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Suspended Microplastic in Sorsogon Bay Attributing *Perna viridis* and *Atrina pectinata* Contamination

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Abstract

Marine microplastic pollution is becoming more visible and pervasive in various aquatic environments and species, including those intended for human consumption. The present study evaluated the occurrence of suspended microplastics in surface waters, the water column, and bivalves, such as *Perna viridis* and *Atrina pectinata* in Sorsogon bay. Microplastics were detected in all sampling sites and bivalve tissue samples. Surface water (0 m) and water column (5 m) samples taken from six sampling stations representing spatial consideration of the bay showed an average of 5.55 ± 1.74 items/m^3 (range: 2.27 - 1.66 items/m^3) and 5.80 ± 1.94 items/m^3 (range: 1.93 - 14.55 items/m^3), respectively. The mean microplastic number in farmed mussels and wild pen shells collected around the bay varied from 0.31 - 2.50 items/individual for mussels and 0.93 - 4.27 items/individual for pen shells. FTIR spectroscopy revealed that microplastics made up 55% of the debris analyzed, with an additional 45% natural materials, including aluminum silicate, cellulose, and chitin. It is becoming increasingly evident that Sorsogon Bay is not exempt from this paradigm. Hopefully, this will drive the community to support measures to address this issue, such as social perception and behavioral change.

Keywords

Microplastic, Seawater, Bivalve Tissues, FTIR, Philippines

1. Introduction

It has been shown that the Philippines is one of the top contributors of marine plastics to the environment (0.28 - 0.75 million metric tons per year) [1] [2].

Marine plastics are increasingly being recognized as having a significant impact on the degradation of the marine and coastal ecosystems, including adverse effects on biodiversity and ecosystem functioning, resilience, and contribution to socio-economic well-being [3]. Although it is now a global challenge, there is a startling lack of published scientific literature on marine plastic in the country [4]. The majority of the available literature is from reports, with only three peer-reviewed publications on Litterbase [5] [6] [7] from the Philippines [8] and others stating the presence of marine plastic [9] [10] but not directly focussing on the problem, as cited by Abreo [4].

The surface ocean is probably the best sampled of the ocean compartments because it has significantly higher concentrations of microplastics (MPs) than the underlying layers [11], which can be re-dispersed or transported to any of the other four ocean compartments: water column, seafloor, shoreline, and biota.

The bioavailability of marine organisms is one of the primary environmental risks associated with microplastics [12] [13]. Because of their extensive filter-feeding activity, bivalves are of particular interest since they are directly exposed to microplastics in the water column. Microplastics can even be passed down the food chain from mussels to crabs, increasing the concern of microplastics reaching higher trophic levels, including humans [14] [15].

Microplastic monitoring has already been focused on surface accumulations surrounding emission sources [13]. However, because microplastics behave dynamically, fluctuate, and are vertically distributed in water, water column samples were evaluated to provide a supplemental comparison on the microplastics found on the Bay's surface water. The bathymetry of the bay is shallow, with a maximum depth of only nine meters (9 m), while the narrow mouth widens up to depths of 25 meters (m). As a result, the five-meter (5 m) water column potentially supports a representative of midwater. Seawater outside the bay exchanges once a week, with an average residence length of approximately three months. As a result, extrinsic water inputs have less of an effect on bay microplastic detection. Providing generic microplastic structure and residency from several spatially identified point sources.

Microplastic in biota is being studied in the same way that seawater samples are. Bivalves, which are abundant in the municipalities of Sorsogon Bay, are also popular seafood. Seafood-lovers who eat all of the soft parts of bivalves may be at risk of potential health complications if they consume microplastic-polluted bivalves [16]. Microplastic detection was tested on both cultured and wild bivalves from Sorsogon Bay. Green mussels, which are traditionally cultured in Sorsogon Bay with stakes, are hung in the water column. It is also hypothesized that the results will be equivalent to the suspended microplastic in the bay's surface water and water column. While wild pen shell is a bottom dweller organism, with its ventral section exposed to the current, it may be contaminated with settleable microplastics. As a result, both biota representatives can reflect a diverse range

of microplastic inferences.

Thus, the present study was conducted to investigate the abundance and characteristics of microplastics in the seawater (surface water and water column) and in the biota (*Perna viridis* and *Atrina pectinata*), to distinguish the differences in microplastic pollution between these environmental compartments, and to provide implications for the existing marine microplastic pollution in the bay.

2. Methodology

2.1. Sample Collection

The present study was carried out at Sorsogon Bay. To provide a comprehensive picture of the bay, farmed *P. viridis* and wild *A. pectinata* were collected from three different sites along the coastal water of Sorsogon Bay from January to March 2021. These bivalves are sorted into various "grading" labels: with sizes, small (5.0 - 6.9 cm), medium (7.0 - 8.9 cm), and jumbo (≥9.0 cm) for green mussel; and small (<14 cm) medium (14 - 22 cm) and big (22 cm) for pen shell. It is primarily exported outside the province, with the rest of its production is consumed locally. With smaller sizes also sold to fishpond owners as trash feed for their mangrove crab culture and to fisherman as bait. Thirty individuals per size category were collected for the biota samples (mussel, n = 150 and pen shell, n = 90) (Table 1 and Table 2).

For environmental samples, six sampling stations were identified representing spatial considerations of the bay, including 1) outside the bay, 2) along with the mouth of the bay, 3) significant river outflows, 4) potential land-based source with high population density, 5) occurrence of vulnerable or sensitive habitat, such as estuary area, and 6) on the central bay (Table 3).

Table 1. Length and weight and microplastic abundance in *P. viridis*.

Class size (cm)	Market category	Number of individuals	Shell length (cm)	*Soft tissue weight* (*g*/*ind*)	*Items*/*individual*	*Number of items*/$g_{wet\ weight}$
<2.9	Trash feed	30	2.37 ± 0.07	0.37 ± 0.03	0.31 ± 0.03	0.84 ± 0.16
3.0 - 4.9	Trash feed	30	3.99 ± 0.09	2.02 ± 0.17	2.08 ± 0.29	1.14 ± 0.26
5.0 - 6.9	Small	30	5.66 ± 0.11	4.58 ± 0.32	2.50 ± 0.35	0.42 ± 0.06
7.0 - 8.9	Medium	30	7.27 ± 0.07	6.45 ± 0.30	1.97 ± 0.29	0.28 ± 0.04
>9.0	Jumbo	30	9.39 ± 0.06	9.85 ± 0.12	2.33 ± 0.39	0.23 ± 0.04

Table 2. Length and weight and microplastic abundance in *A. pectinata*.

Class size (cm)	Market category	Number of individuals	Shell length (cm)	*Soft tissue weight* (*g*/*ind*)	*Items*/*individual*	*Number of items*/$g_{wet\ weight}$
<14.51	Small	30	13.90 ± 0.09	28.10 ± 0.89	0.93 ± 0.21	0.03 ± 0.00
14.51 - 22.24	Medium	30	19.78 ± 0.31	44.51 ± 1.66	2.37 ± 0.76	0.06 ± 0.02
>22.24	Jumbo	30	28.03 ± 0.46	76.36 ± 3.02	4.27 ± 1.27	0.06 ± 0.01

Table 3. The list of the sampling stations used for data collection in the present study.

Station	Ocean compartment	Location	Volume sampled (m^3)	*Mean plastic item*/m^3
Outside the bay	Surface water	12˚49'44"N 123˚47'9"E	51.92	02.27
	Water Column		64.13	02.18
The mouth of the bay	Surface water	12˚52'12"N 123˚49'40"E	49.05	03.02
	Water Column		63.28	03.57
Major river mouth	Surface water	12˚56'27"N 123˚53'14"E	28.77	03.02
	Water Column		37.11	05.04
Urban proper	Surface water	12˚57'11"N 123˚58'58"E	40.54	02.98
	Water Column		52.24	01.93
Major estuary area	Surface water	12˚52'10"N 123˚53'60"E	10.63	11.66
	Water Column		13.41	07.53
Central bay	Surface water	12˚55'17" N 123˚56'22"E	11.39	10.36
	Water Column		14.71	14.55

During the same low tide, the sampling was carried out on January 25-26, 2021 (**Figure 1**). To obtain comparable results, conditions that are highly abundant like strong winds, waves, or plankton were avoided during the sampling.

Surface water samples were collected using a nueston net with a 30 × 35 cm^2 opening and 333 μm mesh size [17]. The net was towed along the surface layer at a nominal of 2 knots (average 1.90 knots) for 10 - 15 min towed off the vessel's port side to avoid disturbance by the tow wave. Water column samples were collected using horizontally hauled plankton net 26 cm Ø at 5 meters depth for 10 - 15 min at a speed of 1.5 - 2.0 knots (average 1.83 knots) depending on the sea condition. Contents were washed into a sample jar and were fixed in a 5% buffered formalin solution.

2.2. Hydrogen Peroxide (H_2O_2) Treatment of Soft Tissue and Seawater

The mussel tissues were extracted using the already reported method [18]. Briefly, the shell length and weight of each bivalve were measured and recorded. Following this, the soft tissues of mussels were subjected to wet peroxide oxidation (WPO) using 30% H_2O_2. The bottles were covered and incubated in a drying oven maintained at 65˚C for 24 h and then at room temperature for 24 - 48 h to ensure complete digestion of the soft tissue. The digestion was confirmed once the bottle contents appeared clear with no noticeable/visible particles.

The seawater samples were filtered with a 5 mm pore size stainless steel sieve. The sieves were rinsed thoroughly using a squirt bottle with distilled water to transfer all residual solids to the sieves and remove salts from the field sample. All materials retained on a 5 mm sieve were discarded. The collected material was carefully transferred into a 500 ml beaker and dried at over 90˚C for 24

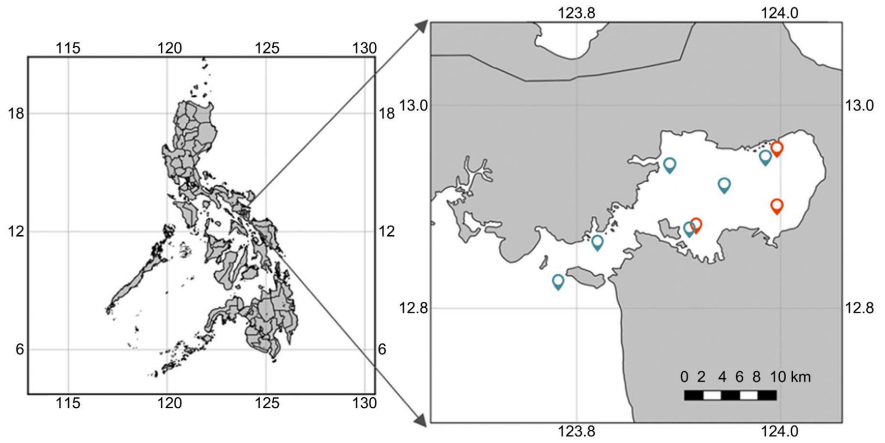

Figure 1. Sorsogon Bay is located within the Philippines and zoomed in showing the sampling sites: seawater samples (blue marker) and bivalve collection sites (orange marker).

hours. The samples were subjected to WPO to remove the organic matter. A total of 20 mL of aqueous 0.05 M Fe(II) solution was poured into the beaker containing 20 mL of 30% H_2O_2 and were stirred for 30 minutes on a hotplate at a temperature of 75˚C. When required, more than 30% H_2O_2 was added to the beaker til no natural organic material was visible.

To avoid contamination, all of the liquids (*i.e.*, freshwater, saltwater, and H_2O_2) were filtered using qualitative grade 1 filter paper before use. All of the containers and beakers were rinsed three times with filtered water. The samples were immediately covered if they were not in use.

2.3. Density-Separation and Filtration with Saline (NaCl) Solution

A concentrated saline solution was used to isolate microplastics and other anthropogenic debris from the dissolved liquid of the samples via density separation. To make float the microplastic, approximately 6 g of table salt (NaCl) per 20 mL of sample were added to the beaker to enhance the density of the aqueous solution (~5 M NaCl). The samples were heated to 75˚C til all the added salt get dissolved. Following this, the WPO solution was transferred to a density separator, and the solids were allowed to settle overnight. Settled solids were drained, and floating plastic was filtered using a glass microfiber filter (pore size = 1.2 µm, diameter = 90 mm, GF/C Whatman) under vacuum. The filters were then was transferred to clean petri dishes and covered till further analysis.

2.4. Observation of Microplastics and Validation of Microplastics and Other Anthropogenic Debris

The filters were observed under a stereomicroscope, and digital inspection microscope powered by Proview v.4.815674.20191008 for imaging, particle size, and shape determination and quantification. Colors were identified using Colors exe software [19], adopting the 12 basic color terms of the ISCC-NBS (Inter-Society Color Council National Bureau of Standards) System of Color De-

signation as recommended by GESAMP [20]. A proportion of 10% from all of the samples visually examined was validated by attenuated total reflectance-fourier transform infrared spectroscopy (ATR-FTIR), Perkin Elmer FT-IR Spectrometer Frontier)).

2.5. Statistical Analysis

All the obtained results were statistically analyzed for normality using Statistical Package for the Social Sciences (SPSS version 25.0) at a confidence level of 95% ($p = 0.05$). The shell length (cm), shell weight (g), and soft tissue weight (g) were presented as mean ± standard error (SE). Any differences in the abundance of total microplastics in bivalve tissue samples were determined using One-Way ANOVA with a post hoc Tukey test. In contrast, the Kruskal-Wallis test was used in seawater samples. A Chi-square Test was used to determine the relationship of microplastic characteristics (size, shape, and color) between the *P. viridis* and *A. pectinata* and between the surface water samples and water column samples. A multiple regression analysis was employed to determine the relationship between seawater and tissue levels of microplastics.

3. Results

3.1. The Abundance of Microplastic in Water Samples and Bivalve Tissues

Microplastic items were observed in all collected seawater samples of all sampling stations and the tissue collected from bivalves. The average microplastics density in surface water was found to be 5.55 ± 1.74 items/m^3, ranging from 2.27 items/m^3 to 11.66 items/m^3. In contrast, the average density of microplastic in the water column was found to be 5.80 ± 1.94 items/m^3, ranging from 1.93 items/m^3 to 14.55 items/m^3. The highest microplastic density was found in the significant estuary area (11.66 items/m^3) in surface water. In contrast, the highest density was detected in the central bay (14.55 items/m^3) in the water column. Furthermore, there were no significant differences in terms of the density of items collected from different stations, both for surface water (Kruskal-Wallis test, $p = 0.416 < 0.05$) and water column (Kruskal-Wallis test, $p = 0.416 < 0.05$) (**Figure 2**).

The mean microplastics per class size ranged from 0.31 to 2.50 items/individual in mussels. Mussels with a size range of 5.0 - 6.9 cm had the highest mean detected microplastics (2.50 items/ individual), while mussels with a sizes range of less than 2.9 cm had the least (0.31 item/individual). Whereas, the mean microplastics per class size ranged from 0.93 to 4.27 items/individual in the pen shell. Pen shells larger than 22.24 cm had the highest mean microplastics (4.27 items/individual), whereas those smaller than 14.51 cm had the least (0.93 item/individual). The statistical analysis revealed no significant differences in the number of items per individual across the class sizes of green mussel $F(4, 91) = 0.954$, $p = 0.437$ but not with the pen shell $F(4, 91) = 28.651$, $p \leq 0.001$. In addition,

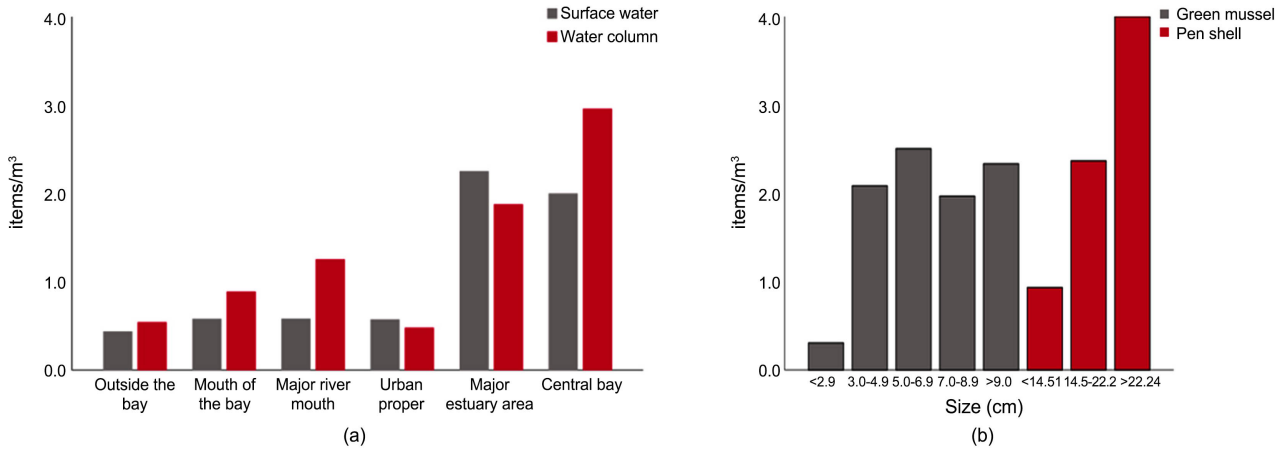

Figure 2. Mean abundance of microplastics in (a) surface waters and in (b) bivalve tissues.

Tukey post hoc analysis displayed that the microplastic item in pen shell was significantly lower in class sizes 14.51 - 22.24 cm (2.36 ± 0.76 items/ind, p = 0.015), class size < 14.51 cm (0.93 ± 0.21 items/ind, $p \leq 0.001$) in comparison to class size > 22.24 cm (4.27 ± 1.27 item/ind, $p = 0.005$).

Multiple-regression analysis found no relationship on the detected microplastic both in green mussel to surface water and water column microplastics $F(2, 3) = 1.055$, $p < 0.0005$, $R^2 = 0.413$ and in pen shell to surface water and water column microplastics $F(2, 3) = 1.516$, $p < 0.0005$, $R^2 = 0.503$.

3.2. Microplastic Characteristics in Water Samples and Bivalve Tissues

Multiple kinds of microplastic were found in seawater and bivalve tissue samples, including fragments, foams, films, lines, and pellets. Lines or fibers were the most common type of microplastic detected in surface water (ranging from 20% to 80%) and water column (ranging from 36% to 73%), followed by fragments (between 11% to 33% in surface water and 2% to 51% in the water column). Lines were also prevalent in the green mussel, ranging from 57% to 100%, but not in pen shell, where films predominated, with 28% to 42%. Pellets were the least common shape observed in the seawater samples and bivalves.

Diverse colors were observed both in seawater samples and bivalve samples. In the surface water and water column, the blue (26.4%; 27.9%), green (24.0%; 26.6%) and yellow (15.7%; 12.4%) were the most popular colors. Among bivalves, green mussels had a high percentage of blue (40.4%) and clear (15.6%), while pen shells had an overall percentage of clear (37.9%) and white (20.3%).

The size of microplastic items ranged from 100 μm to 5 mm in both seawater and bivalve samples. The most common microplastics sizes were 500 μm in green mussel (26%), 5 mm in pen shell (75%), 5 mm in surface (36%), and also 5 mm in the water column (33%). Compared to the pen shell and the seawater samples, mussel tissues contained a relatively high proportion of smaller-sized items (Figure 3).

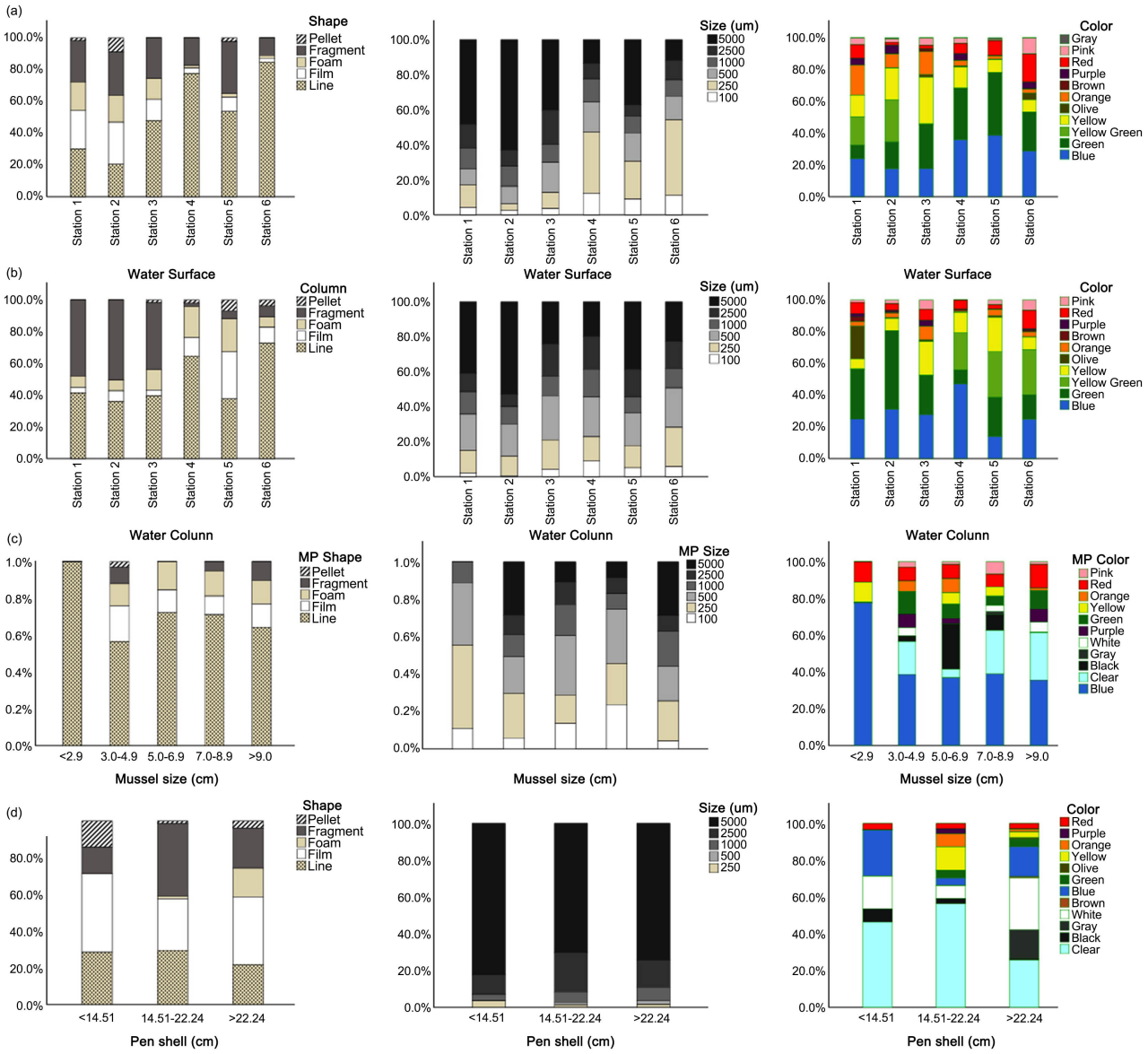

Figure 3. Characteristics of microplastic in terms of shape, size, and color found in (a) surface waters, (b) water column, (c) green mussel, and (d) pen shell in Sorsogon Bay.

3.3. Composition of Microplastics in Water Samples and Bivalve Tissues

Of the debris items isolated on filters, ~10% of these (mostly of dominant shapes to reflect the overall pattern of the debris item) were randomly selected from all the filters analyzed. Of these, 55% were identified by ATR-FTIR within a spectrum range of 4000 - 600 cm^{-1}. Half of these were confirmed to have microplastics, including polyethylene, polyethylene terephthalate (PET) or polyester, polystyrene, and thermo polyurethane. Polyethylene was found mainly in the pen shell, PET in surface waters and green mussels, polystyrene in the surface waters, and thermo polyurethane in the water column. Among the other debris item, organosiloxanes was found in green mussels, and aluminum silicate was observed

in pen shells. An additional 45% of debris items were made up of chitin and cellulose, which were considered to be naturally occurring (Figure 4).

4. Discussion

In the present study, we examined the occurrence of microplastic debris in the surface water, water column, pen shell, and green mussels in Sorsogon Bay. The results revealed that microplastic contamination is widespread in seawater and commercially available bivalve species in Sorsogon Bay.

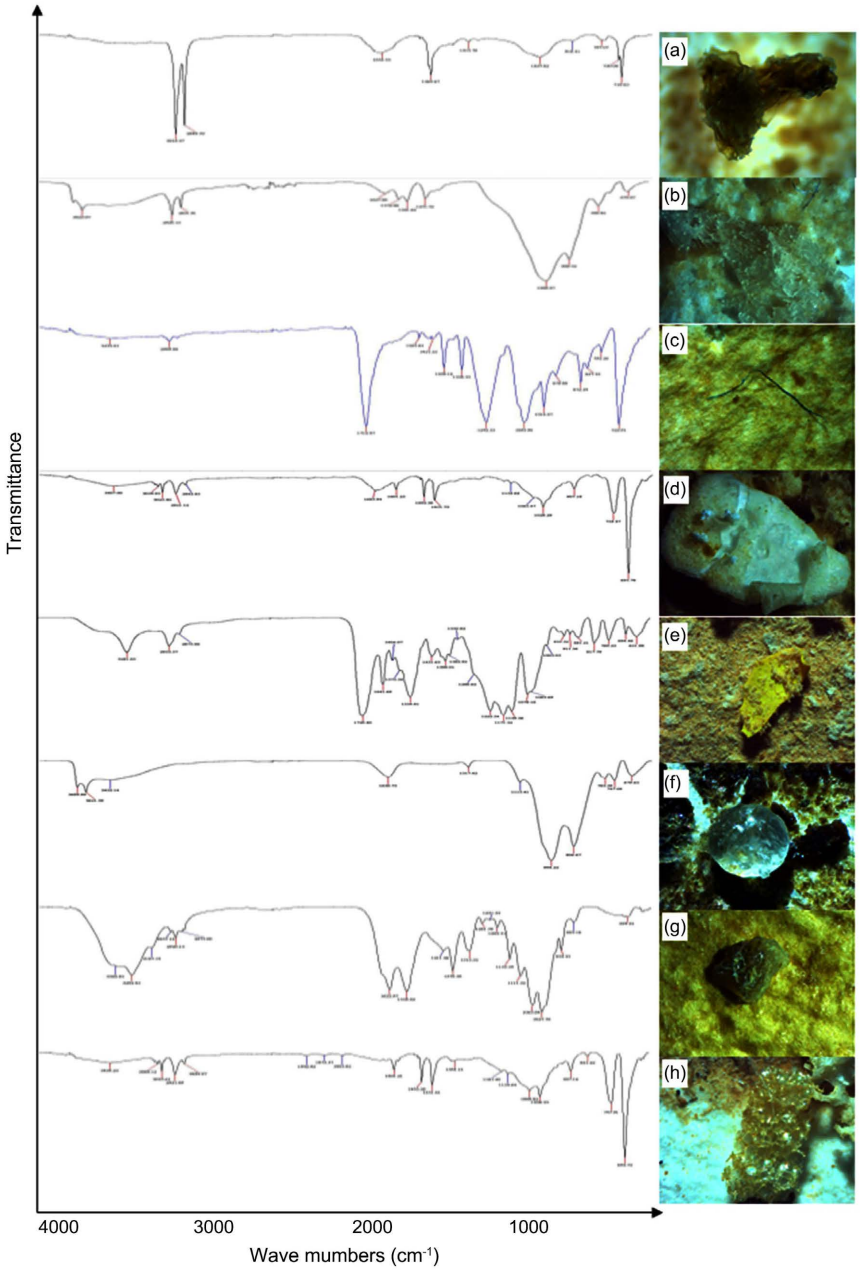

Figure 4. Light microscope images and IR spectra of the most frequently observed microparticles: (a) polyethylene, (b) organosiloxane, (c) polyethylene terephthalate, (d) polystyrene, (e) thermo polyurethane, (f) aluminum silicate, (g) chitin, and (h) cellulose.

4.1. Microplastics and Other Anthropogenic Debris in Seawater

There are spatial differences in the extent of debris items on seawater sampling stations. The microplastic abundances found in this study are comparable to those found in the previous studies [21] [22] [23] [24]. The seawater values ranged from 2.98 - 11.65 items/m^3, which is the middle of local and international studies. These results are consistent with the water column values that ranged from 1.93 - 14.54 items/m^3 (**Table 1**). This may be due to genuine spatial differences.

Furthermore, in the present study, we did not observe a correlation between the seawater and the bivalve tissues levels (**Figure 2**). Browne, Dissanayake *et al.* 2008 suggested that smaller polystyrene particles translocate more readily in mussels than larger polystyrene particles [25]. Our results showed that mussels contained more of the smaller sizes of microplastic (37%, less than 250 μm) compared to surface waters and water column, which had 28% and 19%, respectively (**Figure 3**), which are consistent with the previous findings [25].

In terms of debris items found in surface waters and water columns, fibers were the most predominant type, which is consistent with the local studies [26] ASEAN countries [21] [22] [24] [26] [27] and international studies [28] [29] (**Table 4**).

Material analysis showed that polyethylene (PE), polystyrene (PS), polyethylene terephthalate (PET) are the prevalent polymer items in the seawater, which is comparable to previous studies [30] [31]. These plastics, along with polypropylene (PP) and polyvinyl chloride (PVC), constitute approximately 90% of worldwide plastic production [32].

Table 4. Microplastic pollution in bivalves in the present study compared to previous studies.

Country	Microplastic concentration	Size range	Depth (m)	Microplastic category	Polymer type	References
Sorsogon Philippines	5.55 items/m^3	>100 μm	0	Line, fragment	PS, PE, PET	This study
Sorsogon Philippines	5.80 items/m^3	>100 μm	5	Line, fragment	Thermo Polyurethane, PS	This study
Oslob, Cebu Philippines	5.83 items/m^3	>160 μm	1	Fragments, fiber	PP, PEST, PA	Yong *et al.*, 2021 [26]
Roxas, Palawan Philippines	3.48 items/m^3	>1.8 mm	NA	Fiber, fragment, film	NA	de Castro 2021 [23]
Riau Island Province Indonesia	0.45 items/m^3	>100 μm	0	Fragment, fiber, film, granules	PP, PE, LDPE, PS	Syakti *et al.* (2018) [24]
Semarang Indonesia	0.90 - 11.10 items/m^3	>1 μm	NA	Fiber, filament	PP	Khoironi *et al.* (2020) [22]
East Nusa, Tenggra Indonesia	0.00 - 120.00 items/m^3	>300 μm	5, 50, 100, 300	Fiber, granule	PE, PP, PS, PA	Cordova and Hernawan (2018) [21]

PET and cellulose lines are also commonly used in everyday life. Laundry activity or clothe-derived MPs, which are directly or indirectly disposed of by the coastal communities, are widely indicated as lines or fibers in other studies [33]. The PE is standardly found as fragments, films, while the PS is in foam shapes. Thermo polyurethanes have explicitly occurred in the water column. Paint fragments and coatings are found in diverse colors, which are thought to have come from the municipal boats fishing in the vicinities of the bay. These MP shapes are generally formed from large plastic debris, broken down to MPs by mechanical, photolytic, and biological processes [34].

4.2. Microplastics and Other Anthropogenic Debris in Bivalve Tissues

Both *P. viridis* and *A. pectinata* were found to have microplastic pollution. The level of microplastic in *P. viridis* in Sorsogon Bay was comparatively lower (**Table 5**) than that as reported in earlier published literature, but no records of published literature are available for *A. pectinata*.

Table 5. Microplastic pollution in bivalves in the present study compared to previous studies.

Species and sources	Treatment method	Identification method	Types of microplastic	Levels of microplastic	References
Perna viridis Philippines	30% H_2O_2	Visual identification and verified with ATR-FTIR	Lines (fibers)	0.3 - 2.5 items/individual	This study
Perna viridis Philippines	30% H_2O_2	Visual identification and verified with ATR-FTIR	Lines (fibers)	0.23 - 1.15 items/$g_{wet\ weight}$	This study
Atrina pectinata Philippines	30% H_2O_2	Visual identification and verified with ATR-FTIR	Films	0.93 - 4.27 items/individual	This study
Atrina pectinata Philippines	30% H_2O_2	Visual identification and verified with ATR-FTIR	Films	0.03 - 0.06 items/$g_{wet\ weight}$	This study
Perna viridis Philippines	30% H_2O_2	Visual identification	Fibers	0.27 - 0.41 items/$g_{wet\ weight}$	Bilugan *et al.*, 2021 [35]
Perna viridis Vietnam	10% KOH	Visual identification and verified with an μ-FT-IR	Fibers	2.6 items/individual	Nam, P.N. *et al.*, 2019 [36]
Perna viridis China	30% H_2O_2	LUMOS microscopy ATR mode	Fibers	0.77 - 8.22 items individual	Qu *et al.*, 2018 [37]
Mytilus edulis United Kingdom	30% H_2O_2	Visual identification and verified with an μ-FT-IR	Fibers	1.1 - 6.4 items/individual	Li *et al.*, 2018 [29]
Mytilus edulis China	30% H_2O_2	Visual identification and verified with an μ-FT-IR	Fibers	1.5 - 7.6 items/individual	Li *et al.*, 2016 [18]
Mytilus galloprovincialis Northern Ionian Sea	30% H_2O_2	Visual identification and verified with ATR-FTIR	Fibers, fragments	1.95 ± 1.14 items/individual	Digka *et al.*, 2018 [38]

We predicted that larger mussels and pen shells would have more microplastic in terms of variation. As expected, microplastic abundance in the larger bivalves was relatively higher than that of the smallest bivalves. Mean microplastic detection was found to be 2.19 ± 0.18 items/individual in mussels and 2.52 ± 0.22 items/ individual in pen shell. There was no significant difference in mean values between the bivalves.

FTIR analysis revealed that the common polymer types were PE and PET items and organosiloxanes in green mussels. Although they are not considered microplastics, aluminium silicate items were also identified in pen shells. *Scapharca subcrenata* has also been found to contain aluminum silicates, which are suggested to be derived from coal ash and accumulate in the biota [18]. This can be hypothesized to the *A. pectinata* samples in this study, which can be correlated to volcanic ash soils originating from Mt. Bulusan draining to the bay. Otsuka and Sentā demonstrated that aluminum silicates are present in the volcanic ash soils of Mt. Bulusan in Sorsogon [39].

4.3. The Implication of Microplastic Contamination on Seawater and Bivalve Tissues

The detection of microplastics in seawater and bivalves in Sorsogon Bay merely adds to the increasing evidence of microplastic contamination in the marine environment and the available seafood and its presence in our diet results from the waste that we dispose of [40].

Polyethylene terephthalate (PET) detection is mainly employed in the plastics industry. PET is widely used in the plastics industry as resin for plastic bottles, food jars, food trays, and as a fiber form for textiles (also known as polyester), monofilament, carpet, and films. While it is typically considered as "safe" plastic because it does not contain BPA, which can leach out antimony trioxide and phthalates in the presence of heat. Both of them are dangerous to health. Antimony can contribute to menstrual and pregnancy issues, and phthalates are endocrine disruptors.

Organosiloxanes are a type of waste found in silicon-containing products such as baking utensils and pans, baby nipples, pacifiers, medical devices and implants, water-repellent windshield coating, construction lubricants, and sealants, as well as deodorant creams and moisturizers. The most serious health concerns of siloxanes are primarily on D_4 and D_5 compounds that are toxic and bio-accumulative. Siloxane products should be avoided by reading product labels and purchasing toxic-chemical-free cookware alternatives like glass or ceramics.

In the Sorsogon Bay scenario, plastic bag waste composition in Sorsogon city alone was 18.50%, above the global average of 7% to 13% for municipal solid waste [41]. Based on international data of countries with similar socio-economic status and weather patterns, this level is slightly higher than Cambodia (3% - 15%) and Vietnam (9% - 16%). According to detailed waste composition by mass shows that PET bottles make up 2.40%, fabric, and leather 4.17%, diapers 10.99%, and Styrofoam 0.84%. There is no recycling option for fabric and leath-

er, diapers, and styrofoam in the area, and local junk shops are not willing to buy these wastes. Following protracted storm events, local litter is washed into local drainage canals and rivers, causing a considerable litter problem [42].

The number of microplastics is more valuable than the total mass when it comes to seafood safety. Consumers purchasing mussels of grading labels small to jumbo sizes (5.0 to >9.0 cm) are likely to ingest ~42 to ~23 particles per 100 g portion during exposure diet. If the actual microplastic found in this study is represented by 57%, this results in ~24 to ~13 microplastic particles per 100 g. Consumers who purchase pen shells with a grading label small to big sizes (~14.51 to >22.24) are likely to ingest ~1 to ~1 microplastic particle per 100 g. This number is comparably smaller to the ~70 microplastic particles per 100 g portion of microplastic in UK supermarkets [29].

Only microplastics smaller than 150 μm may translocate across the human gut epithelium (EFSA CONTAM Panel, 2016), which equates to an estimated 15% of the particles recovered from farmed mussels in Sorsogon Bay (**Figure 2**), and the absorption of these penetrating organs may be limited to ≤0.3% (EFSA CONTAM Panel, 2016). Similarly, the initial study of [43] found that the risk of plastic ingestion from mussel consumption is low compared to fiber exposure during a meal via dust fallout in a household.

Even though investigations into human health problems related to the consumption of contaminated marine seafood and its associated chemicals prove inconclusive, our seafood safety acceptance will still be directly affected. Suppose consumers perceive that the seafood and its environment include microplastic. In that case, their interpretation of the relative risks may lead to behavioral changes or reduced seafood consumption which may translate into the loss of income in the seafood industry and loss of safe, nutritious protein for the consumers (Bergmann *et al.*, 2015).

This evidence of microplastic occurrence in Sorsogon Bay's seawaters and commercial bivalves will hopefully drive adequate social perception and behavioral change work on supporting measures addressing the issue. However, this marine pollution concern is ubiquitous and increasingly evident, with Sorsogon Bay being no exception to this paradigm.

5. Conclusion and Recommendation

In the present study, we investigated the abundance and characteristics of microplastic in the surface water, water column, green mussel, and pen shell in Sorsogon bay. The main findings of this study are: 1) low abundance of microplastic on both seawater samples and bivalve tissue samples, compared to other published literature, with no significant differences in microplastic abundance between seawater and bivalve tissue samples, 2) lines or fibers dominated the microplastic shape in seawater samples and green mussel, while films were predominant in pen shell; green and blue as the most popular color for seawater samples, whereas blue and clear for bivalve samples; 5000 μm to seawater samples

and pen shell while <500 μm for mussels as the most common microplastic size; PE, PET, PS, organosiloxane, and thermos polyurethane were the detected polymer types. Their detection in Sorsogon Bay on cultured green mussels is a piece of evidence that the bay is no exception to this sort of marine pollution. It indicates a haphazard waste-mismanagement introduction into the bay that necessitates further inspection and investigation. Thus, waste characterization and investigation of potential macro and micro-plastic litter sources and pathways surrounding the bay are recommended, as well as an additional sampling of other ocean compartments and a perception survey on marine plastic pollution and its detection in seafood. These initiatives will assist in bay-wide risk assessments and mitigating marine plastic pollution in Sorsogon bay.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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