Microplastic occurrence in the coastal sediments of selected barangays of Anilao, Iloilo, Philippines

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Abstract

Microplastics have been identified as a significant threat towards aquatic ecosystems and human life as they can easily be ingested due to their microscopic size. Due to this, there has been a demand to conduct research on the occurrence of the material. However, there is currently a lack of studies pertaining to the problem in the Philippines despite it being an archipelago. This paper presents the investigation of microplastic occurrence in the coastal sediments of Anilao, Iloilo, Philippines. Sediment samples were collected and were subjected to sieving, density separation, and wet peroxide oxidation for microplastic extraction. The acquired microplastics were observed under a compound inverted microscope for quantification and classification, and analyzed using ATR-FTIR spectroscopy for the identification of their chemical compositions. The study found that fibers and fragments comprise the majority of the extracted microplastics. It was also determined that a total of approximately 1 particle/g d.w., 5 particles/g d.w., and 2 particles/g d.w. constitute the sediments collected from Barangays Dangula-an, Pantalan, and San Carlos, respectively. Only two microplastic particles were successfully analyzed by FTIR and both were identified to be polyethylene.

Keywords: *microplastics, abundance, composition, fibers, fishing*

Introduction. Since the introduction of plastics in the 1860s, there has been a rapid increase in its annual production, from 1.5 million tonnes in the 1950s to an estimate of 320 million tonnes in the year 2015 [1]. Furthermore, it was discovered that approximately 8% of these materials end up in marine systems every year, leading to marine plastic pollution [2]. This is mainly attributed to the poor waste management of industrial factories, fishing activities, and discharges from residential areas transported through sewage systems and natural waterways [3].

Aside from large plastic materials, however, plastics also come in the form of small particles called microplastics, defined as plastics of size 5 mm and below [4]. Compared to plastics of larger sizes, microplastics can be ingested by a wider range of organisms, obstructing their digestive tracts, and accumulating during digestion [5]. This may then facilitate the release of toxic chemicals that they have previously acquired during their manufacture and other contaminants that may have adsorbed onto their surfaces during their stay in the environment [6].

This phenomenon may also pose great risks to humans due to their regular seafood consumption. Furthermore, the toxins that these plastics contain may include those which are fatal to human health such as carcinogens, endocrine disruptors, and neurotoxic chemicals [7].

Studies have been conducted investigating the occurrence of microplastics in various coastal areas of the world. Stolte et al. [8] examined the microplastic concentrations along the beach sediments of the German Baltic Coast, while Vianello et al. [9] observed the occurrence and spatial patterns of microplastics in the lagoon sediments of Venice, Italy. Evidence suggests that shore sediments may be considered as a representative of aquatic ecosystems as they reflect the interactions between the water and land surface, thus providing information on the transportation of pollutants in the environment [10].

Despite microplastics being one of the most persistent pollutants in coastal environments today, studies pertaining to the topic have only emerged in the last few years [3]. At present, only a few studies tackling microplastic pollution have been published in the Philippines, including that of Kalnasa et al. [11] wherein the surface sand of Macajalar Bay, Bohol, Philippines was assessed for microplastic occurrence.

According to DENR and DILG [12], 54% of all Philippine municipalities are coastal, leading to the emergence of fishing and mariculture as one of the primary sources of food and livelihood in the country. Included in these coastal municipalities is Anilao, Iloilo, a community known for its large-scale cultivation and production of various seafood such as shrimp paste, mussels, and oysters which are widely distributed to different parts of the province. Despite playing a significant role in the local seafood industry, there is still a lack of information concerning microplastic pollution in the area.

Thus, this study aimed to acquire further information on the topic by investigating three barangays of Anilao, Iloilo based on the occurrence

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of microplastics in their coastal sediments. It specifically aimed to:

(i) determine the relative abundance in percent of microplastics of each morphological type – fiber, film, fragment, and pellet;

(ii) determine the total abundance in particles/g dry weight (d.w.) of microplastics contained in the collected sediment samples;

(iii) compare the relative and total abundances of microplastics in the three barangays; and

(iv) identify the chemical composition of the extracted microplastics through Attenuated Total Reflection - Fourier Transformed Infrared (ATR-FTIR) spectroscopy.

Methods. The data gathering procedure was divided into four general steps. These include the sample collection, microplastic extraction, visual inspection, and the FTIR analysis.

Sample Collection. Anilao, Iloilo was selected as the coastal community to investigate due to its large impact on the province's seafood industry, as well as its accessibility to the researchers. Three coastal areas in the municipality, specifically Barangays Dangula-an (10°58'58.2" N 122°46'44.2" E), Pantalan (10°57'5" N 122°45'52" E), and San Carlos (10°58"48" N 122°46'42" E), were selected as sampling sites based on the fishing and mariculture activities in the areas. Three quadrats were randomly positioned along a stretch of 100 m on the high tide line of each site. Coastal sediments were collected to a depth of approximately 2 cm from the surface. The samples were properly stored and transported to the Philippine Science High School – Western Visayas Campus' (PSHS-WVC) research laboratory immediately after collection.

Extraction. The sediment samples were oven-dried at 60°C for 48 h. They were then passed through a stack of 4 mm and 2 mm sieves. The retained fraction on both sieves were properly disposed while those which passed through were temporarily stored for further processing.

Sieved samples of mass 500 g were mixed with 2000 mL of saturated NaCl solution. The mixture was stirred for five minutes and was allowed to stand for an hour. The top layer of the mixture was filtered with Whatman No. 41 filter paper and was then oven-dried at 50°C for 48 h.

The dried particles were then treated with 20 mL of 30% hydrogen peroxide and incubated at 60°C for 24 h. The treatment setup was filtered, and the acquired particles were oven-dried at 50°C for 48 h. The dried samples were transferred into a glass petri dish for storage.

Visual Inspection. The microplastics of size ≤2 mm acquired after the extraction process were inspected using a compound inverted microscope at 40x magnification. Microplastics were identified based on the criteria presented by Norén [13]. They were also classified into four types namely fiber, film, fragment, and pellet based on the criteria provided by Free et al. [14] and Frias et al. [15]. The microplastics were manually counted to determine their total and relative abundances.

FTIR Analysis. Petri dishes containing the obtained microplastics of size ≤2 mm from each sampling location were sent to Advanced Device and Materials Testing Laboratory (ADMATEL) in Taguig City, Metro Manila for analysis. The Perkin Elmer FTIR Spectrometer Frontier ATR-FTIR model was used to determine the chemical composition of the identified microplastics. One representative microplastic piece from each sample was selected and subjected to the analysis. The instrument was set to reflection mode with a 4000-600 cm^{-1} range with 20 scans at 8 cm^{-1} resolution. A spectra library linked to the ATR-FTIR was used to determine the identity of the acquired sample spectra.

Calculations. Relative abundance is defined as the amount of microplastics for each morphological type relative to the total amount of microplastics present in each sediment sample in percent. The relative abundance of microplastics per morphological type was computed using the equation below.

$$Abundance_{Relative} = \frac{no.\,of\ microplastics\ (based\ on\ type)}{total\ no.\,of\ microplastics} \times 100\%$$

Total abundance refers to the total amount of microplastics extracted from each sampling site. The total abundance of microplastics per sample was computed using the following equation.

$$Abundance_{Total} = \frac{no.\,of\ microplastics\ (particles)}{mass\ of\ treated\ sediment\ sample\ (g\ d.w.)}$$

Results and Discussion. The results and discussion of the study is divided into three sections, specifically relative abundance, total abundance, and chemical composition.

Relative Abundance. In Barangays Dangula-an and San Carlos, fiber was found to be the most abundant type of microplastic, followed by fragments, and lastly, films. Meanwhile, fragments constitute the highest percentage of the total abundance in Barangay Pantalan, as shown in Figure 1. This is then followed by fibers and films, respectively. Little to no amount of pellets was found from all sampling locations.

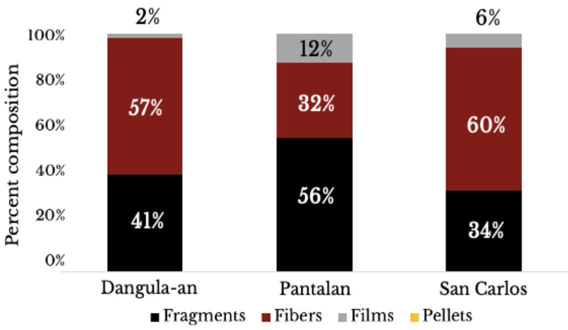

Figure 1. The relative abundances (%) of microplastics in the barangays.

Microfibers in marine ecosystems may come from various sources such as the breakdown of fishing ropes and/or nets caused by ocean currents and exposure to UV-B light, and frequent anthropogenic activities such as the washing of textiles [16,17]. Meanwhile, fragments may result from the degradation of plastic bottles and other sturdy plastics from nearby households [18]. The presence of films is mainly attributed to the breakdown of plastic bags, wrappers, and sheeting carried off from residences near the coastal areas [14]. Unlike fibers, fragments, and films, micro-pellets are directly manufactured in microscopic sizes. They are usually found in cleaning and cosmetic products [19].

From these information, it is deduced that the active fishing and mariculture activities in the coastal areas may have resulted to the detected high microfiber abundance. Meanwhile, as fragments and films mostly originate from plastics used in households, the large number of residences in Barangay Pantalan may have attributed to fibers and films comprising a higher percentage of the total microplastic abundance in the area compared to that of the other two sampling sites. Additionally, the data also suggests that plastics carried off from these households constitute more of hard, sturdy plastics compared to thin, flimsy ones as films account for a smaller portion of the total abundance than fragments. Lastly, the trace amount of pellets in all sampling sites suggests that only a small portion of the microplastics originated from cleaning and cosmetic products.

Total Abundance. The study shows that Barangay Pantalan has the greatest number of microplastics with 5 particles/g d.w., followed by Barangay San Carlos with 2 particles/g d.w., and Barangay Dangula-an with 1 particle/g d.w., as shown in Figure 2.

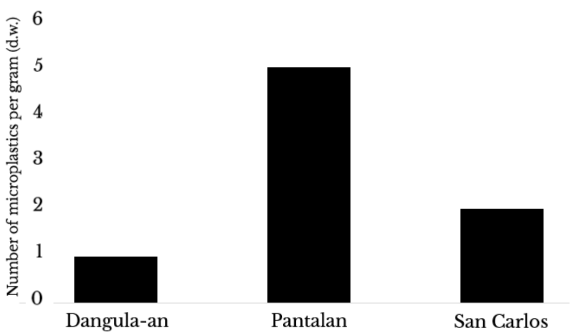

Figure 2. The total abundance (particles/g d.w.) of microplastics in the barangays.

Barangay Pantalan was determined to have the most number of microplastics among the three sampling sites. In accordance with the study of Brown et al. [18], wherein it was stated that population density may be a potential factor affecting microplastic abundance, Barangay Pantalan also has the largest population residing near its coastal area, with a total of 22 households compared to only 3-4 households each in Barangays Dangula-an and San Carlos. This may have resulted to higher amounts of plastic waste carried off from the residences in Barangay Pantalan in comparison to the other two.

Based on the coastal activity survey conducted by the researchers, all three sampling sites are in close proximity with rivers and fishing facilities, but only Barangays Pantalan and San Carlos are located near sewage inputs. The study by Brown et al. [18] states that sewage is one of the most prevalent sources of microplastic pollution, thus supporting the detection of larger amounts of microplastics in the two sites compared to Barangay Dangula-an.

Aside from these, the large amount of microplastics may have also resulted from the transport of plastic waste to the sampling sites from different areas through water circulation [20]. According to the barangay officials, the sites serve as “catch basins” of interconnecting rivers, serving as transport pathways of debris from a nearby municipality, Banate, Iloilo, and three other provinces, Negros, Guimaras, and Cebu. In relation to this, Claessens et al. [21] and Faure et al. [22] also reported that high microplastic concentrations are attributed to the discharge of rivers potentially containing microplastics to larger bodies of water.

Another notable mechanism for the transport of microplastics to the coastal environment are the monsoons. Frequent heavy and prolonged downpour during the monsoon season in urban areas causes plastic litter to be washed down in storm drains, flowing into the rivers and seas [23]. In this study, the sediment samples were collected outside the monsoon season of the particular area of study. However, it is still possible that the microplastics found in the coastal sediments of the barangays were previously transported through this natural phenomenon.

Chemical composition. The chemical composition of two microplastic particles, with one acquired from Barangay San Carlos and one from Barangay Pantalan, were determined through analysis using an ATR-FTIR spectrophotometer. The infrared vibration spectra acquired from the spectroscopy presented the peaks exhibited by both materials. Five peak assignments of the analyzed sample from both locations matched with the polyethylene standard supported by Table 1, as shown below.

Table 1. Peak assignments in the infrared spectrum of microplastic samples from Barangay San Carlos (Sample 1) and Barangay Pantalan (Sample 3).

Wavenumber (cm^{-1})			Bonds*
Polyethylene Standard	SAMPLE 1	SAMPLE 3	
2916	2916.61	2916.06	C – H Anti-symmetric Stretching
2849	2849.52	2848.61	C – H Symmetric Stretching
1472	1471.57	1470.31	C – H Deformation/ Bending
-	-	1375.79	
730	730.24	730.23	C – C Skeletal Bending
719	717.27	716.98	

* References: [1] Spectrum Search Plus Library, Perkin Elmer. [2] Pretsch, E., et al. (2009), Structure Determination of Organic Compounds, 4th Ed., Springer – Verlag Berlin Heidelberg.

Polyethylene can be further classified into two structural isomeric polymers namely low-density polyethylene (LDPE) and high-density polyethylene (HDPE) [24]. According to the criteria proposed by Jung et al. [24], an LDPE infrared spectrum can be differentiated from that of an HDPE with the peak it exhibits at 1377 cm^{-1}. Thus, from the provided peaks in Table 1, sample 3 from Barangay Pantalan can be classified as LDPE with the distinct peak it forms at 1375.79 cm^{-1}. Sample 1, on the other hand, is identified as HDPE due to the absence of the said peak.

Globally, polyethylene is one of the most common polymer types found in coastal environments [25]. Potential sources of LDPE microplastics include plastic bags, plastic bottles, and fishing nets while HDPE ones may be sourced from milk jugs [19]. Additionally, Andrady [19] reported that 18% of marine debris comes from fishing ropes and nets commonly composed of polyethylene, polypropylene, and nylon. Thus, the analyzed microplastics may be primarily attributed to the fishing ropes and nets used in the mariculture activities in the coastal areas, as well as plastic containers utilized in nearby residences.

Limitations. The microplastics included in the study were limited to those of size ranging from 20 μm to 2 mm which are the grid sizes of the utilized filter paper and sieve, respectively. Additionally, only microplastics of density lesser than 1.2 g/cm^3, the density of the saturated salt solution used in the density separation method, were included in the scope of the study. It should also be considered that the possible sticking of microplastics onto the filter papers might have caused some particles to not be taken into account.

Furthermore, only an ATR-FTIR equipment, an apparatus that requires the manual handling of samples, was utilized for the chemical composition analysis of the microplastics. Hence, due to the absence of a microplastic particle from the Barangay Dangula-an sample that can be manually handled, no microplastic piece from its coastal area was analyzed for chemical composition.

As the researchers were unable to conduct an in-depth study on the water circulation flow in the areas, no concrete report can be made with regards to the different areas contributing to the microplastic abundance in the sampling sites. The study is also unable to conclude whether the total abundance values for each barangay can be considered as pollution as no standard criteria are available regarding this matter.

Conclusion. Microplastics were confirmed to be present in the coastal areas of the three barangays. They were found to be abundant in various morphological types, with fibers and fragments accounting for the majority of the total abundances. Among the three sampling sites, Barangay Pantalan was determined to have the most number of microplastics. Due to resource limitations, only two microplastic pieces were analyzed through FTIR analysis, and both were identified to be polyethylene. The results of this study may be used in the making of policies for the protection of seafood consumers and as a baseline for more in-depth research on microplastics.

Recommendations. In order to improve the entirety of the study and provide more accurate results, it is recommended that a more appropriate tool, specifically corers, will be utilized in the collection of coastal sediments. It is also suggested that a more appropriate equipment, specifically a micro-FTIR, will be utilized for the visual identification and chemical composition analysis of microplastics. Furthermore, subjecting a greater amount of sediments with sizes less than 2 mm to density separation is also recommended. Utilizing a saturated NaCl solution of higher purity for the density separation process may also help in improving the results of the study. Lastly, in order to assure the digestion of most or all biological matter in the samples, it is also suggested that wet peroxide oxidation will be conducted twice or will be replaced with a more efficient method.

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