JIPK. Volume 12 No 1. April 2020
Sinta 2 (Decree No: 10/E/KPT/2018)
e-ISSN:2528-0759; p-ISSN:2085-5842
DOI=10.20473/jipk.v12i1.17963
Available online at https://e-journal.unair.ac.id/JIPK/index

JIPK
(JURNAL ILMIAH PERIKANAN DAN KELAUTAN)

SCIENTIFIC JOURNAL OF FISHERIES AND MARINE

Review Article

Plastic Litter as Pollutant in the Aquatic Environment: A mini-review

Rifka Rimbi Anggraini[1], , Yenny Risjani[2], Uun Yanuhar[2]

[1]Master Program in Fisheries and Marine Science, Brawijaya University. Indonesia
[2]Department of Aquatic Resources Management, Faculty of Fisheries and Marine Science, Brawijaya University. Indonesia

OPEN ACCESS

ARTICLE INFO

Received: Desember 11, 2019
Accepted: February 16, 2020
Published: March 11, 2020

*) Corresponding author:
E-mail: rifkarimbi@gmail.com

Keywords:
plastic litter
microplastic,
aquatic environment
biota

This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/)

Abstract

The negative impact that comes from plastic litter in the aquatic environment is a scourge for the entire world including Indonesia.Plastic litter has a huge influence on the most biota who lives in symbiosis with along the aquatic environment as it is able to sustainability. Moreover, there are other factors that cause the death of aquatic biota. Nowadays, the negative impact of plastic litter occurs on an ongoing basis through the food chain process which until now has not been well studied. Therefore, it is necessary to do further studies on the influence of the food chain as a vector of plastic litter distribution, particularly microplastic on aquatic biota from the first trophic level to high trophic levels.

Cite this as: Anggraini, R. R., Risjani, Y., & Yanuhar, U. (2020). Plastic Litter as Pollutant in the Aquatic Environment: A mini-review. *Jurnal Ilmiah Perikanan dan Kelautan*, 12(1):167–180. http://doi.org/10.20473/jipk.v12i1.17963

Copyright ©2020 Universitas Airlangga

1. Introduction

Plastic waste is the biggest problem in the world since it is the type that dominant marine debris (CBD-STAP, 2012). It is formed by a synthetic organic polymer that has the characteristics of materials that are suitable in daily life. Plastic litter is also a complex problem for people who live in an areas near the mouth of the river. The impact of plastic waste is able to cause damage to the aesthetics of aquatic ecosystems and also to the biota that lives in it, causing various diseases, influencing food webs and reducing the productivity of captured fish (Dewi *et al.*, 2015; Gall and Thompson, 2015).

Plastic waste is going to influence the food chain in waters and ecosystems, the economy and public health (Citrasari*et al*., 2012). Plastic waste is also can be swallowed by marine mammals, seabirds or sea turtles (Coppock *et al*., 2017). Anthropogenic activities such as domestic activities, agriculture, industry, tourism and other activities have the potential to become sources of plastic waste, especially microplastics. Plastic wasteenters the water column until it is finally accumulated in the sediment. The type of plastic litter that has negative and great influence on the food chain and is harmful to aquatic biota is microplastic. Microplastics pose a very serious threat compared to other plastic materials, particularly in the biota that digests them (NOAA, 2016).

If microplastics are accumulated in sediments, it is going to cause disruption of the balance of ecosystems and food chains in biota, especially for the fishes. The result is going to influence high trophic organisms through the process of bioaccumulation (Bergmann *et al*., 2015). Microplastics in sediments are going to rise to the water column through an upwelling process which is going to be swallowed and digested by the biota that lives in the water column such as fishes (Tankovic*et al*., 2015).

Furthermore, fish is one of the biotas who is often used see to the spread of microplastic. There are more than 100 species of fish from all over the world who was detected to contain microplastics. Microplastics that enter the fish's body is able to be harmful to the health of individuals and population development. The results of laboratory studies revealed that the negative effects of microplastic on fish include: intestinal damage and short-term to long-term inflammation (Jabeen *et al*., 2017; Miranda and de Carvalho-Souza, 2016; Wesch *et al*., 2016;). In thisreview, we provide information on plastic litter in general for study on plastic litters that pollute the aquatic environment including the aquatic environment in Indonesia.

2. Plastic Litter

Industrialization and anthropogenic activities in various parts of the world is the main cause of pollution (Risjani *et al*., 2014), including the problem of plastic litters. Based on environmental regulation of Republic of Indonesia UU No. 18 of 2008 a litter is a remnant of human daily activities and or natural processes that produce solid formations and do not contain hazardous litter. Based on that decree, it's known that the primary focus concerning waste management in the environment explains that litter is the residue away from human activities or natural activities in the figuration of solid or semi-solid in the configuration of organic and inorganic matter which have biodegradable or non-biodegradable properties which are regarded as of anymore useless and disposed of neighborhood. According to Kodoatie (2003) debris is solid, semi-solid debris or debris which is the result of population activities or the life cycle of humans, animals and plants. Debris is a man-made concept in natural processes.

Marine litters is a solid material which is produced and processed directly or indirectly, intentionally or not which flows into the aquatic environment (CSIRO, 2014). Marine litters is defined as residual litters due to anthropogenic activities that enter the coastal environment or the environmental (NOAA, 2015; Hetheringthon *et al*., 2005). One type of marine litter that is currently in the hot news is plastic. This is related to the amount of what increase that occurs in the environment (Lee and Sanders, 2015; Suaria *et al*., 2015).

Plastic litter itself can last up to hundreds of years and become a trigger for pollution in the environment. If the plastic litter is burned, it will produce gas that can pollute the air, as well as endanger the human respiratory system. In addition, plastic litter piled up in the ground will pollute the soil and groundwater. The amount of plastic that has been consumed is around 100 million tons/year worldwide. This is able to be a direct threat to the aquatic biota, aesthetics of the ecosystem, human health and safety of navigation, which in turn will have a major loss. Around 12 billion tons of marine litter are dumped every year at sea (NOAA, 2016).

The enhancement and increase in the number of plastic litter in waters originate from anthropogenic activities where the source of the pollution is materials that are not from nature and are influenced by human intervention (Jambeck *et al*., 2015). Plastic litter entering the ecosystem of the water comes from the input of river, estuary and ocean waste itself, as well as the presence of intrusion from land waste. Sources of plastic waste in accordance with NOAA (2016):

Mainland Activities

Waste from settlements or domestic (household) activities is not well managed end up in the waters through river mouths (Syakti *et al*., 2017). About 80% of plastic waste comes from land activities (NOAA, 2016).

Industry

One of the wastes produced in the industry is plastic, paper, bottles and so on. The most dominant and most found marine trash is plastic (CBD-STAP, 2012).

Fishermen Activities

The activities of fishermen are one of the factors increasing the amount of waste in sea waters. This is because fishermen deliberately dispose off debris in the form of fishing gear which is plastic material such as unused nets into aquatic ecosystems, particularly at sea. The United States government issued a regulation prohibiting disposure of debris at sea because it could disrupt navigation of the shipping lanes, particularly those from fishing activities (NOAA, 2015).

3. Type of Plastic Polymers and Size

Plastics are polymers composed of hydrocarbon chains consisting of long chains of carbon (carbon molecules and hydrogen atoms). The term plastic includes synthetic or semi-synthetic polymerization products, but there are a number of natural polymers classified as plastic. The plastic itself is formed from the evaporation of organic material or the addition of other polymers to increase selling value and durability. Since the 20th century, the use of plastic has expanded widely to reach 220 million tons/year in 2005 (Heteringthon, 2005; Kadir, 2012).

There are two categories of plastic with different functions these are thermoplastic type and thermosetting type (UNEP, 2009). The categories of plastic are presented in Table 1. There are seven types of plastic polymers that are found in the environment based on the specific gravity and function of the plastic itself. The types of plastic polymers are presented in Table 2. To find out the size of the plastic whisis able to have a negative impact on biota, the size of the plastic got categorized into several types of different sizes (Ryan *et al*., 2009). According to Barnes *et al*. (2009); GESAMP (2016) is known that types of plastic sizes are able to be broadly grouped into four types such as: mega plastic, macroplastic, mesoplastic and microplastic (Table 3).

The larger size of the plastic fragments creates the risk of being entangled, swallowed to suffocation on biota. This event often occurs in most seabirds, fish and marine mammals that live in areas that are contaminated with microplastics, while themesoplastic and microplastic types can be swallowed by various marine organisms such as fish, dugongs, turtles and others. This is able to cause concern for this species, particularly for endangered species (Gall and Thompson, 2015).

4. Microplastic

Plastic is a common comodity in modern society. The most plastic consumption is only used once. As a result, a pile of plastic litter will pollute the environment and become marine litter (Wang *et al*., 2016). The Ministry of Industry in Indonesia hasconfirm that around 4 million of tons of plastic have been produced since 2016. It is known that 0.52 kg/person of litters is released or discarded every day and more than 83% of the litter is not managed properly or in other words, it is just thrown away into the environment. Among the volume of litters, about 11% is plastic litter that is dumped into the sea (Jambeck *et al*., 2015). Indonesia has produced more than 5.4 million tons of plastic litter. Around 3.22 million tons are not managed. Around 0.48-1.29 million tons end up being a marine litters (Jambeck *et al*., 2015). Microplastic is part of plasticless than 5 mm - 0.33 mm in size (GESAMP, 2015; NOAA, 2015). Microplastic is divided into two these are primary microplastic and secondary microplastic (GESAMP, 2015).

Primary microplastic is a plastic that has a microscopic size (UNEP, 2016). Primary microplastics include pre-production (before production) of pellets in companies or the plastics industry. Microbeads or primary microplastics are used as additions to cosmetic ingredients (da Costa *et al*., 2016; Napper *et al*., 2015; Murphy, 2017). Meanwhile, secondary microplastics are plastic particles that are formed due to the degradation of plastic material due to environmental factors such as sunlight, wind, rain and water wave activity (Cole *et al*., 2013). Microplastic can be divided into several types of plastics including film, fibre, fragments, and pellets as below table

Copyright ©2020 Universitas Airlangga

Table 1. Categorise of Plastics

No.	Categorize of Plastic	Character	Example	Reference
1.	*Thermoplastic*	Small molecular weight, easy to melt when heated and easy to harden when cooled, flexible, low melting point, linear molecular structure	Polyethylene (PE), Polyvinyl Chloride (PVC), Polypropylene (PP), Polystyrene, LDPE, PP, ACETATE, packing material	Elzubair *et al.* (2006)
2.	*Thermosetting*	Inflexible, cannot melt (rigid), difficult to be reshaped, resistant to acid-base, has crosslinking	Bakelite (ashtrays, electric light fittings, electric plugs, photographic equipment, radios, plywood adhesives)	UNEP, 2009; Sofiana, 2010

Table 2. Types of Plastic Polymers

No.	Name	Abbre viation	Spesific Gravity	Character	Function	References
1.	*Polyethylene Terephthalate*	PETE/ PET	1.37	Clear, strong, resistant solvent, can be used for food (oven and microwave)	Lightweight bottles, fast food jars, rigid sheets and fibres	Andrady, (2011); Li *et al.* (2016)
2.	*High Density Polyethylene*	HDPE	0.94-0.96	A type of plastic that is difficult to semi-flexible, opaque surfaces	Freezer, milk bottle, bleach bottle, bucket and others	Adhikary *et al.* 2008; Andrady, (2011); Li *et al.* (2016)
3.	*Polyvinyl Chloride*	PVC	1.37-1.39	Flexible, elastic properties, can be dissolved	Shoe soles, cables and others	UNEP, 2009; Andrady, (2011); Li *et al.* (2016)
4.	*Low Density Polyethylene*	LDPE	0.91-0.93	A soft, flexible and waxy surface that is translucent, resistant to solution	NA	UNEP, 2009; Andrady, (2011); Li *et al.* (2016)
5.	*Polypropylene*	PP	0.83-0.85	Hard, flexible, translucent and resistant to chemicals	NA	Andrady, (2011); Li *et al.* (2016)
6.	*Polystyrene*	PS	1.04	Properties Clear, glassy, rigid, brittle, opaque, melting at 95°C	Refrigerator and clothes hanger	UNEP, 2009; Andrady, (2011); Li *et al.* (2016)
7.	The other ones			Resin and multi-material	*Acrylonitrile butadi ene styrene (ABS), acrylic, nylon, poly urethane* (PU), *poly carbonates (PC)* and *phenolics*	Andrady, (2011); Li *et al.* (2016)

Table 3. Categorise Size of Plastic Litter

Types	Diameter	Source	Example
Megaplastic	>100 mm	Abandoned gear, the result of natural disasters	Nets, fish traps, broken fishing lines, ropes, ship hulls, plastic litter from the agricultural industry
Macroplastic	>20 mm	Disposal resulting from a maritime activity or from rivers	Plastic bags, packaging of food and others, floats of fishing and another buoy, balloons
Mesoplastic	5–20 mm	Large plastic fragmentation	Bottle caps, plastic litter
Microplastic	≤5 mm	Primary and secondary microplastics	Industrial and domestic products (primary), as well as textiles, fibre, tire dust (secondary)

Source: Barnes *et al.*, 2009; GESAMP, 2016

(UNEP, 2016). The film is a plastic polymer particle which comes from fragmentation of plastic bags or plastic packaging and has a very low density or volume (GESAMP, 2015). Kingfisher (2011) states that fibre is an elongated plastic particle or fiber derived from monofilament fragmentation in fishing nets, plastic ropes and synthetic fabrics. Fragments are microplastic particles produced by products of plastic with plastic polymers that dominant likebottles of drink, gallons of plastic and so on. Pellets are primary microplastics that originate directly from industry or factories as raw materials for making plastic products (Kingfisher, 2011; Tanada and Takada, 2016).

4.1 Primary Microplastic

Primary microplastic is parts of plastic with microscopic size. Mostly, primary microplastics are the industrial result and domestic litter (Betts, 2008; Moore, 2008) which is generally used as media of blasting (Gregory, 1996) to women's needs, such as cosmetics (Zitko and Hanlon, 1991), as well as on the medical field widely used as a vector in drug manufacturing. One example of this microplastic is melamine or polyester with a size of 0.25-1.7 mm which is often used to rust off coat and paint cleaner (Browne *et al.*, 2007).

On polyethene and particle of polypropylene (<5 mm) and particle of polystyrene (<2 mm) are found as a mixture in cosmetic products (Fendall and Sewell, 2009). There was microplastic contamination along the coastline at 18 stations representing six continents (poles to the equator). One of the most significant microplastic sources in the ocean is pollutants in the form of fibre. About 78% of the polyester fibre and 22% of acrylic are found in coastal areas and come from washing machine disposal. This is due to the large proportion of fibres of polyester found at wastewater and ocean deep sediments (Browne *et al.*, 2011; Oerlikon, 2009).

4.2 Secondary Microplastic

Secondary microplastic is part of the result of the fragmentation of large plastics into plastic litter (Ryan *et al.*, 2009). This microplastic takes thousands of years to be degraded (Barnes *et al.*, 2009). This plastic fragmentation process is an impact produced by sundry physical, biological and chemical processes to degrade the plastic presence (Browne *et al.*, 2007). Corrosion process is one of the triggers for fragmentation of plastic (Arthur *et al.*, 2009). The beach is an area that strongly supports plastic fragmentation due to chemical weathering activities (Corcoran *et al.*, 2009).

Another equally important process which is no less important is photodegradation due to sunlight. Ultraviolet radiation from the sun contributes to oxidation processes in the polymer matrix, causing damage to the plastic chemical structure (Barnes *et al.*, 2009). The process of plastic degradation in coastal areas is faster than in cooler waters. This is caused by the high availability of oxygen and the intensity of sunlight more frequently, resulting in damaged molecular groups from plastic (Browne *et al.*, 2007). Mechanical processes such as abrasion, waves and turbulence also affect plastic fragmentation (Barnes *et al.*, 2009).

5. The Risk of Plastic Litter in the Aquatic Environment

Ingestion of plastic litter through the digestive tract is a big threat and very dangerous for aquatic biota. The effects of plastic consumption on the health of wildlife can be divided into two major groups which are physical effects and physiological effects that are interrelated. It also provides a retention effect on any biota that accidentally swallows plastic litter. All physical effects will ultimately lead to physiological effects on biota (Barboza *et al.*, 2019; NOAA Marine Debris Programme, 2014). In addition, plastic litter is often associated with chemical poisons that contribute to sublethal effects on biota, particularly aquatic biota (Thompson *et al.*, 2009). The effects of ingestion of plastic litter on aquatic biota are presented in table 4.

A species of aquatic biota can be affected by the consumption of plastic litter due to the transfer and accumulation of plastics as pollutants. The amount of plastic litter swallowed by aquatic biota has been documented. Seabirds and sea turtles are one of examples of aquatic biota that consume the most plastic litter (Barboza *et al.*, 2109). About >90% of seabirds store plastic litter on the intestines (Wilcox *et al.*, 2015) which is thought to be a natural feed as well as fish eggs and crustaceans (Azzarello and Vleet, 1987). Most of the world's sea turtles have consumed plastic and plastic litter produced by humans (Schuyler *et al.*, 2016). Furthermore, sea turtles also ingest plastic litter which is thought to be a jellyfish which is a natural food for turtles while in the waters (Laist, 1987; Schuyler *et al.*, 2014).

Use of plastic litter, mostly microplastic trapped on the beach is higher because the coastal area is a spawning ground, feeding ground and nursery ground. The symptoms of hunger of seabirds and sea turtles is higher and truly worrisome. This aquatic biota will stop eating because of a false sense of fullness due to the volume of plastic that cannot be digested in the stomach

Copyright ©2020 Universitas Airlangga

Table 4. Effects caused by plastic Litter on aquatic biota

No.	Condition	Organ	Effect	Biota	References
1.	Physical	Digestive system, skin and muscle tissue	Lacerations, lesions, ulcerations, inflammation and blockages in the stomach	Aquatic Biota	NOAA *Marine Debris Programme*, 2014
2.	Physiological	Digestive System, Immune System	Inhibition of absorption of nutrients, disruption of the body's immunological development, the presence of toxicology	Aquatic Biota	Barboza *et al*., 2019
3.	Sublethal	Reproductive System, Digestive System	Inflammatory bowel, Reproductive cycle problems	Seabirds, turtles	Thompson *et al*., 2009; Wilcox *et al*., 2015; Azzarello dan Vleet, 1987; Schuyler *et al*., 2016; Laist, 1987; Schuyler *et al*., 2014
4.	Retention	Digestive system	Inflammation until blockage in the stomach	Aquatic Biota	Barboza *et al*., 2019

Table 5. Effects of microplastics on aquatic biota

No.	Type of Plastic	Concentration	Biota	Effect	References
1.	Polystyrene	0.22-103 mg nano polystyrene/L	*Daphnia magna*	Shrinking body size and reproduction	Besseling *et al*. (2014)
2.	Polystyrene	>30 mg nano polystyrene/L	*D. magna*	Increased neonatal malformation problems	Besseling *et al*. (2014)
3.	Polystyrene	5-100 µg/mL	*Artemia francis cana* larvae	Sublethal effect (adsorption on antennules who increase the amount of moulting)	Bergami *et al*. (2016)
4.	Nano Polystyrene Particles	3,85 µg/mL	Sea urchin embryo (*Paracentrotuslividus*)	Disposition and toxicity, and gene upregulation of cellular stress response	Della Torre *et al*. (2014)
5.	Nano Polystyrene Particles (-NH_2)	2,61 µg/mL	Sea urchin embryo (*P. lividus*)	Disablement	Della Torre *et al*. (2014)
6.	Nano Polystyrene Particles (–COOH)	>50 µg/Ml	Embryonic digestive tract *P. lividus*	Cessation of growth	Della Torre *et al*. (2014)
7.	Polystyrene (0,05; 0,5 dan 6 µm)	NA	Monogonont rotifer (*Brachionuskoreanus*)	Disorders of the digestive process	Jeong *et al*. (2016)
8.	Polyethylene	12,5-400 mg/L	Monogonont rotifer (*B. koreanus*)	Decreased growth rate, decreased the fertility of a biota, shortened life span, longer periods to reproduce and increased levels of enzymatic biomarkers from stress	Jeong *et al*. (2016)
9.	Polyethylene	57,43 mg/L	*D. magna*	Effects of immobilization	Rehse *et al*. (2016)
10.	Polystyrene	NA	Fish (*Crassiuscrassius*)	Changes in fish behaviour, decreased appetite for fish, changes in fish metabolism, Change of morphology on the brain and cellular disorders	Mattsson *et al*. (2015)
11.	Microplastic (general)	NA	Copepoda	Inhibiting the ability to swim if it is attached to the carapace	Cole *et al*. (2013)

.**Table 6.** Problems on Plastic Litter in Indonesia

No.	Location	Type of litter	Type of plastic	Impact	References
1.	Cilacap Bay	Microplastic	*Polypropylene* (68%) and *low-density polyethylene* (11%)	Cilacap Bay in Indonesia is contaminated with microplastics at a concentration of 2.5 mg/m^3	Syakti et al., 2017
2.	Surabaya North Coast	Microplastic	Polystyrene (500-1000 µm and 300-500 µm)	NA	Cordova et al., 2019
3.	Wonorejo Estuary, Surabaya	Microplastic	*Low-density polyeth ylene* (LDPE)	NA	Kurniawan dan Imron, 2019
4.	Bintan Island	Microplastic	*Low-density polyeth ylene* (LDPE)	Corals underwent bleaching and necrosis along with *zooxanthellae* release	Syakti et al., 2019
5.	Bintan Island	Microplastic	*Polyethylene (PE), Ox idized LDPE, Polypro pylene (PP), Atactic PP, PP isotactic and Poly styrene (PS)*	Microplastic contamination of small island areas in Bintan Regency, Riau Islands Province, Indonesia, around 0.45 pieces/m^3	Syakti et al., 2018
6.	Lorok Coast, Central Java	Microplastic	NA	The shells were contaminated with microplastics with a size of 211,163 µm	Khoironi *et al.*, 2018
7.	Makassar, South Sulawesi	Microplastic	Fragments, monofila ment, film	21 of the total sample (76 individuals) contained microplastics in the digestive tract	Rochman *et al.*, 2015
8.	Jakarta Bay	Macro debris	NA	After reclamation, macro litter tends to accumulate in the eastern part of Jakarta Bay during the rainy season (January), and in the western and eastern regions during the dry season (July)	Jasmin *et al.*, 2019
9.	Pangandaran Beach, West Java	Microplastic	Fibre, fragment and film	The distribution and total distribution of microplastic trapped in sediment is 68 microplastic grains	Septian et al., 2018

so that this constant sense of fullness causes the aquatic biota to starve to death (Gregory, 2009). Plastics in the aquatic environment itself beisable to cause physical or nutritional disorders directly when consumed by the biota that lives in these waters. This can be made worse by the attendance of plasticizers at the plastic granules themselves of other toxic pollutants attached to the plastic surface. Some indications suggest that microplastics are able to plague main producers at the bottom of food webs in the aquatic environment (Harmon, 2018).

Microplastics are small in size and move freely in the water column making it similar to plankton which enable their consumption by aquatic biota at different trophic levels. This is consistent with what was conveyed by do Sul and Costa (2014); Anderson *et al.* (2016); Ivleva *et al.* (2017) which is known that the highest level of microplastic consumption is found in fish, seabirds, marine mammals, and a number of invertebrates on marine and estuarine.

Meanwhile, microplastic exposure on freshwater is well known. This is known from research conducted by Biginagwa *et al.* (2016); Faure *et al.* (2015); Mc Goran *et al.* (2017); Peters and Bratton (2016); Phillips and Bonner (2015); Silva-Cavalcanti *et al.* (2017); Eerkes-Medrano *et al.* (2015) that the results showed that fish originating from freshwater were exposed to microplastic by consuming the microplastic. It thereby shows microplastics are not accidentally or selectively digested by aquatic biota (Harmon, 2018).

5.1 Microplastics in Sediments and Water

In the aquatic ecosystems, microplastics have been found in sediments which float on the surface or float across the columns of water, which eventually leads down to the potential of both biota and populations problems in these waters (Harmon, 2018). Research on microplastics in sediments and water is aimed at looking at the abundance of microplastic as pollutants in freshwater (Anderson *et al.*, 2016; Eerkes-Medrano *et al.*, 2015; Ivleva *et al.*, 2017; Mason *et al.*, 2016), estuary until ocean waters (Enders *et al.*, 2015; Ivleva *et al.*, 2017; van Sebille *et al.*, 2015).As for the results of the microplastics analysis on the sediments and water obtained it vary greatly in certain amounts. This shows that microplastic has become a very serious problem because of its enormous quantity and has been identified from plastic materials derived from oceans, lakes and rivers. This problem is exacerbated by the fact that microplastics are one of the pollutants that pollute the atmosphere (Dris *et al.*, 2016), Arctic ocean and sea ice (Obbard *et al.*, 2014; Lusher *et al.*, 2015; Amelineau *et al.*, 2016; Tekman *et al.*, 2017), waters of remote lake (Free *et al.*, 2014; Zhang *et al.*, 2016), as well as aquatic biota obtained from seabed sediments (Taylor *et al.*, 2016).

5.2 Plastic Litter in Mangrove Ecosystems

Mangrove ecosystems are found in intertidal areas and they adapt to developing root systems that surface. This occurs as a process of physiological adaptation of mangroves where pneumatophores and buffer roots will function as effective filters by holding back the wave energy and turbulence produced by the sea (Horstman *et al.*, 2014; Norris *et al.*, 2017).Such a mechanism also allows mangroves to trap objects carried by currents entering the coastal area, for example, plastic litter. The role of pneumatophores mangrove as a plastic litter trap has a higher contribution in trapping waste (Barasarathi *et al.*, 2011; Lima *et al.*, 2014; Mohamed Nor and Obbard, 2014; Lourenço *et al.*, 2017; Naji *et al.*, 2017). Plastic litter caught in the mangrove ecosystem shows different retention depending on the hydrodynamics of the object. This process shows a differential interaction between mangrove stands and plastic litter, giving an indication that plastic debris is considered as plastic litter disposed off in the ecosystem (Ivar do Sul *et al.*, 2014).

Plastic litter found at mangrove ecosystems is garbage originating from land or river basins. Trapped plastic in pneumatophore or buffer roots is a physical obstacle to mangroves and can have a negative effect on the mangroves themselves and the biota in symbiosis with mangroves. One of the negative impacts caused is the inhibition of the process of respiration which will cause death slowly (Cordeiro and Costa, 2010). Potential chemical effects are more likely to increase with decreasing plastic particle size, whereas physical effects will increase with increasing plastic litter size. Macro debris has physical effects such as covering the surface of sediments and preventing the growth of mangrove seeds (Smith, 2012).

5.3 Microplastic Effects on Aquatic Biota

Microplastics with a size of 1 μm or less is able to cause problems for aquatic biota and came to particular attention because they have the capability to get through membrane of cells (Mattsson *et al.*, 2015b; da Costa et al., 2016). One type of microplastic is polystyrene (Besseling *et al.*, 2014) and polyethylene (Rehse *et al.*, 2016). Effects whichoccur at the trophic level due to trophic transfer from the food chain have been suggested by Mattsson *et al.* (2015). This effect is likely due to morphological changes in the brain and cellular disorders. This suggests that microplastic exposure at lower trophic levels are able to produce effects on higher predatory consumers. Microplastic effects on these aquatic biotas are presented in table 5.

6. Plastic Litter Problems in Indonesia

In the mid-20th century, the amount of plastic litter increased from 1% (EPA, 2011) to 10% in 61 countries in 2005 from a total of 105 countries (Hoornweg *et al.*, 2013). The total amount of plastic litter discharged into the sea ranges from 1.7-4.6% (Jambeck *et al.*, 2015) and can even reach 10% (Avio *et al.*, 2015). The amount of plastic litter is directly proportional to the population in a country with the fastest economic growth rate (Jambeck *et al.*, 2015). In Indonesia, plastic litter is dominant and concentrated in largely populated cities, especially on Java (Table 6).

7. Conclusion

Over the past ten years, research on plastic litter has been a particular concern, mostly for the aquatic environment. Various studies explicate that plastic litter are water contaminants, particularly marine waters, which are spread throughout the water column. The level of plastic litter pollution in the aquatic environment including the biota which lives in a symbiosis get a lot of negative effects from marine waste, both from mega plastic to microplastic sizes. The process of transferring toxic substances contained in the plastic litter, particularly microplastics, attracts a lot of attention for researchers to examine this issue further. Therefore, research on the transfer of pollutants, mostly microplastics, have to be examined more closely related to the food chain that exists in the aquatic environment who can end in humans too.

Acknowledgement

All Author are grateful to Mr. Nur Habibi, Mrs Siti Nur Chotipha and Mr. Mijan for helping us to participate in writing this manuscript

Authors' Contribution

Author R. R A colleted data, drafted and wrote the manuscript while authors Y. N, and UUN devised the main conceptual ideas and critical revision of the article.

Conflict of Interest

All the authors of this review declare that they have no conflict of interest.

Funding Information

No direct funding was received for this work

References

Adhikary K. B., Pang, S., & Staiger, M. P. (2008). Dimensional stability and mechanical behaviour of wood–plastic composites based on recycled and virgin high-density polyethylene (HDPE). *Journal of Composites.* 38: 807-815.

Amelineau, F., Bonnet, D., Heitz, O., Mortreux, V., Harding, A. M. A., Karnovsky, N., Walkusz, W., Fort, J., & Gremillet, D. (2016). Microplastic pollution in the Greenland Sea: background levels and selective contamination of planktivorous diving seabirds. *Environmental Pollution*. 219: 1131–1139.

Anderson J. C., Park, B. J., & Palace, V. P. (2016). Microplastics in aquatic environments: implications for Canadian ecosystems. *Environmental Pollution*. 218: 269–280.

Andrady A. (2011). Microplastics in the marine environment. *Marine Pollution Bulletin*. 62: 1596–1605.

Arthur C., Baker, J., & Bamford, H. 2009. Proceedings of the International Research Workshop on the Occurrence, Effects and Fate of Micro-plastic Marine Debris, September 9–11, 2008. NOAA Technical Memorandum NOS-OR&R-30.

Avio C. G., Gorbi, S., & Regoli. F. (2015). Experimental development of a new protocol for extraction and characterization of microplastics in fish tissues: first observations in commercial species from Adriatic Sea. *Marine Environmental Research*. 111: 18–26.

Azzarello M. Y., & Vleet, E. S. V. (1987). Marine birds and plastic pollution. *Marine Ecology Progress Series*. 37: 295–303.

Barasarathi J., Periathamby, A., & Fauziyah, S. H. (2011). Microplastic abundance in selected mangrove forest in Malaysia. In: Proceeding of the ASEAN Conference on Science and Technology 2014, 18-20.

Barboza, L. G. A., Cozar, A., Gimenez, B. C. G., Barros, T. L., Kershaw, P. J., & Guilhermino, L. (2019). Macroplastic Pollution in The Marine Environment. *Elsevier*. Chapter 17: 305-328.

Barnes, D. K. A., Galgani, F., Thompson, R. C., & Barlaz, M. (2009). Accumulation and fragmentation of plastic debris in global environments. *Philosophical Transactions of the Royal Society B: Biological Science*. 364 (1526): 1985–1998.

Bergami E., Bocci, E., Vannuccini, M. L., Monopoli, M., Salvati, A., Dawson, K. A., & Corsi, I. (2016). Nanosized polystyrene affects feeding, behavior and physiology of brine shrimp Artemia franciscana larvae. *Ecotoxicology and Environmental Safety*. 123: 18–25.

Bergmann M, Lars, G., & Michael, K. (2015). *Marine antropogenic litter*. Swedia: Sven Lovén Centre for Marine Sciences. University of Gothenburg.

Besseling E., Wang, B., Lurling, M., & Koelmans, A. A. (2014). Nanoplastic affects growth of S. obliquus and reproduction of *D. magna*. *Environmental Science and Technology*. 48 (20): 12336–12343.

Besseling E., Quik, J. T. K., Sun, M., & Koelmans, A. A. (2017). Fate of nano- and microplastic in freshwater systems: A modeling study. *Eironmental Pollution*. 220: 540-548.

Betts K. (2008). Why small plastic particles may pose a big problem in the oceans. *Environmental Science and Technology*. 42: 8995.

Biginagwa F. J., Mayoma, B. S., Shashoua, Y., Syberg, K., & Khan, F. R. (2016). First evidence of microplastics in the African Great Lakes: Recovery from Lake Victoria Nile perch and Nile tilapia. *Journal of Great Lakes Research.* 42 (1): 146-149.

Browne M. A., Crump, P., Nivens, S. J., Teuten, E., Tonkin, A., Galloway, T., & Thompson, R. (2011). Accumulation of microplastics on shorelines worldwide: sources and sinks. *Environmental Science and Technology*. 45 (21): 9175–9179.

Browne M. A., Galloway, T., & Thompson, R. (2007). Microplastic An Emerging Contaminant of Potential Concern? Integr. *Environmental Assessment and Management*. 3: 559–561.

[CBD-STAP] Secretariat of the Convention on Biological Diversity and the Scientific and Technical Advisory Panel—GEF. (2012). *Impacts of Marine Debris on Biodiversity: Current Status and Potential Solutions* Montreal: Technical Series.61 pg.

[CSIRO] Ocean and Atmosphere Flaship. (2014). Marine Debris sources, distribution and fate of plastic and other refuse – and its impact on ocean and coastal wildlife [*online*]. www.csiro.au/marine-debris. diakses pada pukul 21.38 WIB Pada tanggal 20 Juli 2019.

Citasari N., Nur, I. O., & Nuril, A. (2012). Analisis Laju Timbunan dan Komposisi Sampah di Permukiman Pesisir Kenjeran Surabaya. *Berkas Penelitian Hayati*. 18: 83–85.

Costa J. P. D., Ana, R. N., Patricia, S. M. S., Ana, V. G., Armando, C. D., & Teresa, R. S. (2018). Degradation of polyethylene microplastics in seawater: Insights into the environmental degradation. *Journal of Environmental Science and Health*. 1-10.

Cole M., Lindeque, P., Fileman, E., Halsband, C., Goodhead, R., Moger, J., & Galloway T. S. (2013). Microplastic ingestion by zooplankton. *Environmental Science and Technology*. 47 (12): 6646–6655.

Coppock R. L., Matthew, C., Penelope, K. L., Ana, M. Q., & Tamara, S. G. (2017). A small-scale, portable method for extracting microplastics from marine sediments. *Journal of Environmental Pollution*. 230: 829-837.

Corcoran P. L., Biesinger, M. C., & Grifi, M. (2009). Plastics and beaches: A degrading relationship. *Marine Pollution Bulletin*. 58: 80-84.

Cordeiro C. A. M. M., Costa, T. M. (2010). Evaluation of solid residues removed from a mangrove swamp in the Sao Vicente Estuary, SP, Brazil. *Marine Pollution Bulletin*. 60(10): 1762-1767.

Cordova M. R., Purwiyanto, A. I. S., & Suteja, Y. (2019). Abundance and characteristics of microplastics in the northern coastal waters of Surabaya, Indonesia. *Marine Pollution Bulletin*. 142: 183-188.

da Costa J. P., Santos, P. S. M., Duarte, A. C., & Rocha-Santos, T. (2016). Nano plastics in the environment sources, fates and effects. *Science of the Total Environ*ment. 566: 15–26.

Della Torre C., Bergami, E., Salvati, A., Faleri, C., Cirino, P., Dawson, K. A., & Corsi, I. (2014). Accumulation and embryotoxicity of polystyrene nanoparticles at early stage of development of sea urchin embryos *Paracentrotus lividus*. *Environmental Science and Technology*. 48 (20): 12302–12311.

Dewi I. S., Budiarsa, A. A., Ritonga, I. R. (2015). Distribusi mikroplastik pada sedimen di Muara Badak, Kabupaten Kutai Kartanegara. *Depik Journal*. Desember 2015 ISSN 2089-7790.

Dris R., Gasperi, J., Saad, M., Mirande, C., & Tassin, B. (2016). Synthetic fibers in atmospheric fallout: a source of microplastics in the environment. *Marine Pollution Bulletin*. 104 (1–2): 290–293.

do Sul J. A. I., & Costa, M. F. (2014). The present and future of microplastic pollution in the marine environment. *Environmental Pollution*. 185: 352–364.

Eerkes-Medrano D., Thompson, R. C., & Aldridge, D. C. (2015). Microplastics in freshwater systems: a review of the emerging threats, identification of knowledge gaps and prioritisation of research needs. *Water Research*. 75: 63–82.

Elzubair A., Elias, C. N., Suarez, J. C. M., Lopes, H. P., & Vieira, M. V. B. (2006). The physical characterization of a thermoplastic polymer for endodontic obturation. *Journal of Dentistry*. 34 (10): 784-789.

Enders K., Lenz, R., Stedmon, C. A., & Nielsen, T. G. (2015). Abundance, size and polymer composition of marine microplastics _10 μmin the Atlantic Ocean and their modelled vertical distribution. *Marine Pollution Bulletin*. 100 (1): 70–81.

Faure F., Demars, C., Wieser, O., Kunz, M., & de Alencastro, L. F. (2015). Plastic pollution in Swiss surface waters: nature and concentrations, interaction with pollutants. *Environmental Chemistry*. 12(5): 582-591.

Fendall L.S., & Sewell, M.A. (2009). Contributing to marine pollution by washing your face: microplastics in facial cleansers. *Marine Pollution Bulletin*. 58: 1225–1228.

Free C. M., Jensen, O. P., Mason, S. A., Eriksen, M., Williamson, N. J., & Boldgiv, B. (2014). High-levels of microplastic pollution in a large, remote, mountain lake. *Marine Pollution Bulletin*. 85 (1): 156–163.

Gall S. C., & Thompsom, R. C. (2015). The impact of debris on marine life. *Marine Pullution Bulletin*. 92 (1-2):170-179

[GESAMP] Group of Experts on Scientific Aspects of

Marine Protection. (2015). *Sources, Fate and Effects of Microplastics in the Marine Environment: Part 2 Of A Global Assessment*. International Maritime Organization b4 Albert Embankment, London SE1 7SR. www.imo.org

Gregory M. R. (2009). Environmental implications of plastic debris in marine settings–entanglement, ingestion, smothering, hangers-on, hitch-hiking and alien invasions. *Philosophical Transactions of the Royal Society of London Series B, Biological Sciences*. 364: 2013–2025.

Gregory M. R. (1996). Plastic "scrubbers" in hand cleansers: a further (and minor) source for marine pollution identified. *Marine Pollution Bulletin*. 32: 867–871.

Harmon S. M. (2018). The Effect of Microplastic Pollution on Aquatic Organism. *Elsevier*. Chapter 8: 249-270.

Hetherington J., Leous, J., Anziano, J., Brockett, D., Cherson, A., Dean, E., Dillon, J., Johnson, T., Littman, M., Lukehart, N., Ombac, J., & Reilly, K. (2005). *The Marine Debris Research, Prevention and Reduction Act: A Policy Analysis*. Columbia University New York, New York.

Hoornweg D., Bhada-Tata, P., & Kennedy, C. (2013). Environment: Waste production must peak this century. *Nature*. 502 (7473): 615-617.

Horstman E. M., Dohmen-Janssen, M., Narra, P., Van den Berg, N. J. F., Siemerink, M., & Hulscher, S. (2014). Wave attenuation in mangroves: a quantitative approach to field observations. *Coastal Engineering*. 94: 47-62.

Ivar do Sul J.A., Costa, M. F., Silva-Cavalcanti, J. S., & Araujo, M.C. (2014). Plastic debris retention and exportation by a mangrove forest patch. *Marine Pollution Bulletin*. 78 (1-2): 252-257.

Ivleva N.P., Wiesheu, A.C., & Niessner, R. (2017). Microplastic in aquatic ecosystems. *Angewandte Chemie International Edition*. 56 (7): 1720–1739.

Jabeen K., Su, L., Li, J., Yang, D., Tong, C., Mu, J., & Shi, H. (2017). Microplastics and mesoplastics in fish from coastal and fresh waters of China. *Environmental Pollution*. 221: 141-149.

Jambeck J. R., Geyer, R., Wilcox, C., Siegler, T. R., Perryman, M., Andrady, A., Narayan, R., & Law, K. L. (2015). Plastic waste inputs from land into the ocean. *Science*. *347*: 768–771.

Jasmin H. H., Purba, N. P., Harahap, S. A., Pranowo, W. S., Syamsudin, M. L., & Faizal, I. (2019). The Model of Macro Debris Transport Before Reclamation and in Existing Condition in Jakarta Bay. *Jurnal Ilmu dan Teknologi Kelautan Tropis*. 11 (1): 131-140.

Jeong C. B., Won, E. J., Kang, H. M., Lee, M. C., Hwang, D. S., Hwang, U. K., Zhou, B., Souissi, S., Lee, S. J., & Lee, J.S. (2016). Microplastic sizedependent toxicity, oxidative stress induction, and p-JNK and p-p38 activation in the monogonont rotifer (*Brachionus koreanus*). *Environmental Science and Technology*. 50 (16): 8849–8857.

Kadir K. (2012). Kajian Pemanfaatan Sampah Plastik Sebagai Sumber Bahan Bakar cair. *Jurnal Ilmiah Teknik Mesin*. 3 (2).

Kingfisher J. (2011). Micro-Plastic Debris Accumulation on Puget Sound Beaches. Port Townsend Marine Science Center [*Internet*].

http://www.ptmsc.org/Science/plastic_project/Summit%20final%20Draft.pdf. [17 Juli 2019].

Kodoatie R. J. (2003). *Manajemen dan Rekayasa Infrastruktur*. Yogyakarta: Pustaka Pelajar.

Khoironi A., Anggoro, S., & Sudarno. (2018). The existence of microplastic in Asian green mussels. *IOP Conference Series: Earth and Environmental Science*. 131.

Kurniawan S. B., & Imron, M. F. (2019). The effect of tidal fluctuation on the accumulation of plastic debris in the Wonorejo River Estuary, Surabaya, Indonesia. *Environmental Technology and Innovation*. 15: 100420.

Laist D. W. (1987). Overview of the Biological effects of lost and discarded plastic debris in the marine environment. *Marine Pollution Bulletin*. 18 (6): 319–326.

Lee R. F., & Sanders, D. P. (2015). The amount and accumulation rate of plastic debris on marshes and beaches on the Georgia coast. *Marine Pollution Bulletin*. 91 (1): 113–119.

Li J., Qu, X., Su, L., Zhang, W., Yang, D., Kolandhasamy, P., Li, D., & Shi, H. (2016). Microplastics in mussels along the coastal waters of China. *Environmental Pollution*. 214: 177–184.

Lima A. R. A., Costa, M. F., & Barletta, M. (2014). Distribution patterns of microplastics within the plankton of a tropical estuary. *Environmental Research*. 132: 146-155.

Lourenço P. M., Serra-Goncalves, C., Ferreira, J. L., Catry, T., & Granadeiro, J. P. (2017). Plastic and other microfibers in sediments, macroinvertebrates and shorebirds from three intertidal wetlands of southern Europe and west Africa. *Environmental Pollution*. 231: 123-133.

Lusher A. L., Tirelli, V., O'Connor, I., & Officer, R. (2015). Microplastics in Arctic polar waters: the first reported values of particles in surface and sub-surface samples. *Scitific Reports*. 5: 1494.

Mason S. A., Kammin, L., Eriksen, M., Aleid, G., Wilson, S., Box, C., Williamson, N., & Riley, A. (2016). Pelagic plastic pollution within the surface waters of Lake Michigan, USA. *Journal of Great Lakes Research*. 42 (4): 753–759.

Mattsson K., Ekvall, M. T., Hansson, L. A., Linse, S., Malmendal, A., & Cedervall, T. (2015a). Altered behavior, physiology, and metabolism in fish exposed to polystyrene nanoparticles. *Environmental Science and Technology*. 49 (1): 553–561.

Mattsson K., Hansson, L. A., & Cedervall, T. (2015b). Nanoplastics in the aquatic environment. *Environmental Science: Process and Impacts*. 17 (10): 1712–1721.

McGoran A., Clark, P., & Morritt, D. (2017). Presence of microplastic in the digestive tracts of European flounder, *Platichthys flesus*, and European smelt, *Osmerus eperlanus*, from the River Thames. *Environmental Pollution*. 220: 744-751.

Miranda D. D. A., & de Carvalho-Souza, G. F. (2016). Are we eating plastic-ingesting fish? *Marine Pollution Bulletin*. 103: 109-114.

Mohamed Nor N. H., & Obbard, J. P. (2014). Microplastics in Singapore's coastal mangrove ecosystems. *Marine Pollution Bulletin*. 79 (1-2): 278-283.

Moore C. J. (2008). Synthetic polymers in the marine environment: a rapidly increasing, long-term threat. *Environmental Research*. 108: 131–139.

Murphy F., Russell, M., Ewins, C., & Quinn, Brian. (2017). The uptake of macroplastic and microplastic by demersal and pelagic fish in the Northeast Atlantic around Scotland. *Journal Marine Pollution Bulletin*.

Naji A., Esmaili, Z., & Khan, F. R. (2017). Plastic debris and microplastics along the beaches of the strait of Hormuz, Persian Gulf. *Marine Pollution Bulletin*. 114 (2): 1057-1062.

Napper I. E., & Thompson, R. C. (2016). Release of synthetic microplastic plastic fibres from domestic washing machines: effects of fabric type and washing conditions. *Marine Pollution Bulletin*. 112 (1–2): 39–45.

NOAA Marine Debris Program. (2014). *Report on the occurrence and health effects of anthropogenic debris ingested by marine organisms, Charleston, South Carolina*. Silver Spring, MD.

[NOAA] National Ocean and Atmosfere Administration. (2016). *Marine Debris Impacts on Coastal and Benthic Habitats*. NOAA Marine Debris Habitat Report.

[NOAA] National Ocean and Atmosfere Administration. (2015). *Turning The Tide On Trash. A Learning Guide on Marine Debris*. NOAA PIFSC CRED.

[NOAA] National Ocean and Atmosfere Administration. (2015). *Laboratory Methods for the Analysis of Microplastics in the Marine Environment: Recommendations for quantifying synthetic particles in waters and sediments***.** NOAA Marine Debris Program National Oceanic and Atmospheric Administration U.S. Department of Commerce Technical Memorandum NOS-OR & R-48.

Norris B.K., Mullarney, J.C., Bryan, K. R., & Henderson, S. M. (2017). The effect of pneumatophore density on turbulence: a field study in a Sonneratia-dominated mangrove forest, Vietnam. *Continental Shelf Research*. 147: 114-127.

Obbard R. W., Sadri, S., Wong, Y. Q., Khitun, A. A., Baker, I., & Richard, C. (2014). Global warming releases microplastic legacy frozen in Arctic Sea ice. *Earth's Future*. 2 (6): 315–320.

Oerlikon. (2009). The Fiber Year 2008/09: A world Survey on Textile and Nonwovens Industry. Oerlikon: Switzerland.

Peters C. A., & Bratton, S. P. (2016). Urbanization is a major influence on microplastic ingestion by sunfish in the Brazos River Basin, Central Texas, USA. *Environmental Pollution*. 210: 380-7.

Phillips M. B., & Bonner, T. H. (2015). Occurrence and amount of microplastic ingested by fishes in watersheds of of the Gulf of Mexico. *Marine Pollution Bulletin*. 100 (1): 264-269.

Rehse S., Kloas, W., & Zarfl, C. (2016). Short-term exposure with high concentrations of pristine microplastic particles leads to immobilisation of Daphnia magna. *Chemosphere*. 153: 91–99.

Rochman C. M., Tahir, A., Williams, S. L., Baxa, D. V., Lam, R., Miller, J. T., Teh, F. C., Werorilangi, S., & Teh, S.J. (2015). Anthropogenic debris in seafood: Plastic debris and fibers from textiles in fish and bivalves sold for human consumption. *Nature*. 5: 14340.

Ryan P. G., Moore, C. J., van Franeker, J. A., & Moloney, C. L. (2009). Monitoring the abundance of plastic debris in the marine environment. *Philosophical Transactions of the Royal Society B*. 364: 1999–2012.

Schuyler Q. A., Wilcox, C., Townsend, K., Hardesty, B., & Marshall, N. (2014). Mistaken Identity Visual similarities of marine debris to natural prey items of sea turtles. *BMC Ecology*. 14: 14.

Schuyler Q. A., Wilcox, C., Townsend, K. A., Wedemeyer-Strombel, K. R., Balazs, G., van Sebille, E., & Hardesty, B. D. (2016). Risk analysis reveals global hotspots for marine debris ingestion by sea turtles. *Global Change Biology*. 22: 567–576.

Septian F. M., Purba, N. P., Agung, M. U. K., Yuliadi, L. P. S., Akuan, L. F., & Mulyani, P. G. (2018). Microplastic Spatial Distribution in Sediment at Pangandaran Beach, West Java. *Jurnal Geomaritim Indonesia*. 1 (1): 1-8.

Silva-Cavalcanti J. S., Silva, J. D. B., de França, E. J., de Araújo, M. C. B., & Gusmão, F. (2017). Microplastics ingestion by a common tropical freshwater fishing resource. *Environmental Pollution*. 221: 218-226.

Smith S. D. A. (2012). Marine debris: a proximate threat to marine sustainability in Bootless Bay, Papua New Guinea. *Marine Pollution Bulletin*. 64 (9): 1880-1883.

Sofiana Y. (2010). Pemanfaatan Limbah Plastik Sebagaib Alternatif Bahan Pelapis (*Upholstery)* Pada Produk Interior. *Jurnal Inasea*. 11 (2): 96-102.

Suaria G., Melinte-Dobrinescu, M. C., Ion, G., & Aliani, S. (2015). First observations on the abundance and composition of floating debris in the North-western Black Sea. *Marine Environment Research*. 107: 45–49.

Syakti A. D., Rafika, B., Nuning, V. H., Candra, J.K., Abdelaziz, B., Isdy, S., Stephanie, L., Syafsir, A., Pierre, D., & Wong Wah-Chung, P. (2017). Beach Macro-Litter Monitoring ang floating Microplastic in a Coastal Area of Indonesia. *Marine Pollution Bulletin*. 122 (2017): 217-225.

Syakti A. D., Hidayati, N. V., Jaya, Y. V., Siregar, S. H., Yude, R., Suhendy, Asia, L., Wong Wah-Chung, P., & Doumenq, P. (2018). Simultaneous grading of microplastic size sampling in the Small Islands of Bintan water, Indonesia. *Marine Pollution Bulletin*.137: 593-600.

Syakti A. D., Jaya, J. V., Rahman, A., Hidayati, N. V., Raza'I, T. S., Idris, F., Trenggono, M., Doumenq, P., & Chou, L. K. (2019). Bleaching and necrosis of staghorn coral (*Acropora formosa*) in laboratory assays: Immidiate impact of LDPE microplastic. *Chemosphere*. 228: 528-535.

Tanaka K., Takada, H. (2016). Microplastic fragments and Microbeads in Digestive Tracts of palnktivorous fish from urban Coastal water. *Scientific Reports*. 6: 34351.

Tanković, M. S. Perusco, V. S., J. Godrijan, D., & M. Pfannkuchen. (2015). Marine plastic debris in the northeastern Adriatic. Micro 2015. Book of abstracts. National Oceanic and Atmospheric Administration. 2013. Programmatic environmental assessment (PEA) forthe NOAA Marine Debris Program (MDP). Maryland (US): NOAA. 168 p.

Taylor M. L., Gwinnett, C., Robinson, L. F., & Woodall, L. C. (2016). Plastic microfibre ingestion by deep-sea organisms. *Scientific Reports*. 6: 33997.

Tekman M. B., Krumpen, T., & Bergmann, M. (2017). Marine litter on deep Arctic seafloor continues to increase and spreads to the North at the HAUSGARTEN observatory. *Deep-Sea Research Part I: Oceanographic Researh Paper*. 120: 88–99.

Thompson R. C., Moore, C. J., vom Saal, F. S., & Swan, S. H. (2009). Plastics, the environment and human health: current consensus and future trends. *Philosophical Transaction of the Royal Society B: Biological Science*. 364: 2153–2166.

[UNEP] United Nations Environment Programme. (2016). Marine plastic debris and microplastics—Global lessons and research to inspire action and guide policy change. United Nations Environment Programme, Nairobi. 252 pp.

[UNEP] United Nations Environment Programme. (2009). *Converting Waste Plastics Into a Resource, Division of Technology, Industry and Economics International Environmental Technology Centre*, Osaka Shiga.

van Sebille E., Wilcox, C., Lebreton, L., Maximenko, N., Hardesty, B.D., van Franeker, J.A., Eriksen, M., Siegel, D., Galgani, F., & Law, K. L. (2015). A global inventory of small floating plastic debris. *Environmental Research Letters*. 10 (12): 124006.

Wang J. D., Peng, J. P., Tan, Z., Gao, Y. F., Zhan, Z. W., Chen, Q., & Cai, L. (2017). Microplastics in the surface sediments from the Beijiang River littoral zone: composition, abundance, surface textures and interaction with heavy metals. *Chemosphere*. 171: 248–258.

Wilcox C., Sebille, E. V., & Hardesty, B. D. (2015). Threat of plastic pollution to seabirds is global, pervasive, and increasing. *Proceedings of the National Academy of Sciences*. 112: 11899–11904.

Zhang K., Su, J., Xiong, X., Wu, X., Wu. C.X., & Liu, J. T. (2016). Microplastic pollution of lakeshore sediments from remote lakes in Tibet plateau, China. *Environmental Pollution*. 219: 450–455.

Zitko V., & Hanlon, M. (1991). Another source of pollution by plastics: skin cleaners with plastic scrubbers. *Marine Pollution Bulletin*. 22: 41–42.