207	8/16/2016 8:16:00AM	1/24/2017 2:43:48PM

CLIENT: Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project

Lab Order: 16H0908

Volatile Organic Compounds by EPA 524.2 - Quality Control

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
---------	--------	-----------------	-------	-------------	---------------	------	-------------	-----	-----------	-------

Batch 1634032 - VOC PREP

Blank (1634032-BLK1)

Prepared & Analyzed: 08/12/16

Benzene BDL 0.500 ug/L

LCS (1634032-BS1)

Prepared: 08/12/16 Analyzed: 01/24/17

1,1,1,2-Tetrachloroethane	BDL	0.500	ug/L	5.000			70-130			
1,1,1-Trichloroethane	BDL	0.500	ug/L	5.000			70-130			L
1,1,2,2-Tetrachloroethane	BDL	0.500	ug/L	5.000			70-130			L
1,1,2-Trichloroethane	BDL	0.500	ug/L	5.000			70-130			L
1,1-Dichloroethane	BDL	0.500	ug/L	5.000			70-130			
1,1-Dichloroethene	BDL	0.500	ug/L	5.000			70-130			L
1,1-Dichloropropene	BDL	0.500	ug/L	5.000			70-130			
1,2,3-Trichlorobenzene	BDL	0.500	ug/L	5.000			70-130			
1,2,3-Trichloropropane	BDL	0.500	ug/L	5.000			70-130			
1,2,4-Trichlorobenzene	BDL	0.500	ug/L	5.000			70-130			
1,2,4-Trimethylbenzene	BDL	0.500	ug/L	5.000			70-130			
1,2-Dibromoethane	BDL	0.500	ug/L	5.000			70-130			
1,2-Dichlorobenzene	BDL	0.500	ug/L	5.000			70-130			
1,2-Dichloroethane	BDL	0.500	ug/L	5.000			70-130			
1,2-Dichloropropane	BDL	0.500	ug/L	5.000			70-130			
1,3,5-Trimethylbenzene	BDL	0.500	ug/L	5.000			70-130			
1,3-Dichlorobenzene	BDL	0.500	ug/L	5.000			70-130			
1,3-Dichloropropane	BDL	0.500	ug/L	5.000			70-130			
1,4-Dichlorobenzene	BDL	0.500	ug/L	5.000			70-130			
2,2-Dichloropropane	BDL	0.500	ug/L	5.000			70-130			
2-Chlorotoluene	BDL	0.500	ug/L	5.000			70-130			
4-Chlorotoluene	BDL	0.500	ug/L	5.000			70-130			
4-Isopropyltoluene	BDL	0.500	ug/L	5.000			70-130			
Benzene	6.19	0.500	ug/L	5.000		124	70-130			
Bromobenzene	BDL	0.500	ug/L	5.000			70-130			L
Bromochloromethane	BDL	0.500	ug/L	5.000			70-130			
Bromodichloromethane	BDL	0.500	ug/L	5.000			70-130			
Bromoform	BDL	0.500	ug/L	5.000			70-130			L
Bromomethane	BDL	0.500	ug/L	5.000			70-130			
Carbon Tetrachloride	BDL	0.500	ug/L	5.000			70-130			L
Chlorobenzene	BDL	0.500	ug/L	5.000			70-130			
Chloroethane	BDL	0.500	ug/L	5.000			70-130			
Chloroform	BDL	0.500	ug/L	5.000			70-130			L
Chloromethane	BDL	0.500	ug/L	5.000			70-130			
cis-1,2-Dichloroethene	BDL	0.500	ug/L	5.000			70-130			
cis-1,3-Dichloropropene	BDL	0.500	ug/L	5.000			70-130			
Dibromochloromethane	BDL	0.500	ug/L	5.000			70-130			
Dibromomethane	BDL	0.500	ug/L	5.000			70-130			L
Dichlorodifluoromethane	BDL	0.500	ug/L	5.000			70-130			
Ethylbenzene	BDL	0.500	ug/L	5.000			70-130			
Xylenes (Total)	BDL	0.500	ug/L	15.00			70-130			
Hexachlorobutadiene	BDL	0.500	ug/L	5.000			70-130			

CLIENT: Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project

Lab Order: 16H0908

Volatile Organic Compounds by EPA 524.2 - Quality Control

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch 1634032 - VOC PREP										
LCS (1634032-BS1)				Prepared: 08/12/16 Analyzed: 01/24/17						
Isopropylbenzene	BDL	0.500	ug/L	5.000			70-130			
Methylene Chloride	BDL	0.500	ug/L	5.000			70-130			
Methyl tert-Butyl Ether	BDL	0.500	ug/L	5.000			70-130			
Naphthalene	BDL	0.500	ug/L	5.000			70-130			
n-Butylbenzene	BDL	0.500	ug/L	5.000			70-130			
n-Propylbenzene	BDL	0.500	ug/L	5.000			70-130			
sec-Butylbenzene	BDL	0.500	ug/L	5.000			70-130			
Styrene	BDL	0.500	ug/L	5.000			70-130			
tert-Butylbenzene	BDL	0.500	ug/L	5.000			70-130			
Tetrachloroethene	BDL	0.500	ug/L	5.000			70-130			
Toluene	BDL	0.500	ug/L	5.000			70-130			
trans-1,2-Dichloroethene	BDL	0.500	ug/L	5.000			70-130			
trans-1,3-Dichloropropene	BDL	0.500	ug/L	5.000			70-130			
Trichloroethene	BDL	0.500	ug/L	5.000			70-130			L
Trichlorofluoromethane	BDL	0.500	ug/L	5.000			70-130			
Vinyl Chloride	BDL	0.500	ug/L	5.000			70-130			
Surrogate: 1,2-Dichlorobenzene-d4	0.00		ug/L	10.00			70-130			
Surrogate: 4-Bromofluorobenzene	0.00		ug/L	10.00			70-130			

Batch 1634116 - VOC PREP

Blank (1634116-BLK2)				Prepared & Analyzed: 08/15/16						
Benzene	BDL	0.500	ug/L							
LCS (1634116-BS2)				Prepared: 08/15/16 Analyzed: 01/24/17						
1,1,1,2-Tetrachloroethane	BDL	0.500	ug/L	5.000			70-130			
1,1,1-Trichloroethane	BDL	0.500	ug/L	5.000			70-130			
1,1,2,2-Tetrachloroethane	BDL	0.500	ug/L	5.000			70-130			
1,1,2-Trichloroethane	BDL	0.500	ug/L	5.000			70-130			
1,1-Dichloroethane	BDL	0.500	ug/L	5.000			70-130			
1,1-Dichloroethene	BDL	0.500	ug/L	5.000			70-130			
1,1-Dichloropropene	BDL	0.500	ug/L	5.000			70-130			
1,2,3-Trichlorobenzene	BDL	0.500	ug/L	5.000			70-130			
1,2,3-Trichloropropane	BDL	0.500	ug/L	5.000			70-130			
1,2,4-Trichlorobenzene	BDL	0.500	ug/L	5.000			70-130			
1,2,4-Trimethylbenzene	BDL	0.500	ug/L	5.000			70-130			
1,2-Dibromoethane	BDL	0.500	ug/L	5.000			70-130			
1,2-Dichlorobenzene	BDL	0.500	ug/L	5.000			70-130			
1,2-Dichloroethane	BDL	0.500	ug/L	5.000			70-130			
1,2-Dichloropropane	BDL	0.500	ug/L	5.000			70-130			
1,3,5-Trimethylbenzene	BDL	0.500	ug/L	5.000			70-130			
1,3-Dichlorobenzene	BDL	0.500	ug/L	5.000			70-130			
1,3-Dichloropropane	BDL	0.500	ug/L	5.000			70-130			
1,4-Dichlorobenzene	BDL	0.500	ug/L	5.000			70-130			
2,2-Dichloropropane	BDL	0.500	ug/L	5.000			70-130			
2-Chlorotoluene	BDL	0.500	ug/L	5.000			70-130			

CLIENT: Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project

Lab Order: 16H0908

Volatile Organic Compounds by EPA 524.2 - Quality Control

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
---------	--------	-----------------	-------	-------------	---------------	------	-------------	-----	-----------	-------

Batch 1634116 - VOC PREP

LCS (1634116-BS2)

Prepared: 08/15/16 Analyzed: 01/24/17

4-Chlorotoluene	BDL	0.500	ug/L	5.000			70-130			
4-Isopropyltoluene	BDL	0.500	ug/L	5.000			70-130			
Benzene	4.50	0.500	ug/L	5.000		90.0	70-130			
Bromobenzene	BDL	0.500	ug/L	5.000			70-130			
Bromochloromethane	BDL	0.500	ug/L	5.000			70-130			
Bromodichloromethane	BDL	0.500	ug/L	5.000			70-130			
Bromoform	BDL	0.500	ug/L	5.000			70-130			
Bromomethane	BDL	0.500	ug/L	5.000			70-130			
Carbon Tetrachloride	BDL	0.500	ug/L	5.000			70-130			
Chlorobenzene	BDL	0.500	ug/L	5.000			70-130			
Chloroethane	BDL	0.500	ug/L	5.000			70-130			
Chloroform	BDL	0.500	ug/L	5.000			70-130			
Chloromethane	BDL	0.500	ug/L	5.000			70-130			
cis-1,2-Dichloroethene	BDL	0.500	ug/L	5.000			70-130			
cis-1,3-Dichloropropene	BDL	0.500	ug/L	5.000			70-130			
Dibromochloromethane	BDL	0.500	ug/L	5.000			70-130			
Dibromomethane	BDL	0.500	ug/L	5.000			70-130			
Dichlorodifluoromethane	BDL	0.500	ug/L	5.000			70-130			
Ethylbenzene	BDL	0.500	ug/L	5.000			70-130			
Xylenes (Total)	BDL	0.500	ug/L	15.00			70-130			
Hexachlorobutadiene	BDL	0.500	ug/L	5.000			70-130			
Isopropylbenzene	BDL	0.500	ug/L	5.000			70-130			
Methylene Chloride	BDL	0.500	ug/L	5.000			70-130			
Methyl tert-Butyl Ether	BDL	0.500	ug/L	5.000			70-130			
Naphthalene	BDL	0.500	ug/L	5.000			70-130			
n-Butylbenzene	BDL	0.500	ug/L	5.000			70-130			
n-Propylbenzene	BDL	0.500	ug/L	5.000			70-130			
sec-Butylbenzene	BDL	0.500	ug/L	5.000			70-130			
Styrene	BDL	0.500	ug/L	5.000			70-130			
tert-Butylbenzene	BDL	0.500	ug/L	5.000			70-130			
Tetrachloroethene	BDL	0.500	ug/L	5.000			70-130			
Toluene	BDL	0.500	ug/L	5.000			70-130			
trans-1,2-Dichloroethene	BDL	0.500	ug/L	5.000			70-130			
trans-1,3-Dichloropropene	BDL	0.500	ug/L	5.000			70-130			
Trichloroethene	BDL	0.500	ug/L	5.000			70-130			
Trichlorofluoromethane	BDL	0.500	ug/L	5.000			70-130			L
Vinyl Chloride	BDL	0.500	ug/L	5.000			70-130			
Surrogate: 1,2-Dichlorobenzene-d4	0.00		ug/L	10.00			70-130			
Surrogate: 4-Bromofluorobenzene	0.00		ug/L	10.00			70-130			

CLIENT: Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project

Lab Order: 16H0908

Volatile Organic Compounds by EPA 524.2 - Quality Control

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC Limits	RPD	RPD Limit	Notes
Batch 1634127 - VOC PREP									
Blank (1634127-BLK1)				Prepared & Analyzed: 08/15/16					
Benzene	BDL	0.500	ug/L						
LCS (1634127-BS1)				Prepared: 08/15/16 Analyzed: 01/24/17					
1,1,1,2-Tetrachloroethane	BDL	0.500	ug/L	5.000		70-130			
1,1,1-Trichloroethane	BDL	0.500	ug/L	5.000		70-130			
1,1,2,2-Tetrachloroethane	BDL	0.500	ug/L	5.000		70-130			
1,1,2-Trichloroethane	BDL	0.500	ug/L	5.000		70-130			
1,1-Dichloroethane	BDL	0.500	ug/L	5.000		70-130			
1,1-Dichloroethene	BDL	0.500	ug/L	5.000		70-130			
1,1-Dichloropropene	BDL	0.500	ug/L	5.000		70-130			L
1,2,3-Trichlorobenzene	BDL	0.500	ug/L	5.000		70-130			
1,2,3-Trichloropropane	BDL	0.500	ug/L	5.000		70-130			
1,2,4-Trichlorobenzene	BDL	0.500	ug/L	5.000		70-130			
1,2,4-Trimethylbenzene	BDL	0.500	ug/L	5.000		70-130			
1,2-Dibromoethane	BDL	0.500	ug/L	5.000		70-130			
1,2-Dichlorobenzene	BDL	0.500	ug/L	5.000		70-130			
1,2-Dichloroethane	BDL	0.500	ug/L	5.000		70-130			
1,2-Dichloropropane	BDL	0.500	ug/L	5.000		70-130			
1,3,5-Trimethylbenzene	BDL	0.500	ug/L	5.000		70-130			
1,3-Dichlorobenzene	BDL	0.500	ug/L	5.000		70-130			
1,3-Dichloropropane	BDL	0.500	ug/L	5.000		70-130			
1,4-Dichlorobenzene	BDL	0.500	ug/L	5.000		70-130			
2,2-Dichloropropane	BDL	0.500	ug/L	5.000		70-130			
2-Chlorotoluene	BDL	0.500	ug/L	5.000		70-130			
4-Chlorotoluene	BDL	0.500	ug/L	5.000		70-130			
4-Isopropyltoluene	BDL	0.500	ug/L	5.000		70-130			
Benzene	5.69	0.500	ug/L	5.000		114 70-130			
Bromobenzene	BDL	0.500	ug/L	5.000		70-130			
Bromochloromethane	BDL	0.500	ug/L	5.000		70-130			
Bromodichloromethane	BDL	0.500	ug/L	5.000		70-130			
Bromoform	BDL	0.500	ug/L	5.000		70-130			
Bromomethane	BDL	0.500	ug/L	5.000		70-130			
Carbon Tetrachloride	BDL	0.500	ug/L	5.000		70-130			
Chlorobenzene	BDL	0.500	ug/L	5.000		70-130			
Chloroethane	BDL	0.500	ug/L	5.000		70-130			
Chloroform	BDL	0.500	ug/L	5.000		70-130			L
Chloromethane	BDL	0.500	ug/L	5.000		70-130			
cis-1,2-Dichloroethene	BDL	0.500	ug/L	5.000		70-130			
cis-1,3-Dichloropropene	BDL	0.500	ug/L	5.000		70-130			
Dibromochloromethane	BDL	0.500	ug/L	5.000		70-130			
Dibromomethane	BDL	0.500	ug/L	5.000		70-130			
Dichlorodifluoromethane	BDL	0.500	ug/L	5.000		70-130			
Ethylbenzene	BDL	0.500	ug/L	5.000		70-130			
Xylenes (Total)	BDL	0.500	ug/L	15.00		70-130			
Hexachlorobutadiene	BDL	0.500	ug/L	5.000		70-130			

CLIENT: Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project

Lab Order: 16H0908

Volatile Organic Compounds by EPA 524.2 - Quality Control

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch 1634127 - VOC PREP										
LCS (1634127-BS1)				Prepared: 08/15/16 Analyzed: 01/24/17						
Isopropylbenzene	BDL	0.500	ug/L	5.000			70-130			
Methylene Chloride	BDL	0.500	ug/L	5.000			70-130			L
Methyl tert-Butyl Ether	BDL	0.500	ug/L	5.000			70-130			
Naphthalene	BDL	0.500	ug/L	5.000			70-130			
n-Butylbenzene	BDL	0.500	ug/L	5.000			70-130			
n-Propylbenzene	BDL	0.500	ug/L	5.000			70-130			
sec-Butylbenzene	BDL	0.500	ug/L	5.000			70-130			
Styrene	BDL	0.500	ug/L	5.000			70-130			
tert-Butylbenzene	BDL	0.500	ug/L	5.000			70-130			
Tetrachloroethene	BDL	0.500	ug/L	5.000			70-130			
Toluene	BDL	0.500	ug/L	5.000			70-130			
trans-1,2-Dichloroethene	BDL	0.500	ug/L	5.000			70-130			
trans-1,3-Dichloropropene	BDL	0.500	ug/L	5.000			70-130			
Trichloroethene	BDL	0.500	ug/L	5.000			70-130			
Trichlorofluoromethane	BDL	0.500	ug/L	5.000			70-130			
Vinyl Chloride	BDL	0.500	ug/L	5.000			70-130			
Surrogate: 1,2-Dichlorobenzene-d4	0.00		ug/L	10.00			70-130			
Surrogate: 4-Bromofluorobenzene	0.00		ug/L	10.00			70-130			

Batch 1634207 - VOC PREP

Blank (1634207-BLK1)				Prepared: 08/16/16 Analyzed: 01/24/17						
1,1,1,2-Tetrachloroethane	BDL	0.500	ug/L							
1,1,1-Trichloroethane	BDL	0.500	ug/L							
1,1,2,2-Tetrachloroethane	BDL	0.500	ug/L							
1,1,2-Trichloroethane	BDL	0.500	ug/L							
1,1-Dichloroethane	BDL	0.500	ug/L							
1,1-Dichloroethene	BDL	0.500	ug/L							
1,1-Dichloropropene	BDL	0.500	ug/L							
1,2,3-Trichlorobenzene	BDL	0.500	ug/L							
1,2,3-Trichloropropane	BDL	0.500	ug/L							
1,2,4-Trichlorobenzene	BDL	0.500	ug/L							
1,2,4-Trimethylbenzene	BDL	0.500	ug/L							
1,2-Dibromoethane	BDL	0.500	ug/L							
1,2-Dichlorobenzene	BDL	0.500	ug/L							
1,2-Dichloroethane	BDL	0.500	ug/L							
1,2-Dichloropropane	BDL	0.500	ug/L							
1,3,5-Trimethylbenzene	BDL	0.500	ug/L							
1,3-Dichlorobenzene	BDL	0.500	ug/L							
1,3-Dichloropropane	BDL	0.500	ug/L							
1,4-Dichlorobenzene	BDL	0.500	ug/L							
2,2-Dichloropropane	BDL	0.500	ug/L							
2-Chlorotoluene	BDL	0.500	ug/L							
4-Chlorotoluene	BDL	0.500	ug/L							
4-Isopropyltoluene	BDL	0.500	ug/L							

CLIENT: Naval Medical Research Unit-Dayton
 Project: USUHS-WFA Project

Lab Order: 16H0908

Volatile Organic Compounds by EPA 524.2 - Quality Control

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch 1634207 - VOC PREP										
Blank (1634207-BLK1)				Prepared & Analyzed: 08/16/16						
Benzene	BDL	0.500	ug/L							
Bromobenzene	BDL	0.500	ug/L							
Bromochloromethane	BDL	0.500	ug/L							
Bromodichloromethane	BDL	0.500	ug/L							
Bromoform	BDL	0.500	ug/L							
Bromomethane	BDL	0.500	ug/L							
Carbon Tetrachloride	BDL	0.500	ug/L							
Chlorobenzene	BDL	0.500	ug/L							
Chloroethane	BDL	0.500	ug/L							
Chloroform	BDL	0.500	ug/L							
Chloromethane	BDL	0.500	ug/L							
cis-1,2-Dichloroethene	BDL	0.500	ug/L							
cis-1,3-Dichloropropene	BDL	0.500	ug/L							
Dibromochloromethane	BDL	0.500	ug/L							
Dibromomethane	BDL	0.500	ug/L							
Dichlorodifluoromethane	BDL	0.500	ug/L							
Ethylbenzene	BDL	0.500	ug/L							
Xylenes (Total)	BDL	1.00	ug/L							
Hexachlorobutadiene	BDL	0.500	ug/L							
Isopropylbenzene	BDL	0.500	ug/L							
Methylene Chloride	BDL	0.500	ug/L							
Methyl tert-Butyl Ether	BDL	0.500	ug/L							
Naphthalene	BDL	0.500	ug/L							
n-Butylbenzene	BDL	0.500	ug/L							
n-Propylbenzene	BDL	0.500	ug/L							
sec-Butylbenzene	BDL	0.500	ug/L							
Styrene	BDL	0.500	ug/L							
tert-Butylbenzene	BDL	0.500	ug/L							
Tetrachloroethene	BDL	0.500	ug/L							
Toluene	BDL	0.500	ug/L							
trans-1,2-Dichloroethene	BDL	0.500	ug/L							
trans-1,3-Dichloropropene	BDL	0.500	ug/L							
Trichloroethene	BDL	0.500	ug/L							
Trichlorofluoromethane	BDL	0.500	ug/L							
Vinyl Chloride	BDL	0.500	ug/L							
Surrogate: 1,2-Dichlorobenzene-d4	0.00		ug/L	10.00			70-130			
Surrogate: 4-Bromofluorobenzene	0.00		ug/L	10.00			70-130			

CLIENT: Naval Medical Research Unit-Dayton
 Project: USUHS-WFA Project

Lab Order: 16H0908

Volatile Organic Compounds by EPA 524.2 - Quality Control

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch 1634207 - VOC PREP										
LCS (1634207-BS1)				Prepared: 08/16/16 Analyzed: 01/24/17						
1,1,1,2-Tetrachloroethane	BDL	0.500	ug/L	5.000			70-130			
1,1,1-Trichloroethane	BDL	0.500	ug/L	5.000			70-130			
1,1,2,2-Tetrachloroethane	BDL	0.500	ug/L	5.000			70-130			
1,1,2-Trichloroethane	BDL	0.500	ug/L	5.000			70-130			
1,1-Dichloroethane	BDL	0.500	ug/L	5.000			70-130			
1,1-Dichloroethene	BDL	0.500	ug/L	5.000			70-130			
1,1-Dichloropropene	BDL	0.500	ug/L	5.000			70-130			
1,2,3-Trichlorobenzene	BDL	0.500	ug/L	5.000			70-130			
1,2,3-Trichloropropane	BDL	0.500	ug/L	5.000			70-130			
1,2,4-Trichlorobenzene	BDL	0.500	ug/L	5.000			70-130			
1,2,4-Trimethylbenzene	BDL	0.500	ug/L	5.000			70-130			
1,2-Dibromomethane	BDL	0.500	ug/L	5.000			70-130			
1,2-Dichlorobenzene	BDL	0.500	ug/L	5.000			70-130			
1,2-Dichloroethane	BDL	0.500	ug/L	5.000			70-130			
1,2-Dichloropropane	BDL	0.500	ug/L	5.000			70-130			
1,3,5-Trimethylbenzene	BDL	0.500	ug/L	5.000			70-130			
1,3-Dichlorobenzene	BDL	0.500	ug/L	5.000			70-130			
1,3-Dichloropropane	BDL	0.500	ug/L	5.000			70-130			
1,4-Dichlorobenzene	BDL	0.500	ug/L	5.000			70-130			
2,2-Dichloropropane	BDL	0.500	ug/L	5.000			70-130			
2-Chlorotoluene	BDL	0.500	ug/L	5.000			70-130			
4-Chlorotoluene	BDL	0.500	ug/L	5.000			70-130			
4-Isopropyltoluene	BDL	0.500	ug/L	5.000			70-130			
Benzene	4.33	0.500	ug/L	5.000		86.6	70-130			
Bromobenzene	BDL	0.500	ug/L	5.000			70-130			
Bromochloromethane	BDL	0.500	ug/L	5.000			70-130			
Bromodichloromethane	BDL	0.500	ug/L	5.000			70-130			
Bromoform	BDL	0.500	ug/L	5.000			70-130			
Bromomethane	BDL	0.500	ug/L	5.000			70-130			
Carbon Tetrachloride	BDL	0.500	ug/L	5.000			70-130			
Chlorobenzene	BDL	0.500	ug/L	5.000			70-130			
Chloroethane	BDL	0.500	ug/L	5.000			70-130			
Chloroform	BDL	0.500	ug/L	5.000			70-130			
Chloromethane	BDL	0.500	ug/L	5.000			70-130			
cis-1,2-Dichloroethene	BDL	0.500	ug/L	5.000			70-130			
cis-1,3-Dichloropropene	BDL	0.500	ug/L	5.000			70-130			
Dibromochloromethane	BDL	0.500	ug/L	5.000			70-130			
Dibromomethane	BDL	0.500	ug/L	5.000			70-130			
Dichlorodifluoromethane	BDL	0.500	ug/L	5.000			70-130			
Ethylbenzene	BDL	0.500	ug/L	5.000			70-130			
Xylenes (Total)	BDL	1.00	ug/L	15.00			70-130			
Hexachlorobutadiene	BDL	0.500	ug/L	5.000			70-130			
Isopropylbenzene	BDL	0.500	ug/L	5.000			70-130			
Methylene Chloride	BDL	0.500	ug/L	5.000			70-130			
Methyl tert-Butyl Ether	BDL	0.500	ug/L	5.000			70-130			

CLIENT: Naval Medical Research Unit-Dayton
 Project: USUHS-WFA Project

Lab Order: 16H0908

Volatile Organic Compounds by EPA 524.2 - Quality Control

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
---------	--------	--------------------	-------	----------------	------------------	------	----------------	-----	--------------	-------

Batch 1634207 - VOC PREP

LCS (1634207-BS1)

Prepared: 08/16/16 Analyzed: 01/24/17

Naphthalene	BDL	0.500	ug/L	5.000			70-130			
n-Butylbenzene	BDL	0.500	ug/L	5.000			70-130			
n-Propylbenzene	BDL	0.500	ug/L	5.000			70-130			
sec-Butylbenzene	BDL	0.500	ug/L	5.000			70-130			
Styrene	BDL	0.500	ug/L	5.000			70-130			
tert-Butylbenzene	BDL	0.500	ug/L	5.000			70-130			
Tetrachloroethene	BDL	0.500	ug/L	5.000			70-130			
Toluene	BDL	0.500	ug/L	5.000			70-130			
trans-1,2-Dichloroethene	BDL	0.500	ug/L	5.000			70-130			
trans-1,3-Dichloropropene	BDL	0.500	ug/L	5.000			70-130			
Trichloroethene	BDL	0.500	ug/L	5.000			70-130			
Trichlorofluoromethane	BDL	0.500	ug/L	5.000			70-130			
Vinyl Chloride	BDL	0.500	ug/L	5.000			70-130			
Surrogate: 1,2-Dichlorobenzene-d4	0.00		ug/L	10.00			70-130			
Surrogate: 4-Bromofluorobenzene	0.00		ug/L	10.00			70-130			

CLIENT: Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project

Lab Order: 16H0908

Notes and Definitions

- P Sample preservation does not meet method specified requirements.
- L Laboratory control sample recovery outside of acceptance limits high, sample results are below detection limits. Sample data is still acceptable.
- J Estimated Value less than the Reporting Limit, but above the Method Detection Limit. Not valid for quantitative use.
- BDL Analyte is below detection limits
Sample preservation was met unless otherwise noted.

ju H D9D8 F

The Chain-of-Custody is a LEGAL DOCUMENT. All relevant fields must be completed accurately.

Page 52 of 56ORIGINAL

Important Note: By signing this form you are accepting Pace's NLT 30-day payment terms and agreeing to late charges of 1.5% per month for any invoices not paid within 30 days.

F-ALL-Q-020rev.07, 15-May-2007

CHAIN-OF-CUSTODY / Analytical Request Document
The Chain-of-Custody is a LEGAL DOCUMENT. All relevant fields must be completed accurately.

Section A
Required Client Information:

Section B
Required Project Information:

Section C
Invoice Information:

Page: _____ of _____

2078834

Company:		Report To:		Attention:		Company Name:		REGULATORY AGENCY	
Address:		Copy To:		Purchase Order No.:		Address:		☐ NPDES ☐ GROUND WATER ☐ DRINKING WATER ☐ UST ☐ RCRA ☐ OTHER _____	
Email To:		Project Name:		Purchase Order No.:		Reference:		Site Location	
Phone:		Project Number:		Date:		Manager:		STATE:	
Requested Due Date/AT:									

Section D Required Client Information		Matrix Codes MATRIX / CODE		COLLECTED		SAMPLE TEMP AT COLLECTION		# OF CONTAINERS		Preservatives		Analysis Test		Residual Chlorine (Y/N)		Pace Project No./ Lab I.D.																			
Matrix Codes Drinking Water Water Waste Water Product Soil/Solid Oil Wipe Air Tissue Other		MATRIX CODE (see valid codes to left)		SAMPLE TYPE (G=GRAB C=COMP)		DATE		TIME		DATE		TIME		UNPRESERVED		H ₂ SO ₄		HNO ₃		HCl		NaOH		Na ₂ S ₂ O ₃		Methanol		Other		Analysis Test		Residual Chlorine (Y/N)		Pace Project No./ Lab I.D.	
SAMPLE ID (A-Z, 0-9 /, -) Sample IDs MUST BE UNIQUE																																			
1		65-7-8-7R-50								08/07/16		1920		1																					
2		65-7-8-6B-50								08/07/16		1920		1																					
3		65-7-8-C1-50								08/07/16		1420		2																					
4		65-7-8-C2-50								08/07/16		1520		2																					
5		65-7-8-C3-50								08/07/16		1620		2																					
6		65-7-8-C4-50								08/07/16		1720		2																					
7		65-7-8-C5-50								08/07/16		1820		2																					
8		65-7-8-C6-50								08/07/16		1920		2																					
9																																			
10																																			
11																																			
12																																			
ADDITIONAL COMMENTS		RELINQUISHED BY / AFFILIATION		DATE		TIME		ACCEPTED BY / AFFILIATION		DATE		TIME		SAMPLE CONDITIONS																					
																										</									

ADDITIONAL COMMENTS		RELINQUISHED BY / AFFILIATION		DATE		TIME		ACCEPTED BY/AFFILIATION		DATE		TIME		SAMPLE CONDITIONS	

SAMPLER NAME AND SIGNATURE		DATE Signed	
PRINT Name of SAMPLER:		(MM/DD/YY):	
SIGNATURE of SAMPLER:		08/07/16	
Temp in °C		Received on ice (Y/N)	
Custody Sealed Cooler (Y/N)		Samples Intact (Y/N)	

The Chain-of-Custody is a LEGAL DOCUMENT. All relevant fields must be completed accurately

Page 54 of 56

bioRxiv preprint doi: <https://doi.org/10.1101/2019.05.20.256444>; this version posted May 20, 2019. The copyright holder for this preprint (which was not certified by peer review) is the author/funder, who has granted bioRxiv a license to display the preprint in perpetuity. It is made available under aCC-BY-NC-ND 4.0 International license.

CHAIN-OF-CUSTODY / Analytical Request Document
The Chain-of-Custody is a LEGAL DOCUMENT. All relevant fields must be completed accurately.

Section A Required Client Information:		Section B Required Project Information:		Section C Invoice Information:	
Company:	Report To:	Company Name:	Attention:	REGULATORY AGENCY	Page: _____ of _____ 2078840
Address:	Copy To:	Address:		NPDES ☐ GROUND WATER ☐ DRINKING WATER ☐	
Email To:	Purchase Order No.:	Address:	Reference:	Site Location	
Phone:	Project Name:	Address:	Reference:	UST ☐ RCRA ☐ OTHER ☐	
Requested Due Date/AT:	Project Number:	Address:	Reference:	STATE:	

Section D Required Client Information		Matrix Codes MATRIX / CODE		COLLECTED		SAMPLE TEMP AT COLLECTION		Preservatives		Analysis Test ↓		Residual Chlorine (Y/N)		Page Project No./ Lab I.D.	
SAMPLE ID (A-Z, 0-9, -,) Sample IDs MUST BE UNIQUE		MATRIX CODE (see valid codes to left)		SAMPLE TYPE (G=GRAB C=COMP)		DATE		# OF CONTAINERS		↓ Analysis Test ↓					
Drinking Water Water Waste Water Product Soil/Solid Oil Wipe Air Tissue Other		WT WT WW P SL OL WP AR TS OT		COMPOSITE START		COMPOSITE END/GRAB		Unpreserved H ₂ SO ₄ HNO ₃ HCl NaOH Na ₂ S ₂ O ₃ Methanol Other		Y/N					
ITEM #				DATE	TIME	DATE	TIME								
1	45-9-8-T 8-Aqua					8 Aug 16	1751	1	X						
2	45-9-8-F 13-Aqua						1751	1	X						
3	45-9-8-P 1-50-Aqua						1230	2	X						
4	45-9-8-C 1-50-Aqua						1230	1	X						
5	45-9-8-P 1-200-Aqua						1445	2	X						
6	45-9-8-P 1-200-Aqua						1445	4	X						
7	45-9-8-C 1-200-Aqua						1751	1	X						
8	45-9-8-P 1-350-Aqua						1751	2	X						
9	45-9-8-C 1-350-Aqua						1751	1	X						
10	45-9-8-P 1-350-Aqua						1751	1	X						
11	45-9-8-C 2-350-Aqua						1751	1	X						
12															
ADDITIONAL COMMENTS		RELINQUISHED BY / AFFILIATION		DATE		TIME		ACCEPTED BY / AFFILIATION		DATE		TIME		SAMPLE CONDITIONS	

ADDITIONAL COMMENTS RELINQUISHED BY / AFFILIATION: _____ DATE: _____ TIME: _____ ACCEPTED BY / AFFILIATION: _____ DATE: _____ TIME: _____ SAMPLE CONDITIONS: _____	
SAMPLER NAME AND SIGNATURE PRINT Name of SAMPLER: _____ SIGNATURE of SAMPLER: _____ DATE Signed (MM/DD/YY): 5 Aug 16	
Temp in °C	Received on Ice (Y/N)
Custody Sealed Cooler (Y/N)	Samples Intact (Y/N)

Important Note: By signing this form you are accepting Page's N+1 30 day payment terms and agreeing to late charges of 1.5% per month for any invoices not paid within 30 days.

CHAIN-OF-CUSTODY / Analytical Request Document
The Chain-of-Custody is a LEGAL DOCUMENT. All relevant fields must be completed accurately.

Section A

Section B

Section C

Invoice Information:

Page: _____ of _____

2078841

Required Client Information:
Company: Karim Elyamani
Address: _____
Copy to: _____
Purchase Order No.: _____
Email To: Karim.Elyamani@pawh.edu
Phone: 706/718-546 Fax: _____
Project Name: _____
Requested Due Date/TAT: _____
Project Number: _____

Attention: Accounts Payable
Company Name: Henry M. Jackson Foundation
Address: 8720 A Rockledge Drive, Suite 100
Reference: Reference number: 00025130
Pace Project Manager: _____
Pace Profile #: _____

REGULATORY AGENCY
☐ NPDES ☐ GROUND WATER ☐ DRINKING WATER
☐ UST ☐ RCRA ☐ OTHER _____
Site Location
STATE: _____

Section D
Required Client Information
MATRIX CODES
Matrix Codes: DW, WT, Water, Waste Water, WW, Product, P, Soil/Solid, SL, Oil, OL, WPF, WP, Air, AR, Tissue, TS, Other, OT
SAMPLE ID
(A-Z, 0-9 / . -)
Sample IDs MUST BE UNIQUE
ITEM #
1 45-10-8-TR-Aqua
2 45-10-8-FB-Aqua
3 45-10-8-P1-500-Aqua
4 45-10-8-C1-500-Aqua
5 45-10-8-P1-650-Aqua
6 45-10-8-C1-650-Aqua
7 45-10-8-P1-800-Aqua
8 45-10-8-C1-800-Aqua
9
10
11
12

MATRIX CODE (see valid codes to left)
SAMPLE TYPE (G=GRAB C=COMP)
COLLECTED
COMPOSITE START
COMPOSITE END/GRAB
DATE TIME DATE TIME
SAMPLE TEMP AT COLLECTION
OF CONTAINERS
Unpreserved
H₂SO₄
HNO₃
HCl
NaOH
Na₂S₂O₃
Methanol
Other
Analysis Test
5-24.2 SPM Benzene only
Preservatives
Y/N
Requested Analysis Filtered (Y/N)
Residual Chlorine (Y/N)
Pace Project No./ Lab I.D.

ADDITIONAL COMMENTS
RELINQUISHED BY / AFFILIATION
DATE
TIME
ACCEPTED BY / AFFILIATION
DATE
TIME
SAMPLE CONDITIONS
Temp in °C
Received on ice (Y/N)
Custody Sealed Cooler (Y/N)
Samples Intact (Y/N)

ORIGINAL
SAMPLER NAME AND SIGNATURE
PRINT Name of SAMPLER:
SIGNATURE of SAMPLER:
DATE Signed (MM/DD/YY): 10 Aug 16
Temp in °C
Received on ice (Y/N)
Custody Sealed Cooler (Y/N)
Samples Intact (Y/N)



Tuesday, January 24, 2017
Analytical Results

Karim Elyamani
Naval Medical Research Unit-Dayton
2729 R Street, Building 837, Area B
Wright-Patterson AFB, OH 45433
TEL: (937) 904-9460
FAX

RE: USUHS-WFA Project

Work Order: 16H0915

PACE Analytical received 23 sample(s) on 8/12/2016 for the analyses presented in the following report.

PACE Analytical attests that all analytical methods were performed using acceptable methods, and that the QA/QC procedures stipulated in these methods were followed. This report shall not be reproduced except in full. All samples are reported on a dry-weight basis unless otherwise stated.

If you have any questions regarding the test results, please feel free to call me at (937) 832-8242.

Respectfully submitted,

Alison Hudson
Client Services Manager

25 Holiday Drive * Englewood, Ohio 45322 * 1.937.832.8242 * 1.937.832.2868 Fax

Certifications: NELAP/NELAC - #04130 VAP - #CL0032 OEPA DW - #872 KDEP WW - #98039

931 Dudley Road * Edgewood, Kentucky 41017 * 1.859.341.9989 * 1.937.832.2868 Fax

Certifications: KDEP WW- #00053 KDEP DW- #00053

CLIENT: Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project

Lab Order: 16H0915

Work Order Sample Summary

The results of analyses performed on the following samples submitted to Pace Analytical Dayton are found in this report.

Field Sample ID	Lab ID	Matrix	Method Reference	Subcontract Lab
65-11-8-FB-Aqua	16H0915-01	Water	EPA 524.2	
65-11-8-P1-200 -Aqua	16H0915-02	Water	EPA 524.2	
65-11-8-C1-200 -Aqua	16H0915-03	Water	EPA 524.2	
65-11-8-P1-350 -Aqua	16H0915-04	Water	EPA 524.2	
65-11-8-C1-350 -Aqua	16H0915-05	Water	EPA 524.2	
65-11-8-FB-Aqua	16H0915-06	Water	EPA 524.2	
65-11-8-P1-500 -Aqua	16H0915-07	Water	EPA 524.2	
65-11-8-C1-500 -Aqua	16H0915-08	Water	EPA 524.2	
65-11-8-P1-650 -Aqua	16H0915-09	Water	EPA 524.2	
65-11-8-C1-650 -Aqua	16H0915-10	Water	EPA 524.2	
45-11-8-FB-650	16H0915-11	Water	EPA 524.2	
45-11-8-C1-650	16H0915-12	Water	EPA 524.2	
45-11-8-C2-650	16H0915-13	Water	EPA 524.2	
45-11-8-C3-650	16H0915-14	Water	EPA 524.2	
45-11-8-C4-650	16H0915-15	Water	EPA 524.2	
45-11-8-C5-650	16H0915-16	Water	EPA 524.2	
45-11-8-C6-650	16H0915-17	Water	EPA 524.2	
65-12-8-FB-Aqua	16H0915-18	Water	EPA 524.2	
65-12-8-P1-50-Aqua	16H0915-19	Water	EPA 524.2	
65-12-8-C1-50-Aqua	16H0915-20	Water	EPA 524.2	
65-12-8-P1-800-Aqua	16H0915-21	Water	EPA 524.2	
65-12-8-C1-800-Aqua	16H0915-22	Water	EPA 524.2	
Trip Blank [65-11-8-TB-Aqua]	16H0915-23	Water	EPA 524.2	

CLIENT: Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project**Lab Order:** 16H0915

CASE NARRATIVE:

This report is being revised to generate J-values, if applicable, for detections below the Practical Quantification Limit (PQL) and the Method Detection Limit (MDL). MDL values represent a statistical calculation of the point at which the analyte can be said to be present at an amount greater than zero for this analysis. While values between the MDL and the PQL should not generally be considered reliable enough for regulatory purposes they may provide useful information for experimental purposes.

PACE Analytical**Date:** 1/24/2017**CLIENT:** Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project**Lab Order:** 16H0915**Lab ID:** 16H0915-01
Client Sample ID: 65-11-8-FB-Aqua**Collection Date:** 8/10/2016 6:20:00PM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
VOC 524.2		EPA 524.2						Analyst: NKK	
Benzene	BDL	0.130	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	8/16/2016 1:21:00PM

Date: 1/24/2017

Lab Order: 16H0915

Collection Date: 8/10/2016 4:55:00PM
Matrix: Water

Analyst: NKK

Date: 1/24/2017

Lab Order: 16H0915

Collection Date: 8/10/2016 4:55:00PM
Matrix: Water

VOC 524.2		EPA 524.2		Analyst: NKK					
Benzene	BDL	0.130	0.500	ug/L	1	1634207	8/16/2016 8:16:00AM	8/16/2016 1:59:00PM	

Date: 1/24/2017

Lab Order: 16H0915

Collection Date: 8/10/2016 6:20:00PM
Matrix: Water

VOC 524.2		EPA 524.2		Analyst: NKK				
Benzene	7.24	0.130	0.500	ug/L	1	1634207	8/16/2016 8:16:00AM	8/16/2016 2:19:00PM

PACE Analytical

Date: 1/24/2017

CLIENT: Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project**Lab Order:** 16H0915**Lab ID:** 16H0915-05
Client Sample ID: 65-11-8-C1-350 -Aqua**Collection Date:** 8/10/2016 6:20:00PM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
VOC 524.2									
		EPA 524.2							
Benzene	BDL	0.130	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	8/16/2016 2:38:00PM

Analyst: NKK

PACE Analytical**Date:** 1/24/2017**CLIENT:** Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project**Lab Order:** 16H0915**Lab ID:** 16H0915-06
Client Sample ID: 65-11-8-FB-Aqua**Collection Date:** 8/11/2016 10:51:00AM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
VOC 524.2									
		EPA 524.2							
								Analyst: NKK	
Benzene	BDL	0.130	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	8/16/2016 2:58:00PM

PACE Analytical

Date: 1/24/2017

CLIENT: Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project**Lab Order:** 16H0915**Lab ID:** 16H0915-07
Client Sample ID: 65-11-8-P1-500 -Aqua**Collection Date:** 8/11/2016 8:53:00AM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
VOC 524.2		EPA 524.2						Analyst: NKK	
Benzene	4.89	0.130	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	8/16/2016 3:17:00PM

PACE Analytical**Date:** 1/24/2017**CLIENT:** Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project**Lab Order:** 16H0915**Lab ID:** 16H0915-09
Client Sample ID: 65-11-8-P1-650 -Aqua**Collection Date:** 8/11/2016 10:51:00AM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
VOC 524.2									
		EPA 524.2							
Benzene	5.88	0.130	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	8/16/2016 3:56:00PM

Analyst: NKK

PACE Analytical

Date: 1/24/2017

CLIENT: Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project**Lab Order:** 16H0915**Lab ID:** 16H0915-10
Client Sample ID: 65-11-8-C1-650 -Aqua**Collection Date:** 8/11/2016 10:51:00AM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
VOC 524.2		EPA 524.2						Analyst: NKK	
Benzene	BDL	0.130	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	8/16/2016 4:15:00PM

PACE Analytical**Date:** 1/24/2017**CLIENT:** Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project**Lab Order:** 16H0915**Lab ID:** 16H0915-11
Client Sample ID: 45-11-8-FB-650**Collection Date:** 8/11/2016 7:18:00PM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
VOC 524.2									
		EPA 524.2							
								Analyst: NKK	
Benzene	BDL	0.130	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	8/16/2016 4:35:00PM

PACE Analytical

Date: 1/24/2017

CLIENT: Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project**Lab Order:** 16H0915**Lab ID:** 16H0915-12
Client Sample ID: 45-11-8-C1-650**Collection Date:** 8/11/2016 2:18:00PM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
VOC 524.2									
		EPA 524.2							
Benzene	BDL	0.130	0.500		ug/L	1	1634207	8/16/2016 8:16:00AM	8/16/2016 4:54:00PM

Analyst: NKK

CLIENT: Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project

Lab Order: 16H0915

Lab ID: 16H0915-13
Client Sample ID: 45-11-8-C2-650

Collection Date: 8/11/2016 3:18:00PM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
VOC 524.2		EPA 524.2						Analyst: NKK	
Benzene	0.300	0.130	0.500	J	ug/L	1	1634207	8/16/2016 8:16:00AM	8/16/2016 5:13:00PM

CLIENT: Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project

Lab Order: 16H0915

Lab ID: 16H0915-14
Client Sample ID: 45-11-8-C3-650

Collection Date: 8/11/2016 4:18:00PM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
VOC 524.2									
			EPA 524.2						Analyst: NKK
Benzene	0.400	0.130	0.500	J	ug/L	1	1634279	8/17/2016 8:50:00AM	8/17/2016 2:18:00PM

Date: 1/24/2017

Lab Order: 16H0915

Collection Date: 8/11/2016 5:18:00PM
Matrix: Water

Analyst: NKK

CLIENT: Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project

Lab Order: 16H0915

Lab ID: 16H0915-16
Client Sample ID: 45-11-8-C5-650

Collection Date: 8/11/2016 6:18:00PM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
VOC 524.2									
		EPA 524.2						Analyst: NKK	
Benzene	0.680	0.130	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	8/17/2016 2:57:00PM

CLIENT: Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project

Lab Order: 16H0915

Lab ID: 16H0915-17
Client Sample ID: 45-11-8-C6-650

Collection Date: 8/11/2016 7:18:00PM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
VOC 524.2									
		EPA 524.2						Analyst: NKK	
Benzene	0.750	0.130	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	8/17/2016 3:16:00PM

Date: 1/24/2017

Lab Order: 16H0915

Collection Date: 8/12/2016 10:30:00AM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
VOC 524.2		EPA 524.2						Analyst: NKK	
Benzene	BDL	0.130	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	8/17/2016 3:36:00PM

Date: 1/24/2017

Lab Order: 16H0915

Collection Date: 8/12/2016 9:59:00AM
Matrix: Water

Analyst: NKK

Date: 1/24/2017

Lab Order: 16H0915

Collection Date: 8/12/2016 9:59:00AM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
VOC 524.2		EPA 524.2						Analyst: NKK	
Benzene	BDL	0.130	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	8/17/2016 4:15:00PM

Lab Order: 16H0915

Collection Date: 8/12/2016 10:30:00AM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
VOC 524.2	EPA 524.2			Analyst: NKK					
Benzene	7.30	0.130	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	8/17/2016 4:34:00PM

Date: 1/24/2017

Lab Order: 16H0915

Collection Date: 8/12/2016 10:30:00AM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
VOC 524.2		EPA 524.2						Analyst: NKK	
Benzene	BDL	0.130	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	8/17/2016 4:53:00PM

CLIENT: Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project

Lab Order: 16H0915

Lab ID: 16H0915-23
Client Sample ID: Trip Blank [65-11-8-TB-Aqua]

Collection Date: 8/10/2016 6:20:00PM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
VOC 524.2_TB		EPA 524.2						Analyst: ACH	
1,1,1,2-Tetrachloroethane	BDL	0.133	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
1,1,1-Trichloroethane	BDL	0.158	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
1,1,2,2-Tetrachloroethane	BDL	0.113	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
1,1,2-Trichloroethane	BDL	0.162	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
1,1-Dichloroethane	BDL	0.127	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
1,1-Dichloroethene	BDL	0.245	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
1,1-Dichloropropene	BDL	0.123	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
1,2,3-Trichlorobenzene	BDL	0.119	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
1,2,3-Trichloropropane	BDL	0.162	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
1,2,4-Trichlorobenzene	BDL	0.0745	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
1,2,4-Trimethylbenzene	BDL	0.0832	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
1,2-Dibromoethane	BDL	0.160	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
1,2-Dichlorobenzene	BDL	0.129	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
1,2-Dichloroethane	BDL	0.127	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
1,2-Dichloropropane	BDL	0.101	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
1,3,5-Trimethylbenzene	BDL	0.0846	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
1,3-Dichlorobenzene	BDL	0.128	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
1,3-Dichloropropane	BDL	0.173	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
1,4-Dichlorobenzene	BDL	0.147	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
2,2-Dichloropropane	BDL	0.0905	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
2-Chlorotoluene	BDL	0.113	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
4-Chlorotoluene	BDL	0.0992	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
4-Isopropyltoluene	BDL	0.0905	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
Benzene	BDL	0.130	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	8/17/2016 5:13:00PM
Bromobenzene	BDL	0.120	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
Bromochloromethane	BDL	0.116	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
Bromodichloromethane	BDL	0.133	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
Bromoform	BDL	0.0884	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
Bromomethane	BDL	0.216	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
Carbon Tetrachloride	BDL	0.108	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
Chlorobenzene	BDL	0.137	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
Chloroethane	BDL	0.137	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
Chloroform	BDL	0.103	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
Chloromethane	BDL	0.150	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
cis-1,2-Dichloroethene	BDL	0.130	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
cis-1,3-Dichloropropene	BDL	0.115	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
Dibromochloromethane	BDL	0.0940	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
Dibromomethane	BDL	0.129	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
Dichlorodifluoromethane	BDL	0.133	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
Ethylbenzene	BDL	0.133	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
Xylenes (Total)	BDL	0.340	1.00		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
Hexachlorobutadiene	BDL	0.122	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM

CLIENT: Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project

Lab Order: 16H0915

Lab ID: 16H0915-23
Client Sample ID: Trip Blank [65-11-8-TB-Aqua]

Collection Date: 8/10/2016 6:20:00PM
Matrix: Water

Analysis	Result	MDL	PQL	Qual	Units	Dilution	Batch	Date Prepared	Date Analyzed
Isopropylbenzene	BDL	0.133	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
Methylene Chloride	BDL	0.193	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
Methyl tert-Butyl Ether	BDL	0.0940	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
Naphthalene	BDL	0.126	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
n-Butylbenzene	BDL	0.100	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
n-Propylbenzene	BDL	0.0920	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
sec-Butylbenzene	BDL	0.120	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
Styrene	BDL	0.104	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
tert-Butylbenzene	BDL	0.121	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
Tetrachloroethene	BDL	0.155	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
Toluene	BDL	0.127	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
trans-1,2-Dichloroethene	BDL	0.101	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
trans-1,3-Dichloropropene	BDL	0.128	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
Trichloroethene	BDL	0.113	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
Trichlorofluoromethane	BDL	0.0745	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
Vinyl Chloride	BDL	0.143	0.500		ug/L	1	1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
Surrogate: 1,2-Dichlorobenzene-d4	%				70-130		1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM
Surrogate: 4-Bromofluorobenzene	%				70-130		1634279	8/17/2016 8:50:00AM	1/24/2017 3:01:57PM

CLIENT: Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project

Lab Order: 16H0915

Volatile Organic Compounds by EPA 524.2 - Quality Control

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch 1634207 - VOC PREP										
Blank (1634207-BLK1)				Prepared & Analyzed: 08/16/16						
Benzene	BDL	0.500	ug/L							
LCS (1634207-BS1)				Prepared: 08/16/16 Analyzed: 01/24/17						
1,1,1,2-Tetrachloroethane	BDL	0.500	ug/L	5.000			70-130			
1,1,1-Trichloroethane	BDL	0.500	ug/L	5.000			70-130			
1,1,2,2-Tetrachloroethane	BDL	0.500	ug/L	5.000			70-130			
1,1,2-Trichloroethane	BDL	0.500	ug/L	5.000			70-130			
1,1-Dichloroethane	BDL	0.500	ug/L	5.000			70-130			
1,1-Dichloroethene	BDL	0.500	ug/L	5.000			70-130			
1,1-Dichloropropene	BDL	0.500	ug/L	5.000			70-130			
1,2,3-Trichlorobenzene	BDL	0.500	ug/L	5.000			70-130			
1,2,3-Trichloropropane	BDL	0.500	ug/L	5.000			70-130			
1,2,4-Trichlorobenzene	BDL	0.500	ug/L	5.000			70-130			
1,2,4-Trimethylbenzene	BDL	0.500	ug/L	5.000			70-130			
1,2-Dibromochloroethane	BDL	0.500	ug/L	5.000			70-130			
1,2-Dichlorobenzene	BDL	0.500	ug/L	5.000			70-130			
1,2-Dichloroethane	BDL	0.500	ug/L	5.000			70-130			
1,2-Dichloropropane	BDL	0.500	ug/L	5.000			70-130			
1,3,5-Trimethylbenzene	BDL	0.500	ug/L	5.000			70-130			
1,3-Dichlorobenzene	BDL	0.500	ug/L	5.000			70-130			
1,3-Dichloropropane	BDL	0.500	ug/L	5.000			70-130			
1,4-Dichlorobenzene	BDL	0.500	ug/L	5.000			70-130			
2,2-Dichloropropane	BDL	0.500	ug/L	5.000			70-130			
2-Chlorotoluene	BDL	0.500	ug/L	5.000			70-130			
4-Chlorotoluene	BDL	0.500	ug/L	5.000			70-130			
4-Isopropyltoluene	BDL	0.500	ug/L	5.000			70-130			
Benzene	4.33	0.500	ug/L	5.000		86.6	70-130			
Bromobenzene	BDL	0.500	ug/L	5.000			70-130			
Bromochloromethane	BDL	0.500	ug/L	5.000			70-130			
Bromodichloromethane	BDL	0.500	ug/L	5.000			70-130			
Bromoform	BDL	0.500	ug/L	5.000			70-130			
Bromomethane	BDL	0.500	ug/L	5.000			70-130			
Carbon Tetrachloride	BDL	0.500	ug/L	5.000			70-130			
Chlorobenzene	BDL	0.500	ug/L	5.000			70-130			
Chloroethane	BDL	0.500	ug/L	5.000			70-130			
Chloroform	BDL	0.500	ug/L	5.000			70-130			
Chloromethane	BDL	0.500	ug/L	5.000			70-130			
cis-1,2-Dichloroethene	BDL	0.500	ug/L	5.000			70-130			
cis-1,3-Dichloropropene	BDL	0.500	ug/L	5.000			70-130			
Dibromochloromethane	BDL	0.500	ug/L	5.000			70-130			
Dibromomethane	BDL	0.500	ug/L	5.000			70-130			
Dichlorodifluoromethane	BDL	0.500	ug/L	5.000			70-130			
Ethylbenzene	BDL	0.500	ug/L	5.000			70-130			
Xylenes (Total)	BDL	0.500	ug/L	15.00			70-130			
Hexachlorobutadiene	BDL	0.500	ug/L	5.000			70-130			

CLIENT: Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project

Lab Order: 16H0915

Volatile Organic Compounds by EPA 524.2 - Quality Control

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch 1634207 - VOC PREP										
LCS (1634207-BS1)				Prepared: 08/16/16 Analyzed: 01/24/17						
Isopropylbenzene	BDL	0.500	ug/L	5.000			70-130			
Methylene Chloride	BDL	0.500	ug/L	5.000			70-130			
Methyl tert-Butyl Ether	BDL	0.500	ug/L	5.000			70-130			
Naphthalene	BDL	0.500	ug/L	5.000			70-130			
n-Butylbenzene	BDL	0.500	ug/L	5.000			70-130			
n-Propylbenzene	BDL	0.500	ug/L	5.000			70-130			
sec-Butylbenzene	BDL	0.500	ug/L	5.000			70-130			
Styrene	BDL	0.500	ug/L	5.000			70-130			
tert-Butylbenzene	BDL	0.500	ug/L	5.000			70-130			
Tetrachloroethene	BDL	0.500	ug/L	5.000			70-130			
Toluene	BDL	0.500	ug/L	5.000			70-130			
trans-1,2-Dichloroethene	BDL	0.500	ug/L	5.000			70-130			
trans-1,3-Dichloropropene	BDL	0.500	ug/L	5.000			70-130			
Trichloroethene	BDL	0.500	ug/L	5.000			70-130			
Trichlorofluoromethane	BDL	0.500	ug/L	5.000			70-130			
Vinyl Chloride	BDL	0.500	ug/L	5.000			70-130			
Surrogate: 1,2-Dichlorobenzene-d4	0.00		ug/L	10.00			70-130			
Surrogate: 4-Bromofluorobenzene	0.00		ug/L	10.00			70-130			

Batch 1634279 - VOC PREP

Blank (1634279-BLK1)				Prepared: 08/17/16 Analyzed: 01/24/17						
1,1,1,2-Tetrachloroethane	BDL	0.500	ug/L							
1,1,1-Trichloroethane	BDL	0.500	ug/L							
1,1,2,2-Tetrachloroethane	BDL	0.500	ug/L							
1,1,2-Trichloroethane	BDL	0.500	ug/L							
1,1-Dichloroethane	BDL	0.500	ug/L							
1,1-Dichloroethene	BDL	0.500	ug/L							
1,1-Dichloropropene	BDL	0.500	ug/L							
1,2,3-Trichlorobenzene	BDL	0.500	ug/L							
1,2,3-Trichloropropane	BDL	0.500	ug/L							
1,2,4-Trichlorobenzene	BDL	0.500	ug/L							
1,2,4-Trimethylbenzene	BDL	0.500	ug/L							
1,2-Dibromochloroethane	BDL	0.500	ug/L							
1,2-Dichlorobenzene	BDL	0.500	ug/L							
1,2-Dichloroethane	BDL	0.500	ug/L							
1,2-Dichloropropane	BDL	0.500	ug/L							
1,3,5-Trimethylbenzene	BDL	0.500	ug/L							
1,3-Dichlorobenzene	BDL	0.500	ug/L							
1,3-Dichloropropane	BDL	0.500	ug/L							
1,4-Dichlorobenzene	BDL	0.500	ug/L							
2,2-Dichloropropane	BDL	0.500	ug/L							
2-Chlorotoluene	BDL	0.500	ug/L							
4-Chlorotoluene	BDL	0.500	ug/L							
4-Isopropyltoluene	BDL	0.500	ug/L							

CLIENT: Naval Medical Research Unit-Dayton
 Project: USUHS-WFA Project

Lab Order: 16H0915

Volatile Organic Compounds by EPA 524.2 - Quality Control

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
---------	--------	--------------------	-------	----------------	------------------	------	----------------	-----	--------------	-------

Batch 1634279 - VOC PREP

Blank (1634279-BLK1)

Prepared & Analyzed: 08/17/16

Benzene	BDL	0.500	ug/L							
Benzene	BDL	0.500	ug/L							
Bromobenzene	BDL	0.500	ug/L							
Bromochloromethane	BDL	0.500	ug/L							
Bromodichloromethane	BDL	0.500	ug/L							
Bromoform	BDL	0.500	ug/L							
Bromomethane	BDL	0.500	ug/L							
Carbon Tetrachloride	BDL	0.500	ug/L							
Chlorobenzene	BDL	0.500	ug/L							
Chloroethane	BDL	0.500	ug/L							
Chloroform	BDL	0.500	ug/L							
Chloromethane	BDL	0.500	ug/L							
cis-1,2-Dichloroethene	BDL	0.500	ug/L							
cis-1,3-Dichloropropene	BDL	0.500	ug/L							
Dibromochloromethane	BDL	0.500	ug/L							
Dibromomethane	BDL	0.500	ug/L							
Dichlorodifluoromethane	BDL	0.500	ug/L							
Ethylbenzene	BDL	0.500	ug/L							
Xylenes (Total)	BDL	1.00	ug/L							
Hexachlorobutadiene	BDL	0.500	ug/L							
Isopropylbenzene	BDL	0.500	ug/L							
Methylene Chloride	BDL	0.500	ug/L							
Methyl tert-Butyl Ether	BDL	0.500	ug/L							
Naphthalene	BDL	0.500	ug/L							
n-Butylbenzene	BDL	0.500	ug/L							
n-Propylbenzene	BDL	0.500	ug/L							
sec-Butylbenzene	BDL	0.500	ug/L							
Styrene	BDL	0.500	ug/L							
tert-Butylbenzene	BDL	0.500	ug/L							
Tetrachloroethene	BDL	0.500	ug/L							
Toluene	BDL	0.500	ug/L							
trans-1,2-Dichloroethene	BDL	0.500	ug/L							
trans-1,3-Dichloropropene	BDL	0.500	ug/L							
Trichloroethene	BDL	0.500	ug/L							
Trichlorofluoromethane	BDL	0.500	ug/L							
Vinyl Chloride	BDL	0.500	ug/L							
Surrogate: 1,2-Dichlorobenzene-d4	0.00		ug/L	10.00			70-130			
Surrogate: 4-Bromofluorobenzene	0.00		ug/L	10.00			70-130			

CLIENT: Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project

Lab Order: 16H0915

Volatile Organic Compounds by EPA 524.2 - Quality Control

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
---------	--------	-----------------	-------	-------------	---------------	------	-------------	-----	-----------	-------

Batch 1634279 - VOC PREP

LCS (1634279-BS1)

Prepared: 08/17/16 Analyzed: 01/24/17

1,1,1,2-Tetrachloroethane	BDL	0.500	ug/L	5.000			70-130			
1,1,1,2-Tetrachloroethane	BDL	0.500	ug/L	5.000			70-130			
1,1,1-Trichloroethane	BDL	0.500	ug/L	5.000			70-130			
1,1,1-Trichloroethane	BDL	0.500	ug/L	5.000			70-130			
1,1,2,2-Tetrachloroethane	BDL	0.500	ug/L	5.000			70-130			
1,1,2,2-Tetrachloroethane	BDL	0.500	ug/L	5.000			70-130			
1,1,2-Trichloroethane	BDL	0.500	ug/L	5.000			70-130			
1,1,2-Trichloroethane	BDL	0.500	ug/L	5.000			70-130			
1,1-Dichloroethane	BDL	0.500	ug/L	5.000			70-130			
1,1-Dichloroethane	BDL	0.500	ug/L	5.000			70-130			
1,1-Dichloroethene	BDL	0.500	ug/L	5.000			70-130			
1,1-Dichloroethene	BDL	0.500	ug/L	5.000			70-130			
1,1-Dichloropropene	BDL	0.500	ug/L	5.000			70-130			
1,1-Dichloropropene	BDL	0.500	ug/L	5.000			70-130			
1,2,3-Trichlorobenzene	BDL	0.500	ug/L	5.000			70-130			
1,2,3-Trichlorobenzene	BDL	0.500	ug/L	5.000			70-130			
1,2,3-Trichloropropane	BDL	0.500	ug/L	5.000			70-130			
1,2,3-Trichloropropane	BDL	0.500	ug/L	5.000			70-130			
1,2,4-Trichlorobenzene	BDL	0.500	ug/L	5.000			70-130			
1,2,4-Trichlorobenzene	BDL	0.500	ug/L	5.000			70-130			
1,2,4-Trimethylbenzene	BDL	0.500	ug/L	5.000			70-130			
1,2,4-Trimethylbenzene	BDL	0.500	ug/L	5.000			70-130			
1,2-Dibromoethane	BDL	0.500	ug/L	5.000			70-130			
1,2-Dibromoethane	BDL	0.500	ug/L	5.000			70-130			
1,2-Dichlorobenzene	BDL	0.500	ug/L	5.000			70-130			
1,2-Dichlorobenzene	BDL	0.500	ug/L	5.000			70-130			
1,2-Dichloroethane	BDL	0.500	ug/L	5.000			70-130			
1,2-Dichloroethane	BDL	0.500	ug/L	5.000			70-130			
1,2-Dichloropropane	BDL	0.500	ug/L	5.000			70-130			
1,2-Dichloropropane	BDL	0.500	ug/L	5.000			70-130			
1,3,5-Trimethylbenzene	BDL	0.500	ug/L	5.000			70-130			
1,3,5-Trimethylbenzene	BDL	0.500	ug/L	5.000			70-130			
1,3-Dichlorobenzene	BDL	0.500	ug/L	5.000			70-130			
1,3-Dichlorobenzene	BDL	0.500	ug/L	5.000			70-130			
1,3-Dichloropropane	BDL	0.500	ug/L	5.000			70-130			
1,3-Dichloropropane	BDL	0.500	ug/L	5.000			70-130			
1,4-Dichlorobenzene	BDL	0.500	ug/L	5.000			70-130			
1,4-Dichlorobenzene	BDL	0.500	ug/L	5.000			70-130			
2,2-Dichloropropane	BDL	0.500	ug/L	5.000			70-130			
2,2-Dichloropropane	BDL	0.500	ug/L	5.000			70-130			
2-Chlorotoluene	BDL	0.500	ug/L	5.000			70-130			
2-Chlorotoluene	BDL	0.500	ug/L	5.000			70-130			
4-Chlorotoluene	BDL	0.500	ug/L	5.000			70-130			
4-Chlorotoluene	BDL	0.500	ug/L	5.000			70-130			
4-Isopropyltoluene	BDL	0.500	ug/L	5.000			70-130			

CLIENT: Naval Medical Research Unit-Dayton
 Project: USUHS-WFA Project

Lab Order: 16H0915

Volatile Organic Compounds by EPA 524.2 - Quality Control

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
---------	--------	-----------------	-------	-------------	---------------	------	-------------	-----	-----------	-------

Batch 1634279 - VOC PREP

LCS (1634279-BS1)

Prepared: 08/17/16 Analyzed: 01/24/17

4-Isopropyltoluene	BDL	0.500	ug/L	5.000			70-130			
Benzene	4.55	0.500	ug/L	5.000		91.0	70-130			
Benzene	4.55	0.500	ug/L	5.000		91.0	70-130			
Bromobenzene	BDL	0.500	ug/L	5.000			70-130			
Bromobenzene	BDL	0.500	ug/L	5.000			70-130			
Bromochloromethane	BDL	0.500	ug/L	5.000			70-130			
Bromochloromethane	BDL	0.500	ug/L	5.000			70-130			
Bromodichloromethane	BDL	0.500	ug/L	5.000			70-130			
Bromodichloromethane	BDL	0.500	ug/L	5.000			70-130			
Bromoform	BDL	0.500	ug/L	5.000			70-130			
Bromoform	BDL	0.500	ug/L	5.000			70-130			
Bromomethane	BDL	0.500	ug/L	5.000			70-130			
Bromomethane	BDL	0.500	ug/L	5.000			70-130			
Carbon Tetrachloride	BDL	0.500	ug/L	5.000			70-130			
Carbon Tetrachloride	BDL	0.500	ug/L	5.000			70-130			
Chlorobenzene	BDL	0.500	ug/L	5.000			70-130			
Chlorobenzene	BDL	0.500	ug/L	5.000			70-130			
Chloroethane	BDL	0.500	ug/L	5.000			70-130			
Chloroethane	BDL	0.500	ug/L	5.000			70-130			
Chloroform	BDL	0.500	ug/L	5.000			70-130			
Chloroform	BDL	0.500	ug/L	5.000			70-130			
Chloromethane	BDL	0.500	ug/L	5.000			70-130			
Chloromethane	BDL	0.500	ug/L	5.000			70-130			
cis-1,2-Dichloroethene	BDL	0.500	ug/L	5.000			70-130			
cis-1,2-Dichloroethene	BDL	0.500	ug/L	5.000			70-130			
cis-1,3-Dichloropropene	BDL	0.500	ug/L	5.000			70-130			
cis-1,3-Dichloropropene	BDL	0.500	ug/L	5.000			70-130			
Dibromochloromethane	BDL	0.500	ug/L	5.000			70-130			
Dibromochloromethane	BDL	0.500	ug/L	5.000			70-130			
Dibromomethane	BDL	0.500	ug/L	5.000			70-130			
Dibromomethane	BDL	0.500	ug/L	5.000			70-130			
Dichlorodifluoromethane	BDL	0.500	ug/L	5.000			70-130			
Dichlorodifluoromethane	BDL	0.500	ug/L	5.000			70-130			
Ethylbenzene	BDL	0.500	ug/L	5.000			70-130			
Ethylbenzene	BDL	0.500	ug/L	5.000			70-130			
Xylenes (Total)	BDL	0.500	ug/L	15.00			70-130			
Xylenes (Total)	BDL	1.00	ug/L	15.00			70-130			
Hexachlorobutadiene	BDL	0.500	ug/L	5.000			70-130			IS-01
Hexachlorobutadiene	BDL	0.500	ug/L	5.000			70-130			IS-01
Isopropylbenzene	BDL	0.500	ug/L	5.000			70-130			
Isopropylbenzene	BDL	0.500	ug/L	5.000			70-130			
Methylene Chloride	BDL	0.500	ug/L	5.000			70-130			
Methylene Chloride	BDL	0.500	ug/L	5.000			70-130			
Methyl tert-Butyl Ether	BDL	0.500	ug/L	5.000			70-130			
Methyl tert-Butyl Ether	BDL	0.500	ug/L	5.000			70-130			

CLIENT: Naval Medical Research Unit-Dayton
 Project: USUHS-WFA Project

Lab Order: 16H0915

Volatile Organic Compounds by EPA 524.2 - Quality Control

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch 1634279 - VOC PREP										
LCS (1634279-BS1)				Prepared: 08/17/16 Analyzed: 01/24/17						
Naphthalene	BDL	0.500	ug/L	5.000			70-130			
Naphthalene	BDL	0.500	ug/L	5.000			70-130			
n-Butylbenzene	BDL	0.500	ug/L	5.000			70-130			
n-Butylbenzene	BDL	0.500	ug/L	5.000			70-130			
n-Propylbenzene	BDL	0.500	ug/L	5.000			70-130			
n-Propylbenzene	BDL	0.500	ug/L	5.000			70-130			
sec-Butylbenzene	BDL	0.500	ug/L	5.000			70-130			
sec-Butylbenzene	BDL	0.500	ug/L	5.000			70-130			
Styrene	BDL	0.500	ug/L	5.000			70-130			
Styrene	BDL	0.500	ug/L	5.000			70-130			
tert-Butylbenzene	BDL	0.500	ug/L	5.000			70-130			
tert-Butylbenzene	BDL	0.500	ug/L	5.000			70-130			
Tetrachloroethene	BDL	0.500	ug/L	5.000			70-130			
Tetrachloroethene	BDL	0.500	ug/L	5.000			70-130			
Toluene	BDL	0.500	ug/L	5.000			70-130			
Toluene	BDL	0.500	ug/L	5.000			70-130			
trans-1,2-Dichloroethene	BDL	0.500	ug/L	5.000			70-130			
trans-1,2-Dichloroethene	BDL	0.500	ug/L	5.000			70-130			
trans-1,3-Dichloropropene	BDL	0.500	ug/L	5.000			70-130			
trans-1,3-Dichloropropene	BDL	0.500	ug/L	5.000			70-130			
Trichloroethene	BDL	0.500	ug/L	5.000			70-130			
Trichloroethene	BDL	0.500	ug/L	5.000			70-130			
Trichlorofluoromethane	BDL	0.500	ug/L	5.000			70-130			L
Trichlorofluoromethane	BDL	0.500	ug/L	5.000			70-130			L
Vinyl Chloride	BDL	0.500	ug/L	5.000			70-130			
Vinyl Chloride	BDL	0.500	ug/L	5.000			70-130			
Surrogate: 1,2-Dichlorobenzene-d4	0.00		ug/L	10.00			70-130			
Surrogate: 1,2-Dichlorobenzene-d4	0.00		ug/L	10.00			70-130			
Surrogate: 4-Bromofluorobenzene	0.00		ug/L	10.00			70-130			
Surrogate: 4-Bromofluorobenzene	0.00		ug/L	10.00			70-130			

CLIENT: Naval Medical Research Unit-Dayton
Project: USUHS-WFA Project

Lab Order: 16H0915

Notes and Definitions

- P Sample preservation does not meet method specified requirements.
- L Laboratory control sample recovery outside of acceptance limits high, sample results are below detection limits. Sample data is still acceptable.
- J Estimated Value less than the Reporting Limit, but above the Method Detection Limit. Not valid for quantitative use.
- IS-01 Associated internal standard outside of control limits low, leading to a high bias. No hits were detected in the sample
- BDL Analyte is below detection limits
- Sample preservation was met unless otherwise noted.

Page 35 of 38

F-FALL-Q-Q20rev.07. 15-May-2007

The Chain-of-Custody is a LEGAL DOCUMENT. All relevant fields must be completed accurately

Page 36 of 38ORIGINAL

The Chain-of-Custody is a LEGAL DOCUMENT. All relevant fields must be completed accurately.

Page 37 of 38

ORIGINAL

F-ALL-Q-020rev.07; 15-May-2007

The Chain-of-Custody is a **LEGAL DOCUMENT**. All relevant fields must be completed accurately,

Page 38 of 38ORIGINAL