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**CHARACTERISTICS AND SAMPLING EFFICIENCIES
OF PORTABLE HIGH THROUGHPUT LIQUID-ASSISTED
AEROSOL SAMPLER MODEL APAS-2
(PHTLAAS-APAS-2)**

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14. ABSTRACT Characteristics and aerosol sampling efficiencies of a Portable High Throughput Liquid-Assisted Air Sampler Model APAS-2 (PHTLAAS-APAS-2) (Zaromb Research Corp., Hinsdale, IL) were determined at the U.S. Army Edgewood Chemical Biological Center (ECBC). The PHTLAAS-APAS-2 is a portable, battery-operated bioaerosol sampler designed to collect 0.5- to 10-µm particles into a buffer solution to preserve the viability of bio-organisms. Sampling efficiency tests were conducted with 1- and 3-µm polystyrene latex microspheres and 3-, 5-, and 8-µm fluorescent oleic acid particles. The results show that the sampler has a high (>55%) sampling efficiency for the particle sizes tested with a peak sampling efficiency of 87.7 ± 3.8% for 3-µm particles. The sample collection liquid (25 mL) was placed in the cyclone before each sampling. After 10 min of sampling, the average sample output was 18.1 ± 1.0 mL. The measured air flowrate using a hot wire anemometer was 305.9 Lpm at the inlet. A previous version, the PHTLAAS, was also tested at ECBC, and the results show that the PHTLAAS-APAS-2 is smaller, lighter, and has a slightly higher sampling efficiency for larger size (>5 µm) particles compared to the PHTLAAS (its predecessor).					
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PREFACE

The work described in this report was authorized under Project No. 306033.84BP0, Non Medical CB Defense. The work was started in September 2004 and completed in September 2005. The data are recorded in Laboratory Notebook No. 03-0186, pages 41-45.

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CONTENTS

1.	INTRODUCTION	7
2.	EQUIPMENT AND FACILITIES.....	7
2.1	Chamber.....	7
2.2	Portable High Throughput Liquid-Assisted Aerosol Sampler Model APAS-2 (PHTLAAS-APAS-2).....	8
2.3	Sampler Characteristics	9
3.	TEST PROCEDURES AND ANALYSIS.....	10
3.1	Sampling Efficiency Measurements	10
3.2	PSL Microsphere Tests.....	10
3.3	Sodium Fluorescein Tagged Oleic Acid (Fluorescent Oleic Acid) Tests	11
3.4	Analysis.....	12
4.	RESULTS	12
5.	DISCUSSION AND CONCLUSIONS.	13
	LITERATURE CITED	15

FIGURES

1.	70-m ³ Aerosol Chamber at ECBC	8
2.	PHTLAAS-APAS-2.....	9
3.	Microscopic Picture of Fluorescent Oleic Acid Droplets	11
4.	Sampling Efficiencies of the PHTLAAS-APAS-2 and the PHTLAAS as Functions of Particle Size	13

TABLES

1.	Characteristics of the PHTLAAS-APAS-2.....	10
2.	Sampling Efficiency of the PHTLAAS-APAS-2	12

CHARACTERISTICS AND SAMPLING EFFICIENCIES OF PORTABLE HIGH THROUGHPUT LIQUID-ASSISTED AEROSOL SAMPLER MODEL APAS-2 (PHTLAAS-APAS-2)

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 samplers/concentrators. This report is not intended to be a comprehensive study or analysis. A technical note simply records a limited set of observations, offers some preliminary analysis, and if appropriate, provides a record of the measured data to the group that provided the device. Results of more thorough studies may be found in technical reports.

Air samplers/concentrators and detectors are important in the war against terrorism and on the battlefield to detect the presence of chemical, biological, and nuclear aerosols. Samplers/concentrators and detection systems must be evaluated and their performance efficiencies 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. An ideal aerosol concentrator should be small, portable, use minimal power, and have a high concentration efficiency.

Some aerosol samplers are designed to collect bioaerosols into liquid either for wet analysis or to preserve the viability of organisms. Wetted wall cyclone (WWC) samplers [e.g., the Portable High Throughput Liquid Assisted Air Sampler Model APAS-2 (PHTLAAS-APAS-2) (Zaromb Research Corp., Hinsdale, IL)] collect aerosols in this manner. In this study, the characteristics and sampling efficiencies of a PHTLAAS-APAS-2 were determined at the U.S. Army Edgewood Chemical Biological Center (ECBC). The PHTLAAS-APAS-2's previous version, the PHTLAAS, that has the same WWC but has big and heavy packaging was also characterized at ECBC, and the results are presented in ECBC-TR-267.¹ The results for the PHTLAAS (previous version) showed the highest sampling efficiency of $84.3 \pm 4.2\%$ for 4- μm particles.

2. EQUIPMENT AND FACILITIES

2.1 Chamber.

The tests were conducted in a 70-m³ biosafety Level 1+ chamber (Figure 1) at ECBC. Chamber temperature and humidity can be set and maintained easily and accurately by a computer. This computer also controls the power receptacles inside the chamber.

HEPA filters are installed at the air inlet to filter air entering the chamber to achieve very low particle concentrations in the chamber. Similarly, HEPA filters are also installed at the exhaust port to filter particles leaving the chamber. The aerosol concentration in the chamber is reduced by exhausting the chamber air through the HEPA filters, and by pumping

HEPA-filtered air into the chamber. The maximum amount of airflow that can be exhausted from the chamber is approximately 700 ft³/min (approximately 2 x 10⁴ 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.

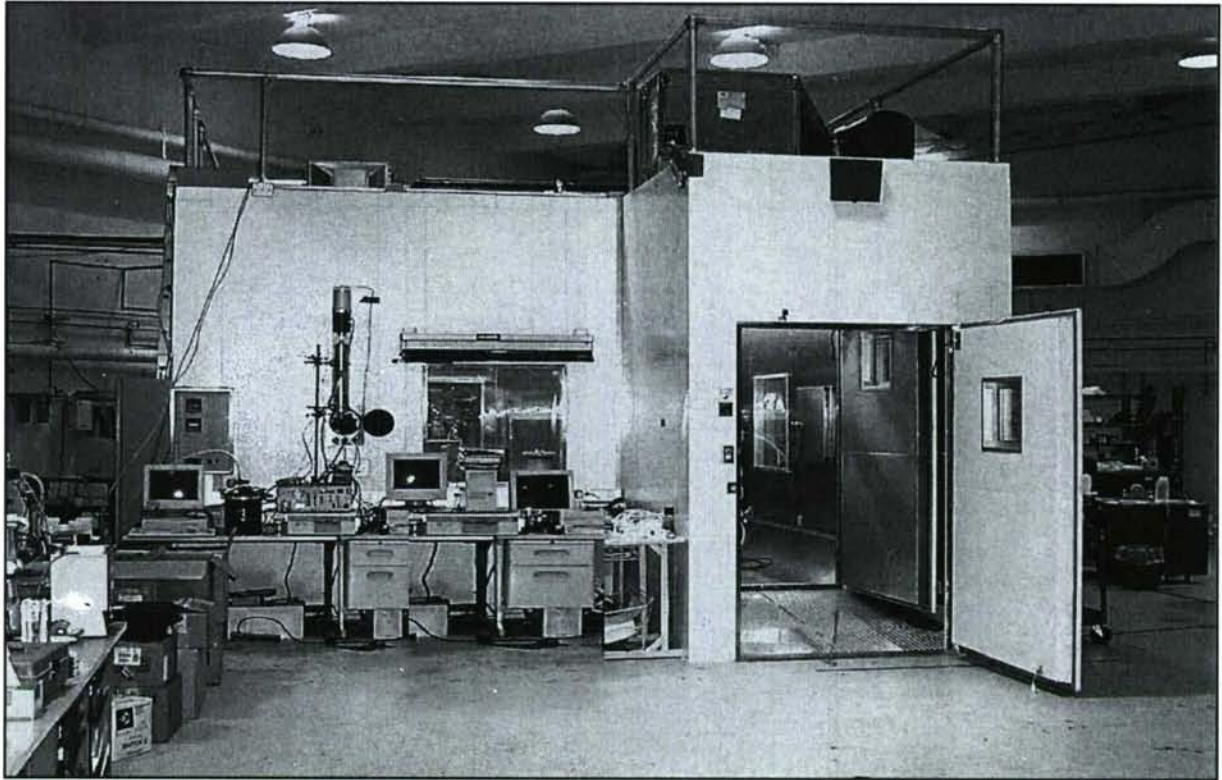


Figure 1. 70-m³ Aerosol Chamber at ECBC

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 Portable High Throughput Liquid-Assisted Aerosol Sampler Model APAS -2 (PHTLAAS- APAS-2).

The PHTLAAS-APAS-2 aerosol sampler, shown in Figure 2, is a portable, light weight, and high volume sampler. The sampler has straps attached for easy carrying. It has a WWC for aerosol collection. There is a re-circulation tube that brings the liquid from the top of the cyclone to the bottom for continuous cyclone wetting. Unlike the PHTLAAS (previous

model), this model does not have a liquid reservoir for adding liquid as liquid evaporates. Such design limits sample time to a short time due to the cyclone not containing enough liquid.

The PHTLAAS-APAS-2 has a hydrosol concentration system to concentrate the samples collected. This feature was not used in the ECBC tests. The sampler was operated using a power supply during the tests for easy turn on and off from outside the chamber.

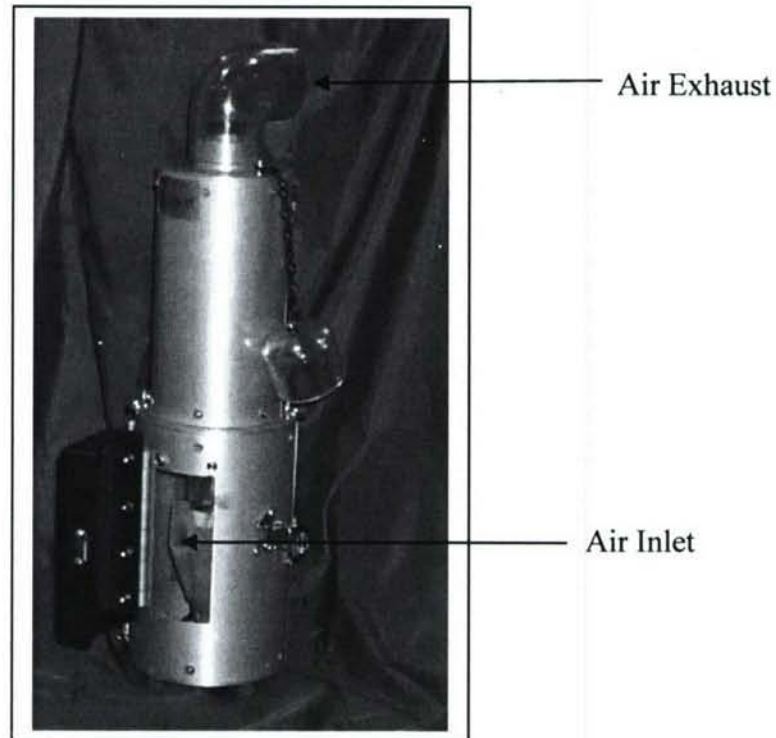


Figure 2. PHTLAAS-APAS-2

2.3 Sampler Characteristics.

Air flowrates of the reference filters and samplers were measured using a mass flow meter (4000 Series, TSI Inc., St. Paul, MN) and a Kurz airflow meter (Kurz Instruments Inc., Monterey, CA). The air flowrates, liquid input volume, sample output volume, weight, and dimensions of the samplers were measured and are listed in Table 1.

Table 1. Characteristics of the PHTLAAS-APAS-2

Air sampling rate, L/min	305.9
Liquid input volume, ml	25
Sample Volume after 10 min, mL	18.1 ± 1.0
Weight without the batteries, lb	5.5
Dimensions, inches	
Height	20
Diameter	6
Power, W	49
Voltage, V	11.5
Current, A	4.18

3. TEST PROCEDURES AND ANALYSIS

3.1 Sampling Efficiency Measurements.

The sampling efficiency tests were conducted with two kinds of aerosols and corresponding analysis methods. The first method used monodisperse 1- and 3- μm fluorescent polystyrene latex (PSL) microspheres, and the second method used monodisperse 3-, 5-, and 8- μm fluorescent oleic acid particles. The aerosol generation and analysis methods are described in Sections 3.2, 3.3, and 3.4.

3.2 PSL Microsphere Tests.

Sampling efficiency tests were conducted with 1- and 3- μm fluorescent PSL microspheres (Duke Scientific, Corp., Palo Alto, CA). The PSL aerosols were generated using a 24-jet Collison nebulizer and then passed through a radioactive isotope (Kr-85) neutralizer to reduce the charge on the particles. The PSL aerosol was delivered into the 70- m^3 chamber where the samplers and reference filters were placed. The aerosol was generated for a short time and mixed before sampling by the samplers and reference filters.

The samplers and the corresponding reference filters sampled the PSL aerosol simultaneously and for the same amount of time. Polycarbonate membrane filters (Osmonics, Inc., Minnetonka, MN) were used as reference filters to collect the fluorescent PSL microspheres. After sampling, the samples were collected from the samplers and reference filters. Removing particles from the membrane filter consists of placing the membrane filters into 20 mL of filtered deionized water, shaking the mixture by hand for 10 s, followed by vortexing it for 50 s. The hand shaking and vortexing were repeated four more times for a total of 5 min. The fluorescence of the samples was measured using a fluorometer (Model 450, Sequoia-Turner, Dubuque, IA).

Sampling efficiency tests were also conducted with 3-, 5-, and 8- μm fluorescent oleic acid particles. The monodisperse fluorescent oleic acid particles were generated using a Vibrating Orifice Aerosol Generator (VOAG, TSI Inc., 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. The sizes of the fluorescent oleic acid particles were determined by sampling the aerosol onto a microscope slide using the impaction mechanism and then measuring the droplet size using a microscope. A microscopic picture of 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)² and density. 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. Glass fiber filters (Pall Corp., Ann Arbor, MI) were used as the reference filters to collect fluorescent oleic acid particles.

The glass fiber filters were removed from the filter holders, placed into a fluorescein recovery solution, and shaken on a table rotator (Lab-Line Instruments, Inc., Melrose Park, IL) for 1 hr. The recovery solution used in these tests had water with a pH between 8 and 10, obtained by adding a small amount of NH_4OH (e.g., 999 mL of water with 1 mL of 14.8 N NH_4OH).

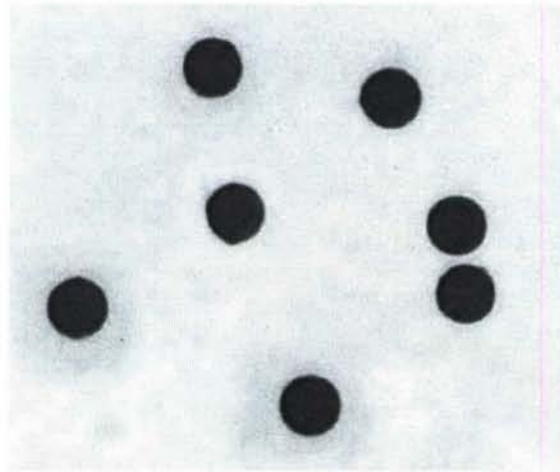


Figure 3. Microscopic Picture of Fluorescent Oleic Acid Droplets

Factors that affect fluorescein analysis and fluorescein removal 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 of the experiment or the next day.

3.4 Analysis.

The sampling efficiency was determined by comparing the amount of fluorescent material collected by the sampler and the reference filters. The air flowrate of the sampler and the reference filters, and the liquid volume of the samples and reference solutions were considered in the calculation.

The concentration efficiency was calculated using the following equation:

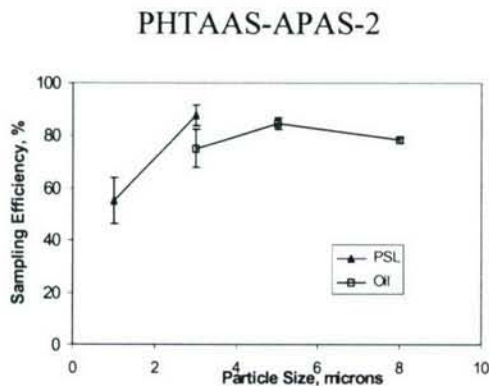
$$\text{Sampling Efficiency} = \frac{\left[\frac{(\text{fluorometer reading of sampler}) \times (\text{liquid volume})}{(\text{air flow rate})} \right]}{\left[\frac{(\text{fluorometer reading of reference filter}) \times (\text{liquid volume})}{(\text{air flow rate})} \right]} \times 100$$

4. RESULTS

The sampler characteristics and sampling efficiency results are summarized in Tables 1 and 2. The sampling efficiency graphs for the PHTLAAS-APAS-2 and the PHTLAAS (previous version) are shown in Figure 4. The results for the PHTLAAS-APAS-2 show that its sampling efficiency is high (>55%) for particle sizes tested with the highest sampling efficiency being 87.7 % for 3- μm particles.

Table 2. Sampling Efficiency of the PHTLAAS-APAS-2

Particle Size (Type)	Sampling Efficiency (%) + 1 St. Dev.
1 μm (PSL)	55.1 \pm 8.8
3 μm (PSL)	87.7 \pm 3.8
3 μm (Fl. Oleic Acid)	75.0 \pm 7.2
5 μm (Fl. Oleic Acid)	84.6 \pm 2.1
8 μm (Fl. Oleic Acid)	78.2 \pm 1.0



Previous Version Called PHTLAAS

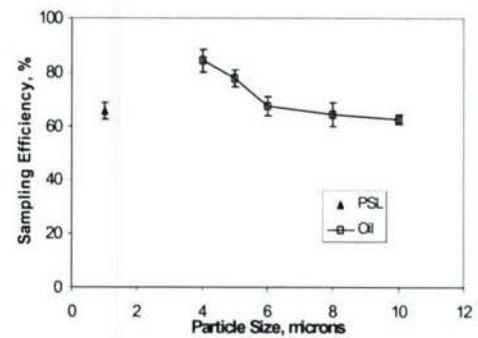


Figure 4. Sampling Efficiencies of the PHTLAAS-APAS-2 (left) and the PHTLAAS (right) as Functions of Particle Size

5. DISCUSSION AND CONCLUSIONS

A sampling efficiency of the Portable High Throughput Liquid-Assisted Aerosol Sampler Model APAS-2 (PHTLAAS-APAS-2) was characterized at the U.S. Army Edgewood Chemical Biological Center (ECBC). Sampling efficiency tests were conducted with 1- and 3- μm fluorescent polystyrene latex (PSL) microspheres, and 3-, 5-, and 8- μm fluorescent oleic acid particles. Results show that the sampling efficiency is high for the particle sizes tested (>55%) with a peak sampling efficiency of $87.7 \pm 3.8\%$ for 3- μm particles.

The PHTLAAS (predecessor of the PHTLAAS-APAS-2) was also tested at ECBC, and results show that the highest sampling efficiency of $84.3 \pm 4.2\%$ is for 4- μm particles. The PHTLAAS-APAS-2 is an improvement over the PHTLAAS (its predecessor) in that the PHTLAAS-APAS-2 is smaller, lighter, and has a slightly higher sampling efficiency for larger size particles (> 5 μm).

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