X-Ray Analysis of Airborne Particulate Matter Collected by Passive Samplers in the Chicago Area

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Abstract

Exposure to high concentrations of metal particulates may increase the potential risk for future health problems[1]. Therefore, analyzing particulate composition using passive air filters can help researchers understand the causes and sources of particulate pollution in differing environments. Air quality research places new information in the hands of communities, but also air quality regulators as insight into how particulate matter composition is related to location and environment.

Background

Airborne particulate matter is a threat to the safety of people as it can have drastic impacts on the respiratory system. The International Agency for Research on Cancer (IARC) found that particulate matter in outdoor pollution may cause lung cancer and other respiratory diseases[1]. Metals such as magnesium, lead, copper, nickel, barium, and zinc can be absorbed into a particulate matter surface and may become toxic[1]. Metal pollution can be enriched by atmospheric particles from urban areas that are densely populated[2]. Understanding the composition of the particulate matter could help locate its source and even lead to a reduced quantity.

Purpose

This research project aimed to determine the amount, size, and chemical composition of particulates collected through five passive air filters sampled from various locations around Chicago, Illinois, and suburbs using X-Ray Fluorescence Imaging and X-ray Absorption Spectroscopy. This research project builds upon the 2021-2022 Argonne National Laboratory Exemplary Student Research Program (ESRP) project completed by Mundelein High School by adding multiple research sites for comparison rather than collecting particulates from one location for an extended period, allowing for comparisons of collected particulates by geographic areas.

Methodology

The five locations chosen to place the filters included: Wolf Wildlife Preserve in Oak Lawn, a factory in Blue Island, downtown Chicago in the River North neighborhood, the Cook County Forest Preserve in Oak Forest, and the clean room at Rush University Medical Center. The locations were chosen to maximize the environmental variance to observe the most significant differences in particulates, while the clean room acted as a control group.

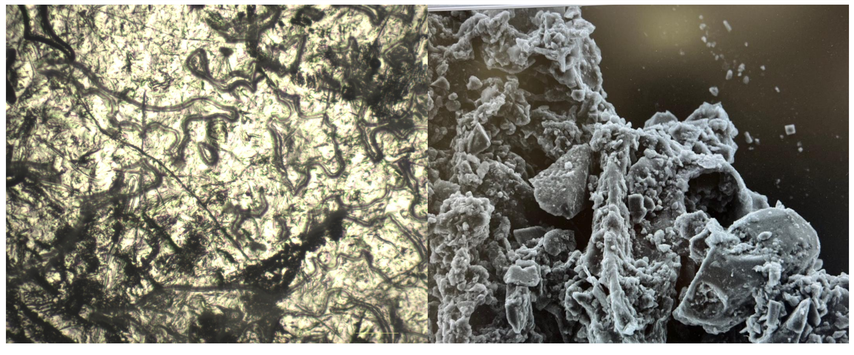
The passive air samplers were composed of metal SEM (Scanning Electron Microscope) stubs with adhesive carbon tape and were provided by the faculty mentors. The filters were 3D printed and cut with a Full Spectrum Pro Laser Cutter to replicate and improve on passive air filters already created[3]. In addition, we designed and 3D-printed color-coded collection boxes to hold the filters to reduce the impact of external factors that threatened the filters, including bugs, small animals, and inclement weather. Each collection box was then covered in cheesecloth and set out for twenty-four hours for passive-air collection.

Analysis

The samples were taken to the Advanced Photon Source (APS) at Argonne National Laboratory to examine the chemical composition of the particulates on the filters. The carbon filter was carefully removed from the SEM stub over a laminar flow hood, and each stub was mounted on a sample holder. First, x-ray Absorption Spectroscopy was used to determine the particulate matter type, size, and chemical identity. This was done by directing X-ray Fluorescent beams at each sample, causing each atom to emit a certain amount of Fluorescent Radiation. By scanning a focused beam over the sample, a spatial map of each element was measured and compared to the map of a reference measurement to determine the chemical composition. Next, a Scanning Electron Microscope (SEM) was used. In the SEM, a beam of electrons is focused on the sample causing the electrons to deflect and rebound towards the microscope's detectors resulting in topographic images of individual particles in the sample down to a scale of 20 nanometers.

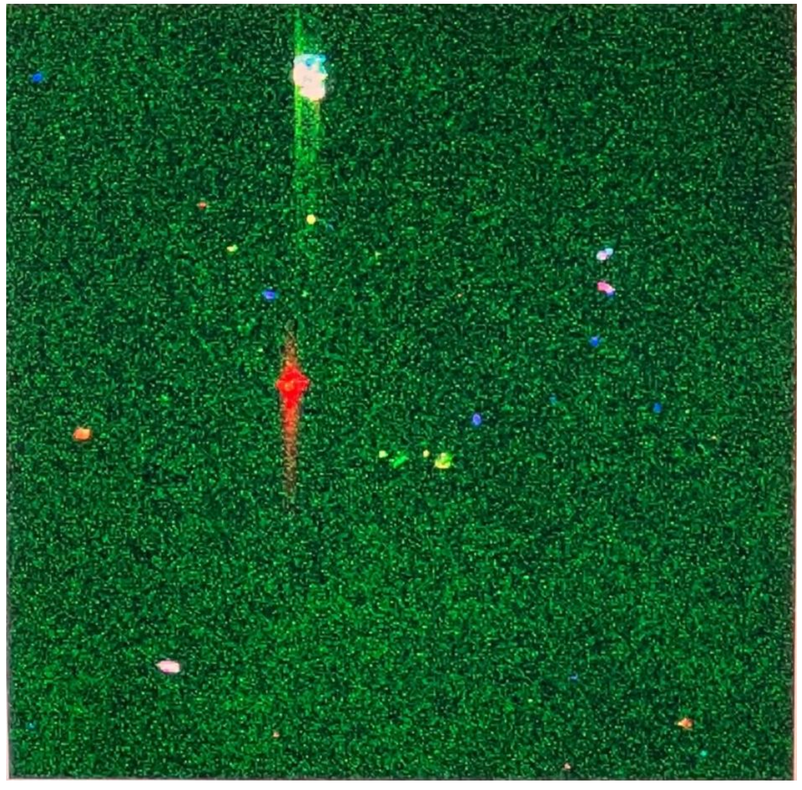
Results

An insufficient amount of particulate matter was found in four of the five samples: Rush Hospital clean room, Wolf Wildlife Preserve, Blue Island factory, and Cook County Forest Preserve. However, the River North sample contained substantial amounts of iron as well as trace amounts of germanium, zinc, magnesium, and calcium. Even though there was evidence of these metals present, the overall concentration was low.



Conclusions

The twenty-four-hour collection window may not have been long enough to collect enough particulates to analyze. While we were initially concerned with overexposure, we discovered twenty-four hours was insufficient. Future research should extend the duration of collection using the exact locations. Additionally, since the samples were placed on the ground, future research could examine the effects of altitude on collected particles by using the exact sites and the same twenty-four-hour period but placing the samples higher up. Conducting experiments such as these will contribute to the fundamental understanding of particulate pollution, which is an area of study with possibly life-changing implications.



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