Ubiquitous Microplastics in Fluvial Sediments of Urban Stream Systems in Davenport and Bettendorf, Iowa

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Abstract

This research delves into the pervasive issue of microplastic pollution, aiming to provide a more comprehensive understanding of its occurrence in urban stream sediments. Microplastics are generally defined as plastic particles less than 5 mm in diameter. Microplastics can be derived from diverse sources, and once released in the environment they can persist for years, posing potential threats to the ecosystems. Study sites are located within three small urban watersheds in Davenport and Bettendorf, IA: Goose, Pheasant, and Silver Creeks, all tributaries of Duck Creek and the Mississippi River. All sites are close to urban communities and are home to a diverse assemblage of aquatic organisms. 50 grams of sediment were collected for each sample from sedimentary banks, which were generally sandy and non-vegetated. Samples were processed by sieving, density separation, organic digestion, and vacuum filtration. Nile Red Dye was added to each sample to facilitate the identification and quantification of microplastics. All study sites contained microplastics in the sediments, with microplastic concentrations generally increasing downstream in each system. These findings underscore the need for continued efforts to monitor microplastic pollution in bed load and suspended load sediments and to investigate their potential impacts on ecosystems.

Methods

A total of 3 replicates of sediment microplastics (MPs) were collected from 9 different sites in Bettendorf and Davenport, Iowa (Figure 1). The samples were collected from non-vegetated silt-sandy sediments and 48 hours after any precipitation events (Figure 2). After collection, sediment samples were sieved with 1mm and 50$_{um}$ sieves. Density separation followed using a concentrated saline NaCl solution (Figure 3). Samples were then digested using Hydrogen Peroxide (30%) to account for organics before being filtered through a vacuum pump to be collected in 8-micron polycarbonate filters (Figure 4) (Nakijima, 2019; Masura, 2015). After filtration, the Nile Red method (Labbe, 2020) was adopted to analyze the samples. A custom flashlight shining 470 nm of light was used to shine directly on the sample, allowing for microplastics to be quantified (Figure 5). Each replicate was counted by different individuals to account for counting errors. Blank samples of 3 replicates were also analyzed to identify possible contaminants. Values of microplastics over the three samples at every site were then averaged and cross-analyzed with multiple parameters in SPSS.

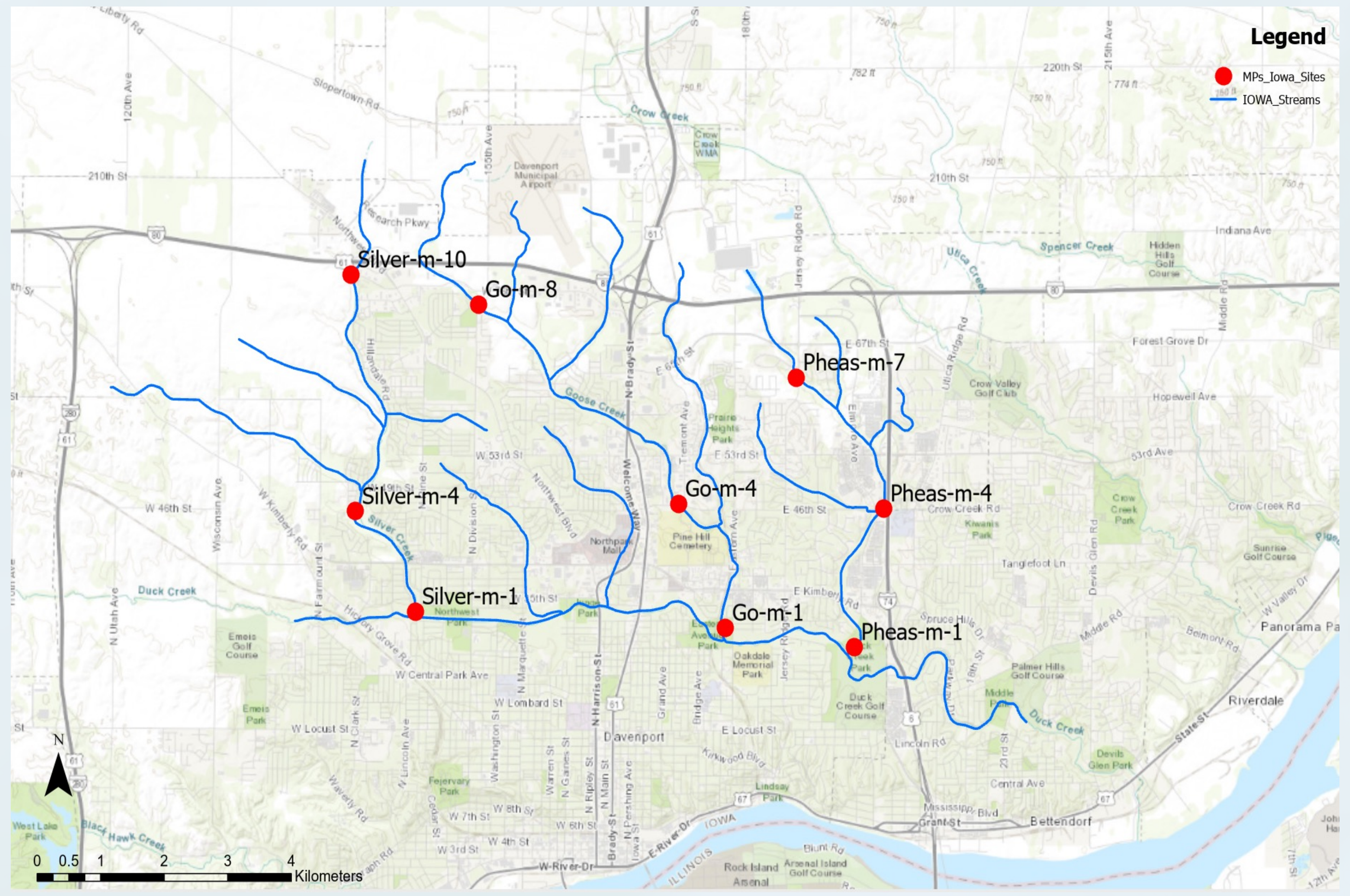

Figure 1: Map of study sites in Bettendorf and Davenport, Iowa 1:53,515

Methods

Figure 2: Collection of sediment samples

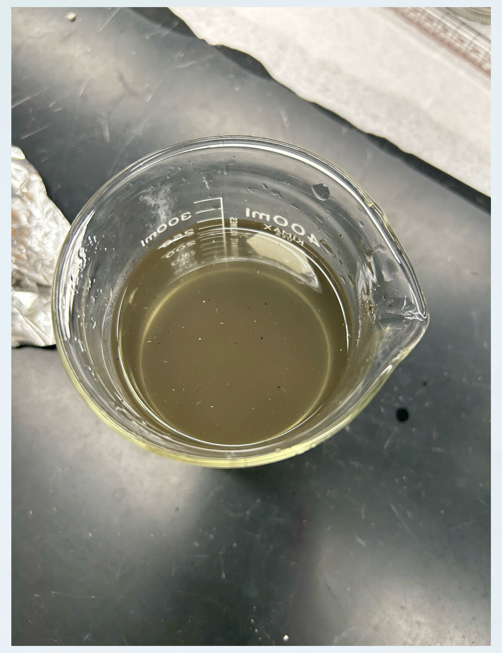

Figure 3: Density separation of MPs from sediments

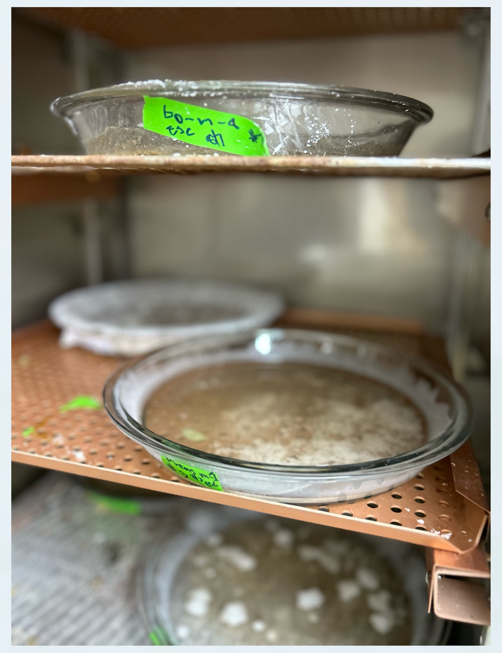

Figure 4: Digestion of MPs in oven

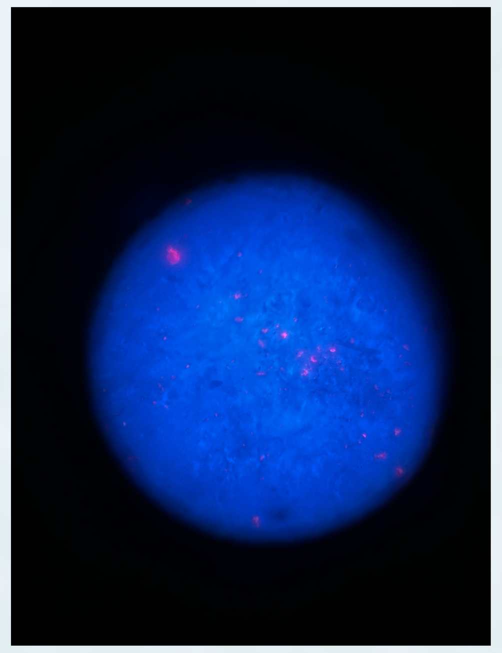

Figure 5: MPs under Fluorescent Microscopy at 15x magnification

Results

The highest bivariate correlation yield between all parameters samples was 0.911 (p-value <0.001) between the Average Microplastics of water samples per 32 oz and Average Microplastics of Sediment samples per 50g (Figure 6.3). This was followed by the Average Sediment Microplastics by Total Fecal Coliforms CFU/100ml with 0.462 (p-value 0.044) (Figure 6.1). There was also a correlation between Total E.coli CFU/100ml with the Average Sediment Microplastic amounting to the R-value of 0.310, however, the p-value of 0.113, suggests there is no statistical significance between the two (Figure 6.2). The observed highest variation in microplastic count between replicates is seen in site Pheas-M-1, whereas the rest of the samples remained relatively consistent throughout all the sampling replicates (Figure 6.4). Overall, mean microplastic abundance can also be noted to be the highest on-site Pheas-M-1. Blank samples across 3 replicates averaged to 4.3 counts per sample.

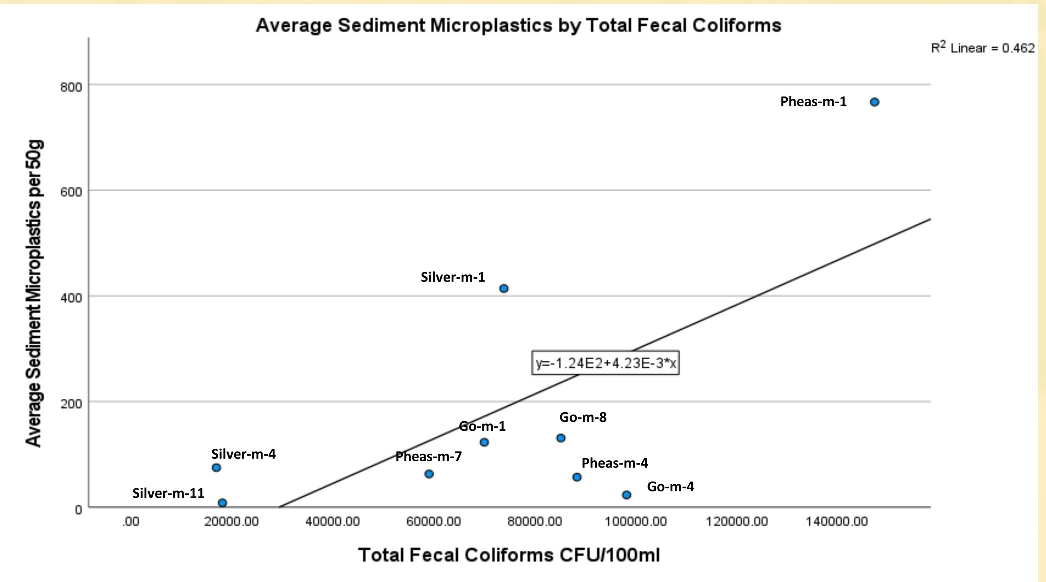

Figure 6.1: Average Sediment Microplastics per 50g by Total Fecal Coliforms measured in CFU/100ml

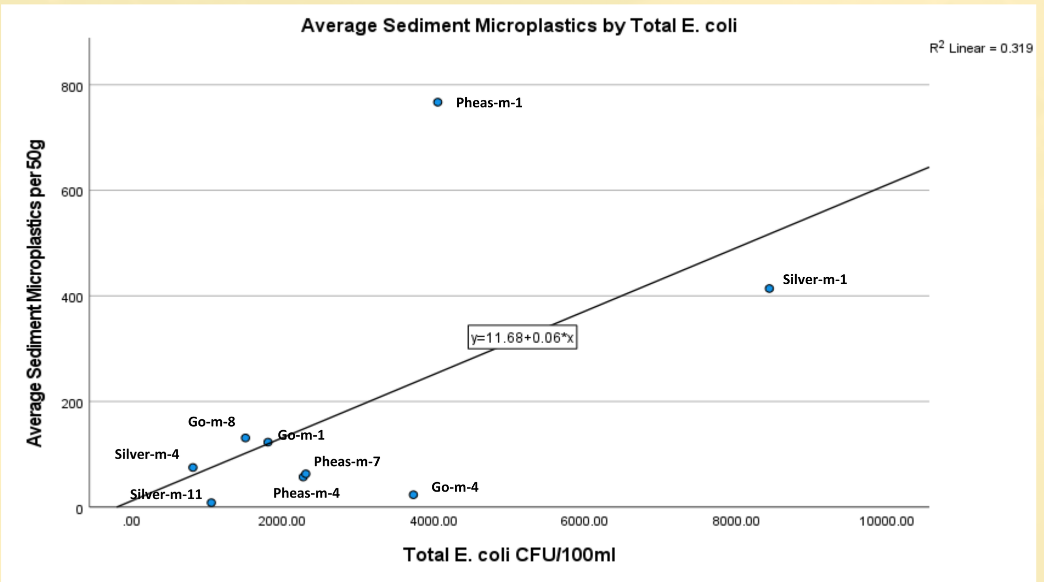

Figure 6.2: Average Sediment Microplastics per 50g E.coli measured in CFU/100ml

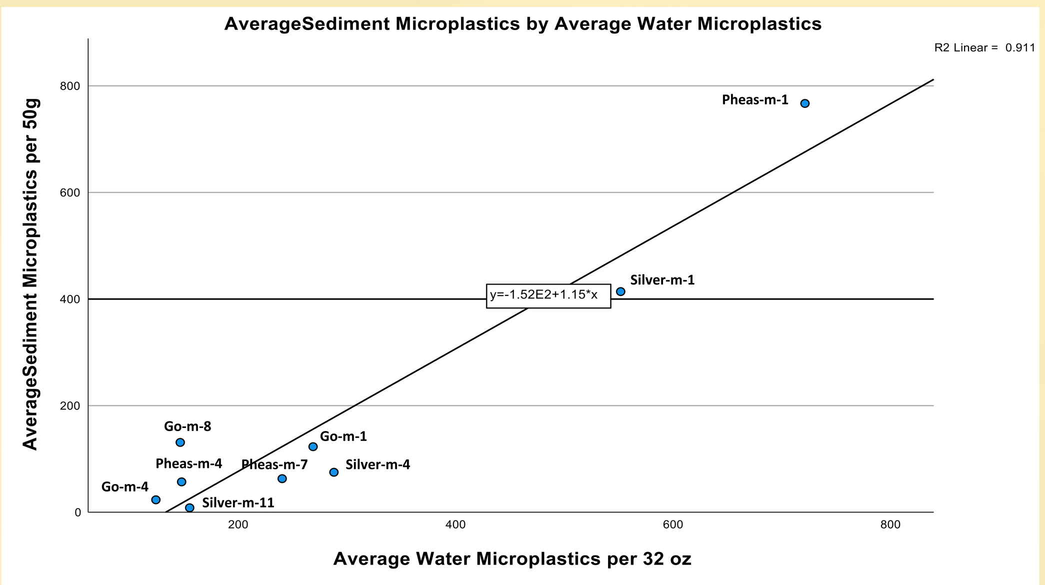

Figure 6.3: Average Sediment Microplastics per 50g by Average Water Microplastics per 32 oz

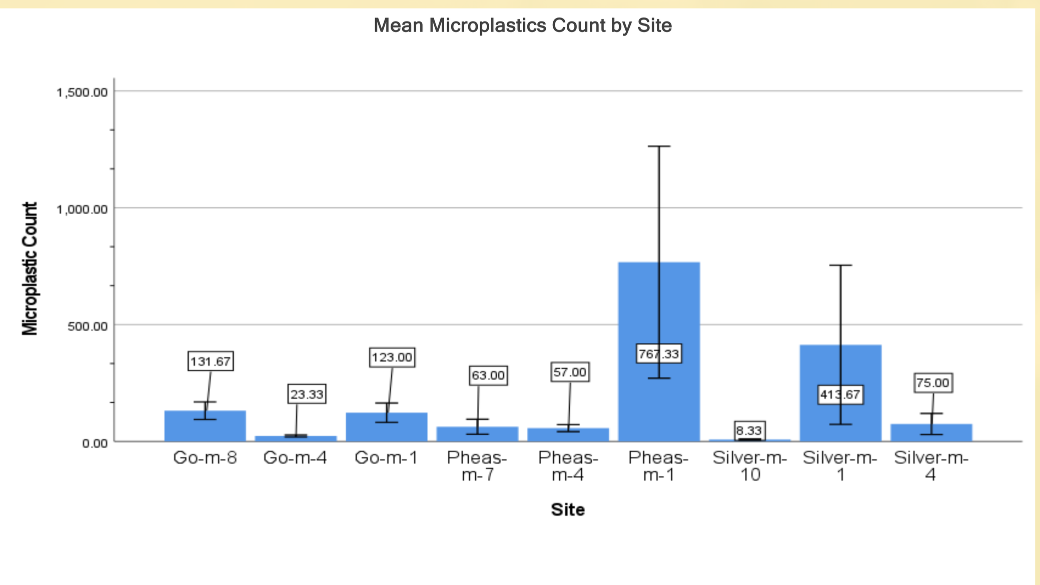

Figure 6.4: Mean Microplastics Count by Site

Discussion

The findings of this study reveal important insights into the relationships between microplastic contamination and various environmental parameters, particularly within water and sediment samples. The highest bivariate correlation observed, with a coefficient of 0.911, was between the average microplastic concentrations in water samples per 32oz and sediment samples per 50g. P-value of <0.001 further strengthens the statistical significance of the relationship. It is important to note that the sample sizes are different between the sediment and water samples, though the strong correlation suggests a close association between microplastic contamination in water and sediment, indicating a potential source-sink relationship between these two environmental compartments. The correlation coefficient of 0.462 between the average sediment microplastic concentrations and the total fecal coliform counts (CFU/100ml) highlights a potential link between microplastic pollution and fecal contamination in aquatic environments. This correlation is statistically significant as supported by its p-value of 0.044. The correlation coefficient of 0.310 between microplastic concentrations and E.coli (CFU/100ml) signifies a moderate relationship, though the p-value of 0.113 indicates that the correlation is not statistically significant. Fecal coliforms and E.coli, often linked with fecal contamination, are found to form biofilms on plastic surfaces. Within these biofilms, microbial communities secrete enzymes capable of breaking down plastic polymers, potentially contributing to plastic degradation processes. (Cunliffe and Lobelle, 2011; Boni, 2021). Land use characteristics were examined but did not yield any significant correlation. Other anthropogenic activities and sediment characteristics may contribute to stronger results and should be considered in future research efforts. The addition of more replicates per sample would prove useful for creating stronger data. An increased number of study sites would also allow for possible predictive geospatial analysis.

Conclusions

- **Strong correlations and statistical significance between water microplastics and sediment microplastics (r^2 = 0.911, p-value = <0.001) indicate a possible source-sink relationship between streams and sedimentary banks.**
- **Total Fecal Coliform (r^2 = 0.462, p-value = 0. 044) has a stronger relationship with sediment microplastics than E.coli.**
- **Biofilm accumulation has a role in breaking down plastics creating microplastics.**

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