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Mechanical Engineering Department

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Payload Number:
#6

Payload Title:

Evaluation of Atmospheric Particles Collection Performance of Three Sampling Substrates at Different Layer of the Atmosphere

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Abstract

The composition and size distribution of atmospheric aerosol particles vary temporary and spatially. Their occurrence, residence times, physical and chemical properties, such as size distributions and chemical composition, all vary in different magnitudes. Therefore, the vertically resolved measurements of these particles' physical properties are of great interest. This study aims to determine and interpret: (1) changes in the size and shape of the atmospheric particles, and (2) measures concentrations of trace metals and persistent organic compounds along three altitudinal gradients. The management of the payload will be at the charge of the two advisors and the research team. This trial is expected to yield insight into aerosol particles size distributions and atmospheric contamination with metals and persistent organic pollutants (POPs) with the intent of replicating future experiments in the tropical atmosphere of Puerto Rico.

Introduction

In this study, aerogel, polyurethane foam (PUF) and Mylar discs were used to collect atmospheric particles at three different layers of the atmosphere in order to evaluate their particle collection performances and to quantify atmospheric concentrations of persistent organic compounds at different atmospheric layers. With the data we compare which sponges are the best to use for that type of experiment. With the according data we can use the same experiment for future capsules and check the particles at the atmosphere of Puerto Rico. For later then to compare the data. The Puerto Rico HASP team will make a payload of three drawers that each one will contain an aerogel, PUF and a Mylar disc. The drawers will be operated by servos and the servo will get command from an altimeter and an Arduino Mega.

Background Research

Aerosols are of major importance for atmospheric chemistry and physics, the hydrological cycle, climate, and human health. The primary parameters that determine the environmental and health effects of aerosol particles are their concentration, size, structure, and chemical composition. However, these parameters vary depending in space and time of meteorological processes. In the troposphere, the total particle number and mass concentrations typically vary in the range of about 10^2–10^5 /cm^3 and 1–100 mg/m^3, respectively [Raes et al., 2000; Williams et al., 2002; Krejci et al., 2005]. In general, the predominant chemical components of air particulate matter (PM) are sulfate, nitrate, ammonium, sea salt, mineral dust, organic compounds, and black or elemental carbon, each of which typically contribute about 10–30% of the overall mass load. However, the relative abundance of each component can vary by an order of magnitude or more at different locations, times, meteorological conditions, and particle size fractions [Raes et al., 2000; Han et al., 2007].

The physical and chemical properties of atmospheric particles in the troposphere are highly diverse, due to different sources and meteorological processes. Atmospheric aerosol particles originate from a wide variety of natural and anthropogenic sources. Meteorological conditions such as wind speed, temperature and relative humidity influence aerosol shape and size distributions, and chemical levels. Measurements of size distributions and chemical composition of atmospheric aerosols are crucial in advancing our understanding of their fate and transport.

The scientific payload will be running once the launch begins. The payload will depend in the altitude of the satellite. Figure 1 shows the concept of operations. The first collector assembly containing all the three substrates will activate when the payload reaches to 5 km altitude. The substrates will collect particles from troposphere between 5 and 10 km of altitude (point 1 to 2). The second collector assembly will allow us to obtain the samples on the three sampling substrates from 10 to 20 km (point 2 to 3). From 20 to 35 km (point 3 to 5), the third collector assembly will stay open to provide the three substrates exposure to the particles at those altitudes.

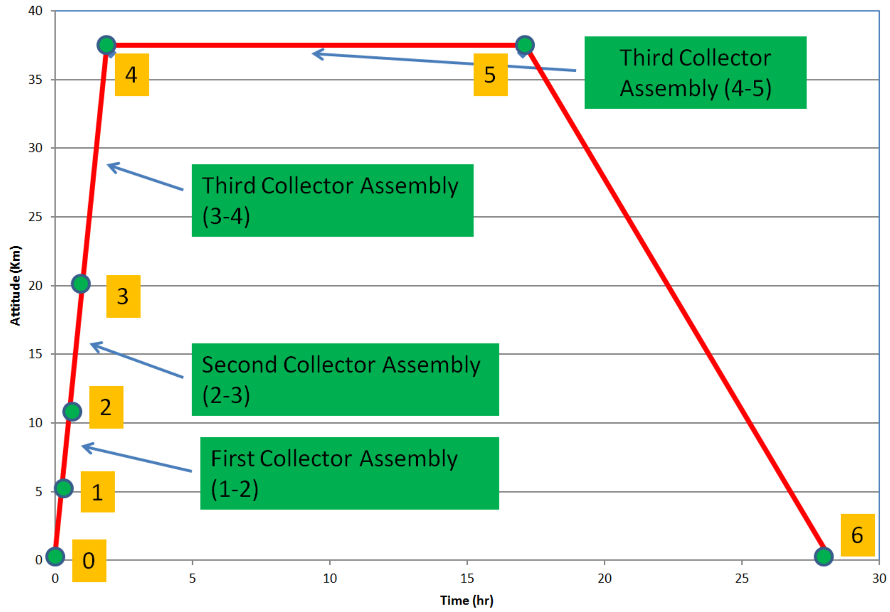

Figure 1 Concept of Operation

Material List

Table 1 Materials used in the HASP Payload

Materials List	Quantity
Angle Aluminum 3/4 in	4 x 15.24
Aluminum Sheet / Side Plate	4 x 464 cm^2
Aluminum Sheet / Base Plate	4 x 232.26 cm^2
Filament (ABS) 3D Printer	150 g (approx.)
Servo (HS - 785HB)	3
Gear Rack Kit 785 (Single Parallel)	3
Crown Bolt 6-32 x 1/2 in	54 (approx.)
Nut 6-32	54 (approx.)
Monokote	1
Based (HASP)	1
Arduino Mega	1
Voltage Regulator	4
Jumper Wires	45 (approx.)
Aerogel	3
Mylars Discs	3

Experimental Procedure

Structure Design Assembly

1. Use the pane of aluminum and is cut 3 plates of 6 in x 12 in, 4 plates square 6 in X 6 in, and a plate of 6 in X 12 in which it will be cutting some holes for the drawers designed to your choice, which will allow for the operation of the servo motors.
2. To the 3 plates square makes it a hole proximately of ¼ in the left corner to 1 in both walls.
3. With the angle of ¾ cuts the following:
4. The exterior part of the capsule is mounted: 3 aluminum badges of 4 in X 2 in, with the angular ones of ¾ in, using as a base the platform of the HASP or a base to your choice.
5. Mount the servos motors to the plates of 6 in X 6 in, that are the floors, the servos motors are located to 1.5 in the left wall in frontal plane. The servos are adjusted with a few angular ¾ in the floor plate.
6. Then prints the CADS of the drawer and bars to be mounted to the bar servo motor
7. Mounts the floors with the drawers already fitted and its servos engines
8. Install the front plate of the capsule, uniting it with the angular to each floor
9. After the plates already installed you located silicon in each crack or opening of plates to seal the capsule.

Electrical assembly

1. With the PArallax MS5607 altimeter is connected to the Arduino Mega in the following way: SDI to..., SCL to... and Vin to... And GND to...
2. To the source of Voltage of 30, is you connects a regulator of voltage 3 of 5V and one of 12V, to its GND and Vin.
3. The Vout of 5V voltage regulator are connected to the servo motors.

4. the yellow wires are connected to the pin of your choice according to the Arduino programming.
5. the regulator's voltage, Vout of 12 is connected to the Arduino mega.

Data Analysis and Discussion

Particles collected on the surfaces of Mylar strips and PUFs were extracted with 20 ml of DI water by sonication. The extracts were used to obtain size distribution of atmospheric particle with IZON qNano instrument. This instrument uses Tunable Resistive Pulse Sensing (TRPS) technology which enables measurements of nanoparticles suspended in electrolytes. Resistive Pulse Sensors measure the increased electrical resistance brought about by a particle passing through a nanopore filled with a conductive electrolyte. Particle concentration is determined by measuring particle count rate, and as a guide the particle rate should ideally not exceed 1000 particles per min, with an optimum range between 500–700 particles per min. At least 500 particles have to be counted by the system in 10 minutes in order to obtained accurate results with this instrument. Unfortunately, our samples had very low particle count rate, and thus particle count resulted significantly less than 500 particles during each run time. Scanning electron microscope (SEM) images of the PUF, aerogel and Mylar samples would have help us to verify whether samples contain low number of particles.

Possible reasons for this low rate could be;

a) introduction of particles into water may invariably alter the particles due to dissolution and surface tension driven rearrangement.

b) small particles may go undetected if they do not displace an appropriate volume of electrolyte to create a resistive pulse event signal larger than the background noise. Using Malvern Zetasizer

Nano ZS dynamic light scattering system may solve this problem; however, this instrument is not available in our campus. The particle size distribution often be difficult to obtain due to the inherent limitations in each established measurement techniques.

It was planned to use TESCAN Model VEGA 3 XMU scanning electron microscopy coupled with Energy-Dispersive X-ray analysis (EDX) to characterize physical and chemical properties of particles collected at different altitudes of the atmosphere. However, our SEM was damaged due to poor electrical power (fluctuating *voltage) and working environment conditions (high humidity).* We made an arrangement to use an SEM belongs to Turabo university, but their SEM also had malfunction after having chance to analyze only two out of nine samples. Figure 1 shows the SEM images of few particles collected on aerogels.

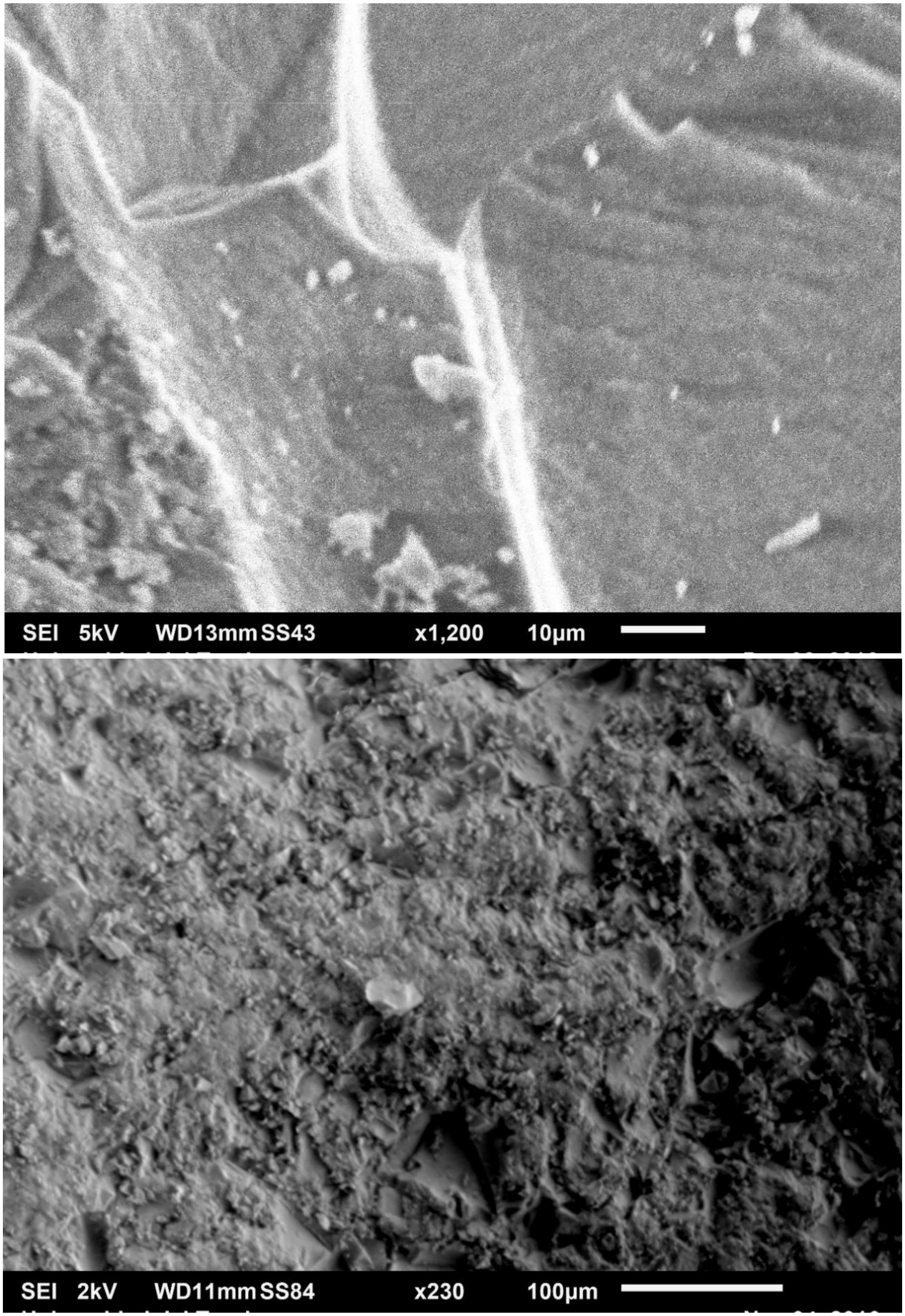

Figure 2 SEM Images of Aerogel 1 and Aerogel 2.

Chemical analysis of the samples was performed on PUF samples since they capture chemicals not only in particle phase but also in gas phase. Each PUF sample was Soxhlet extracted with a 20:80 dichloromethane (DCM): petroleum ether (PE) solution for 24 h. Prior to extraction, the PUFs were spiked with deuterated PAH surrogate standards to determine recovery efficiencies of target compounds. The extracts were concentrated by rotary evaporation to approximately 5 mL. Solvent was exchanged for hexane by adding 15 mL hexane and evaporating the mixture again to 5 mL. The concentrated extracts were reduced to 2 mL by inert nitrogen gas blowdown. After volume reduction the samples were cleaned up on an alumina-silicic acid column. The clean-up column contained 3 g of silicic acid (3% water), 2 g of alumina (6% water) and about 1 cm anhydrous sodium sulfate (Na_2SO_4). Sample in 2 mL of hexane was added to the top of column and PAHs were eluted with 20 mL of DCM. After solvent exchanging into hexane, the final sample volume was adjusted to 1 mL by nitrogen blowdown. The analysis of the samples was performed using a Varian 450-GC coupled to an ion trap mass spectrometer Varian 240 MS. A Varian factor 4 capillary column (30 m, 0.25 mm, 0.25 µm) was used. The GC oven temperature was programmed from 60°C (held one minute) to 130°C at 7°C min^{-1}, then raised to 200°C at 5°C min^{-1}, and finally increased from 260 to 320°C at 6°C min^{-1}. The injector temperature was maintained at 295°C. Identification of individual PAHs was based on the retention times of target ion peaks (within ±0.05 minutes of the retention of the calibration standard). Identification was confirmed by the abundance of the qualifier ion relative to target ion.

There are hundreds of PAH compounds in the environment, but only 16 of them are included in the priority pollutants list of US EPA. Therefore, the samples were analyzed for only 16 PAH compounds. PAH levels for each individual compound were presented in Figure 2. The compounds in these Figure are listed in their order of elution from the GC/MS. Only low molecular weight PAHs were detected due to their presence in gas phase at high concentrations. FLN, PHE and FL represent the highest proportions of the total concentration. The PAH levels measured in lower atmosphere (PUF1) are much higher than those measured for the other two samples.

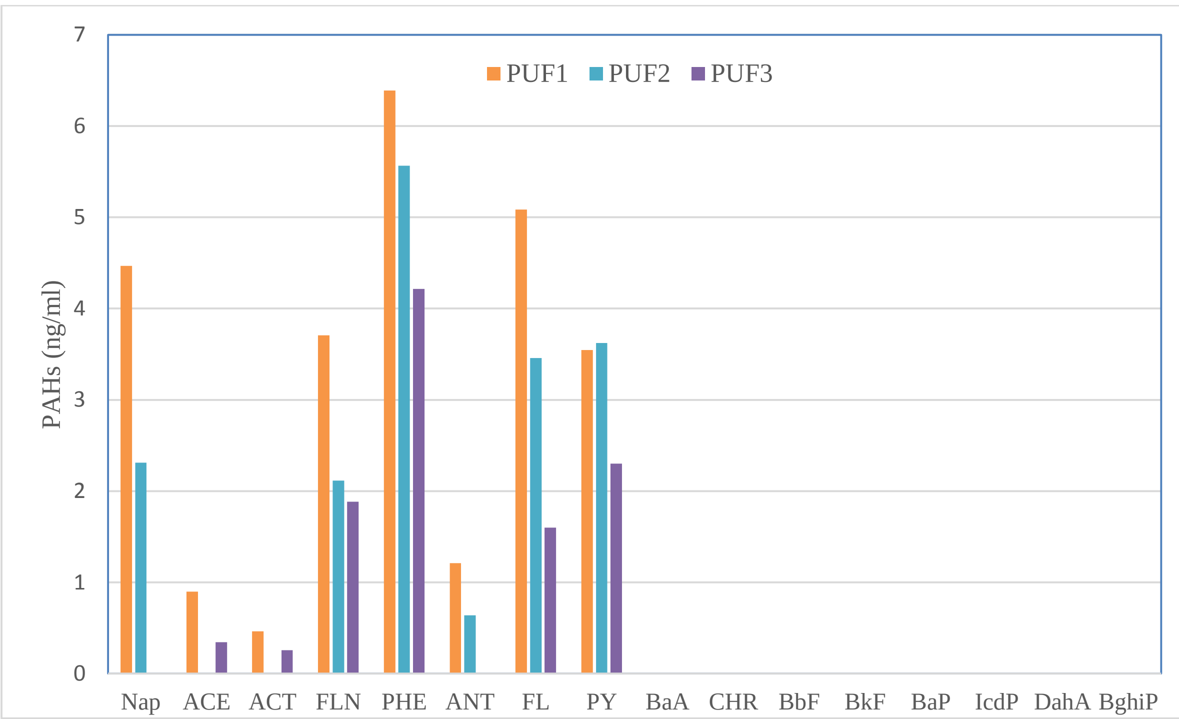

Figure 3 PAH Levels for Each Individual Compound (Naphthelene(Nap), acenaphthene (ACE), fluorine (FLN), phenanthrene (PHE), anthracene (ANT), fluoranthene (FL), pyrene (PY), benz(a)anthracene (BaA), chrysene (CHR), benzofluoranthenes (BbF, BkF), benzo(a)pyrene (BAP), indeno(1,2-cd)pyrene (IcdP), dibenz(a,h)anthracene (DahA), and benzo(ghi)perylene BghiP).

Payload Performance, Problem Encounter & Lesson Learned

Payload Performance

The payload worked better than we expected. The team was receiving all information wanted. The Arduino code worked without a problem and according the data we were gathering from the Arduino and the altimeter, all servo motors opened and close on the altitude and time programed.

Figure 4 Arduino Code

Problem Encounter

The problem that we encounter was that we did not tested the circuit of the payload to ensure that we weren't giving those current spikes. Also our altimeter at a certain height it stopped working at a certain height and we had to program our Arduino using time delay for the third servo motor to open. The Inter-American Scanning electron microscope (SEM) has some issues that does not work and it was hard to find a University in PR to help us as fast as possible. Then when the collage was found their SEM was damaged and seven out of nines sponges could not be examined by the SEM. Others material where examined chemically.

Lesson Learned

The team learned that these type of project requires more time than usual and more preparation. It was a great experience working in a NASA facility and working with professionals. The team realized that we are not completely ready as they expected and need more practice. Possibly for future projects if the team will use an altimeter, a test will be compulsory to check if the altimeter can handle the height and the rough condition that a capsule suffer at those heights.

Students Participated in Project

Table 2 Demographic of PR HASP Team

Students:	**William E. Roman**	**Euric H. Payano**	**Asuwie Serrano**	**Alexandra Reyes**
Gender	Male	Male	Female	Female
Ethnicity	Hispanic	Hispanic	Hispanic	Hispanic
Race	White	Black	White	African-American
Student Status	Undergraduate	Undergraduate	Undergraduate	Undergraduate
Disability that limits a life activity	No	No	No	No

Conclusion

The experiments were completely successful on the HASP platform for the PR team payloads, but more research and preparations have to be made to get big results from the tests. Thank to figure 2 we can see that there is more concentration of PAH in the first layer of the atmosphere. Also as shown in the aerogels there is more dust particles between the first and the second layer of the atmosphere. For futures projects the teams and advisor need to be more prepare to encounter problems of the machinery that is going to use to see the data. Because the team was caught out of guard when knowing that the SEM was not working.

Acknowledgement

The HASP team of Puerto Rico give thanks to our science advisor and our advisor for working hard on helping us on getting the data on the sponges as soon as possible. Also thank to all HASP team and the HASP crew for helping us when we had a problem with the program and or electric problem. Finally, a thank for the University of Turabo in Puerto Rico for helping us use their machines to examine the sponges.

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