Occurrence and abundance of microplastics in coral reef sediment: a case study in Sekotong, Lombok-Indonesia

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Abstract. Microplastics are categorized as less than 5 mm in length - sized plastics. Lombok is located in Indonesia, part of the coral triangle region, and one of the out flow locations of the Indonesian Through Flow (ITF). There is likelihood that microplastics would flow across the ITF and would be accumulated in the coral reef ecosystem, especially in biota and sediment. To improve the knowledge of microplastics pollution in Indonesia, we analyzed sediment samples from 10 stations at coral reef habitats in Sekotong, Lombok - Indonesia. The microplastics concentration in Sekotong varied from 35 to 77 particles per-kg, with average 48.3±13.98 (SD) particles per-kg, found in all ten sampling location. The highest concentration was found in the south-west of Gili Gede Island (77 particles per-kg). All of the microplastics collected were foam (41.20%), fragment (32.51%), granule (22.77%) and fiber (3.52%). Microplastic with size more than 1000 µm found at most, followed by size range of 500-1000 µm, 200-500 µm and particle size less than 200 µm in length. Polystyrene was the most abundant type of plastic polymer identified, followed by polyethylene and polypropylene. This type of polymers indicates that the primary source of microplastics in the Sekotong's coral reef sediment was from the usage of styrofoam, food and beverage packages, also fishing devices. It is strongly suggested that the management of plastic waste to be improved and it is essential to develop an environmentally friendly substance to replace plastics in near future.
Key Words: microplastics, pollution, sediment, coral reefs, Indonesia.

Introduction. Plastic production has been increasing rapidly and became a potential threat to the marine environment. Plastic production in a wide variety of products reached 335 million tons worldwide and is estimated to have an upward trend of 1.5-2.5% on 2017 and 2018 (PlasticEurope 2018). High consumption of plastics exceeds the recycle rates. Most of the plastic packages are not recycled, only 14% plastics package collected for recycling, 40% of which go to landfill, 32% leaks to the environment including marine ecosystem and the other 14% plastics wastes incinerated and/or used as energy recovery (Ellen MacArthur Foundation 2016). Recent studies indicate that plastic debris in the ocean are between 7,000 and 250,000 metric tons (Cozar et al 2014; Eriksen et al 2014). This prevailing condition is enough to notice that plastics have been a new potential threat to the environment.

Based on the size, plastic particles in the marine environment are categorized into megaplastics (≥ 1 m), macroplastics (≥ 2.5 cm - 1 m), mesoplastics (≥ 1 mm - 2.5 cm), microplastics (≥ 1 µm - 1 mm) and nanoplastics (≤ 1 µm) (GESAMP 2015). However, < 5 mm sized plastics are categorized as microplastics. Large sized plastics (mega and macro sized plastics) have direct external effects, such as entanglement and swallowing, not only cause damage for marine organisms (Laist 1997; Cole et al 2011; Gall & Thompson 2015), but also impact the death of large marine organisms, like marine mammals, seabirds and sea turtles (Coppock et al 2017).

The effects of small sized plastic pollution (microplastics) are not apparent due to lack of research. However potential environmental risks are known, but real consequences are mostly unknown. Marine organisms are discovered accumulating microplastics (Browne et al 2008; Boerger et al 2010; Van Cauwenberghe et al 2012; Cole et al 2013; Farrell & Nelson 2013; Van Cauwenberghe & Janssen 2014). Microplastics could leach additive substances and also transfer high concentration of pollutants (Avio et al 2015; Paul-Pont et al 2016).

Coral reefs, one of the richest marine habitat, have biotic ecological services as important spawning, nursery, breeding and feeding areas for a multitude of organisms (Moberg & Folke 1999). The entry of microplastic into coral reefs ecosystem potentially threatens the living organisms. Small sized microplastics vary in colors, making marine organism (e.g., fish) mistaken it to plankton (Jovanović 2017).

Lombok is located in Indonesia which is well known as part of coral triangle regions and one of the out flow locations of the Indonesian Through Flow (ITF). In this ITF area, shipping activity is really active, that pass through the center Indonesian archipelagic. There is a possibility of microplastics flowing across the ITF and to the coral reef ecosystems in the region, especially West Lombok area. Sekotong is one district in West Lombok that has developed economic activities such as fisheries and tourism (Wildan et al 2016). The anthropogenic activities, along with ITF effects, could be potential sources for microplastic pollution in this area. This study aims to analyze occurrence, distribution, and characteristics of microplastics in the coral reef sediment in Sekotong, Lombok, Indonesia.

Material and Method. Sediment samples were taken on east monsoon season on December 2015 by diving in coral reef habitats (depth range between 3 and 5 m) in Sekotong, Lombok Island, Indonesia (Figure 1). There were 10 stations spreading in the bay of Sekotong. Sediment samples (1000 g) were taken using a stainless shovel within the sediment surface (5-10 cm). The samples then were stored in the room temperature. We conducted modified flotation methods to extract microplastic from sediment (Thompson et al 2004; Claessens et al 2011; Nor & Obbard 2014).

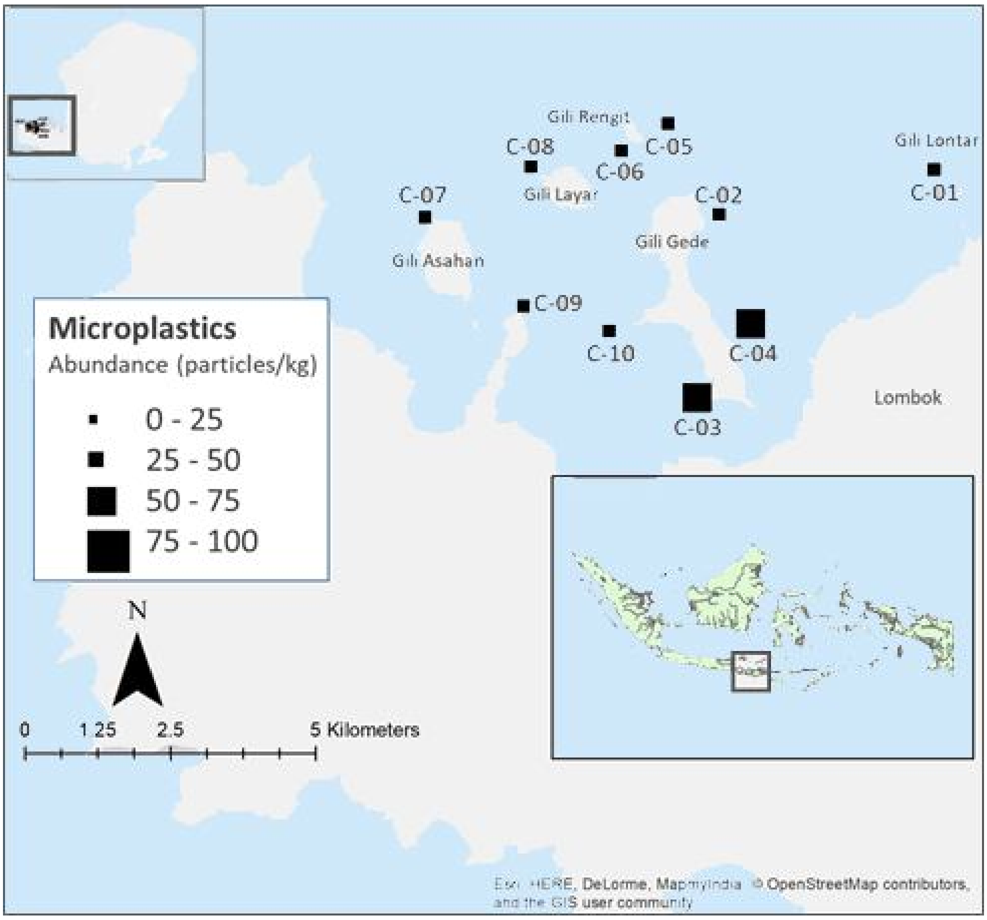

Figure 1. Sampling location and microplastics abundance.

Sediment samples were dried in the oven at temperature of 75°C for 24 hours. To eliminate organic matters we applied wet peroxide oxidation (Masura et al 2015). Samples were added with 30% H_2O_2 and heated on a hot plate (80-90°C), and then the visible froths were removed. The sediment was put on Erlenmeyer bottle with 250 mL concentrated saline solution (1.18 g L^{-1} NaCl on double-distilled deionized water), and then was stirred using mechanical shaker (1000 rpm, 10 minutes). After 6 hours, the supernatant was extracted from the mixture, and then was filtered into Whatman cellulose filter paper (dØ: 47 mm; pore size 0.45 µm). Vacuum filtration unit was used to accelerate the filtration process. To prevent airborne contamination, filter paper were stored in petri-disk, covered with Parafilm®, within a vacuum desiccator.

We conducted sample observation and quantitative analysis using microscope Nikon Eclipse E600. The criteria for identifying microplastic follows Cole et al (2013), Hidalgo-Ruz et al (2012), and Nor & Obbard (2014), namely: (a) organic or cellular structure is absent, (b) homogenous color, it is not shiny or sparkling, (c) plastic fiber are unbranched and not tapered at the ends, (d) there is no segmented fibers. The particles which are identified as microplastic were counted and measured. Plastic polymer identification was applied using Nicolet™ iS5 FT-IR Spectrometer with diamond crystal attenuated total reflectance (ATR) based on report from Löder & Gerdts (2015), on wavenumber spectral range 650-4000 cm^{-1} at resolution 8 cm^{-1} 16 scans and an aperture 100 µm.

Results. Figure 1 and Table 1 show microplastics abundance in the coral reef sediment in all stations, averaging at 48.3±13.98 particles per-kg. The highest microplastic concentration was found in the C-03 at south west of Gili Gede (77 particles per-kg), followed by sediment from C-04 at south east of Gili Gede Island (69 particles per-kg). On the other hand, the lowest concentrations were found in two stations C-06 (Gili Rengit) and C-08 (Gili Layar), by 35 particles per-kg.

Table 1

Microplastics abundance and characteristic in every sites

Code	*Area name*	*Depth (m)*	*Microplastics abundance (n particles per-kg)*											*Total*
			Form				*Polymer type*			*Size*				
			Fb	*Fr*	*Gr*	*Fm*	*PS*	*PE*	*PP*	*A*	*B*	*C*	*D*	
C-01	Gili Lontar	3	1	10	13	23	23	10	14	2	9	12	24	47
C-02	NE Gili Gede	4	2	18	12	17	17	20	12	2	13	12	22	49
C-03	SW Gili Gede	4	1	32	18	26	26	32	19	4	15	21	37	77
C-04	SE Gili Gede	3-4	2	30	15	22	22	27	20	4	13	24	28	69
C-05	Gili Anyaran	5	3	9	23	12	12	12	23	1	13	15	18	47
C-06	Gili Rengit	5	2	11	4	18	18	11	6	2	14	15	4	35
C-07	Gili Asahan	4-5	2	16	8	17	17	16	10	1	13	9	20	43
C-08	Gili Layar	4-5	1	7	5	22	22	7	6	1	11	13	10	35
C-09	Siong	4-5	2	13	7	18	18	12	10	1	7	8	24	40
C-10	W Gili Gede	4-5	1	11	5	24	24	9	8	1	13	13	14	41
	Total		17	157	110	199	199	156	128	19	121	142	201	483
	Percentage (%)		3.52	32.51	22.77	41.20	41.20	32.30	26.50	3.93	25.05	29.40	41.61	100

Mark: Form category [Fb: Fiber, Fr: Fragment, Gr: Granule, Fm: Foam]; Polymer type [PS: Polystyrene, PE: Polyethylene, PP: Polypropylene]; size category [A: < 200 µm, B: 200-500 µm, C: 500-1000 µm, D: > 1000 µm].

We found microplastic in four different forms, including fiber, fragment, granules and foam (Table 1). The most common form is foam, by 199 particles (41.20%), then followed by plastic fragment (157 particles, 32.51%). The south west of Gili Gede holds the highest concentration of foam form (26 particles per-kg), followed by the sediment in Gili Lontar (23 foam particles per-kg). In the south west of Gili Gede, we also found the highest concentration of plastic fragment (32 foam particles per-kg), followed by sediment from the south east of Gili Gede (30 foam particles per-kg). Based on the size of microplastics in this study, the most abundant size is more than 1000 µm (201 particles). Subsequently, we found 142 particles in the size range of 500-1000 µm, then size between 200-500 µm (121 particles). Least of all, 19 particles are in the size less than 200 µm. In the south west of Gili Gede and the south east of Gili Gede, we found the highest size of plastic particles is more than 1000 µm, respectively by 37 and 28 particles per-kg, and plastics particles size between 500-1000 µm (21 and 24 particles per-kg). The polymer types found was polystyrene (199 particles, 41.20%), followed by polyethylene (156 particles, 32.30%) and polypropylene (128 particles, 26.50%). In the south west of Gili Gede, we also found the highest polymer type of polyethylene (26 particles per-kg) and polystyrene (32 particles per-kg).

Microplastics comparison in coastal sediment is presented in Table 2. Compared to other locations, the concentration of microplastics in this study was similar to study of microplastics in mangrove area in Singapore (Nor & Obbard 2014) and higher from beach sediment from Norderney, Germany (Dekiff et al 2014). Coral reef sediment in this study was less polluted than other sediment from other coastal habitats, for instance sediment in harbor, sublittoral area and beach in Belgian coast (Claessens et al 2011), subtidal sediment from Venice Lagoon, Italy (Vianello et al 2013), beach sediment from Slovenia (Laglbauer et al 2014) and intertidal sediment from Halifax harbor in Nova Scotia, Canada (Mathalon & Hill 2014).

Table 2

Microplastic concentrations in coastal sediments

Location	*Origin*	*Range size (µm)*	*Microplastics concentration (particles per-kg)*	*References*
Belgian coast	Harbor	> 63	167±92	Claessens et al (2011)
Belgian coast	Sublittoral	> 63	97±19	Claessens et al (2011)
Belgian coast	Beach	> 63	93±38	Claessens et al (2011)
Singapore	Mangrove	< 20-5000 <	37±24	Nor & Obbard (2014)
Venice Lagoon, Italy	Subtidal	30-5000	1445±460	Vianello et al (2013)
Norderney, Germany	Beach	100-1000	4	Dekiff et al (2014)
Slovenia	Beach	250-5000	156	Laglbauer et al (2014)
Nova Scotia, Canada	Harbor	> 50	200-800	Mathalon & Hill (2014)
Sekotong, Indonesia	Coral reefs	< 200-5000 <	48.3±13.98	This study

Discussion. Microplastic particles found in all study sites are presumably derived from anthropogenic activities on main land of Lombok, such as tourism and fisheries. Wildan et al (2016) reported tourism sector is the second biggest contributor to the West Lombok's Regional Gross of Domestic Product and it has an ascending trend from 2012 to 2013, increase by 43.07%. Furthermore, this condition might be likely attributable to ocean current-driven microplastic that contains plastic waste (Nor & Obbard 2014). Hence, ITF in this area could be possibly as a source of microplastics.

Shipping is suspected as a source of plastics debris in this area. There are about 3900 ships (~140 million metric tons) that pass through the center Indonesian archipelagic, crossing from Sulawesi Sea, Makassar Strait, Flores Sea, Lombok Strait; and transit in Lombok Strait annually (Wu & Zou 2009). Our result is consistent with a statement that indicates the area near the port or vessel traffic has high presence of microplastic (Claessens et al 2011). In general, microplastics in Sekotong coral reef sediment were on lower magnitude from other sediment from coastal area, except from Singapore and Norderney, Germany. We predict sources of plastics in shoreline come from local resident activities and tourism. Generally, fishermen use polystyrene block to float their nets. Whereas, tourism and local residents often discard plastic bags and trash on the recreational beaches. Plastic waste could also be discharged from the mainland through the river system as found in Cilacap (Indonesia) coastal area (Syakti et al 2017). Andrady (2011) and Cole et al (2011) estimated fishing and aquaculture activities contribute a small portion (18%), while land-based activities take the bulk of main source of microplastics in the ocean (~80%). Passing ships also discard macroplastics in the ocean. Although there are some national and international regulations controlling this prevailing issue, this issue is still difficult to address globally and locally (Čulin & Bielić 2016).

We found three polymer types in this area. Highest microplastic forms were foam which is fully polystyrene. Polystyrene (styrofoam) is one of the most widely used plastics. Polystyrene usage includes food, beverage and fish containers, protective packaging, lids, bottles, trays, tumblers, and disposable cutlery (Wunsch 2000). Other forms of microplastics found were fragment, granule and fiber; these are categorized as polypropylene and polyethylene. Polypropylene has the highest melting point, the lowest density and excellent chemical resistance. Furthermore, it has an important use as fiber (textiles), also packaging and labeling, stationery, plastic parts and reusable containers of various types, laboratory equipment, loudspeakers, automotive components, and polymer banknotes (Miller 1990; Arutchelvi et al 2008; Allahvaisi 2012). Polyethylene is the most common plastic, used in packaging such as plastics bottle, plastics container, plastic bags, and plastic films (Arutchelvi et al 2008; Roy et al 2011). We assumed microplastics found in coral reef sediment in Sekotong, Lombok were mainly derived from anthropogenic activities as the most present sizes of microplastics found were more than 1000 µm (41.61%) and 41.20% of which were styrofoam. This evidence can be a marker of additional pollution risk to organisms living in this region. It is necessary to undertake additional studies of microplastic emissions on coral reefs in more detail, on water and sediments over a period of time, to see the potential of microplastic contamination in coral reef areas. In this case, we strongly suggested that management of plastic waste needs to be improved, particularly plastics debris from polystyrene, polypropylene and polyethylene based. It is essential to develop an environmentally friendly substance to replace plastics in near future.

Conclusions. The frequent and high use of plastics in daily activities is inevitable and thus may result in highly microplastic-contaminated water. Furthermore, water current may exacerbate the negative impact by driving and accumulating the microplastics in the areas in which the current pass through. Although the adverse effects on human are not yet studied, the effects can be utterly lethal to marine organisms which are parts of our food chains. We strongly suggested that management of plastic waste needs to be improved, particularly plastics debris, it is essential to develop an environmentally friendly substance to replace plastics in near future.

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