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Occurrence of microplastic fragments in the Pasig River

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Abstract

Microplastics are plastic fragments with dimensions of less than 5 mm. These materials are formed within bodies of water by the forces shearing on the large plastics. Ultraviolet light from sunlight also degrades plastic materials causing discoloration and disintegration into smaller, micro- or even nano-sized particles. This study reports the isolation of microplastic fragments from the Pasig River within the vicinity of the Polytechnic University of the Philippines. The collection of floating particulates was done by sieving the river water (flow rate = 0.31 m s^{-1}) through a 0.35 mm mesh for 10 minutes. Through this method, 25.7 m^3 of river water was sieved over three samplings. Microplastics were isolated through a series of peroxide oxidation and sedimentation methods. All microplastic fragments were viewed and photographed under a compound microscope (40–100× magnification). A total of 34 microplastic fragments with lengths ranging from 0.56 to 4.58 mm were categorized. Microplastic fragments were categorized into two categories: small (1.16 ± 0.42 mm) and large (4.13 ± 0.37 mm), based on the size distribution. The microplastic fragments isolated were partially rounded and some showed signs of discoloration indicating mechanical and photo-degradation. The presence of microplastic fragments in Pasig River indicates persistent plastic pollution from the river source (Laguna de Bay), its tributaries, as well as the communities and industries situated along the river. Programs on solid waste management especially on plastic wastes could mitigate the production of microplastics in the river.

Key words: microplastics, Pasig River, plastics, pollution

INTRODUCTION

The Pasig River is an important river system in Metro Manila since it connects two large water bodies in Metro Manila: Laguna de Bay (the largest freshwater lake in the country) and Manila Bay (the country's main port for maritime trade and travel). The flow of the Pasig River through the urban areas comes from its upstream portion located in Laguna de Bay, then moves through the Napindan Channel, and joins the Marikina River at the boundary of Pasig and Taguig. It links further with the San Juan River and finally flows out into Manila Bay. The river is approximately 27 km long, with an average width of 91 m, and depths ranging from 0.5 to 5.5 m. The annual average volume of water flowing into Manila Bay is 6.6 million cubic meters. During low flow, from March to May, the discharge

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volume is 12 $m^3 s^{-1}$, while high flow during October to November reaches 275 $m^3 s^{-1}$. According to Gorme *et al.* (2010), domestic waste accounts for about 60% of the total pollution in the Pasig River, with the rest originating from industrial wastes (33%), such as tanneries, textile mills, food processing plants, distilleries, chemical, and metal plants, as well as from solid waste (7%) dumped into the rivers. The Pasig River has become the dumping ground of informal settlers living along the banks of the river and its tributaries, as well as surrounding establishments (Helmer & Hespanol 1997).

A study by the DENR-NSWMC in 2012 projected that the solid waste generation in Metro Manila is about 8,200 tons per day (DENR-NSWMC 2012). Plastic is estimated to comprise 16% of the solid waste in the Philippines. This proportion is higher (25%) in Metro Manila (Department of Environment and Natural Resources – National Solid Waste Management Commission 2004). In waste analysis and characterization studies conducted by the City of Manila in 2015, the estimated production of solid waste is 1,030.16 tons/day, of which 17.75% is plastics. Metro Manila generates about 7,000 metric tons of solid waste daily, with a daily waste generation of 0.66 kg per capita per day. Only 85% of these wastes are collected (Department of Environment and Natural Resources–Environmental Management Bureau 1999). The Philippines is ranked in third position by mass of mismanaged plastic waste, following China and Indonesia. In 2010, plastic marine debris in the Philippines ranged from 0.28 to 0.75 MMT per year (Jambeck *et al.* 2015).

According to Lebreton *et al.* (2017), the Pasig River belongs in the top 20 polluters of plastics in the world's oceans, dumping an estimated 3.88×10^4 tons of plastics annually. It has been estimated that up to about 12.7 million tons of plastic still ended up in the ocean in 2010 (Jambeck *et al.* 2015). At present, the widely accepted definition of microplastics is a plastic material with a size <5 mm (Browne *et al.* 2008; Arthur *et al.* 2009; Bowmer & Kershaw 2010). Earlier definitions of microplastic size include: 20 microns or 0.02 mm (Thompson *et al.* 2004); 1 mm (Browne *et al.* 2010; Vianello *et al.* 2013; Dekiff *et al.* 2014); and a range between 1 micron and 1,000 microns (Karami *et al.* 2017). Microplastics may exist in two forms – primary and secondary. Primary microplastics consist of manufactured raw plastic material, such as virgin plastic pellets, scrubbers, and microbeads produced from synthetic sandblasting media, cosmetic formulations, and textiles (Reddy *et al.* 2006; Browne *et al.* 2007; Arthur *et al.* 2009; Fendall & Sewell 2009; Pirc *et al.* 2016). Primary microplastics move directly into water bodies through ground runoff (Andrady 2011). Secondary microplastic introductions occur when larger plastic items (meso- and macro-plastics) enter a beach or ocean and undergo mechanical weathering, photo-oxidation, and biological degradation (Thompson *et al.* 2004; Browne *et al.* 2007; Andrady 2011). This degradation breaks the larger pieces into progressively smaller plastic fragments which become invisible to the naked eye.

The pollution in the Pasig River was hypothesized to generate microplastics that enter the world's ocean through Manila Bay and the South China Sea. Argamino & Janairo (2016) reported microplastics in the cultured mussels (*Pernia viridis*) harvested from Bacoor Bay. This body of water is an inlet on the southeastern part of Manila Bay, the mouth of the Pasig River. The present study determines the presence of floating microplastics passing through the Pasig River that faces the Polytechnic University of the Philippines. The sampling point is approximately 7 km from Manila Bay (river mouth) and 20 km from Laguna de Bay (river source).

MATERIALS AND METHODS

Collection of water samples

The sampling site is located at the side of the Pasig River facing the Polytechnic University of the Philippines (14°35′46″ N, 121°00′36″ E) (Figure 1). Three sampling collections were done on three occasions: August 18, 22, and 23, 2017.

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Figure 1 | Google Map image of Pasig River highlighted in yellow. The Google Earth of sampling point marked by a circle.

Microplastics were collected using Manta trawls, described in the paper of Brown & Cheng (1981). This method of collecting microplastics on surface water has been used by the US National Oceanic and Atmospheric Administration (NOAA) – Marine Debris Program (Masura *et al.* 2015). For this study, two Manta trawls were created for the sampling of microplastics: (1) 25.7-cm diameter opening (used on August 18 and 22 collections) and (2) 10.4-cm diameter opening (used on August 23, 2018). Both Manta trawls were fitted with a 0.355-mm mesh net. The Manta trawls were attached to a bamboo pole (Figure 2(a)) and deployed approximately 2 m from the river bank for 10 minutes.

Figure 2 | Collection and isolation of microplastic (MP): (a) manta trawl deployment, (b) manual separation of MP from large debris, (c) density separation.

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The velocity of the water on the surface was estimated at 0.31 m s^{-1} by floatation method. The amount of water filtered by the trawls were 7,700 L for the August 18 and 22 samplings and 5,000 L for the August 23 sampling. These estimates were based on the method of United States Department of Agriculture (2001).

Isolation of microplastics: sieving and wet peroxide oxidation (WPO)

The materials collected by the Manta trawls (Figure 2(a)) were initially poured through a stacked arrangement of 5.6-mm and 0.3-mm mesh sieves. The mesh net of the Manta trawl was rinsed thoroughly with distilled water and the washings were poured onto the same mesh sieve setup. The materials trapped on the first sieve (5.6-mm mesh) were washed thoroughly with distilled water and discarded. The materials trapped on the second sieve (0.355-mm mesh sieve) were transferred to a 500-mL beaker and dried in a laboratory oven set at 90 °C, until dry.

The method used in isolating microplastics was the wet peroxide method (WPO) (Masura *et al.* 2015). Briefly, 20 mL 0.05 M ferrous sulfate solution was added to the beaker containing the dried solid fraction from the 0.355-mm mesh sieve. The oxidation was initiated by adding 20 mL of 30% hydrogen peroxide and heating at 75 °C for 30 minutes. The oxidation was repeated by the addition of more hydrogen peroxide and heating. Sodium chloride was dissolved into the mixture to adjust the density up to 1.190 g cm^{-3}, the density of 5 M NaCl solution. The microplastic in the salt solution separated overnight in the density separator setup (Figure 2(c)). The floating microplastics were collected, air dried, and stored in vials for microscopic examination.

Microscopic examination and image analysis

The fragments were examined under the microscope at 40–100× magnification. Photographs were taken for each fragment. The length of each fragment was measured from the photomicrographs using ImageJ software (Schneider *et al.* 2012). The RGB component of each fragment was measured using the Colors.exe software (Otaka *et al.* 2002). The RGB values of the fragments were matched to its corresponding hue using Colblindor (Colblindor nd). Roundness scores of each microplastic fragments were calculated from the circularity and aspect ratios obtained from ImageJ using the formula of Takashimizu & Iiyoshi (2016). The roundness score described has a range from 0 (angular) to 1 (perfect circle). Descriptive statistics were performed for the sizes of the fragments collected. The statistical analysis was done using R 3.5.0 (R Core Team 2018).

RESULTS AND DISCUSSION

Sizes of isolated Pasig River microplastics

After solation, 34 fragments were isolated and documented (Table 1 and Figure 3). The collected fragments were classified as microplastics based on the descriptions of Hidalgo-Ruiz *et al.* (2012). The microplastics collected have densities lower than the density of 5 M NaCl (1.190 g/cm^3). Plastic materials that fall in this density range are polymethylpentene (TPX: 0.83 g/cm^3), polypropylene (PP: 0.90–0.91 g/cm^3), low-density polyethylene (LDPE: 0.92–0.94 g/cm^3); high density polyethylene (HDPE: 0.95–0.97 g/cm^3), and polystyrene (PS: 1.05–1.07 g/cm^3) (Kolb & Kolb 1991). The microplastic fragments isolated from the river have lengths ranging from 0.56 to 4.58 mm. The size distribution of the microplastic fragments cataloged formed two distinct groups of fragments, conveniently categorized as small and large microplastic fragments (Figure 4). The two groups were: (1) small microplastic fragments ($n = 28$), having a mean size of 1.16 ± 0.42 mm

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Table 1 | Profile of microplastic fragments isolated from the Pasig River between August 18 and 23, 2017

Microfragment ID	Length (mm)	Area (mm^2)	Roundness*	RGB	Hue
A1	1.700	0.480	0.592	(227, 56, 26)	Red
A2	1.877	1.184	0.509	(214, 26, 23)	Red
A3	1.320	1.340	0.699	(150, 8, 3)	Red
A4	2.019	2.381	0.602	(201, 107, 36)	Brown
A5	1.409	1.297	0.572	(186, 112, 84)	Red
A6	1.280	0.848	0.465	(84, 31, 8)	Brown
A7	1.544	1.642	0.617	(196, 64, 38)	Red
A8	2.132	2.503	0.490	(212, 138, 94)	Orange
A9	1.707	1.880	0.617	(173, 115, 89)	Orange
A10	1.060	0.544	0.604	(128, 107, 89)	Brown
A11	1.101	0.744	0.521	(186, 112, 64)	Orange
A12	1.030	0.806	0.783	(71, 71, 89)	Violet
A13	3.580	9.944	0.804	(105, 125, 133)	Blue
A14	4.580	6.085	0.230	(133, 135, 130)	Gray
A15	1.200	0.936	0.315	(219, 133, 105)	Red
B1	0.947	0.307	0.684	(199, 125, 117)	Red
B2	0.696	0.207	0.419	(43, 54, 20)	Green
B3	0.873	0.271	0.453	(128, 107, 77)	Green
B4	0.961	0.554	0.519	(122, 94, 102)	Brown
B5	0.557	0.215	0.705	(117, 232, 161)	Green
B6	0.754	0.391	0.322	(61, 61, 66)	Gray
B7	0.877	0.257	0.706	(235, 235, 214)	Green
B8	0.799	0.251	0.663	(156, 150, 120)	Green
B9	0.705	0.316	0.552	(153, 107, 112)	Violet
B10	1.006	0.402	0.352	(66, 61, 87)	Violet
B11	0.781	0.452	0.669	(176, 54, 18)	Red
B12	0.975	0.495	0.615	(105, 130, 161)	Blue
B13	0.975	0.307	0.552	(199, 125, 117)	Red
B14	1.202	0.551	0.465	(120, 79, 92)	Violet
B15	0.964	0.587	0.439	(181, 77, 46)	Orange
C1	4.120	9.867	0.787	(56, 161, 128)	Green
C2	4.010	9.985	0.683	(171, 209, 176)	Green
C3	4.510	9.944	0.804	(163, 209, 176)	Green
C4	4.060	6.586	0.679	(196, 204, 217)	Green

*Roundness parameter estimates based on Takashimizu & Iiyoshi (2016).

and (2) large microplastic fragments ($n = 6$) with a mean size of 4.13 ± 0.37 mm. Smaller microplastic fragments (<2.5 mm) were more frequent than the larger ones (>2.5 mm) (see Figures 3 and 4). Degrading forces (i.e., ultra-violet radiation and weathering) reduces the size of microplastics in the river and prolonged exposure to these degrading forces degrades the large microplastics into small microplastics (Barnes *et al.* 2009; Cole *et al.* 2011). In a similar study, microplastics with sizes <2.8 mm were most abundant along the Pacific Coast (McDermid & McMullen 2004; Browne *et al.* 2010). Smaller microplastics (<0.3 mm) are a worry as they are small enough to be ingested by marine microorganisms and larger organisms (Browne *et al.* 2008; Cole *et al.* 2011).

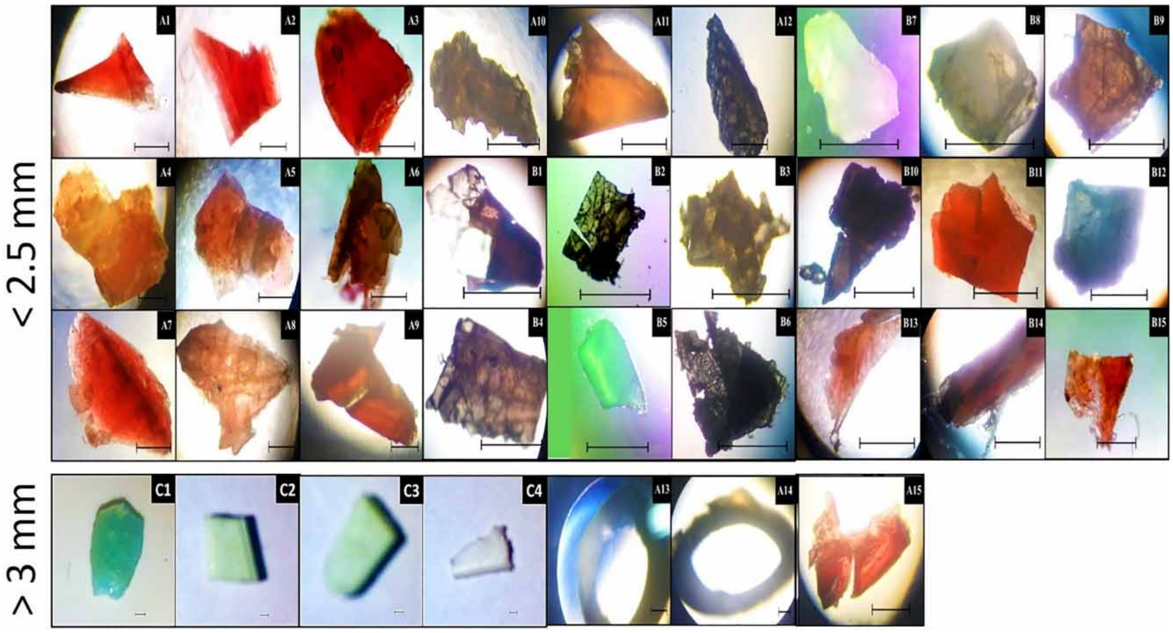

Figure 3 | Photographs of microplastic (MP) fragments isolated from the Pasig River and segregated by length (<2.5 mm and >3 mm). Scale bar = 0.5 mm.

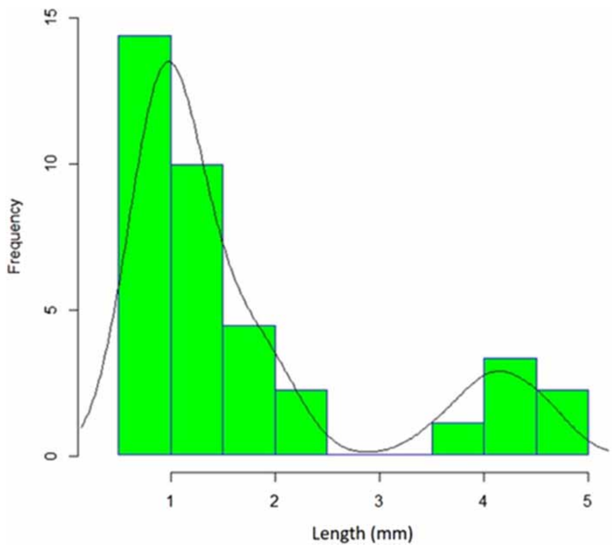

Figure 4 | Histogram of microplastic fragment sizes.

Photodegradation and mechanical weathering of MP in the Pasig River

Photodegradation of plastics is caused by ultraviolet (UV) radiation via photo-Fries rearrangement which occurs at <290 mm. Bleaching occurs at wavelengths within 330 nm; the reaction can result in a yellow hue and clearing of the plastic material (Humphrey *et al.* 1973; Andrady *et al.* 1991). The familiar shades that can be observed from the microplastics isolated from the Pasig River are brown, red, orange, green, blue, violet, and gray (see Table 1). Several microplastics isolated show signs of discoloration (Figure 5). The mean roundness of the isolated microplastics was

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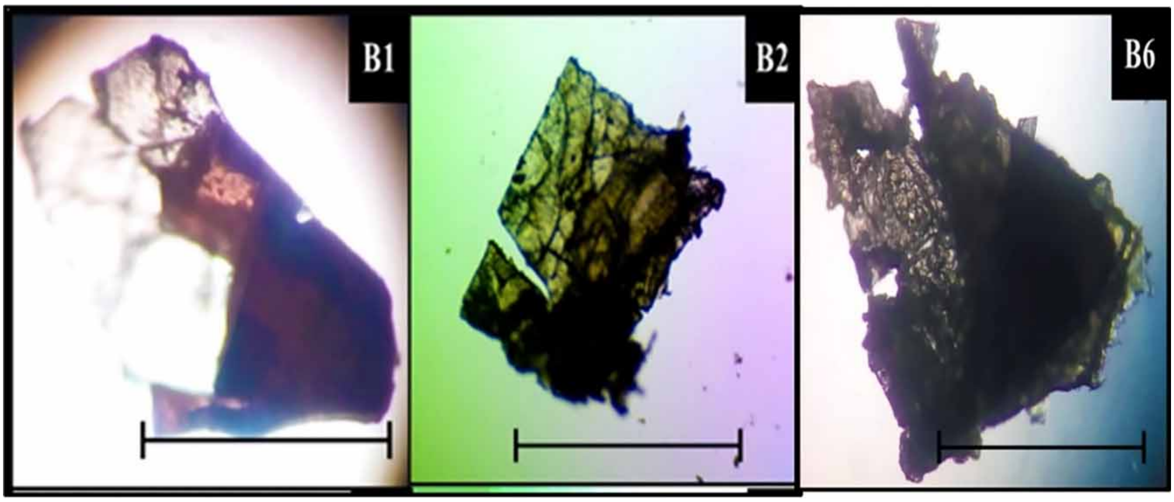

Figure 5 | Selected microplastic fragments showing faded areas. Scale bar = 0.5 mm.

0.588 ± 0.144 suggesting partial rounding of the microplastic fragments. Formation of microplastics through mechanical stress tends to achieve rounder shapes. The study of Kowalski *et al.* (2016) demonstrated the rounding of microplastic fragments after a month of mechanical stress, which includes shaking and the abrasive actions of salt and sand. They also relate the rounding of microplastics to the loss of mass and, subsequently, the reduction of the particle density.

Implications of microplastic fragments in Pasig River

The presence of microplastics in the Pasig River indicates plastic pollution occurrences along the river, its tributaries and up to its source which is Laguna de Bay. Microplastics and plastics, in general, carried by the Pasig River could end up in Manila Bay and eventually the West Philippine Sea and the South China Sea. The pollution from the South China Sea could reach the Pacific and Indian Oceans. The microplastics from the Pasig River could be ingested by organisms in Manila Bay such as mollusks and fish. These organisms are commonly harvested for human consumption. The West Philippine Sea and the South China Sea have a rich diversity of marine organisms, i.e., fish, oysters, corals, etc. Microplastics originating from the Pasig River could reach these bodies of water affecting its marine biota.

Rivers, especially those located in urban areas, are used as outlets of waste water treatment plants. The microorganisms from waste can grow on the surface of microplastics. This was demonstrated in the studies of McCormick *et al.* (2014, 2016) that showed bacterial assemblages being identified from microplastics isolated from various urban rivers. In the case of the Pasig River, rain water canals, sewage and solid wastes enter the river through its many tributaries. The microorganisms, including pathogenic bacteria from these wastes, can attach to microplastic surfaces and be ferried along the river and to larger bodies. As fomites, contaminated microplastics fragments can cause infections in humans and animals that comes into contact with them.

CONCLUSION

The present study reports the occurrence of microplastic fragments in the Pasig River. From the 34 microplastic fragments isolated, 28 fragments belong to the smaller group (<2.5 mm in length), suggesting advanced degradation of their plastic source and longer persistence of plastics in the river. Smaller microplastic fragments could have originated near the river source, Laguna de Bay,

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and nearby tributaries. With the current polluted situation of the Pasig River and this reported occurrence of microplastics in its surface water, it is likely that the Pasig River contributes to the microplastic burden of Manila Bay and connecting larger bodies of water. Microplastic fragments could have been ingested by marine organisms, i.e., fish and mussels in Manila Bay and nearby Bacoor Bay, making their way into the human food supply. Microplastics in the Pasig River could be more likely to be contaminated by pathogenic microorganisms since domestic and industrial wastes pollute the river. The occurrence of microplastics in the Pasig River could be prevented through effective solid waste management of the cities along the river and its tributaries.

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