ARTICLE

Microplastic occurrence in rural and urban surface waters: the cases of Lake Sampaloc and Lake Yambo in San Pablo City, Laguna, Philippines

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ABSTRACT

The widespread microplastic occurrence has invaded both marine and freshwater ecosystems. However, most studies are focused on marine microplastics and there is still insufficient knowledge and understanding of microplastics in freshwater ecosystems like small lakes. Known as one of the largest contributors of plastics to the aquatic environment, the Philippines has begun ventures on studying microplastic pollution, although, still, there are no accurate figures on the extent of the microplastic problem in the country, especially in its freshwater environment. In this study, a comparative assessment of microplastic concentration and characterization between Lake Yambo, an ecotourism and rural lake, and Lake Sampaloc, an aquaculture and urbanized lake, in San Pablo City, Laguna, Philippines was conducted through microplastic isolation and optical examination. Results revealed that the average microplastic concentration in Lake Sampaloc and Lake Yambo ranges from 483 to 989 n/m^3 and 344 to 789 n/m^3, respectively. Generally, the sampling sites in Lake Sampaloc had a higher mean concentration of microplastics than those in Lake Yambo. The key features of the microplastics detected in the surface waters of the studied lakes are fibrous, colored, and small-sized (<2 mm). In addition to proving the assumption that there are more microplastics observed in a highly-populated or urbanized freshwater ecosystem like Lake Sampaloc, this study also contributed to the meager evidence that microplastics are present even around scarcely-populated lakes like Lake Yambo. The outcome of this study is relevant for the local government unit (LGU) of San Pablo to make sustainable environmental policies regarding plastic waste management and disposal.

KEYWORDS

environmental science, plastic pollution, solid waste, microplastics, lakes, Lake Sampaloc, Lake Yambo

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INTRODUCTION

Plastic has been a ubiquitous and persistent contaminant in all terrestrial and aquatic environments due to its durability, unsustainable use, and lack of appropriate waste management (Barnes et al. 2009, Bouwman et al. 2018, National Oceanic and

Atmospheric Administration [NOAA] 2015-2017). Since plastics are made from synthetic polymers, which are designed to withstand and last for a very long time, these mostly non-biodegradable materials could accumulate, rather than decompose, in landfills or the natural environment. In 2015, about 6.3 billion tons of plastics were generated, of which about 567 million tons (9%) were recycled, 756 million tons (12%) were incinerated, and a bulk of it at about 4.98 billion tons (79%) were accumulated in the natural environment or landfills (Geyer et al. 2017, Bouwman et al. 2018). As one of the world's biggest environmental crises, plastic pollution is an emerging issue that might negatively affect human health and biodiversity in the near future, evidences of which are being observed now (Sutherland et al. 2010).

In the Philippines, plastic pollution remains one of the country's perennial environmental problems as many people use single-use plastics for food packaging, hygienic products, and other purposes (Enano 2019). In March 2019, a waste assessment report by the Global Alliance for Incinerator Alternatives (GAIA) showed that Filipinos use over 59 billion pieces of sachets annually and throw almost 163 million pieces of it daily.

Microplastics are any plastic particles less than five millimeters in size in their largest dimension and without specified lower limit. However, the lower bound is defined often by the mesh or sieve size (usually 0.33 mm) use in the method of collection (Li et al. 2018, Wagner et al. 2014, Arthur et al. 2009, Thompson et al. 2009, NOAA 2015-2017, MSFD Technical Subgroup on Marine Litter 2013). These bit-sized plastic particles can be categorized into two distinct types – primary and secondary microplastics (Cole et al. 2011). Primary microplastics are specifically manufactured to have a dimension less than 5 mm and are usually found in medicines, textiles, plastic pellets used for cleaning boat hulls, and personal care or cosmetic products such as facial and body scrubs. They are typically smooth and rounded because of their purpose in cosmetics and personal care products (Cole et al. 2011, Browne 2015). Meanwhile, secondary microplastics are fragmented plastic particles that resulted from the natural degradation with the help of ultraviolet radiation and physical abrasion of larger plastics into smaller fragments and fibers, which are jagged and uneven (Wagner et al. 2014, Cole et al. 2011). This type of microplastic can be created by larger plastic litter and be brought to long distances through watersheds. The densities of this microplastic type make them become the majority of microplastics in the environment (Anderson et al. 2017, Ryan 2015). Also, secondary microplastics make up most of the microplastic particles found in those high-population-density marine systems (Browne et al. 2011, Bouwman et al. 2018, Hidalgo-Ruz et al. 2012). A study confirmed that anthropogenic factors like daily routines, for instance, brushing teeth, taking a bath, or washing clothes, affect the microplastic abundance in urban surface waters (NOAA 2015-2017, Wang et al. 2017). In the last few years, microplastics which have been recorded in abundance in seawater, sediment, and even marine animals, are also discovered in the most isolated places such as the Tibet plateau (Zhang et al. 2016), the deep sea (Van Cauwenberghe et al. 2013), and the Arctic (Obbard et al. 2014). Consistent with many researches, fibers were the most abundant type of microplastic found in various water bodies (Sutton et al. 2016, Claessens et al. 2011, Mason et al. 2016, Stolte et al. 2015, Thompson et al. 2004). In a study by Koelmans et al. (2019), fibers, fragments, foam, pellets, and film were the most frequently reported shapes. Film was the most common type of microplastic in urban rivers found by Phillips and Bonner (2015). While in nonurban, rivers, filaments, or fibers are more common (Bouwman et al. 2018).

Relative to their overall size, the large surface area of microplastics allows them to transport a large amount of contaminant. Their small size permits minute aquatic organisms to mistakenly take them for food, increasing their exposure and enabling bioaccumulation in organisms on top of the food chain (Avio et al. 2015, Setala et al. 2014). They are of special concern because of their bioaccumulation effect or the process wherein the contaminant in an organism increases as the organism decreases in size. Microplastics are not just capable of facilitating bioaccumulation, but also biomagnification or the increase in the concentration of harmful substance as it goes up the food chain (Koelmans et al. 2013). If this is so, then, human beings would probably experience some adverse effects, especially those who rely on seafood and fish as their primary source of animal protein (Sumaila et al. 2007). Although there is a lack of evidence of the transmission of chemicals from plastics into the tissues of organisms when ingested, still, its effect on the aquatic food chain could pose both potential human health and ecological risks which could then lead to socio-economic costs (Tanaka et al. 2013).

The presence of microplastics has been extensively reported and studied in the marine environment (Derraik 2002, Cole et al. 2011), however, there is still insufficient information about microplastics in freshwater ecosystems such as rivers and lakes (Li et al. 2018). In fact, there are below 4% of studies related to microplastics that are apparently linked with freshwaters (Wagner and Lambert 2018). As per the data gathered in these limited studies, loads of microplastics in freshwaters were revealed to be comparable to or more serious than that of the marine environment (Peng et al. 2017, Wu et al. 2018). Hence, scientific knowledge on microplastics in freshwater is now being documented. Also, existing research works and methodologies on freshwater microplastics are needed to review urgently, so that suitable collection, sampling, identification, and characterization approaches can be enhanced for more future studies of freshwater samples (Li et al. 2018). More efforts should be made to monitor the microplastics in freshwater because such ecosystems can be the sources (e.g. WWTPs), transferring media (e.g. rivers), and sink (e.g. lakes) of microplastics (Klein et al. 2018) as well as the closeness of lakes and rivers to densely populated areas, where higher microplastic abundance was detected according to Eriksen et al. (2013). Filling this knowledge gap on microplastics will have implications for food safety and security since Filipinos highly depend on fish as their staple food and major source of protein (Presidential Decree No. 577 1976).

This study was conducted to increase the pool of knowledge about the presence and distribution of microplastics in the freshwater environment, specifically in Lakes Sampaloc and Yambo, two of the seven lakes of San Pablo City in the province of Laguna, Philippines. In addition to proving the assumption that there is a higher microplastic number or concentration observed in a highly-populated or urbanized freshwater ecosystem like Lake Sampaloc, this study also contributed to the meager evidence that microplastics are present even around rural freshwater ecosystems like Lake Yambo.

MATERIALS AND METHODS

This study aimed to determine the concentration, characterization, and distribution of microplastics in surface waters of Lakes Sampaloc and Yambo. Lake Sampaloc, with an area of 104 ha and a maximum depth of 27 m, is the largest among the seven lakes. This aquaculture lake is the most accessible lake for locals and tourists since it is just located near the city proper. On the other hand, Lake Yambo, known as

Pandin's twin lake, has an area of 36 ha and a maximum depth of 40 m. Based on the water quality parameters evaluated by the Laguna Lake Development Authority from 2002 to 2005, this ecotourism lake has the best water quality of all the seven lakes. The map of Lakes Sampaloc and Yambo is shown in Figure 1.

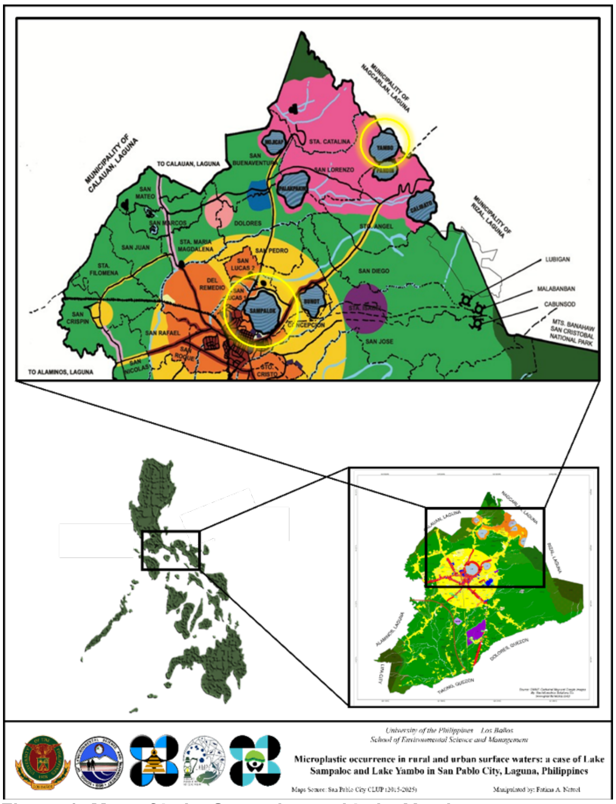

Figure 1: Map of Lake Sampaloc and Lake Yambo

Precautionary Measures

The researchers ensured that no bias or contamination would affect the results of their study by taking all necessary precautions from field sampling to laboratory analysis. Aside from having a well-maintained clean work environment and laboratory equipment, metal or glass materials instead of plastic were used and nitrile gloves and laboratory coats instead of synthetic clothing were worn throughout the entire process.

Water Sampling

Volume-reduced sampling of surface water was conducted on November 2019 in the 13 purposively selected sampling stations within each lake, of which 3 are located in the lake's limnetic zone and the rest are in its littoral section (Figs. 2 and 3). The littoral sampling sites were divided into two categories: those located near residential areas and those located near vegetation. Three duplicates of 10 L each of surface water samples were taken from each location using a metal bucket. After filtering the samples using a stainless-steel sieve with a mesh size of 63 m, a total of 39 volume-reduced duplicates from each lake were obtained. 250 mL of distilled water was used to rinse the residues into a glass jar, where they were then stored in the lab until microplastic isolation could take place.

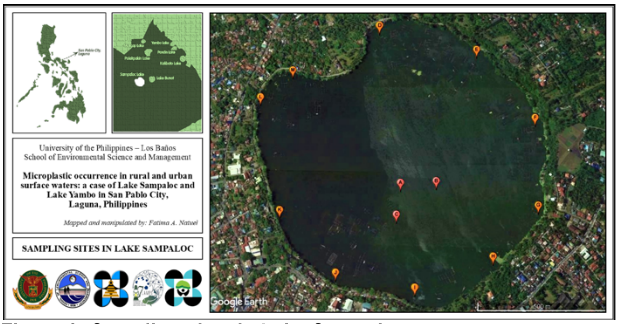

Figure 2: Sampling sites in Lake Sampaloc

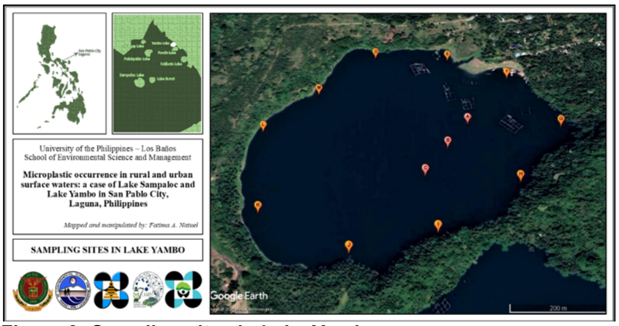

Figure 3: Sampling sites in Lake Yambo

Microplastic Isolation

Since there are no standardized methods on microplastic analysis yet (Li et al. 2018), the researcher merely adapted and modified the methods used by Wang et al. (2018) on isolating microplastics from water samples. All water samples underwent a pre-treatment procedure to aid in the oxidation of organic matter. Each sample was treated in the lab with 20 mL of 30% hydrogen peroxide at room temperature for anywhere between 12 and 48 hours. The solution was continued to be added in increments of 20 mL until no longer detectable natural organic material was present. However, throughout the microplastic isolation procedure, the researcher did not account for the necessity to filter away suspended inorganic particles, such as minerals and decomposing organic waste. Using a vacuum pump and a filter funnel holder, the solution was filtered through 1.2 µm glass microfiber filter paper (GF/C, 47 mm ø, Whatman). After that, the filter paper was dried for 24 hours in an oven at 40°C.

Microscopic Examination

After isolating the suspected microplastics, they were then subjected for optical examination using an Olympus stereomicroscope with 5 to 10x magnification. The microplastic samples collected on the filter paper were subjected to various processes. These processes included photography, documentation, counting, and measurement of their maximum length. The samples were also physically categorized using a standard developed by Hidalgo-Ruz et al. (2012). All detected plastic particles less than 5 mm in any dimension were counted and presented as particles per cubic meter of water (n/m^3) and only described in terms of size, shape, and color (Hidalgo-Ruz et al. 2012). The suspected microplastics were classified into six different size classes. Class 1 ranges from 0.06 to 0.33 mm, Class 2 from 0.34 to 1.00 mm, Class 3 from 1.01 to 2.00 mm, Class 4 from 2.01 to 3.00 mm, Class 5 from 3.01 to 4.00 mm, and Class 6 from 4.01 to 5.00 mm. These classes were established based on the size range of each particle.

As for shapes, microplastics were categorized into fragments, fibers, filaments, films, foams, and microbeads. Further, all the observed colors of microplastics were documented and photographed. The polymer or chemical characterization of the microplastics was not determined in the conduct of this study due to time constraints and unforeseen circumstances.

Data Analysis
Statistical analysis was performed using JASP Version 14.1 and Microsoft Excel. The differences of microplastic abundances among the sampling sites of the two studied lakes were analyzed using the Kruskal-Wallis test, ANOVA's non-parametric counterpart. This is because ANOVA's assumptions such as the Levene's test for equal variance and the Shapiro-Wilk test for normality were not satisfied.

RESULTS AND DISCUSSION

Microplastic Concentration
Results showed that the average microplastic concentration in Lake Sampaloc and Lake Yambo ranges from 483 to 989 n/m^3 and 344 to 789 n/m^3, respectively. As shown in Figure 4, all the sampling sites in Lake Sampaloc had higher mean concentration of microplastics than those in Lake Yambo. Lake Sampaloc, the largest and most accessible of the seven lakes, is surrounded by five barangays making it an urban body of water. Meanwhile, Lake Yambo is less populous and is surrounded by farms. Apparently, the microplastic distribution in both lakes were somehow human-related. More so, more microplastics might have been produced from the fragmentation and decay of fishing ropes and nets in Lake Sampaloc as the lake has been used as a site for extensive fisheries and aquaculture since the 1970s (Santiago et al. 2001).

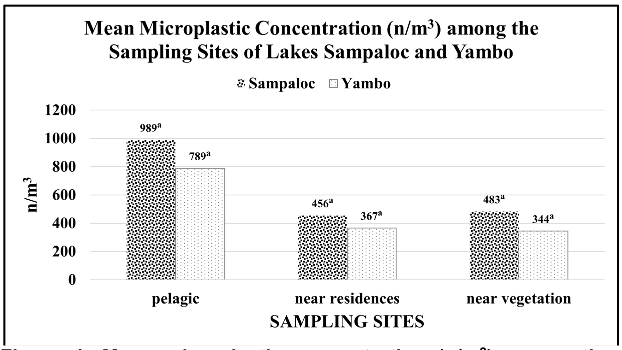

Figure 4: Mean microplastic concentration (n/m^3) among the sampling sites of Lakes Sampaloc and Yambo

The Kruskal-Wallis test was used to evaluate whether there were any statistically significant variations in the concentrations of microplastics between the sampling locations in the investigated lakes. The similar letters above the bars in the graph mean that there were no significant differences in the test results (Fig. 4). This suggests that even though the environmental factors and locations at the study sites may vary, the microplastic amounts found there were essentially the same. The result also revealed that, among the sampling sites, the limnetic portions of both the studied lakes had the highest levels of microplastics. It is interesting to see that the site closest to Lake Sampaloc's residences had the fewest microplastics. This implies that the presence and dispersion of microplastics are influenced not only by anthropogenic factors, but also by environmental factors (Dris et al. 2015, Kim et al. 2015, Veerasingam et al. 2016). According to Mehra et al. (2020), these environmental factors include runoff, infiltration, river discharge, wind action, ocean currents, cyclones, tides, turbulence, wave current, hydrodynamics, microplastic size and shape, plastic density, and dispersion or movement of animals.

Microplastic Distribution
A study by Wichmann et al. (2018) sought to understand which hydrodynamic processes greatly influence the microplastic distribution around the world. Their study supported past researches, which show that wind-driven surface currents or Ekman currents are responsible for the floating microplastic concentrations at the surface in the subtropical ocean gyres. They also found that the net drift velocity in the direction of wave propagation or Stokes drift is responsible for pushing microplastics to the Arctic region (Wichmann et al. 2018, van den Bremer and Breivek 2017). Meanwhile, the hydrodynamic processes in the lake include hydraulic effects such as inflows and outflows, vertical circulation, thermal stratification, wind shear, gyres and seiches, and turbulence (Bek et al. 2018). Any of these processes could probably be the reason why in this study, the highest microplastic concentration constituting to 51.30% and 52.60% of the total concentration was found in the limnetic part of Lake Sampaloc and Lake Yambo, respectively (Fig. 5). Furthermore, a high number of microplastic concentration ranging from 501 n/m^3 to 1,000 n/m^3 was found in the sampling sites near houses and fish cages of both lakes. As the entire 4-km surrounding of the lake is accessible to the public for recreational purposes like picnic, jogging, and biking, the tourism-related wastes like water bottles, plastic bags, and many others could end up in the lake. More so, there are several ways that plastic particles found in nearby homeowners' wastewater could end up in Lake Sampaloc, especially since the lake is adjacent to the city proper where many people are living or coming back and forth. Although Lake Yambo, on the other hand, is a sparsely populated lake, the result showed that there is a higher microplastic concentration detected in the near residences of the lake. This might be because this site is closer to the lake's most accessible gateway for both locals and tourists. Further, the lake's very few aquaculture structures are concentrated nearby this region of the lake.

Microplastic Characterization
The identified microplastics were classified into six different types based on their shapes, which included fragment, fiber, filament, film, foam, and microbead. Table 1 below shows the definitions and potential sources of microplastic types (Free et al. 2014). Also, typical photographs of the suspected microplastics under the stereomicroscope were given in Figure 6. The majority of the microplastics found in both of the investigated lakes were fibers in terms of shape type (Fig. 7). Fibers were the most prevalent and plentiful type of microplastic found in the aquatic environment, which is consistent with many researches (Mason et al. 2016, Thompson et al. 2004, Claessens et al. 2011, Stolte et al. 2015, Sutton et al. 2016). Dominance of fibrous microplastics might be associated to the breakdown of fishing ropes and nets used for various kinds of fishing methods in the lakes, especially in Lake Sampaloc. In addition, other probable sources of plastic fibers in the lake include domestic and sewage plant effluents, atmospheric deposition, agriculture, and surface runoff (Wang et al. 2017, Wang et al. 2018, Dris et al. 2015, Mason et al. 2016, Fischer et al. 2016). Filaments and films were also widely present in surface waters of both lakes.

As shown in Figure 8, the findings revealed that the majority of the microplastics identified in the two lakes were in the range of 1-2 mm, followed by 2-3 mm. The presence of microplastics with smaller sizes, less than 2 mm, implies that the breaking down of larger plastic particles into smaller fragments has been occurring in the lakes' surface waters for a significant period already. Notably, microplastics with a size of <2000 μm or 2 mm are similar in size to zooplankton, suggesting a high probability of accidental ingestion by the lake's organisms (NOAA 2015-2017).

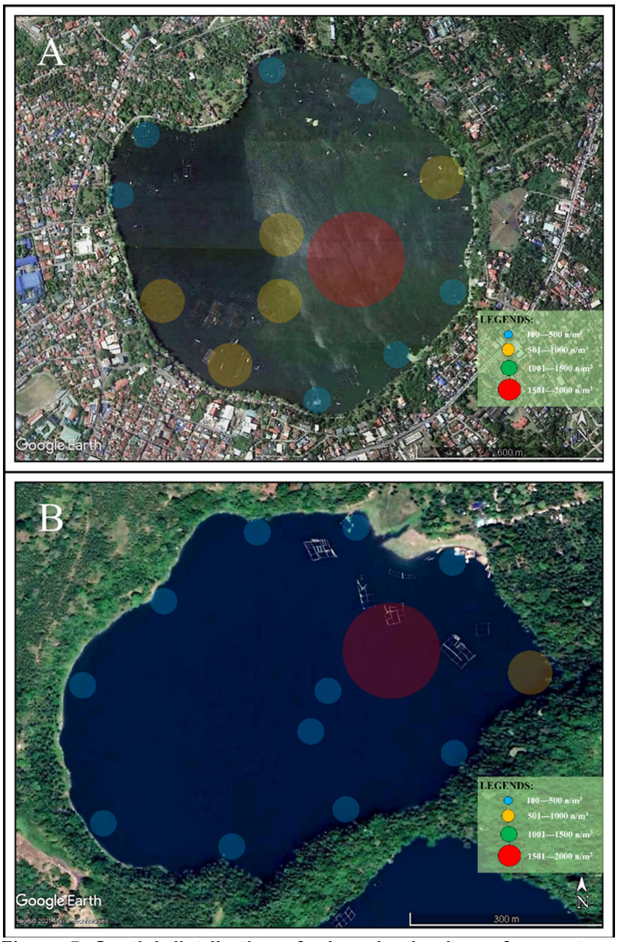

Figure 5: Spatial distribution of microplastics in surface waters of Lake Sampaloc (A) and Lake Yambo (B)

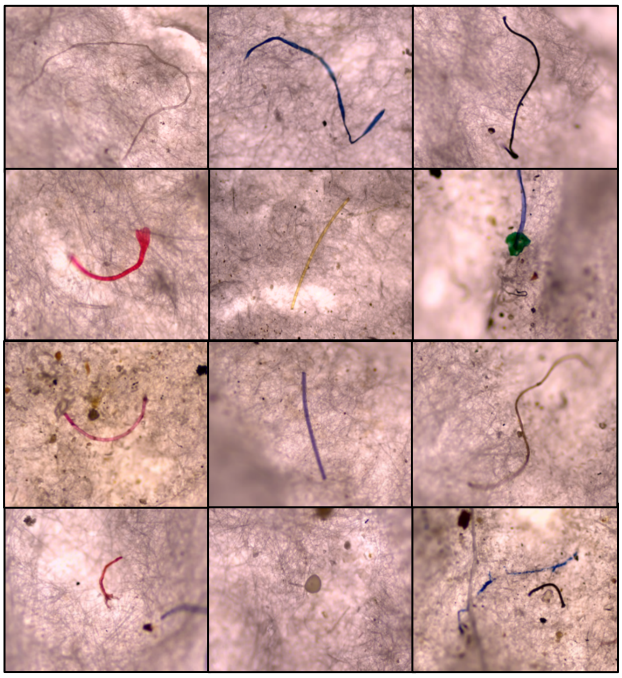

Figure 6: Sample photographs of microplastics under the stereomicroscope

Table 1: Definitions and potential sources of microplastic types

Microplastic Type	Definition	Potential Sources
fragment	hard, jagged plastic particle	bottles, hard, sturdy plastics
line (fiber, filament)	*fiber* – thin or fibrous; straight plastic *filament* – thicker type of line	fishing line/nets, clothing or textiles
film	thin plane of flimsy plastic	plastic bags, wrappers, or sheeting
foam	lightweight, sponge-like plastic	foam floats, styrofoam, cushioning
microbead	white, little squishy, rounded plastic particle	facial cleansers, toothpaste, cosmetics, exfoliants

Note: This table was adapted and modified from the study of Free et al. (2014).

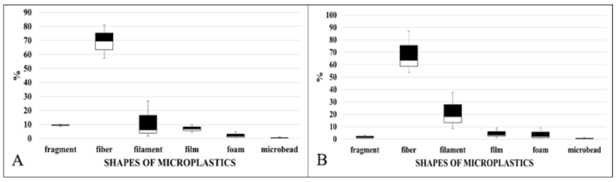

Figure 7: Microplastic concentration (%) in terms of shape between Lake Sampaloc (A) and Lake Yambo (B)

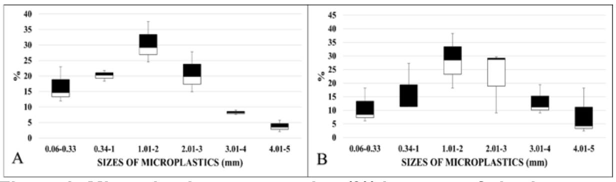

Figure 8: Microplastic concentration (%) in terms of size between Lake Sampaloc (A) and Lake Yambo (B)

As shown in Figure 9, the vibrant fisheries and aquaculture businesses, notably in Lake Sampaloc, can be connected to the occurrence of clear, blue, blue and white, and black microplastics in both lakes. Moreover, given that fishing nets and ropes are frequently translucent, black, or blue in color, this proves that fishing-related activities may add to the microplastic pollution in the lakes. Further, the community nearby Lake Yambo is fond of using rice sacks as container of their organic and domestic waste, perhaps, indicating the potential source of blue and white plastic items detected. In general, there were many other colors observed in the lakes, which might have fragmented from various colorful large plastic sources. This wide variety of colored plastic items might be attributed to the wide range of domestic and tourism-related wastes like plastic bottles, bags, rope, food packaging, and many others. Because these tiny, colored plastic particles mimic the color of their prey or food particles, aquatic creatures may perhaps unintentionally consume microplastics (Wright et al., 2013, NOAA 2015–2017).

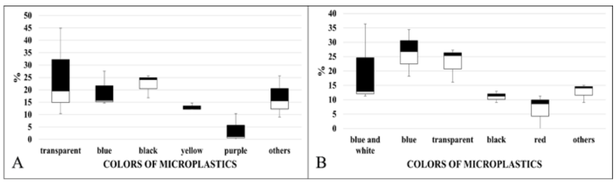

Figure 9: Microplastic concentration (%) in terms of color between Lake Sampaloc (A) and Lake Yambo (B)

CONCLUSION

Lakes Sampaloc and Yambo both play a significant role in fishery, tourism, water supply, and flood regulation of the nearby residential areas. Unfortunately, the rapid increase in the human population and their intensive activities have been exacerbating pollutions in both lakes, especially in Lake Sampaloc. This study provided researchers with baseline assessment on microplastics in surface waters of Lakes Yambo and Sampaloc for sustainable management of these lakes. The outcome of this study is a relevant contribution for decision makers or the LGU of San Pablo to make environmental policies regarding plastic waste management and disposal.

The microplastic analysis indicated that there were no significant differences in microplastic concentrations among the sampling sites in both lakes. Generally, Lake Sampaloc, an urbanized lake, had a higher mean microplastic concentration (587 n/m^3) than Lake Yambo (449 n/m^3), a rural lake. Although Lake Yambo is a sparsely populated lake, the result showed that there was a higher microplastic concentration detected in the near residences or tourists' entrance of the lake, indicating that aside from fishery activity, domestic and tourism waste could be important sources of microplastics as well. The findings showed that the main characteristics identified in the surface waters of both lakes were small-sized (<2 mm), fibrous, and colored particles. Moreover, our understanding of the pathways, fate, and distribution of microplastics is still limited despite the fast development and growing number of emerging studies onto it (Lusher 2015, Kanhai et al. 2020). Hence, this study recommends for future researchers to analyze microplastics in different sample matrix, for instance, sediment and biota of Lakes Sampaloc and Yambo, as well as the relationship of hydrodynamics with microplastic abundance and distribution.

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CONFLICT OF INTEREST

The authors declare no potential conflict of interest.

CONTRIBUTION OF INDIVIDUAL AUTHORS

The main author of this paper carried out the sampling, microplastic analysis, microplastic optical examination, and writing. All authors reviewed and approved the final manuscript.

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