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CHARACTERISTICS AND SAMPLING EFFICIENCIES OF SPINCON AND PRE-PRODUCTION OMNI MODEL AEROSOL SAMPLERS

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14. ABSTRACT
Characteristics and aerosol sampling efficiencies of one SpinCon and two pre-production (PP) Omni model aerosol samplers (Omni-2 and Omni-3) (Sceptor Industries, Inc., Kansas, MO) were determined at the U.S. Army Edgewood Chemical Biological Center. All three samplers have non-traditional wetted-wall cyclones to collect and concentrate aerosols in liquid. The Omni aerosol sampler is designed to be approximately half the weight, half the size, and a quarter of the power of the SpinCon. The sampling efficiency tests were conducted with monodisperses 1- and 3-μm fluorescent polystyrene latex (PSL) microspheres and 3.5- and 5-μm fluorescent oleic acid particles. The results show that the sampling efficiency of SpinCon is 47.3 ± 2.1, 56.1 ± 3.9, 14.6 ± 0.6, and 13.8 ± 2.2 for 1-, 3-, 3.5-, and 5-μm particles. The sampling efficiency of PP Omni-2 is 12.0 ± 3.1, 38.0 ± 3.3, 21.0 ± 0.6, and 18.4 ± 1.3 for 1-, 3-, 3.5-, and 5-μm particles. The sampling efficiency of PP Omni-3 is 22.7 ± 7.0, 53.9 ± 12.3, 19.7 ± 0.2, and 17.4 ± 3.7 for 1-, 3-, 3.5-, and 5-μm particles. Sampler characterization results show that Omni aerosol samplers had an air flowrate of 300 L/min and a power of 72 W. The SpinCon had an air flowrate of 450 L/min and a power of 283 W.

15. SUBJECT TERMS

Omni	SpinCon	Fluorescein	Vibrating Orifice Aerosol Generator
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PREFACE

The work described in this report was authorized under Project No. 206023.84BPO, Non-Medical CB Defense. The work was started in May 2005 and completed in July 2005. The data are recorded in Laboratory Notebook No. 03-0186, pages 86-93.

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CHARACTERISTICS AND SAMPLING EFFICIENCIES OF SPINCON AND PRE-PRODUCTION OMNI MODEL 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 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 company that provided the devices. 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 to preserve the viability of organisms. Wetted-wall cyclones (WWCs) such as SpinCon and Omni collect aerosols in this manner to preserve viability. In this study, the characteristics and sampling efficiencies of one SpinCon and two pre-production (PP) Omni Model aerosol samplers, both manufactured by Sceptor Industries, Inc. (Kansas City, MO) were characterized. In addition, characteristics such as dimensions and air flowrates were also 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 can be set and maintained easily and accurately by a computer. This 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 also 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 can be exhausted from the chamber is approximately 700 ft^3/min (approximately 2 x 10^4 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.

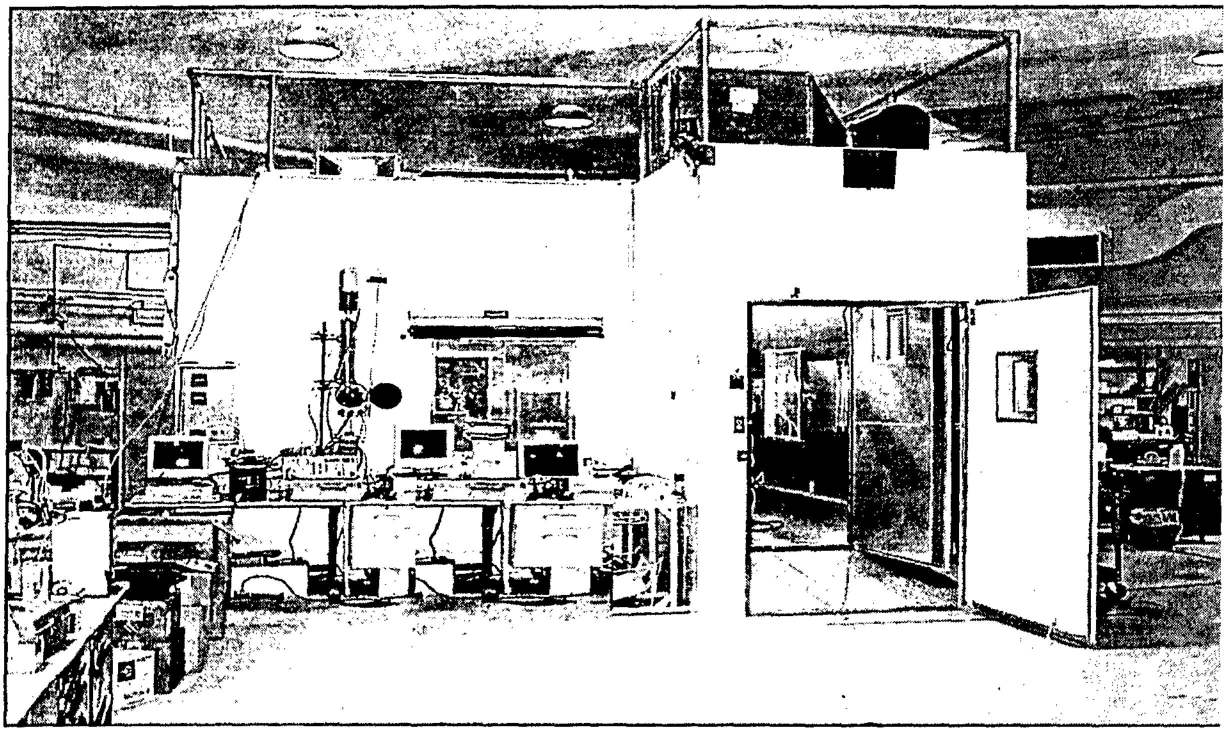

Figure 1. 70-m^3 Aerosol Chamber at ECBC

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 SpinCon Aerosol Sampler.

SpinCon, shown in Figure 2, is manufactured by Sceptor Industries, Inc. (Kansas City, MO). It has a nontraditional WWC to collect and concentrate aerosols in liquid. The SpinCon is designed to sample air at a flowrate of 450 L/min, and it can run in either single sample or continuous monitoring mode. The manufacturer states that the SpinCon is designed to collect particles down to 0.2 µm. The characteristics of SpinCon aerosol sampler are given in Table 1.

The contactor, shown in Figure 2, has a plenum that is connected to the inlet. The aerosol enters the contactor through a narrow slit. Two bags with liquid are attached to the contactor. One bag is filled with phosphate buffered saline (PBS) and the other with de-ionized water. Initially, during sampling, a set amount of PBS is delivered to the contactor. As the liquid evaporates during sampling, de-ionized water is then delivered to the contactor. There is an infrared photosensor that detects the liquid level and regulates the amount of liquid in the contactor. The unit retains the water in the cyclone and does not produce a continuous liquid output stream. The sample volume is independent of sampling time.

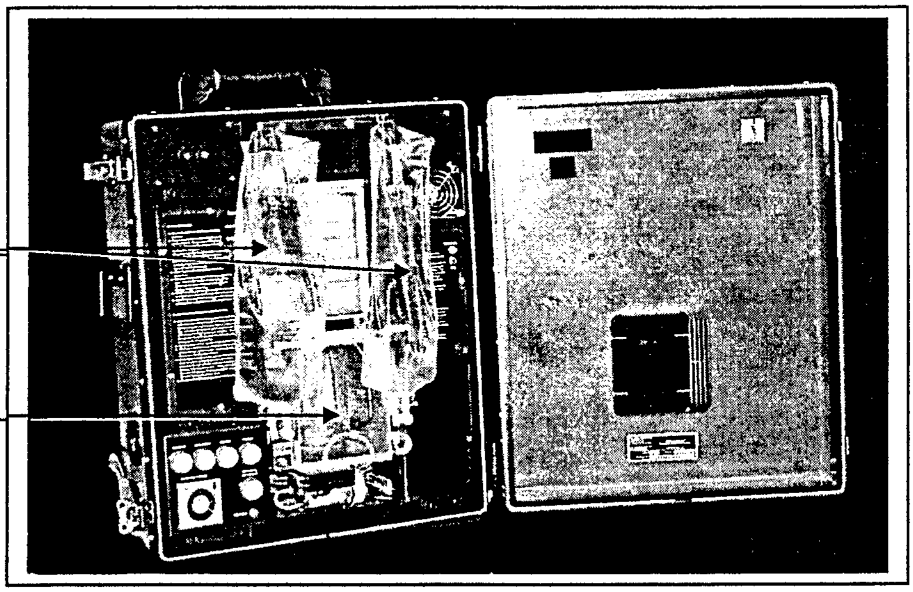

Figure 2. SpinCon Aerosol Sampler

2.3 PP Omni Aerosol Sampler.

The Omni aerosol sampler is a nontraditional WWC designed to be approximately half the weight, half the size, and with a quarter of the power of the SpinCon. A picture of PP Omni is shown in Figure 3, and the sampler characteristics are given in Table 1. The Omni aerosol sampler's contactor has a plenum connected to the inlet. Air enters the contactor (Figure 4) through two narrow slits that are slightly different from the SpinCon slits. The unit retains the water in the cyclone and does not produce a continuous liquid output stream. The sample volume is independent of sampling time.

The sample is contained in the sample vial (Figure 5) that comes out for easy handling; thus, the operator does not have to come in contact with the liquid. A liquid pouch is placed inside the sampler, and it adds liquid to the contactor as water evaporates during sampling. An air filter, shown in Figure 5, is connected to the exhaust of the sampler in situations where all the aerosol entering the sampler needs to be captured. One advantage of the Omni aerosol sampler is that it is easy to decontaminate inside and outside.

Table 1. Characteristics of SpinCon, PP Omni-2, and PP Omni-3 Aerosol Samplers

		SpinCon	PP Omni-2	PP Omni-3
Serial No.		*	Pre-Prod 2	Pre-Prod 3
Air Flowrate, L/min		457	299	305
Power, W		283	71.8	71.9
PF/VA		1.0	0.99	0.99
Voltage (V)		117.2	119	118
Currents (Amp)		2.41	0.61	0.61
Weight (lb)		46	14	14
Dimensions (in.)	Length	15	8.5	8.5
	Width	10	7	7
	Height	19	17	17
Sample Volume, cc		PSL tests: 9.1 - 11.5	10.2 - 12.8	9.3 - 10.8
		Oleic Acid: 5.9 - 7.6	9.5 - 12.9	8.1 - 10.9

*045010AD-00053DPPWW90

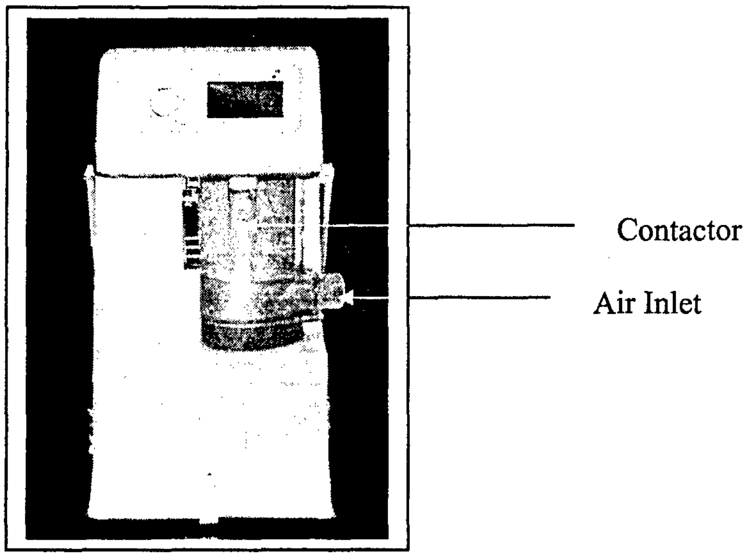

Figure 3. PP Omni Aerosol Sampler

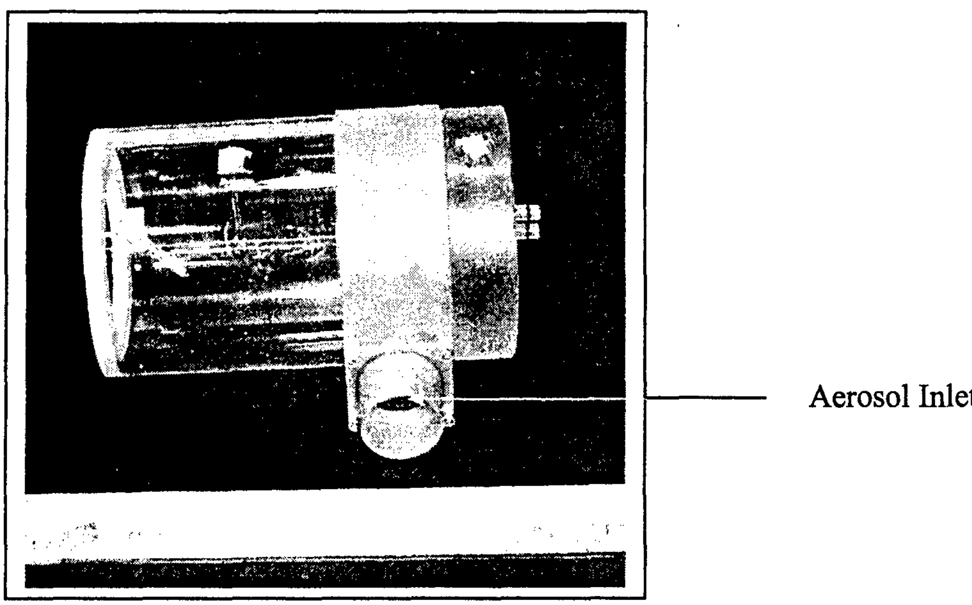

Figure 4. Contactor of PP Omni Aerosol Sampler

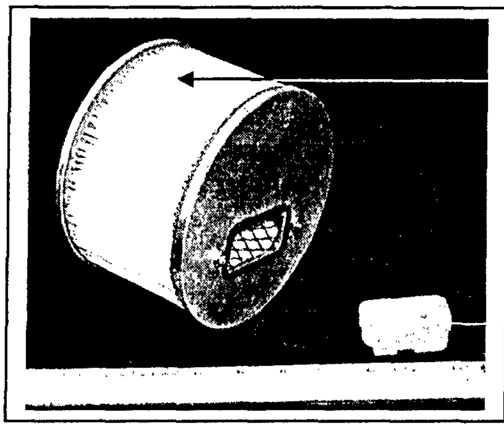

Figure 5. Exhaust Air Filter and Liquid Cartridge of PP Omni Aerosol Sampler

2.4 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 Kurz airflow meter (Kurz Instruments Inc., Monterey, CA). The air flowrates, power, weight, and dimensions of the samplers are listed in Table 1.

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 5-µm fluorescent oleic acid particles. The concentrators and corresponding reference filters sampled the air simultaneously. The aerosol generation and analysis methods are described in Sections 3.2 and 3.3.

3.2 PSL 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. The samplers and reference filters were placed in the chamber, and aerosol was generated for a short time and mixed 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 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. The removal procedure consisted of placing each membrane filter into 20 mL of filtered deionized water, shaking the mixture by hand for 10 s, and then vortexing it for 50 s. The hand shaking and vortexing were repeated four more times for a total of 5 min.

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

Sampling efficiency tests were also conducted with 3.5- and 5-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 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. A microscopic picture of fluorescent oleic acid droplets on a slide is shown in Figure 6. The measured fluorescent oleic acid particle diameter was converted to an aerodynamic particle size using a spread factor (Olan-Figueroa et al., 1982)[1] 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 and alcohol with a pH between 8 and 10, which was obtained by adding a small amount of NH_4OH (e.g., 999 mL of water with 1 mL of 14.8 N NH_4OH).

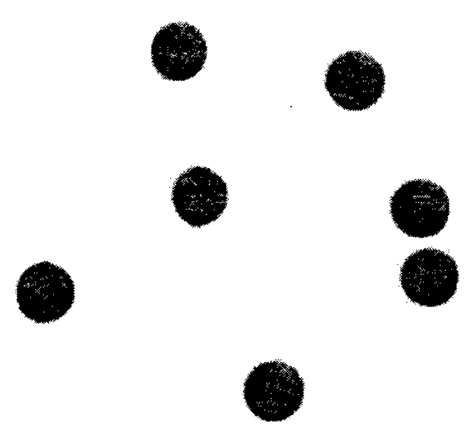

Figure 6. Microscopic Picture of Fluorescent Oleic Acid Droplets

Factors that affect fluorescein analysis and fluorescein removal from filters are described in detail by Kesavan et al. (2001).[2] 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:

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

4. RESULTS

The sampler characteristics and sampling efficiency results are summarized in Tables 1 and 2. The sampling efficiency graphs for SpinCon, PP Omni-2, and PP Omni-3 are shown in Figure 7. The results show that the highest sampling efficiency is for the 3-µm particles, and it decreases for smaller and larger sizes.

Table 2. Average Sampling Efficiency of SpinCon, PP Omni-2, and PP Omni-3 Aerosol Samplers

Particle Size (µm)	Particle Type	Sampling Efficiency (%)		
		SpinCon	Omni-2	Omni-3
1.0	PSL	47.3 ± 2.1*	12.0 ± 3.1	22.7 ± 7.0
3.0	PSL	56.1 ± 3.9	38.0 ± 3.3	53.9 ± 12.3
3.5	Oil	14.6 ± 0.6	21.0 ± 0.6	19.7 ± 0.2
5.0	Oil	13.8 ± 2.2	18.4 ± 1.3	17.4 ± 3.7

* mean ± std

5. DISCUSSION

One SpinCon and two PP Omni aerosol samplers were characterized at ECBC. The samplers were provided by Sceptor Industries 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 sampling efficiency results show that the sampling efficiency is highest for 3-μm particles for all three samplers. SpinCon has higher sampling efficiency for 1- and 3-μm PSL microsphers and PP Omni has a slightly higher sampling efficiency for 3.5- and 5-μm fluorescent oleic acid particles. Sampler characterization results show that PP Omni aerosol samplers have lower air flowrates, power, sample volume, and are smaller in size. The sampling efficiency decreases significantly with the liquid fluorescent oleic acid particles for all three samplers. This may be due to solid particles bouncing at the slit and entering the sampler compared to the liquid particles (fluorescent oleic acid) being removed by the slit.

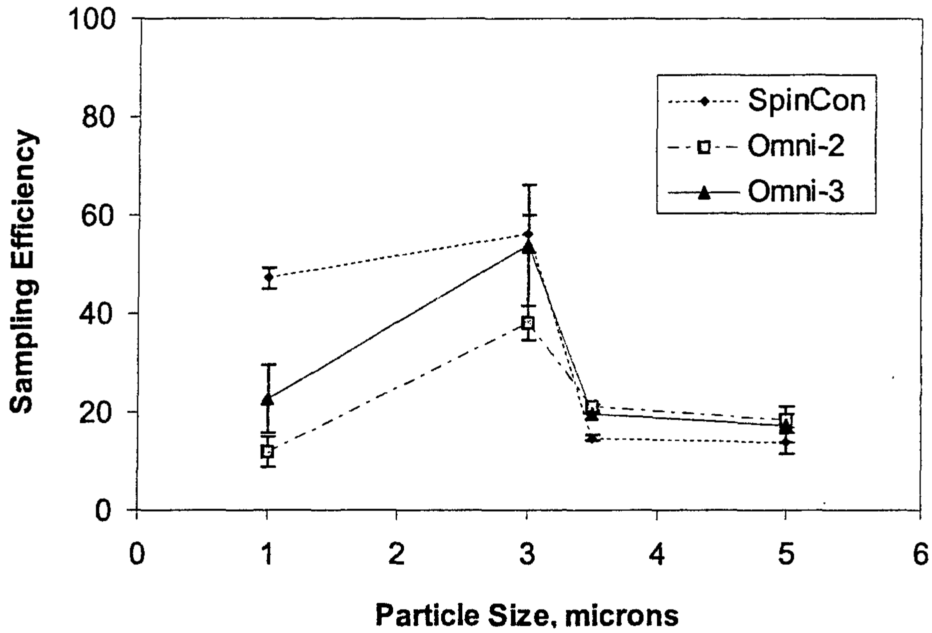

Figure 7. Sampling Efficiency of SpinCon, PP Omni-2, PP Omni-3 Aerosol Samplers

The SpinCon is designed to maintain 10 mL of liquid in the contactor during sampling, and a volume of 9-to-12 mL was maintained for the PSL tests; however, during the fluorescent oleic acid tests, only 6 - 8 mL was maintained in the contactor. The lower liquid sample volume of SpinCon may be due to SpinCon's infrared photosensor that controls the liquid volume being affected by the fluorescent oleic acid aerosols. Similar results were seen in our previous tests with the SpinCon; however, the Omni aerosol samplers did not show reduced liquid volume when sampling fluorescent oleic acid aerosols. The results of a few tests conducted to determine the reason for the reduced volume of the SpinCon with the fluorescent oleic acid tests showed that when fluorescent oleic acid was added to the contactor, and the SpinCon was turned on to sample from a room free of fluorescent oleic acid aerosols, the SpinCon was able to maintain the liquid volume; however, SpinCon does not maintain the liquid volume when it is exposed to fluorescent oleic acid aerosols.

6. CONCLUSIONS

The SpinCon, pre-production (PP) PP Omni-2, and PP Omni-3 aerosol samplers were characterized at the U.S. Army Edgewood Chemical Biological Center (ECBC) using 1- and 3-µm fluorescent polystyrene latex (PSL) microspheres and 3.5- and 5-µm fluorescent oleic acid particles. Sampler characterization results show that PP Omni aerosol samplers have lower air flowrates, power, sample volume, and are smaller in size. For all three samplers, the highest sampling efficiency was for 3-µm particles. SpinCon has higher sampling efficiency for 1- and 3-µm PSL microspheres, and PP Omni has slightly higher sampling efficiency for 3.5- and 5-µm fluorescent oleic acid particles.

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, pressure drop (not measured in this study), 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 than discussed in this technical note.

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