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Assessment of Brown Algae (Phaeophyceae) and Sediment Collected from Sanur Coastal Waters Based on Bioaccumulation Factors and Human Health Risks Related to Microplastic Ingestion Exposure

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ABSTRACT This study aimed to analyze Microplastics (MPs) contamination in brown algae and sediments, and their bioaccumulation factors, and estimate the risk to human health associated with exposure to ingested MPs collected from the water of the Sanur Beach, Bali Province. The samples were collected from three beaches which were determined using a purposive sampling method. The mean number of MPs found in *P. australis* was the same on all beaches, namely 17 items/seaweed, higher than *S. aquifolium* on all beaches. Line-shaped MPs were dominantly found in all algae (98.76%). A high percentage of line-shaped MPs was found in sediments at Mertasari and Semawang Beaches, but not at Sindhu Beach. The highest mean size of MPs in algae was found in *P. australis* at Semawang Beach, and sediments at Mertasari beach. The highest concentrations of MPs were also found in *P. australis* on the three coasts. The BAF value showed that the absorption of MPs in the sediment to brown algae was still low (<1). Values related to intake of brown algae consumption ranged from 190.58-1429.41 MPs item/week adjusted for calculation recommendations.

Keywords: Bioaccumulation factor; brown algae; contamination; microplastics

INTRODUCTION

Plastic waste is the biggest problem worldwide and is one of the dominant types of waste that pollutes the aquatic environment. Plastic is synthetic organic polymers that is lightweight, strong, and malleable (Oliveira *et al*., 2020), and generally used for various needs both domestic and industrial. The high intensity of plastic use that is not followed by correct and wise post-use management may cause its abundance and may increase and pollute the environment, especially aquatic ecosystems (Diggle & Walker, 2022; Rai *et al*., 2023). Plastic pollution may harm the aesthetically of aquatic ecosystems as well as the biota, cause illnesses, disrupt food webs, and diminish the productivity of fish captured (Thushari and Senevirathna, 2020). Plastic is capable of undergoing physical, mechanical, and biological fragmentation into smaller particles, so they are classified into microplastics (MPs) (<5.00 mm), mesoplastics (2.50-5.00 mm), and macroplastics (>2.50 mm) (Mariano *et al*., 2021; Sari *et al*., 2021).

Plastics may be damaged in the environment by a variety of processes, including solar radiation, mechanics, and the activities of microbes that produce fragmentation or convert plastics to microplastics (MPs) (van Sebille *et al*., 2015; da Costa *et al*., 2017). MPs are polymer particles ranging in size from 5 mm to several microns and nanometers that come from two main sources: the fragmentation of larger plastic wastes (secondary MPs) and the production and introduction of microparticles into the environment (primary MPs) such as through natural or anthropological processes (Andredy, 2011). Although the prevalence and risk of MPs have been studied for a long time (Carpenter *et al*., 1972), the presence of MPs members in marine waters has become a global concern today (Yu & Ma, 2022; Otegui *et al*., 2023; Romano *et al*., 2023). According to Geyer *et al*. (2017), the aquatic environment in some locations of Indonesia is extensively polluted by MPs, and Indonesia is regarded as one of the world's greatest suppliers of plastic garbage to the oceans, with an annual contribution of 1.29 tons. Since MPs are difficult to disintegrate and can adsorb hydrophobic chemicals that are persistent and poisonous in the aquatic environment, this situation has a severe influence on the aquatic ecosystem and human health (Fu *et al*., 2021).

In aquatic ecosystems, MPs have become a serious threat and their presence has been documented in all types of marine animals (Weis, 2019), not only through direct consumption but also through trophic transfer (Walkinshaw *et al*., 2020), for instance from zooplankton, mollusk, to various species of fish. Although several MPs research papers still concentrate on shellfish, fish, and plankton (López-Rosales *et al*., 2021; Rodrigues *et al*., 2021), however, studies of MPs contamination on macroalgae have not been widely investigated.

The presence of macroalgae in the aquatic environment is required for production and for the marine forest to be ecologically important (D'Archino & Piazzi, 2021). Many macroalgae species, including *Posidonia oceania* and *Lami-*

naria sp., which are abundant in the Mediterranean Sea and the eastern Atlantic on the Iberian Peninsula, provide the foundation of the food chain. Aquatic wildlife can also find refuge in macroalgae. Macroalgae, on the other hand, have a long history as traditional medicine and food in nations such as Japan, China, and Indonesia (Buschmann *et al*., 2017). As a medicinal ingredient, macroalgae have been classically proven as a hepatoprotective drug, a reliever of cough with phlegm, and diuresis, and used as a cancer treatment (Husain *et al*., 2021). Generally, as a traditional food ingredient, macroalgae are generally processed in a raw preparation known as “Rujak Bulung” in the Province of Bali.

Based on this study, it is important to highlight the presence of MPs in macroalgae. Brown macroalgae is one of the macroalgae families that is frequently used as industrial and medicinal raw materials, because it is capable of producing bioactive compounds such as fucoidan, alginate, laminarian, etc. Therefore, brown algae can potentially serve as a hotspot for monitoring studies because of their potential to accelerate/facilitate particle settling and absorb particles that settle in sediments and float on waves. Previous findings showed that more MPs were found in infested sediments on *Enhalus acoroides* than those not infested. On the other hand, the characteristics of algae stranded along the coast may be a strong signal of MPs accumulation (Cozzolino *et al*., 2020). Because of the significant activity of hospitality, fishing, marine tourism, and estuarine domestic waste from metropolitan areas, the waters of Sanur Beach were chosen as a sampling location for brown macroalgae in this study. As a result, the primary goals of this research were to (i) discover MPs contamination in brown algae and sediments; (ii) estimate the brown algal bioaccumulation factor (BAF) to MPs; and (iii) estimate MPs intake by the human population consuming brown algae based on EFSA (2016) recommendation. The results of this study can provide a new perspective on trends in MPs contamination in aquatic biota for human health. Relevant authorities will be warned to provide concrete policies regarding the impact of MPs, especially in the contamination of products that have economic and health values.

MATERIALS AND METHODS

Study site

To analyze MPs contamination in brown algae and sediment, we chose three sampling locations in the Sanur Coast region: (1) Mertasari Beach (8°42’48.5”S 115°15’02.9”E to 8°42’45.6”S 115°15’06.4”E), (2) Semawang Beach (8°42’27.1”S 115°15’46.2”E to 8°42’13.8”S 115°15’-52.3”E), and (3) Sindhu (8°41’02.1”S 115°15’54.5” E to 8°40’57.1”S 115°15’53.5”E) (Figure 1). The selection of these locations refers to previous study that have monitored the accumulation of heavy metals in brown algae (Rosiana *et al*., 2022). Alternatively, the selection of these three locations considered with the high activity of marine tourism, social activities, religious activities, hospitality, and being an estuary for domestic waste originating from the mainland.

Figure 1. Brown seaweed and sediment sampling locations map along the Sanur Beach Coast, Denpasar City, Bali Province.

Sampling method
Samples of brown algae (Phaeophyceae) were collected from Mertasari, Semawang, and Sindhu Beaches. These three sampling points were based on the high activity of the tourism and fishing industry carried out by local fishermen and the Badung river estuary. Two species of brown algae collected consisted of *Sargassum aquifolium* and *Padina australis*. Brown algae samples were collected at the lowest ebb in the intertidal zone during the rainy season.

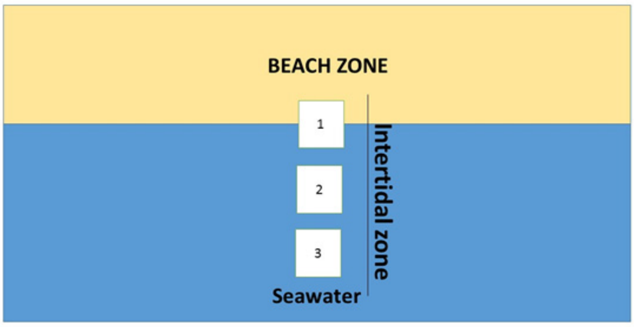

Figure 2. Illustration of MPs sampling technique on sediment samples carried out in this study using the quadrant transect method.

Sediment samples were collected at the same point as the brown algae sampling location. The surface sediment in each 1×1 m^2 transect was homogenized and taken as much as 200 g to obtain a total of 1 kg of sediment. Sediment collection was carried out using a shovel and then put into sterile plastic bags that was equipped with a label. The brown algae samples obtained were then put into sterile plastic bags on the type of algae and equipped with a label and sampling location. The algae and sediment samples obtained were then stored in a cooler box and then brought to the laboratory for the identification of microplastic content (Mauludy *et al.*, 2019). For each beach, sampling locations were selected from the coastline to the midpoint (intertidal zone), which is assumed to approximate the area. There are four sediment sample substations on each beach, with a 10-meter range between each (Arisa *et al.*, 2014; Sagawa *et al.*, 2018). An illustration of the MPs sampling method for sediments carried out can be seen in Figure 2.

Sampling preparation
Laboratory analysis was carried out to identify microplastics in brown algae with several steps such as sample preparation, microplastic extraction, microplastic screening, and observation. Laboratory analysis for brown algae started with measuring the weight of each brown algae (g) using an analytical balance. Measurement of sample weight is to determine the abundance of microplastic units using particles/individuals (item/ind) or particles/gram (item/g) (Arias *et al.*, 2019).

The extraction stage started with the degradation of organic matter using several types of solutions. In this study, the brown algae degradation process used the principle of alkaline degradation, namely degrading organic particles in the sample using a weak base solution such as 10% KOH (Jönsson *et al.*, 2020). This degradation process used a 10% KOH: sample volume ratio of 3:1. A total of 10% KOH is effective in destroying organic particles around microplastics without destroying the types of microplastic polymers observed. After the degradation process was complete, the samples were dried in an oven at 60°C for 24 hours. The degradation of organic matter in the sample ended when the solution was clear yellow with some organic particles deposited at the bottom of the beaker glass.

The sediment sample was weighed to 150 g and placed in a glass beaker, then combined with 100 ml of a 6-10% H2O2 solution and swirled for two minutes to eliminate the organic matter content in the sediment. The sediment was then permitted to stand until the reaction was complete, and an indication of the loss of gas bubbles in the sediment was used to determine when the reaction was complete. The sediment was dried in an oven at 70°C for 72 hours before being separated using a 5 mm filter and 100 g was removed. The saturated salt solve was then added in a 3:1 ratio and agitated for two minutes (Mardiansyah *et al.*, 2022).

MPs identification
The tools used for identification and sample analysis were cleaned using alcohol to prevent contamination by microplastic materials. All samples were stored at room temperature for 24 hours and then the surface was separated for observation under a microscope. Liquid samples or 5 mL/sample of brown algae and sediment were observed using light microscope with a magnification of 400× and an Olympus BX 51 microscope. The amount and type of microplastics were then counted and then categorized based on their shape that included fragments, pellets, and fibers.

Statistical analysis
Statistical data obtained from this study were analyzed descriptively and precisely to analyze the amount and types of microplastic members identified in brown algae and sediments. The average analysis of each form of microplastic obtained from each type of brown algae was analyzed descriptively using SPSS 23.0 software (IBM, USA). Microplastic data on brown algae and sediments were analyzed for Bioaccumulation Factor (BAF) values using the following equation:

$$BAF = {}^{C_B}/_{C_{WD}}$$

When C_B is the amount of microplastics in brown algae and C_{WD} is the amount of microplastic obtained from sediment. The BAF value was obtained from a comparison of the number of microplastic particles absorbed in brown algae with the amount of microplastic in the sediment. BAF >1, means that aquatic biota has a high potential to accumulate pollutants, especially MPs (Mardiansyah *et al.*, 2022; Rosiana *et al.*, 2022).

Two methods were used to calculate the estimated value of human MP exposure from seaweed ingestion. First, an assessment based on European Food Safety Authority (EFSA) recommendations for seafood consumption: children under one year (40 g/week); children aged two to six years (50 g/week); children aged six years (200 g/week); and children over 18 years, adults, or the general population (300 g/week). Second, based on recommendations from the European Market Observatory for Fisheries and Aquaculture Products (EUMOFA) and the National Fisheries Service (NOAA), which were then adjusted to Indonesia's level of seafood consumption, namely 55.37 kg/year/

capita (Barboza *et al*., 2020). Human MPs ingestion/week (MPs items/week): average MPs items in brown algae (MPs items/g) × recommended seafood ingestion/week (g) by EFSA. Annual human MPs ingestion (MPs items/year): average MPs items in brown algae (MPs items/gr) × recommended seafood intake/week (g) × number of weeks/year (52 weeks). Human MPs ingestion/week per capita (MPs items/week/capita): average MPs items in brown algae (MPs items/g) × seafood consumption/week per capita in Indonesia (g). Human MPs intake/capita per year (MPs items/year/capita): average MPs items in brown algae (MPs items/g) × seafood consumption per year/capita in Indonesia (g).

RESULTS AND DISCUSSION

Content of MPs on sediment and brown algae

The identification of MPs on brown algae collected on the three beaches in the waters of Sanur Beach showed varying amounts. The findings in this study showed that *P. australis* had the same average number of MPs contaminants on each beach that were 17 items/seaweed. The average number was higher compared to *S. aquifolium* on each coast Mertasari (6 items/seaweed); Semawang (16 items/seaweed); and Sindhu (8 items/seaweed) (Figure 3).

Based on the shape, MPs that were identified in brown algae were in the form of the line (98.76%) and fragments (1.23%) (Figure 4). Totally, the number of MPs obtained in the brown algae samples was 81 items/seaweed. This finding is the first information that revealed MPs contamination in brown algae growing under natural conditions in the waters of Sanur Beach, Bali Province.

Previous reports revealed that Nori seaweed (*Pyropia* spp.) was polluted by MPs both at the cultivation stage and into commercial products. The abundance of MPs found ranged from 0.9-3.0 items/g in commercial Nori products (Li *et al*., 2020). Laboratory-scale studies reported that perinkle *Littorina littorea* consumed marine algae *Fucus vesiculosus* that had been contaminated with MPs (Gutow *et al*., 2016). Furthermore, 75% of the *Thalassia testudinum* specimens collected in Belize contained MPs of up to 3.69±0.99 plastic fibers and more than 0.75±0.59 plastic particles/leaf (Goss *et al*., 2018). *Zostera marina* as marine algae was able to absorb MPs of 4.25±0.59 with the main polymer being PET (Jones *et al*., 2020). In another study, five species of macroalgae (*Gracilaria lemaneiformis*, *Chondrus ocellatus*, *Ulva lactuca*, *Ulva prolifera*, *Saccharina japonica*) were found to have MPs contamination more than 1243±1394 MPs/Kg of dry weight (Li *et al*., 2022). It confirms that seaweed can absorb MPs in aquatic environments and help facilitate their transfer to organisms with the higher trophic levels in an ecosystem.

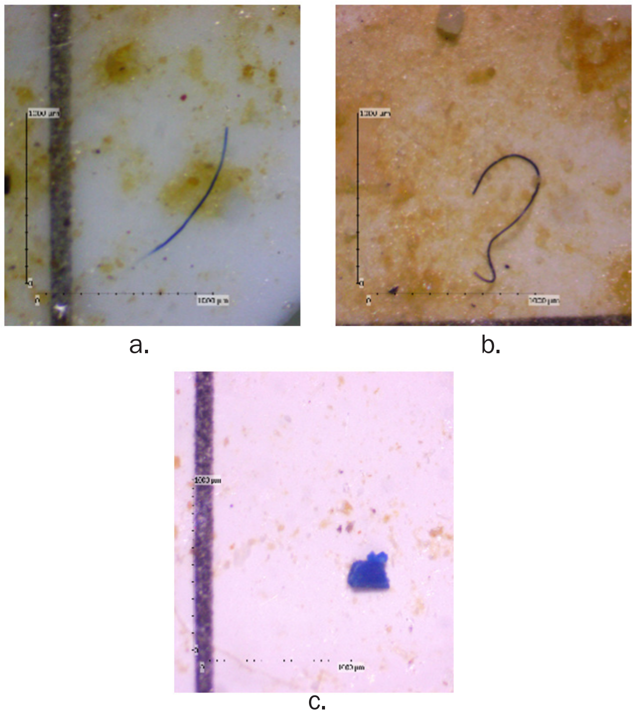

Figure 4. MPs contamination was found in brown algae and sediments in the waters of Sanur Beach, Bali Province; a). MPs are in line form in *P. australis* samples; b). MPs are in line form in *S. aquifolium* samples; c). MPs are in the form of fragments.

The number of MPs contamination found in the sediments on the three beaches in the Sanur Coastal Waters Area were 96 items with two forms of MPs namely Film and Line. MPs in the form of Line had higher percentage on both coasts when compared to the form of Film Mertasari (Film; 3% and Line; 38%) and Semawang (Film; 2% and Line; 26%). In contrast to the two beaches, at Sindhu Beach, only 30% of MPs in the form of film were found (Figure 5). The high MPs in the form of lines on Mertasari beach can be caused by the high pollution load in the form of clothing waste which is carried through the river flow and accumulates in the estuaries on Mertasari Beach, while the

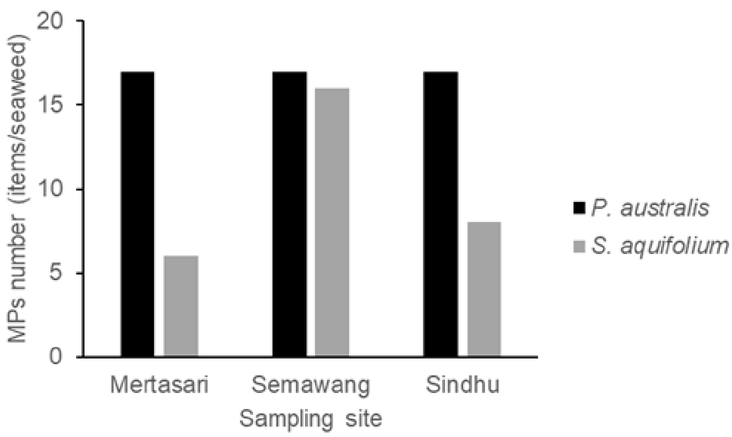

Figure 3. The average number of MPs contamination in brown algae collected from the Sanur Beach waters, Bali Province.

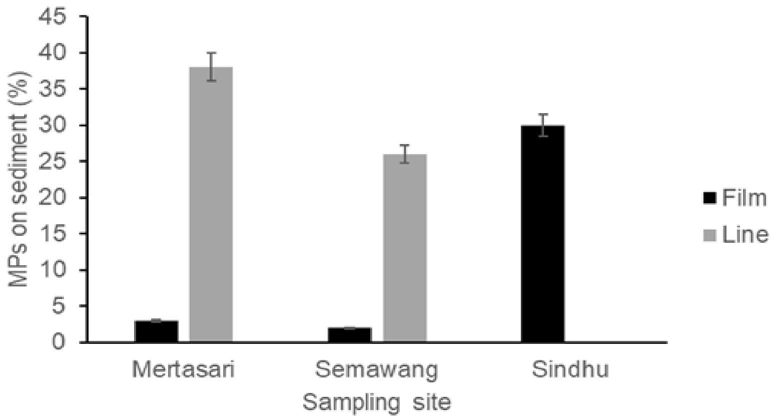

Figure 5. Percentage of MPs contamination found in sediments in the waters of Sanur Beach, Bali Province.

estuary area is not found on Semawang Beach. This was confirmed in previous studies which revealed that MPs contamination was higher in estuary areas compared to areas not traversed by estuaries (Vandermeersch *et al*., 2015).

The sediments collected in this study came from the intertidal zone that is a tidal zone that includes various types of habitats with various species of marine animals and plants. This zone is very vulnerable to exposure to terrestrial pollutant agents, including MPs. Some studies showed that higher MPs were found in intertidal sediments by 85% when compared to subtidal (62%) with larger MPs size (1 mm) (Markic *et al*., 2023). Another study showed that MPs pollution isolated from sediments on three shores in the west of Lake Superior showed MPs contamination with an average of 65 MPs particles/kg sediment with significant variability at each beach and dominated by polyester fibers (Davidson *et al*., 2022). Further research is needed to investigate the polymer from MPs that accumulates in brown algae and sediments on each beach in this study. However, the results of this study can be used as an initial reference for MPs contamination in brown algae and sediments in coastal waters.

Size of MPs in brown algae and sediments

The identification results showed that the overall size of MPs in brown algae collected in the waters of Sanur Beach, Bali Province was > 1 mm. The mean size of MPs found in *P. australis* at Semawang Beach was 2.94 mm, it was

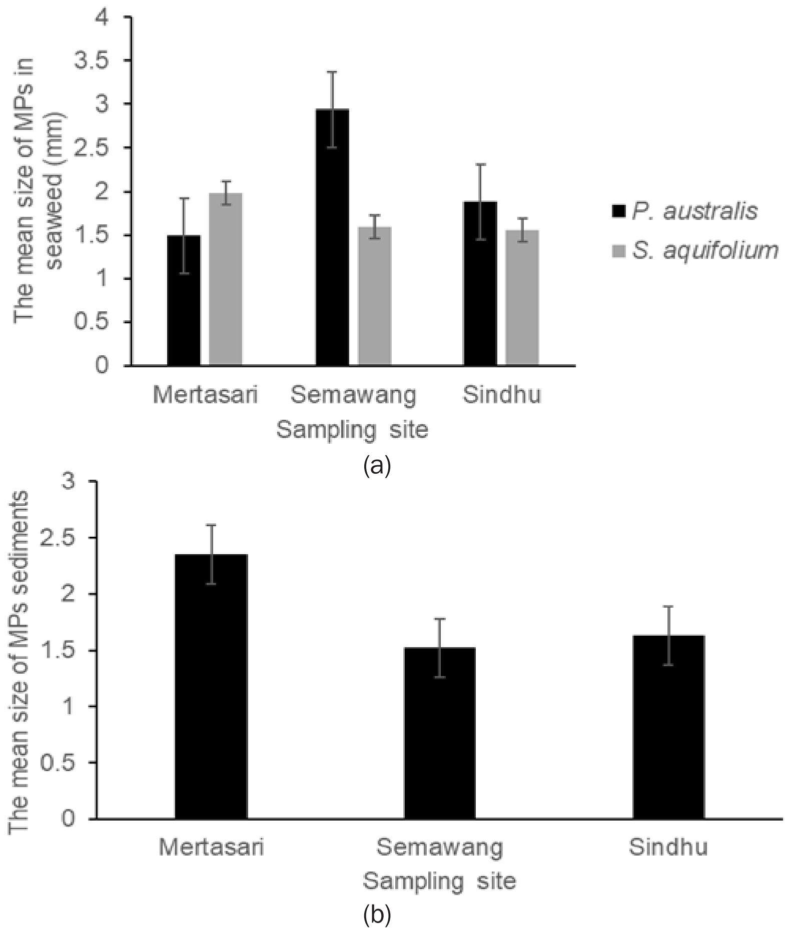

Figure 6. Mean size of MPs contamination in (a) brown algae and (b) sediments collected from the Sanur Beach area, Bali Province.

higher than the average MPs size of *P. australis* at Mertasari Beach (1.49 mm) and Sindhu Beach (1.88 mm). The mean size of MPs in *S. aquifolium* was lower when compared to *P. australis* in Semawang and Sindhu Beaches of 1.59 mm and 1.56 mm, respectively, but not in Mertasari Beach of 1.98 mm (Figure 6[a]).

The same thing was also found in the size of MPs in sediment samples collected all over the coast in the waters of Sanur Beach having MPs size > 1 mm (Figure 6_b). The study showed that the highest MPs mean size was found in sediment samples collected from Mertasari Beach that was 2.35 mm followed by Sindhu Beach that was 1.63 mm, and Semawang Beach that was 1.52 mm. We suspect that the high size of MPs found in both brown algae and sediments in this study can be caused by the high size of plastic contaminants that decompose on beach, especially plastic contaminants originating from human activities around the coast that include water tourism activities, hotel waste, and domestic waste.

The particle size of MPs found in brown algae in this study was smaller than the size of MPs identified in nori products that was 1-5 mm in previous studies (Li *et al.*, 2020). Likewise, the MPs particle sizes found in two types of cultivated algae such as *Gracilaria fisheri* and *Caulerpa lentilifera* in Thailand range from 100-500 µm and 501-1,000 µm (Klomjit *et al.*, 2021). In opposite, MPs contamination also accumulated in sediments on each in this study. Naturally, MPs that enter the marine environment may experience physical, chemical, and biological degradation. Ultraviolet radiation below a wavelength of 400 nm can accelerate the degradation of plastic polymers due to photolytic, photo-oxidative, and thermo-oxidative reactions.

In the coastal environment, plastic polymers such as polyethylene and polypropylene also experience degradation due to abrasion activity due to wave action which eventually settles into sediments of various sizes (Wang *et al.*, 2016). On the other hand, the biological activities played by bacteria and fungi are also able to degrade natural and synthetic polymers from plastic through various enzyme activities (Sánchez, 2020). Smaller MPs (<1 mm) have the potential to be ingested easily by aquatic biota and affect the food chain (Adams *et al.*, 2021). In shallower sediments, resuspended MPs with small in size were easier to be transported to the water column with lower concentrations than in deeper sediments (Bayo *et al.*, 2022).

MPs concentration in brown algae and sediments

The highest concentration of MPs contamination in brown algae was found in *P. australis* with the same MPs concentration value on each beach that was 2.83 particles/g. Meanwhile, the highest concentration of MPs contained in *S. aquifolium* was found at Semawang Beach at 2.67 Particles/g, followed by Mertasari Beach at 1.5 particles/g, and Sindhu Beach at 1.33 particles/g (Figure 7[a]). Meanwhile, the highest concentration of MPs found in the sediment samples was obtained at Mertasari Beach that was 0.133 particles/g, followed by Sindhu Beach that was 0.097 particles/g, and Semawang Beach that was 0.090 particles/g (Figure 7[b]).

Monitoring of MPs concentration particles had also been reported in previous studies along the Baltic coast of Germany. The study revealed that the concentration of MPs

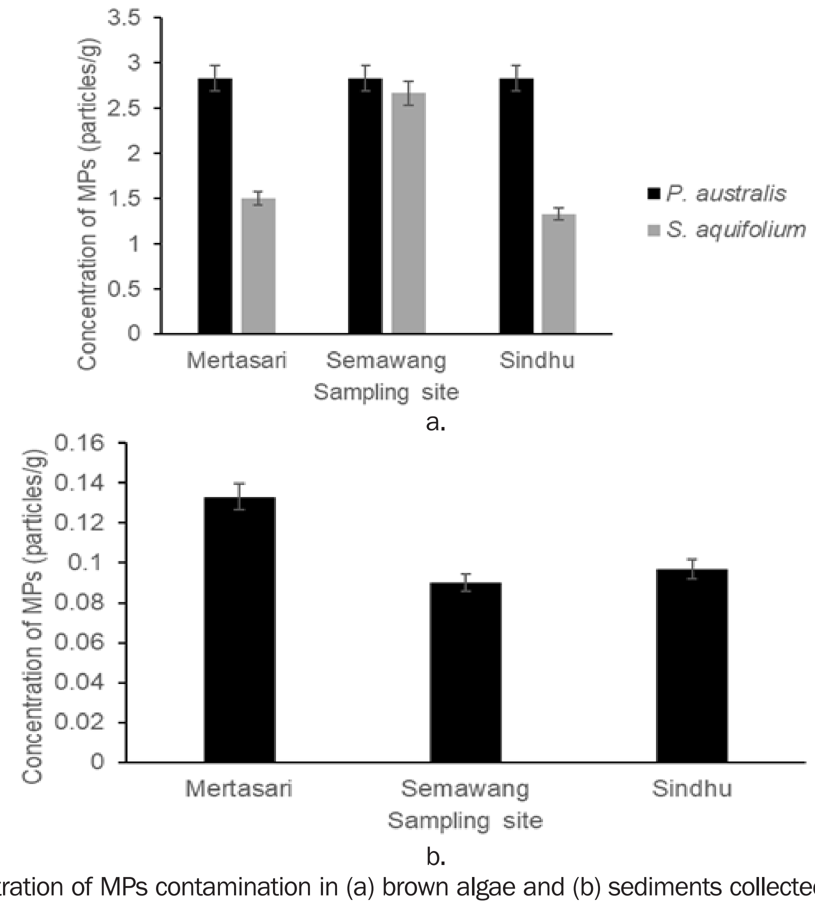

Figure 7. The concentration of MPs contamination in (a) brown algae and (b) sediments collected from the waters of Sanur Beach, Bali Province.

found in sediments ranged from at least 0-7 particles/kg with harbor, industry, and tourism activities considered as sources of MPs pollutants (Stolte *et al*., 2015). MPs contamination was also identified in beach sediments in Dubai that found that the MPs contamination level was 0.33 mg/g that was dominated by MPs in the form of fibers (Aslam *et al*., 2020). Otherwise, previous research revealed that MPs found in edible seaweed in Thailand ranged from 16.46±2.56 - 181.73±86.42 particles/100 g ww (Klomjit *et al*., 2021). Likewise, the concentration of MPs found in 24 brands of commercially packaged nori samples ranged from 0.9-3.0 items/g (dw) (Li *et al*., 2020).

It should be noted that the difference in the concentration of MPs at each location varies greatly was influenced by biotic and abiotic factors. Biotic factors consist of the ability of organisms to absorb MPs (Botterell *et al*., 2019), the ability of organisms to degrade MPs (Zeenat *et al*., 2021), to the organism's ability to act as a vector of MPs (Santos *et al*., 2021). Meanwhile, abiotic factors consist of seasonal differences, rainfall, humidity, temperature, and ocean currents (Oliveira *et al*., 2020; Qaiser *et al*., 2023). The process of abiotic plastic degradation induces a decrease in the pH of seawater (especially if the plastic is old). Furthermore, the decrease in pH is enhanced by solar radiation and is probably caused by a combination of organic acid release and CO_2 production (Romera-Castillo *et al*., 2023).

Bioaccumulation factor (BAF) of MPs

The bioaccumulation factor (BAF) can be determined by considering the amount of MPs contamination in aquatic biota and related to the amount of MPs contamination in the environment. A BAF value > 1 indicates that the higher accumulation in organisms than in the media (eg soil, sediment, and water) from which MPs were collected (Borgå, 2013; Koleli *et al*., 2015). Based on the BAF value, MPs contamination in brown algae has various values at each sampling location. The highest BAF values were obtained for brown algae collected from Semawang Beach, each of *P. australis* (0.629) and *S. aquifolium* (0.592). Likewise, the BAF values of brown algae from Sindhu Beach were *P. australis* (0.586) and *S. aquifolium* (0.275) respectively. The lowest BAF values were found in brown algae from Mertasari Beach, namely *P. australis* (0.425) and *S. aquifolium* (0.15) (Figure 8). However, overall the BAF value found in brown algae was still below 1 (<1), so that each brown algae that did not accumulate MPs contamination was higher than the sediments in the waters of Sanur Beach.

Brown algae besides having a role as a promising raw material for traditional medicine, on the other hand, it can also accumulate pollutants from the surrounding environment and act very well as biofiltration agents. The ability to absorb these pollutant agents depends on the concentration of pollutant agents from the ambient waters and sediment subsystems that is then expressed as BAF (Agarwal *et al*., 2022). Several pollutant agents with determined BAF values in seaweed such as heavy metals and pesticide residues. For example, the BAF value of *Enteromorpha compressa* is very good for Pb compared to Zn and Cu (Agarwal *et al*., 2022). Then, the BAF value of *E. compressa* from the Egyptian Mediterranean Coast is excellent at accumulating Mn metal based on the BAF value (Shams El-Din *et al*., 2014). To our knowledge, it is the first study to report the value of BAF in brown algae that is then developed as a raw material for traditional medicine. Further research is still urgently needed to assess the value of BAF in brown algae based on seasonal variations and other pollutant agents.

Estimated intake of MPs by the human population consuming brown algae

Based on the total average of MPs found in brown algae (4.762.38 MPs/g brown algae) and the recommended daily seafood consumption for different age groups (EFSA, 2011), this study discovered around 190.58 MPs item/week (1 year), 138.23 MPs item/week (2-6 years), 952.94 MPs item/week (> 6 years), and 1429.411 MPs item/week (adult population) (Table 1).

Ecologically, seaweed forms marine forests that have vital role in ecological balance of waters (Huang *et al*., 2020; Jones *et al*., 2020). Seaweed plays an important role in supporting economic welfare because it can be used as a raw material for the cosmetic and food industries because of its taste and nutritional profile (Widhiantara *et al*., 2022). Nevertheless, ingesting MP-containing foodstuff, particularly seaweed, might be hazardous to one's health, especially if ingested over an extended period of time. There are currently no particular studies that indicate clinical consequences of MPs dosages on human health.

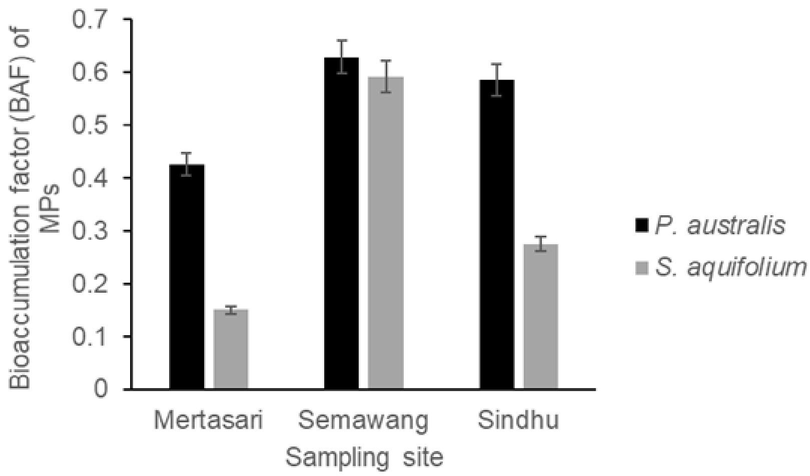

Figure 8. The average BAF value of brown algae collected from the Sanur Coastal Waters, Bali Province.

Table 1. Estimation of human intake of MPs from seafood consumption based on MPs found in brown algae based on EFSA recommendation for weekly consumption.

	Children			Adults or the general population
	(1 year)	(2-6 years)	(>6 years)	(>18 years)
Weight of brown algae/week	40 g	50 g	200 g	300 g
MPs items/week	190.58	238.23	952.94	1429.41
Weight of brown algae/year	2.080	2.600	10.400	15.600
MPs items/year	9910.58	12388.23	49552.94	74329.41

Note: *amount of seafood consumption based on recommendations from the EFSA (2011).

However, it should be noted as an important part wof further research in providing more comprehensive information about the impact of consuming food contaminated with MPs. Research reports reveal that the excretory system in the human body is capable of removing > 90% MPs of micro and nano plastics ingested through feces (da Costa *et al.*, 2016). Our study indicates that MPs may penetrate brown algal tissues and be consumed, increasing the quantity of human exposure through the consumption of contaminated seafood items (Fossi *et al.*, 2012). Some groups consume whole algae that is processed as traditional food, especially in Bali Province. While there are also developing brown algae as commercial products such as medicinal and cosmetic ingredients.

Our data indicate that annual ingestion of brown algae has a high value. Considering the significant human exposure rates linked with the study's findings, there is still doubt about the dosage and toxicity of MPs. Although this study gave basic information on MPs contamination in brown algae and sediments in Sanur Beach water, we recognize that more research is needed to determine the kind of polymer and the toxicity that MPs can cause in a broader range.

CONCLUSION AND RECOMMENDATION

Conclusion

Brown algae and sediments in the Sanur Beach waters, Bali Province have been contaminated with MPs with various sizes and concentrations. The BAF value shows that the uptake of MPs into the brown algae tissue is low (<1). The values related to intake of brown algae consumption ranged from 190.58-1429.41 MPs item/week adjusted for calculation recommendations values. MPs contamination of brown algae and sediments is a threat to aquatic biota and consumers. The action to clean up the beach environment is a method that can be proposed to reduce plastic contamination. It is also important to know the dominant plastic release locations and the influence of the season on MPs contamination by implementing monitoring program and mitigating the efforts to control plastic waste.

Recommendation

Further research regarding the range of doses, exposure time, and clinical symptoms caused by the consumption of seafood including brown algae on health risks.

AUTHOR'S CONTRIBUTIONS

IMGSS and PAW; Conceptualization, drafting scripts, acquiring projects, and designing drawings. IGW, IWR, and AAAPP; collect data, monitor, and carry out research. EMH; sampling, observation, and technical laboratory. AS and BY; Supervision, editing and review of manuscripts. All authors discussed the results and contributed to the final manuscript.

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