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# A juxtaposition of airborne microplastics and fiber contamination in various environments

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## SUMMARY

**Microplastics can have detrimental effects on various wildlife, as well as pollute aquatic and atmospheric environments. The term microplastics refers to miniscule pieces of plastic that are either deliberately produced at that small size or are broken down from larger pieces of plastic. This study focused on air samples collected from five locations to investigate microplastic concentrations in atmospheric fallout from indoor and outdoor settings, through a process utilizing a hand-held vacuum pump and a rotameter. The samples were collected over a five-month period, and the number, as well as the morphologies, of the microplastics were recorded for each of the five sample locations. The amount of microplastic debris found in the urban setting was larger compared to the amount found in the rural setting. Furthermore, we found that the difference between the average number of microplastic fragments and fibers collected from all locations was not large enough to be statistically significant. Since the amount of published research on airborne microplastics is very minimal, the results collected in this study will help us better understand the prevalence of airborne microplastics.**

## INTRODUCTION

Plastic has become an integral feature of everyday life, especially with the commercial industry of polymers rapidly expanding every year. Due to the high demand for this synthetic material, concerns regarding its long-term effects on humans and the environment have gained more attention. Over time, plastic disintegrates into microscopic particles called microplastics which are usually 5 mm or less (1). Microplastics can accumulate in the atmosphere, resulting from fragmentation of plastic products (2). The contamination of microplastics in varying environments has become a pressing issue in the scientific community. As plastic production increases, more microplastics are released into the atmosphere. Although there have been several studies completed that examine the impacts of microplastic in different water sources, there is a limited amount of published work on airborne microplastics. Previous studies investigated the impacts of airborne microplastics on human health and explored different methods to collect microplastic debris (2).

Mass production of plastics has significantly surged within the past decade, increasing the atmospheric exposure to synthetic particles, including microplastic fibers and fragments. Fibers are long strands of microplastics that are the same width throughout their entire length, while fragments resemble a small droplet or stain. Both morphologies of the microplastics are characterized during the fragmentation of the original piece of plastic and have the same impact on the environment. Roughly 8.3 billion metric tons of plastic have been produced in the past six decades (3). This quantity of plastic distributed by commerce has resulted in high amounts of plastic particles throughout the environment. These plastic particles have been identified in urban centers, freshwater sources, uninhabited islands, sea surfaces, as well as polar regions (3). Additionally, research has shown that microplastics and synthetic fibers are found in indoor settings and residential areas (4).

The objective of this study of airborne microplastics is to expand public knowledge of atmospheric contamination, which can be utilized to find potential solutions to combat the issue. The research focused on examining the difference in airborne microplastic concentrations in various environments and the potential factors that may impact concentration levels. Because of the considerable rise in plastic production, this concern is expected to expand into a more serious problem that can negatively impact ecosystems and human health (2). Microplastics are 5 mm or smaller, which means that they are often difficult to identify and analyze (1). Common sources of these microscopic contaminants include microbeads from cosmetics, microfibers from clothes, and synthetic polymers from motor vehicle tires (2). Airborne microplastics has been linked to environmental pollution, airborne contamination, as well as human health degradation, including serious health concerns such as chronic bronchitis, asthma, sinusitis, and interstitial fibrosis (4). Workers in certain industries, specifically synthetic textile and flock production, are exposed to high concentrations of airborne fibers and contaminants, which may lead to occupational diseases (4).

The goal of this study was to determine whether measurable quantities of airborne microplastics were present in the atmosphere of various locations tested in mid-Michigan. We hypothesized that airborne microplastic debris would be significantly different between an urban and rural environment. We also hypothesized that the number of microplastics from areas with a higher population density or more human movement would differ from the number of microplastics from areas with less movement and people. Airborne microplastic accumulation may be primarily driven by human activity, industrial debris, motor vehicle pollution, and synthetic fibers from clothes dryer discharge (3). All four of these can be sourced and found outdoors. Our data provides evidence to support the claim that the number of microplastics from the atmosphere of the urban location was statistically different to those from the rural location. Furthermore, the results showed that the hallway compared to the lunchroom concentrations, as well as the lunchroom compared to the research classroom concentrations, were not statistically different. Comparing the collected microplastics from the locations to each other provided insight into the varying levels of airborne contamination in different regions.

**Table 1. Summary data of measured microplastics by site.**

| Sample Location | Sample Size | Mean | Median | Std. Dev. |
|---|---|---|---|---|
| | | MPs per m³ | MPs per m³ | MPs per m³ |
| Research Classroom | 4 | 5.1 | 3.9 | 3.5 |
| Rural Location (Lounsbury Rd.) | 4 | 3.7 | 3.4 | 2.2 |
| Urban Location (W Oakland Ave.) | 6 | 31.9 | 25 | 21.2 |
| Lunchroom | 4 | 16.2 | 16.2 | 3.7 |
| Performing Arts Hallway | 4 | 64.6 | 62.4 | 19.8 |

Note: "MP" is the abbreviation for microplastics.

## RESULTS

We examined the concentrations of airborne microplastics by collecting numerous air samples from each location selected and calculating the microplastics per cubic meter in the air samples. At least four samples were collected from each location to investigate the varying quantities of airborne microplastics. We used a handheld vacuum that is attached to a Buchner funnel, which is equipped with Whatman filter paper, to collect air particles. Additionally, air flow rate, the amount of air being vacuumed into the funnel over time, was controlled using a rotameter. While analyzing each sample, the specific qualities of the microplastics were recorded, as well as the type of the microplastic (fiber or fragment).

We collected airborne microplastic samples from varying locations that associate with varying levels of human activity and movement. We selected a rural location to simulate an environment with reduced human and automobile traffic, while an urban location is selected to simulate an environment with high levels of human and automobile traffic. Furthermore, a high school classroom represented an area with low human activity, the lunchroom characterized an area with moderate human activity, and the performing arts hallway represents an area with high human activity (**Figure 1**). The raw number of microplastics on each filter was another key focus. A condensed summary table comparing all five locations using the data collected for each sample is shown in **Table 1**.

For each location, four to six individual samples were collected, and every sample contained at least one cubic meter of filtered air. In total, 22 air samples were collected over the five-month period. After we examined and analyzed the samples, a 2-tailed Mann-Whitney U-test was used for the four hypotheses (5). This was done by dividing the original alpha value of 0.05 by three, which was the number of comparisons being made. Therefore, the adjusted alpha value for the three hypotheses comparing microplastics between each location was 0.017; a result was considered statistically significant if the $p$-value was found to be less than 0.017. Next, we wanted to examine the average number of microplastic fragments from all locations versus the average number of microplastic fibers from all locations. Since this hypothesis was evaluated independently, the alpha value remaining was 0.05.

Using the air filtering setup described previously, samples were collected from urban and rural locations (**Figures 2 and 3**). We found that the airborne microplastic concentration was significantly higher in urban samples (Mann Whitney U, 2-tailed; urban $n$ = 6; rural area $n$ = 4; $p$ = 0.0095). The number of total microplastics collected in the urban samples greatly outnumbered the total number of microplastics from the rural

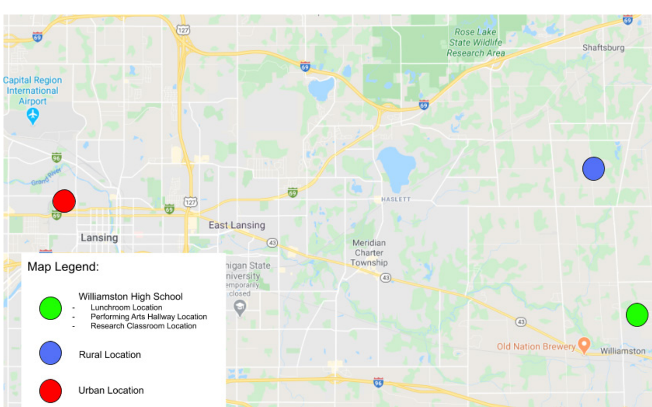


**Figure 1. Map displaying the five different locations that were sampled.** The research classroom, the lunchroom and the performing arts hallway were all located within the same building.

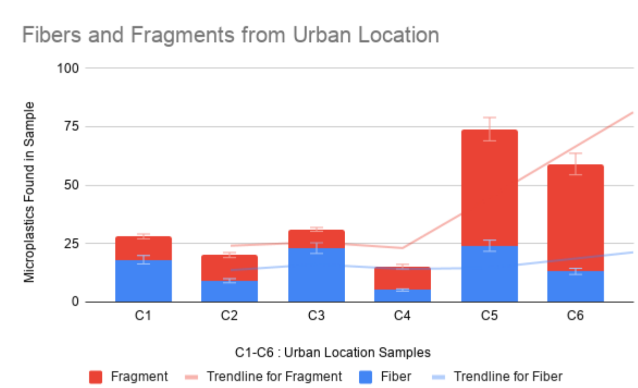


**Figure 2. Microplastic fragments and fibers found across the urban location samples (C1-C6).** The moving average and error bars (estimated error) are displayed.

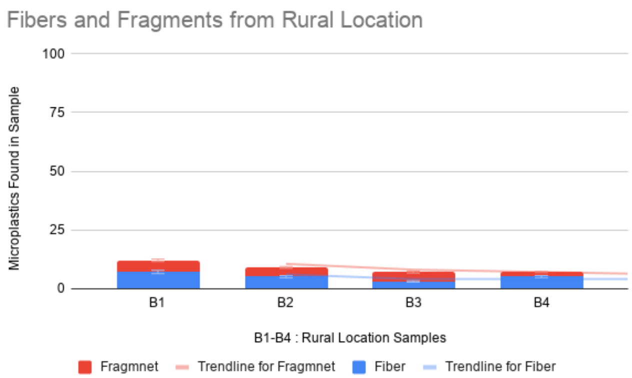


**Figure 3. Microplastic fragments and fibers found across the rural location samples (B1-B4).** The moving average and error bars are displayed.

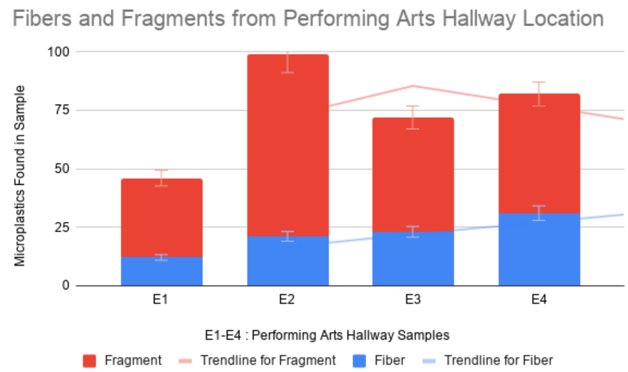


**Figure 4. Microplastic fragments and fibers found across the performing arts hallway samples (E1-E4).** The moving average and error bars are displayed.

samples. The raw data showed how these two locations varied immensely, in regard to airborne microplastics concentrations.

We wanted to examine an environment that could simulate a high and moderate traffic level. The Williamston High School performing arts hallway and the lunchroom, respectively, were the locations utilized to collect the data (**Figures 4 and 5**). The difference between the amount of microplastics per cubic meter in a hallway sample was not significantly different than that of the lunchroom (Mann Whitney U, 2- tailed; hallway $n$ = 4; lunchroom $n$ = 4; $p$ = 0.0286).

The lunchroom simulated a location with moderate traffic, while the research classroom simulated a location with low traffic (**Figure 5 and 6**). We did not observe a significant difference between the amount of microplastic debris collected from the lunchroom air compared to the classroom air (Mann Whitney U, 2- tailed; lunchroom $n$ = 4; classroom $n$ = 4; $p$ = 0.0286).

Lastly, we sought to compare the average number of microplastic fragments and microplastic fibers from all locations (**Table 1**). There was no significant difference between the average number of microplastic fragments versus fibers across all sample locations (Mann Whitney U, 2- tailed; fibers $n$ = 5; fragments $n$ = 5; $p$ = 1.000).

## DISCUSSION

The samples collected during this experiment yielded varying results regarding the comparison of airborne microplastics in multiple locations. The data showed that the concentration of microplastics per cubic meter of air from the urban location was not equal to the microplastics per cubic meter of air from the rural location. The number of airborne microplastics collected from the urban area had higher concentrations compared to those of rural areas. The data indicated that the difference between the microplastics per cubic meter of air from the performing arts hallway compared to the lunchroom, as well as the difference between the microplastics from the lunchroom and research classroom, were both too small to be considered statistically significant. Additionally, we found that there was insufficient evidence to support the hypothesis that the average concentration of fragments versus fibers across all locations were different from each other.

The samples were collected at each different location

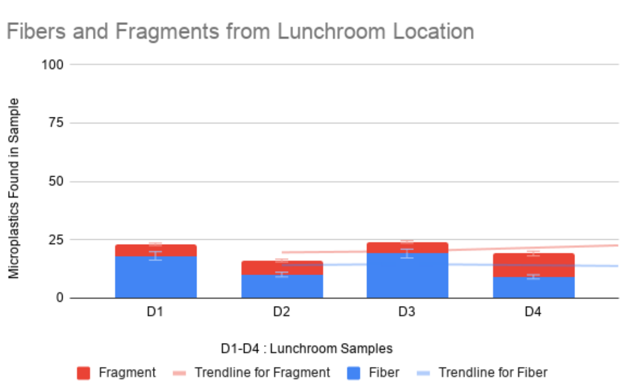


**Figure 5. Microplastic fragments and fibers found across the lunchroom location samples (D1-D4).** The moving average and error bars are displayed.

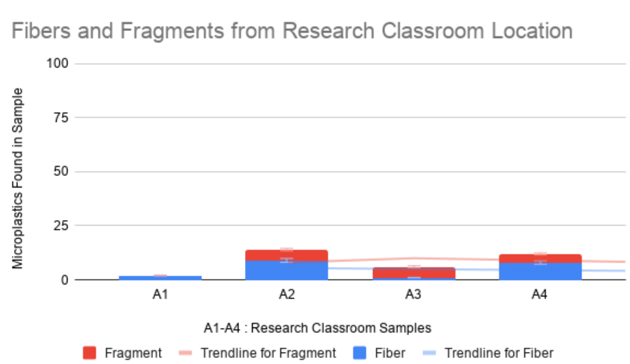


**Figure 6. Microplastic fragments and fibers found across the research classroom samples (A1-A4).** The moving average and error bars are displayed.

on different days due to time restrictions. This was a key limitation in the study because the varying conditions, such as weather, that each collection date could have an impact on the quantity of microplastics. Another limitation that was encountered during this experiment was how samples that were collected for the urban and rural location had more exposure time to factors that could confound the results. Since these were the two locations that were away from the high school and research room where the data was analyzed, the filter paper had to be transferred outside of the building with glass microscopes slides. During this process, the filters for the urban and rural samples had a higher risk of capturing microplastics from other sources of contamination.

The urban sample was collected with a setup facing W Oakland Avenue, a road that often experiences heavy traffic throughout the day. This location was selected to simulate a metropolitan area with high levels of human and automobile traffic. Cars and other motor vehicles often release microplastics pollutants through mechanical abrasions of the tires (2). Another factor to consider was that the location was next to a residential neighborhood. Since textiles and fabrics are known to release large quantities of microplastic fibers and fragments, clothes washers and dryers can impact the amount of fibers released into the air in certain areas. Previous research has shown that each garment may release approximately 1900 fibers per wash (3). Additionally, regarding the urban samples, the fluctuation in the number of microplastics, specifically fragments, could be due to the various dates and times in which the samples were collected. Samples C1, C2, C3 and C4 were collected on the same Sunday at various points of the day. Sample C5 was collected on a Friday at around 5 PM, and sample C6 was collected on a different Friday at around the same time. Samples C5 and C6 were collected during similar conditions and yielded similar results.

The rural sample was taken in Williamston, Michigan. The setup was facing Lounsbury Road, which did not receive much traffic. Additionally, the location was surrounded by farmland. This location was selected to mimic an agricultural area with low human and automobile traffic. These factors may have contributed to the difference in the number of microplastic debris in the urban and rural sample. The Mann-Whitney U-test gave evidence that the urban air sample contained significantly higher amounts of microplastics, compared to rural air samples ($p$-value = 0.0095). The urban location was in an area exposed to more factors that could potentially release more microplastics, as opposed to the rural sample, which did not get as much exposure to these elements.

The lunchroom samples were collected by a wall on the edge of the lunchroom in the school building, an area that a limited number of students walked through. On the contrary, the setup for the performing arts hallway was in an area that many students frequently walked through. Both locations had the setup placed on ground level. The number of microplastics in the performing arts hallway was not significantly different from the microplastics in the lunchroom ($p$-value = 0.0286). An interesting feature of the performing arts hallway samples was that they all contained many microplastics fragments compared to the other locations (**Figure 4**).

The performing arts hallway samples were the only ones to contain these concentrated fragments in small clusters throughout the filter paper. Heavy walking traffic, the height of the air collection setup from ground level, and different air ventilation patterns could possibly explain this difference. Additionally, since the sample was taken at ground level in an area with heavy human exposure, synthetic materials from shoes and fabric could also contribute to the explanation of the microplastic fragments. Even though the lunchroom sample was taken on ground level, there was little human movement.

With a $p$-value of 0.0286, we did not observe a difference in microplastics between the research classroom and the lunchroom. The classroom sample was collected along a wall of the room on a counter at approximately waist level. There were roughly ten students in the classroom during the times of the air collection. Students in the classroom were required to wear cotton lab coats, which prevented the transfer of microplastics from clothing into the air. Also, since the classroom air sample was taken on a counter, it was not directly exposed to foot movement, or the synthetic materials from shoes.

The goal of this research was to determine whether quantifiable values of airborne microplastics could be detected in varying outdoor and indoor locations. Previous studies have shown similar results regarding the presence of microplastics in the atmosphere. Specifically, one study discussed how the number of airborne microplastics found in an indoor environment will be dependent on the "lifestyle" of the residents and environment of the tested location (6). The conductors of that study concluded that humans are exposed to natural and synthetic fibers when indoors (6). Similarly, our data, collected from the three indoor locations, demonstrated how airborne microplastics can be found in areas with humans. The results of this study showed how human activity can have an impact on microplastic values too.

Although a few possibilities explaining variations in the numbers of microplastics for each location were explored, a limited amount of research has been done to support how these parameters could impact the airborne microplastics concentration. Since only four to six samples were collected per location, the results came from a limited sample size. Additionally, time to collect all the samples was limited, since the data collection period was cut short due to the COVID-19 pandemic.

Future research studies and experiments could focus on the sample intake location, specifically looking at how the floor level, the waist level and the head level could affect results. Another interesting aspect to explore is whether the temperature of the environment impacts the number of airborne microplastics collected. In addition, we recommend measuring the specific lengths of microplastics detected, as well as whether they are fibers or fragments. Further research should use a larger sample size in terms of the number of air collections from each location. These suggestions will help determine the origin of the microplastics and can be applied to find possible solutions to combat this category of airborne pollution. Understanding the influx of airborne microplastics in various areas is a critical component in learning about the overall quality and conditions of the environment. The data compiled demonstrated how microplastics are currently present in various atmospheres and are more concentrated in certain areas. These findings can be utilized to find realistic measures to prevent the release of more plastic contaminants into the atmosphere. By looking at areas with higher concentrations and narrowing down the sources of this pollution, scientists and engineers can develop new technologies for essential items, such as automobile cars and clothes dryers that release lower amounts of plastic into the air. Although the findings of this experiment yield useful information in the understanding of airborne microplastic contamination, there is still a need for additional research to further the knowledge in this scientific area.

## MATERIALS AND METHODS

For each sample that was collected, a blank No. 1 Whatman filter paper (diameter of 42.5 mm) was first examined under the 10x microscope. A ⅛ inch grid was printed on each individual filter to easily quantify the number of microplastics examined. Looking at the filter prior to the air collection ensured that the microplastics that may have been on the filters beforehand were taken into account. To collect reliable samples, a PVC rotameter with a brass flow control valve and an EPR O-Ring was utilized. The rotameter was first mounted onto a retort stand. Using a piece of rubber tubing, a handheld vacuum was connected to the top outlet of the rotameter. The bottom outlet of the rotameter was connected to the outlet in a glass Buchner flask, using a piece of plastic tubing. A rubber bung was inserted at the top of the flask, and the Buchner funnel was placed firmly within the bung. The filter paper was then placed in the Buchner funnel (**Figure 7**). This setup allowed the suction from the vacuum to create a partial vacuum within the flask. When the vacuum was turned on, the suction was able to hold the filter paper in place, while also collecting the circulating air.

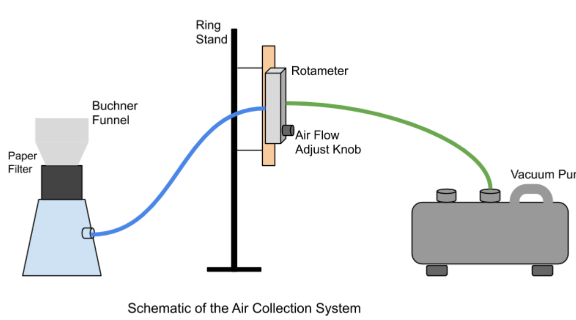


**Figure 7. A schematic diagram of the air collection system involving the Buchner funnel, the rotameter and the vacuum pump.**

Previous research suggested that there was an average of 5-50 plastic particles found in one cubic meter of air (2). The rotameter was monitored to ensure it ran long enough to collect at least one cubic meter of air to have a reliable sample size. This was done by controlling the volumetric flow of the air collected through the Buchner funnel using the rotameter's valve, which then dictated how long to collect each independent sample. The duration time for all the samples collected ranged from 40-75 minutes. For each location, four to six samples were collected over different days and times to examine the overall numbers of microplastic particles per cubic meter of air. The number of samples that were collected for each location varied because time limitations impeded the ability to collect the same number of samples from each site. The samples were then taken back to the research room at Williamston High School and examined for air contamination on the filter under a 10x microscope. The filter papers were placed under the microscope and visually inspected. Each microplastic fiber or fragment was manually identified, counted, and recorded. Since the filter was examined before the air collection was taken place, we could accurately identify which were the new particles from the sample location.

Five independent locations were tested, which included both urban and rural settings, as well as indoor settings with minimal to heavy human interaction to simulate a low and high population density. The first air samples were taken from inside the research classrooms at Williamston High School on four different days, and each sample was examined independently. These collections spanned from late November to early December. The rural samples were collected from a classmate's house on Lounsbury Road in Williamston, which was surrounded by several large farm fields, over the span of four days in December of 2019. The vacuum was plugged in using an electrical outlet by the side of the house and collected each sample independently. Next, the urban air samples were collected from metropolitan downtown Lansing at St. Andrew Dung Lac Catholic church, located on Oakland Avenue in January to February of 2020.

Indoor samples taken in the lunchroom simulated an area with a low population density. These were collected over the range of two weeks in February of 2020 and occurred during the lunch period, approximately 11:15 AM to noon. The samples for the performing arts hallway took place during the same time of the day. These were collected in February and March of 2020. However, this sample location was by the entrance of the performing arts hallway. Band class took place during this time, which meant that many students walked past this area in the hallway to get to their class. These samples took into account the heavy human interaction and movement and simulated an area with a high population density.

Once all locations were sampled, analyzed, and recorded, the total count of plastic particles, the color, and the type (fragment or fiber) were recorded in a Google Spreadsheet. The mean and standard deviation of microplastics 5 mm or less per cubic meter of air for each sample location was calculated. Since the three hypotheses evaluate the same issue simultaneously, the alpha value used for these significance tests needed to be adjusted to avoid the probability of making a false statistical inference. The Bonferroni adjustment was used to control the increased chances of making a false inference.

The last hypothesis of this study was looking at a different issue: the average number of microplastic fragments from all locations versus the average number of microplastic fibers from all locations. Since this hypothesis was evaluated independently, the alpha value remained as 0.05. The data for each location was put on separate bar graphs, and the centered moving average was also included. This trendline calculates the average several times for the several subsets within the data. Moving average values were placed at the center of the range for the subset in which the mean value was computed, so the result's average may shift the trendline past the first sample.

These results were then compared using a 2-tailed Mann-Whitney U Test for each hypothesis. This nonparametric test was used because the sample sizes for each location did not meet the statistical guidelines for a parametric test, and normality could not be assumed with the data. A popular factor that is often considered when deciding whether to use a parametric or nonparametric statistical test is the sample size. Oftentimes, a sample size of 30 or more observations is considered sufficient to use a parametric test and assume normality. Since each location in this study had only four to six samples, the sample sizes were too small to meet this requirement. Additionally, with small sample sizes, we had difficulties determining the distribution of the data because the normality tests had inadequate power to provide useful results. Furthermore, a 2-tailed test was performed for each hypothesis to avoid bias of the results. It tested the possibility for both positive and negative differences in the sample distribution and made it possible to distinguish the various statistical relationships among the data, while also avoiding prior assumptions regarding which location would have more microplastics.

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