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Microplastic abundance and distribution in surface water and sediment collected from the coastal area

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ABSTRACT

BACKGROUND AND OBJECTIVES: Rapid development has increased the microplastics discharges into marine environments, including coastal waters at Jakarta Bay, Indonesia. This study is proposed to assess microplastics abundance and distribution in surface water and sediment from coastal water at Jakarta Bay.
METHODS: The samples were collected from 12 locations representing Ancol, Muara Baru, and Muara Angke- Muara Karang. Samples of water and sediment were extracted to obtain the microplastics. The microplastics were identified based on their morphology (shape) and numbered for their abundance. The polymer of microplastics was determined using Raman Spectrophotometer.
FINDINGS: The results showed that microplastics were successfully identified and counted in water and sediment samples at all collection points. The number of microplastics was 1532 particles in the water sample and 1419 particles in the sediment sample. The shape of microplastics observed in the water and sediment samples were fibers, films, fragments, and pellets. Among those, fiber and film were the most dominant microplastic detected both in surface water and sediment in all locations. Three polymers, namely polyethylene, polypropylene, and polystyrene, were detected in the microplastic samples. These findings prove that microplastics with their various types are capable contaminate the aquatic environment.
CONCLUSION: The most common microplastics shapes in sediment were fiber (55.7%) > film (31.1%) > fragment (9.9%) > pellet (3.2%) and for the surface water were film (53.5%) > fiber (33.9%) > fragment (7.8%) > pellet (4.7%). The abundance of microplastics in the sediment (166.8 particles/kg, 95%CI: 148.0-185.0) was significantly higher ($p < 0.05$) than in surface water (70.9 particles/L, 95%CI: 55.6-86.2). The abundance of microplastics was significantly different among locations ($p < 0.05$, $F = 2.115$), with microplastics in sediments were higher in Ancol, and Muara Angke - Muara Karang have the highest microplastics in surface water. These results can provide valuable information on which parts of the Jakarta Bay areas should be prioritized first regarding microplastics management.

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INTRODUCTION

The use of plastics as a crucial component in modern society worldwide is increasing (Andrady and Neal, 2009). Plastics are employed because they are not only versatile, lightweight, strong, and sturdy but also inexpensive; hence, they have been applied in many industries. In recent years, the rate of plastics production in the world has risen from 0.5 million to 288 million tons between 1950 and 2012 (Plastics Europe, 2013). In 2016, the rate increased by 4% and reached 360 million tons in 2018 (Plastics Europe, 2019). Marine environments in Indonesia are also threatened by plastic debris, with an assumption that about 10% of plastics would end up in seas (Van Cauwenberghe *et al.*, 2015). In total, Indonesia is the second-largest country after China that discharged plastic waste into the ocean. The amount is about 0.48 – 1.29 MMT (Purba *et al.*, 2019). According to Hastuti *et al.*, (2014), about 165,000 tons of plastics debris annually pollute Indonesia's marine environment. Due to the fragmentation process, larger plastic and litter become small particles. Some of them are scrubbers in cosmetics and abrasive beads used to clean the ships (Browne *et al.*, 2007). Microplastics are plastic particles with a diameter of <5 mm (GESAMP, 2015). Based on the origin of the waste, microplastics are divided into two types, namely primary microplastics and secondary microplastics. Primary microplastics are microplastic particles derived from small particles with a size of <5 mm. In general, primary microplastics are also derived from chemical waste such as soap, called 'Scrubbers'. Scrubbers sizes ranging from 2-5mm impact filter-feeding organisms (Fendall and Sewell 2009). Secondary microplastics are particles derived from large, degraded plastic particles (Browne *et al.*, 2011). Microplastics threaten marine ecosystems, not only on the photosynthesis process in algae (Della Torre *et al.*, 2014) but also on the reproduction and hatching in certain organisms (Sussarellu *et al.*, 2016). Microplastics can accumulate in the bodies of animals such as fish, shellfish, and others. (Oehlmann *et al.*, 2019). Sources of microplastic pollution can come from a point or scattered sources. Siegfried *et al.* (2017) stated that microplastics come from a source from land-based and sea-based sources. Microplastics in household waste or industrial waste are discharged to a wastewater treatment plant (WWTP) or discharged without treatment into adjacent water bodies such as rivers. Disposal of this household waste is a potential entry point for microplastics because it can come from overflowing combined sewers. The discharge stream will lead to rivers, which are important pathways for microplastic waste generated from land to reach the marine environment (Lebreton *et al.*, 2017). Sources of microplastic pollution originating from scattered sources are waste sources without a specific point of disposal. Plastic is easier to enter the aquatic environment due to currents, rainfall, or wind (Siegfried *et al.*, 2017). Study about microplastics pollution on surface waters of marine environments in Indonesia's has been reported quite a lot, such as in the Jeneberang Estuary, South Sulawesi (Wicaksono *et al.*, 2020), coastal area of Nusa Penida, Bali, and coastal water of Bentar, East Java (Germanov *et al.*, 2019), Benoa Bay estuary, Bali (Suteja *et al.*, 2021), and Musi River estuary, South Sumatera (Purwiyanto *et al.*, 2020). Some studies also reported the existence of microplastics in sediments, such as in Sumatra west coast (Cordova and Wahyudi, 2016), Banten Bay (Falahudin *et al.*, 2020), and Muara Angke, Jakarta (Cordova *et al.*, 2021). Jakarta Bay is one of the plastic contributors, even the highest to marine environments in Indonesia. This condition becomes very threatening and needs attention. Wastewater with various pollutants enters flowing river waters (Suteja and Purwiyanto, 2018) and carries the water to Jakarta Bay, thus worsening the condition of waters in Jakarta Bay (Kunzmann, *et al.*, 2018). Heavy pollution in the Jakarta Bay area reached a high level where dissolved oxygen levels exceeded the quality standard, causing mass fish deaths on the north coast of Jakarta in 2004 (Sachoemar and Wahjono, 2007). Mass mortality of fish occurred repeatedly after, including in 2005 and 2007 (Anugrahini and Adi, 2018). Based on Cordova and Nurhati (2019), among wastes that enter Jakarta Bay, plastic waste accounts for 59 percent of abundance and 37 percent of weight. Dwiyitno *et al.* (2020) confirmed that plastic debris in Jakarta Bay ranged from 7,400 to 10,300 items/ km^2. That plastic debris is the potential source for contributing to the microplastics abundance in Jakarta Bay. The investigation on microplastics in the riverbed near Jakarta Bay has been reported by Manalu *et al.* (2017). As the riverbed is part of the river channeling to the coastal water, there might be a chance that microplastics can be carried through water flow. This number can be higher or even lower. Research conducted by Manalu *et al*. (2017) was lack with data on microplastics in water. According to Efadeswarni *et al*. (2019), microplastics were also detected in the digestive tract of several fishes collected in Jakarta Bay. The area of Jakarta Bay, especially in Muara Angke, was known to be an aquaculture area for mussel *Perna viridis*, which is marketed and consumed by locals or visitors (Irnidayanti, 2021). As the mussels live in the aquatic environment, understanding the existence of microplastics in their habitat is necessary. Related to food security, the contamination of food sources by microplastics in the environment could harm the consumer's health. Further, information about microplastics distribution is urgently required to develop efficient and effective microplastics management, especially in Jakarta Bay that receives high plastic discharges. The objectives of this study are 1) to determine the microplastics based on their shape (morphotype), 2) to determine the abundance and distribution of microplastics, and 3) to determine the polymer type of microplastics found on surface water and sediment in coastal water of Jakarta Bay. This study was conducted in 2020.

MATERIALS AND METHODS

Study area

The sampling site location was in the water of Jakarta Bay, Indonesia. Jakarta Bay covers 595 km^2 with a coastline of 149 km and a water depth of 15 meters. As the estuary of thirteen rivers, the condition of Jakarta Bay is influenced by the flow of waste carried by these rivers. The numbers of sampling site were 12 sites to represent Ancol (1-3), Muara Baru (4-6), Muara Angke (7-9), Muara Karang (10-12) as illustrated in Fig. 1. Ancol was dominated by vegetation, industrial and fishery activities in the central, and a combination of settlement and marine port in the Muara Angke - Muara Karang (Putri *et al.*, 2019). Coastal development, growing urbanization, and industrialization have increased pollution and sedimentation rates in the bay. Sediments in the inner part of Jakarta Bay were greyishly dominated by sand and clay, and shell fragments were also found. While in the outer part of the bay, the sediments were clayey sand and contained shell fragments. Lubis *et al.*, (2007) have estimated that the sedimentation rates in Jakarta Bay ranging from 0.074 cm/y to 0.852 cm/y. The climate observed in Jakarta Bay is tropical monsoon. This climate is characterized by a rainy season in October to March and a dry season in April – September (Dsikowitzky *et al.*, 2016). In the rainy season, Jakarta Bay also has high input of pollutants (ammonium and nitrate) (Suteja, 2016). The water in the bay of Jakarta has a counterclockwise movement and originates from the eastern part (van der Wulp *et al.*, 2016). The temperature range at Jakarta Bay is low and high at the nearshore within a range of 30 – 32 ^{o}C (Ladwig *et al.*, 2016). Salinity in Jakarta varies depending on the distance from river-mouth to the open sea (Huhn *et al.*, 2016). Chlorophyll-a decreased further away from river-mouth, in line with nitrogen and phosphate content (Damar *et al.*, 2020). Several types of demersal (*Argyrosomus amoyensis*, *Siganus guttatus*) and pelagic (*Rastrelliger kanagurta*, *Ilisha elongata*) fishes were also found in Jakarta Bay (Dwiyitno *et al.*, 2016). Several types of plankton (*Skeletonema costatum*, *Prorocentrum micans*) were recorded to have bloomed in Jakarta Bay (Ladwig *et al.*, 2016).

Surface water and sediment samplings

Surface water and sediment sampling activities were conducted two days on 3 and 10 August 2020, covering 12 sampling sites of Jakarta Bay during daytime starting 08.00 AM to 12.00 PM. A plankton net mounted with a 350 µm mesh size (net length 0.6 m, round opening diameter 16 cm) was used. Plankton net was towed horizontally to sample microplastics in surface water (Manbohi *et al.*, 2021). After the sampling in water was completed, the plankton net was lifted and flushed using surrounding water to limit potential microplastic contamination. Distilled water is also used to clean the inner part of 1 L high-density polyethylene bottle (Li *et al.*, 2021). Samples of sediment were taken using Stainless Steel Van Veen Grab with 15 – 30 cm wide and 5 L capacity (Manalu *et al.*, 2017). Amounts of 600 – 880 gram sediment were used (Li *et al.*, 2021). The sediment samples were then put into a high-density polyethylene bottle. During the field activity and transport, samples were kept in an iced box. In each sampling point, samples were collected with three replication. Each sample was then composited. The total samples collected were 24 samples consisting of 12 water samples and 12 sediment samples.

Isolation of microplastics

The microplastics in samples were separated

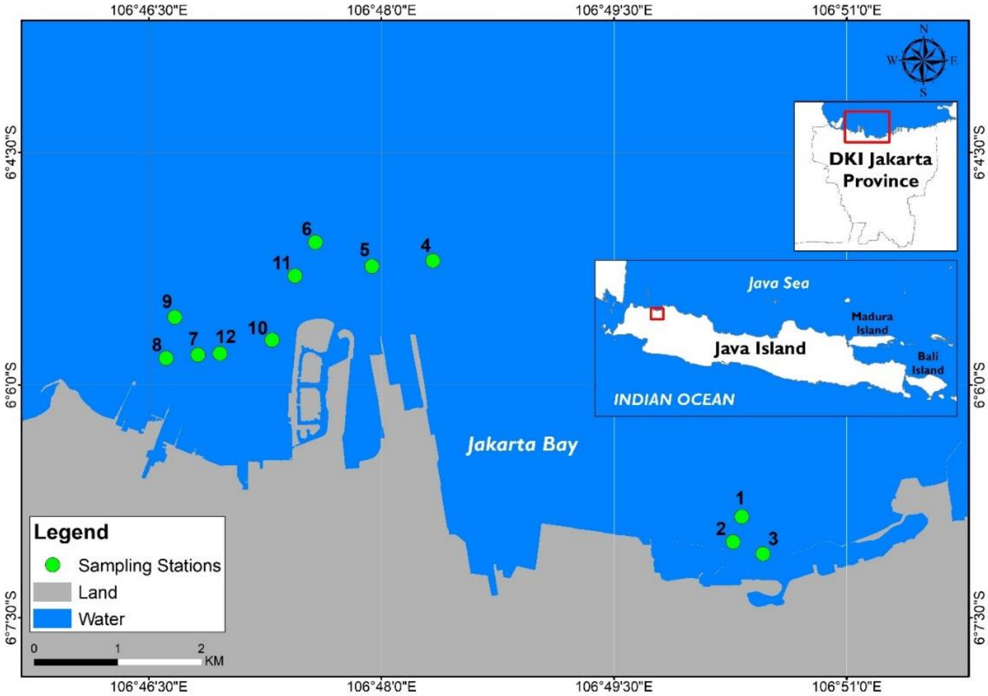

Fig. 1: Geographic location of the study area and sampling stations in Jakarta Bay, Indonesia

using the floating method based on the factor of densities differences. The water sample was filtered on test sieve analysis (ABM, with American Society for Testing and Materials E-11; aperture 200 mm; mesh no. 10) on the first layer and 500 µm (ABM, with American Society for Testing and Materials E-11; aperture 500 µm; mesh no. 35) on the layer below. The samples (filtered water) were shifted in beaker glass. Microplastics extraction of water samples was carried out by mixing the water sample into a measuring cup containing saturated NaCl solution with a ratio of 1:3 water volume (mL). The filtered water sample was around 500 mL then poured with NaCl Solution to make the microplastics float by the factor of densities. Samples were suspended using NaCl solution for 24 h to separate the sample from the remaining impurities, minimize the washing process, and increase the density of water samples (Nuelle *et al.*, 2014). After 24 h, microplastics floated at the surface, and heavier material was drained from the sample. 40 mL of the surface water sample was filtered on Whattman filter paper (cellulose nitrate 0.47 nm pore size 0.45 µ) adjusted with a vacuum pump (Millipore, 17 kPa). The filtered paper was placed into a Petri-dish for further identification. Sediment samples were dried at 40 °C for at least 48 h to obtain dry weight. Each dried sediment sample weighed around 50 g and then put into 1 L glass beaker and added with a saturated NaCl solution with a volume of 200 mL (density 1.20 g/cm^3) (Peng *et al.*, 2017). The suspension was stirred for two minutes and then allowed to stand until the sediment and impurities settled to the bottom of the measuring cup and left 24 h to extract microplastics by floating densities. After 24 h, 40 mL from the surface of the solution was filtered on Whattman paper using a vacuum pump (Millipore, 17 kPa). A vacuum pump (Millipore) filtration unit helps the filtration process in a shorter time. Samples from the filter paper were stored in Petri-dish for further identification.

Identification of microplastics

The identification of microplastics was performed visually using an Olympus CX21 microscope at magnification of 10x4 or 10x10. Indomicro View software was installed on the computer connected to the microscope and support better sample photographs. Visual identification of microplastics is grouped into four shapes, namely film, fiber, fragments, and pellets (Hidalgo-Ruz *et al.*, 2012). The samples of water and sediment at each location were taken and identified which has the most dominant shape as a representative sample for polymer analysis. Microplastics polymer analysis using the Micro-Raman Spectroscopic method was carried out using a Senterra II Compact Raman Microscope coupled with an optical microscope with a graft of 1200 lines/mm with a magnification of 20x and 50x. Each microplastics sample was excited with a 532 nm visible diode 1 laser and 785 nm - 60 mW near-infrared focused onto the sample for 10 - 60 seconds. Raman's spectrum was recorded as line measurements (N4 points) on different parts of the particle focused on avoiding dirt contamination. All spectra with a frequency resolution of 35/cm and a range of 400 – 4000/cm were analyzed using OPUS 7.5 software (Liu *et al.*, 2021). The obtained Raman spectra were then compared to the reference polymer plastic spectrum (Alam *et al*., 2019).

Quality control

For preventing contamination during the whole procedures of the microplastics analysis, precaution and quality control are applied. This procedure aims to make sure the microplastics data gained from this study is accurate. The distilled water was used to clean all equipment (Suteja *et al.*, 2021). The cotton-based gloves were chosen to avoid cross-contamination. During sampling, the plankton net was attached to the side of the boat to reduce contamination. All equipment used for laboratory purposes are sterile and made from non-plastics materials (Falahudin *et al.*, 2020).

Statistical analysis

PAST software was used to perform statistical analysis. The abundance of microplastics was expressed in the form of average values and confidence intervals visualized in box plots. The abundance of microplastics in surface water was recorded as the number of particles of microplastics per liter of seawater (particles/L). The abundance of microplastics in sediments was noted as the number of microplastic particles per kilogram of sediment (particles/kg). To observe variations between sampling sites, medium (sediment and water), and microplastic shapes (fiber, film, fragment, pellet), the t-test and 1 way ANOVA test were performed. The microplastic abundance in sediment and surface water from 12 sites was recorded for its geographical coordinate. The distribution map of microplastic was created using QGIS.

RESULTS AND DISCUSSION

Microplastics abundance and distribution

The 1532 microplastics particles were identified in surface water while a lesser number of 1419 microplastics were detected sediments from 12 sampling sites, with mean abundance varied from 55.8 to 86.6 particles/L in water and from 152.4 to 188.9 particles/L per kg dry weight in sediment. Sampling sites on Jakarta Bay were divided into 3 groups, namely the east group including three sites along the Jakarta shorelines (sites 1–3), the central group including four sites (4, 5, 6, 10, 11), and the west group (sites 7, 8, 9, 12). The East group represents microplastic discharges from vegetation-based sources, the central group represents microplastic discharges from industrial and fishery activities, and the west group represents microplastic discharges from settlement and marine port-based sources. Fibers, fragments, films and pellets are microplastic shapes found in this study (Fig. 2)

Among microplastic shapes, the mean abundance of the highest shapes of microplastic in sediment was fiber. While on the surface water, the mean abundance of the highest shapes of microplastic shapes was film (Fig. 3).

Table 1 summarized the Anova one-way result for abundance between morphotypes, while Table 2 showed the result based on location and Table 3 based on medium (water and sediment). All the results showed a significant difference ($p < 0.05$). This indicates there is a difference in the abundance of microplastic in terms of morphotype, location, and medium. The predominant shape of microplastics found in surface water was films, with an average proportion of 40 – 70 % (Fig. 4). Films were high in sites 4, 6, 8, 9 and covering Muara Angke - Muara Karang with maximum abundances equal to 181.3 particles/L. The second highest shape of microplastic abundance (107.1 particles/L) in surface water was fiber. The high abundance was also observed in the Muara Angke - Muara Karang, mainly in sites 12 and 10. Conversely, fragment microplastic was lower in Muara Angke - Muara Karang, and the highest

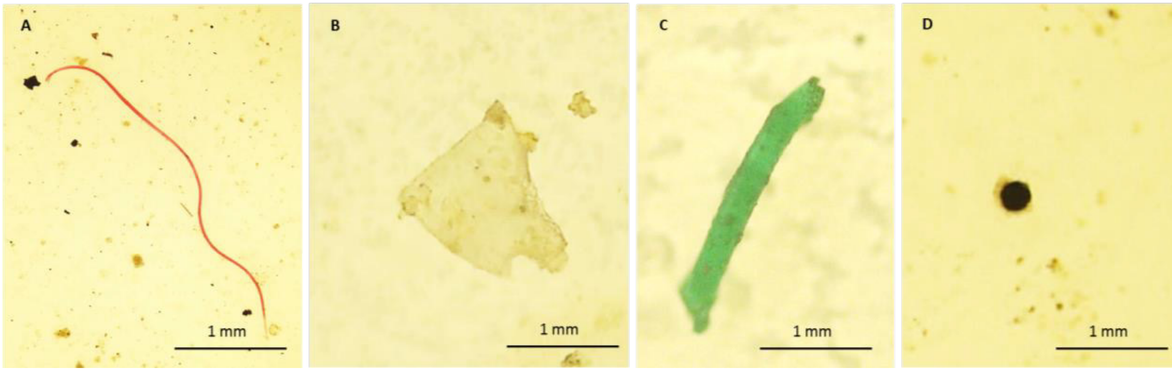

Fig. 2: Microplastics shape found in selected sample, a) fiber, b) film, c) fragment, d) pellet

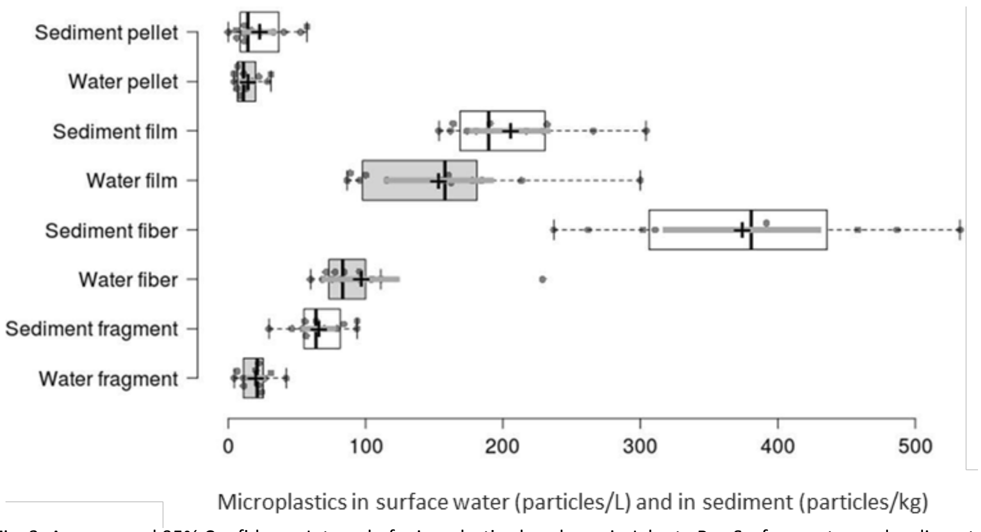

Fig. 3: Average and 95% Confidence Interval of microplastic abundance in Jakarta Bay Surface water and sediment

abundance was observed in the surface water in Ancol (27.4 particles/L) in particular sites 1 and 2. Pellet was a less common microplastic with an average proportion below 10%. Pellet abundance showed increasing trends to Muara Angke - Muara Karang with the highest abundance (15.5 particles/L) in site 6.

The abundance of microplastic in sediment observed was higher compared to the microplastic in surface water. The distribution and abundance of microplastics in sediment are showed in Fig. 5. Ancol has maximum abundances of fibers (416.9 particles/kg). Film was the second high microplastic in sediment with the highest abundance of 201.4 particles/kg in central parts covering sites 6, 8, and 11. Fragment microplastic was lower in Muara Angke - Muara Karang, and the highest abundance was observed in the sediments in Muara Baru and Ancol (78.5 particles/kg) in particular sites 2 and 4. Pellet was less common microplastic in sediments with an increasing trend to Ancol with the highest abundance of 42.8 particles/kg in site 3.

Jakarta Bay provides not only spaces for residential but also industrial activities on its shore and even in terms of ecological on spawning and feeding grounds for pelagic organisms in surface water and benthic mollusc in sediment (Cappenberg, 2017). At the same time, the surface water and sediment of Jakarta Bay were threatened by microplastics pollution based on the result of this study. The surface water of Jakarta

Tabel 1: Anova one way between morphotype

Summary	Sum of sqrs	df	Mean square	F	p (same)
Between groups	230641	3	76880,3	67,91	0,00
Within groups	104156	92	1132,13	Permutation p (n=99999)	
Total	334797	95	0,00		
Components of variance (only for random effects):					
Var(group)	3156,17	Var(error):	1132,13	ICC:	0,735996
Omega-2	0,6765				
Levene´s test for homogeneity of variance, from means	p (same):	0,00			
Levene´s test, from medians	p (same):	0,00			
Welch F test in the case of unequal variances: F=75,51, df=46,57, p=6,568E-18					

Tabel 2: Anova one way between location

Summary	Sum of sqrs	df	Mean square	F	p (same)
Between groups	245986	15	16399,1	14,77	0,00
Within groups	88810,4	80	1110,13	Permutation p (n=99999)	
Total	334797	95	0,00		
Components of variance (only for random effects)					
Var(group)	2548,16	Var(error):	1110,13	ICC:	0,696544
Omega 2	0,6827				
Levene´s test for homogeneity of variance, from means	p (same)	0,00			
Levene´s test, from medians	p (same)	0,00			
Welch F test in the case of unequal variances: F=24,44, df=29,38, p=1,387E-12					

Tabel 3: Anova one way between medium

Summary	Sum of sqrs	df	Mean square	F	p (same)
Between groups	270775	7	38682,2	53,17	0,00
Within groups	64021,8	88	727,52	Permutation p (n=99999)	
Total:	334797	95	0,00		
Components of variance (only for random effects)					
Var(group)	3162,89	Var (error)	727,52	ICC	0,812996
Omega 2	0,7918				
Levene´s test for homogeneity of variance, from means	p (same)	0,00			
Levene´s test, from medians	p (same)	0,00			
Welch F test in the case of unequal variances: F=55,52, df=37,16, p=9,48E-18					

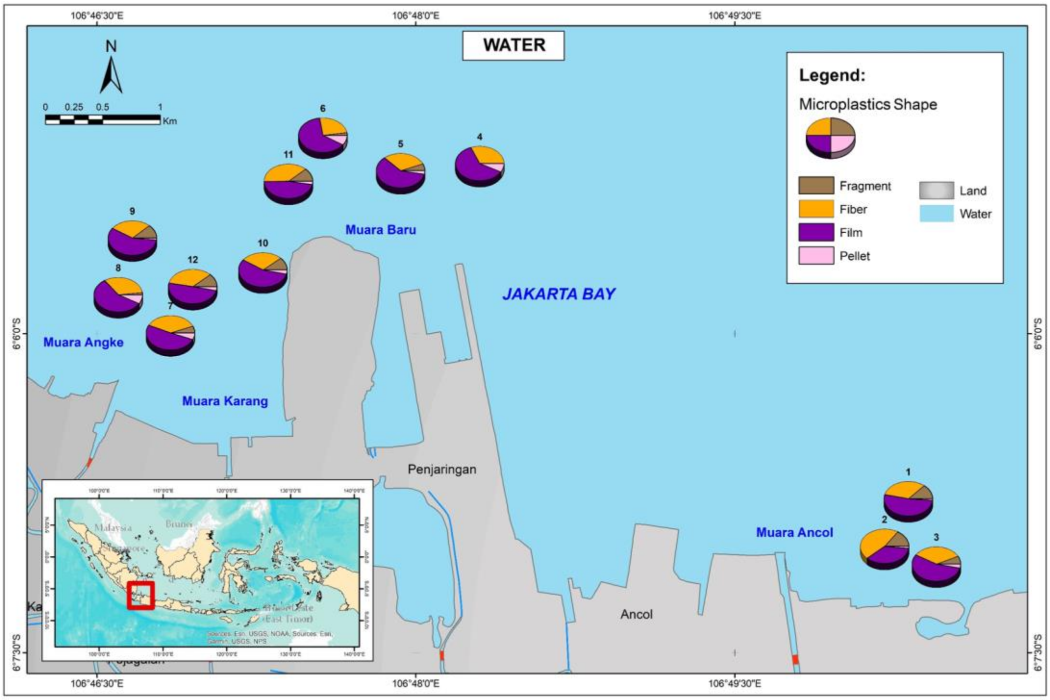

Fig. 4: Distribution and abundance (particles/L) of microplastic in Jakarta Bay surface water

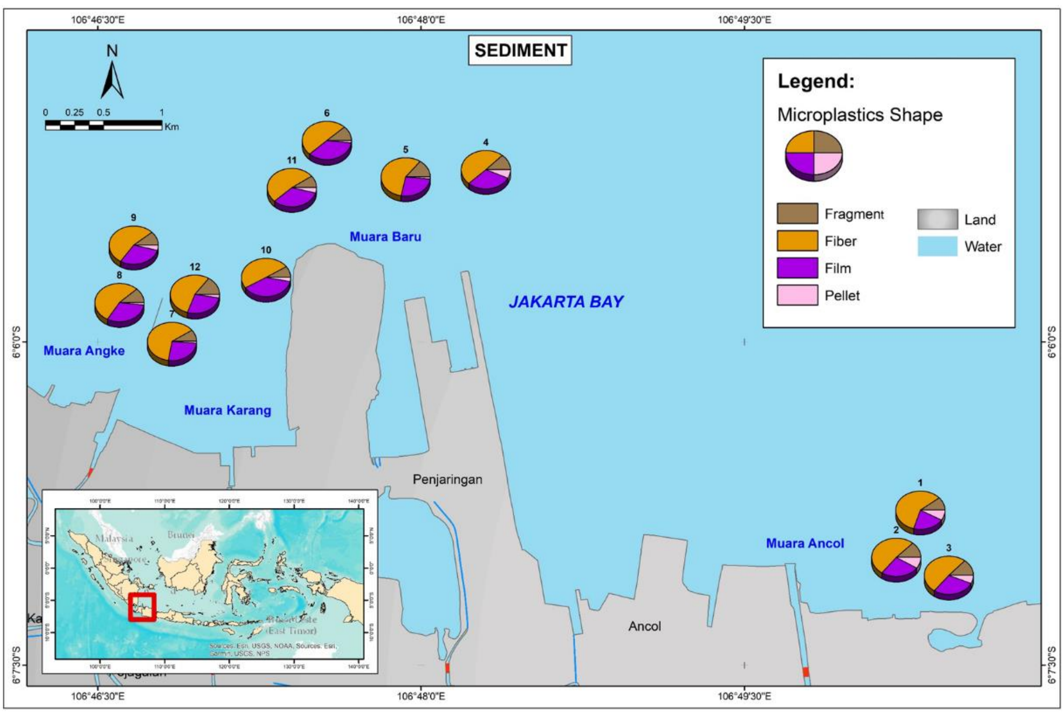

Fig. 5: Distribution and abundance (particles/kg/dry weight) of microplastic in Jakarta Bay sediment

Bay contains an average of 70.9 ± 27.1 particles/L. Its recorded microplastic abundance was higher compared to intact Benoa Bay, Bali-Indonesia (0.002 particles/L) (Suteja *et al.*, 2021), in Shanghai (27.84 ± 11.81 particles/L) (Zhang *et al.*, 2019), and Yellow River Bay (497 particles/L) (Han *et al.*, 2020). Microplastics abundance in sediment in this study (166.9 particles/kg) was 6 folds greater than microplastic in the sediment of the intact bay (28.1 ± 10.28 particles/kg) (Cordova *et al.*, 2021), whereas it is comparable to the microplastic from Banten Bay (267 ± 98 particles/kg) (Falahudin *et al.*, 2020) that also has been surrounded by settlement and industrial activities. Interestingly, in Jakarta Bay, the abundance and shape distribution of microplastic in surface water was contradicted the abundance of microplastic in sediments. In surface waters, microplastic abundance trends were increasing from Ancol to Muara Angke - Muara Karang. In contrast, microplastic abundance trends in sediment were opposite trends. High microplastic in surface water in Muara Angke - Muara Karang was correlated with low microplastic abundance in sediment in this part. A possible explanation for this is that microplastic particles from sediments experience sediment resuspension from the bottom. It causes the microplastics to rejoin the water column (Lambert and Wagner, 2018). As a result of this resuspension, microplastic abundance in sediment was lower than in surface water. This resuspension is influenced by nearshore circulation, offshore tides, and sedimentation rates. Another cause is related to the sedimentation rate. Radjawane and Riandini (2009) explained that the sedimentation rate in Ancol was lower than in Muara Angke - Muara Karang, which explains the higher microplastic abundance in this part. As can be seen in Ancol, the presence of a layer of microplastic in sediment aligns with the relatively low sedimentation rates (Martin *et al.*, 2017). The abundance of microplastic in found sediment in particular inshore of Ancol because those microplastics trapped into the vortex, eventually settling on the sediment instead of flushing out to the offshore (Claessens *et al.*, 2011). Film and fiber were microplastic shapes with the highest abundances, and both were high in surface water of Muara Angke - Muara Karang and Muara Baru, where fishery activities and settlements dominated the land use. Films in sediment in central parts were also observed high. There is Muara Angke fishery port in those location, with an average of 275 ships visiting this port every month. The presence of films in high quantity was in agreement with Yona *et al.*, (2019) that film high abundances were related to the presence of the fish landing area nearby. Li *et al.*, (2020) reported that the presence of an aquaculture market nearby might accumulate microplastics within marine environments. Fibers were also related to the fishing activities as mostly local fishermen use plastic fishing nets. Zhu *et al.*, (2018) observed a high abundance of fibers in the North Yellow Sea due to constant use of plastic fishing and nets and ropes as the main fishing tools. The settlements in Muara Angke - Muara Karang of the bay were also contributing to the fiber abundances. Besides originating from fishing activities, fiber microplastics are widely used originated from clothing from nearby settlements. Fragments were higher in surface water and sediment in the exact location in Ancol near site 3. High abundances of fragments in the precise location were related to the presence of a river nearby. The riverbank of this area was dominated by combinations of industrial and residential land uses. The high fragment shape in an aquatic environment indicates that microplastics are produced from waste originating from population activities either through rivers or landfills. The fragment is a microplastic shape formed from macroplastic fragmentation due to weather, mechanical processes, and the domestic waste discharges from nearby settlements. In this study, pellets have the lowest abundance compare to other shapes. This type of microplastic is known as the primary material for making plastics produced directly from factories and industries (Sulistyo *et al.,* 2020) and is used to produce of larger plastic products (Espiritu *et al.,* 2019). The absences of plastic factories near the sampling sites may explain the low abundance of pellets compared to other microplastics. Microplastics abundance in sediment tend to be higher than abundances in surface water can be seen in fragment and film microplastics. Fragment abundances in Ancol in the sediment of site 3 were 3 folds greater than in water. The same condition can be seen from film abundance in the sediment of Muara Angke - Muara Karang that 16% higher than film abundance in surface water. Higher microplastic in sediment was in agreement with the microplastic accumulation and sea bottom as a sink for plastic debris. The accumulation and sinking

Table 4: Microplastic polimer

Sample	Ancol			Muara Baru			Muara Angke			Muara Karang		
	1	2	3	4	5	6	7	8	9	10	11	12
Surface water	PE	PE	PE	PE	PE	PE	PE	PP	PP	PE	PE	PE
Sediment	PP	PP	PS	PP	PE	PE	PE	PP	PP	PE	PS	PP

of plastic debris are related to plastic's buoyancy (Woodall *et al*., 2014). Fragment and film have less buoyancy and sinking fast. In contrast, fibers and pellets were more buoyant and stayed longer at the surface water (Chubarenko *et al.*, 2016). It explains why fiber and pellet abundances in Muara Angke - Muara Karang were high in surface water, and in contrast, the fiber and pellet abundance in sediment were low. The study location is 1-2 km from the mainland. This location is considered as nearshore where freshwater input is still influential. Currents in this area are generally high at low tide, especially those close to river mouths. At low tide, the current is influenced by flood discharge, especially during the rainy season. Currents in Jakarta Bay move from east to west (Yayah Surya *et al*., 2019). It may explain that the Muara Karang and Muara Angke areas have the highest abundance of microplastics in surface water. In this study, where most inputs from freshwater affect the sampling site, we assume that any municipal or industrial waste carried by the flow also contributes to the source of microplastics. Based on the study of Hidayaturrahman and Lee (2019), microplastics were detected in municipal and industrial wastewater treatment. In addition, Liu *et al.* (2019) found that microplastic detected industrial, agricultural, and municipal waste on wastewater treatment. Unfortunately, Jakarta municipality is a lack wastewater treatment. Wastewater generated from both residents and industry runs to surface water. It is estimated that 1,3 million people in slum areas drop their waste into the river without treatment (Luo *et al.*, 2019). Alam *et al.* (2019) reported that microplastics were detected in river waters near slum areas in Majalaya. Ancol waters are the estuary of the Ciliwung river, while the waters of Muara Baru are one of the estuaries of the Krukut river. Ancol is located close to artificial beach tourism activities.

Microplastic polymer

Microplastic polymers in surface water and sediment in this study are shown in Table 4. Two polymers, polyethylene and polypropylene were detected in surface water. The most common type of polymer was found in all locations was polyethylene. Polypropylene in surface water was only detected at points 8 and 9 of Muara Angke. The detected polymers in sedimentary microplastics consisted of polyethylene, polypropylene, and polystyrene. Polypropylene and polyethylene were detected more in the sediment at the sampling site compared to polystyrene.

The polymers were found during this study can come from the waste that enters the waters of Jakarta Bay which is dominated by plastic bags and merchandise packaging (Manalu *et al.*, 2017). All the polymers found have a lower density than water and cause microplastics to float on the water surface so that they are easy to detect. Microplastics with concentrated colors an initialed as identification of polyethylene polymers that are widely found in surface waters. Polyethylene is the main material for creating plastic bags and containers (GESAMP, 2015).

CONCLUSION

This study succeeded in identifying microplastics in Jakarta Bay in number about 2900 particles of microplastics. The microplastics found in both surface water and sediment are fibers, films, fragments and pellets. There are three forms of polymers detected in microplastics in Jakarta Bay, namely polyethylene, polypropylene and polystyrene. Microplastic fibers and film forms were the most dominant based on their abundance, both in surface water and in sediments. In this study, the pattern seen is in sediment, fiber > film, in surface water, film> fiber. When viewed from the type of polymer, polyethylene is the most dominant polymer compared to other polymers in microplastics detected in surface water and sediment. This indicates that the degraded and accumulated microplastics in surface waters and sediments in Jakarta Bay originate from plastics made from these polymers that produce microplastic fibers and films through specific degradation mechanisms. Based on distribution, the highest microplastic abundance in surface water was found in the Muara Angke - Muara Karang following the presence of industrial, settlement, and fishery activities. These anthropogenic activities have contributed to the particular microplastic shapes, including fibers and films. The presence of a river with its riverbank dominated by combinations of residential and industrial have also contributed to the discharges of fragment microplastics in the bay. By comparing the microplastic both in surface water and sediment, it can be seen that some microplastic can stay longer at the surface, and some were sinking to the bottom. The existence of differences in the character of microplastics in both shape and polymer indirectly helps control contaminants in the aquatic environment. Microplastics abundances both in sediment and surface water were higher near inshore areas than offshore areas. Referring to the results of this study, in managing microplastic in Jakarta Bay and considering the abundance distributions, management of surface water should be prioritized in Muara Angke - Muara Karang while management of sediment should be maximized in Ancol. With these findings, the amount of microplastics is higher than in previous studies, indicating the increasing number. We might assume that this increasing number may be related to land-based activities and sea-based activities. As a further recommendation, the study can be expanded to detect marine microplastics in each municipal and industrial waste so the contributed number can be accurately determined.

AUTHOR CONTRIBUTIONS

N.D. Takarina performed the conception and design, drafting manuscript, obtaining funding, supervision. A.I.S. Purwiyanto analysed and interpreted data, critical revision of the manuscript for important intellectual content. A.A. Rasud administrated the technical, material support, drafting of the manuscript and statistical analysis. A.A. Arifin administrated technical, material support, statistical analysis. Y. Suteja performed the acquisition of data, supervise, analyisis and interpretated data, and also critical revision of the manuscript for important intellectual content

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CONFLICT OF INTEREST

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues including plagiarism, informed consent, misconduct, data fabrication and, or falsification, double publication and, or submission, and redundancy have been completely witnessed by the authors.

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ABBREVIATIONS

ANOVA	Analysis of variance
ASTM	American Society for Testing and Materials
$C_6H_7O_2(ONO_2)_3$	Cellulose nitrate
cm/y	Centimeters per year
/cm	Reciprocal centimeter
GESAMP	Group of experts for scientific aspects of marine protection
g/cm^3	Gram per cubic centimeter, unit of density
h	Hour
HDPE	High-density polyethylene (kind of plastic polymer)

items/km²	Items per square kilometer
kg	Kilogram
km	Kilometer
km²	Square kilometer
kPa	Kilopascal, unit of pressure
L	Liter
m	Meter
mL	Milliliter
mm	Millimeter
MMT	Million metric ton
mW	Mega watt
NaCl	Sodium chloride
nm	Nanometer
particles/kg	Particles per kilogram
particles/L	Particles per liter
PAST	Paleontological statistics
PE	Polyethylene
PP	Polypropylene
PS	Polystyrene
QGIS	Quantum geographic information system
WWTP	Wastewater treatment plant
µ	Micron
µm	Micrometer
%	Percent
°C	Degree of Celcius

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