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CHARACTERISTICS AND SAMPLING EFFICIENCIES OF TWO BIOGUARDIAN® 12.03 AEROSOL SAMPLERS

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PREFACE

The work described in this report was authorized under Project No. 622384/ACB2. The work was started in October 2003 and completed in November 2003.

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CONTENTS

1.	INTRODUCTION	7
2.	EQUIPMENT AND FACILITIES	7
2.1	Chamber.....	7
2.2	Improved BioGuardian® 12.03 (BG12.03).....	8
2.3	Sampler Characteristics Measurements	8
3.	TEST PROCEDURES AND ANALYSIS.....	8
3.1	Sampling Efficiency Measurements	8
3.2	PSL Microsphere Tests.....	9
3.3	Sodium Fluorescein Tagged Oleic Acid (Fluorescent Oleic Acid) Tests.....	10
3.4	Analysis	10
4.	RESULTS	10
5.	DISCUSSION.....	12
6.	CONCLUSIONS	12
7.	RECOMMENDATIONS FOR FUTURE WORK	12
	LITERATURE CITED	13

FIGURES

1.	BioGuardian® (BG12.03).....	9
2.	Sampling Efficiencies for BG12.03-1 and BG12.03-2.....	11

TABLE

Sampler Characteristics and Efficiencies for BG12.03-1 and BG12.03-2.....	11
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CHARACTERISTICS AND SAMPLING EFFICIENCIES OF TWO BIOGUARDIAN® 12.03 AEROSOL SAMPLERS

1. INTRODUCTION

This technical note is one in a continuing series of short reports intended to document and preserve the record of data from characterizing aerosol collector technology. These reports are only "snapshots" of progress as part of a Department of Defense (DOD) technology watch on the evolution of a critical supporting technology for biodetection capability. This report is not intended to be a comprehensive study or analysis. For such studies, look for documents in the technical report series. A technical note simply records a limited set of observations and provides the company that provided the device for characterization with a record of the data measured.

Air samplers are gaining importance in the war against terrorism and on the battlefield to detect the presence of chemical, biological, and nuclear aerosols. Samplers and detection systems must be tested and their performance efficiencies determined so that suitable samplers and detectors can be used for each condition. Knowledge of equipment performance enhances the ability to protect soldiers, first responders, and the general public.

Air samplers for biological materials must collect them in a gentle manner to reduce destruction of the organism if the analysis method requires live organisms. Vegetative bacteria may be killed if collected dry; therefore, to reduce the drying of the organism, samplers may collect biological material in liquid. An ideal biological sampler should be small, portable, use minimal power, and have a high sampling efficiency.

In this study, characteristics and sampling efficiencies of two BioGuardian® aerosol samplers were evaluated. InnovaTek, Incorporated (Richland, WA) manufactured the samples, which were only available for 2 weeks of testing; therefore, the number of tests and the number of particle sizes tested were limited. Each sampler's characteristics (e.g., size, weight, airflow rate, and power consumption) were measured. These studies were conducted at calm air conditions and do not include inlet efficiencies at varying wind velocities.

2. EQUIPMENT AND FACILITIES

2.1 Chamber.

Tests were conducted in a 70-m³ biosafety level 1 chamber at the U.S. Army Edgewood Chemical Biological Center (ECBC). Temperature and humidity of the chamber can be set and maintained easily and accurately by a computer. The computer also controls power receptacles inside the chamber.

HEPA filters are installed at the air inlet to filter the air entering the chamber to achieve very low particle concentrations in the chamber. Similarly, HEPA filters are installed at the exhaust port to filter particles leaving the chamber. The aerosol concentration in the chamber is reduced by exhausting chamber air through the HEPA filters, and by pumping HEPA-filtered air into the chamber. The maximum amount of airflow that the exhaust pump can exhaust from the chamber is approximately 700 ft³/min (approximately 2x10⁴ L/min). There is also a small re-circulation system that removes air from the chamber, passes it through a HEPA filter, and delivers it back to the chamber. This system is useful when the aerosol concentration in the chamber needs to be reduced by a small amount.

Aerosols can either be generated outside and delivered to the chamber, or they can be generated inside the chamber. A fan mixes chamber air before and/or during the experiment to achieve uniform aerosol concentration in the chamber. Previous tests show that mixing the aerosol in the chamber for 1 min is adequate to achieve uniform aerosol concentration.

2.2 Improved BioGuardian® 12.03 (BG12.03).

Two BioGuardian® aerosol samplers (BG12.03-1 and BG12.03-2) were tested at ECBC. A picture of the BG12.03 is shown in Figure 1. BioGuardian® 12.03 is improved from BG12.02 in that the machining of the interior cyclone was improved to achieve a more finished surface. These two samplers were of the same make and model with the following serial numbers: BG12.03-1 = 0009, BG12.03-2 = 0010. These two devices were provided on loan from InnovaTek for the characterization experiments. BG12.03 has 12 wetted wall cyclones for aerosol collection. This is a programmable sampler that can sample from 5 s to 24 hr, and the computer can adjust the liquid input to the cyclone. There is a preseparator to remove large particles before the air enters the cyclones. The designed airflow rate is 1000 L/min; however, the airflow rate measurements at ECBC were low (BG12.03-1 = 896.4 L/min; BG12.03-2 = 824.2 L/min). It is speculated that the small diameter flow meter used in the laboratory to make these measurements created a pressure drop that reduced the airflow through the sampler. Therefore, a flowrate of 1000 L/min was used in the calculation. The BG12.03 is a cylindrical sampler that is 25 in. tall and 14.5 in. in diameter, and weighs approximately 70 lb (manufacturer reported).

2.3 Sampler Characteristics Measurements.

The airflow rates of the reference filters and samplers were measured using a Buck Calibrator (A.P. Buck, Incorporated, Orlando, FL) and Kurz airflow meter (Kurz Instruments, Incorporated, Monterey, CA). The weight and dimensions of the samplers were measured, and the power usage was measured using a power meter (Extech Instruments, Taiwan).

3. TEST PROCEDURES AND ANALYSIS

3.1 Sampling Efficiency Measurements.

Sampling efficiency tests were conducted with 1-, 2-, and 3- μ m fluorescent PSL microspheres and 4.5- and 8.5- μ m fluorescent oleic acid particles. The precollector was removed, and the sampling efficiency tests were conducted with 5- and 8.5- μ m fluorescent oleic acid particles to determine the effect of the precollector. Tests were conducted with 10-min sampling times. The samplers and corresponding reference filters sampled the air simultaneously and for the same amount of time. The samplers were prewashed before each test to ensure that they were free of fluorescent material. Many washes were conducted to remove the fluorescent material from the samplers after each test. If there was a significant amount of fluorescence in the prewash solution, it was subtracted from the sample fluorescence.

Sampling efficiency tests were conducted with two kinds of aerosols and corresponding analysis methods. The first method used monodisperse fluorescent PSL microspheres, and the second method used monodisperse fluorescent oleic acid particles. Aerosol generation and analysis methods are described in Sections 3.3 and 3.4.

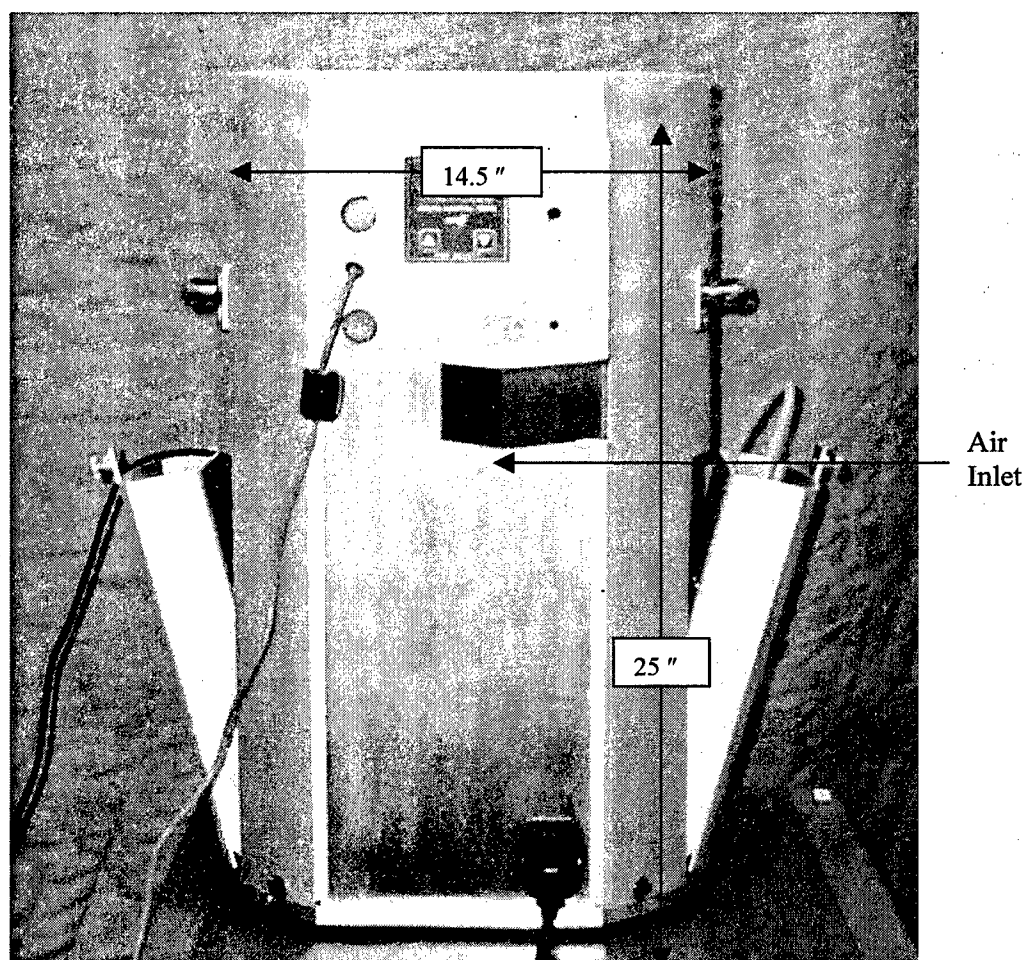


Figure 1. BioGuardian® (BG12.03)

3.2 PSL Microsphere Tests.

Sampling efficiency tests were conducted with 1-, 2-, and 3- μ m blue fluorescent PSL microspheres (Duke Scientific, Corporation, Palo Alto, CA). The PSL aerosol was generated using a 24-jet Collison nebulizer, then passed through a radioactive isotope (Kr-85) neutralizer to reduce the charge on particles. The aerosol was generated for 10 min, and mixed in the chamber for 1 min before sampling.

The samplers and the corresponding reference filters sampled the PSL aerosol simultaneously and for the same amount of time. Polycarbonate membrane filters (Osmonics Incorporated, Minnetonka, MN) were used as reference filters to collect the fluorescent PSL microspheres. All samplers used the manufacturer's recommended liquid for collecting PSL microspheres. After sampling, the sample liquid and reference filters were collected. Sample liquids were directly analyzed by the fluorometer; however, the membrane filters were processed to remove

microspheres from the filters into the liquid for fluorometer analysis. The removal procedure consisted of placing each membrane filter into 20 mL of filtered deionized water, and shaking the mixture by hand for 30 s. The test tubes were then vortexed in a holder for 30 min. The samples were removed from the vortexer every 10 min and were shaken by hand for 10 s.

3.3 Sodium Fluorescein Tagged Oleic Acid (Fluorescent Oleic Acid) Tests.

Sampling efficiency tests were also conducted with 4.5, 5, and 8.5 μm fluorescent oleic acid particles. The monodisperse fluorescent oleic acid particles were generated using a Vibrating Orifice Aerosol Generator (VOAG, TSI Incorporated, St. Paul, MN). As with the PSL tests, the generated aerosol was passed through a Kr-85 radioactive isotope neutralizer to eliminate the charge on particles, and then delivered to the chamber. The sizes of the fluorescent oleic acid particles were determined by sampling the aerosol onto a microscope slide inserted into an impactor. Then, the droplet size was measured with a microscope. The measured fluorescent oleic acid particle diameter was converted to an aerodynamic particle size using a spread factor (Olan-Figueroa et al., 1982).¹ At the end of aerosol generation, the aerosol in the chamber was mixed for 1 min before sampling. The samplers and the corresponding reference filters sampled the aerosol simultaneously and for the same amount of time. The samplers used the manufacturer's supplied liquid. Glass fiber filters (Pall Corporation, Ann Arbor, MI) were used as reference filters to collect fluorescent oleic acid particles.

The pH of samples from the BioGuardian[®] samplers was adjusted to between 8 and 10 by adding NH_4OH before measurement by the fluorometer (Barnstead/Thermolyne, Dubuque, IA). Glass fiber filters were removed from filter holders, placed into a fluorescein recovery solution, and shaken on a table rotator (Cole Parmer, Vernon Hills, IL) for 1 hr. The recovery solution used in the tests had water with a pH between 8 and 10, obtained by adding a small amount of NH_4OH (e.g., 1000 mL of water with 0.563 mL of 14.8 N NH_4OH). Kesavan et al.² describes, in detail, factors that affect fluorescein analysis and the removal of fluorescein from filters. The fluorescence of the solution was measured using a fluorometer. All the samples were analyzed either the same day of the experiment or the next day.

3.4 Analysis.

The sampling efficiency using the fluorescent method was determined by comparing the fluorometer-measured fluorescence of the sampler liquids to the reference filters. The airflow rate of the samplers and the reference filters, and the liquid volume of the samples and reference solutions were considered in the calculation. An airflow rate of 1000 L/min was used in the calculations even though the measured airflow rate was lower (Section 2.2).

4. RESULTS

The sampler characteristics, sampling efficiency, and concentration factor results of the BG12.03s are shown in the Table and Figure 2. The sampling efficiency results of BG12.03-1 show a peak of $65.6\% \pm 3.6$ and $63.8\% \pm 3.3$ for 2- and 3- μm particles, respectively. The sampling efficiency results of BG12.03-2 show $52.4\% \pm 4.0$ and $56.1\% \pm 1.4$ for 2- and 3- μm particles, respectively. The average liquid output volume of BG12.03-1 was 28.9 ± 2.0 mL. For BG12.03-2, it was 25.1 ± 1.7 mL. Power usage during sampling was 378 W. The sampling efficiency without the preseparator was higher for both BioGuardians[®]. For 8.5- μm particles, the sampling efficiency without the preseparator was $69.2\% \pm 2.1$ for BG12.03-1 and $63.9\% \pm 2.0$ for BG 12.03-2.

Table. Sampler Characteristics and Efficiencies for BG12.03-1 and BG12.03-2.

	<i>BG 12.03-1</i>	<i>BG 12.03-2</i>
<i>Number of Cyclones</i>	12	12
<i>Designed airflow rate (L/min)</i>	1000	1000
<i>Measured airflow rate (L/min)</i>		
<i>With preseparator</i>	896.4	824.1
<i>Without the preseparator</i>	862.6	863.2
<i>Power, measured at ECBC (W)</i>	378	378
<i>Weight (lb) (approximately)</i>	70	70
<i>Dimensions (in.)</i>	Diameter = 14.5 Height = 25	Diameter = 14.5 Height = 25
<i>Sample Volume, mL</i>	28.9 ± 2.02	25.07 ± 1.74
<i>Particle Size (μm)</i>	<i>Sampling Efficiency with the preseparator</i>	<i>Sampling Efficiency with the preseparator</i>
1	51.8 ± 2.9	43.3 ± 2.3
2	65.6 ± 3.6	52.4 ± 4.0
3	63.8 ± 3.3	56.1 ± 1.4
4.5	53.9 ± 5.5	52.4 ± 5.8
8.5	53.6 ± 1.7	46.8 ± 1.2
<i>Particle Size (μm)</i>	<i>Sampling Efficiency without the preseparator</i>	<i>Sampling Efficiency without the preseparator</i>
5	60.6 ± 2.3	57.3 ± 2.7
8.5	69.2 ± 2.1	63.9 ± 2.0

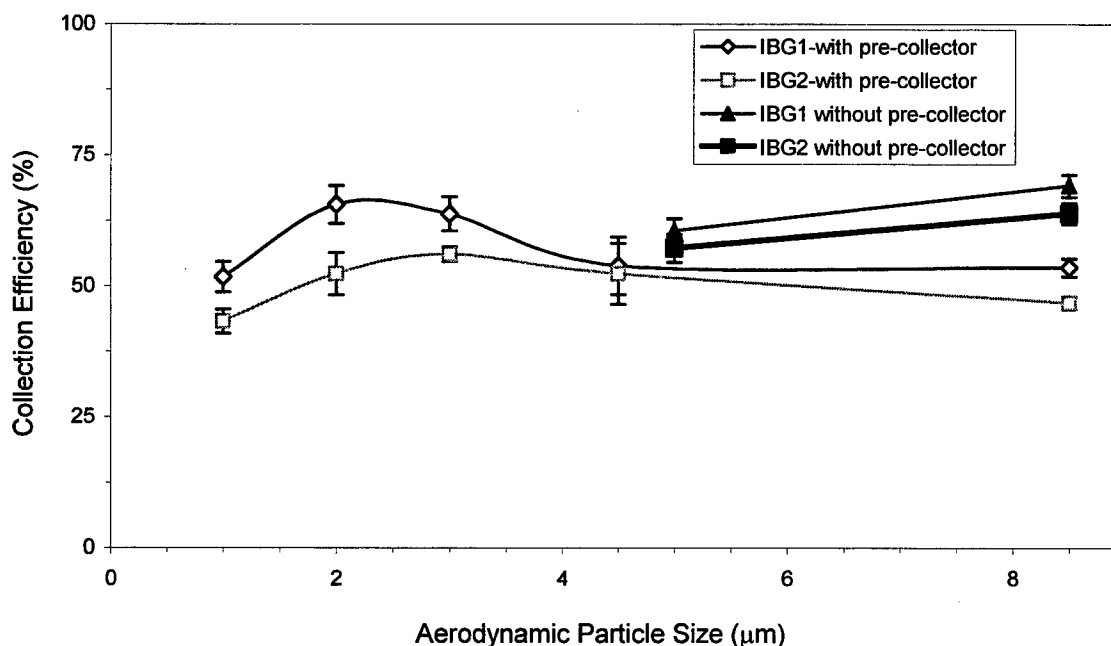


Figure 2. Sampling Efficiencies for BG12.03-1 and BG12.03-2.

5. DISCUSSION

Two BioGuardian® 12.03 (BG12.03) aerosol samplers were characterized at ECBC for 2 weeks. These samplers were provided by InnovaTek and were only available for testing for 2 weeks; therefore, the number of particle sizes and the number of tests were limited. The samplers were prewashed before each test to ensure that they were free of fluorescent material. In tests, if there was a significant amount of fluorescence in the prewash, then the prewash counts were subtracted from the sample counts.

The measured airflow rate at ECBC was <1000 L/min; however, the airflow rate of 1000 L/min (measurement at the manufacturer's facility) was used in the calculations. If the airflow rate through the cyclone during the experiment was less than the rate measured at the manufacturer's laboratory, the sampling efficiency would be higher.

A previous version of the BioGuardian® (BioGuardian® 12.02) was tested with 1- and 2- μ m PSL microspheres and 4- and 6- μ m fluorescent oleic acid particles. The sampling efficiencies for 1-, 2-, 4-, and 6- μ m particles were 26.5%, 31.7%, 31.8%, and 25.8%, respectively. Results show that the BG12.03 has a significantly higher sampling efficiency than the previous version.

The preseparator currently in the system removes particles greater than 5 μ m. For 8.5- μ m particles, the sampling efficiency is $53.6\% \pm 1.7$ with the preseparator and $69.2\% \pm 2.1$ without the preseparator. Either removing or modifying the preseparator will improve the sampling efficiency of particles >5 μ m.

6. CONCLUSIONS

The BioGuardian® 12.03 demonstrated significantly higher collection efficiencies than the previously characterized BioGuardian® 12.02 (Kesavan and Hottell, 2003).³ The preseparator reduces collection of 5- and 8.5- μ m particles. There is a significant difference in the collection efficiency between the two units, even if the flow rate of BG12.03-2 is lower than the rate of BG12.03-1 to the degree (92%) indicated by U.S. Army Edgewood Chemical Biological Center flow measurements.

Information on sampling efficiency, concentration factor, size, weight, airflow rate, and power consumption of the samplers is given in Section 4. The decision to consider a sampler for an application will have to include all the above factors. Readers are advised that some of these samplers may be modified and/or improved based on test results and may be improved as new technology becomes available. Therefore, a modified or improved sampler may have very different characteristics from those discussed in this report.

7. RECOMMENDATIONS FOR FUTURE WORK

Recommendations for future work are listed below:

- Conduct studies to determine the optimum liquid use in the sampler.
- Measure (accurately) flow rate of the sampler at ECBC for accurate sampling efficiency calculations.
- Investigate sampling efficiency with large particle sizes (up to 25 μ m).

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