EDGEWOOD

CHEMICAL BIOLOGICAL CENTER

U.S. ARMY RESEARCH, DEVELOPMENT AND ENGINEERING COMMAND

ECBC-TN-024

CHARACTERISTICS AND SAMPLING EFFICIENCIES OF BIOBADGE® AEROSOL SAMPLERS

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May 2005

ABERDEEN PROVING GROUND, MD 21010-5424

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
XX-05-05	Final	Jan 2000 - Jan 2003

4. TITLE AND SUBTITLE
Characteristics and Sampling Efficiencies of BioBadge® Aerosol Samplers

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Kesavan, Jana S.; Hottell, Karen Aubrey*

5d. PROJECT NUMBER
PR-622384/ACB2

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) AND ADDRESS(ES)
DIR, ECBC, ATTN: AMSRD-ECB-RT-TA, APG, MD 21010-5424

8. PERFORMING ORGANIZATION REPORT NUMBER
ECBC-TN-024

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

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

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

13. SUPPLEMENTARY NOTES
*Student contractor assigned to Research and Technology Directorate, U.S. Army Edgewood Chemical Biological Center (ECBC).

14. ABSTRACT
The aerosol sampling efficiencies of four BioBadge® samplers manufactured by MesoSystem Technology, Incorporated (Richland, WA) were determined at the U.S. Army Edgewood Chemical Biological Center. BioBadge® samplers are battery operated personal samplers that use the rotating impactor/impellor technology to collect particles. Collected particles are removed from the impellor using either the lab or the field method. These methods require that the impellor be put into a zip lock bag with liquid for the particle removal procedure. The lab method sonicates the zip lock bag to remove the collected particles, and the field method claps the zip lock bag using a hand. Sampling efficiency tests were conducted with 1- and 2.26-μm fluorescent PSL beads, 3- and 8-μm fluorescent oleic acid particles, and approximately 1-μm BG [*Bacillus subtilis var. niger* (*Bacillus globigii*)] aerosol particles. The results show that the sampling efficiency is highest for 8-μm particles using both recovery methods. The lab method shows a sampling efficiency of 74.3% ± 3.0, and the field method shows a sampling efficiency of 65.5% ± 5.4 for the 8-μm particles. For 1-μm particles, the sampling efficiency drops to 4.0% ± 0.9 and 9.3% ± 1.1 for the lab and field methods, respectively. BG results were similar to the 1-μm PSL results.

15. SUBJECT TERMS

BG	Fluorescein	Fluorometric analysis
Aerosol	Aerosol samplers	Vibrating oriface generator

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Sandra J. Johnson
U	U	U	UL	17	19b. TELEPHONE NUMBER *(include area code)* (410) 436-2914

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PREFACE

The work described in this report was authorized under Project No. 622384/ACB2. The work was started in January 2000 and completed in January 2003.

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Acknowledgment

The authors acknowledge John Knapton for his editorial assistance.

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CHARACTERISTICS AND SAMPLING EFFICIENCIES OF BIOBADGE® AEROSOL SAMPLERS

1. INTRODUCTION

This technical note is part of a continuing series of short reports intended to record and preserve data from characterizing aerosol collectors. This report is not intended to be a comprehensive study or analysis. A technical note simply records a limited set of observations, offers preliminary analysis, and, if required, submits a record of the measured data to the company providing the device. The results of more thorough studies may be found in technical reports.

Air samplers are important in the war against terrorism and on the battlefield to detect the presence of chemical, biological, and nuclear aerosols. Air samplers for biological aerosols must collect the material in a gentle manner to reduce destruction of the organism if the analysis method requires live organisms. Samplers and detection systems must be evaluated and their performance efficiency determined so that suitable samplers and detectors can be used. Knowledge of equipment performance enhances the ability to protect soldiers, first responders, and the general public. There is a need for determining personal exposure to biological material. An ideal personal biological sampler should be small, portable, use minimal power, and have a high sampling efficiency. The BioBadge® sampler could fulfill this need.

In this study, the characteristics and sampling efficiencies of four BioBadge® aerosol samplers (MesoSystem Incorporated, Richland, WA) were evaluated using two rinse procedures developed by MesoSystems. The first method (lab rinse) uses a sonicator, and the second method (field rinse) uses hand clapping.

Sampling efficiency is defined as the efficiency with which an aerosol sampler collects the particles from the air. The total efficiency of an aerosol sampler is the product of the sampler's aspiration, transmission, and collection efficiencies. The aspiration efficiency of a sampler gives the efficiency with which particles enter the sampler inlet. Transmission efficiency gives the efficiency with which the particles are transported to the collection point, and the collection efficiency gives the efficiency with which particles are captured and retained by the sampling medium. The sampling efficiency was determined by comparing the sample collected by the sampler to reference samples collected by two stationary open face air filters. In addition, characteristics such as dimensions and airflow rate were measured.

2. EQUIPMENT AND FACILITIES

2.1 Chamber.

The tests were conducted in a 70-m^3 biosafety Level 1 chamber (Figure 1) at the U.S. Army Edgewood Chemical Biological Center (ECBC). Chamber temperature and humidity

were set and maintained easily and accurately by a computer. This computer also controlled power receptacles inside the chamber.

HEPA filters were installed at the air inlet to filter air entering the chamber to achieve very low particle concentrations in the chamber. Similarly, HEPA filters were installed at the exhaust port to filter particles leaving the chamber. The aerosol concentration in the chamber was 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 could exhaust from the chamber was approximately 700 ft^3/min (approximately 2 x 10^4 L/min). A small re-circulation system removed air from the chamber, passed it through a HEPA filter, and delivered it back to the chamber. This system is useful when aerosol concentration in the chamber needs to be reduced by a small amount.

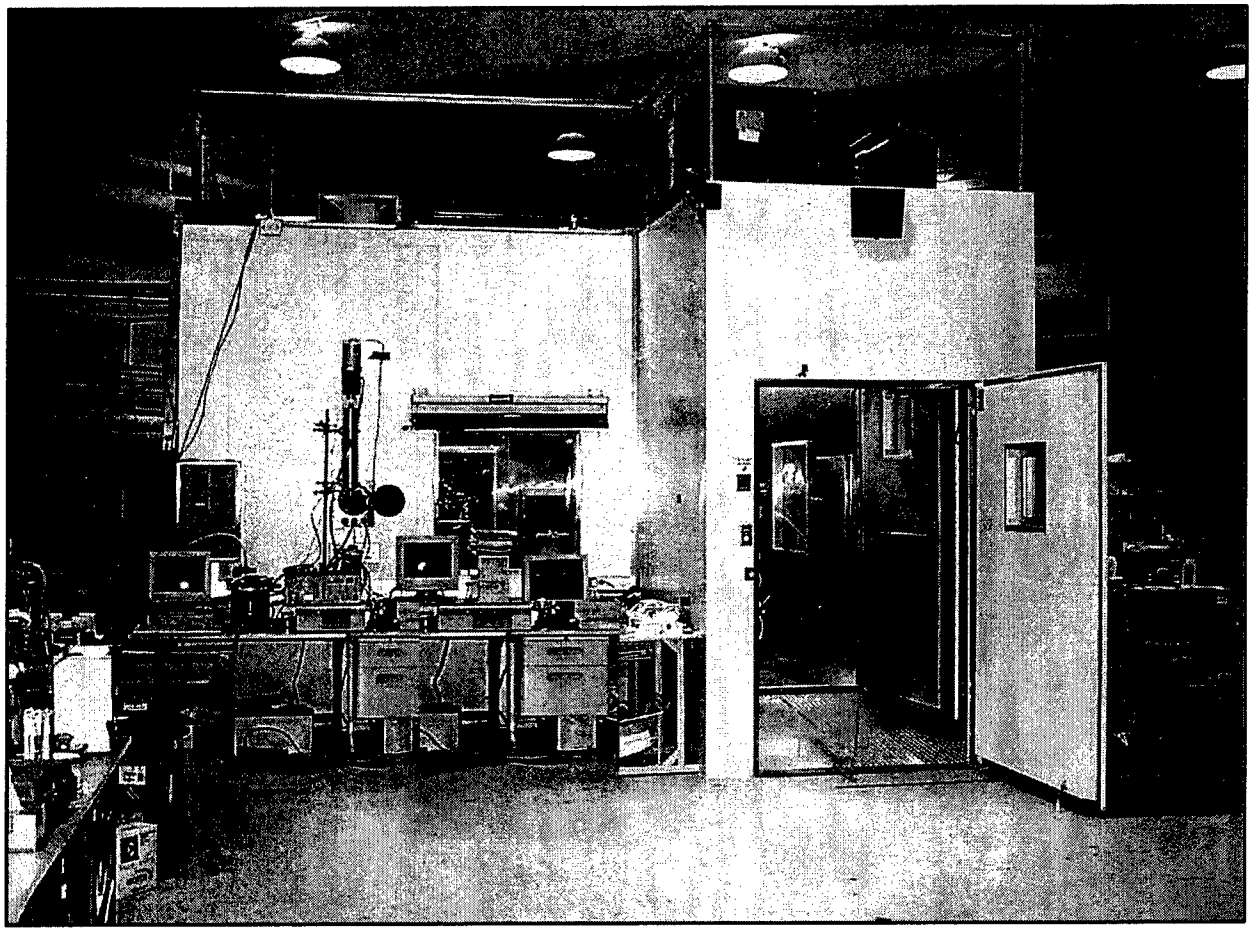

Figure 1. 70-m^3 Aerosol Chamber at ECBC

Aerosols can either be generated outside and then 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 BioBadge® Samplers.

Four BioBadge® aerosol samplers [Serial Numbers 560-001-0010(#10), 560-001-0011(#11), 560-001-0012(#12), and 560-001-0013(#13)] were tested at ECBC. BioBadge® is shown in Figure 2.

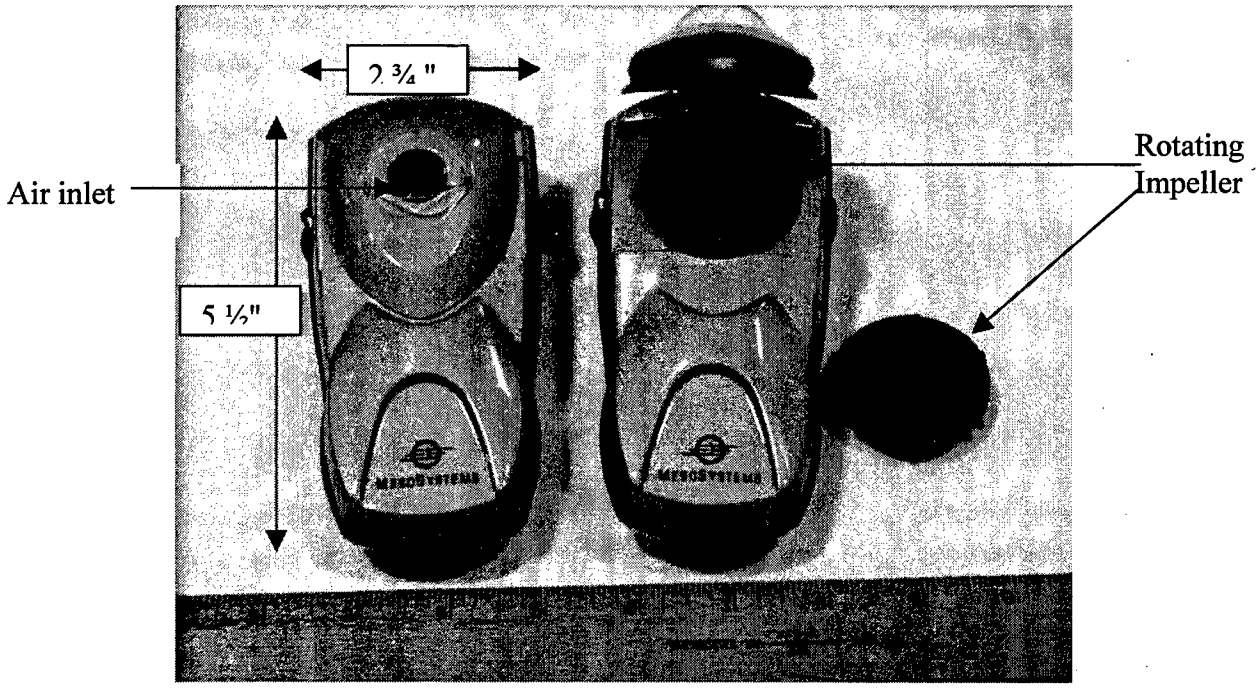

Figure 2. BioBadge®

The BioBadge® is a small, battery operated sampler that can be used as a personal sampler. The sampler is designed to sample air at a flowrate of 35 L/min. The sampler uses MesoSystems rotating impactor/impeller technology. The impeller is used to move air and collect particles. The particles are collected dry and then removed into a liquid by either the lab or field method.

For each test, two samplers were analyzed by the lab method, and the other two were analyzed using the field method. For both methods, the impeller is placed in a zip lock bag with 5 mL of 0.01% of Triton X, a surfactant, solution. For the lab method, the zip lock bag with the impeller and liquid is sonicated for 5 min. The field method requires hand clapping the ziplock bag containing the impellor and liquid. In this method, the bag with impeller and liquid

is gripped firmly and clapped, over a distance of 15 cm, against a hand 50 times (Kenning, 2003).[1]

During the tests, the sampler was programmed so that once it was turned on, it would wait for 11 min prior to the start of sampling. The 11-min delay included 10-min aerosol generation time and 1-min aerosol mixing time before sampling for 10 min. The reference filters also sampled the air during the 10-min sampling time.

2.3 BioBadge® Sampler Characteristics.

Airflow rates of the reference filters and samplers were measured using a DryCal Dc-Lite Primary Flow Meter (model #: DCL-H Rev. 1.08; Bios, Butler, NJ) and a Velocicheck Portable Air Velocity Meter (Model #: 8330-M, TSI Incorporated, St. Paul, MN). The airflow rate results, weight, and sampler dimensions are listed in Table 1.

Table 1. Characteristics of the BioBadge® Samplers: 11, 12, and 13

Designed airflow rate (L/min)	35
#10	Not measured at ECBC
Measured airflow rate (L/min) (measured at ECBC) #11 #12 #13	 31.9 37.4 33.3
Power	Battery operated
Weight (g)	250 (listed by MesoSystems)
Sample Volume (mL)	5
Dimensions (in.)	L = 5 ½ W = 2 ¾ D = 1 ½

3. SAMPLING EFFICIENCY MEASUREMENTS AND ANALYSIS

The sampling efficiency tests were conducted with three kinds of aerosols and corresponding analysis methods. The first method used monodisperse fluorescent Polystyrene Latex (PSL) microspheres. The second method used monodisperse fluorescent oleic acid particles, and the third method used dry *Bacillus subtilis var. niger* [*Bacillus globigii* (BG)] aerosol. The samplers and corresponding reference filters sampled the air simultaneously for 10 min. The aerosol generation and analysis methods are described in Sections 3.1 through 3.4.

3.1 PSL Microsphere Tests.

Sampling efficiency tests were conducted with 1- and 2.26-μm 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 the particles. The aerosol was generated for 10 min and mixed in the chamber for 1 min before sampling.

The samplers and corresponding reference filters sampled the PSL aerosol simultaneously for the same amount of time. Polycarbonate membrane filters (Osmonics Incorporated, Minnetonka, MN) were used as reference filters to collect the fluorescent PSL microspheres. After sampling, the sample impeller and reference filters were collected. The membrane filters and the impeller were processed to remove microspheres from the filters into the liquid for fluorometer analysis. Normally, for the removal procedure, the membrane filters are placed in 20 mL of filtered deionized water and shaken by hand for 30 s. The test tubes are then vortexed in a holder for 30 min. The samples were removed from the vortexer every 10 min and shaken by hand. Either the field or the lab method, described in Section 2.2, removes particles from the BioBadge® impeller.

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

Sampling efficiency tests were also conducted with 3 and 8 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 reduce the charge on the particles, and then delivered to the chamber. Sampling the aerosol onto a microscope slide inserted into an impactor and then measuring the droplet size using a microscope, determined the sizes of the fluorescent oleic acid particles. A microscopic picture of 10 μm fluorescent oleic acid droplets on a slide is shown in Figure 3. The measured fluorescent oleic acid particle diameter was converted to an aerodynamic particle size using a spread factor (Olan-Figueroa et al., 1982).[2] 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 for the same amount of time. Glass fiber filters (Pall Corporation, Ann Arbor, MI) were used as reference filters to collect fluorescent oleic acid particles.

Cartridges were processed by the lab and field methods. Before they were measured with the fluorometer (Barnstead/Thermolyne, Dubuque, IA), samples from the BioBadge® samplers were corrected for pH by adding NH_4OH. In addition, glass fiber filters were removed from the filter holders, placed into a fluorescein recovery solution, and shaken on a table rotator (Lab-Line Instruments, Incorporated, Melrose Park, IL) for 1 hr. The recovery solution used in the tests contained 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).

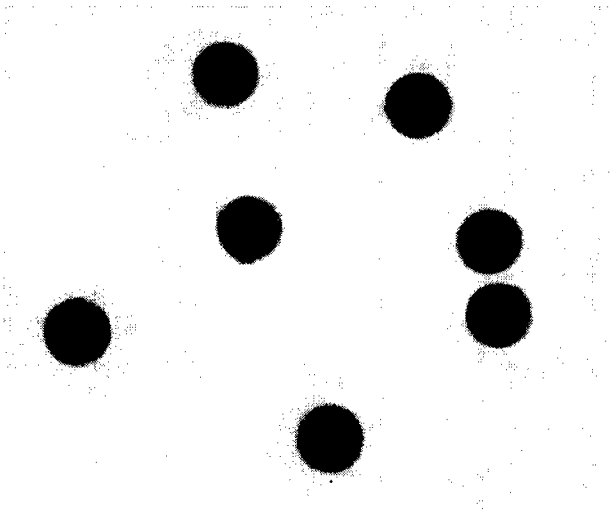

Figure 3. Microscopic Picture of Fluorescent Oleic Acid Droplets
(Droplet Size = ~10 μm)

Factors that affect fluorescein analysis and the removal of fluorescein from filters are described in detail by Kesavan et al. (2001).[3] The fluorescence of the solution was measured using a fluorometer. All the samples were analyzed either the same day as the experiment or the day after it.

3.3 Bioaerosol Tests.

BG powder was aerosolized using a sonic nozzle in the 70-m^3 chamber. Particle sizes were approximately 1 μm. Before sampling, the aerosol was mixed in the chamber for 30 - 60 s. Samplers and the reference filters sampled the aerosol for 10 min. Cartridges were processed by the lab and field methods, and the liquid and reference filters were sent to the microbiology laboratory at ECBC for culturing. The results were obtained in colony forming units (CFU) per liquid volume.

3.4 Analysis.

The sampling efficiency was determined by comparing the amount of fluorescent material collected by the BioBadge® and reference filters. The airflow rate of the sampler and reference filters, and the liquid volume of the samples and reference solutions were considered in the calculation. An airflow rate of 35 L/min was used in the calculations even though the measured airflow rate at ECBC was low.

The sampling efficiency was calculated using the following equation:

$$\text{Sampling Efficiency} = \frac{\left[\frac{(\text{fluorometer reading of sampler}) \times (\text{liquid volume})}{(\text{air flow rate})}\right]}{\left[\frac{(\text{fluorometer reading of reference filter}) \times (\text{liquid volume})}{(\text{air flow rate})}\right]} \times 100$$

4. RESULTS

The sampler characteristics are summarized in Table 1, and the sampling efficiency results are summarized in Table 2 and plotted in Figure 4. The sampling efficiency for both analysis methods shows a broad peak of 66 to 74% for 8-μm particles using the field and lab methods.

Table 2. Average Sampling Efficiency of the Four BioBadge® Aerosol Samplers for Various Particle Sizes

Particle Size (μm)	Particle Type	Sampling Efficiency (%)	
		Lab Method	Field Method
1	PSL	4.0 ± 0.9	9.3 ± 1.1
2.26	PSL	25.7 ± 4.0	38.1 ± 2.5
3	Oil Drops	64.4 ± 2.3	60.5 ± 1.9
8	Oil Drops	74.3 ± 3.0	65.5 ± 5.4
0.9*	BG	3.78 ± 1.2 *	8.43 ± 0.9 *

* Size of the BG particles generated by the Sonic Nozzle is approximately 1 μm. For purposes of display in Figure 4, the particle size is set at 0.9 μm.

5. DISCUSSION

The samplers were provided by MesoSystem, Incorporated and were only available for 1 week of testing. Due to the limited time, the number of particle sizes and the number of tests were limited.

The measured airflow rate at ECBC was <35 L/min; however, the airflow rate of 35 L/min (claimed by the manufacturer) was used in the calculations because it is possible that

the measurement methods at ECBC affected the sampler airflow. The irregular shape of the sampler made it harder to measure the airflow rate accurately. If airflow rate through the sampler is less than the rate claimed by the manufacturer, then sampling efficiency will be higher.

The sampling efficiency methods using lab and field extraction methods were significantly different. The field method gave higher efficiency for PSL and BG particles, and the lab method gave higher efficiency for fluorescent oleic acid particles. The BG single spore aerosol and 1-μm PSL aerosol results were similar for both methods. This suggests that in other sampler characterization tests, 1-μm PSL can be used instead of the BG single spore tests.

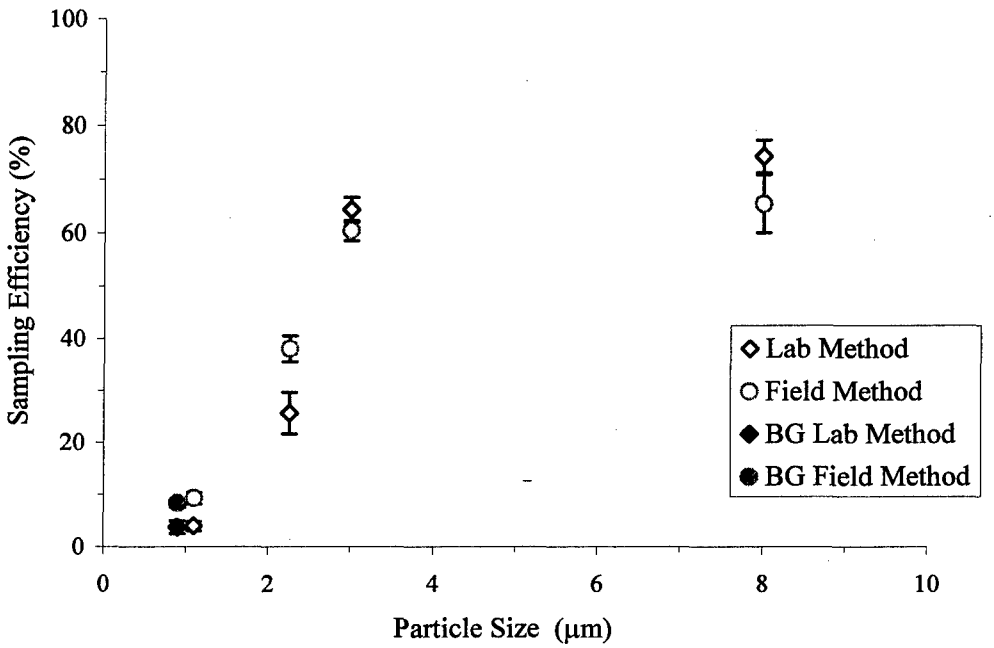

Figure 4. Sampling Efficiency of BioBadge®

The sampling efficiency of single spore BG is 3.8% ± 1.2 for the lab method and 8.3% ± 0.9 for the field methods; however, the manufacturer's calculations[1] show a higher efficiency because the BG data sent to the manufacturer did not subtract the empty test tube weight (tare).

6. CONCLUSIONS

BioBadge® samplers are small, battery-operated, personal samplers that are designed to pull 35 L/min of airflow. The sampling efficiency of four BioBadge® samplers was determined at the U.S. Army Edgewood Chemical Biological Center (ECBC) using 1- and

2.26-μm fluorescent Polystyrene Latex (PSL) microspheres, 3- and 8-μm fluorescent oleic acid, and single spore *Bacillus Subtilis var. niger [Bacillus globigii* (BG)] particles. The highest sampling efficiency is for 8-μm particles where the lab extraction method gave 74%, and the field extraction method gave 66%. The PSL microspheres, and BG spores of 1 μm, had lower but similar sampling efficiencies for both sample extraction methods. The 1-μm PSL microspheres and BG spores had approximately 4% sampling efficiency using the lab extraction method and 8 to 9% sampling efficiency for the field extraction method.

Many samplers are characterized at ECBC, and the results are published in technical notes. When considering a sampler for an application, the decision should include information on sampling efficiency, concentration factor, sampler size, weight, airflow, and power consumption. Readers are advised that these samplers may be modified and/or improved based on our tests, and may be further improved as new technology becomes available. Therefore, a modified or improved sampler may have very different characteristics from those discussed in this report.

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LITERATURE CITED

1. Kenning, V. *BioBadge ™Test Report*; MesoSystems Technology, Inc.: Kennewick; WA 99336, 2003.

2. Olan-Figueroa, E.; McFarland, A.R.; Ortiz, C.A. Flattening Coefficients for DOP and Oleic Acid Droplets Deposited on Treated Glass Slides, *Am. Ind. Hyg. Assoc. J.* **1982**, *43*; pp 395-399.

3. Kesavan, J.; Doherty, R.W.; Wise, D.G.; McFarland, A. *Factors That Affect Fluorescein Analysis*; ECBC-TR-208; U.S. Army Edgewood Chemical Biological Center: Aberdeen Proving Ground, MD, 2001; UNCLASSIFIED Report (AD-A397 677).