Microplastic Pollution in Indonesia: The Contribution of Human Activity to the Abundance of Microplastics

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Abstract. Plastic in Indonesia are used as wrappers on household scale to large industrial products. To reach low-income consumers the company releases cheap plastic products and daily necessities in smaller plastic wrap which causes high use of plastics even in rural areas and causes macro to micro-sized plastics pollution. This study used a systematic literature review method. Google Scholar and Science Direct databases are used in this literature study. The inclusion criteria in selecting articles to be reviewed contain the keywords "microplastic", "microplastic abundance" and "urban areas". Based on these criteria 32 articles published since 2014. Most of the research was carried out in coastal and marine environment. The greatest abundance of microplastic is found in coastal areas sediments and estuary water. The dominant forms are fragments and fibers with polypropylene (PP) and polyethylene (PE) types. The morphology and types indicate that the source is secondary microplastics mostly comes from human activities in urban areas. More microplastic research is needed in Indonesia, especially in the terrestrial area including in soil and groundwater to identify the main sources of pollution, the effect of waste management on microplastic abundance and identify pathways for microplastic pollution from land to the sea.

1 Introduction

Plastic is a material that is widely used in daily life because of its strong, lightweight, and practical so it is often used as a packaging material, furniture material, etc. Humans are estimated to have produced and used plastic up to 8.3 billion tons since the beginning of the plastic usage [1]. The dominates use of plastics in human activities causes an increase in the world's plastic waste [2]. Conventional waste recycling measures are only able to recycle 15-20% of plastic waste, the inability of humans to process plastic waste causes the plastic become the dominant pollutant [2].

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Countries with large populations and poor waste management can cause 40% [2] plastic wastes dumped into the sea and causes pollution on a wide scale [3]. The population in Indonesia reaches 263.9 million and occupies 17.504 islands [4] because Indonesia's coastal areas develop into densely populated areas, the potential for plastic pollution from the Indonesian archipelago is very large. 3.2 out of 64 million tons of plastic waste are dumped into the ocean through rivers [5], so that Indonesia is considered as the second-largest contributor to plastic waste in the world after China [2]. The largest plastic waste is produced from human activities on land so that waste management has an important role in controlling the entry of plastic pollution into the environment [5]. Plastic waste in urban areas with good waste management can be lower than in rural areas [6]. This needs to be a concern because waste management in Indonesia is still constrained by high landfill waste due to high population growth rates, poor of waste management, limited funding, and lack of landfills [7]. The low public awareness of good waste management along the watershed increases plastic pollution in rivers because less than 40% of the community sells their plastic waste to waste banks, and the rest is burned or left on vacant land or rivers [8].

Plastic waste from settlements and other human activities can easily move towards waters with runoff and slope as main influence [9] so that rural and suburban areas along the catchment area are important contributors of plastic pollution [10]. Plastic waste can be degraded and fragmented through the process of photooxidative degradation [11] and physical damage due to human activities [12] into plastic flakes measuring less than 5 mm [13] till 1 µm [14] which is called microplastic. Human activities that produce microplastics include household activities [15], washing machine use [16], waste disposal [17] wastewater irrigation [18], the using of organic fertilizer [19], the using of plastic coatings/mulch [20] and others that use plastic as the main material or mixture material. Microplastic can be different from the original form [21] generally found in the form of pellets, fragments, fiber, film and foam [22].

Microplastics in water, sediments and marine organisms can cause danger if consumed by humans because they can absorb toxic compounds such as bisphenol A (BPA), polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) and dichlorodiphenyltrichloroethane (DDT) and heavy metals from the environment [23] although the magnitude of the impact of microplastic accumulation on human health is not known with certainty [24].

2 Method

Microplastic pollution in Indonesia is studied based on a comprehensive literature review. Article collection is done by using access through Science Direct (http://www.sciencedirect.com) and Google Scholar (https://scholar.google.co.id/) by using the keywords microplastic pollution, microplastic abundance, and Indonesia. To minimize the bias, the articles used are refined by area, that is only articles with research sites in Indonesia, articles made based on field research with samples of sediment, water, and organisms and are articles that can be accessed openly using the access mentioned. From these criteria, 32 articles were obtained as material for review.

3 Result

Research on microplastics in the world has been conducted since 1972 by Carpenter et al [25] and more intensive research began in the 2000s when it was found that the number of plastic particles in film form and polypropylene type in the northern Pacific Ocean was six times greater than plankton. Research on plastic pollution in Indonesia began in 1986 by
Willoughby who examined macrodebris on Pulau Seribu, Jakarta [26] and developed more specifically into microplastic research since 2014 through microplastic publications on mangrove ecosystems in Pantai Indah Kapuk, Jakarta [27], followed by other research that proves that the Indonesia terrestrial and marine areas have been contaminated with microplastic pollution with the discovery of microplastics in water, sediments and organisms with abundance, shapes, and types as diverse as summarized in Table 1.

Microplastic abundance in Indonesia, especially in water and sediments in open sea is relatively same as the average abundance of other countries due to the movement of ocean currents. In general, microplastic abundance in Indonesia varies from 15-38,790 n/kg in sediments and 0.002-7000 n/m³ in water. At the same location, the abundance of microplastics in sediment is greater than in water such as in Kemal Estuary, Jakarta Bay where the microplastics in water are 103.8 n/lt or smaller than those in sediments which is 111.68 n/kg [28] This is consistent with Hidalgo-Ruz's (2012) research which shows that the highest microplastic abundance is found in sediments compared to water surface [29].

The mangrove area can hold microplastic to reduce the entry of microplastic in the sea, this is evidenced by the high abundance of microplastics in the Pantai Indah Kapuk area of Jakarta [27], Gresik, East Java [30] and Mempawah West Borneo [31]. Because the size is so small, microplastics depend strongly on the flow conditions [32] so that it can be found even in remote [33] and non-industrialized places [34]. Likewise in Indonesia where 41 microplastic particles were found in the form of pellets in deep-sea sediments in Southwestern Sumatra [34]. Microplastics can be misinterpreted as food by marine organisms [35] so that microplastics enter into organisms such as commercial fishes where the abundance reaches 4.9-20 n/individual [36], sea urchin 8-35 n/individual [37] even the sea cucumber reaches 1503-2239 n/0.25 gr [38].

Table 1. Summary of microplastic study area, sample, abundance and dominant shape In Indonesia

<table>
<thead>
<tr>
<th>No</th>
<th>Study Area</th>
<th>Sample</th>
<th>Abundance (n=particle)</th>
<th>Dominant Shape (%)</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pantai Indah Kapuk, Jakarta</td>
<td>Coastal sediment</td>
<td>216.8-2218.4 n/kg</td>
<td>Film (74.1)</td>
<td>[27]</td>
</tr>
<tr>
<td>2</td>
<td>Muara Badak, East Borneo</td>
<td>Coastal Sediment</td>
<td>277.2-360.5 n/kg</td>
<td>Fragment (60.2)</td>
<td>[39]</td>
</tr>
<tr>
<td>3</td>
<td>Southwestern Sumatera</td>
<td>Deepsea Sediment</td>
<td>41 n</td>
<td>Pellet (85.4)</td>
<td>[34]</td>
</tr>
<tr>
<td>4</td>
<td>Jakarta Bay</td>
<td>River Sediment</td>
<td>18405-38790 n/kg</td>
<td>Fragment (97)</td>
<td>[40]</td>
</tr>
<tr>
<td>5</td>
<td>Cilacap Bay, Central Java</td>
<td>Coastal water</td>
<td>16.8-41.6 n/m³</td>
<td>-</td>
<td>[41]</td>
</tr>
<tr>
<td>6</td>
<td>Bintan Island</td>
<td>Sea Water</td>
<td>1.2-4.7 n/m³</td>
<td>Fragment (64.9)</td>
<td>[42]</td>
</tr>
<tr>
<td>7</td>
<td>Sekotong, Lombok</td>
<td>Sea Sediment</td>
<td>35-77 n/kg</td>
<td>Foam (41.2)</td>
<td>[43]</td>
</tr>
<tr>
<td>8</td>
<td>Langkat, North Sumatra</td>
<td>Coastal Sediment</td>
<td>64-326.33 n/kg</td>
<td>Film (52.3)</td>
<td>[44]</td>
</tr>
<tr>
<td>9</td>
<td>Pangandaran, West Java</td>
<td>Coastal Sediment</td>
<td>33-68 n/kg</td>
<td>Fiber (61.7)</td>
<td>[45]</td>
</tr>
<tr>
<td>10</td>
<td>Tambaklorok, Semarang</td>
<td>Green mussels</td>
<td>1-5 n/0.25 gr</td>
<td>-</td>
<td>[46]</td>
</tr>
<tr>
<td>11</td>
<td>Tuban Beach, East Java</td>
<td>Coastal Sediment</td>
<td>3040-8870 n/m³</td>
<td>-</td>
<td>[47]</td>
</tr>
<tr>
<td></td>
<td>Location</td>
<td>Type of Water/Sediment</td>
<td>Concentration/Value</td>
<td>Type (%)</td>
<td>Reference</td>
</tr>
<tr>
<td>----</td>
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</tr>
<tr>
<td>12</td>
<td>Surabaya Northern Coastal</td>
<td>Coastal Water</td>
<td>380-610 n/m³</td>
<td>Foam (58.4)</td>
<td>[48]</td>
</tr>
<tr>
<td>13</td>
<td>Estuary of Jakarta</td>
<td>Estuary Sediment</td>
<td>98-112 n/m³</td>
<td>-</td>
<td>[49]</td>
</tr>
<tr>
<td>14</td>
<td>Banyu urip River, Gresik, East Java</td>
<td>Estuary Sediment Sea Water</td>
<td>778-2289 n/ m³</td>
<td>Fragment (54.5)</td>
<td>[30]</td>
</tr>
<tr>
<td>15</td>
<td>Kupang and Rote Sea, NTT</td>
<td>Sea Water</td>
<td>0.002-0.051 n/m³</td>
<td>Fiber (50)</td>
<td>[50]</td>
</tr>
<tr>
<td>16</td>
<td>Liwalengke River, Majalaya, West Java</td>
<td>River Water River sediment</td>
<td>4330-7000 n/m³</td>
<td>Fiber (65)</td>
<td>[51]</td>
</tr>
<tr>
<td>17</td>
<td>Surabaya River, West Java</td>
<td>River Water</td>
<td>7.14-32.38 n/m³</td>
<td>-</td>
<td>[52]</td>
</tr>
<tr>
<td>18</td>
<td>Mempawah, West Borneo</td>
<td>Coastal Sediment</td>
<td>100-953 n/kg</td>
<td>Fiber (52.3)</td>
<td>[31]</td>
</tr>
<tr>
<td>19</td>
<td>Pantai Indah Kapuk, Jakarta</td>
<td>Commercial fishes</td>
<td>4.9-20 n/individu</td>
<td>Fiber (89.6)</td>
<td>[36]</td>
</tr>
<tr>
<td>20</td>
<td>Siak River, Pekanbaru</td>
<td>River Sediment</td>
<td>666.7-13766.7 n/m³</td>
<td>Fiber (92)</td>
<td>[53]</td>
</tr>
<tr>
<td>21</td>
<td>Badung, Bali</td>
<td>Coastal Sediment</td>
<td>67.2-1489 n/kg</td>
<td>Fiber (57.9)</td>
<td>[54]</td>
</tr>
<tr>
<td>22</td>
<td>Kamal Estuary, Marunda, Jakarta Bay</td>
<td>Coastal Water Coastal Sediment Milkfish</td>
<td>90.7-103.8 n/lt</td>
<td>Fiber (52)</td>
<td>[28]</td>
</tr>
<tr>
<td>23</td>
<td>Kartini beach, Jepara, Central Java</td>
<td>Coastal Sediment</td>
<td>438-643 n/50 gr</td>
<td>Fiber (57.6)</td>
<td>Fiber (66.7)</td>
</tr>
<tr>
<td>24</td>
<td>Tidung Besar and Bira Besar Island, Jakarta</td>
<td>Sea Sedimen sea cucumber</td>
<td>2558-3090 n/gr</td>
<td>Fiber (88)</td>
<td>Fiber (90.7)</td>
</tr>
<tr>
<td>25</td>
<td>Giri Labak, Sumenep</td>
<td>Sea Water Sea Sediment</td>
<td>70-330 n/lt</td>
<td>Fiber (57.6)</td>
<td>Fiber (66.7)</td>
</tr>
<tr>
<td>26</td>
<td>Surabaya River, East Java</td>
<td>River Water</td>
<td>1.22-21.16 n/m³</td>
<td>Film (45)</td>
<td>[56]</td>
</tr>
<tr>
<td>27</td>
<td>Teluk, Kendari, Sulawesi</td>
<td>Coastal Sediment</td>
<td>1365-3520 n/kg</td>
<td>Fragment (52)</td>
<td>[57]</td>
</tr>
<tr>
<td>28</td>
<td>Tambaklorok, Coastal Area Semarang</td>
<td>Sea Water Sea Sediment</td>
<td>7-111 n/10 mL</td>
<td>-</td>
<td>[58]</td>
</tr>
<tr>
<td>29</td>
<td>Jagir Estuary, Surabaya</td>
<td>Estuary Sediment Coastal Sediment</td>
<td>92-146 n/kg</td>
<td>Fiber (81)</td>
<td>Fiber (53)</td>
</tr>
<tr>
<td>30</td>
<td>Banten Bay, West Java</td>
<td>Bay Sediment</td>
<td>101-431 n/kg</td>
<td>Foam (30.4)</td>
<td>[60]</td>
</tr>
<tr>
<td>31</td>
<td>Mangunharjo, Tugu, Semarang</td>
<td>Estuary Sediment Coastal Sediment</td>
<td>3585-4523 n/m³</td>
<td>Fiber (63.2)</td>
<td>Fiber (62.8)</td>
</tr>
</tbody>
</table>
The microplastic abundance is significantly correlated with population density and depend on human activities [10], where a large number of microplastics is found in areas that have a high population [27],[61],[30], fishing area [58], close to the industrial area [51] and tourism areas [38],[54]. The existence of a dominant human influence on the abundance of microplastics causes downstream and suburban areas to become important contributors to microplastic pollution [10]. Microplastic pollution is more developed in polluted rivers with poor water quality which indicates the source and entry process of microplastics is similar to other pollutants [32].

The most common form of microplastic is secondary plastic which is derived from the degradation of plastic goods. In percentage, fiber is the dominant microplastic form in 15 locations out of a total of 24 research locations as shown in Fig. 1.

**Fig. 1. Dominant Microplastic Form**

Fiber can come from domestic waste and is a secondary microplastic in the form of fibers, strands, threads, and microfibers whose sources are mostly from washing clothes, ropes, and from fishing gear in the form of various types of fishing rods and fishing nets [22]. The highest fiber abundance is found in coastal sediment [27],[61] and reaches 88% in sea sediment [38]. This is by the research of Browne et. al., where fiber is the most abundant form of sediment [63]. Just as the results of research by Foley et. al., fiber is a form that is often mistaken for food by marine organisms rather than pellets or foam [64], so that the fiber in the body of the organism is very high percentage reaching 90.7% in the sea cucumber [38], 89.63% in commercial fishes [36] and 80% in sea urchins [37].

The types of polymers dominated by PP, PE, and PS indicate that most plastic sources originate from urban areas as in the Onwudili (2009) which state that polyethylene (PE) and polystyrene (PS) are the main components of plastic waste found in urban areas [65] so that microplastic abundance is influenced by anthropogenic factors [66] and the environment [67]. The dominance of PE and PP found in Indonesia is in line with the results of research conducted on rivers in the Kreo Sub-watershed basin, Semarang City, where most of the plastics found are soft and multilayer (plastic wrap and plastic bags) which are generally made of PP and PE [68].

<table>
<thead>
<tr>
<th>Location</th>
<th>Species</th>
<th>Abundance n/individu</th>
<th>Sample Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sayung, Demak, Central Java</td>
<td><em>Pernaviridis</em></td>
<td>4111</td>
<td>Film (47.2)</td>
</tr>
<tr>
<td></td>
<td><em>Penaeus monodon</em></td>
<td>6131</td>
<td>Fragment (36)</td>
</tr>
<tr>
<td></td>
<td><em>Lates calcarifer</em></td>
<td>6596</td>
<td>Fiber (30.8)</td>
</tr>
</tbody>
</table>

[62]
4 Conclusion

Microplastic pollution has occurred in Indonesia, both on land and sea, this is evidenced by the presence of microplastic abundance that is quite high in freshwater environments such as rivers to the sea and even microplastics found in the body of marine organisms commonly consumed by humans.

Microplastic dominance in the form of secondary microplastic shows that the source of microplastic pollution comes from everyday human activities in urban areas. Therefore, it is necessary to conduct more microplastic research, especially on groundwater and soil because until now this research has not been conducted in Indonesia so that it can be known how the path of the spread of microplastic pollution from remote areas in the mountains, areas with a high influence of human activity towards the territorial waters to the sea of Indonesia.

References

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