



Master of Science in  
Cultural Heritage Materials & Technologies



UNIVERSITY OF THE PELOPONNESE  
DEPARTMENT OF HISTORY, ARCHAEOLOGY  
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DEMOKRITOS  
NATIONAL CENTER  
FOR SCIENTIFIC RESEARCH  
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NATIONAL  
OBSERVATORY  
OF ATHENS

**Master of Science in**  
**«Cultural Heritage Materials and Technologies»**

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“Particulate Matter in the libraries of the National Observatory of  
Athens and Moni Velanidias; application of SEM”

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-Patrick

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## **Abstract**

This thesis aims to study books as a passive filter in library environments. Libraries were built to house books, and sometimes books have been in collections long enough that they have a history of the particulate matter (PM) that has entered into the library. It makes sense to test the books when collecting PM data within a library. The PM data for this study was collected using passive paper-based filters in hopes of mimicking the collection rates a book would have, books being of a similar cellulose structure. The sampling occurred over the space of eleven days, with samples taken on day six and day eleven. Collections were made at the libraries at the National Observatory of Athens (NOA) and at Moni Velanidias. The analysis of the results was conducted through backscattering electron imaging through an SEM-EDS located at the campus of the University of the Peloponnese in Kalamata, Greece. The results showed various elemental compounds, some that were expected such as aluminum silica and calcium, crustal elements. Other unexpected components such as barium and molybdenum were also found. Future studies carried out over more time would yield more accurate quantitative results.

# 1. Introduction

## 1.1 Bibliographic Overview

Conservators in libraries, archives and museums are interested in the effect that dust or particulate material (PM) have on their collections and the physical spaces that surround them. Some studies focus on how and where dust is deposited; some are most interested in organic matter found in the PM, and others in chemical or inorganic compounds. Though studies look narrowly at one aspect or another, all are concerned to some degree with what the PM is doing either to physical objects such as books, manuscripts and artifacts, or to people who work in or visit the physical spaces due to the effect of PM on air quality. Therefore, in this review, I will be categorizing the literature based on dust deposition, organic and inorganic compounds, noting that researchers in each of those categories may also address either collection care or air quality or both.

## 1.2 Dust Deposition

Studies about dust deposition seek to discover the rates at which atmospheric particulates settle on collection materials, size of particles, whether or not the particles adhere to mediums such as paper, (put other things here if there are any etc.) Researchers discuss various methods of sampling for dust, and different approaches to the analysis of research findings.

Raunemaa et al. (1989) wrote about the indoor air model, detailing the deposition and transport of fine and coarse particulate matter, research motivated because people were spending 70-90% of their time indoors, and studies involving indoor air quality were limited. The authors' studied occupied Finnish houses and offices, in both urban and suburban environments. The sample size was 30 structures, consisting of 25 houses and 5 office buildings. The samples were collected during the day with average indoor temperatures of 22°C in buildings that all had zone heating. A secondary experiment looked at the effect of ventilation and filtration within an office building in the center of Helsinki. The authors used stacked filter unit collection to separate the fine and coarse particles. Two units were set at each collection site; one to collect samples indoors, and the other to collect outdoor samples. The filters were analyzed using PIXE and the samples checked against a calibrated Sulphur reading from ion-chromatography for accuracy. The results from this study showed that the majority of particles deposited in the buildings were of fine particles between 4 and 67  $\mu\text{m}/\text{m}^3$ . Outdoor particle size had a greater distribution of particle sizes. The ventilation and filtration systems remove a large amount of particulate material but this doesn't take into consideration the

amount of material brought in by the inhabitants, nor the pressure variation between the outdoor and indoor environments. The ways the PM deposited on surfaces were through sedimentation on horizontal surfaces and turbulent diffusion for vertical surfaces and some horizontal surfaces. Raunemaa et al. found that the sulfur deposition for sulfur bearing particles was lower than the deposition velocity of the other elements. Human activity has a huge impact in indoor air pollution and increases the emission sources through cooking, cleaning, which affects the number of aerosols. Cooking presented the greatest variance of results due to temperature, which increases the gas-to-particle conversion rates. Fine particle sampling increased drastically when cooking occurred. The authors conclude that human activity has a significant role on reemission, and dry deposition velocities were determined for some particle compositions.

Ligocki et al. (1990) set out to measure deposition rates in southern California museums. The deposition of particles on art objects causes soiling and darkening. When deposition occurs over a lengthy time, the darkening can be severe. This prompted the authors to study the deposition rate. Deposition rates are calculated as velocity (number per unit area per time) divided by particle number concentration (Number per unit volume). The authors used SEM-EDS and bulk chemical testing to quantify the airborne and deposited particles. The test sites had both indoor and outdoor sample locations to measure the particulates in the air, and inside the museums they also set up vertical and horizontal plates to act as deposition plates. Sampling was taken during both summer and winter to look at variation in deposition rates. Sample sizes of note to the authors were between 0.05 and 2.1 micrometers; past research indicated that the smaller sample diameter was understudied. Large particle distribution indoors and outdoors are inconsistent because the filtration systems inside of museums tend to filter these particles out. The authors find that the fine particle concentrations are equal to the outdoor samples. SEM-EDS is very powerful tool for counting and classifying particle size and elemental characteristics, though it does require long sampling time.

Nazaroff et al. (1990) studied the effect of indoor air pollution within five California museums. They focused on particle size and distribution. The authors used two pairs of optical particle counters; one was located inside while the other monitored the outdoor environment. The study shows that the indoor air particulate mass was roughly 15-20% of that of the outdoor environment, and the coarse particles were less than 5% of the outdoor environment. This was due to the filters in place for the air exchange of the HVAC system of the museums. The number of particles entering the museum was mostly due to this air exchange with the outdoor environment, and the majority of deposition was on the floors. The authors conclude that there is more room for an investigative search into deposition rates and that the effect of building occupancy is under represented in their study, and that it is important to limit outdoor and indoor aerosol sources with outdoor sources being the main source of particulate matter.

Nazaroff partnered with Salmon and Cass, also in 1990, on a study examining modeling and measurement results. The purpose behind the paper was to determine how to protect art from dust deposition and the damage that dust can cause. The comparison the authors use is based on the concentration of the outdoor aerosol and building ventilation. The authors state that deposition velocity was counted as units:  $m\ s^{-1}$ , being the density of particles on a surface ( $m^2s^{-1}$ ) divided by the number of particles in the air from surfaces (number  $m^{-3}$ ). Samples were analyzed in an automated SEM to count the number and size distribution. The air flow in the tested buildings was found to be mechanically driven from the HVAC system, and thermally driven from temperature differences near windows versus walls. The authors utilized a simplified description of fluid behavior to discuss how particles suspended in the air moved into a closed building. A boundary layer is assumed to be found between the core and the walls. The particles move through this boundary area through Brownian and turbulent diffusion. In conclusion, the authors found that their study can be applied to a flat plate for small particle sizes and shows deposition rates on vertical walls. The study also showed that particle deposition was greater on cool surfaces than warm surfaces.

Thatcher and Layton (1994) studied the deposition, resuspension, and penetration of dust particles in a two-story house. Concern about the levels of pollutants within the indoor environment was due to the amount of time people were spending time in their homes. In order to collect the data for deposition the authors used a tygon tube over a stainless-steel screen to reduce the number of large particles collected. Resuspension of particles was shown to have very little impact within the indoor air quality. This study showed that the shell of a building provides little filtration for ambient air, and that the deposition rates of particles is dependent on their density. The authors would have liked to explore more the effects of resuspension of particles to help show the variation of indoor levels of pollution in relation to traffic caused by the human occupants. Although this research was not looking specifically at libraries or other institutions with collections, their findings about particle size are applicable.

Adams (1997) took a different approach to modeling dust deposition. The author looked at the existing analytical technique using an EEL Dust Deposition Meter. The EEL is a box with two holes measuring 26x76 mm over a black hole. A glass slide fits into the hole and a light source and receiver measure the loss of gloss overtime. The normal test involves comparing the data to a clean slide, and a constant is considered for the glass slide. The author changes this by making each slide's "gloss" relative to itself and not a constant "gloss" for the slides in total, and measuring three slides at a time instead of the normal one. The author found that the collection of dust is not linear and that after seven days there would be losses of the dust layer. Therefore, seven days of monitoring dust were critical for the experiments. The main advantage to this technique was the increased sampling size, offering a more representative result of dust deposition, with the main drawback being cleaning the glass slides to have a clear image. Both methods, original and new, yielded similar results and had good agreement.

Kildeso et al. (1998) examined indoor dust within 19 office buildings at Harvard, focusing on the buildup of the particles. The authors noted that outdoor particulate matter has been linked to health issues and that indoor dust is comprised of dusts generated inside a home, and also from the outside. The authors used a tin foil sampling method which measures the amount of dust in a given area by detecting the change in attenuation of light when light is shined through in a laser system. The dust was analyzed three different ways: first, visual analysis of the buildup of the surfaces of the test locations; second, measurement comparing the airborne and dust build-ups; and third, an aerodynamic particle sizer (APS) was used to look at the volume of particle size within the test area of building three. The results from the APS were tested against an outdoor air sampling done at the same time, and a similar distribution of particle sizes was found indoors. The authors found that the larger dust particles were responsible for the majority of build-up, and that dust particles in the size range of PM<sub>2.5</sub> had minor effects on surface dust. These results were used to determine a cost effective and efficient method for cleaning the buildings.

Ford and Adams (1999) studied atmospheric pollutants within museum environments. They chose this topic because of the damage and loss of value that accrues to objects from the deposition of PM. They used glass slides as a method for collecting surface deposition PM. The authors studied the deposition rates in two downtown London Victoria Albert museum sites over a year-long period. The authors found that soiling rates were highest near the entrances, they supposed that this was due to PM being carried into the museum from visitors, and during times of events these locations gathered even more dust. They also found there to be differences in soiling rates between winter and summer months because of a difference in indoor air velocities. They found that the glass slides were effective in monitoring particulate deposition rates, and allows for extensive monitoring because of the low cost. The authors conclude that future studies could try using different substrates to collect samples.

Adams et al. (2002) used glass slides placed in the British Museum to study the accumulation of dust and the loss of gloss. The authors expected dust coverage on surfaces to be exponential. Glass slides were exposed for one week to mimic previous outdoor experiments; none of the spaces chosen for testing were either air conditioned or mechanically ventilated. The differences in indoor and outdoor scouring rates was 5.3: outdoor being 6.1 (indicating that dust had been removed) and indoor being 0.8. Outdoor scouring rates were caused by forces such as wind and rain, and indoor rates had almost no scouring. The authors looked at temperature and relative humidity (RH) to see if there was an effect on deposition. They found that though it was hypothesized that 70% RH might result in greater adhesion, there was little effect of the temperature and RH for deposition rates. The authors concluded that Indoor dust reduces the reflectivity of objects, and the accumulation rate is relatively small under normal conditions.

In a 2002 issue of *Studies in Conservation*, Lloyd et al. discuss dust, dust collection, and dust cleaning. The author notes the two common ways of testing dust deposition within an indoor environment, glass slides or sticky surface. The glass slide looks at the amount of gloss that is reduced while sticky surface testing looks at gathered dust, and measures how much surface area is covered. The author placed sticky surface samplers in areas around the museum and found that the heavier particles were found closer to the ground and decreased on the test strips as they were placed higher within the room. This correlates with the dust deposition rates being higher at lower heights, a sample strip placed at 240 cm had one quarter the deposition rate than a strip placed at 120 cm. Dust has the ability to cement on horizontal surfaces over long periods of time with a high RH. The availability of salts and sugars might increase the amount of fungal and microbial growth that could be responsible for this cementation process. The author concludes that this project will help the historic environment and increase the discussion about indoor air pollution.

Lloyd et al. (2007) studied the economics of dust and how the deposition of dust poses a significant risk to indoor collections. Dust coats objects reducing the shine and luster of the object by creating a patina. When cleaning the dust more damage can happen to the objects due to the abrasion of the dust and the cleaning tools, and aggressive cleaning methods for dirt that has cemented due to high RH. The authors looked at the number of visitors in relation to the deposition of dust. Most dust due to visitors is deposited near entrances and within the first 3m of an entrance. The authors conclude with strategies for mitigating dust, and cleaning the dust from the surfaces of the area.

The study done by Wei et al. (2006) also used glass slides to gather dust particles from the environment in three Dutch museums, to try and determine quantitatively the subjective measure of “too much” dust. The authors evaluated the loss of gloss these slides experienced and measured the dust using SEM-EDS. Gloss measurements are based on the principle that if light is shined at a specific angle, it will be reflected with energy relative to the energy of the source light. When there is a buildup of dust the light will scatter and the intensity of the reflected light on the given angle will be significantly less than a non-dusty surface. To look at the dust under SEM-EDS a carbon tape was mounted to an aluminum disc and left to collect the dust, which was then inserted into the machine. The authors found that the loss of gloss measurements can be used to determine the rate and changes of dust deposition within a sealed library environment.

Adams et al. (2010) compared the use of glass slides to a sticky surface to measure dust accumulation. Dust is a concern for libraries and museums because the dust can soil objects and act as an abrasion source for wear on the objects. The authors focused on the amount of dust being deposited on surfaces and focused on creating a cheap and unobtrusive way to measure the collected dust. Dust from glass slides were looked at for loss of gloss to help determine the amount of accumulation in a given time and the sticky sampling had manual counts of particles

adhering, which were expressed as particle flux ( $\text{m}^{-2}\text{s}^{-1}$ ). The authors found the glass slides to be easier to deploy and had a variety of analytical techniques that could be applied. While the sticky sampling method was slower, it provided quantitative data and allowed for the precise identification of the make-up of the dust. The authors conclude that both methods have advantages and disadvantages and no recommendations on sampling techniques have been made yet, but further work should be done to determine a best practice.

Lloyd et al. (2011) looked at low-technology dust monitoring techniques. The authors used a label from packaging to gather the dust for their sampling. They examined the slides through optical microscopy at 10x magnification, under bright lights. Images of the dust particles were compared to those compiled in an atlas to identify possible sources. Quantitative data was gathered through these comparisons, but qualitative data could be seen as well. Looking at the images with a scale present can allow for the measuring of grain size and distribution. The dust shows a history of the collection, and can show how the dust was transported within the collection, such as particles carried in from outside on shoes, or someone rubbing against a wall and transporting plaster or fibers. Leather found in the dust could indicate improper storage, handling, or even deterioration of the bindings. Dust can show how often a collection needs to be cleaned, and the monitoring of dust can help inform staff where resources are needed most to best protect cultural heritage. The authors conclude that practice is required to correctly identify dust and that there is need to expand an atlas detailing more of the dust found within historic sites, allowing for a dust atlas to become a tool that can be a resource for conservators in the heritage sector.

Wilson and VanSnick (2017) tracked dust redepositing and accumulation using fluorescent substances and SEM-EDS within the Natural Archives in the United Kingdom. As part of the study, the authors identified how frequently the collection is cleaned: four years for low use items and twice a year for the frequently viewed collection items. They needed to know the risk dust presents to a collection, and focused on cleaning and transfer of dust particles. The authors used microfiber cloths, dusters, and HEPA vacuums to clean prepared test storage materials using UV-fluorescing material as a substitute for dust. Hands were found to transfer substantial amounts of dust from the boxes to the documents housed within. The authors found that the most effective way to mitigate dust on collection items was to house the collection items in folders within boxes in addition to regular cleaning. Cleaning methods should involve vacuuming with a HEPA filter vacuum and then wiping down the shelving with a damp microfiber cloth.

### 1.3 Organic Compounds in Dust

Although this thesis is focused on examining inorganic compounds in PM, rather than organic compounds, the methodology and findings of studies that examine organic particulates in samples of dust are still of interest. Most

PM gathered in various studies is a mix of organic and inorganic particles. All of this PM can land on and affect books, papers and artifacts, therefore, an understanding of both types of particles is important to the researcher.

Allou et al. (2007) measured the amounts of Aldehydes and BTEX in university libraries in Strasbourg. 20 libraries were chosen for the sample sites using passive sampling systems containing DNPH or activated charcoal. Aldehydes, which have the potential to impact the allergies of library patrons, come from a large number of sources. Aldehydes in an indoor environment can start to oxidize due to O<sub>3</sub>. Formaldehyde is the most commonly produced aldehyde in an indoor environment and was found to make up of 98% or more of total exposure. The objective of this study was to quantify the concentrations of aldehydes. Paper and ink can act as a Volatile Organic Compound, which generates O<sub>3</sub> that increases the formaldehyde formation. Libraries were found to have high concentrations of formaldehyde, particle board being the principal source for formaldehydes. The 11<sup>th</sup> library in the authors study had unusually high concentrations due to the HVAC system being shut-off during the day. BTEX's were present in all of the libraries with Benzene and Toluene being the most abundant chemicals. The authors found the doses in the libraries to be less than 7% of overall exposure and were well within the EU guidelines for annual limit value, 10  $\mu\text{m}^3$ . The authors conclude that BTEX concentrations were low, nearly the same as the outdoor air but lower than other studies indicated. Formaldehyde, acetaldehyde, and hexanal were found most abundantly in the libraries. Of these aldehydes, formaldehyde had the largest concentrations. Working in libraries increases the person's exposure to aldehydes but not to BTEX.

Cincinelli et al. (2016) measured volatile organic compounds in libraries in Italy. With libraries having large collections of cultural heritage objects that attract visitors, it is important to preserve collections for future generations. Library collections are comprised of many types of organic materials, including cellulose, silk, ink, glues. These materials require that steps are taken to control, temperature, relative humidity, light, biological infestation, and air circulation. The authors state that in recent years there has been an increase in studying the impact of air pollution on indoor and outdoor collections. The major outdoor pollutants that pose the greatest risk are: sulphur dioxide, nitrogen dioxide, ozone, reduced sulphur gases, and some VOCs. VOCs found indoors can often be attributed to outdoor sources such as vehicle traffic, and industrial pollution. Indoor VOCs are exacerbated by the off gassing of building materials and collection items. Indoor air pollution can have a significant impact on human health and can accelerate the deterioration of collection items. The most common VOCs found in a library or archive are: acetic acid, formic acid, furfural, 4-hydroxy benzoic acid, and 4-hydroxy acetophenone. These VOCs have been linked to lignin and cellulose degradation, and are used as deterioration markers. Sampling was done with Tenax GR (35/60 mesh) wrapped Graphite carbon Black sorbent tube. Field blanks were collected at each sampling area and precautions were taken to keep the tubes sample ready, such as not wearing care products when handling the tubes. The authors found benzene,

toluene, ethylbenzenes, xylenes, organic acids, aldehydes, terpenes, and siloxanes were collected in all samples and the concentrations of VOCs were between 68.4 and 317  $\mu\text{g}\cdot\text{m}^{-3}$ . A PCA analysis was done to show correlations between compounds, a high correlation indicating a potential common source. The authors PC1 showed BTEX to be most common due to vehicular traffic, PC2 was most aldehydes, and PC3 was mostly acetic acid. PC1 was the only sample that could be traced to a source material. The authors conclude that BTEXs were the most abundant chemicals found, and that libraries and archives are influenced by the outside air. There is no guideline to what the indoor air quality should be for preserving cultural property and that VOCs indoors should be regularly tested with test aims being focused on the VOCs that are known to cause paper degradation.

Fantuzzi et al (1996) studied the air quality in university libraries in northern Italy, looking into their volatile organic compounds (VOCs), such as formaldehyde. Studies in the United States had showed that VOC levels in libraries are often higher than outdoor concentrations. VOCs in buildings come from construction materials and various products such as adhesives, copy-machines, and people. When people access libraries, they can have symptoms resembling allergies, or irritations of the eyes, nose, throat, and sometimes, mental fatigue or headache. These symptoms when present in a library can suggest that the building has sick building syndrome (SBS), if it has mean concentrations of 34 VOCs, from VOC's notably Formaldehyde, C<sub>2</sub>-C<sub>5</sub> compounds, Benzene, Toluene, and Xylene. The authors looked at the total dusts and VOCs inside and outside during the study, as well as, temperature, and RH was also studied. All windows were closed during the collecting of samples to minimize ventilation. Filters were used to gather air samples, and VOCs were gathered using a SIPIN sampling pup. Dust in libraries is a main source of exposure to humans. Fine particle size is the most present health risk because they can be inhaled and bring high concentrations of harmful substances into the body. In the authors' study formaldehyde production was less than the international limit of 120  $\mu\text{g}/\text{m}^3$ . Their study suggests that there are no major concerns due to indoor air pollution but recommend that more investigation into the sources of the contaminants and defining a relationship between indoor and outdoor pollutant levels would be worthwhile. They also suggest looking more into the apparent issue of SBS in relation to the dust particles.

Maggi et al. (2000) propose a new way of detecting fungal spores within dust in archives. Samples were collected using Millipore samplers, which are a membrane filter supported by plastic. The authors electrostatically charged their samplers by rubbing them with wool to increase the dust collection. The authors conclude that an electrostatically charged sample kit is a valid way to collect dust, and that many species of fungus spores found in the study are harmful to collections, and that the damage can be prevented through regular dusting and monitoring the RH.

Lloyd et al. (2007) discuss the appropriate frequency of cleaning historic libraries. Dust detracts from the artistic value of historic objects and the cost of cleaning is high. This stated, dust can, conversely, add a sense of age to objects for visitors. Libraries are a challenge to clean due to the volume of books stored. The time it takes to clean the library is also dependent because of the tools used, a brush and variable speed vacuum. Dust that has collected in a historic library has a greater concentration of mold spores and mold has the potential to cause damage to the immune system. Books are organic materials; this means that as historic books have aged and become fragile, they breakdown and create dust. This dust further damages the books by the abrasion that occurs while cleaning. For collections that aren't actively handled, cleaning becomes the main source of mechanical damage. Every style of book within a collection present different challenges for cleaning (such as uncut pages in a publisher's binding) and time must be taken to work at cleaning individual pages to prevent staining due to dust cementation. The authors sampled using glass slides or sticky sampling, the sampling was carried out over the space of 3 years with samplers being changed out every 3 months. The samplers were placed in various locations within the libraries at heights and locations near the path visitors took through the libraries, height from the ground, and the space between the top of the books and the shelf. Libraries and archives differ in dust deposition, with visitors to libraries being the main source of coarse dust particles for libraries and the deterioration of books the main source of dust for archives. Cementation occurs when dust can't be appropriately cleaned from the surface and becomes ingrained. It tends to occur with high RH that helps facilitate biological, physical and chemical processes. In the presence of high RH bacterial cells create exo-polymers which bind dust particles to the substrate. When the book cycles moisture the pore structure of paper opens up and dust is pulled deeper into the structure, and chemically a high RH allows for calcium ions to leach from the dust and create microcrystalline calcite which binds to the paper substrate. In high RH the chemical process can happen within a day. All of these processes work because of the hygroscopic nature of books. Mold is also a major issue for collections and can be seen to grow at RH values around 65%. The authors tested RH for two libraries and selected books of about equal size and location. They used RH and T data-loggers for a year to monitor the collections, for the first six months with dust falls in place. Dust falls are strips of cloth that limit the exposure of the tops of books to falling dust, after the first six months dust falls were removed. The results from this experiment showed that with the dust falls in place the collection had less air exchange and a more stable RH. The authors suggest some methods of controlling dust within the libraries. Steps to controlling dust cementation issues within a collection is to control the RH where possible and aim for 50-65%, clean the books more frequently, keep visitors away from the shelves for historic library collections, have less hours for visitors to view the books, and keep windows and doors closed which can reduce the amount of dust present. The authors conclude that if dust can accumulate for long periods of time and with periods of high RH, cementation can quickly occur and it is critical to control the RH to prevent damage to the collection.

Borrego et al. (2012) studied the link between Indoor Air Quality and bio-deterioration of documents in archives. Archives and libraries store documents comprised of papyrus, parchment, and paper. Microorganisms attack these different materials and as the environment increases in temperature and humidity, the microorganisms can increase the deterioration of the materials. The authors looked at the number of microorganisms within the environment to help define the air quality. Open-faced Petri dishes were used to collect the samples and fungi cultures were created to isolate the total bacteria. The authors note that there is no international standard to determine if an environment is contaminated. They suggest that the combined amounts of bacteria and fungi should not exceed  $750 \text{ CFU} \cdot \text{m}^{-3}$  and above this level the environment is contaminated. A few bacteria strains were found to significantly increase the degradation of paper materials. Of note *Bacillus* spp. and the *Streptomyces* strains have been shown to be able to degrade paper in 24 hours, with 90% RH. The authors conclude that the biological events that have happened to the object could be recorded in the microbial and fungal presence.

Mahmood and Mari (2013) explore many different factors that damage and destroy library materials. Biological factors, usually consisting of mold and fungi, increase with high humidity. Mold spores remain in the air until they find good conditions for their growth. Mold favors growth on organic materials that are packed together tightly, an area where moisture can gather. Dust can provide for the right nutrients and environment for mold to grow. Temperature changes and RH can also affect the strength of paper, and can weaken the materials over time. Holding the objects within a ten-degree range and 15% RH can limit the effect of this weakening. Some chemical factors go into the deterioration of organic materials especially those of sulfur dioxides, nitrogen oxides and ozone. Brown and brittle edges are most indicative of sulfur dioxide. Nitrogen dioxide will combine with water to form nitric acid which destroys the dyes, and ozone fades the covers and binding materials. The authors state that if indoor air pollution is controlled through air conditioning, then the paper materials will not suffer from these chemical factors. If air conditioning is not possible, books should be dusted to reduce the buildup of pollutants and kept inside closed cupboards or enclosures. The authors do not have an absolute conclusion, but point out ways of dealing with air pollution within a library collection.

Hayleeyesus and Manaye (2014) studied the microbial quality of indoor air within eight libraries using petri dishes. The settle plate method using the petri dishes had the sampling height at 1m which approximated human breathing. Samples were collected twice a day and incubated to grow the cultures for testing. The concentrations of bacteria collected within each library environment was significantly different from each other. This is due in part to the locations, but mostly due to the variation of ventilation and number of occupants during assessment. The authors found that the average fungal density found followed the same trend of bacteria growth. Indoor library environments are favorable for fungal and bacterial growth, especially in humid conditions. The authors conclude that the libraries

were heavily contaminated with bacteria and fungi and that care must be taken to control the growth and spread of microbes in the libraries.

#### 1.4 Inorganic Compounds in Dust

The experiments performed for this particular paper on dust deposition are intended to look at specific inorganic compounds; therefore, literature on these compounds is necessary to inform the research.

For example, in the National Observatory of Athens, large traces of Aluminum appeared in dust samples, which is an inorganic compound discussed by Vest and Wouters. Their 1999 study examined alum tawed leather for bookbinding in 12<sup>th</sup> to 18<sup>th</sup> century European collections. Alum tawed leather has been widely used in bookbinding for 600 years, the authors set out to identify the dyestuffs and pigments used on alum tawed leather. High performance liquid chromatography (HPLC) and diode-array detection (DAD) were selected for their performance in identifying organic dyes and pigments. Inorganic pigments were used in a low vacuum scanning electron microscope with energy dispersive x-ray analysis being performed for element composition. Recipes from the medieval time were compared to the dyestuffs found through HPLC-DAD and LV SEM-EDS and found that variations to the techniques and materials but little change to the process. The authors concluded that blue dyed leather had Indigoid dyes in all cases, red dyed leather all contained lac or Indian lac, and green dyed leather contained copper chloride.

Drakou et al. (2000) produced a numerical simulation of indoor air pollution in a church and museum in Thessaloniki. The air in Greece, like many Mediterranean countries is rich in photochemical air pollutants that affect museums and other historic collections. Some of these pollutants are Ozone (O<sub>3</sub>), nitrogen dioxide (NO<sub>2</sub>) and Sulfur dioxide (SO<sub>2</sub>). These air pollutants are generated outside and migrate to the indoor environment. The authors based their study on an experiment setup by Nazaroff and Cass that measured the outdoor pollutant concentrations, meteorological data, and the concentration of pollutants. The sites chosen for this study were the Agia Sofia church, and Vergina, an exhibition hall of the Thessaloniki archaeological museum. Data for the locations was retrieved in consultation with the HVAC system engineer of the museum to get the air exchange rates, and for the church, air velocity was tested with a hot-wire anemometer by the windows and door. The authors found that the levels of NO<sub>2</sub> concentrations in both of the buildings exceeded the outdoor concentrations for long periods of time. However, this data is slightly skewed due to the issue of directional wind change and the free exchange with the environment that Agia Sofia has. The museum had no filtration system built into their HVAC system and showed lower levels at night when the system was shut down. Lighting within the museum increased the amount of O<sub>3</sub> present. The study concludes that the indoor air pollutions were higher than the recommended levels for air quality. To improve the air quality within a building, a

deeper look at the outdoor pollution trend, indoor emissions, and occupancy need to be studied before HVAC systems can be recommended.

In 2003 Bolourchi authored a paper titled “Pay Attention to Books’ Deadly Dust” in which he discusses different pollutants associated with dust and the link to lung cancer and heart attacks in some public library patrons. The author states that dust acts as a polar molecule as does paper. Therefore, the dust particles are attracted to and deposited on paper surfaces. For books, the paper acts as a magnet for dust particulates, and the opening and reading action of the books create air currents that redeposit the dust. Dust is created through natural and man-made processes. Sulfur oxide is an example of a man-made dust that is created through the incomplete combustion of car engines and is soluble in water and can attach to dust particles and be deposited on books that way. The author concludes that there is a significant impact of dust, more than just appearance. He recommended that more research needed to be done in various libraries to investigate this topic.

Ito and Aguiar (2006) looked at Indoor air quality (IAQ) of library environments in Brazil. Indoor pollutants can cause diseases in the eyes, throat, nose, skin, head, and lungs and, with people spending 80-90% of their time indoors this has become a prominent subject. Libraries are of particular interest because of their high concentrations, and the amount of traffic, of people, the abundance of paper materials, photocopiers and printers, and the ventilation systems. Libraries focus on the preservation of books and try to create low temperature and humidity to preserve the collections, which may not be adequate for human comfort or a good indoor air quality. The authors used a small volume sampler to collect indoor dust particles and studied two libraries within the city of San Paulo. The inside PM concentrations were compared to the outdoor PM. The inside average of PM<sub>10</sub> concentrations were from 166.7 to 334.6 µg/m<sup>3</sup> and the average PM<sub>2.5</sub> were 132.4 to 303.6 µg/m<sup>3</sup>. The outside environment showed 129.5 to 141.9 µg/m<sup>3</sup> for PM<sub>10</sub> and 101.2 to 196.6 µg/m<sup>3</sup> for PM<sub>2.5</sub>. The outside air was within the legal standards, but the indoor air quality was higher than the standards set for PM<sub>2.5</sub>, which should not exceed 100µg/m<sup>3</sup> for 1 hour, with the largest values being three times this value. The authors conclude that particulate material in libraries is affected by outside air quality, and poor ventilation plays a major role in these concentrations.

Kyropoulou (2013) used a SEM-EDS to examine the distribution of dust in books. The focus of the paper was on coarse grained PM 2 µm and greater of inorganic dust particles. The goal of the paper is to create a dust management plan and reduce the amount of dust deposited in the library. The location of the study was a wooden bookshelf in the upper floors of a library in downtown Dublin. The books were in open display and there was no HVAC system in place and they were chosen as a representative example of the accumulated dust in the collection. Paper samples were taken from the books to see how much dust had cemented to the pages, how much degradation had occurred, and as

a control sample. The PM resting on the pages was collected on a carbon disc with the carbon disc pressed against the edge of the pages with the most accumulated dust. The samples were carbon coated to reduce charging and then put into the SEM-EDS machine. Oxygen was not analyzed but was calculated on the basis of stoichiometry, for example sodium oxide ( $\text{Na}_2\text{O}$ ) is reported but particle analysis showed that sodium chloride ( $\text{NaCl}$ ) made up the majority of the  $\text{Na}_2\text{O}$  readings. Imaging was performed using backscattered electron (BEI) and secondary electron detector (SEI). In BEI the heavier the element the brighter the image. BEI helps to show the composition of dust particles while secondary electron images show the morphology of the dust particles. The author found that SEM-EDS was very effective in characterizing the inorganic compounds of dust. Bulk analysis gives good relative concentrations of the inorganic compounds across multiple books.

Smolík et al. (2013) analyzed the deposition and penetration of fine particulate matter (PM) using Whatman paper filters over the course of one year in the Baroque Library Hall of the National Library located in Prague, Czech Republic. The authors indicate that PM causes material deterioration through chemical reactions. The PM carry with them soot and other organic matter that transport acids deeper into the paper of the books. The finer grained PM contained ammonium sulfate, ammonium nitrate, and even sulfuric acid; while the coarser particles contain crustal elements, and some alkaline particles from concrete structures. The collection of PM in most studies were carried out using vertical and horizontal collection plates and filters. These studies shared three common traits being: 1. PM deposits on horizontal surfaces more readily than vertical surfaces, 2. The PM composition corresponds to the suspended PM in the indoor air, 3. Vertical surfaces collect mostly soot, organic matter, and ammonium sulfate. The authors set out to test if submicron particles can penetrate by diffusion into the inner pages of a book. 12 sets of filters were laid out on an unused library shelf, each filter was a group of 10 papers. These filters were to represent books on a shelf. Whatman filters were the material used because the low blank allowed for studying the effect of deposited PM on degradation of cellulose, and it provided a suitable area for deposits. The filters were examined 4 times, within a year long period, every 3 months. Brownian diffusion models were made to estimate the penetration of particles, and these models showed that the concentration of deposited particles decreased as the distance from the edge increased. Particle penetration, over the course of a year, depended on particle size and with width of the gap in the filter paper. Smaller particles penetrated deeper with higher concentration but particles of a larger size deposited a higher mass. The authors examined the first two filter papers through SEM, the large particles were found to be  $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$ , and Ca which indicated a mineral origin. Water-soluble compounds were tested for using Ion Chromatography and ammonium sulfate was found to be 60% of the mass of the water-soluble PM. The results from the Ion Chromatography tests confirmed that fine PM will deposit on all available surfaces of the books.

Besis et al. (2014) studied the exposure of occupational indoor environments with polybrominated diphenyl ethers (PBDEs), PBDEs are widely used as a flame retardant, and have been added to products to decrease their likelihood to burn. The PBDEs come as either reactive or additive, and it was found that additive PBDEs are more likely to leech out of plastics and foams because they do not form chemical bonds. PBDEs can accumulate in organisms and because everyone is spending most of their time inside, about 90% of their time according to the study, it is important to measure the chemicals in indoor air and dust. Two dusts have been studied for PBDEs settled and floor dust, settled dusts that were deposited by the indoor air allowed for a more realistic test, as they mirrored the dust accidentally consumed, because of this the dust found in the A/C filters was selected for testing. The authors assumed that the fine particles of dust, those less than 10  $\mu\text{m}$  in diameter, would be suspended in the air and gathered by the filters, so the filter dust would be better to understand the occurrence and health concerns. Twenty air filter samples were collected and tested and the filters were known to have been changed out yearly so the dust collected represented a year's worth of dust. The samples were tested using gas chromatography, and the samples were handled in low light environment to reduce the chances of photolysis of the PBDEs to happen and the samples getting corrupted. This study was the first study looking at PBDEs and the authors found that the daily intake of PBDEs was about 3 to 40 ng day<sup>-1</sup>.

Chatoutsidou et al. (2015) studied the way aerosols move into the Baroque Library Hall in Prague. They measured both indoor and outdoor conditions using SMPS and APS instruments. The samples were taken throughout spring, summer, and winter of 2009. The authors used a dynamic balance model to look at the intake of outdoor PM and the losses from indoor PM, in essence looking at deposition versus ventilation. This model was used to predict a deposition rate ( $k$ ), and penetration efficiency ( $P$ ) at various sizes of grain diameter, the authors then tested the model using the coefficient of determination ( $R^2$ ) by selecting random pairs of  $k$  and  $P$ . When they found no unique solution, the averages were used and found to have good agreement with the monitored I/O ratio. The study found that penetration efficiency was not related to particle size, high penetration rates of ultra-fine particles could be attributed to infiltration of outdoor particles, but the coarse particles were found to be deposited during periods of high traffic from foot traffic within the library.

Maskova et al. (2015) studied and identified the composition of indoor particulate matter in four archives in the Czech Republic. Of these buildings, three were naturally vented, while the fourth had filters in place. The authors set out to study the chemical composition of the indoor and outdoor PM to try and determine the source. All samples were taken over the course of two days in all four seasons using Teflon and quartz filters in Leckel LVS-3 instruments focusing on  $\text{PM}_1$  to  $\text{PM}_{10}$ . Along with the PM sampling, the ventilation rate was also measured.  $\text{CO}_2$  was used as a tracing gas and pumped through the ventilation, and represented 5-20% of the aerosols collected. The authors found

that there were six major components to the PM<sub>10</sub> ratios these were: SO<sub>4</sub><sup>2-</sup>, NO<sub>3</sub><sup>-</sup>, NH<sub>4</sub><sup>+</sup>, Crustal Material, Trace elements, K, Sea Salt. With the sulphates, nitrates and ammonium being found in the PM<sub>1</sub>, or fine fraction, range. Minor elements and trace elements observed included non-crustal K and sea salt which could be used as markers for PM sources. The authors found that high amounts of K correspond with seasonal burning of biomass for heating during the colder months. All PM found in indoor collection spaces is potentially damaging to preservation. Coarse particles can cause abrasive damage during deposition and while cleaning. Some particles, such as ammonium sulfate and some organic compounds, are hygroscopic and can move deeper into the surfaces causing soiling, moistening and acidic buildup and decay. Sulfur rich particles also lead to greater discoloration. Of PM in indoor environments the greatest damage to collections is due to soiling and discoloration. The authors conclude that the majority of PM found was organic matter with the main source being the outdoor environment moving into the buildings.

Vivhi et al. (2016) measured nitrous acid, nitric acid and nitrogen dioxide within four library and archive environments using a multipollutant diffusive sampler. Nitric acid is a very aggressive acid and can cause oxidation and hydrolytic degradation; this acid when combined with other nitrogen oxides can lead to severe damage to collections. The authors found there to be emerging research of nitric acid as an indoor air pollutant but few studies had been published on collecting these samples in cultural heritage buildings. They used the multipollutant sampler over the course of four years, during two seasons. Three of the sample areas had a HVAC system while the other four locations only had double glass paned windows with an electrical heating system. They recommend that filtration systems should avoid forming NO<sub>2</sub> instead of trying to remove it from the air. The results showed that the multipollutant sampler is an effective tool, and the sampling and analytical procedure are easily reproducible. The efficiency of insulating systems within libraries and archives creates conditions where HONO and HNO<sub>3</sub> are often lower than detection limits and sampling for those pollutants should be carried out in a clean environment.

## 1.2 Thesis Scope

While studying at the University of the Peloponnese in Kalamata Greece in 2018–2019, on a class trip to the National Observatory of Athens we were introduced to the library to look at some of the original books from the founder of the Observatory. The books occupy a glass case in the center of the room. They appeared relatively untouched by the dust, although dust was present. In talking with the personnel in charge of the library, the idea formed to study how the dust was entering the library. My original idea was to use books as a passive filter and compare substances found on the books to active sampling to see exactly what the makeup of the dust was on the books. This idea evolved into a multi-site survey on dust, or as it will be referred to from now on, as a survey on particulate matter (PM), and to discover if a passive filter made of a similar substrate would collect as much dust as the books in these libraries. A

second library, the library at Moni Velanidias, was selected for this study for several reasons. First, they were responsive. Second, Moni Velanidias was in the vicinity of the university. Thirdly, and serendipitously, both libraries had similar characteristics. Neither library possesses HVAC systems, so in order to illicit cooling in both libraries, the windows must be opened; and both libraries have a small electric heating unit to provide for heat in the winter, and used as an air conditioner in the summers for meetings but not always on.

The library at the National Observatory of Athens is a closed library and special permission must be sought to gain access to it, and the library in Moni Velanidias is of a similar nature where people of the general public are not allowed to browse the books. Placing passive filters into these libraries was ideal because the filters would not be touched and the experiment disrupted. I had hoped to compare the outdoor air environment to the indoor air environment looking at how the books interacted with the PM. To do this would have required more equipment, a longer survey period, and additional analytical tools, such as Gas Chromatography. This multi-site study would not have been feasible within the available time and so the study needed to be shortened and the testing limited to only SEM-EDS analysis of the PM collected on the passive filters and the books.

### 1.3 Thesis Overview

This thesis aims to look at paper as a passive filter choice and if the books themselves within a library would be more effective tools for sampling than the passive filters. First the literature was studied to see what had already been done in the field of dust deposition within libraries. There were studies that had focused on PM collection in libraries, archives or other buildings with similar use to libraries that informed my research. Some studies looked particularly at organic PM, while others investigated inorganic PM. All the studies were interested in either how PM might damage books, or how it might be unhealthy for people who work in or visit libraries. Reading these discussions helped to explain what PM was expected from the results.

The reading and studying on this topic, which will be discussed in Chapter 1, took place both before and after the samples were gathered from the two locations. The readings changed the thoughts behind the experiment, and helped suggest areas for improvement. The readings have helped in identifying future ideas for PM measuring in library environments.

Chapter 2 describes the methodology and limitations of this study. After gathering the samples, they were taken to the laboratory in Kalamata and a 1 cm by 1.5 cm cutout from the filter paper where the most PM was visible. These samples were placed on carbon tape attached to the SEM sampling disk, and placed into the SEM. The results of this

analysis will be presented in Chapter 3, in tables detailing the elements found in compound structures in the PM displayed as baseline (what is normal for each location), in the passive filters, and the books. The sampling started at the National Observatory of Athens and then moved on to the Monastery. The same order in my exposition of the results.

In the discussion section, Chapter 4, a description of the results of the PM found in both libraries. Notably of the elements that were unusual to find; that were unexpected. Next a discussion on the importance of this study: knowing what dust is in the library or cultural heritage site. This can help conservators to know what is affecting their collections, and better preserve their collections through this knowledge.

Chapter 5 is the conclusion. The conclusion will show that books appear to collect more PM than a passive filter.

Chapter 6 will give suggestions on how to clean a library collection and give some perspectives learned from this study.

The concluding chapter is chapter 7 the bibliography. The bibliography shows all of the research and readings that were necessary to complete this thesis.

## 2. Methodology



Figure 1 Sample location at the National Observatory of Athens

were first swabbed to gather a baseline of dust particles found in each location. Once this baseline was retrieved, the books in question were dusted, along with the shelf, to reduce contamination of the samples and to see how much dust was accumulated after 11 days. Three sample locations on each shelf were identified and the trays were placed. One tray was placed on the top shelf, one on the middle, and one on the lowest shelf accessible. This was repeated 60 cm away for the second set of testing. The sampling was taken on day 6 and 11; time constraints contributed to this decision, but this timing was felt to be sufficient for data collection.

In order to collect the dust from the library at the National Observatory of Athens, and Moni Velanidias, Kalamata, a new method was tested. Filter paper was used in the bottom of plastic containers to act as a petri dish. The containers were 10x15 cm with a depth of 5 cm shown in figure 1 for the National Observatory of Athens, and figure 2 showing the location and placement in Moni Velanidias. Filter paper was cut down to 7 x 8 cm in order to be able to manipulate the filter paper and retrieve it from the containers. Once the collection method was determined, the experiment was set up. The books that were being compared to the passive filter



Figure 2 Sample location at Moni Velanidias

When it was time to collect the samples, they were collected from the bottom to the top to reduce the chance of

disturbing the dust and collecting non settled dust. The samples were taken out of the container by folding the ends together to trap the collected dust in the fold; the sample tray was shaken into the sample bag to collect any large particulate matter that may have been collected.

Sampling started at the National Observatory of Athens (NOA) on 11 July 2019, with the first sample collection date being on 17 July, 2019. Final collection date was 22 July 2019. Moni Velanidias sampling started on 12 July 2019, with the first samples being collected on 18 July 2019, and the final collection date taking place on 23 July 2019.

A Scanning Electron Microscope coupled with Electron Dispersive X-Ray Spectroscopy was used to review all of the samples. The SEM-EDS used was a JSM-6510 series from Oxford Instruments with the quantification being made using INCA Software. The accelerating voltage was 20 kV, with a collection time of three minutes for bulk and sixty seconds for sites of interest. Bulk analysis was at 100x magnification in an area of 1.3 mm x 900 nanometers. Site sampling was carried out at 1800x magnification. The detection limit was between .1–.3 percent. The SEM-EDS was operated under backscattering with a low vacuum to lower the electron charge and protect the organic filter. Backscattering also reduced the electron discharge that was present in the secondary scanning. Ultrafine particles were not counted due to the selection of backscattering as they would not appear in the images. Sites of interest were chosen to represent areas of major dust collection and are the areas viewed with data displayed within the tables in the results, a site of interest is chosen because of the variety of particles and the intensity of the weight. The weight of the element increases the amount of white shown on a black or grey background, the brighter the colour the heavier the element. The spectrums expected to be observed were established by looking at a base dust collection taken from books located within the collection, some common oxides were found: MgO, Al<sub>2</sub>O<sub>3</sub>, SiO<sub>2</sub> these are considered common because they are crustal components and are found everywhere. Spectrum are generated from the coupled Electron Dispersive X-Ray Spectroscopy that provides a chemical analysis of the sample, this is what is looked at and charts generated from this help determine what the chemical make-up of the sample is. Some interesting elements were found within each site such as: BaO, and Cr<sub>2</sub>O<sub>3</sub> that were completely unexpected to find within the samples.

## 2.1 Limitations

This thesis set out to show that books are a better potential collection device for testing indoor dust samples. Most current research on dust (or PM sampling) uses glass slides as the mode of studying passive dust buildup. This is due mostly to the glass loss of shine through dust accumulation. This loss of shine is referred to as “Gloss” and it has been found to show estimates for how much dust has fallen within an environment and the potential damage this can cause historic objects. In a study by Ford and Adams where they studied atmospheric pollutants, they suggested at

the end of their study that future studies could use different substrates to collect samples (1999). The other common substrate used to measure gloss is a piece of sticky carbon tape that can be easily transferred to a SEM-EDS for study. This thesis wanted to look at using a similar substrate as the target material to note any differences in collection rates. The main limitation to this study is the lack of atmospheric data. Dust has two main modes of transfer to get into a built environment. The first mode of transfer would be differences in air pressures and temperatures within a building and the outdoor environment. These differences create areas where the outside air and indoor environments exchange and try to normalize, this leads to PM from the outside moving inside the building. This happens near windows, and doorways through improper seals, and when they are open. The second main transfer pathway of PM to an indoor environment is people, as they utilize the spaces provided. PM is picked up as they walk and is deposited indoors. Not knowing what PM is naturally inside the building and what the makeup of the outdoor PM leads to inconclusive results with regards to where the PM came from and probable sources.

With the books being in-situ for years, especially in the case of the National Observatory of Athens, it is difficult to determine if the PM is from the surrounding environment or coming from the book itself. In future studies test books should be placed in the library environment after being fully sampled in order to establish the exact composition to have accurate readings.

The timing of the study in July 2019 was extremely short, most studies looking at indoor PM deposits are at minimum 6-months but last longer. If more time was given in the sampling and analysis period it may have been possible to replicate some of the findings from other papers and results.

### 3. Results

#### 3.1 PM Grain Description

Grain description is defined based on the size of the grain, Super Coarse grains are  $>10\ \mu\text{m}$ , Coarse grains are between  $2.5\text{--}10\ \mu\text{m}$ , Fine grains are between  $0.1\text{--}2.5\ \mu\text{m}$ , and Ultrafine grains are  $<0.1\ \mu\text{m}$ .

Table 1 Grain Description

Grain Type	PF NOA 6-day Totals	BK NOA 6-day totals	PF NOA 11-day Totals	BK NOA 11-day Totals
Super Coarse	0	6	8	12
Coarse	9	76	33	98
Fine	41	62	17	44
Ultra-fine	0	0	0	0
<b>Total PM</b>				
<b>Count</b>	<b>50</b>	<b>144</b>	<b>58</b>	<b>154</b>

Grain Type	PF MON 6-day Totals	BK MON 6-day totals	PF MON 11-day Totals	BK MON 11-day Totals
Super Coarse	1	5	3	5
Coarse	7	42	22	71
Fine	7	35	36	45
Ultra-fine	0	0	0	2
<b>Total PM</b>				
<b>Count</b>	<b>15</b>	<b>82</b>	<b>61</b>	<b>123</b>

The amount of grains found by both filters varies drastically. The passive filters collected significantly less PM than the books. This table also shows an increase of PM collected over the sample period, with a major increase in PM collected at the Monastery from 15 PM count to 61 PM count collected by the passive filter. The National Observatory of Athens' 11-day passive filter did not collect a significant number of PM more than its 6-day counterpart, having a difference of only 8 PM. The filters and books at the Monastery show a significant increase in the PM collected between day 6 and day 11. There is a 46-count difference between the day 6 total and the day 11 total for the passive filter and a 41-count difference between the day 6 and day 11 book totals.

### 3.2 PM Grain Distribution

The grain distribution helps to show where the grains have settled and can help in discovering how the PM is moving within the libraries. Coarser grains brought in from users in the library are generally deposited near the ground and entrances showing a deposition area around the entryway and from the bottom up, pollutants from the outside environment settle from the top down as they enter the library environment.

Table 2 Grain description breakdown by site (NOA)

6-day National Observatory			11-day National Observatory		
Grain size	PF Top	BK Top	Grain size	PF Top	BK Top
Super Coarse >10 $\mu$ m	0	5	Super Coarse >10 $\mu$ m	3	1
Coarse 2.5–10 $\mu$ m	2	25	Coarse 2.5–10 $\mu$ m	8	37
Fine 0.1–2.5 $\mu$ m	13	30	Fine 0.1–2.5 $\mu$ m	5	7
Ultrafine 0.1 $\mu$ m	0	0	Ultrafine 0.1 $\mu$ m	0	0
Grain size	PF Mid	BK Mid	Grain size	PF Mid	BK Mid
Super Coarse >10 $\mu$ m	0	1	Super Coarse >10 $\mu$ m	3	3
Coarse 2.5–10 $\mu$ m	5	26	Coarse 2.5–10 $\mu$ m	15	39
Fine 0.1–2.5 $\mu$ m	18	13	Fine 0.1–2.5 $\mu$ m	6	19
Ultrafine 0.1 $\mu$ m	0	0	Ultrafine 0.1 $\mu$ m	0	0
Grain size	PF Bot	BK Bot	Grain size	PF Bot	BK Bot
Super Coarse >10 $\mu$ m	0	0	Super Coarse >10 $\mu$ m	2	8
Coarse 2.5–10 $\mu$ m	2	25	Coarse 2.5–10 $\mu$ m	10	22
Fine 0.1–2.5 $\mu$ m	10	19	Fine 0.1–2.5 $\mu$ m	6	18
Ultrafine 0.1 $\mu$ m	0	0	Ultrafine 0.1 $\mu$ m	0	0

The grain distribution at the National Observatory is shifted mostly towards the top and middle collection sites which indicates that the PM settling in the library are generally lighter materials settling from the top down and are most likely due to differences in air pressure in the library and the outdoor environment creating a vortex that allows for exchange between the inside air and the outdoor environment.

Table 3 Grain description breakdown by site (MON)

6-day Moni Velanidias			11-day Moni Velanidias		
Grain size	PF Top	BK Top	Grain size	PF Top	BK Top
Super Coarse >10nm	0	0	Super Coarse >10nm	1	0
Coarse 2.5–10nm	2	8	Coarse 2.5–10nm	6	15
Fine 0.1–2.5nm	7	6	Fine 0.1–2.5nm	3	22
Ultrafine 0.1nm	0	0	Ultrafine 0.1nm	0	2
Grain size	PF Mid	BK Mid	Grain size	PF Mid	BK Mid
Super Coarse >10nm	0	4	Super Coarse >10nm	0	3
Coarse 2.5–10nm	3	19	Coarse 2.5–10nm	10	20
Fine 0.1–2.5nm	0	17	Fine 0.1–2.5nm	30	14
Ultrafine 0.1nm	0	0	Ultrafine 0.1nm	0	0
Grain size	PF Bot	BK Bot	Grain size	PF Bot	BK Bot
Super Coarse >10nm	1	1	Super Coarse >10nm	2	2
Coarse 2.5–10nm	2	15	Coarse 2.5–10nm	6	36
Fine 0.1–2.5nm	0	12	Fine 0.1–2.5nm	3	9
Ultrafine 0.1nm	0	0	Ultrafine 0.1nm	0	0

The grain distribution at Moni Velanidias is shifted mostly towards the bottom and mid filters and books. This indicates that there is more traffic moving through the library with PM entering the library with the users. With the number of grains captured between the 5 days of sampling dates it could indicate an increase in the use of the library.

### 3.3 SEM-EDS Analysis

The full tables of spectra from the SEM-EDS analysis can be found in Appendix 1 and 2, in this section a few graphs will be shown that highlight a few elements of interest.

The first interesting element was found in Spectrum 6 in the NOA Book sample from the top shelf. Titanium was found to make up 34.3 percent of the total mass from the EDS as seen in chart 1.

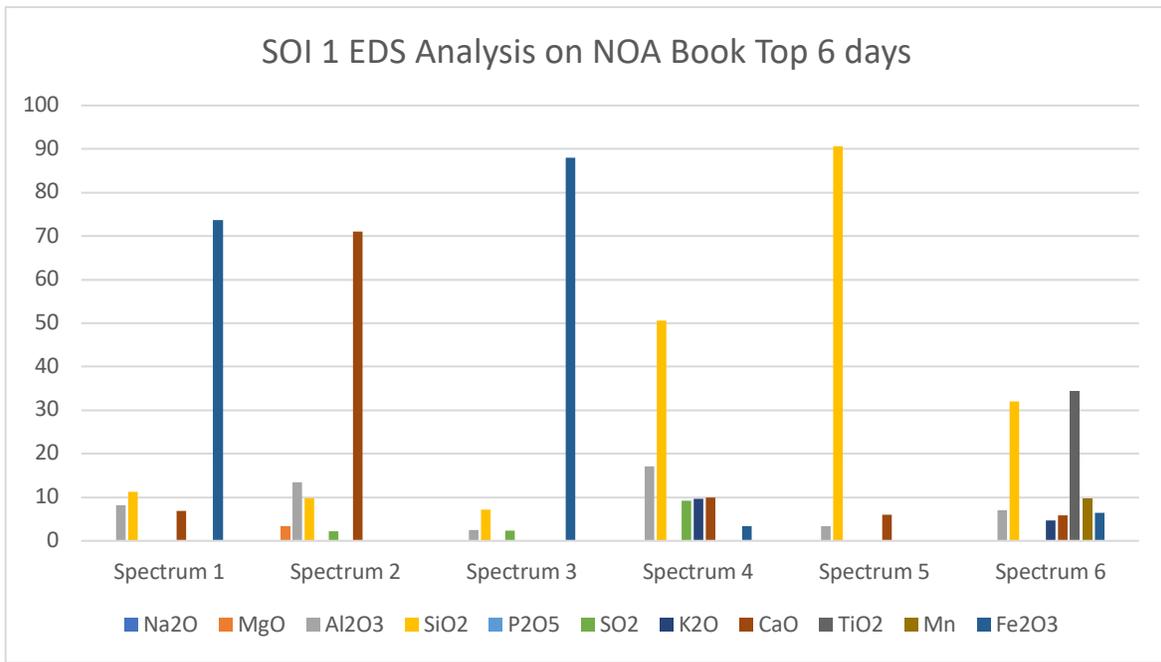


Chart 1 EDS Analysis of Site of Interest 1 of NOA Book Top 6-day sampling

Any amount of  $TiO_2$  was unexpected to find within the samples, with the majority of samples expected to resemble a moderate trend towards more crustal components,  $Al_2O_3$  and  $SiO_2$  being the most anticipated compounds.

Barium was found on the sample taken from the book on the bottom shelf of NOA and is seen in spectrum 1 in chart 2.  $BaO$  was completely unexpected to find within the data set and is always paired with  $SO_2$  this creates the question of if Barium-Sulfate is the dust but further research is necessary. The remaining spectra appear fairly typical for these samples with high levels of  $SiO_2$  and  $Al_2O_3$  with Spectrum 6 being the most indicative of what was expected in the EDS analysis.

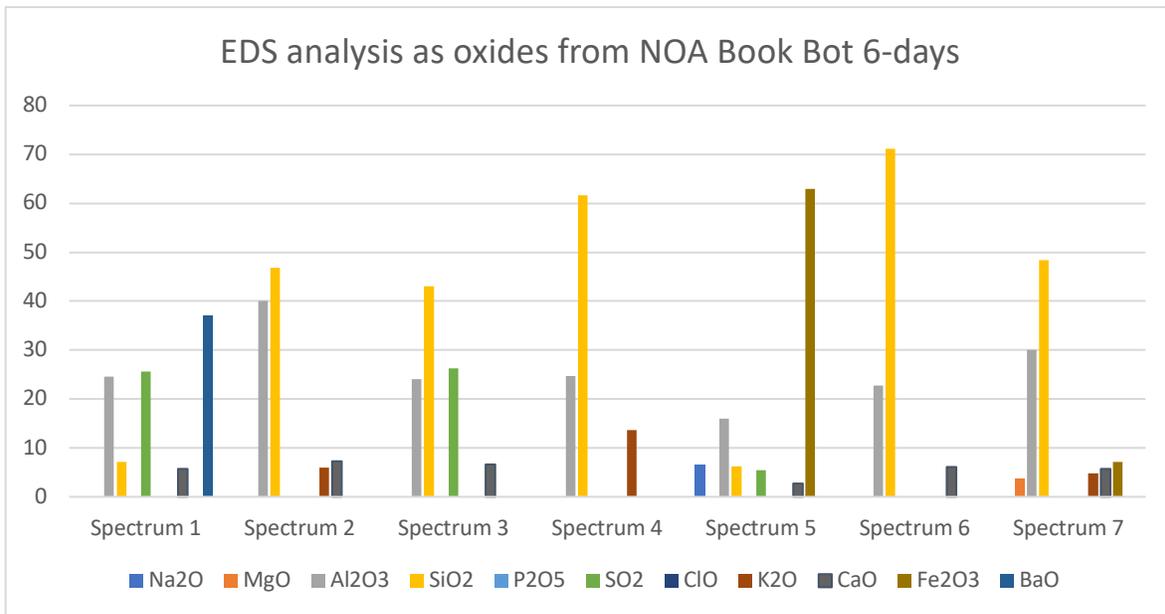


Chart 2 EDS Analysis of Site of Interest 1 of NOA Book Bot 6-day sampling

Most of the random heavier elements that were unexpectedly found in this study were found at NOA but chart 3 shows off high levels of ZnO on one spectrum found on a MON book. The sample shows primarily ZnO and Al<sub>2</sub>O<sub>3</sub> in spectrum 1 but also a small amount of TiO was found in Spectrum 4. The source of these oxides is unknown.

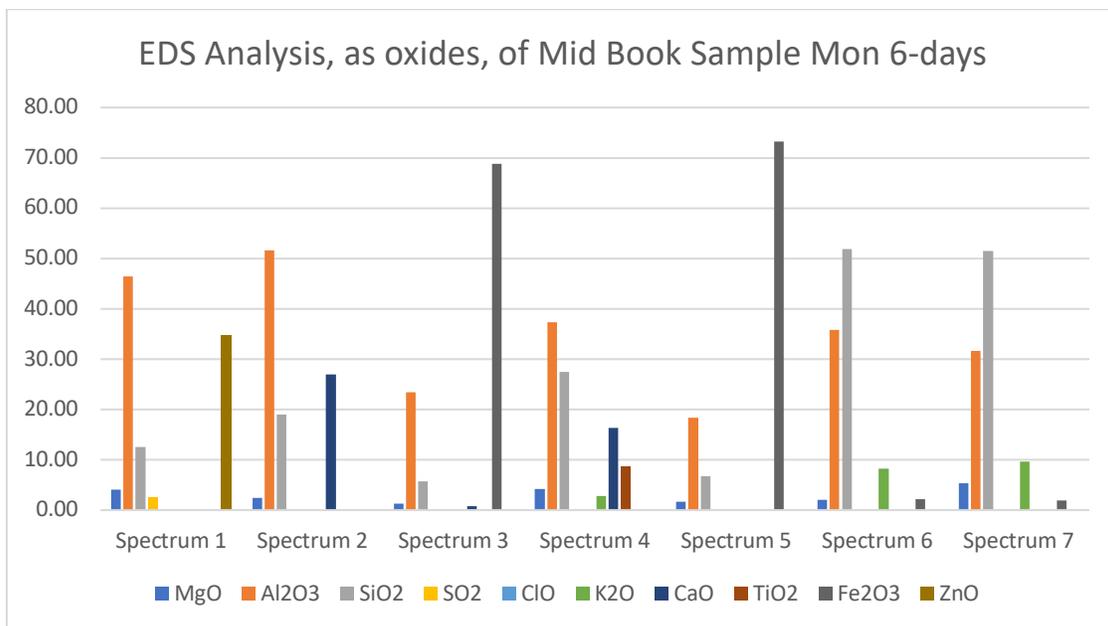
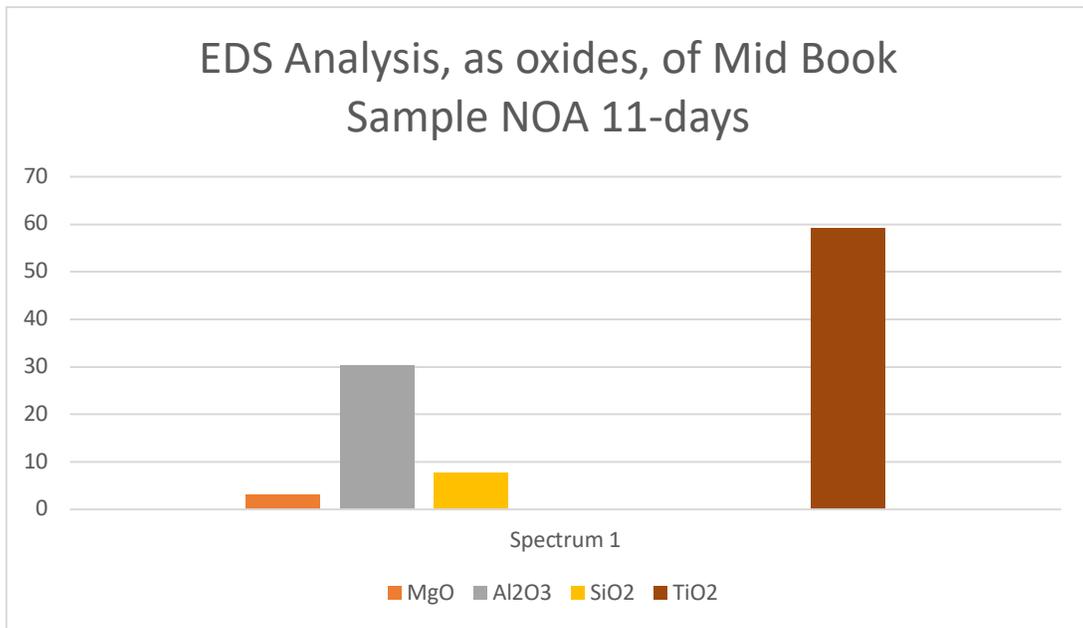


Chart 3 EDS Analysis of Site of Interest 1 of Mon Book Mid 6-day sampling

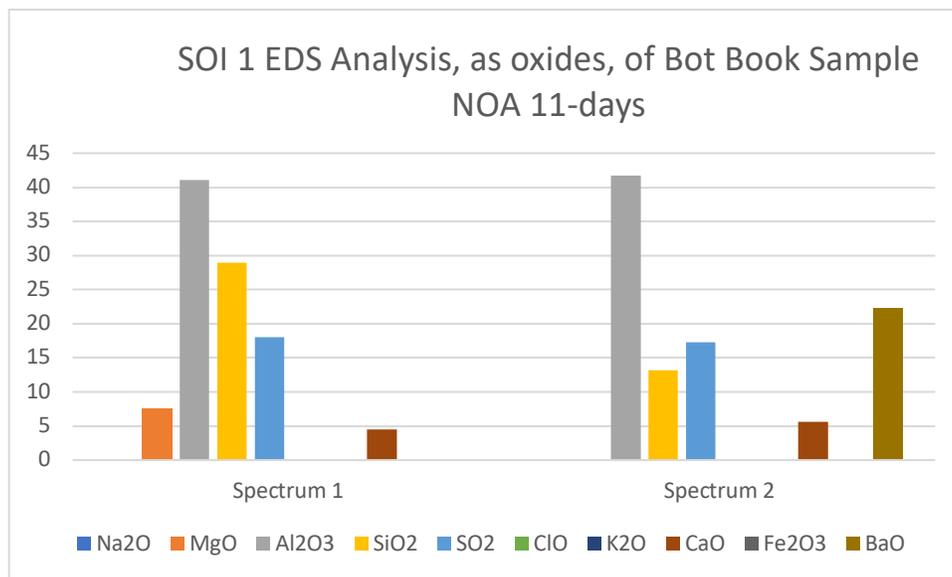
Finding heavier elements within the dust raised more questions and further testing of the outside environment might provide more answers about the dust that is settling within the indoor library environment.



*Chart 4 EDS Analysis of Site of Interest 1 of NOA Book Mid 11-day sampling*

Chart 4 shows high levels of Titanium that was found in the SOI 4 from NOA’s book mid-level. The amount of TiO was significantly larger than any other oxide.

Charts 5 and 6 are both showing spectra from the National Observatory of Athens libraries book from the bottom shelf. In both samples it is possible to see very high levels of Barium. Barium is a radioactive material and it was completely unexpected to find as part of the makeup of the dust within the library. The passive filters did not find this so this may have been dust already in the library or carried in by a library user.



*Chart 5 EDS Analysis of Site of Interest 1 of NOA Book Bot 11-day sampling*

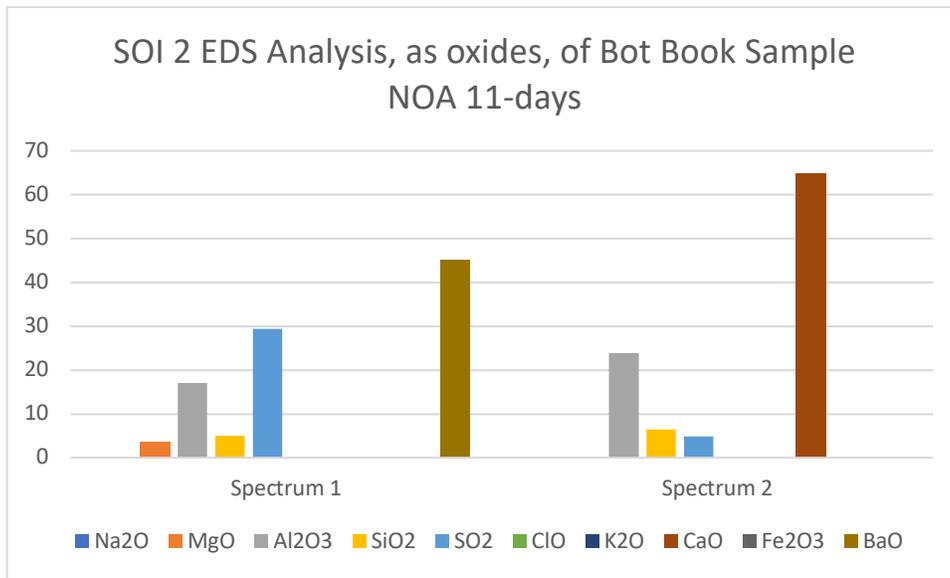


Chart 6 EDS Analysis of Site of Interest 2 of NOA Book Bot 11-day sampling

The final chart, chart 7, is made up from the Site of Interest 1 from the Moni Velanidias library bottom book. It was the only place where Molybdenum was found. The amount of MoO<sub>3</sub> found was 5.5% of the overall spectrum and while this is not a majority it is a significant amount to see within a dust sample size and again one of the unexpected elements found during the course of this study.

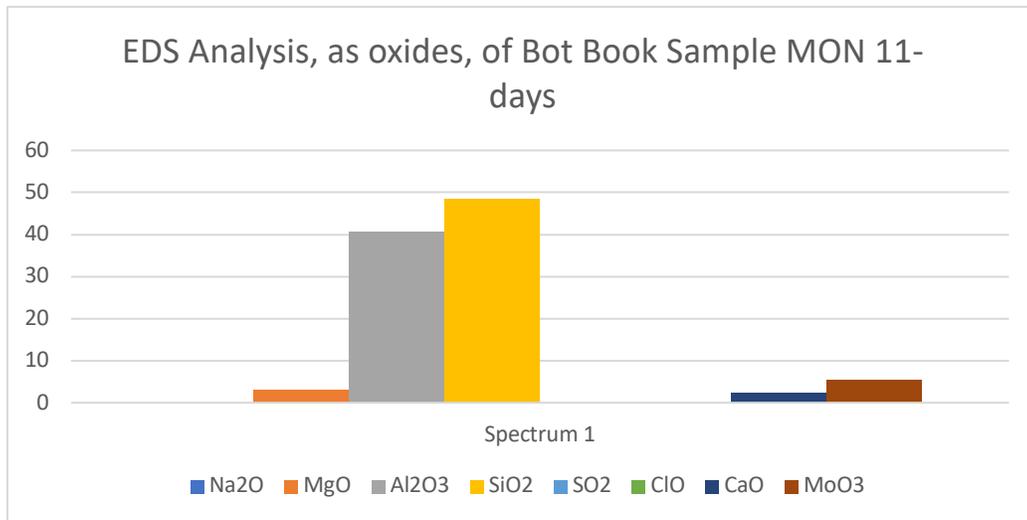


Chart 7 EDS Analysis of Site of Interest 1 of MON Book Bot 11-day sampling

## 4. Discussion

The results from the sampling were mostly as expected. The hypothesis suggests that more particulate matter (PM) would be collected from the books compared to the passive filters. The PM found within the results resembles crustal components with a few outliers. Aluminum (Al) and Silica (Si) are the major crustal components found, and so we should expect to find those. Iron (Fe), sodium (Na), potassium (K), and magnesium (Mg) are also common crustal components, though the number of salt (NaCl) compounds found is greater near Moni Velanidias due to its proximity to the sea. Barium (Ba), molybdenum (Mo), phosphorus (P), titanium (Ti) and zinc (Z) are not normally found deposited on books and fall outside of the range of compounds hypothesized to find indoor in case of controlled microclimatic conditions. Both the passive filters and the books collected a few of these unexpected compounds that could be considered outliers, or depict the interaction of indoor-outdoor environments. All elements in this section are listed in oxide format due to how the SEM collects samples.

### 4.1 Barium

Both of the Top filter sampling locations of 6 days at the National Observatory of Athens (NOA) are presented here. In Figure 3 the passive filter from NOA Top 6-day is shown, in spectrums: 1, 2, 3, and 5 the EDS registered the compounds as BaO, with spectrums 1 and 4 being 100% Barium, spectrum 4 is located at the very edge of the image at the bottom, and the target was displaced below the image line. Within the image taken during the EDS process, it was possible to see 4 in the figure to get the reading, but the image in Figure 3 fails to show it. The amount of Barium is high and the source should be investigated since Ba could be related to non-exhaust traffic emissions (Juda-Rezler, et

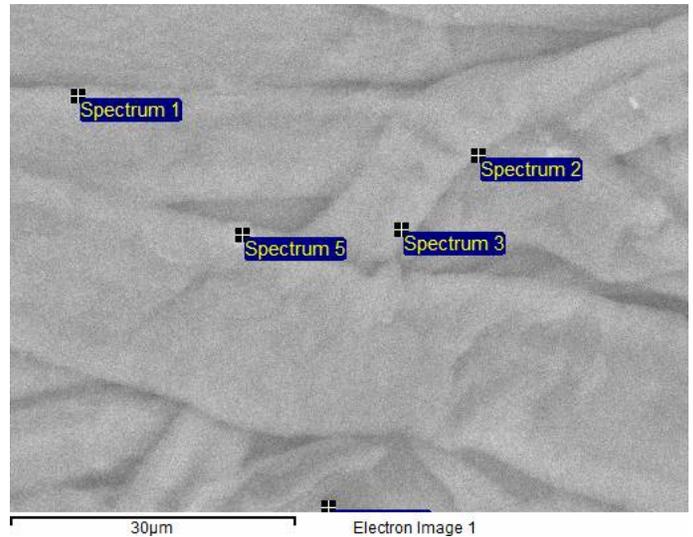


Figure 3 SEM Image of NOA Passive Filter Top Location Site of Interest 2

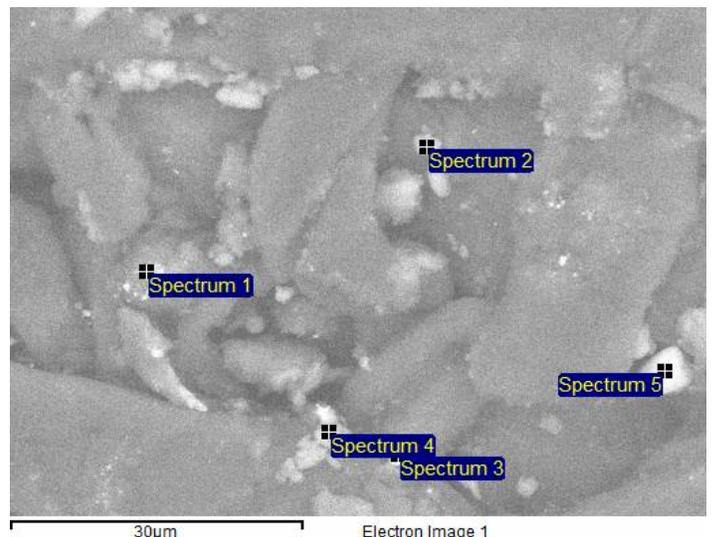


Figure 4 SEM Image from NOA Book Site of Interest 3

al. 2020) such as abrasion of brake pads. Ba in this study was found to make up 21% of the non-exhaust traffic emissions.

In Figure 4 the image is from the book sample site of interest 3; in both spectrums 1 and 3 BaO is found in a lower concentration but more spread out. Spectrum 1 is composed of: 6.32% Na<sub>2</sub>O, 20.78% Al<sub>2</sub>O<sub>3</sub>, 7.8% SiO<sub>2</sub>, 24.74% SO<sub>2</sub>, 5.79% Ca, and 34.57% BaO. Spectrum 3 is composed of: 26.10% Al<sub>2</sub>O<sub>3</sub>, 10.06% SiO<sub>2</sub>, 11.12% O<sub>2</sub>, 8.98% Ca, 36.04% Fe<sub>2</sub>O<sub>3</sub>, and 7.70% BaO. Both samples of BaO are always found in conjunction with SO<sub>2</sub>. It is interesting to note that there were no BaO samples without the presence of SO<sub>2</sub>. The finding could support the vehicle related emissions since both Ba and SO<sub>2</sub> reflect an anthropogenic origin. Looking at the data visible from the passive filters and books it is impossible to find an indoor source for the compound. The passive filter only found 4 areas of note all with a grain size  $\geq 1\mu\text{m}$ . The samples found on the book range from  $1\mu\text{m}$ — $5\mu\text{m}$  diameter with approximately 34 particles found within one site of interest. This included: NaCl, MgO, Al<sub>2</sub>O<sub>3</sub>, SiO<sub>2</sub>, K, and Ca. BaO was found primarily in the National Observatory of Athens but in the baseline sampling of Moni Velanidias BaO was found in one location and not again.

## 4.2 Chlorine

Chlorine is not an unexpected compound to find within the samples, but finding it without Na<sub>2</sub>O created gaps in the results making the totals less than 100%. Chlorine was found in the bulk sampling sets in both the MON passive filter 6-day top and the book 6-day top in their bulk analysis. The MON sample, as shown in figure 5, had also found Na<sub>2</sub>O in the SOI 2 at 6.82%. When the instrument found ClO in the system it gave results such as those found in the MON Middle Book 6-day sample where: MgO was 4.25%, Al<sub>2</sub>O<sub>3</sub> 62.25%, SiO<sub>2</sub> 21.05%, SO<sub>2</sub> 2.81%, ClO 0.00%, K 3.04%, and Ca at 5.61% with a total of 99.00%. We can assume that the ClO found would have totaled 1.00% of the total results. This is repeated throughout the results with ClO being found in nearly every sample. Due to the proximity of both locations to the sea some penetration of sea salts should be expected. Sea salts are able to travel 25 km inland (de Leeuw et al. 2001).

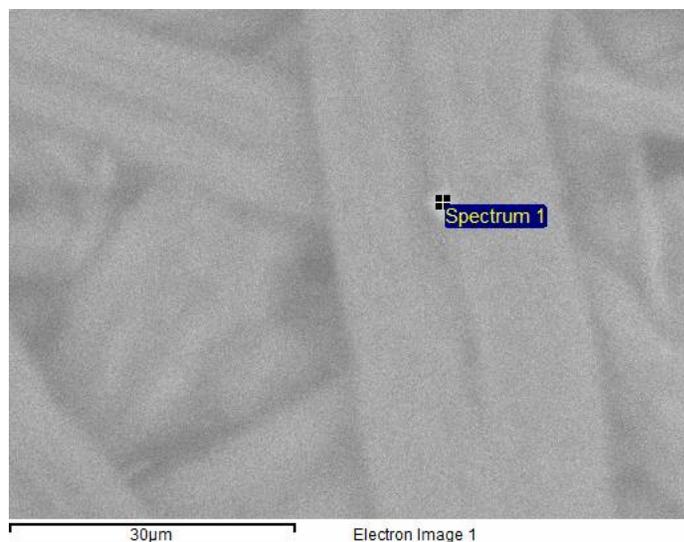
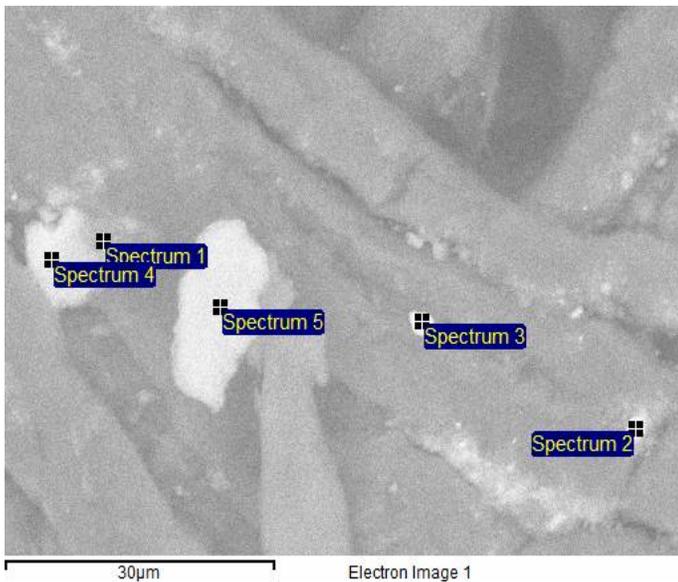


Figure 5 SEM Image of MON PF Top location SOI 2

### 4.3 Iron

Iron ( $\text{Fe}_2\text{O}_3$ ) was expected and is found throughout the samples and shows clearly in the images from the SEM. Iron is known to cause foxing and staining within paper. Most foxing is caused by mold growth on the paper, but if there are embedded  $\text{Fe}_2\text{O}_3$  compounds in the paper matrix, the iron will oxidize and create brown discoloration that

resembles foxing. Treating foxing caused by mold can be done through bleaching methods such as using hydrogen peroxide, or UV radiation. However, if the foxing is caused from  $\text{Fe}_2\text{O}_3$  it is important to remove the  $\text{Fe}_2\text{O}_3$  mechanically before any bleaching can occur (AIC Wiki).



### 4.4 Molybdenum

Molybdenum was only found in one instance within the entire sampling range. The Monastery's book bottom 11-day sample found some  $\text{MoO}_3$  in spectrum 2. The site of interest showed: 3.03%  $\text{MgO}$ , 40.76%  $\text{Al}_2\text{O}_3$ , 48.35%  $\text{SiO}_2$ , 2.36%  $\text{Ca}$ , and 5.50%  $\text{MoO}_3$ .

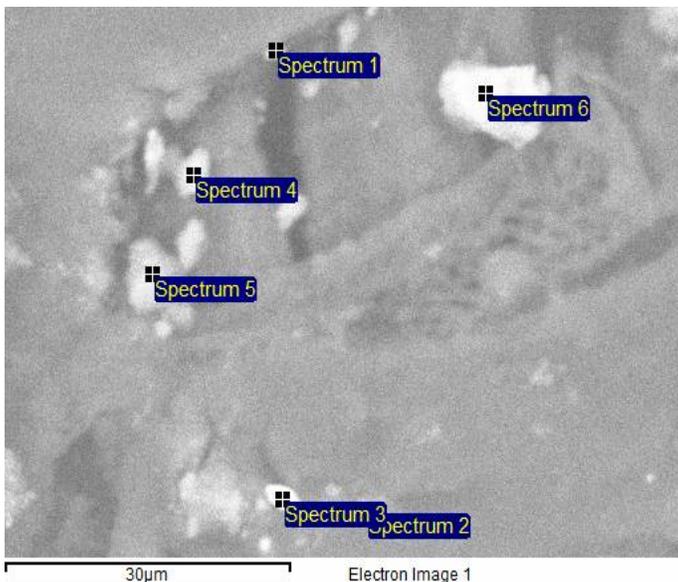
### 4.5 Phosphorus

Phosphorus was found only on the book samples; this compound would most likely have come from insects within the library or as PM brought in by patrons as they moved about the library.

### 4.6 Titanium

Titanium samples were found 4 times throughout the sampling process. The samples including portions of titanium were only found on the books suggesting that titanium is found in the books and were not part of the PM within the library. The largest percentage of titanium was

Figure 6 SEM Image of NOA Book Middle sample with  $\text{TiO}_2$  at 59.12% in spectrum 5



found in Figure 6 located on the NOA mid book sample from 11 days, with a total percentage of 59.12%  $\text{TiO}_2$ , NOA top book 6-day sample also had high concentrations of  $\text{TiO}_2$  at 34.30% shown in Figure 7. Of the remaining 2

Figure 6 SEM Image of NOA Book Top sample 6-day with  $\text{TiO}_2$  of 34.30% in Spectrum 6

samples  $\text{TiO}_2$  is in relatively low concentrations but it is also found on another book at NOA on the middle shelf also at 6-days.

#### 4.7 Zinc

Zinc was found in small amounts throughout the study. The largest percentage of Zinc was found at NOA on the passive filter bottom book with a total percentage of 68.94%. The urban environment of Athens could justify the presence of Zn (Theodosi et al. 2018) derived from anthropogenic sources, i.e., vehicle emissions, including the wearing of brakes and tires.

#### 4.8 PM Grain Differences

The difference in the amount of PM collected by the filters and books over the 11 days of sampling is low. Looking at the passive filters in the National Observatory for day 6 there were only 50 grains of PM found on the samples, this number only increased to 58 after 11 days. This gives the two sampling periods a difference of 8 grains. The difference between what the books found over the course of the 11 days sampling period was 10 grains of PM, with the 6-day total equaling 144 grains, and the 11-day total being 154. This low grain count could indicate a relatively low flow of outdoor PM entering the building and low traffic from patrons. Moni Velanidias's filter and books show a significant difference in the amount of PM collected during the sampling period. The passive filter in the Monastery at 6-days had only collected 15 grains but during the second sample day 61 grains were found on the passive filter this is a difference of 46. The books of the Monastery at 6-day had collected 82 grains of PM, and at 11-days had collected 123 grains, giving the books a difference in collection of 41. This difference could be due to more traffic from patrons, but is most likely due to outside PM infiltration into the library. When the traffic of a library increases the visitors bring in more PM from the outside environment, this added PM generally is made up of coarser grains and they settle between the ground and 1m in height and usually within 3 meters of the entryway. A major difference between the National Observatory and the Monastery is the distribution of where the grains settled. The National Observatory had its majority of PM settle on the top and middle filters, with low amounts settling on the bottom filters. At Moni Velanidias the PM settled primarily on the bottom and middle filters and books, with less settling on the top filters and books. These differences show a difference on how much both libraries are used, the library at the National Observatory sees significantly less traffic than Moni Velanidias based on the way the PM has settled on the filters and books. The majority of the PM moving through the National Observatory is based on differences in air pressure between the closed indoor environment and the surrounding outdoor environment and sees less overall PM transferring into the library environment.

## 4.9 Importance

The measuring of PM within a building, especially libraries, is important to assess the health of the indoor air and check for potential damages to historic buildings, and artifacts. The accumulation of PM can change the way historic artifacts look due to the loss of gloss, cementation of PM, and micro abrasions. As the PM settles on the materials and moves along the surfaces micro abrasions occur resulting cuts and tears that build up over time causing loss of sheen, degrading of color, and loss of title text. The micro abrasions also open up the material to greater penetration of PM material especially hygroscopic pollutants such as: O<sub>3</sub>, NO<sub>3</sub>, and SO<sub>2</sub> that cause significant damage to historic objects during chemical processes converting NO<sub>3</sub> into HNO<sub>3</sub>, and SO<sub>2</sub> into H<sub>2</sub>SO<sub>4</sub> both acids that make historic materials more susceptible to corrosion and other atmospheric conditioning. Indoor air health is one of the major aspects considered when monitoring indoor PM, and focuses mostly on organic contaminants such as mold and pollen, in this study trace amounts of radioactive elements were found within the libraries which could be harmful to users. It is important to study the overall health of the buildings air and environment but this was out of the scope of this thesis.

## 5. Conclusion

The goal of this thesis was set up to prove that the books themselves could be used in place of passive filters for PM collection data. Because books have an exchange of humidity when exposed to variances in temperature and humidity, they will off gas and pull in moisture from the surrounding area to reach a moisture equilibrium. Glass slides, which were the most common PM collecting material used in most studies, do not behave the same way that a cellulose structure, such as a book, behaves. And so, by comparing the paper filters to the books, it was possible to see if they would act the same.

The National Observatory in Athens and Moni Velanidias were chosen due to their availability and contact with the staff overseeing the library. Whatman paper filter was cut down into squares and rested in plastic containers then suspended with tabs to collect dust near the books. On collection day the books chosen for the sampling were wiped with a clean filter and bagged, while the filter paper was folded and bagged in order to trap the most PM for review. The samples were taken to the SEM lab in Kalamata for preparation and analysis.

The samples showed that books collected on average 3x's the amount of dust at the National Observatory of Athens and 2x's the amount of dust at Moni Velanidias. Some unexpected elements were found deposited in the samples namely Barium, Molybdenum, Titanium, and Zinc. Considering the absence of HVAC systems in both libraries, infiltration of particulates is not excluded, depicting thus the influence of the dominant ambient emission sources and

atmospheric processes that could be related with the presence of the species observed in general in the indoor environment of the libraries.

The experimentation done for this thesis went well, but the results do not reach a strong enough conclusion because there are too many unknown variables. More information would be needed from more extensive testing in order to get conclusive results. The results do suggest that using books in place of passive filters would be viable for future studies, but more testing is required.

## 6. Perspectives

### 6.1 Cleaning

As part of the research into PM within libraries and museums, cleaning was an interesting topic. The cleaning of PM from surfaces is an important work for preserving historic value but doing so improperly can increase the rate of deterioration of the objects, while not cleaning can also increase the rate of deterioration. Wilson et al. studied the effectiveness of cleaning methods using microfiber cloths, cotton rags, and vacuums with HEPA filters. It was found that vacuuming the PM off of the objects was the least damaging and most effective; it captured the majority of PM. The most effective way to reduce the build-up of dust on the shelves is to vacuum the dust off of the shelves before wiping the shelves down with a damp microfiber cloth followed by a dry microfiber cloth. This method of wet and dry cleaning will remove the majority of PM and prevent a buildup and cementation of the PM. It is important to clean the books and shelves to discourage pests and mold growth, by removing the PM a potential food source is removed as well. It is recommended to clean as often as budget and staffing restrictions allow, though cleaning every 3 months would be suitable for most locations (Wilson, et al. 2017).

### 6.2 Future Studies

Future studies at the National Observatory of Athena and Moni Velanidias should include sampling of the outdoor and indoor air environments to better explain what PM has been collected. PM settles from the surrounding air, so studying the suspended PM helps justify the results. These future studies should also go beyond a look at the surface PM and delve deeper into what the PM is doing to the books. This may involve sampling from the pages of the books themselves and using more analytical techniques, such as High Performance Liquid Chromatography and/or High Performance Gas Chromatography. These tests would give accurate counts of the exact chemical compounds that are reacting within the pages of the books (Kyropoulou 2013).

In future studies, doing a side by side comparison of a glass slide with a stack of paper-based filters, to mimic a book, building on the 2013 study by Smolik et al, which looked at the suspension of fine PM in a library would be of benefit

to the research, because the stack of passive filters can help show the depth of penetration of the PM, whereas the glass slide will only show the accumulated PM.

Glass slides have limitations because they only can show surface dust, and cannot show PM that is actually being deposited within the cellulose structure. Various authors chose glass slides to measure loss of gloss as a method of determining the amount of PM that had fallen in museums, and quantifying how much dust is too much dust (Wei et al. 2006).

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# Appendix 1 National Observatory of Athens

## Baseline Sample

Table 4 EDS analysis listed as oxides of the Baseline sample from the National Observatory of Athens (NOA)

<b>SOI 1</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>Cr<sub>2</sub>O<sub>3</sub></b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>TiO<sub>2</sub></b>	<b>PbO</b>	<b>Total</b>
Spectrum 1		16.47	9.95	62.54		0		8.57					97.53
Spectrum 2	20.1		48.3	31.62									100
Spectrum 3		5.4	20.4	44.44	6.25		4.7	3.42		13.7	1.66		100
Spectrum 4			17.2	38.12				44.7					100
Spectrum 5			42.6	38.9				18.5					100
Spectrum 6		1.97	24.8	47.18	10.3		1.7	8.92		5.28			100
Spectrum 7			35.5	46.46				18.1					100
Spectrum 8			17.1	55.46			5.7	21.7					100
<b>SOI 2</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>Cr<sub>2</sub>O<sub>3</sub></b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>TiO<sub>2</sub></b>	<b>PbO</b>	<b>Total</b>
Spectrum 1		3.15	15.4	22.46				14.2	10.9			33.9	100
Spectrum 2		0.66	12.1	14.03				8.13	8.88			56.3	100
Spectrum 3		17.79	26	36.62				6.06		13.51			100
Spectrum 4			3.88	86.58				4.85		4.69			100
Spectrum 5			11.7	20.69				3.69			64		100
Spectrum 6		2.91	20.1	41.27	15.3		5.4	9.5		5.49			100
Spectrum 7			29.1	43.06				27.8					100
Spectrum 8		30.83	8.57	56.04				4.56					100
<b>SOI 3</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>Cr<sub>2</sub>O<sub>3</sub></b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>TiO<sub>2</sub></b>	<b>PbO</b>	<b>Total</b>
Spectrum 1			4.99	10.56				2.45		82			100
Spectrum 2		6.88	15.2	59.6				18.3					100
Spectrum 3		1.6	3.93	88.36				4.1		2.01			100
Spectrum 4		9.43	30.5	36.45				23.6					100
Spectrum 5		6.64	20.6	32.76				3.12		36.89			100
<b>SOI 4</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>Cr<sub>2</sub>O<sub>3</sub></b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>TiO<sub>2</sub></b>	<b>PbO</b>	<b>Total</b>
Spectrum 1			14.4	73.23				12.4					100
Spectrum 2		8.99	18.3	32.85	9.43			30.5					100
Spectrum 3			3.84	91.8				4.36					100

Spectrum 4		4.94	11.3	29.73				54					100
Spectrum 5		18.47	3.09	75.13				3.32					100
<b>SOI 5</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>Cr<sub>2</sub>O<sub>3</sub></b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>TiO<sub>2</sub></b>	<b>PbO</b>	<b>Total</b>
Spectrum 1			8.98	15.34	4.45	0		10.5		52.27			91.5
Spectrum 2			6.55	11.13	4.03	0		7.38		66.15			95.24
Spectrum 3										100			100
Spectrum 4		3.73	7.64	16.82	9.31	0		30					67.55
<b>Bulk 1</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>Cr<sub>2</sub>O<sub>3</sub></b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>TiO<sub>2</sub></b>	<b>PbO</b>	<b>Total</b>
Spectrum 1		5.17	19.4	38.25	8.59		2.6	19.9		6.11			100
<b>Bulk 2</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>Cr<sub>2</sub>O<sub>3</sub></b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>TiO<sub>2</sub></b>	<b>PbO</b>	<b>Total</b>
Spectrum 1		5.63	38.2	30.1	6.65			15.2		4.23			100

First Sample Set: 6 days

Table 5 EDS analysis listed as oxides of the Field Blank from NOA after 6 days

<b>SOI 1</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>CaO</b>	<b>Total</b>
Spectrum 1				100	100
Spectrum 2	32.81		67.19		100
<b>Bulk</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>CaO</b>	<b>Total</b>
Spectrum 1		100			100
Spectrum 2		78.08		21.92	100

Table 6 EDS analysis listed as oxides of the Top Passive Filter from NOA after 6 days

<b>SOI 1</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>CaO</b>	<b>BaO</b>	<b>Total</b>
Spectrum 1						100.00	100
Spectrum 2	28.20		71.80				100
Spectrum 3	32.68		67.32				100
<b>SOI 2</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>CaO</b>	<b>BaO</b>	<b>Total</b>

Spectrum 1						100.00	100
Spectrum 2		6.89				93.11	100
Spectrum 3		15.71				84.29	100
Spectrum 4						100.00	100
Spectrum 5	33.58	4.38	62.04				100
<b>SOI 3</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>CaO</b>	<b>BaO</b>	<b>Total</b>
Spectrum 1		9.85			90.15		100
Spectrum 2	35.43		64.57				100
Spectrum 3				38.38		61.62	100
Spectrum 4		4.65		12.22	83.13		100
Spectrum 5	100.00						100
<b>SOI 4</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>CaO</b>	<b>BaO</b>	<b>Total</b>
Spectrum 1		6.89			93.11		100
<b>SOI 5</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>CaO</b>	<b>BaO</b>	<b>Total</b>
Spectrum 1	26.08	18.55	55.37				100
<b>Bulk 1</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>CaO</b>	<b>BaO</b>	<b>Total</b>
Spectrum 1		100.00					100
Spectrum 2	5.92	91.29			2.79		100
<b>Bulk 2</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>CaO</b>	<b>BaO</b>	<b>Total</b>
Spectrum 1	10.54	53.13	19.58		16.75		100
<b>Bulk 3</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>CaO</b>	<b>BaO</b>	<b>Total</b>
Spectrum 1	5.60	94.40					100

Table 7 EDS analysis listed as oxides of the Mid Passive Filter from NOA after 6 days

<b>SOI 1</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>Total</b>
Spectrum			16.73	83.27						100
<b>SOI 2</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>Total</b>
Spectrum 1			100							100
Spectrum 2			34.44	17.23				48.33		100

Spectrum 3	26.29	8.02	19.77		21.72	0		8.09		83.89
Spectrum 4		12.55	16.78	43.23	4.32		3.33	14.62	5.17	100
Spectrum 5		2.77	10.92	5.59	1.79			78.93		100
<b>SOI 3</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>Total</b>
Spectrum 1			22.06	7.58				70.36		100
Spectrum 2			16.86	4.53				78.6		100
Spectrum 3		4.85	24.62	15.19			12.45	19.26	23.63	100
Spectrum 4		2.18	8.85	13.59				75.39		100
<b>SOI 4</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>Total</b>
Spectrum 1			12.3	6.29				81.41		100
Spectrum 2			7.05	4.43	4.47				84.05	100
Spectrum 3			5.31	4.67					90.02	100
Spectrum 4		32.34	3.91	63.75						100
<b>Bulk 1</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>Total</b>
Spectrum 1		6.01	58.83	11.41	11.03			12.73		100
<b>Bulk 2</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>Total</b>
Spectrum 1		7.64	58.38	12.9	9.71			11.36		100
<b>Bulk 3</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>Total</b>
Spectrum 1		5.97	87.35	2.11	1.32	0		2.4		99.15

Table 8 EDS analysis listed as oxides of the Bot Passive Filter from NOA after 6 days

<b>SOI 1</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>CaO</b>	<b>ZnO</b>	<b>Total</b>
Spectrum 1	4.60	80.69				14.71		100.00
Spectrum 2	3.80	71.09				25.11		100.00
Spectrum 3	3.48	74.71				21.81		100.00
Spectrum 4	4.80	95.20						100.00
Spectrum 5	3.97	75.43				20.60		100.00
<b>SOI 2</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>CaO</b>	<b>ZnO</b>	<b>Total</b>
Spectrum 1		27.57				3.49	68.94	100.00
<b>SOI 3</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>CaO</b>	<b>ZnO</b>	<b>Total</b>
Spectrum 1	18.99	10.02	32.59		0.00	35.71		97.32
Spectrum 2	5.81	12.20	12.04			69.94		100.00
Spectrum 3	6.12	11.35			0.00	80.34		97.82
Spectrum 4		8.86				91.14		100.00
Spectrum 5	28.57	4.19	67.24					100.00
<b>Bulk 1</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>CaO</b>	<b>ZnO</b>	<b>Total</b>
Spectrum 1		60.14	9.75	11.60	0.00	14.55		96.05
<b>Bulk 2</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>CaO</b>	<b>ZnO</b>	<b>Total</b>
Spectrum 2	6.33	73.59	6.05	5.45	0.00	6.60		98.02

Table 9 EDS analysis listed as oxides of the Top Book Sample from NOA after 6 days

<b>SOI 1</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>P<sub>2</sub>O<sub>5</sub></b>	<b>SO<sub>2</sub></b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>TiO<sub>2</sub></b>	<b>Mn</b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>ZnO</b>	<b>BaO</b>	<b>Total</b>
Spectrum 1			8.15	11.31				6.83			73.71			100.00
Spectrum 2		3.31	13.52	9.85		2.26		71.07						100.00
Spectrum 3			2.49	7.14		2.40					87.96			100.00
Spectrum 4			17.13	50.61		9.19	9.67	9.96			3.43			100.00
Spectrum 5			3.39	90.68				5.93						100.00
Spectrum 6			6.98	32.08			4.75	5.89	34.3	9.59	6.41			100.00
<b>SOI 2</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>P<sub>2</sub>O<sub>5</sub></b>	<b>SO<sub>2</sub></b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>TiO<sub>2</sub></b>	<b>Mn</b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>ZnO</b>	<b>BaO</b>	<b>Total</b>
Spectrum 1			22.53	36.22		15.44	3.95	11.24	10.62					100.00
Spectrum 2		5.91	6.66	14.01		5.07		68.35						100.00
Spectrum 3	2.48	3.18	27.44	50.00		2.84	2.77	6.29			5.01			100.00
Spectrum 4			20.66	58.76			11.30	9.28						100.00
Spectrum 5		2.52	7.60	11.89		5.05		72.95						100.00
Spectrum 6		2.12	24.92	31.93		12.75		11.66					16.61	100.00
<b>SOI 3</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>P<sub>2</sub>O<sub>5</sub></b>	<b>SO<sub>2</sub></b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>TiO<sub>2</sub></b>	<b>Mn</b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>ZnO</b>	<b>BaO</b>	<b>Total</b>
Spectrum 1	6.32		20.78	7.8		24.74		5.79					34.57	100.00
Spectrum 2			22.62	30.96		28.00		18.41						100.00
Spectrum 3			26.10	10.06		11.12		8.98			36.04		7.70	100.00
Spectrum 4		7.05	22.4	5.41		3.85		51.59				9.70		100.00
Spectrum 5		2.87	19.02	11.02	4.45	2.58		17.02			43.04			100.00

<b>Bulk 1</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>P<sub>2</sub>O<sub>5</sub></b>	<b>SO<sub>2</sub></b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>TiO<sub>2</sub></b>	<b>Mn</b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>ZnO</b>	<b>BaO</b>	<b>Total</b>
Spectrum 1	1.35	5.13	67.67	12.25		4.97		8.63						100.00
<b>Bulk 2</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>P<sub>2</sub>O<sub>5</sub></b>	<b>SO<sub>2</sub></b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>TiO<sub>2</sub></b>	<b>Mn</b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>ZnO</b>	<b>BaO</b>	<b>Total</b>
Spectrum 1			65.38	19.74				14.88						100.00
Spectrum 2	1.64	4.66	53.18	17.91		6.47	0.70	13.43			2.01			100.00

Table 10 EDS analysis listed as oxides of the Mid Book Sample from NOA after 6 days

<b>SOI 1</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>P<sub>2</sub>O<sub>5</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>TiO<sub>2</sub></b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>MoO<sub>3</sub></b>	<b>BaO</b>	<b>Total</b>
Spectrum 1	4.01	35.66	10.93		13.49			20.96		3.30		11.67	100.00
Spectrum 2	5.07	39.34	16.15					4.69	19.92	14.84			100.00
Spectrum 3	3.77	41.24	14.25		4.61			36.13					100.00
Spectrum 4	5.55	31.82	22.18					32.39			8.06		100.00
Spectrum 5	3.15	31.61	7.27		23.79			34.18					100.00
Spectrum 6	3.19	27.28	3.95					65.58					100.00
<b>SOI 2</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>P<sub>2</sub>O<sub>5</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>TiO<sub>2</sub></b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>MoO<sub>3</sub></b>	<b>BaO</b>	<b>Total</b>
Spectrum 1	1.48	5.29	7.95	35.22				50.07					100.00
Spectrum 2	5.46	10.53	12.42		3.29			68.30					100.00
Spectrum 3	3.46	17.07	42.77		17.66			19.03					100.00
Spectrum 4	7.02	14.79	20.56					57.63					100.00
<b>SOI 3</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>P<sub>2</sub>O<sub>5</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>TiO<sub>2</sub></b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>MoO<sub>3</sub></b>	<b>BaO</b>	<b>Total</b>
Spectrum 1	7.07	89.25						3.67					100.00
Spectrum 2	3.89	49.30	35.48		2.55		1.87	3.26	3.64				100.00
Spectrum 3	4.20	47.82	2.30					45.68					100.00
Spectrum 4	4.30	46.10	2.93					21.61		25.08			100.00
<b>Bulk 1</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>P<sub>2</sub>O<sub>5</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>TiO<sub>2</sub></b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>MoO<sub>3</sub></b>	<b>BaO</b>	<b>Total</b>
Spectrum 1	5.42	71.33	13.21		2.56			6.04		1.44			100.00
<b>Bulk 2</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>P<sub>2</sub>O<sub>5</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>TiO<sub>2</sub></b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>MoO<sub>3</sub></b>	<b>BaO</b>	<b>Total</b>

Spectrum 1	6.04	25.60	31.47		7.63	0.00	1.59	21.91		5.07			99.32
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Table 11 EDS analysis listed as oxides of the Bot Book Sample from NOA after 6 days

<b>SOI 1</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>P<sub>2</sub>O<sub>5</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>BaO</b>	<b>Total</b>
Spectrum 1			24.55	7.08		25.55			5.72		37.11	100.00
Spectrum 2			40.00	46.79				5.91	7.30			100.00
Spectrum 3			24.08	43.03		26.27			6.62			100.00
Spectrum 4			24.70	61.65				13.64				100.00
Spectrum 5	6.56		16.02	6.20		5.47			2.74	63.01		100.00
Spectrum 6			22.72	71.20					6.09			100.00
Spectrum 7		3.81	30.09	48.37				4.85	5.71	7.17		100.00
<b>SOI 2</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>P<sub>2</sub>O<sub>5</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>BaO</b>	<b>Total</b>
Spectrum 1			17.89	10.48		6.55			8.08	57.01		100.00
Spectrum 2		6.43	10.75	11.84		26.86			6.09		38.03	100.00
Spectrum 3		1.93	28.08	45.24				9.97	5.23	9.54		100.00
Spectrum 4			18.97	38.31		9.24		7.11	12.31	14.17		100.00
<b>SOI 3</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>P<sub>2</sub>O<sub>5</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>BaO</b>	<b>Total</b>
Spectrum 1			38.76	61.24								100.00
Spectrum 2		4.02	26.69	50.12				8.50	2.93	7.74		100.00
Spectrum 3			20.54	64.63				14.83				100.00
Spectrum 4			41.06	14.00	34.13				10.82			100.00
<b>Bulk 1</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>P<sub>2</sub>O<sub>5</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>BaO</b>	<b>Total</b>
Spectrum 1		5.65	24.81	35.38		8.27	0.00		20.26	4.39		98.76
<b>Bulk 2</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>P<sub>2</sub>O<sub>5</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>BaO</b>	<b>Total</b>
Spectrum 1	1.70	5.26	56.18	18.93		5.80	0.00		8.74	2.81		99.43

Second Sample Set: 11 days

Table 12 EDS analysis listed as oxides of the Field Blank from NOA after 11 days

SOI 1	Al <sub>2</sub> O <sub>3</sub>	SiO <sub>2</sub>	SO <sub>2</sub>	CaO	Total
Spectrum 1	74.82			25.18	100
Bulk	Al <sub>2</sub> O <sub>3</sub>	SiO <sub>2</sub>	SO <sub>2</sub>	CaO	Total
Spectrum 1	25.66	18.05	28.51	27.79	100

Table 13 EDS analysis listed as oxides of the Top Passive Filter from NOA after 11 days

SOI 1	Na <sub>2</sub> O	MgO	Al <sub>2</sub> O <sub>3</sub>	SiO <sub>2</sub>	SO <sub>2</sub>	ClO	K <sub>2</sub> O	CaO	Fe <sub>2</sub> O <sub>3</sub>	Total
Spectrum 1		11.13	15.58	73.29						100.00
SOI 2	Na <sub>2</sub> O	MgO	Al <sub>2</sub> O <sub>3</sub>	SiO <sub>2</sub>	SO <sub>2</sub>	ClO	K <sub>2</sub> O	CaO	Fe <sub>2</sub> O <sub>3</sub>	Total
Spectrum 2		4.73	15.21	4.51				75.55		100.00
SOI 3	Na <sub>2</sub> O	MgO	Al <sub>2</sub> O <sub>3</sub>	SiO <sub>2</sub>	SO <sub>2</sub>	ClO	K <sub>2</sub> O	CaO	Fe <sub>2</sub> O <sub>3</sub>	Total
Spectrum 3	1.92	7.46	17.54	28.42	9.78		2.46	26.88	5.54	100.00
Bulk	Na <sub>2</sub> O	MgO	Al <sub>2</sub> O <sub>3</sub>	SiO <sub>2</sub>	SO <sub>2</sub>	ClO	K <sub>2</sub> O	CaO	Fe <sub>2</sub> O <sub>3</sub>	Total
Spectrum 1		5.26	43.32	15.18	12.79	0.00		21.40		97.95

Table 14 EDS analysis listed as oxides of the Mid Passive Filter from NOA after 11 days

SOI 1	Na <sub>2</sub> O	MgO	Al <sub>2</sub> O <sub>3</sub>	SiO <sub>2</sub>	SO <sub>2</sub>	ClO	K <sub>2</sub> O	CaO	Fe <sub>2</sub> O <sub>3</sub>	PbO	Total
Spectrum 1	3.71	3.59	46.41	5.53	7.81	0.00	2.78	6.62		18.34	94.77
SOI 2	Na <sub>2</sub> O	MgO	Al <sub>2</sub> O <sub>3</sub>	SiO <sub>2</sub>	SO <sub>2</sub>	ClO	K <sub>2</sub> O	CaO	Fe <sub>2</sub> O <sub>3</sub>	PbO	Total
Spectrum 1		4.71	44.76	7.54	4.70			35.56	2.73		100.00
SOI 3	Na <sub>2</sub> O	MgO	Al <sub>2</sub> O <sub>3</sub>	SiO <sub>2</sub>	SO <sub>2</sub>	ClO	K <sub>2</sub> O	CaO	Fe <sub>2</sub> O <sub>3</sub>	PbO	Total
Spectrum 1		5.41	52.24	31.81			2.06		8.48		100.00
SOI 4	Na <sub>2</sub> O	MgO	Al <sub>2</sub> O <sub>3</sub>	SiO <sub>2</sub>	SO <sub>2</sub>	ClO	K <sub>2</sub> O	CaO	Fe <sub>2</sub> O <sub>3</sub>	PbO	Total
Spectrum 1		4.45	46.85	23.07	3.19		2.63	16.47	3.34		100.00
SOI 5	Na <sub>2</sub> O	MgO	Al <sub>2</sub> O <sub>3</sub>	SiO <sub>2</sub>	SO <sub>2</sub>	ClO	K <sub>2</sub> O	CaO	Fe <sub>2</sub> O <sub>3</sub>	PbO	Total
Spectrum 1	1.66	4.87	46.09	15.21	9.98			22.20			100.00
Bulk	Na <sub>2</sub> O	MgO	Al <sub>2</sub> O <sub>3</sub>	SiO <sub>2</sub>	SO <sub>2</sub>	ClO	K <sub>2</sub> O	CaO	Fe <sub>2</sub> O <sub>3</sub>	PbO	Total

Spectrum 1		5.73	61.14	9.62	6.94	0.00		15.04			98.47
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Table 15 EDS analysis listed as oxides of the Bot Passive Filter from NOA after 11 days

<b>SOI 1</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>ClO</b>	<b>CaO</b>	<b>Total</b>
Spectrum 1		2.52	24.63	4.8		68.04	100
<b>SOI 2</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>ClO</b>	<b>CaO</b>	<b>Total</b>
Spectrum 1	1.6	1.5	25.07	6.75		65.09	100
<b>Bulk</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>ClO</b>	<b>CaO</b>	<b>Total</b>
Spectrum 1		5.29	88.26	2.19	0	3.44	99.18

Table 16 EDS analysis listed as oxides of the Top Book Sample from NOA after 11 days

<b>SOI 1</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>P<sub>2</sub>O<sub>5</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>Total</b>
Spectrum 1			22.65	77.35						100.00
Spectrum 2			10.96						89.04	100.00
<b>SOI 2</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>P<sub>2</sub>O<sub>5</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>Total</b>
Spectrum 1		4.34	12.7	49.44		6.57			26.95	100.00
Spectrum 2			8.06	2.73					89.2	100.00
<b>SOI 3</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>P<sub>2</sub>O<sub>5</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>Total</b>
Spectrum 1		6.70	18.65	58.58		5.43		2.84	7.80	100.00
Spectrum 2			49.63						50.37	100.00
<b>Bulk</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>P<sub>2</sub>O<sub>5</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>Total</b>
Spectrum 1	2.04	4.12	38.09	25.05	4.40	8.39	0.00		16.54	98.62

Table 17 EDS analysis listed as oxides of the Mid Book Sample from NOA after 11 days

<b>SOI 1</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>TiO<sub>2</sub></b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>Total</b>
Spectrum 1		6.36	43.58	13.75			3.09		33.22	100
Spectrum 2			44.77	8.92			46.31			100
<b>SOI 2</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>TiO<sub>2</sub></b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>Total</b>
Spectrum 1		3.81	38.6	5.51			52.08			100
Spectrum 2		30.84	25.54	36.41			1.85		5.36	100

<b>SOI 3</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>TiO<sub>2</sub></b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>Total</b>
Spectrum 1		7.01	36.77	39.75	4.47	3.03	5.02		3.96	100
Spectrum 2		3.91	40.55	10.91	4.97		39.67			100
<b>SOI 4</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>TiO<sub>2</sub></b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>Total</b>
Spectrum 1		3.68	39.06	12.34		2.54	2.44		39.93	100
Spectrum 2		3.02	30.17	7.69				59.12		100
<b>Bulk</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>TiO<sub>2</sub></b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>Total</b>
Spectrum 1	1	5.01	24.01	35.56	9.28	2.26	18.3		4.58	100

Table 18 EDS analysis listed as oxides of the Top Book Sample from NOA after 11 days

<b>SOI 1</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>BaO</b>	<b>Total</b>
Spectrum 1		7.50	41.05	28.94	17.98			4.52			100.00
Spectrum 2			41.74	13.15	17.24			5.59		22.28	100.00
<b>SOI 2</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>BaO</b>	<b>Total</b>
Spectrum 1		3.56	17.1	4.97	29.37					45.00	100.00
Spectrum 2			23.89	6.45	4.86			64.80			100.00
<b>SOI 3</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>BaO</b>	<b>Total</b>
Spectrum 1	9.88	2.76	16.2	56.19	8.72		1.48	4.77			100.00
Spectrum 2	11.44		24.33	43.03	20.3		0.90				100.00
<b>Bulk</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>BaO</b>	<b>Total</b>
Spectrum 1	2.07	7.04	27.48	35.06	10.28	0.00	1.57	12.05	3.50		99.04

## Appendix 2 Moni Velanidias EDS analysis

### Baseline Sample

Table 19 EDS analysis listed as oxides of the Baseline sample from Moni Velanidias (MON)

<b>SOI 1</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>ZnO</b>	<b>BaO</b>	<b>Total</b>
Spectrum 1		37.70	48.32			5.13	8.85			100.00
Spectrum 2		12.88	87.12							100.00
Spectrum 3		17.58	77.47		4.95					100.00
Spectrum 4		43.79	9.64	41.26	5.31					100.00
Spectrum 5		6.52	93.48							100.00

Spectrum 6		25.70	32.96	21.71		19.63				100.00
<b>SOI 2</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>ZnO</b>	<b>BaO</b>	<b>Total</b>
Spectrum 1		38.79	36.03	25.19						100.00
Spectrum 2	7.35	15.81	13.42				63.43			100.00
Spectrum 3		100.00								100.00
Spectrum 4		13.95	30.75	30.65		24.66				100.00
Spectrum 5		21.68	54.56			23.76				100.00
Spectrum 6	1.91	23.12	41.40	13.95	3.83	13.90		1.89		100.00
<b>SOI 3</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>ZnO</b>	<b>BaO</b>	<b>Total</b>
Spectrum 1		27.99	57.39		9.37		5.25			100.00
Spectrum 2		10.64	24.08			65.28				100.00
Spectrum 3	2.64	2.70	5.12			89.54				100.00
Spectrum 4		3.57	96.43							100.00
Spectrum 5	15.33	25.10	39.68				19.89			100.00
<b>SOI 4</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>ZnO</b>	<b>BaO</b>	<b>Total</b>
Spectrum 1		7.94	12.68			79.38				100.00
Spectrum 2	2.22	15.97	57.11		8.30	6.14	10.26			100.00
Spectrum 3	2.29	5.70	9.10	33.23		4.51		8.72	36.45	100.00
Spectrum 4	2.73	16.30	38.88	4.21		28.34	9.55			100.00
Spectrum 5		9.24	59.31			31.46				100.00
Spectrum 6		38.21	56.33				5.47			100.00
<b>Bulk 1</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>ZnO</b>	<b>BaO</b>	<b>Total</b>
Spectrum 1	4.21	58.03	23.60	4.81		9.35				100.00
<b>Bulk 2</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>ZnO</b>	<b>BaO</b>	<b>Total</b>
Spectrum 1		18.58	43.16	14.82		23.44				100.00

First Sample Set: 6 days

Table 20 EDS analysis listed as oxides of the Field Blank from MON after 6 days

<b>SOI 1</b>	<b>Total</b>
<b>Bulk</b>	<b>CaO</b>
	<b>Total</b>

Spectrum 1	100	100
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Table 21 EDS analysis listed as oxides of the Top Passive Filter from MON after 6 days

<b>SOI 1</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>CaO</b>	<b>Total</b>
Spectrum 1		30.42	9.25				60.33	100.00
Spectrum 2							100.00	100.00
<b>SOI 2</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>CaO</b>	<b>Total</b>
Spectrum 1	6.82	5.87	36.72	45.00			5.59	100.00
<b>SOI 3</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>CaO</b>	<b>Total</b>
Spectrum 1		4.11	76.60				19.30	100.00
Spectrum 2		5.26	81.26				13.48	100.00
<b>Bulk 1</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>CaO</b>	<b>Total</b>
Spectrum 1		5.49	87.75			0.00	5.05	98.29
<b>Bulk 2</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>CaO</b>	<b>Total</b>
Spectrum 1		5.95	89.99	1.67	0.78	0.00	1.25	99.64

Table 22 EDS analysis listed as oxides of the Mid Passive Filter from MON after 6 days

<b>SOI 1</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>CaO</b>	<b>Total</b>
Spectrum 1	20.66	33.78	45.56				100.00
<b>SOI 2</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>CaO</b>	<b>Total</b>
Spectrum 1	6.06	9.28	12.47			72.19	100.00
<b>SOI 3</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>CaO</b>	<b>Total</b>
Spectrum 1	28.35	4.12	67.53				100.00
<b>Bulk 1</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>CaO</b>	<b>Total</b>
Spectrum 1	5.89	84.65	2.94		0.00	4.40	97.88

<b>Bulk 2</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>CaO</b>	<b>Total</b>
Spectrum 1	5.56	89.03	0.99	1.77	0.00	2.14	99.49

Table 23 EDS analysis listed as oxides of the Bot Passive Filter from MON after 6 days

<b>SOI 1</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>CaO</b>	<b>Total</b>
Spectrum 1	20.55	34.83	44.62				100.00
<b>SOI 2</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>CaO</b>	<b>Total</b>
Spectrum 1	27.08	10.70	62.22				100.00
<b>SOI 3</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>CaO</b>	<b>Total</b>
Spectrum 1	32.10		67.90				100.00
<b>Bulk</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>CaO</b>	<b>Total</b>
Spectrum 1	9.18	41.49	18.85	8.86	0.00	17.47	95.84

Table 24 EDS analysis listed as oxides of the Top Book Sample from MON after 6 days

<b>SOI 1</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>P<sub>2</sub>O<sub>5</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>Total</b>
Spectrum 1	4.66	83.87						11.47	100.00
Spectrum 2	4.01	84.98			6.11			4.90	100.00
Spectrum 3	8.27	75.04	16.69						100.00
Spectrum 4	5.79	66.5						27.71	100.00
<b>SOI 2</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>P<sub>2</sub>O<sub>5</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>Total</b>
Spectrum 1	15.31	39.73	44.95						100.00
<b>SOI 3</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>P<sub>2</sub>O<sub>5</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>Total</b>
Spectrum 1	27.75	11.81	60.44						100.00
<b>SOI 4</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>P<sub>2</sub>O<sub>5</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>Total</b>
Spectrum 1		58.03		41.97					100.00
Spectrum 2		14.99	14.95					70.06	100.00
Spectrum 3		40.59	59.41						100.00
Spectrum 4		44.65	55.35						100.00
Spectrum 5		21.85	65.11				13.04		100.00

Spectrum 6		22.48	63.08				14.43		100.00
<b>Bulk 1</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>P<sub>2</sub>O<sub>5</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>Total</b>
Spectrum 1	3.81	41.26	29.33		9.93	0.00	1.40	10.78	96.52
<b>Bulk 2</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>P<sub>2</sub>O<sub>5</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>Total</b>
Spectrum 1	6.79	49.60	22.63		7.70	0.00		11.94	98.66

Table 25 EDS analysis listed as oxides of the Mid Book Sample from MON after 6 days

<b>SOI 1</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>TiO<sub>2</sub></b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>ZnO</b>	<b>Total</b>
Spectrum 1	5.23	61.29	14.97				18.52				100.00
Spectrum 2	5.76	49.40	7.43				37.42				100.00
Spectrum 3	6.07	38.49	11.21				44.22				100.00
Spectrum 4	3.03	33.39	4.84				58.74				100.00
Spectrum 5	2.91	53.86	16.24				27.00				100.00
Spectrum 6	6.45	41.33	31.64			3.31	12.37		4.89		100.00
Spectrum 7	3.48	43.30	43.76			9.46					100.00
<b>SOI 2</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>TiO<sub>2</sub></b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>ZnO</b>	<b>Total</b>
Spectrum 1	4.07	46.39	12.49	2.40						34.65	100.00
Spectrum 2	2.41	51.65	19.02				26.92				100.00
Spectrum 3	1.25	23.37	5.72				0.81		68.85		100.00
Spectrum 4	4.18	37.35	27.48		0.00	2.79	16.36	8.59			96.74
Spectrum 5	1.64	18.33	6.75						73.28		100.00
Spectrum 6	2.00	35.75	51.83			8.26			2.17		100.00
Spectrum 7	5.30	31.68	51.45			9.67			1.91		100.00
<b>SOI 3</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>TiO<sub>2</sub></b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>ZnO</b>	<b>Total</b>
Spectrum 1		8.99	91.01								100.00
Spectrum 2	0.61	7.04	90.75				1.60				100.00
Spectrum 3	3.78	29.67	56.39			10.16					100.00
<b>SOI 4</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>TiO<sub>2</sub></b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>ZnO</b>	<b>Total</b>
Spectrum 1		9.45	74.66	5.87		4.64	5.38				100.00
Spectrum 2	1.95	35.05	53.72			9.28					100.00

Spectrum 3	4.45	22.70	53.87			18.97					100.00
Spectrum 4	4.33	26.67	58.21			10.79					100.00
<b>Bulk 1</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>TiO<sub>2</sub></b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>ZnO</b>	<b>Total</b>
Spectrum 1	3.49	32.04	45.39	4.51		7.41	7.15				100.00
<b>Bulk 2</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>TiO<sub>2</sub></b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>ZnO</b>	<b>Total</b>
Spectrum 1	4.25	62.25	21.05	2.81	0.00	3.04	5.61				99.00

Table 26 EDS analysis listed as oxides of the Bot Book Sample from MON after 6-  
days

<b>SOI 1</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>P<sub>2</sub>O<sub>5</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>Total</b>
Spectrum 1			46.08	53.92							100
Spectrum 2			35.06	49.99					14.95		100
Spectrum 3		4.11	32.15	54.21					9.54		100
Spectrum 4		4.03	31.74	54.4					9.83		100
<b>SOI 2</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>P<sub>2</sub>O<sub>5</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>Total</b>
Spectrum 1			14.32	9.78		38.78				37.11	100
Spectrum 2			35.56	59.46				4.98			100
Spectrum 3			43.56	56.44							100
Spectrum 4			4.96	2.81						92.23	100
Spectrum 5		5.36	3.78	2.81					88.05		100
<b>SOI 3</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>P<sub>2</sub>O<sub>5</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>Total</b>
Spectrum 1		4.47	12.5	10.07		6.68	0		64.19		97.9
Spectrum 2			37.62	23.38	39						100
Spectrum 3	8.83	11.64	15.18	13.39		21.9			29.06		100
Spectrum 4		1.33	41.3	57.37							100
Spectrum 5			100								100
<b>SOI 4</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>P<sub>2</sub>O<sub>5</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>Total</b>
Spectrum 1			59.34	40.66							100
Spectrum 2		3.12	9.71	13.56						73.61	100
Spectrum 3		25.18	5.63	4.56		56.6			8.04		100
Spectrum 4			2.58	1.31		56.97			39.14		100

Spectrum 5			25.28	51.74				22.98			100
<b>Bulk 1</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>P<sub>2</sub>O<sub>5</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>Total</b>
Spectrum 1		5.27	32.27	28.15		13.94	0	3.94	13.84		97.41
<b>Bulk 2</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>P<sub>2</sub>O<sub>5</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>Total</b>
Spectrum 1		5.19	68.2	12.39		7.22	0	1.34	4.78		99.11

Second Sample Set: 11 days

Table 27 EDS analysis listed as oxides of the Field Blank from MON after 11 days

<b>SOI 1</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>CaO</b>	<b>Total</b>
Spectrum 1		29.15	6.29	64.56				100
<b>Bulk</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>CaO</b>	<b>Total</b>
Spectrum 1	7.66	7.25	36.53	11.91	11.4	0	16.48	91.22

Table 28 EDS analysis listed as oxides of the Top Passive Filter from MON after 11 days

<b>SOI 1</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>Total</b>
Spectrum 1	24.1	21.68	54.22					100.00
<b>SOI 2</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>Total</b>
Spectrum 1		36.73	53.53			9.74		100.00
<b>Bulk</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>Total</b>
Spectrum 1	5.56	90.39	1.40	0.66	0.00		1.49	99.50

Table 29 EDS analysis listed as oxides of the Mid Passive Filter from MON after 11 days

<b>SOI 1</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>CaO</b>	<b>Total</b>
Spectrum 1		29.83				70.17	100.00
<b>SOI 2</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>CaO</b>	<b>Total</b>
Spectrum 2	24.54	12.75	62.71				100.00
<b>Bulk</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>CaO</b>	<b>Total</b>

Spectrum 1	7.20	65.75	10.21	6.33	0.00	7.00	96.49
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Table 30 EDS analysis listed as oxides of the Bot Passive Filter from MON after 11 days

<b>SOI 1</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>CaO</b>	<b>Total</b>
Spectrum 1	19.09	29.24	51.67				100
<b>Bulk</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>CaO</b>	<b>Total</b>
Spectrum 1	9.91	43.25	19.05	6.88	0	17.2	96.29

Table 31 EDS analysis listed as oxides of the Top Book Sample from MON after 11 days

<b>SOI 1</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>Total</b>
Spectrum 1	4.23	62.40	5.15				28.23	100
Spectrum 2	3.89	51.90	35.95		5.63	2.63		100
<b>SOI 2</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>Total</b>
Spectrum 1	5.67	94.33						100
Spectrum 2	3.96	62.73	17.17	10.11		6.03		100
<b>SOI 3</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>Total</b>
Spectrum 1	3.66	54.76	15.45	4.25		18.61	3.26	100
Spectrum 2	4.98	67.79	14.07	6.23		6.93		100
<b>Bulk</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>K<sub>2</sub>O</b>	<b>CaO</b>	<b>Fe<sub>2</sub>O<sub>3</sub></b>	<b>Total</b>
Spectrum 1	5.32	86.87	4.70	1.22		1.89		100

Table 32 EDS analysis listed as oxides of the Mid Book Sample from MON after 11 days

<b>SOI 1</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>CaO</b>	<b>Total</b>
Spectrum 1	4.65	66.58	10.29	13.86		4.62	100
<b>SOI 2</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>CaO</b>	<b>Total</b>
Spectrum 1	4.35	53.97	4.06			37.61	100
<b>Bulk</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>CaO</b>	<b>Total</b>
Spectrum 1	6.43	69.26	7.95	5.69	0	9.13	98.46

Table 33 EDS analysis listed as oxides of the Bot Book Sample from MON after 11 days

<b>SOI 1</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>CaO</b>	<b>MoO<sub>3</sub></b>	<b>Total</b>
Spectrum 1		3.03	40.76	48.35			2.36	5.50	100
<b>SOI 2</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>CaO</b>	<b>MoO<sub>3</sub></b>	<b>Total</b>
Spectrum 1		4.07	59.69	8.30	6.70		21.23		100
<b>SOI 3</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>CaO</b>	<b>MoO<sub>3</sub></b>	<b>Total</b>

Spectrum 1		3.37	59.84	11.60	14.68		10.51		100
<b>Bulk</b>	<b>Na<sub>2</sub>O</b>	<b>MgO</b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>ClO</b>	<b>CaO</b>	<b>MoO<sub>3</sub></b>	<b>Total</b>
Spectrum 1	0.54	4.52	77.98	9.98	2.87	0	3.59		99.48