Microplastics abundance in coastal sediments of Jakarta Bay, Indonesia

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Abstract. Microplastic pollution is currently one of the threats in marine ecosystem and has been focus of researches of environmentalists in all over the world. This problem also occurs in Indonesia, especially in Jakarta Bay. High activities along the rivers flowing to the bay are predicted to be extensive microplastic distribution channels to the sediment of the waters. The purposes of this study were to identify and quantify type and size of microplastics in sediment of Jakarta Bay. Sediment samples were collected twice, in December 2015 and January 2016, on the riverbed in Pluit and Ancol areas. Microplastics from sediment were separated by the following steps: drying, volume reduction, density separation, filtration, and visual sorting. The abundance of microplastic was very high in both locations ranging from 18,405 to 38,790 particles kg^{-1} dry sediment. Fragment with size of 100-500 µm was the most abundant microplastics in the two locations. Majority of polymer found in the sediment were low density polypropylene (PP). Characteristic of microplastic is needed as an approach to determine its main source, so that the microplastic pollution in Jakarta Bay can be managed properly.

Key Words: Ancol, debris, Pluit, pollution, river bed.

Introduction. Plastic is a synthetic polymer derived from various monomers generally as the result of extraction of oil or gas (Guven et al 2017). In 2014, plastic production has reached 311 million metric tons (MT) and this number will be increased every year (Plastics Europe 2015). Increased production of plastic without degradation ability contributes to environmental problems such as the accumulation of plastic in the natural habitat (Barnes et al 2009). Mechanically-assisted wave and photochemical process by UV-B cause the plastic fragmentation (Cooper & Corcoran 2010; Andrady 2011). Small-size fragments of plastic (size <5 mm) are categorized as microplastics by some researchers (Moore 2008).

Based on studies conducted in the last few years, microplastics have become widespread until the waters bottom. For example, it spreads in 10 locations of the coastal region of the Mediterranean affected by anthropogenic activities (farming, industry, and the city center) where both polyethylene and polypropylene are most polymer types commonly found in the sediment (Vinello et al 2013). The widespread, high density (Lusher et al 2013), size (Moore 2008; Fossi et al 2012) and color of microplastics that resembles prey (white, tan and yellow) are potentially consumed by various marine organisms, either invertebrates or fish (Setala et al 2014).

This problem also occurs in Indonesia, especially in Jakarta as the national capital region. High activities along the river flowing to the bay are predicted to be extensive microplastic distribution channels to the sediment of the waters. Pollution related problems in Jakarta Bay and its surrounding areas have been reported (Wardiatno et al 2000; Wardiatno et al 2004; Damar et al 2012; Prabawa et al 2014; Simbolon et al 2014a,b; Wardiatno et al 2017). However, the information about microplastic pollution in sediment is lacking. The purposes of this study were to identify and quantify the type and size of microplastic on the sediment in two riverbeds in Jakarta Bay region.

Material and Method

Description of the study sites. Sediment samples were collected twice, in December 2015 and January 2016, from the riverbed in Pluit and Ancol areas (Figure 1). At both locations, samples were collected in two points, close to the sea and away from the sea with the distance between each point was 10 m. Samples were taken by van Veen grab at the point aligned with the body of the river. The collected samples were placed in sample bottles, and analyzed in the laboratory.

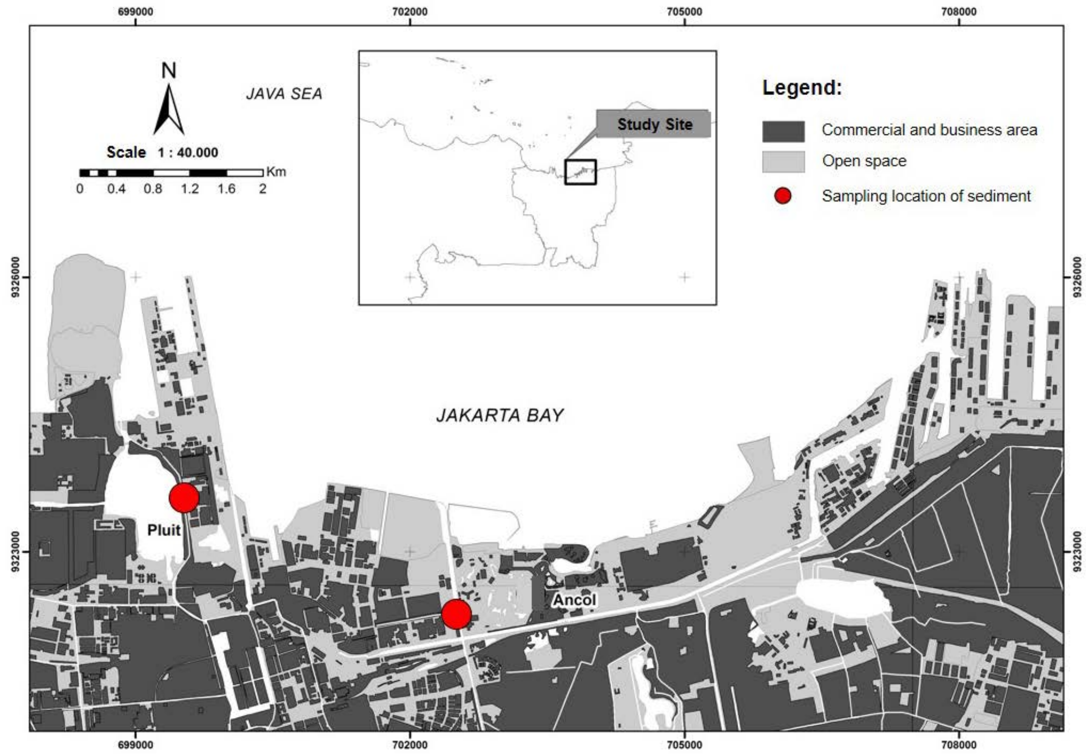

Figure 1. Map showing the sampling location in Pluit and Ancol, Jakarta Bay, Indonesia as indicated by red circles.

Laboratory analysis. Microplastics were separated by the following steps: (a) drying, (b) volume reduction, (c) density separation, (d) filtration, and (e) visual sorting (Hildago-Ruz et al 2012). Sediment samples were dried using 105^{o}C oven for 72 hours (depending on the condition of the sediment). Dried sediments were then ground using a mortar (Nor & Obbard 2014), volume of sediment was reduced by the filtration (5 mm size); thus, sediments with size >5 mm were retained on the filter. The next stage was density separation by mixing a solution of saturated NaCl (3 L) into the sediment, and then stirred for 2 minutes (Claessens et al 2011). Separation was done with the graded-filter (5000 µm, 1000 µm, and 30 µm). Smaller microplastic samples (30-100 µm) were separated using a monocular microscope (magnification 10 x 10). Abundance data oserved were type and size of microplastic. Furthermore, medium size microplastics (500-5000 µm) were sealed in aluminum foil. The abundance of the microplastics was then analyzed and the type of plastic was analyzed specifically using FT-IR.

Statistical analysis. Variations between abundance in two locations, and size group of microplastic were compared using one-way ANOVA, followed by Duncan test. Significance of differences was defined at $p<0.05$. Statistical analyses were performed using SAS.9.1 software.

Results and Discussion. Based on study conducted by Hidalgo-Ruz et al (2012), the highest concentration of microplastic was found in the bottom sediments than in the water surface (Chubarenko et al 2016). Microplastics in the bottom sediments are affected by gravity, and magnitude of the density of the plastic, that is higher than the density of water, causing the plastic sink and accumulation in sediments (Woodall et al 2015).

Microplastic abundance in the sediments of the two study locations was significantly different ($p<0.05$), ranging from 18,405 to 38,790 particles kg^{-1} dry sediment. This finding is higher than previous studies in the mangrove area of Pantai Indah Kapuk (PIK) Jakarta (216.8-2,218.4 particles kg^{-1} dry sediment) as found by Hastuti (2014). In Belgian Coast, the abundance microplastic was 390 particles kg^{-1} dry sediment (Claessens et al 2011), and in China 8,720 particles kg^{-1} dry sediment (Qiu et al 2015). In contrast, this finding is lower than the abundance of microplastics in Kachelotplate Island which ranged from 0 to 62,100 particles kg^{-1} dry sediment (Liebezeit & Dubaish 2012). The abundance differences might be due to the different characteristics and environment of the locations. The study site is a watershed affected by anthropogenic activities, because it is located very close to the dense settlement and high tourism activity which has the potential to generate freely waste release into the environment. The positive correlation between the microplastic abundance and population density has been demonstrated in various locations (Browne et al 2011). The effect of different types and sizes of substrates to the existence of microplastic can also affect microplastic abundance in sediments. The soft sediments have a higher potential to adsorb the microplastic waste. On the other hand, Mathalon & Hill (2014) and Alomar et al (2016) stated that microplastic abundance varied in different particle size of sediment, although both studies have not addressed a clear relationship patterns. Another factor affecting the differences of microplastic abundance in sediment is the difference of experimental method used in each study causing different data validation, so that each study is sometime difficult to compare (Qiu et al 2015). Microplastic abundance in sediment in downstream areas of Pluit and Ancol are presented in Table 1.

Table 1

Microplastic abundance in the sediment at the downstream areas of Pluit and Ancol

Location	*Sampling point*	*Microplastic abundance (particles kg^{-1} dry sediment)*	
		Dec 2015	*Jan 2016*
Pluit	Close to the sea	38,790	38,592
	Away from the sea	38,112	37,440
Ancol	Close to the sea	27,284	19,230
	Away from the sea	22,202	18,405

There is pattern in both locations, i.e. microplastic abundance at point close to the sea was higher than the point away from the sea. Differences in sediment sampling point caused the potential existence of microplastic at point close to the sea higher because microplastic source can be derived from both land and sea territory. The decline trend in the abundance of sediment samples in both times of observation is allegedly influenced by different rainfall. In addition, the decline in abundance at the Ancol sediment in January 2016 could also be due to the regular cleaning activity of the local government. Sampling at this location was done a week after the cleaning process had been done, though it did not significantly affect the reduction of microplastic at both points in the downstream area of Pluit at the same samploing date.

Microplastics type. Three types of microplastic in the sediment samples were found: fibers, fragments, and pellets. Microplastic on each of those types sinks and accumulates in the bottom sediments, which allows it to be digested by benthic organisms (Claessens et al 2011). The highest type abundance in each location was fragment (Figure 2). Although the abundance was different in each sediment sample, but the location, the sampling point, and the time showed no significant difference on the abundance, while type of microplastic showed significant difference (ANOVA: $p<0.05$) with abundance of fiber was significantly higher than other types.

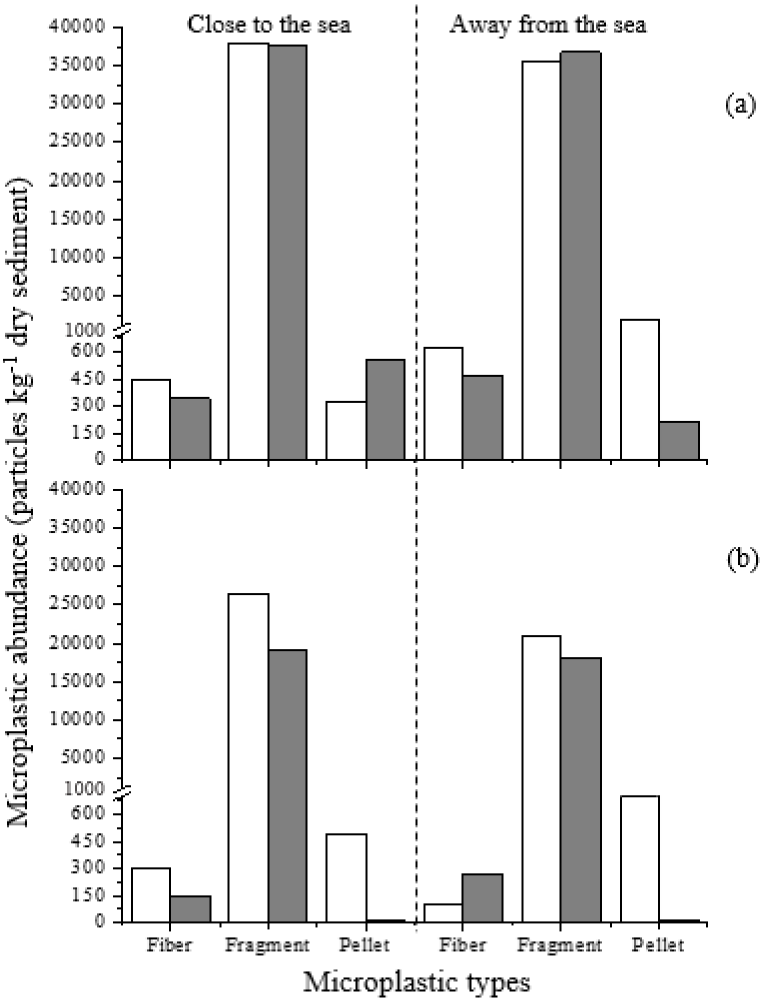

Figure 2. Microplastic abundance based on types in the sediment at downstream areas of Pluit (a) and Ancol (b), ☐ December 2015, ■ January 2016.

Dominant type of microplastic found in this study was different from the results found in several studies around Jakarta and other research. The study conducted by Hastuti (2014) on the mangrove area of PIK showed that film was more dominant by 67.7-74.1% of the total microplastic found. Another study conducted by Assidqi (2015) in Rambut Island showed that fiber was more dominant (50-97%) than other types. Similar results found in studies conducted by Claessens et al (2011) in Belgian Coast; Liebezeit and Dubaish (2012) in Spiekeroog and Kachelotplate Islands; also Nor & Obbard (2014) in mangrove area of Singapore showed fiber as the most common type of microplastic. On the other hand, study conducted by Alomar et al (2016) in Mediterranean Sea showed that the abundance varied in 3 locations, i.e. Andratx, Es Port, and Santa Maria. Fiber was the most abundant type in Andratx, but in Es Port and Santa Maria, fragment was the most abundant.

Alomar et al (2016) reported that fiber found in Andratx was derived from the waste released by the manufacture of synthetic clothing produced by the textile industry as a major source of microplastic contamination. In contrast to the Andraxt, fragment predominantly found in Es Port and Santa Maria was caused by a number of macroplastic found at the time of sampling which floated on the sea surface (Alomar et al 2016), this can be attributed to the process of fragmentation of the larger plastic that can occur (Wagner et al 2014).

Based on the estimation by Wagner et al (2014), similar results possibly occurred in this study. A number of macroplastic floating along the water bodies and covering the surface of the water were found at the location of the sampling. The lower flow of the river (0-0.1 m s^{-1}) at the study site causes the movement of the macroplastic be slow and accumulated, so it is predicted that fragmentation process occurs in the plastic. The macroplastic will be degraded into smaller particles assisted with heat, sunlight, physical (waves) and chemical processes (Andrady 2011; Barnes et al 2009) and sunk in riverbed. Microplastic particles commonly found in sediment had higher density than water, whereas low-density microplastic was commonly found on the surface of the water. In certain cases, low-density microplastic modified through the process of biofouling by prokaryotic, eukaryotic and invertebrates that increase the density of microplastic can also reach the bottom sediments (Andrady 2011; Reisser et al 2013; Zettler et al 2013; Jorissen 2014).

Microplastic size. Microplastic abundance in sediments was distributed in seven groups of microplastic size. The abundance varied in each type of microplastic found at each point during both times of sampling. Similarly, distribution pattern of the abundance of the fragments in the sediment at downstream area of Pluit tend to be the same, while the pattern of both fiber and pellet were different on each point of observation. The most abundance in this study was found generally in the 5th group (100-500 µm). Microplastic abundance based on size in Pluit and Ancol is presented in Figure 3 and 4.

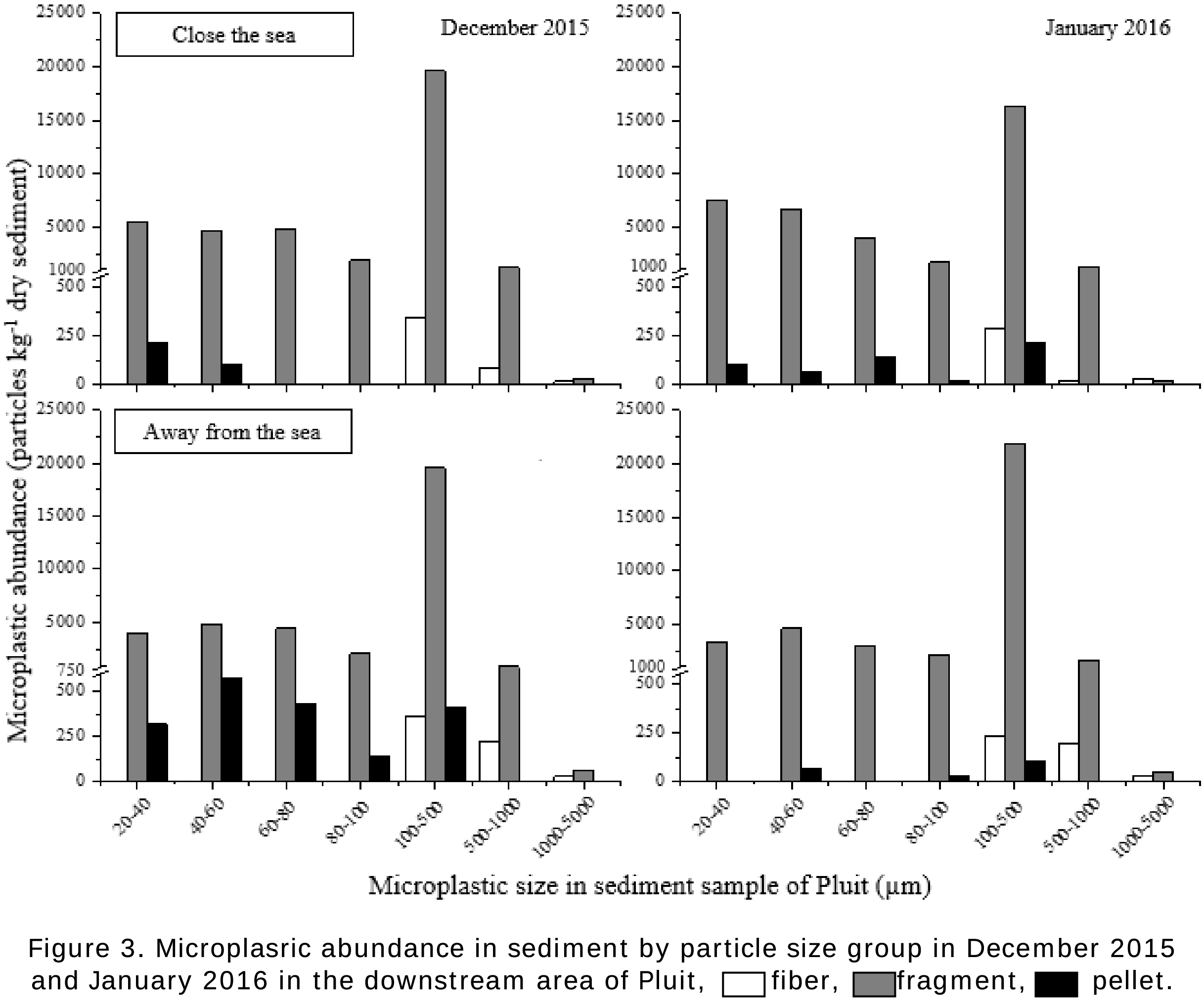

Figure 3. Microplasric abundance in sediment by particle size group in December 2015 and January 2016 in the downstream area of Pluit, ▭ fiber, ▭ fragment, ■ pellet.

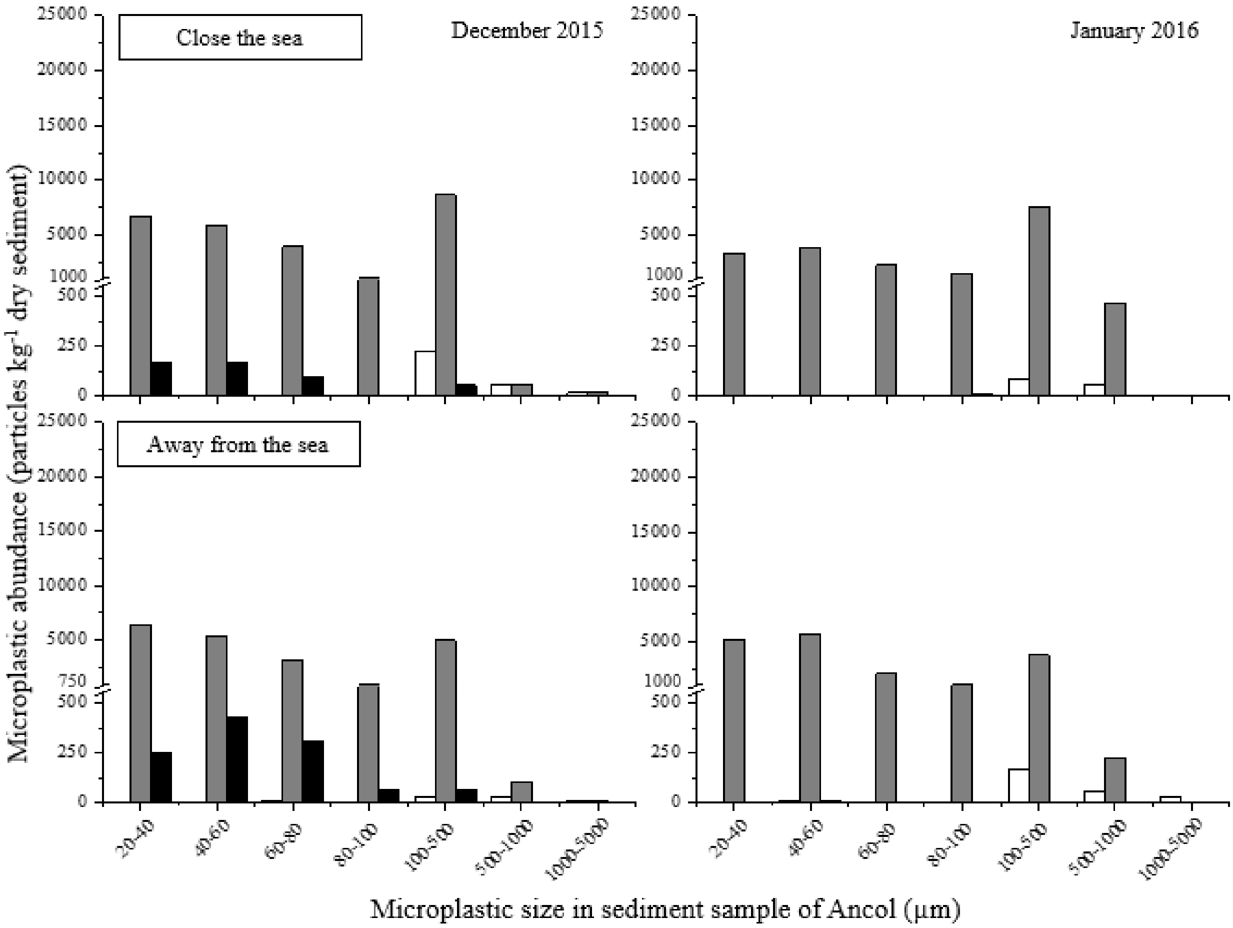

Figure 4. Microplasric abundance in sediment by particle size group in December 2015 and January 2016 in the downstream area of Ancol, fiber, fragment, pellet.

Microplastic size on sediment sample was bigger than that on the water samples. In the sediment samples, the particle size of microplastic was more commonly found in the size of 100-500 μm, whereas in the water sample, the particle size of 20-40 μm was more commonly found. The location, the sampling point, and time did not significantly affect the abundance of each grade, while the abundance in each size group showed significant differences (ANOVA: $p>0.05$) with size group of 100-500 μm was significantly different. It indirectly suggested that the size affected the existence of microplastic, although the density test of the plastic type included in the group of high or low density is necessary.

On the other hand, Nor & Obbard (2014) reported that most microplastic (58%) was found in the size of less than 40 μm which is the same size as micro- and nanoplankton, while research conducted by Strand & Tairova (2016) showed that the size of 20-300 μm contributed to the microplastic abundance by 69-97%. The size obtained in both studies was much smaller than the results of this study. It can be caused by the difference of dominant type of plastic in each study. In this study, fragments tended to be more predominantly derived from plastic bags or food packaging plastic, while in both studies was dominated by fiber which generally has higher density than the density of sea water (Goldstein 2012), such as polyester, acrylic and polyamide (nylon) so that even a smaller size than those found in the study, the plastic is able to sink to the riverbed.

Small size fraction of microplastic in the sediment is not only influenced by the density of the material of the microplastic but can also be affected by other factors. In the case of this study, plastic is allegedly accumulated in a long time in this area so that entrapped in sediments in the form of black mud and stick to the plastic that can increase the density of microplastic. In addition, the process of biofouling by organisms possibly occurred can also cause the microplastic reach the bottom sediments. Microplastic found in the sediment is presented in Figure 5.

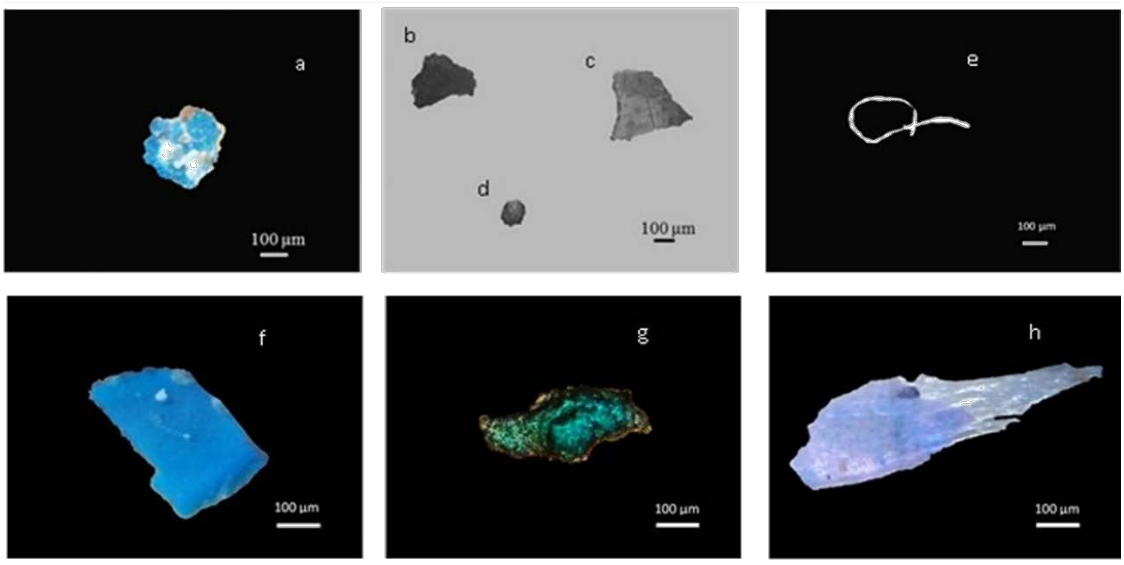

Figure 5. Microplasric found in the sediment with types of blue fragments (a, f, g), black fragments (b,c), white fragment (h), black pellet (d), and white fiber (e).

Macrodebris. Besides microplastic, macrodebris entangled in bottom sediments was also found in the sediment samples. Visual identification resulted in some type of macrodebris in the form of fiber/fabric, glass, rubber, ceramics and plastics (Table 2).

Table 2

Abundance percentage of macrodebris found in sediments of Pluit and Ancol

Location	*Macrodebris type*	*% Macrodebris abundance*
	Fiber/fabric	19.30
	Glass	0.52
Pluit	Rubber	2.70
	Ceramics	0.00
	Plastic	77.48
	Fiber/fabric	51.87
	Glass	2.78
Ancol	Rubber	7.77
	Ceramics	5.18
	Plastic	32.41

The highest percentage of abundance of the macrodebris was found on the plastic in Pluit area, while Ancol was dominated by fiber. The same type was also predominantly found in study conducted by Zhou et al (2011) on the seabed around the northern part of South China Sea. Total abundance of macrodebris is strongly affected by human activity around these waters, such as the results of study conducted on the seabed of Belgian that macrodebris was obtained from ships entering the the harbor (Cauwenberghe et al 2013). On the other hand, macrodebris abundance found around the South China Sea is the result of recreational and fishing activities (Zhou et al 2011). Macrodebris found in this study is more affected by the activity within the land than sea activity which causes macrodebris generated is more in the form of plastic as a result of recreational, housing and industry activities.

Among macrodebris found in sediment samples, 170 units were found to be macroplastic which were further analyzed to determine the type of polymer using FTIR. FTIR analysis showed that six types of polymer, polypropylene (PP), polyethylene terephthalate (PET), polyester fiber, nylon, dipar, and ethylene propylene diene monomer

(EPDM) Peroxide Cure Warco were found. Majority of polymer found in the sediment were low density polypropylene (PP). The similar results were also obtained by Vinnelo et al (2013), polypropylene are most polymer commonly found in the sediment. Polymers of macroplastic found in sediment samples could be used in estimating the type of polymer from microplastic in sediment.

Conclusions. Microplastic abundance in sediment sample was relatively high with the characteristics of different types and sizes in each location. Fragments were the most dominant type with the most size commonly found is 100-500 µm which can be predicted derived from secondary sources in the form of shards of plastic bags released carelessly into the waters. Majority of polymer found in the sediment were low density polypropylene (PP). Physical characteristic of microplastic is needed as an approach to determine the main sources, so that microplastic in Jakarta Bay can be managed properly.

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