# EDGEWOOD

## CHEMICAL BIOLOGICAL CENTER

U.S. ARMY RESEARCH, DEVELOPMENT AND ENGINEERING COMMAND

**ECBC-TN-021**

# CHARACTERISTICS AND SAMPLING EFFICIENCIES OF THE SMART AIR SAMPLER SYSTEM (SASS) 2000$^{Plus®}$

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**14. ABSTRACT**
Sampler characteristics and sampling efficiency measurements of the Smart Air Sampler System (SASS) 2000$^{Plus®}$ were determined at the U.S. Army Edgewood Chemical Biological Center. The sampler is a wetted-wall cyclone sampler that can be easily carried by a single person. The sampler is microcontroller-based and is designed to function as either a stand-alone unit or to be linked to other sampling, detection, or communication systems via an RS-232 data link. These tests were conducted with the unit as a manually operated stand-alone connected to an AC power source. The system continuously recycles the liquid to concentrate the sample. The designed air flow rate of the sampler is 265 L/min; however, the measured air flow rate was 307.4 L/min. (Tests conducted by the manufacturer had flow rates of 270, 320, and 540 L/min.) Sampling efficiency tests were conducted using 1 and 3 µm PSL microspheres, and 5, 7, 9, and 10 µm fluorescent oleic acid particles. The samples were analyzed by fluorometry. The results show that SASS has peak efficiencies of 65.1% ± 3.4 for 7-µm particles and has a low power consumption of 14.4 W.

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## PREFACE

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# CHARACTERISTICS AND SAMPLING EFFICIENCIES OF THE SMART AIR SAMPLER SYSTEM (SASS) 2000$^{Plus®}$

## 1. INTRODUCTION

Air samplers are gaining importance in the war against terrorism and on the battlefields to detect the presence of chemical, biological, and nuclear aerosols. Samplers and detection systems must be tested and their performance efficiencies determined to support optimal decisions regarding aerosol assessment. Knowledge of equipment performance enhances the ability to protect soldiers, first responders, and the general public.

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

In this study, characteristics and sampling efficiencies of a Smart Air Sampler System (SASS) 2000$^{Plus®}$ (Research International, Woodinville, WA),[1] were evaluated. Each sampler's characteristics, e.g., weight, air flow rate, and power consumption, were measured. The tests were conducted at calm air conditions and do not include inlet efficiencies at varying wind velocities.

## 2. FACILITY

The tests were conducted in a 70 $m^3$ 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. In addition, 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 air flow that can be exhausted from the chamber is approximately 700 $ft^3$/min (approximately 2 x $10^4$ L/min) by the exhaust pump. There is also a small recirculation 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 be generated outside and delivered to the chamber, or they can be generated inside the chamber. A fan mixes the chamber air before and/or during the experiment to achieve uniform aerosol concentration in the chamber. Previous tests showed that mixing the aerosol in the chamber for 1 min is adequate to achieve a uniform aerosol concentration.

## 3. SAMPLER: SMART AIR SAMPLER SYSTEM (SASS) 2000$^{Plus®}$

A picture of SASS (Research International, Monroe, WA) is shown in Figure 1. It is a wetted-wall cyclone sampler that can be easily carried by a single person. The company states that distilled water is typically used in the system, and neither additives or surfactants are required for maximum efficiency. The air sampler is microcontroller-based and can function as either a stand-alone unit or be linked to other sampling, detection, or communication systems via an RS-232 link. This system continuously recycles liquid to concentrate the sample. The SASS tested was operated manually as a stand-alone unit on AC power.

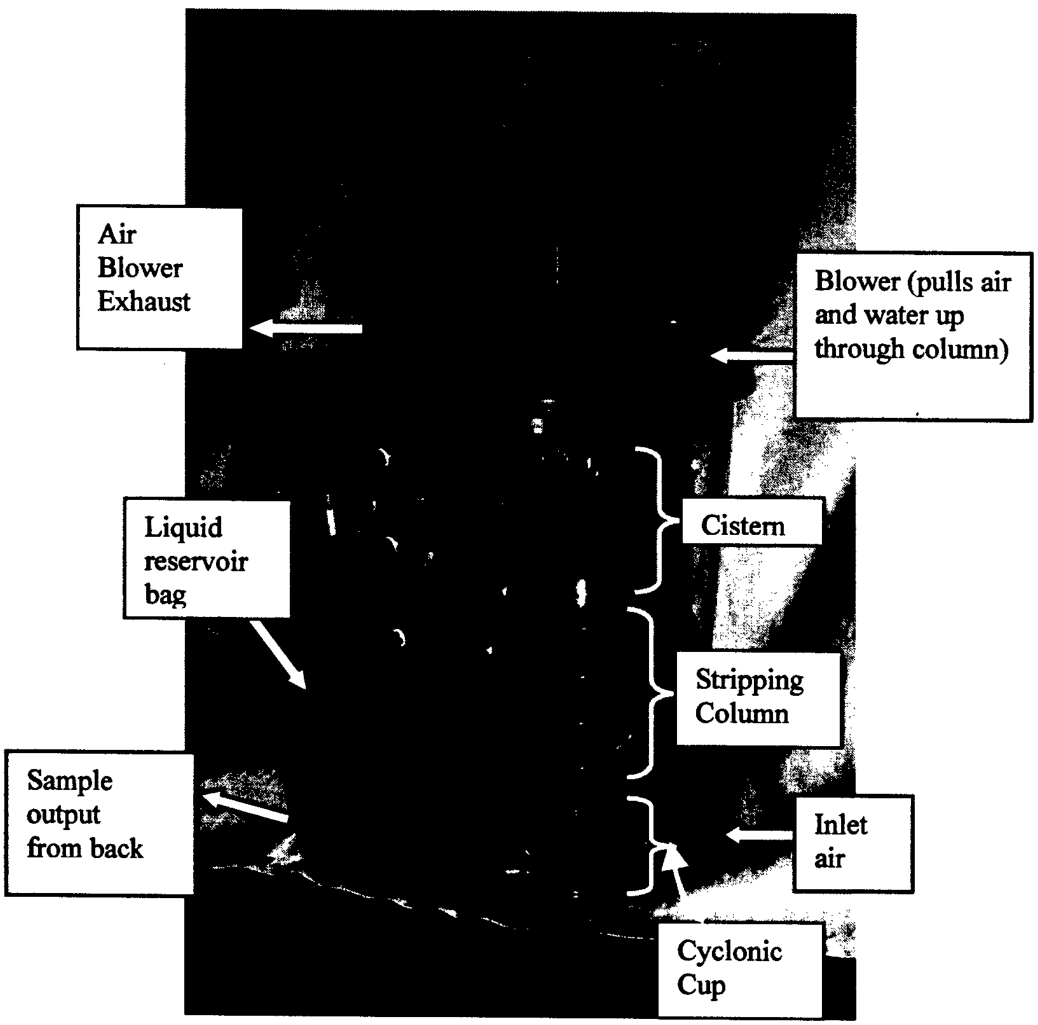


Figure 1. Picture of the SASS

The cyclone has four main sections: a cyclonic cup, stripping column, "cistern," and water feedback loop. There is a water reservoir that pumps water into the cyclone in the beginning of sampling and as the water evaporates. The incoming air enters the cup perimeter, creating strong vortex action and a rapid swirling film of water on the exposed surfaces. Water also passes across the air inlet region, forming a water curtain through which air must pass. There is a centrally located nozzle in the cup base that injects additional water. When water enters the cistern, it is returned back to the cyclonic cup by way of a small liquid return tube. There is a sensor attached to the water feedback tube to add water from the reservoir as needed (Research International, 2004).[1] The designed air flow rate of the sampler is 265 L/min, and the sample volume is 5 mL.

## 4. SAMPLER CHARACTERISTICS AND MEASUREMENTS

The SASS weighs 6 lb (without battery) and is easily transportable with a built-in handle on top. It sits stably on a flat surface and measures approximately 13 in. high with a slightly oval 8 in. x 7½-in. diameter body. The air flow rates of the sampler and reference filters were measured using a Kurz air flow meter (Kurz Instruments, Incorporated, Monterey, CA) and a Buck calibrator (A.P. Buck, Incorporated, Orlando, FL). A power meter (Extech Instruments, Taiwan) measured power usage. Table 1 provides the unit's measurements.

Table 1. SASS 2000® Aerosol Sampler Characteristics

| Characteristics | SASS 2000® Aerosol Sampler |
|---|---|
| Measured air flow rate at inlet (Lpm) | 307.4 |
| Designed air flow rate at inlet (Lpm) | 265 |
| Power measured at ECBC (W) | 14.4 |
| Physical parameters: | |
| Weight (lb) | 6 |
| Height (in.) | 13 |
| Body diameter (in.) | 8 x 7½ oval |

## 5. TEST PROCEDURES AND ANALYSIS

### 5.1 Sampling Efficiency Measurements.

Sampling efficiency tests were conducted with two kinds of aerosols and corresponding analysis methods. The first method used monodisperse fluorescent Polystyrene Latex (PSL) microspheres, and the second method used monodisperse fluorescent oleic acid particles. Particle sizes used in this test were 1 and 3 μm PSL microspheres and 5, 7, 9, and 10 μm fluorescent oleic acid particles. Aerosol generation and analysis methods are described in detail below.

The sampler and corresponding reference filters sampled the air simultaneously and for the same amount of time (10 min). Prewashes were conducted before each test to confirm that the sampler was free of fluorescent material. The sampler was rinsed repeatedly after each test to remove fluorescent material.

5.2 PSL Microsphere Tests.

Sampling efficiency tests were conducted with 1 and 3 μm 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. During the experiment, the aerosol was generated for 10 min and mixed in the chamber for 1 min before sampling.

The sampler 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. The samplers used deionized water for collecting the 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 (Kesavanathan and Doherty, 1999)[2] consisted of placing the membrane filters into 20 mL of filtered deionized water, then hand shaking for 30 s followed by placing the test tubes in a holder attached to a vortexer (Maxi Mix 1, Type 16700 Mixer, Barnstead-Thermolyne, Dubuque, IA) for 30 min. The samples were removed from the vortexer every 10 min and shaken by hand for approximately 10 s, then replaced onto the vortexer for the remainder of the 30 min total time period.

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

Sampling efficiency tests were also conducted with 5, 7, 9, and 10 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 minimize charge on 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 size of the fluorescent oleic acid particles. The measured fluorescent oleic acid particle diameter was converted to an aerodynamic particle size using a spread factor (Olan-Figueroa et al. 1982).[3] 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 (10 min). Glass fiber filters (Pall Corporation, Ann Arbor, MI) were used as the reference filters to collect fluorescent oleic acid particles.

Glass fiber filters were removed from 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 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. (2001)[4] describe, in detail, the factors that affect fluorescein analysis and the removal of fluorescein from filters. The SASS used the recovery solution as the sample collection solution. The fluorescence of the solution was measured using a fluorometer (Barnstead/Thermolyne, Dubuque, IA). All the samples were analyzed either the same day of the experiment or the next day.

### 5.4 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 air flow rate of the samplers and the reference filters, and the liquid volume of the samples and reference solutions were considered in the calculation.

### 5.5 Test Activities.

The final tally of activity shows that 23 tests were performed to characterize six particle sizes for the SASS 2000®.

## 6. RESULTS

The sampling efficiency results for the SASS 2000® are shown in Table 2 and Figure 2. The sampling efficiency results of the SASS show a peak of 65.1% ± 3.4 for 7-µm particles. SASS's average liquid output volume was 5.0 ± 0.5 mL.

Table 2. Summary of Sampler Efficiency Results for SASS 2000® Sampler

| **Particle Size (µm)** | **SASS Sampler Efficiency (%) Average of 4 runs** |
|---|---|
| 1 (PSL) | 5.0 ± 1.1 |
| 3 (PSL) | 35.8 ± 4.1 |
| 5 (SF*) | 52.3 ± 1.2 |
| 7 (SF) | 65.1 ± 3.4 |
| 9 (SF) | 53.9 ± 3.7 |
| 10 (SF) | 59.0 ± 5.4 |

*SF = sodium fluorescein tagged oleic acid particles.

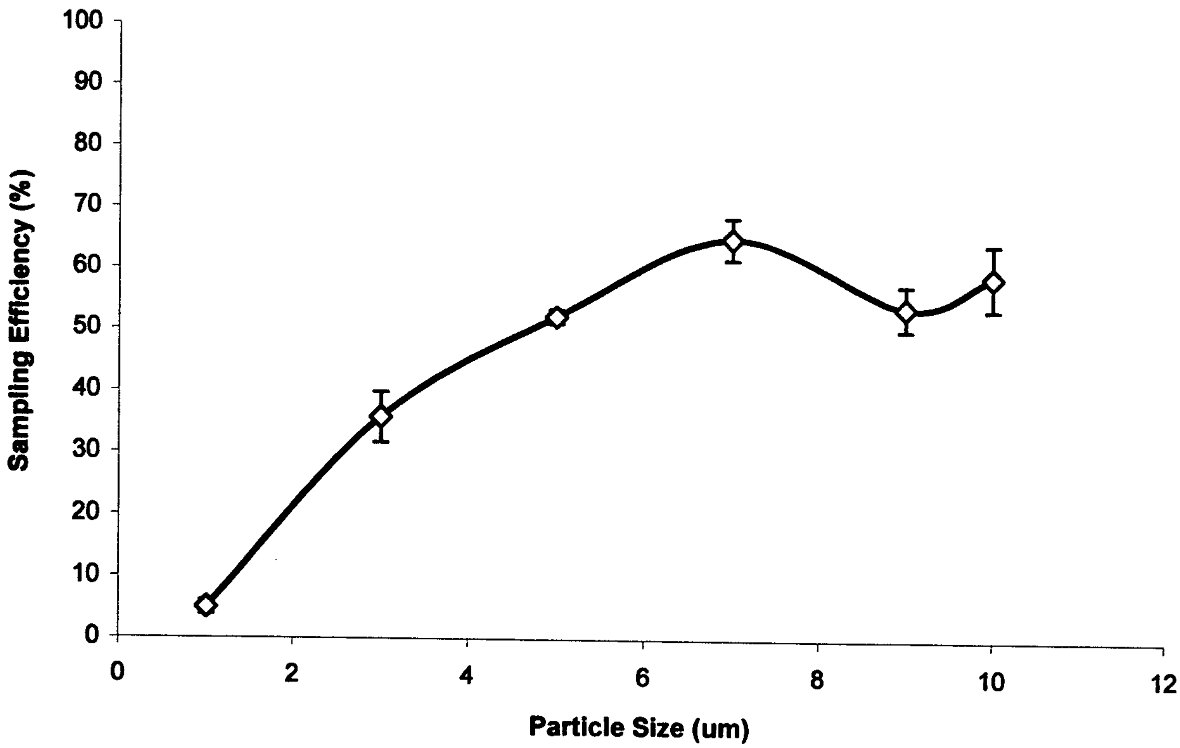


Figure 2. Sampling Efficiencies of SASS 2000® Aerosol Sampler

## 7. DISCUSSION

Prewashes were conducted to confirm that the samplers were free of fluorescent material before each test. If there was a significant amount of fluorescein in the prewash, then the prewash counts were subtracted from the sample counts.

The designed air flow rate is 265 L/min, however, the measured air flow rate at ECBC was 307 L/min. Therefore, the measured air flow rate was used in the sampling efficiency calculations. The sampling efficiency of SASS will be higher if the air flow rate is less than what was used in the calculations.

We tested the sampling efficiency of a previous version of the SASS with PSL microspheres and fluorescent oleic acid particles. That cyclone had a coating to improve surface wetting for more complete liquid distribution through the cyclonic activity. Most of the coating in that cyclone pealed off, and the liquid did not wet the surface uniformly. Thus, the performance of that unit would have been adversely affected. The sampling efficiency of the previous unit increased linearly from approximately 10 to 45% for particle sizes from 2 to 12 μm.

## 8. CONCLUSIONS

The Smart Air Sampler System (SASS) $2000^{Plus®}$ was characterized at the U.S. Army Edgewood Chemical Biological Center (ECBC). Sampler characteristics and sampling efficiency measurements of SASS were determined in this study using 1 and 3 μm polystyrene latex microspheres and 5, 7, 9, and 10 μm fluorescent oleic acid particles. The results show that SASS had a peak efficiency of 65.1% ± 3.4 for 7-μm particles, and had a low power consumption of 14.4 W. SASS is a lightweight, relatively small sampler, which is easy to use.

Information on sampling efficiency, size, weight, air flow rate, and power consumption of the sampler are given in the previous sections. The decision to consider a sampler for an application should include all these factors. Readers are advised that based on these test results, the sampler may be modified and improved as new technology becomes available. Therefore, a modified sampler may have very different characteristics than those discussed herein.

## 9. RECOMMENDATIONS FOR FUTURE WORK

As a result of tests conducted, future studies should consider the following:

- Evaluate the sampling efficiency of particles >10 μm to determine the largest particle size SASS can collect.

- Evaluate additional collection techniques for enhancing sampling efficiency of 1-μm particles.

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