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Factors Controlling the Distribution of Microplastic Particles in Benthic Sediment of the Thames River, Canada

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ABSTRACT: Investigations of microplastic abundances in freshwater environments have become more common in the past five years, but few studies concern the factors that control the distribution of microplastics in river systems. We sampled benthic sediment from 34 stations along the Thames River in Ontario, Canada, to determine the influence of land use, grain size, river morphology, and relative amount of organic debris on the distribution of microplastics. Once counted and characterized for shape, color, and size, microplastic abundances were normalized to the results from Fourier transform infrared spectroscopy on randomly selected particles. The results indicate that 78% of the fragments and only 33% of the fibers analyzed were plastic. The normalized microplastic quantities ranged from 6 to 2444 particles per kg of dry weight sediment (kg^{-1} dw). The greatest number of microplastics were identified in samples of the finest grain sizes and with the greatest amount of organic debris. Although there was no significant difference between microplastic abundances in urban versus rural locations, the average microplastic count for urban samples was greater (269 vs 195 kg^{-1} dw). In terms of river morphology, samples from along straight courses of the river contained fewer microplastics than samples from inner and outer bends. Overall abundances confirm how rivers contain a significant number of plastic particles and thus may be major conduits of microplastics to lake and ocean basins.

1. INTRODUCTION

Plastic debris in the environment is a result of the global production and often uncontrolled discard of plastic products. Based on a global data analysis, Geyer et al.[1] calculated that by the year 2050, 12,000 million metric tons (Mt) of plastic waste will have accumulated in the natural environment and landfills. The amount of this waste reaching the oceans in the year 2010 alone has been estimated at 4.8−12.7 Mt.[2] The main pathway through which plastic waste moves from land to the oceans is through rivers, with an estimated transfer of 0.41−4.0 Mt/y.[3,4] The abundance of plastic debris in rivers, lakes, and oceans creates a serious risk to various organisms and their ecosystems.[5−7] Microplastics are particularly concerning because their small size enables ingestion by a wide variety of species. Once ingested, microplastics can translocate to different tissues and possibly infiltrate many levels of the food chain.[8−10] Small organisms may be affected by microplastic ingestion through accumulation of adsorbed pollutants, reduced food consumption and reproductive output, and decreased energy reserves and growth.[11] Uncovering the potential for ingestion and trophic transfer of microplastics should begin with discovery of the main sources, pathways, and sinks of plastic debris. To date, marine plastic debris has been documented in oceans globally, but only within the last five years has there been a focus on plastic waste in rivers.[12−15] Because rivers are dynamic systems in terms of seasonal discharge variations, flooding and rapidly changing water levels, and bank erosion, the distribution of microplastics in a river system over time is not straightforward. Previous studies have shown that flood events can flush microplastics through river catchments[16] and that microplastic abundances are greater downstream from wastewater treatment plants than upstream.[17] Using a theoretical approach, Nizzetto et al.[18] showed that particle size plays an important role in determining microplastic retention in river bed sediment, with particles finer than 0.2 mm being preferentially passed through the system compared to their larger counterparts. These findings also depend on the morphology of the river, nature of land use areas, and possible sources.

Investigations of plastic debris in the North American Great Lakes have mainly focused on surface waters,[19] shorelines,[20−23] and benthic lake sediment.[24−26] To our knowledge, the only published results from tributaries flowing into the Great Lakes are from Baldwin et al.[27] who studied microplastic abundances in surface waters of twenty-nine U.S. rivers. In addition, we are aware of only one other current study concerning microplastics

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in nine samples from benthic river sediment within the Great Lakes watershed.[28] The objectives of the present study were to: (1) investigate the abundance of microplastics in benthic sediment of the Thames River in Ontario, Canada, which flows through both urban and rural regions, (2) identify the main types of microplastic particles in terms of morphology (fibers, beads, and fragments) and chemical composition, and (3) determine the main controls on abundance of microplastics in a river system. The factors considered in the distribution of microplastics in Thames River sediment include land use type, river morphology, grain size, and relative amount of organic debris.

2. MATERIALS AND METHODS

2.1. Sample Collection. The Thames River is the second largest watershed in southwestern Ontario, stretching 273 km long, with a drainage basin of 5,825 km^2, and an average discharge rate of 0.3 cm s^{-1}.[29] North of London, Ontario, the upper Thames river is divided into North, Middle, and South branches that flow through former glacial spillways (Figure 1).

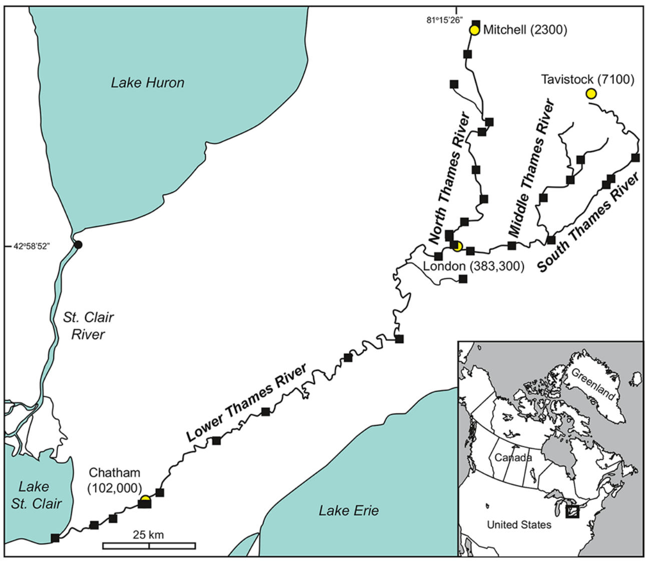

Figure 1. Generalized map of the Thames River study area showing its location within North America (inset). The Thames River is subdivided into north, middle, and south branches north of London, and then becomes the lower Thames River, which flows into Lake St. Clair. The thirty-four sample locations are indicated by black squares. Populations of cities/towns are indicated in brackets.

The lower Thames, located south of London, was created by the flow and erosion of the river itself, with the banks being low enough to result in frequent flooding. Discharge rates in the upper Thames River during the sampling period were <3 m^3/s, whereas discharge rates in the lower Thames River were up to 9.98 m^3/s.[30] The difference in discharge rates can be considered a result of the geomorphological and land use differences through which the river flows. With its deeply incised channel, the upper Thames River encompasses urban and rural regions and floods less often than the lower Thames River; the latter flows mainly through flat, agricultural land. The Thames River is of the sinuous or irregular meandering type with point bar deposits along inner bends, eroded banks along many outer bends, minor vegetated central islands, and portions that are straight.

Benthic sediment samples were collected from 34 locations along the Thames River in Ontario, Canada, in November, 2016 (Figure 1). There were no significant rain events during the sampling period, with only 2 days of drizzle. Sample locations were selected to achieve as regular spacing as possible along the length of the river, but selection was also controlled by accessibility. One sediment sample was collected from each locality and from the morphological compartment (straight, inner, and outer bend) that presented the easiest access. Access depended on slope of the riverbank, depth of the water, and private versus public access. Each sediment sample was collected using a stainless steel petite ponar grab sampler, 16 × 14.5 cm in size. Where possible, bottom sediment was visually scanned to avoid rocky substrate and large boulders. The ponar was lowered onto the streambed by wading out into the river or by standing along the riverbank. All samples were collected from water depths between 90 and 100 cm. The distance from the riverbank therefore varied depending on the slope of the river bottom. The amount of sediment collected varied between locations, but the number of microplastic particles in each sediment sample were normalized to 1 kg (see next section). Each sample was dispensed into 0.5 L Histoplex clear polypropylene containers. The samples were transported to the lab and stored in a fridge at 5 °C until they were ready for laboratory processing.

2.2. Sample Processing and Analysis. The sediment samples were emptied onto aluminum pie trays, covered with aluminum foil, and dried at 70 °C in a drying oven. The dried samples were wet-sieved using a 63 μm stainless steel sieve to remove clay- and silt-size particles. Removal of the fine particle fractions eliminates the issue of clay flocculation while drying in the oven. If the sample becomes caked together during drying, it is difficult to reduce it to the individual grains necessary for the density separation procedure. Each sample was redried, weighed, then sieved using stainless steel mesh sizes of 5.6, 2.0, and 0.063 mm. The grain size fraction >2.0 mm was visually examined for plastics. The grain size fraction between 0.063 and 2 mm was emptied into a glass beaker containing 250 mL of sodium polytungstate (SPT) solution with a specific gravity of 1.5 g/cm^3. The samples were magnetically stirred for 5 min and were then transferred to glass separatory funnels. Additional SPT solution was used to rinse each glass beaker to ensure all sediment was transferred. Once the sediment settled completely, the dense sediment was allowed to pass through the stopcock into a 750 mL glass beaker. The buoyant material was then drained into a separate 750 mL glass beaker containing a glass conical funnel lined with filter paper. The separatory funnel was rinsed with SPT and drained onto the filter paper. Using reverse osmosis (RO) water in a squirt bottle, the material on the filter paper was transferred into a 53 μm polycarbonate/polyester sieve with a diameter of 7.5 cm. The material was rinsed, then transferred using the squirt bottle from the sieve to a glass Petri dish, and then covered with aluminum foil and redried at 70 °C before being microscopically examined.

The material in each Petri dish was examined using a stereomicroscope to separate suspected microplastics from any remaining sediment and organic material. Suspected microplastics were categorized according to their color, morphology (fiber, bead, and fragment) and size. Each particle was removed from the Petri dish using tweezers and placed in a glass vial labelled according to the sample number. A total of 132 (10%) particles identified as suspected microplastics were

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analyzed using micro-Fourier transform infrared spectroscopy (micro-FTIR) for fibers, and attenuated total reflectance (ATR) FTIR for fragments and beads at Surface Science Western, University of Western Ontario. The particles were selected randomly by dumping the contents of each glass vial into Petri dishes and selecting particles within the microscope field of view.

Microplastic abundances in each sample are presented in number of particles per kg of dry weight sediment (n kg^{-1} dw). All statistical analyses were completed in Excel 2016. In order to test the potential influence of land use and river morphology on microplastic abundances and types, *t*-tests were employed.

2.3. Quality Assurance and Quality Control. Throughout the study, consistent efforts were made to minimize sample contamination. Polypropylene sample containers were prewashed with RO water before use. All laboratory materials were made of stainless steel, aluminum or glass, except for the small polycarbonate/polyester sieve used to transfer material from the filter paper to the glass Petri dish. The filter papers were composed of white translucent cellulose and a minor amount of clear resin. Cellulose fibers derived from the paper were easily identified when found in the samples and were not included in the counts. No clear fragments that might represent resin were identified in any of the samples. While stored in aluminum pie plates, beakers, and separatory funnels, the samples were covered with aluminum foil. The amount of time that each sample was exposed to the air (during sieving and transfer from one vessel to another) is estimated to be no longer than 30 min. Cotton lab coats were worn during processing and microscopic examination. The amount of time that each sample was exposed to air during microscopic examination varied depending on the density of organic material in the sample. The average time required for visual analysis was approximately 2 h.

Two field blanks were collected from stations 417 and 426 along the river using open Petri dishes containing pre-examined sediment and organic matter over a period of 5 min (amount of time required to transfer each sample from the ponar into a sample container). Three laboratory blanks were sampled; one from the processing lab for a period of 30 min, and two from the microscope lab for a period of 2 h each. The laboratory blanks were sampled using a Petri dish containing a mixture of pre-examined organic and sedimentary material. The blanks were examined under a dissecting microscope and any particles resembling microplastics were counted. The average number of particles from the two field blanks were added to the average number of particles from the two microscope laboratory blanks, which were then added to the number of particles counted from the processing laboratory blank. The blank total, composed entirely of fibers, was subtracted from each sample according to fiber color found in the blanks.

3. RESULTS AND DISCUSSION

3.1. Microplastic Abundances and Types. Prior to compositional analysis, a total of 1549 particles were visually identified as microplastics in the 34 samples (Table S1). Subtracting the number of fibers in the blanks gave a revised total of 1316 particles and an overall average concentration of 612 kg^{-1} dw (Table S1). All samples contained particles visually identified as microplastics and abundances ranged from 14 to 4452 kg^{-1} dw (Figure 2a).

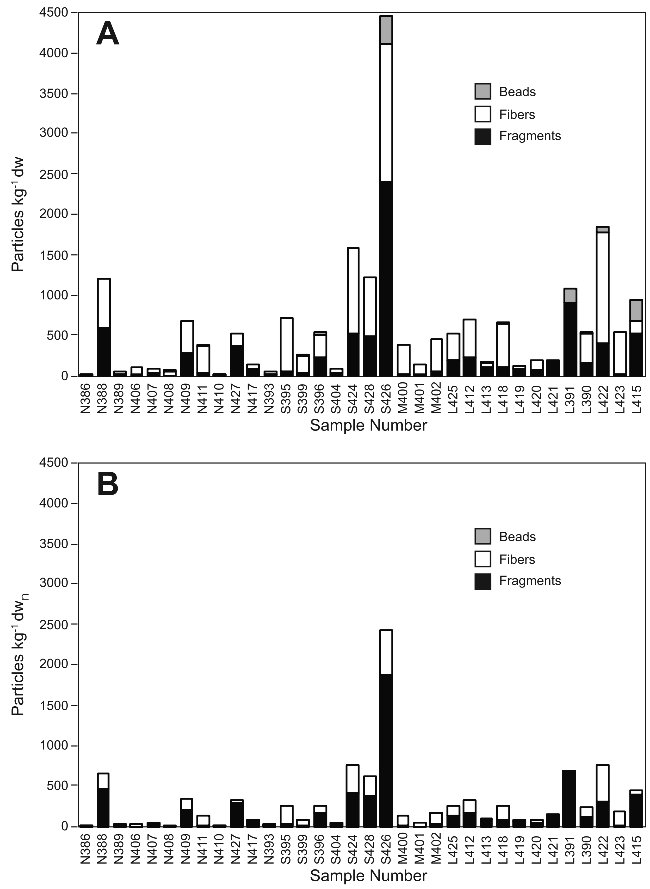

Figure 2. Microplastic abundances in sediment from each sample location, divided into: (A) pre-FTIR normalization, and (B) post-FTIR normalization. Sample locations are grouped from left to right according to river divisions displayed in Figure 1. N-North Thames, S-South Thames, M-Middle Thames, L-Lower Thames.

The morphologies of particles visually identified as microplastics prior to FTIR analysis included fragments (37%), fibers (60%), and minor amounts of beads (3%) (Table S1; Figure 2a). Significant variances were found between sites for total number of microplastics (standard deviation—STDEV = 821). Prior to FTIR analysis, the predominant morphology of visually identified microplastics was fibers, with an average abundance of 336 kg^{-1} dw and a range of 0−1702 kg^{-1} dw. Fiber lengths ranged from 0.18 to 8.70 mm, and in order of most to least abundant, the colors identified included black, blue, white, pink/purple, green, red, and yellow/orange (Figure 3a,b). The average abundance of fragments was 247 kg^{-1} dw, with a range of 0−2413 kg^{-1} dw. The fragments ranged from 0.063 to 2.38 mm in size, and in order of most to least abundant, the colors identified included blue, white/clear, red, yellow/orange, green, pink/purple, black, silver/grey, and brown (Figure 3c−g). Twenty-nine beads were selected from samples 415 and 426 (both within the border of the City of London) for scanning electron microscopy−energy dispersive X-ray spectroscopy. Only 2 of the 29 beads contained sufficient carbon to be considered a polymer (65 and 74 wt % with 18 and 14 wt % oxygen, respectively) (Figure 3g). All other beads contained <46 wt % carbon as well as other elements such as Si, Ca, Fe, K, and Al. Comparisons of the carbon-rich bead textures, colors, and sizes with the remaining beads identified microscopically resulted in a low number of potential plastic

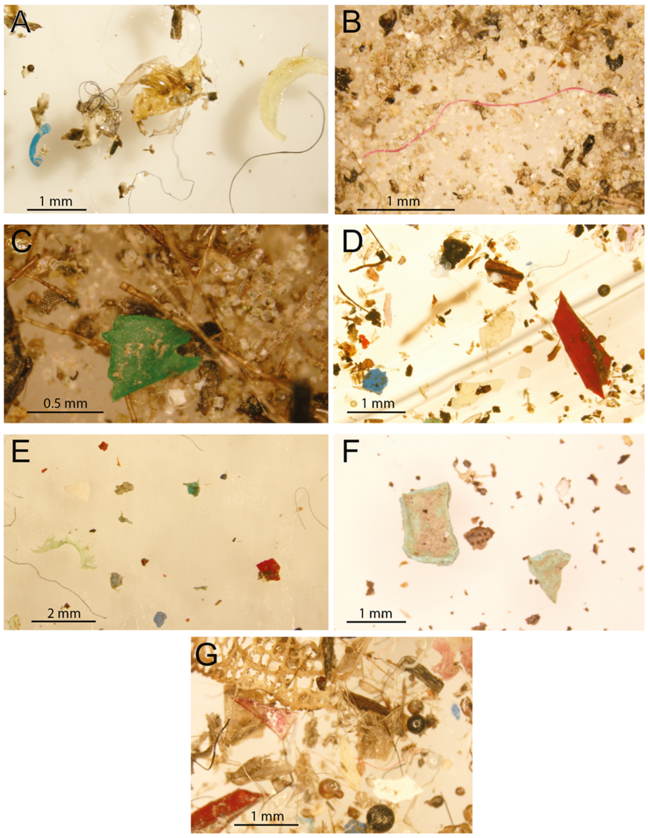

Figure 3. Examples of anthropogenic particles identified in Thames River samples. (A) Black fibers and fragment of blue flashing in sample 409, (B) pink fiber in sample 427, (C) green fragment in sample 427, (D) red, white, and blue fragments in sample 426, (E) multicolored fragments, fibers, and mint green flashing in sample mixed samples, (F) mint green fragments in sample 417, (G) multicolored fragments, and amber and black beads in sample 426. The two black beads contained enough carbon to potentially be microplastics, but the amber beads did not.

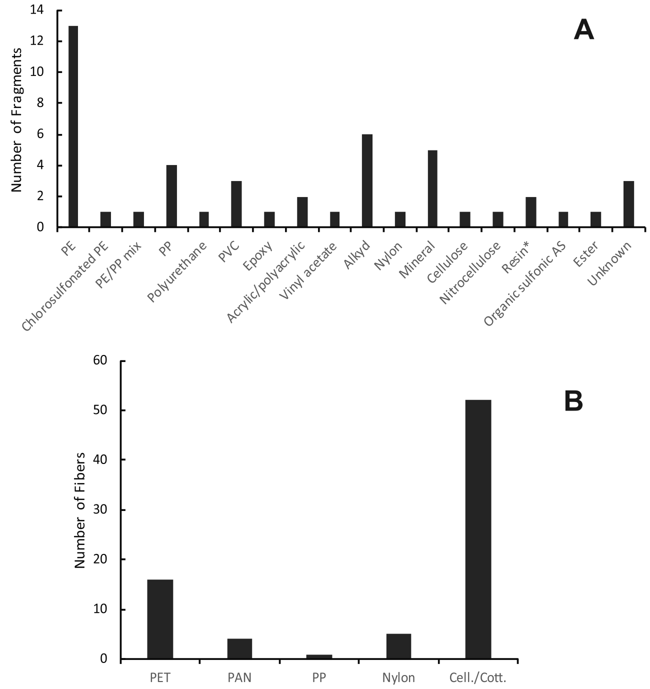

Figure 4. Compositions of particles, as determined from ATR FTIR of fragments (A) and micro-FTIR of fibers (B). PE-polyethylene, PP-polypropylene, PVC-polyvinyl chloride, AS-acid salt, PET-polyethylene terephthalate, and PAN-polyacrylonitrile.

microbeads in the samples (2 kg^{-1} dw; range of 0−60 kg^{-1} dw). The beads with high carbon content ranged from 0.29 to 0.57 mm in size and in order of most to least abundant, the colors identified included black/grey, brown/beige, yellow/orange, white, red, and blue.

3.2. Particle Compositions. Of the 132 particles analyzed by FTIR, 48 were fragments, 78 were fibers, and six were beads. Thirty-eight fragments (78%) were polymers, eight were inorganic (e.g., silicates, carbonates, and organic sulfonic acid salt), and three were unknown (Figure 4a). Twenty-six fibers (33%) were polymers, whereas 52 (67%) were composed of cotton/cellulose (Figure 4b). The six beads analyzed were yellow/orange (4), brown/beige (1), and black (1). The yellow/orange beads were composed of organic sulfonic acid salt (yellow/orange), the black bead was proteinaceous, and the brown/beige bead was an unknown composition. In total, 64 (48%) of the particles analyzed were polymers. If the particle compositions are considered representative of the entire population that was first identified visually, then the average overall abundances become 193 kg^{-1} dw (fragments), 111 kg^{-1} dw (fibers), and 0 kg^{-1} dw (beads). This is a significant decrease in the number of fibers and the revised abundances are displayed in Figure 2b. The relationships between microplastic abundance and land use, river morphology, grain size, and relative amount of organic debris are based on the number of microplastic particles following blank subtraction and FTIR analysis.

3.3. Possible Sources. The most common polymer for fragments was PE, which is the most widely produced polymer and is used in a variety of products. Notably, seven (18%) of the fragments were represented by paint chips (alkyd and polyurethane). Song et al.,[31] and Imhof et al.[32] also reported significant paint chips in their samples from the sea surface off the coast of Korea, and from beaches along Lake Garda, Italy, respectively. The predominant plastic fiber type was polyethylene terephthalate (PET), which is mainly used in synthetic textiles, and particularly clothing. The samples containing microbeads were all from urban locations; specifically from London (samples 415 and 426) and Chatham (samples 390 and 391), but if the FTIR analyses are considered representative, none of these are polymers.

The majority of the black and grey microbeads analyzed by SEM−EDX were composed of aluminum silicate, which is consistent with coal fly ash. The yellow/orange beads are composed of organic sulfonic acid salt, which is mainly used in detergents and as stabilizers in fabric dyes. The paucity of plastic microbeads in our benthic sediment samples is consistent with the low number of plastic microbeads reported from previous investigations of bottom sediment in Lakes Ontario and Erie and their tributaries.[25,26] This is in contrast to the numerous plastic microbeads that were identified in surface water samples from the Great Lakes,[19] and the coastal waters of Hong Kong.[33] A recent paper by Möhlenkamp et al.[34] reports that in laboratory studies, all but one type of plastic microbead from six cleansers remained suspended after 24 h in marine and fresh water. Although the authors did not report polymer composition for each product, their results imply that the majority of plastic microbeads sourced from personal care

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products would be found floating in surface waters and not in benthic sediment. Interestingly, one study reported up to 1.4 × 10^5 microbeads m^{-2} in bottom sediment of the St. Lawrence River, Canada.[35] This indicates that under certain conditions, such as aggregation of suspended minerals and algal material to the microbead surfaces plastic microbeads can sink.[34] Nonetheless, we did not find evidence for this in our Thames River samples.

3.4. Relationship to Land Use. Comparing our results to those from other river studies is difficult because samples from other investigations have mainly been collected from riverbanks,[36,37] or surface waters.[14,27] In addition, studies involving the benthic river sediment matrix use different sampling apparatuses (e.g., a scoop or corer),[15,38] whereas we used a petite ponar grab. We also note that no other published work concerning microplastics in benthic river sediment involves the relatively high sampling density that we undertook in a single river. Nonetheless, we have attempted to compare our results concerning the factors affecting the distribution of microplastics in benthic river sediment with other studies.

In general, the Thames River samples with the greatest number of microplastics were collected from the City of London and south of Chatham-Kent, although sample 388 from the town of Mitchell also contained abundant microplastics (Figure 5). Sample locations found within 5 km of a major town or city border were considered urban as opposed to rural (outside the 5 km radius). The average microplastic abundance in samples from urban regions (269 kg^{-1} dw) was greater than that from rural (195 kg^{-1} dw) locations, but no significant differences were detected ($P = 0.3580$) (Figure 6). Even with removal of the outlier sample 426 from the confluence of the north and south branches, the influence of land use on abundance of fibers and fragments is not significant. These findings are similar to those of Tibbetts et al.[15] and Ding et al.[38] for sediment of the River Thames and the Wei River, respectively, in that a general increase in the number of microplastics with increased population density and urban proximity was identified, but exceptions did exist.

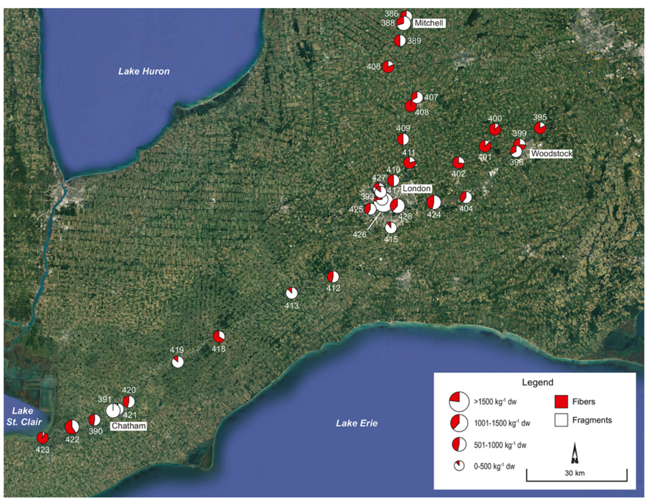

Figure 5. Google Earth Pro image of the Thames River study area with pie charts marking sample locations, post-FTIR abundances of MP particles per kilogram of dry weight sediment (kg^{-1} dw), and relative quantities of fibers and fragments. Take note that following FTIR normalization, no beads were considered plastic and are therefore not included in this diagram.

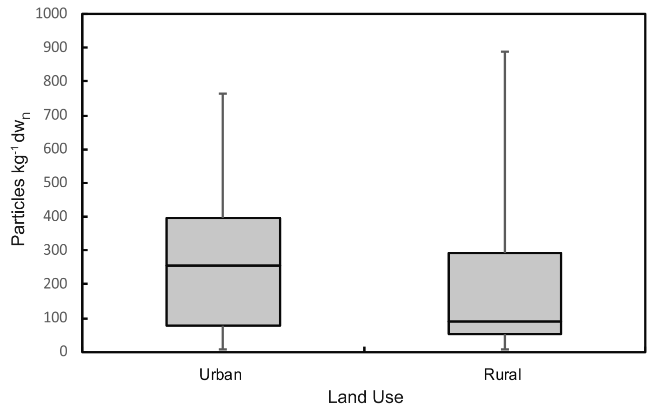

Figure 6. Boxplot displaying the distribution of MP abundances in urban vs rural locations. Urban samples were collected from within 5 km of a major town or city. Although there is no significant difference between land use types, the average abundance of MPs is greater for urban localities.

Studies of microplastics in benthic sediment of the Great Lakes show high abundances to be related to urban proximity and its associated plastic production and use facilities, location of wastewater treatment plants, and high population density.[25,26] River systems, however, are much more dynamic depositional sites than lakes, and seasonal flooding with combined overflow events may result in greater mixing and transport of microplastics throughout the length of a river system.[16]

3.5. Relationship to River Morphology. We investigated whether a correlation could be made between microplastic abundance and river morphology. Six samples were collected from the outer bends of the river, seven from inner bends, 17 along river straights, two from creeks, one from a canal, and one from the "forks of the Thames" (Figure 7a). Averages of samples from the three main morphological feature groups are 441 kg^{-1} dw (outer bends), 276 kg^{-1} dw (inner bends), and 150 kg^{-1} dw (straights). Owing to the low number of samples from creeks, canals, and the forks, only the average abundances of samples from outer and inner bends and straights were considered for statistical analysis (Figure 7b). A significant difference was found between microplastic abundances in outer bends compared with straights ($P = 0.0220$), but no significant difference was identified between inner and outer bends ($P = 0.2747$). Studies have shown that natural sediment, particularly in the size range 1.6−3 mm, is preferentially deposited along the inner bends of a meandering river.[39] Our results do not indicate that microplastic particles are more abundant along inner bends, which may be a function of too few samples from each morphological compartment, or that deposition of microplastics is not solely dependent on particle size, but can be controlled by density and biofilm colonization, as well as flow velocity.[40] As the straights of the river are the sites of highest flow velocity, lower numbers of microplastics are expected to be found there. Tibbetts et al.[15] noted a similar positive relationship between high flow velocity regions and low microplastic counts. Finally, removing the clay and silt-size particles from our samples may have biased the results, as the finest grain fractions have been shown to contain the greatest number of microplastics (see "Relationship to Grain Size").

3.6. Relationship to Grain Size. We investigated whether there is a relationship between microplastic abundance and relative grain size in the sample population. The nature of the sediment through which the Thames River flows is highly

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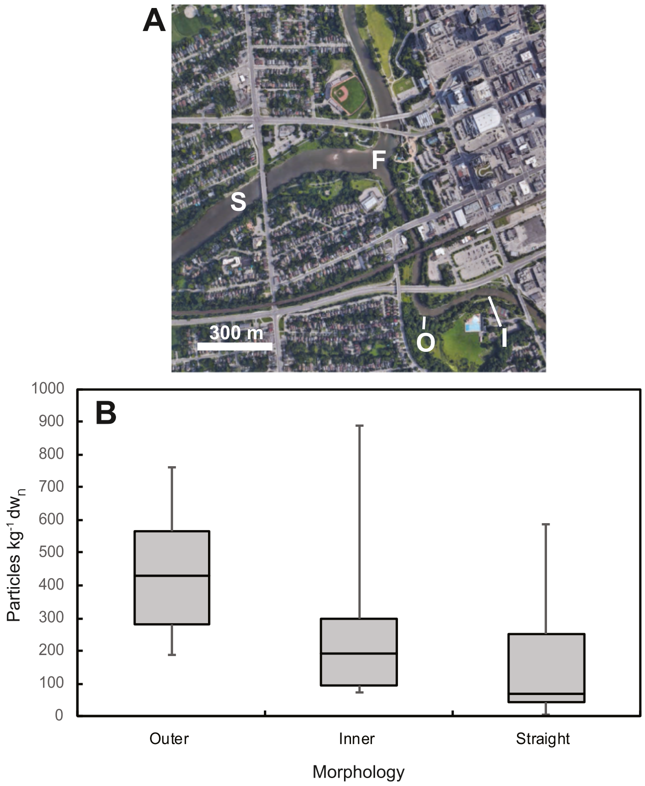

Figure 7. Relationship between MP abundances and river morphology. (A) Google Earth Pro image of the "forks" (F) of the Thames River in London, Ontario, displaying what is meant by inner (I) and outer (O) river bends, and a straight (S) part of the river. (B) Boxplot displaying the distribution of MP abundances in sediment sampled from outer, inner, and straight zones of the river.

heterogenous as a result of the north, middle, and south branches having formed through glacial spillways, and the Thames River proper (south of London to Lake St. Clair) subjected to repeated flooding events. Depending on location, the bottom sediment consists of material ranging from mud- to boulder-size. While collecting and processing the samples, we estimated the mean grain size and compared it to microplastic abundances. The results indicate that there is a significant difference between very fine sand samples and fine sand + medium sand samples (P = 0.0332), but no significant difference between the fine sand + medium sand samples and coarse sand + granular samples (P = 0.6608) (Figure 8a). Vermaire et al.[41] found no significant relationship between MP abundances and mean particle size in their study of benthic sediment from the Ottawa River. However, the authors analyzed the grain size fraction >300 μm whereas we studied the grain size fraction between 63 and 200 μm. Considering that the Thames River microplastic abundances were significantly different for samples of very fine sand compared to coarser grain sizes, and that the upper limit for very fine sand is 125 μm, Vermaire et al.[41] may not have examined a fine enough fraction to recognize a significant relationship between grain size and abundance. Another factor to consider is that our determination of grain size mode was qualitative and future investigations should employ grain size analysis techniques.

Comparing grain size to abundance was also challenging for this study because the sediment grade <63 μm was not considered because of ease of processing. A recent investigation conducted on microplastics in deep sea benthic

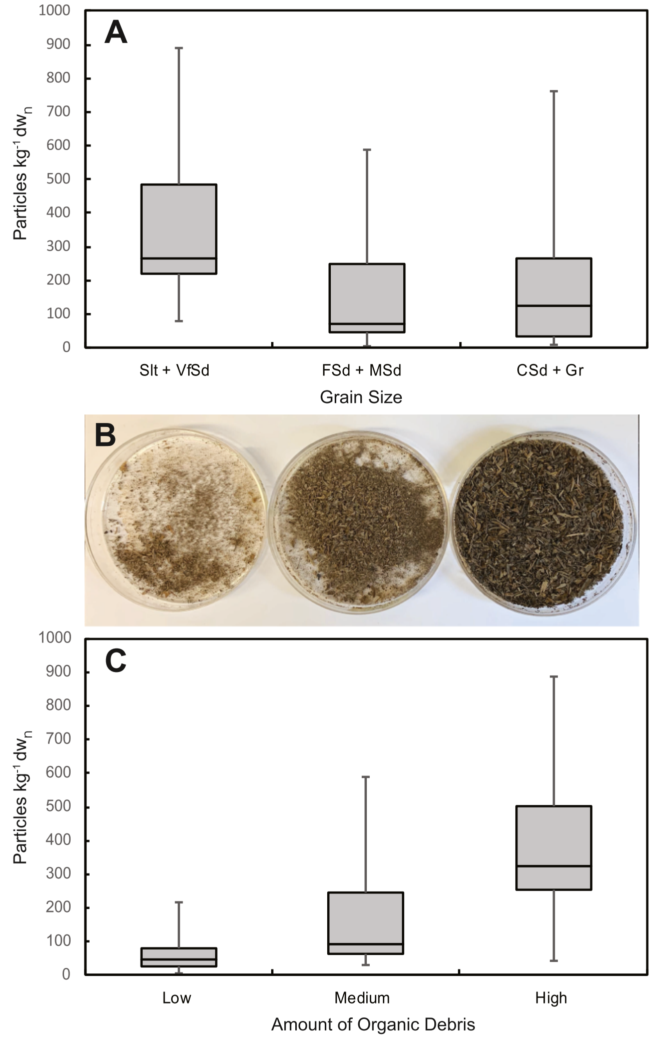

Figure 8. Relationship between MP abundances and grain size, and MP abundances and amount of organic debris. (A) Boxplot displaying the distribution of MP quantities in samples collected from silt (Slt) + very fine sand (VfSd), fine sand (FSd) + medium sand (MSd), and coarse sand (CSd) + granules (Gr). The finest grain sizes contain the greatest amount of MP particles. (B) Photo displaying the relative visual difference between (from left to right) low, medium, and high amounts of organic debris. (C) Boxplot displaying the distribution of MP quantities in samples containing low, medium, and high levels of organic debris.

sediment of the Fram Strait indicates that 42−6595 microplastics kg^{-1} dw were identified, but 80% of the particles were found in sediment <25 μm in size.[42] This suggests that a stronger correlation between grain size and microplastic abundance in the Thames River may have been obvious if smaller grain sizes were considered in this study.

3.7. Relationship to Relative Amount of Organic Debris. Of the four parameters investigated as potential factors controlling microplastic abundance in the Thames River, the relative amount of organic debris appears to be the most significant. This parameter, however, is also qualitative, in that the amount of organic debris (low, medium, and high) was based on visual observation of the sample (Figure 8b). In all cases, samples containing high amounts of organic debris also correlate with large amounts of organic debris in the field. The resultant boxplot displays a significant difference with removal of the outlier sample 426 (low vs medium, P = 0.0943;

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medium vs high, $P = 0.0242$; and low vs high, $P = 0.0006$) (Figure 8c). Along shorelines, the strandline, or high-water mark is often associated with organic debris, such as leaves, sticks, seeds, and logs, and these are the areas also characterized by macroplastic debris. Most polymers have densities similar to organic material and therefore, the positive relationship between the amount of organics and number of plastic particles is not surprising on either the macro- or microscale. Considering that organic debris accumulates in low-flow areas and that the finest sediment grain sizes are deposited where flow velocity is minimal, the positive correlation between relative amount of organic debris, grain size, and microplastic abundance is understandable.

3.8. Long Term Monitoring. The results of the present study indicate a relationship between microplastic abundance, river morphology, grain size, and amount of organic debris in samples collected from the Thames River, Ontario in November of 2016. We have since sampled benthic sediment from the same localities during the summer of 2018 and autumn of 2019, and our goal is to continue sampling for an additional 7 years. In future years, we will attempt to collect samples from the inner and outer bends and straights of the river at each locality. This cross-sectional sampling will enable us to draw firmer conclusions regarding the influence of river morphology on microplastic abundances. We anticipate that long-term monitoring of the Thames River will provide more statistically robust data concerning the factors controlling the deposition of microplastics in river sediment.

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available free of charge at https://pubs.acs.org/doi/10.1021/acs.est.9b04896.

> Spreadsheets of raw and calculated numbers of microplastics and their relation to grain size, morphology, and amount of organic debris (PDF)

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Notes

The authors declare no competing financial interest.

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