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Accumulation of Microplastics (MPs) Sedimentary in Seagrass Meadows on Mare Island Conservation Area, North Maluku, Indonesia

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ABSTRACT

Research on the occurrence and the characteristics of microplastics (MPs) sedimentary in seagrass meadows at the area of Mare Island conservation is the very first study in this region. The objectives of this work is to determine the abundance and the characteristics of MPS and its diversity in the two villages namely Maregam and Marekofo at the Island. Samples are collected using sediment core, then dried and extracted using NaCl (0.5M) to separate the density. MPs were identified under a microscope after going through the filtering process. The abundance of MPs particles ranges from 17,000 - 37,000 particles. kg^{-1}dry weight (dw) sediment at Station 1 (Maregam) and 13.839 - 30,666 particles.kg^{-1} dw sediment at Station 2 (Marekofo Generally, the average values of MPs abundance at station 1 were higher than station 2 that of 27.090 ± 13.908 particles.kg^{-1} dw of sediment and 18,368 ± 10,625 particles.kg^{-1} dw of sediment, respectively. Statistically there were no significance difference of the MPs abundance between the two station Furthermore, the predominance of MPs types were fiber and fragments, while the majority of colors of particles were blue. While the results of the microplastic diversity test indicated that MPS particles at Mare Island were not too complex and were in unstable conditions. Even though the less density of the population at the island, MPs were quite high compared to other areas in the world. This finding is allegedly that those MPs were supplied from the distance which transmitted by hydro-oceanographic and meteorology factors, beyond of local contribution.

Keywords: Microplastic, seagrass bed, sediment, conservation area, Mare Island

ABSTRAK

Penelitian tentang keberadaan dan karakteristik mikroplastik (MPs) pada sedimen padang lamun di area konservasi Pulau Mare baru pertama kali dilakukan. Penelitian ini bertujuan untuk menentukan kelimpahan dan karakteristik MPs serta keberagamannya di dua desa yaitu Maregam dan Marekofo. Kelimpahan MPs terdistribusi pada 30 titik pengamatan masing-masing 15 titik di kedua desa. Sample dikoleksi dengan menggunakan sedimen core dan selanjutnya dikeringkan dan ekstraksi dengan menggunakan NaCl (0.5M) untuk pemisahan densitas. MPs diidentifikasi di bawah mikroskop setelah melalui proses penyaringan. Kelimpahan partikel MPs berkisar antara 17,000 – 37,000 partikel.kg-1 berat kering sedimen di stasiun 1 (Maregam) dan 13,839 – 30,666 partikel.kg-1 berat kering sedimen di stasiun 2 (Marekofo). Secara umum nilai rata-rata kelimpahan MPs di Stasiun 1 dan Stasiun 2 masing-masing adalah 27,090±13,908 partikel.kg^{-1} berat kering dan 18,368±10,625 partikel.kg^{-1}. Hasil analisis statistic terhadap kelimpahan MPs pada kedua stasiun menunjukkan tidak ada perbedaan yang signifikan. Selanjutnya, tipe MPs yang ditemukan didominasi oleh fiber dan fragmen, sedangkan mayoritas warna dari partikel adalah warna biru. Sementara hasil uji keragaman mikroplastik mengindikasikan partikel MPs di Pulau Mare tidak terlalu kompleks dan berada pada kondisi yang belum stabil. Meskipun populasi penghuni Pulau ini tergolong rendah, MPs yang ditemukan cukup tinggi jika dibandingkan perairan-perairan lainnya di dunia. Hal ini diduga kuat MPs yang ditemukan kemungkinan selain dari wilayah setempat juga berasal dari tempat lain yang ditranspor oleh faktor-faktor hidro-oseanografi dan meteorolog, di luar kontribusi lokal.

Keywords: Microplastik, padang lamun, sedimen, kawasan konservasi, Pulau Mare

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1. Introduction

Microplastics (MPs) are categorized as emerging pollutants which are widely known by the society and have an effect on the environmental and human health. Therefore, attention to the existence and distribution of these pollutants have increased from year to year. Microplastics are small plastic particles (< 5mm) which can enter the marine environment from primary sources through the industrial and run-off of waste treatment systems. Primary microplastic sources are generally in the form of microbeads originating from cosmetics and other skin care or pellets, while secondary microplastics are formed through macroplastic fragmentation breaking through UV radiation, mechanical abrasion processes such as waves and weathering (Andrady 2011). Secondary microplastic forms or types are found in the marine environment and the majority sediments in the form of fragments and fiber. Most of the micro fiber found comes from clothing during the washing process that enters the marine environment (Browne et al., 2011), while fragments are plastic fragments from the pieces of macroplastic products.

These microplastic particles can be found ubiquitously throughout the world both in urban (Dehghani et al., 2017), salt marsh habitat (Weinstein et al., 2016; Li et al., 2020) and in the ocean environment such as coastal sediments (Claessens et a.,l 2011 ; Coppock et al., 2017; Bissen and Chawchai 2020; Bakir et al., 2020; Hosseini et al., 2020), seawater (Loughlin et a., 2021, Bakir et al., 2020; Qi et al., 2020; Hosseini et al., 2020), as well as marine biota such as fish (James et al., 2020), clams (Piarulli and Airoldi 2020), echinodermata (Plee and Pomory 2020), crustracea (Bakir et a.,l 2020), and even in deep sea sediments (Van Cauwenberghe et al., 2013; Zhang et al., 2020 ; Barrett et al., 2020). In addition, these microplastics have also been identified in various important ecosystems in the coastal and sea environments such as mangroves (Mohamed Nor et al., 2014; Deng et al., 2020; Zuo et al., 2020), seagrass meadows (Dahl et al., 2021; Goss et al., 2018; Huang et al., 2020; Jones et al., 2020; Unsworth et al., 2021), and coral reefs (Jeyasanta et al., 2020). The extensive distribution in various important ecosystems is feared to have a negative impact both in terms of ecology and human health. The small size allows it to be consumed by low-level fauna which subsequently through trophic transfer in the food web system can result in microplastic biomagnification from prey-contaminated to the predators (Browne et al., 2010; Goss et al., 2018; Jones et al., 2020). Given the high dependence of many species of habitats, especially commercial important species is a special concern because of the risk of microplastics contamination for human as the highest trophic levels (Bonello et al., 2018; Jones et al., 2020; Unsworth et al., 2021).

Seagrass meadows as one of the essential ecosystems in the coastal area due to their ecological role such as spawning ground, feeding ground, and nursery ground of various marine organisms, and as a fine sediment trap has been identified as one of the new hotspots of microplastic accumulation in the coastal area (Huang et al., 2020). The ability of the seagrass that accumulates the microplastics can occur both in the sediment and in seagrass leaves itself (Huang et al., 2020; Goss et al., 2020; Jones et al., 2020). The seabed sediment has been considered the last disposal microplastics site in the marine environment (Bakir et al., 2020) and as a potential long-term absorber for plastic (Browne et al., 2010). Seagrass meadows are able to reduce current and waves so that it can reduce water flow and increase sedimentation of fine particles. In addition, the accumulation of microplastics in sediment is also influenced by the height of the seagrass canopy in trapping the microplastics on the larger leaves and when these seagrass leaves will die, they will be degraded with the remaining microplastics into sediments (Unsworth et al., 2021; Goss et al., 2018; Jones et al., 2020). This can indicate that seagrass meadows are able to act as a place for hoarding microplastic contamination (Jones et al., 2020).

Microplastic contamination in the marine environment has been widely studied but still a little known about the level of microplastic abundance in seagrass (Kreitsberg et al., 2021). Globally research on microplastics in seagrass has been carried out in several areas of the world including Turneffe Atoll Marine Reverse - Belize (Goss et al., 2018), Orkney Islands, Scotland (Jones et a.,l 2020), Hainan - China (Huang et al., 2020), Mediterrania (Dahl et al., 2021), the Baltic-Estonian Sea (Kreitsberg et al., 2021), and United Kingdon (Unsworth et al., 2021). In Indonesia the research related to the microplastics in seagrass meadows has been carried out by Lestari et al., (2021) at Panjang Island - Jepara and Pramuka Island - Seribu Islands (Priscilla et al., 2019). The North Maluku Islands are one of the distribution areas of seagrass beds in the eastern of Indonesia (Ramili et al., 2018) but to date there are still lack of the publications regarding microplastic contamination, especially in seagrass beds.

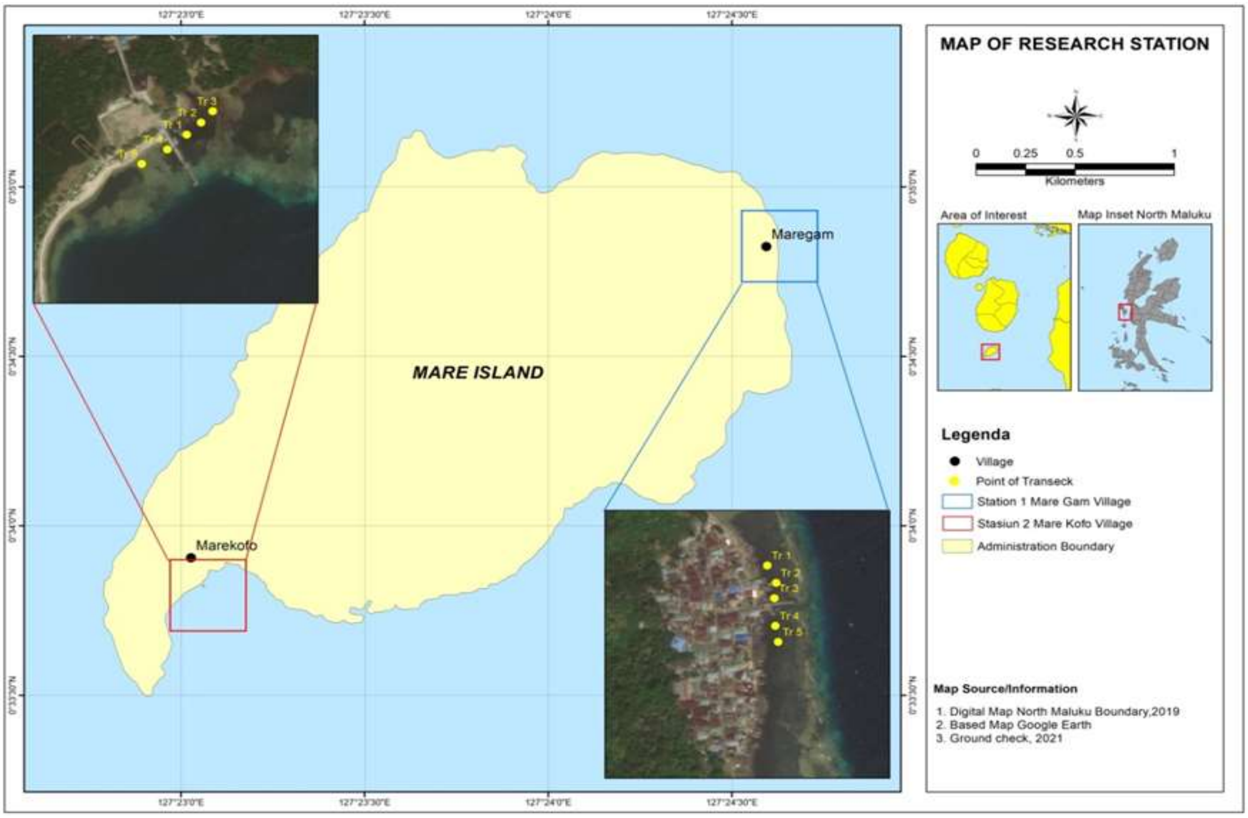

Figure 1. Sampling site at Mare Island and their location at Maregam Village (Station1) and Marekofo Village (Station 2)

Mare Island is one of the conservation areas in North Maluku which was determined through the Decree of the Minister of Maritime Affairs and Fisheries of the Republic of Indonesia No. 66/Kepmen-KP/2020, has several important ecosystems, namely mangrove ecosystems, seagrass ecosystems, and coral reef ecosystems and is a natural habitat for marine life. unique and charismatic biota such as dolphins (Family: Delphinidae) and blackfin sharks (*Carcharhinus melanopterus*) (DKP North Maluku Province, 2019). Mare Island is a small island and can be categorized as a remote area. Several previous studies have shown that small islands, far from urban and industrial areas have also been contaminated with microplastics, such as seagrass beds in the Orkney Islands – Scotland (Jones et al., 2020) and Scilly Island – UK (Nel et al., 2020). In addition, the presence of these microplastic pollutants has also been identified in several marine conservation areas such as in Sri Lanka (Dharmadasaa et al., 2021), Brazil (Lorenzi et al., 2021), as well as in Marine Conservation Zones in Cornwall and Special Conservation areas in North Wales. (Unsworth et al. 2021). Therefore, we are interested in conducting research on the occurrence of microplastics in the Mare Island conservation area which is also one of the small islands in the North Maluku Islands. This study aims to investigate the occurrence, distribution, abundance, characteristics and diversity of microplastics within seagrass sediments at Mare Island. This research is the truly first time research being conducted to reveal the presence of microplastics in the sediments of seagrass beds in the conservation area of Mare Island, North Maluku. The results of this study are expected to provide a new and better understanding of the presence of microplastics in the marine environment, as a basis for further research and as a reference material in the management of conservation areas, especially Mare Island in the future.

2. Material and methods

2.1 Time and Study Site

This work was carried out in August 2021 in the coastal waters of Mare Island. Mare Island is one of a group of small volcanic islands situates at the west side of Halmahera Island and geographically located at 0°33' - 0°35' N and 127°22' - 127°24' East (DKP Malut Province,

Table 1. Microplastic abundance distribution

Study site	MPs Abundance (partikel.kg^{-1} dw of sediment) (±SD)					Average (±SD)
	Transect 1	Transect 2	Transect 3	Transect 4	Transect 5	
Maregam Village (Station 1)	27,000 ± 19078.78	17,000 ± 4358.899	37,333.33± 12342.34	27,528.86 ± 20817	26590.06± 8635.535	27,090.45± 13,908
Marekofo Village (Station 2)	26,590.06 ± 2337.874	13,839.23± 8969.507	30,666.67± 1527.525	24,143.3± 12091.39	17632.55± 1095.602	18,368.11± 10,625.2

2019) . Administratively, Mare Island is included in South Tidore District, Tidore Islands City, North Maluku Province with the population density of 965 spread over the two villages, namely Maregam Village (453 people) and Marekofo Village (512 people) (BPS City of Tidore Islands, 2019). One of the important habitats that can be found at the coastal waters of Mare Island is the seagrass meadows with an area of 9.68 ha (DKP Malut Province, 2019). The research was conducted at two stations, namely Maregam Village (Station 1) and Marekofo Village (Station 2) (Figure 1).

2.2 Data Collection

Sediment samples were taken using the linear transect method (Kreitsberg et al. 2021). Each observation station consists of five transects drawn as long as 50 m to the sea with a distance between transects of 20 m. Each transect consisted of three sampling points at a distance of 0 m (representing the top), 25 m (representing the middle), and 50 m (representing the bottom) from the seagrass beds at the study site. Sediment sampling at each observation point used a sediment core from a PVC pipe (Dahl et al., 2021) (20 cm of the length; 9.0 cm of the diameter). The sediment samples were then put into a ziplock bag for further analysis in the laboratory with a total of 30 samples. In addition, the environmental parameters measured in situ in this study such as temperature, salinity and pH.

2.3 Microplastic Separation and Laboratory Analysis

Sediment samples were dried under the sunlight. The dry sediment samples were then sieved using a sieve shaker (Unsworth et al., 2021; Dharmadasaa et al., 2021) with ten mehsizes (4.75 mm; 2.00mm; 1.18mm; 0.850 mm; 0.425 mm; 0.250; 0.180 mm; 0.150 mm; 0.075. and; 0.045 mm). Each sediment size fraction in each sieve was weighed to determine the sediment composition at the two research sites. The sediment samples in the last sieve, 0.045 mm (silt category) was used for analysis of microplastics content (MPs). This is based on previous research by Coppock et al., (2017) and Bakir et al., (2020) that the density of microplastics was found to be higher in silt category of the sediments.

The separation of microplastic density from dry sediment samples was carried out by taking 1 g of dry sediment and mixing it with NaCl (0.5 M) solution (Jones et al., 2020), then stirred for ±3 minutes and allowed to settle for ±1 hour until the supernatant became clear and allowed microplastics to flout up to the surface. Subsequently, the supernatant was filtered using Whatman No. 40 filter paper (pore size 8 µm) to dry out the samples. Then, the filter paper was placed in a clean petri dish. The petri dish containing the filter paper was allowed to dry at

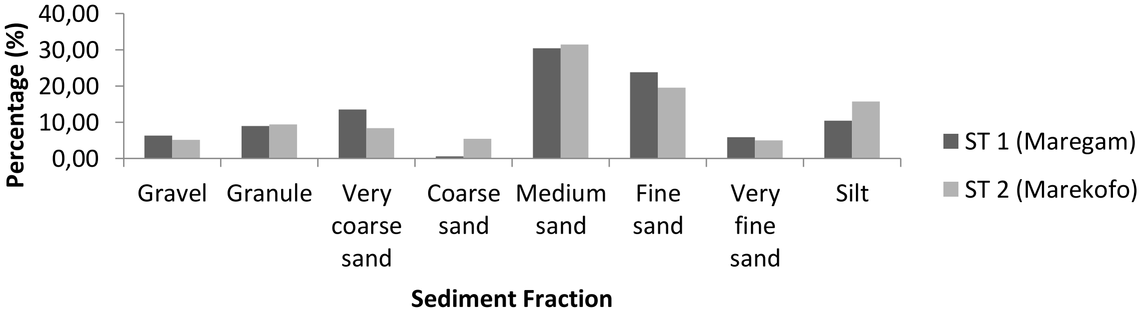

Figure 2. Type and composition of seagrass sediment fraction at Mare Island

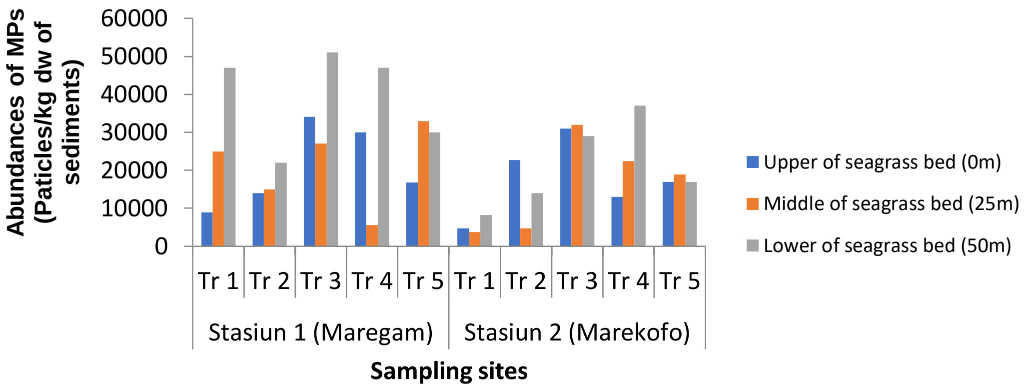

Figure 3. Distribution of microplastic abundance in seagrass beds by vertical distance to the sea at Mare Island

room temperature (± 24 hours). In order to minimize the contamination, the petri dish is covered with aluminum foil.

Microplastic identification were carried out under a digital microscope (with a computer viewer) with a magnification of up to 1000x. Microplastics particles were identified and categorized according to the valid guldens, including microplastics that did not have a cellular structure, were small in size, have a clear and homogeneous color in all parts, and were the same thickness throughout their length. Microplastic profiles were taken for each sample and classified according to the types (fiber, filament, fragment and pellet), and color as well (Hidalgo-Ruz et al., 2012).

2.4 Data analysis

The abundance of microplastics was calculated by comparing the number of microplastic particles with the weight of the analyzed dry sediment sample (particles.g^{-1} dw of sediment) (Huang et al., 2020) which was converted in units of particles.kg^{-1} dw of sediment in this study. The significance of the difference in the abundance of microplastics between the two study sites was tested using the ANOVA – One Way statistical test. The microplastic diversity index (D'(MP) was used to analyze the complexity of microplastic types in certain combinations in each area based on the following formula used by Wang et al., (2019):

$$\mathrm{D1} - \mathrm{D}'(\mathrm{MP}) = 1 - \sum_{i}^{S} q^2 \text{ and } q^2 = \left(\frac{ni}{N}\right)^2$$

Which i = sample number; ni = the number of individuals of the i-the type of microplastic; N = total number of microplastics; S = total number of microplastic types; q = is the relative abundance of each types in the combination of microplastics. The index value ranges from 0 – 1, if the value is close to 1 then the microplastic is more complex and stable.

3. Results and Discussion

3.1 The distribution and abundance of Microplastics

Microplastics (MPs) particles were found in all samples of dry sediment (30 samples) from both research locations, namely in Maregam Village (St 1) and Marekofo Village (St 2). The average values of the abundance of microplastics in the sediments distributed at the two study sites varied between 17,000 – 37,333 particles.kg^{-1} dw of sediment in Maregam Village (Station 1) while in Marekofo Village (Station 2) ranged from 13,839.23 – 30,666.67 particles.kg^{-1} dw. Generally, the average value of microplastics abundance in the seagrass

Table 2. The result of Anova One-Way test

Anova: Single Factor						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	570.5945	1	570.5945	3.725393	0.063778	4.195972
Within Groups	4288.579	28	153.1636			
Total	4859.174	29				

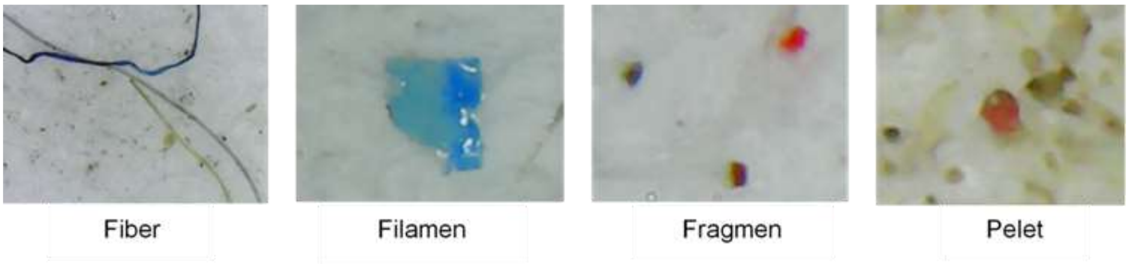

Figure 4. Various types of MPs found at Mare Island

sediments of Mare Island was found being higher in Maregam Village (Station 1) compared to Marekofo Village (Station 2) at 27,090.5±13,908 particles.kg^{-1} dw and 18,368.1±10,625.2, particles.kg^{-1} dw respectively (Table 1), although the sediment fraction in the silt category was found being higher in Marekofo Village than in Maregam Village. The bottom substrate condition of the seagrass beds in the two research locations, namely in Maregam Village and Marekofo Village as a whole is dominated by medium sand and fine sand. The types and composition of the sediment fractions at the study site were shown in Figure 2. The range of environmental parameters measured such as temperature ranged from 28.5°C – 31.5°C, salinity was around 34‰ – 34.5‰, and pH of 7.3 – 7.8.

The results of this study also found that the average value of the abundance of microplastics on the upper of the seagrass beds in Maregam Village was 20,754.04±10,730.67 particles.kg^{-1} dw of sediment, while at Marekofo Village was 17,705.45±9,888.79 particles.kg^{-1}dw of sediment. In the middle of the seagrass beds, the average abundance of microplastics found was 21,117.32±10,834.02 particles.kg^{-1} dw of sediment in Maregam Village and 16,362.51±12,064.01 particles.kg^{-1} dw of sediment in Marekofo Village. The lower of the seagrass beds of the two research stations had a higher average abundance of microplastics than the other two parts, namely 39,400±12,660.96 particles.kg^{-1} dw of sediment in Maregam Village and in Marekofo Village of 21,036.37±11,718.57 particles.kg^{-1} dw of sediment. Thus, this study indicates that the distribution of microplastics abundance in the seagrass beds of Maregam Island tends to be higher at the water edge of the seagrass beds as shown in Figure 3. Although descriptively there was a difference in the abundance of microplastics between the two research stations, the ANOVA One-Way statistical results showed that there was no significance differences in terms of MPs abundance between the two research stations ($p>0.05$) (Table 2).

3.2 Characteristics and Diversity of Microplastics

The microplastic particles found in the two research stations have various shapes and colors with a total of 804 microplastic particles observed. The types or forms of microplastics found in this study were grouped into four types, namely fiber, filament, fragment and pellet (Figure 4).

The results of this study found that the majority of microplastics found were fibers followed by fragments and filaments, while pellets were the least microplastic type contained in seagrass sediments. The most fiber type microplastics were found at Station 2 which ranged from 61.67% – 76.36% compared to the station 1 with a range of 35.65% – 67.01%. Then followed by fragments with a percentage between 29.46 – 31.37% at station 1 and in the range of 16.36 – 31.52% at station 2. Furthermore, the least pellet-type microplastics recorded ranging from 1.03 to 7.84% at Station 1 while at Station 2 it ranged from 0 to 1.82%. The distribution and composition of microplastics types found in the two research stations are shown in Figure 5.

3.3 Distribution and Composition of Microplastic Colors

The microplastic particles (804 particles) found were also identified based on their color. The colors of microplastics found at the research site were grouped into nine colors, namely black, blue, red, green, orange, white, brown, gray and yellow for Station 1, while Station 2 was not found the orange one so it consisted of eight colors as shown in the figure previously mentioned. The distribution and color composition of microplastics varied between the two stations, with blue being the more dominant color found at 32.8%, followed by white at

Table 3. Microplastic abundaces (particles kg^{-1} dry weight (dw) of sediment) reported from several locations of seagrass beds and marine sediment around the world

Region	Sampling area	Characteristics	Abundances of MPs (particles kg^{-1} dry weight (dw) of sediment)	References
Sediment of Seagrass beds				
Asia	Indonesia	Mare Island, North Maluku:		This study
		Maregam village	27,090.45±13,908	
		Marekofo village	18,368.11±10,625.2	
	China	Hainan :		
		Xincun Bay	196.7±16.1	Huang et al., 2021
		Li'an Bay	780.2±147.0	
Europe	United Kingdom	Southern England and Wales	215±163	Unsworth et al., 2021
	Mediterranean	South west of Spain:		
		Agua Amarga	3819	Dahl et al., 2021.
		Roquetas	2173	
		Santa Maria	68 – 362	
	Baltic Sea	Western-Estonian archipelago in the Baltic Sea	0 – 1817	Kreitsberg et al., 2021
Marine Sediment				
Asia	Indonesia	Jakarta Bay	18,405 – 38,790	Manalu et al., 2017
	Indonesia	Coast of Bungus Bay, Padang	191.11±64.07 – 301.11±87.98	Islami et al., 2020
	Indonesia	Coastal beaches, Badung Bali	90.7±59.1	Mauludy et al.,2019
	Iran	Anzali coastland, southwest of Caspian Sea	140 – 2820 and 113 – 3690	Rasta et al., 2020
	Thailand	Beaches along the eastern Gulf of Thailand	420 – 200,000	Bisen and Chawchai 2020
	Iran	Chabahar Bay	112 – 468	Hosseini et al., 2020
Oceania	South Pacific Ocean	Port Vila, Vanuatu	333 – 33,300	Bakir et al., 2020
	South Pacific Ocean	Honiara, Solomon Island	450 – 15,167	Bakir et al., 2020
Europe	United Kingdom	Plym estuary, Plymouth	66.7±17.6 – 72.2±36.2	Coppock et al., 2017
	United Kingdom	Plymouth estuary, Falmouth	97.16±49.42 – 97.87 – 37.74	Nel et al., 2020
		Scilly Islands	357.1 – 7393	Nel et al., 2020
	Scotland	Scapa Flow, Orkney	730 – 2300	Blumenroder et al., 2020

17.28%, and black at 14.86% at Station 1. While at Station 2, blue was 30.8% followed by black 20.68% and red color 16.76%. The color of microplastic which was found the least at station 1 was orange (0.38%) while at Station 2 was yellow (1.89%). The distribution and color composition of the microplastics found at the study site are shown in Figure 6.

3.4 Microplastic diversity

The complexity of microplastics types at both stations analyzed using the microplastic diversity index (D'MP) obtained a microplastic diversity index value at Station 1 of 0.57 and

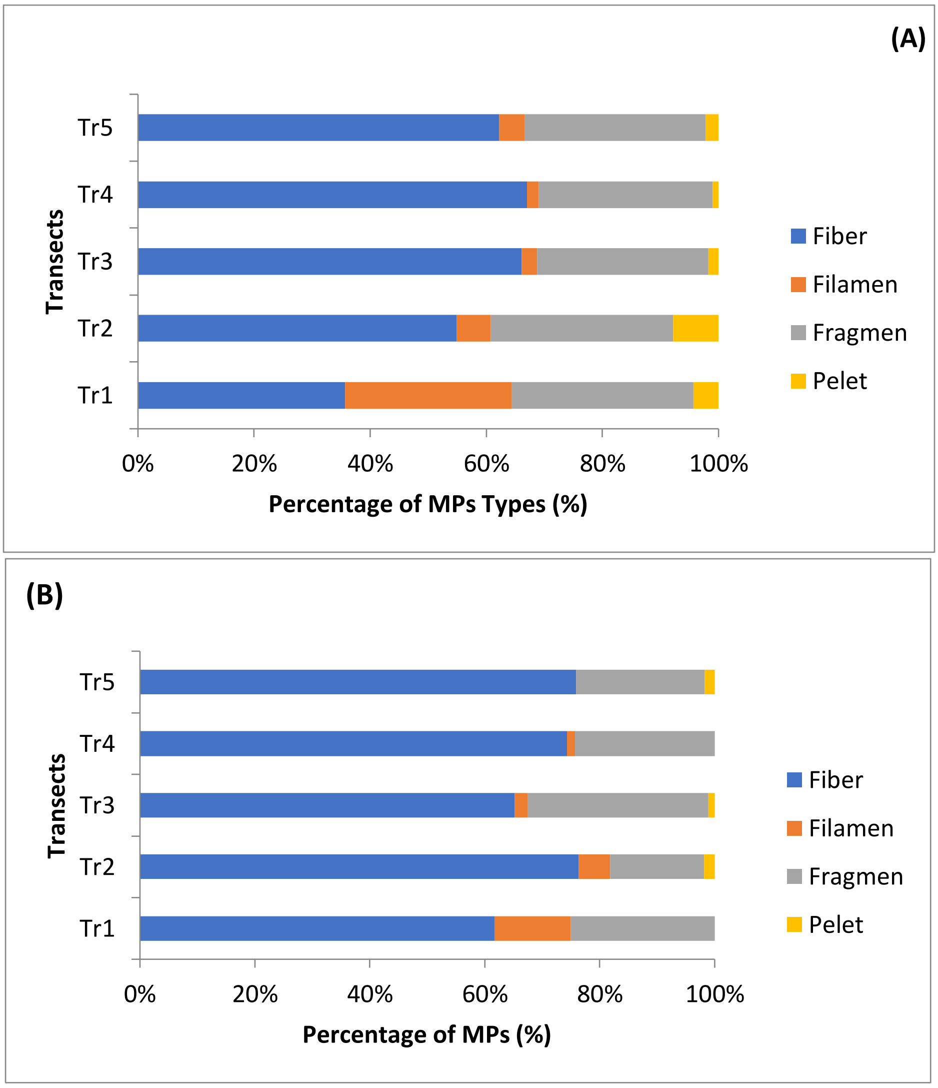

Figure 5. Distribution and composition of microplastic types in seagrass sediments (A) Station 1 (Maregam Village) and (B) Station 2 (Marekofo Village)

Station 2 of 0.44. This value range indicates that the microplastics in the two research stations are not too complex and unstable.

This is the very first work to describe the occurrence of microplastics in seagrass sediments found in one of the conservation areas in North Maluku province, namely Mare Island, which is a small island with ±965 inhabitants (BPS City of Tidore Islands, 2019). The microplastics found in the seagrass sediments of Mare Island indicated that the distribution of microplastics has reached small islands in remote areas. This is in accordance with research conducted by Jones et al., (2020) who found microplastic contamination in seagrass sediments in the Orkney Islands, which is a group of small islands off the East coast of Scotland. There was no previous research published on microplastics in seagrass sediments in other areas of North Maluku which can be compared to this study. The abundance of microplastics in the seagrass sediments of Mare Island varied between transects at each research station The abundance of microplastics at Station 1 (Maregam Village) is higher than Station 2 (Marekofo Village), this may be related to the location of Station 2 which is in the bay, where according to Wang et al., (2020), microplastic pollution in the bay area tends to be lower than in the adjacent coastal areas as a whole. There was no statistically significant difference between the two research stations ($p>0.05$). Research conducted by Kreitsberg et

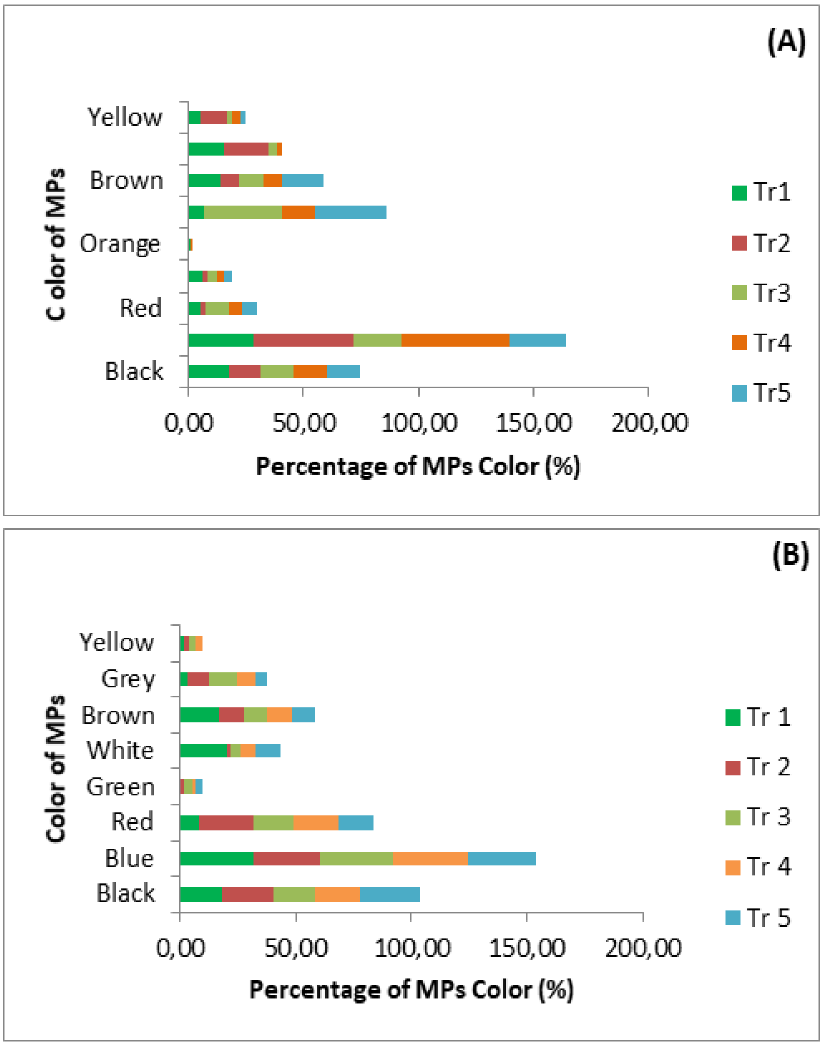

Figure 6. Distribution and color composition of microplastics in seagrass sediments (A) Maregam Village and (B) Marekofo Village

al., (2021), showed that there was a high abundance of microplastics in seagrass beds. The occurrence of microplastic accumulation in seagrass sediments indicated the ability of seagrass beds to trap microplastics as also found in seagrass sediments in China (Huang et al,. 2018), seagrass bed sediments in the UK (Unsworth et al., 2021), seagrass sediments in the Pacific Ocean region, Mediterranean (Dahl et al., 2021) and seagrass sediments in the Baltic Sea (Kreitsberg et al,. 2021). However, the average value of the abundance of microplastics found in the seagrass sediments of Mare Island is higher than several other seagrass beds in several regions of the world that have been studied as well as in marine sediments (Table 3). The difference in the value of the abundance of microplastics can be related to the sampling location and differences in human activities at those locations (Hosseini et al., 2021). Additionally, poor coastal management and high anthropogenic pollution are thought to have contributed to the higher concentrations of microplastics (Huang et al., 2018). The sampling locations at the two research stations are close to residential areas. According to Hosseini et al., (2020), microplastics are generally higher in locations close to populated areas associated with residential waste such as plastic containers, cosmetics, cleaners and other packaging materials. Subsequently, with relatively low population density at Mare Island, the high concentration of microplastic particles in these two villages were presumably supplied from the distance, transported through hydro-oceanographic and climatological factors.

Geographically, the position of Mare Island is close to Tidore Island and Ternate Island which is the center of activity in North Maluku. Lessy and Najamuddin (2020), obtained a high concentration of plastic waste (77%) in Ternate Island due to lack of waste handling and management. This is allegadelly to be a source of microplastics that may be carried by local hydrodynamic conditions to other adjacent areas such as Mare Island. According to Unsworth et al., (2021), the accumulation of microplastics in seagrass sediments is more influenced by local hydrodynamic conditions and local sources of microplastics itself. Beside, a low density population of small island is not a predictor of lower microplastic pollution (Blumenroder et al., 2017). The lack of handling of plastic waste at the research site as seen from the large amount of plastic waste found on the beach is likely to be a source of microplastics through the process of fragmentation, degradation and weathering over time (Andrady 2011).

Microplastics have the potential to be widespread in the marine environment because they are persistent and have buoyancy through hydrodynamic processes and ocean currents (Claessens et al., 2011), as well as local bathymetry conditions and the coastline of a study area (Bakir et al., 2020). The buoyancy density of plastics can change during their exsistency in the ocean due to weathering and biofouling (Hidalgo Ruz et al., 2012). Microplastic particles found in the upper, middle and lower water parts of the seagrass beds showed a wide distribution in the seagrass beds of Mare Island. The abundance of these microplastics tends to be higher at the lower of the seagrass beds when compared to the middle and the top. In general, sediment agitation due to the turbulence of seawater creates sediment deposition difficult at the upper boundary of the waters, this will most likely affect the accumulation of microplastics in the upper part of the seagrass beds. Seagrass beds play an important physical role in stabilizing and consolidating the seabed (Maccarrone et al., 2011), and are able to trap fine sediments so that the rate of sediment accumulation in seagrass beds tends to be higher (Marba et al., 2015). This role is related to the size and shape of the microplastic which allows it to stick or intertwined with elements in the sediment which ultimately prevents redistribution that can lead to accumulation (Plee and Pomory et al., 2020). Given the lower sediment resuspension in seagrass beds, it is highly likely that microplastics in seagrass sediments will remain intact and be stored for a long time (Unsworth et al., 2021). In general, sediment agitation due to seawater turbulence makes sediment deposition difficult in the upper litoral zone, this will most likely affect the low accumulation of microplastics in the upper part of the seagrass beds.

Furthermore, this study also revealed that various types of microplastics such as fibers, fragments, filaments, and pellets were found in seagrass sediments at Mare Island. Fiber and fragment types were found as the highest concentrations than the other two forms of microplastics which were similar to the results of previous studies in seagrass sediments (Plee and Pomory 2020; Huang et al., 2018; Unsworth et al., 2021; Kreitsberg et al., 2021). Fiber is the most common type of microplastic found in the marine environment (Kreitsberg et al., 2021; Qi et al., 2020), as well as in marine sediments (Louhglin et al 2021; Coppock et al., 2017). The main source of this microplastic fiber comes from laundry, fishing nets, and also fishing line (Unsworth et al., 2021). This is accordance with the community's use of sea activities around the waters of Mare Island which are partly aimed at demersal fisheries, small pelagic fisheries, traditional fisheries and reef fisheries using various fishing gears such as drifting gill nets, tonda and handlines as well as bottom drag nets (*kalase* in the local language) especially in Marekofo Village (DKP Malut Province, 2019), most likely to be the main contributor to the presence of microplastics around Mare Island, however this definitely requires further investigation. In addition, the high percentage of fiber-type microplastics in Marekofo Village (Station 2) may also be due to river flows which are the main entry point for microplastics from land to the marine environment. One of the main sources of microplastic fiber is through domestic laundry which can release > 1900 microplastic fibers (Browne et al., 2011) which can be produced through the activities of surrounding residents which contributed to the marine environment through the river flow. This result is in agreement with the research published by Bakir et al., (2021) who found rivers as the main route for microplastics at the Solomon Islands with a high content of microplastics in their sediments. This fiber type was also found to be most abundant in marine sediments (Li et al., 2020; Wang et al., 2020; Firdaus et al., 2019). The accumulation of fiber in seagrass sediments is considered dangerous for seagrass-dwelling invertebrate groups that are very susceptible to the uptake of these fibers (Wright et al., 2013; Plee and Pomory, 2021).

The discovery of a fairly high color variation of microplastics in the study area indicates that the microplastic particles in Mare Island come from various sources. Mare Island as a conservation area with the status of Taman Wisata Perairan can certainly attract tourists to visit. It is feared that this activity will also contribute the use of plastic and the resulting of recreational waste will have an impact on coastal ecosystems. In addition, Mare Island is also a fishing ground area that uses various fishing gear, allegedly contributing to the presence and abundance of microplastics as is the case in Iceland (Loughlin et al., 2021). Furthermore, The dominant color of microplastics found in seagrass sediments at Mare Island was blue, the same color dominance is also found in seagrass sediments in Hainan, China (Huang et al., 2021), in seagrass sediments in the Baltic Sea (Kreitsberg et al., 2021). Meanwhile, yellow MPs were found with the lowest percentage, similar to the results found in marine sediments by Hosseini et al., (2020). The results of this study found that black microplastic particles at both stations with a percentage of 14.86% (third order) at Station 1 and 20.68% (second order) at Station 2 deserve attention regarding the possibility of microplastics entering the food chain system in seagrass meadows. Wang et al., (2018) stated that black-colored microplastic particles are able to absorb chemicals higher than colored and white particles. In addition, the absorption of chemicals by microplastics is higher in the marine environment. The absorption of these microplastics is also influenced by marine environmental factors such as salinity, temperature, and pH. Further exploration of the role of microplastic color in seagrass sediments is needed (Huang et al., 2020).

The complexity of the source of microplastics can be determined through the microplastic diversity index, where the diversity of microplastics decreases with proximity to the beach or coral reefs (Wang et al., 2019). This is in agreement with the Microplastic Diversity Index (D'MP) at the two research stations, which is 0.57 at St 1 and 0.44 at St 2 which indicates that the level of microplastic diversity in the seagrass sediments at the station both study sites are not very complex and unstable. Seagrass beds are ecosystems located in waters close to the coast and coral reef ecosystems. Seagrass habitats, which are generally closer to the coastal zone, are risked to receive input from various major sources of microplastics from the mainland (Andrady 2011). According to Wang et al., (2019), the diversity of microplastics depends on the distance from the source of microplastics where the proportion of microplastics is not uniform in the distribution of different types in the combination of microplastics in the coastal zone so that the diversity is lower compared to marine areas where microplastics have been carried away from the source become uniform which may eventually lead to higher diversity. In addition, Huang et al., (2018) stated that the effect of seagrass traps was not selective on the shape, color and size of microplastics.

The seagrass ecosystem at Mare Island is a mixed vegetation types with a composition of seagrass species, namely *Enhalus acoroides, Thalassia hemprichii, Cymodocea serrulata, C. rotundata, Syringodium isoetifolium and Halophila sp*. The ecological role of seagrass beds and the potential of this important habitat can support the existence of various types of target fish which are the source of livelihood for most people in this small Island. The results of this study have revealed that the occurrence and the accumulation of microplastics in seagrass sediments in the study area needs attention from various stakeholders, given the high dependence of various fish and invertebrate species in this habitat and the potential for microplastics to enter the seagrass food web system. According to Unsworth et al., (2021), microplastic contamination in seagrass sediments can pose the problems that has not been identified yet particularly for human health and food safety. Although there is no conservation policy that specifically objected to the protection of seagrasses from plastic waste (Bonanno et al., 2020), the results of this study are expected to become the basic data as an effort to overcome microplastic problems that require integrated coastal management, especially at the conservation areas.

4. Conclusions

The spatial distribution of MPs particles abundance in seagrass sediments at both research stations descriptively shows that the Maregam station has a higher concentration than the Marekofo station. However, statistical tests showed no significant difference in the quantity of MPs in the two research stations. The physical characteristics of the MPs found were dominated by fiber and fragment types, while the majority colors of the MPs particles were blue. The results of the diversity analysis of MPs complexity indicate that the MPs in Mare Island are not too complex and still unstable. Although with low density population at this island, the MPs abundance value categorized as quite high.

It is suspected that the MPs at the study site originate from the local area itself (autoctonous) and also other places (alloctonous) which are transported by hydro-oceanographic and climatological factors.

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Competing of interests

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