Distribution and mitigation efforts for microplastic pollution in Kendari bay as the mainstay coastal tourism area of Southeast Sulawesi

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Abstract. Marine waste, especially plastic waste, is a complex problem faced by areas close to the beach/coastal area. This problem also occurs in Kendari Bay which has a unique character because of its position stretching in the middle of Kendari City, its shape is like a horse's footprint and as a mainstay tourist attraction in Southeast Sulawesi. This study aims to analyze the distribution of microplastic abundance in sediments and marine biota, analyze water quality in the microplastic abundance distribution area, and determine efforts to mitigate pollution of plastic waste in Kendari Bay. A sampling of sediments and biota from 2 stations (settlement and port) using paralon pipes at depths of 0-5 cm and 5-10 cm. Seawater quality parameters are parameters related to solid waste pollution based on UNESCO-WHO-UNEP and the method for water quality analysis refers to APHA-AWWA-WEF. The results showed that the types of microplastics found were film, fragment, and fiber. The average abundance of microplastics in Station I (Mata Village, Kendari City) and Station II (Kendari Archipelago Harbor) at a depth of 0-5 cm range from 426.82-424.92 particles/kg. This value is higher than the microplastic abundance at 5-10 cm depth, which is between 276.50 to 363.74 particles/kg. The average abundance of film-type microplastics and fragments at 0-5 cm depth was higher at Station I (203.75 particles/kg and 359.90 particles/kg). The microplastic category of fragments/debris at a depth of 5-10 cm, was found at Station II (409.06 particles/kg). Biota found in Station I sediments were blood shells (AnadaraSp) With microplastic fragment type (1 particle) and fiber type (2 particles) with an average abundance of 0.12 particles/Ind. Fiber-type microplastics are found in tofu skin (Maretrixmaretrix) of 5 particles with an average abundance of 0.5 particles/Ind. and Violin Crab (Uca), 1 particle with an average abundance of 0.04 particles/Ind. Water quality in the area of microplastic abundance found NH₃, BOD, Phosphate (PO₄³⁻), Nitrate (NO₃⁻), Phenol (C₆H₅OH), detergent and fat oil content have exceeded the quality standard. Mitigation efforts that can be done are 6R, separating the types of waste from the beginning, encouraging the role of government through education and regulation, research and technology support as well as bay cleaning measures so as to beautify the bay and improve the comfort of the local community and visitors so that the function of Kendari Bay as a tourist area the mainstay coast of Southeast Sulawesi remains sustainable.

1. Introduction
A large amount of garbage from the mainland will enter the water flow and empties into the sea so that the waste in the sea becomes very large[1]. About 60-80% of marine waste is dominated by plastic waste [2] and is a current global problem because it has spread in waters around the world[3]. Indonesia is the second-largest contributor to plastic waste in the world after China, with an estimated
0.48-1.29 million metric tons/year [4]. Plastic waste is difficult to decompose by the environment [5], and will be distributed far from the coast to the high seas and the seabed [6,7,8,9]. A very significant increase in plastic mass from 4.8 to 12.7 million tons was identified in the ocean with various types of plastic sizes namely nano-, micro-, meso-, and microplastic [10,11]. Microplastics are widely distributed in oceans such as on the coast, sea level and the seabed [11] and vary in size, color, shape, density, composition, and other properties [12]. Microplastic is a small plastic (≤ 5 mm) and difficult to decompose so that this material will last a long time in the environment. Microplastic accumulation is very high in seawater and sediments [13]. The impact is very large in the ocean and has a small particle size so that it is ubiquitous and bioavailable for aquatic organisms. Microplastic effects will pollute or inadvertently be digested by marine biotas [14] such as benthic animals and pelagic fish [15,16] because they are shaped like food [17,18].

Kendari Bay is a coastal area located in Southeast Sulawesi Province. Kendari Bay has its own uniqueness that is its position that stretches in the middle of Kendari City, in the form of a horse tread so it is a mainstay tourist attraction in Southeast Sulawesi. Based on the condition of Kendari Bay, there is a possibility that untreated waste will enter the waters. Activities of contributors to waste in Kendari Bay include sea transportation and residential areas. Based on data from the Kendari City Sanitation Office, every day the volume of waste in this city is 516 m$^3$ of the amount of waste that can only be managed by the city government, which is 188 m$^3$ [19]. Waste that is not managed will enter the marine environment if thrown carelessly, then the waste will be carried by rain and then into the river and the flow will be carried to the sea. This research is focused on how the distribution and mitigation of microplastic pollution in Kendari Bay as a mainstay coastal tourism area of Southeast Sulawesi.

2. Method

This research was conducted in Kendari Bay in Kendari City. This area is a tourist area that is visited by many tourists. The location point is determined by Station I in a residential area that is connected directly to the sea around Mata Village, Kendari City with coordinates 3°9627612 latitudes and 122°6096394 East Longitude. Station II is located at the Port of Kendari Archipelago with coordinates 3°973359 South Latitude and 122°582863 East BT which is a fairly busy sea transportation route (Figure 1).

![Figure 1 Map of Research Locations in Kendari City Bay](image-url)

The purposive sampling method was used to determine the location by installing a 50x50cm quadrant [20]. Taking 3 sediment samples are in each quadrant using the random sampling method. Sediment sampling was carried out using a 4-inch paralon pipe based on two depths (0-5 and 5-10...
cm). Measurement of microplastic content is in sediments by stages of drying, volume reduction, density separation, filtering, and visual separation. Drying was carried out in a 105°C oven for 72 hours [13]. Sorting microplastic particles are using a Stereomicroscope and grouped into four types, namely fiber, film, fragments, and pellets. The parameters taken are abundance (particles/kg) [13]. The microplastic abundance data were analyzed descriptively statistically and using Microsoft Excel. Seawater quality parameters are parameters related to solid waste pollution based on [21] and the method for water quality analysis refers to [22].

3. Results and Discussion

3.1. Microplastic Type in Kendari Bay
In general, microplastics consist of four types. At the study site, only three types of microplastics were found, namely the type of film, fragment, and fiber while the type of pellet was not found (Figure 3). There were no pellets found in the Kendari Bay area because there was no plastic industry around the area. Pellet type microplastics are primary microplastics derived from plastic manufacturing raw materials from the plastics industry.

Figure 2. Microplastic particles in the observation station
(a) Film (b) Fragments and (c) Fiber

3.2. Microplastic Abundance Based on Depth
The microplastic abundance at each station is different because it is influenced by several factors including differences in the source of waste that dominates and the amount of waste that enters the research station area. The results showed an average microplastic abundance based on depth did not show too high a difference. The average abundance of microplastics at Station I (Mata village settlement area, Kendari City) and II (Kendari Archipelago Harbor) at a depth of 0-5 cm ranged from 426.82-424.92 particles/kg. This value is higher than microplastic abundance at 5-10 cm depth ranging from 276.50 to 363.74 particles/kg. The abundance of microplastic particles based on depth can be seen in Figure 3.

This happens because the source of rubbish at the Kendari Archipelago Harbor is dominated by visitors/passengers of the ship and rubbish coming from sewers and waterways that directly enter the harbor waters. Meanwhile, in the residential area in Mata village, Kendari City is dominated by rubbish originating from domestic plastic waste that is disposed of intentionally or unintentionally in the surrounding marine environment. This is in line with the results of the report of the Australia Limited Organization relating to marine waste which states that human activity is the largest contributor to waste in the sea at 60-80%. The source of anthropogenic waste is generated from human
activities both on land and in the ocean [23]. The sources of waste in Kendari Bay include waste generated from household and industrial waste, the process of capturing and trading marine life, transportation/ports, and marine tourism.

![Average Microplastic Abundance Based on Depth in Kendari Bay](image)

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### 3.3. Relationship of Microplastic Abundance with Sediment Depth

Microplastic species abundance based on depth 0-5 cm and 5-10 cm. It aims to determine the differences in the abundance of each type of microplastic particles found in the form of film, fragments, and fiber. The average abundance of film-type microplastic particles is found more at 0-5 cm depth than at 5-10 cm depth, this is due to the spread of this microplastic form on the surface other than because the polymer is more tenuous and easily degraded is also influenced by the density this microplastic is lighter than the others. Meanwhile, the abundance of fragment type microplastic particles is more commonly found at depths of 5-10 cm because the density is heavier than the type of film and is easily subjected to precipitation. Microplastic type in the form of fiber or fiber is also commonly found at Station II because it settles and there are many particles at that location. This is due to a large number of aquatic activities carried out such as transportation and fishing, according to [24] generally the number of microplastics, especially the form of fiber or fibers derived from increased water activity. The abundance of microplastic particle type categories with depth can be seen in Figure 4.

The average abundance of microplastic films and fragments at a depth of 0-5 cm is higher than Station I, namely 203.75 Particles/Kg and 359.90 Particles/Kg. Categories of microplastic fragments or fragments to a depth of 5-10 cm are more often found at Station II, which is 409.06 Particles/Kg. Categories of microplastic pellets or beads were not found at either station. The high number of films and fragments at Station I (Settlements) is influenced by a large amount of domestic waste that is disposed of directly or indirectly by the community or trash carried in the form of plastic waste (plastic bags, food packaging, and houses packaging) other ladders). According to [25], settlements make a big contribution to waste and waste to the waters, especially the sea because there are many activities in it such as trade, industry and so on. Meanwhile, many types of fibers found at Station II
(Harbor) occur because at this station there are many using synthetic ropes for anchors, other shipping needs and fishermen/anglers around the port area. High fishing and transportation activities in the ocean will make a lot of donations in the form of a rope or fiber waste [26].

The average abundance of microplastic fragments and film types was more dominant at 0-5 cm depth than at 5-10 cm depth. This happens because this type of film has a more tenuous polymer and is easily degraded. Another factor is that the distribution of this type of microplastic is on the surface because this microplastic density is lighter than the others. Fiber type microplastic particles/fibers are mostly found at Station II because of the nature of the material that is easy to be deposited and many activities carried out in waters such as transportation and fishing also affect the abundance of fiber type microplastic. According to [24] generally the number of microplastics, especially the type of fiber derived from increased activity in the waters.

![Figure 4. Average Abundance of Microplastic Types](image)

a. Depth of 0-5 cm  
b. Depth of 5-10 cm

### 3.4. The Existence and Abundance of Microplastics in Marine Biota

Besides being found in microplastic sediment particles can also be found in the body of marine biota that can threaten the life of marine organisms because microplastics can inhibit metabolism in the body of the organism. Based on the research of [27] there are three types of microplastics found in the body of biotas (mainly benthic organisms) such as film, fragments, and fiber. Types of biota found and types of microplastics in the body of biota in Kendari Bay are presented in Figure 5 and Table 1.

![Figure 5. Types of Biota found at the Observation Station. a. Mangrove Shells b. Violin Crab c. Sea Worms d. Kepah Shells e. Green Clam.](image)

Biota found in sediments at Station I was Blood Shells (*Anadara Sp.*) With microplastic fragments (one particle) and fiber (two particles) with an average abundance of 0.12 Particles/Ind. Fiber type microplastics were found in Tofu Shells (*Maretrixmaretrix*) of 5 particles with an average abundance of 0.5 Particles/Ind. Crab Violin (*Uca*) there is 1 particle with an average abundance of 0.04 Particles/Ind. According to [28] that various forms of microplastic that have been found in organisms both in the marine and freshwater environments. In the seawater environment, microplastics are found in benthic and pelagic animals. These benthic animals include invertebrates including sea cucumbers,
lobsters, shellfish, barnacles and others. The types of microplastics found in biota at Station I can be seen in Figure 6.

**Table 1.** Types of Biota found at the observation station

| No. | Individual                  | Number of Individuals | Microplastic Type | Microplastic Abundance (Particle/Ind) | Average Abundance (Particle/Ind) |
|-----|-----------------------------|-----------------------|------------------|---------------------------------------|----------------------------------|
| 1.  | Blood Shells (<em>Anadara</em> Sp.) | 5                     | 3                | 0.6                                   | 0.12                             |
| 2.  | Tofu Shells (<em>Maretrixmaretrix</em>) | 3                     | 5                | 1.6                                   | 0.5                              |
| 3.  | Sea Worms (<em>Lumbricusterestis</em>) | 3                     | 0                | 0                                     | 0                                |
| 4.  | Crab Violin (<em>Uca</em>) | 5                     | 1                | 0.2                                   | 0.04                             |
|     | Total                       | 16                    | 9                | 2.4                                   | 0.71                             |

**Station II (Around the Port of the Archipelago, Kendari City)**

| 1.  | Crab Violin (<em>Uca</em>) | 10                    | 3                | 0.3                                   | 0.03                             |
| 2.  | Sea Oysters (<em>Crassostreagigas</em>) | 5                     | 2                | 0.4                                   | 0.08                             |
| 3.  | Sea Worms (<em>Lumbricusterestis</em>) | 9                     | 0                | 0                                     | 0                                |
|     | Total                       | 24                    | 5                | 0.7                                   | 0.11                             |

**Figure 6.** Microplastic particles found in biota at Station I (a) Fragments in Blood Shells (P: 1.0 mm, L: 0.51 mm) (b) Fiber in Tofu Shells (P: 1.4 mm, L: 0.01 mm) (c) Fiber on the Violin Crab (P: 4.0 mm, L: 0.01 mm). Using a Stereo Microscope with 4.0x4.0 Lens Magnification

At Station II found 3 fiber type microplastic particles on Violin Crabs (<em>Uca</em>) in an average abundance of 0.03 Particles/Ind. and Sea Oysters (<em>Crassostreagigas</em>) with 2 fiber type microplastic particles with an average abundance of 0.08 Particles/Ind. according to the research of [27] which explains that in general, bivalve type microplastic fibers originating from household waste such as fabric fibers, both fabrics that are thrown directly into the sea or come from washing water, clothing is thrown directly into the water. Microplastic particles found at Station II can be seen in Figure 7.
Figure 7. Microplastic particles found at Station II
(a) Fiber (P: 3.0 mm, L: 0.11 mm) (b) Fiber (P: 4.9 mm, L: 0.024 mm). Using a Stereo Microscope with a 40x40 Lens Magnification

The presence of waste in the sea will continue to increase (Jambeck et al., 2015) and damage the marine ecosystem [29, 30]. According to [31], microplastic waste can be a food source and enter the mesentrial network of coral reefs. Microplastic from macroplastic, if put into the body of marine biota, will become toxic material [3] and disturb health [25] for example in the fish liver [27]. Through the food chain process, plastic pieces will move from a consumer I to consumer II [16] and humans as the last consumer [32]. Plastic materials that enter the human body will interfere with human health, especially in pregnant women and children [33].

3.5. Environmental Parameters in Kendari Bay

Environmental parameters are important parameters in the form of physical, chemical and biological parameters that affect the condition of an ecosystem. The parameters measured in the sediment at the observation station are presented in Table 2.

Table 2. Average Values of Physical, Chemical and Biological Variables in Kendari Bay Waters [21]

| No | Parameter               | Sediment Water | Quality Standards * |
|----|-------------------------|----------------|---------------------|
|    |                         | Station I      | Station II          | Port Marine biota |
| 1  | Temperature (°C)        | 29.8           | 32                  | Natural           |
| 2  | Texture                 | Sandy          | Sandy               | -                  |
| 3  | Current Strength (m/sec)| -              | 0.014               | 0.01               |
| 4  | Salinity (%o)           | -              | 19.4                | 20.03              | 33-34 %o |
| 5  | pH (degree of acidity)  | 7.2            | 7.2                 | 7.26               | 7-8.5  |
| 6  | Dissolved Oxygen (DO)   | -              | 0.087               | 5.2                | > 5    |
| 7  | Ammonia (NH₃) (mg/l)    | -              | 10.8                | 0.528              | < 0.3  |
| 8  | BOD (mg/l)              | -              | 0.004               | 35.1               | < 20   |
| 9  | Phosphate (PO₄³⁻) (mg/l)| -              | 0.006               | 0.008              | < 0.015|
| 10 | Nitrate (NO₃⁻) (mg/l)   | -              | 0.001               | 0.012              | < 0.008|
| 11 | Phenol Compounds        | -              | 0.682               | 0.001              | < 0.002|
|    | (C₆H₅OH)(mg/l)          | -              | -                   | -                  | < 0.002|
| 12 | Detergent (mg/l)        | -              | 1.862               | 0.828              | < 1    |
| 13 | Fat danoil(mg/l)        | -              | 4.2x 10³            | 1.862              | < 1    |
| 14 | Coliform (Total)        | -              | 6.7                 | 3.6x10³            | 1000   |

Note: * Quality standards are based on the Decree of the Minister of Environment No.51 of 2004
From the results of measurement of environmental parameters in Table 1, it can be seen that temperature, sediment texture, current strength, salinity, pH, DO and Phosphate (PO$_4^{3-}$) are still considered safe because they do not exceed the quality standard criteria that have been determined based on the Decree of the State Minister for the Environment No. 51 of 2004. The parameters of NH$_3$, BOD, Phosphate (PO$_4^{3-}$), Nitrate (NO$_3^-$), Phenol Compounds (C$_6$H$_5$OH), detergents and fatty oils appear to exceed specified quality standards. Ammonia (NH$_3$) parameter at Station II reaches 0.528 mg/l while the quality standard is 0.3 mg/l. This happens because Station II has a low oxygen level so that NH$_3$ cannot be oxidized to nitrate so that the ammonia level increases. High ammonia levels are one indicator of water polluted by waste and will be toxic to organisms [34].

The observation of BOD (Biochemical Oxygen Demand) at Station II was 35.1 mg/l, meaning that it exceeded the quality standard of 20 mg/l. This happens because Station II has a location adjacent to several restaurants and traditional markets that do not have waste processing, especially organic waste such as good food scraps. The higher the organic waste in the waters, the higher the BOD in that water [35].

Furthermore, the nitrate content of 0.012 mg/l at Station II also exceeds the quality standard (<0.008 mg/l). The high nitrate is caused by the high organic material input from land activities which can be in the form of land erosion, the input of household waste, agricultural waste in the form of residual fertilization and others carried into sea waters [24]. The location of Station II, which is a port area, is under construction to enable high land erosion at that location. The impact caused by the excessive amount of nitrate in water is that it can cause eutrophication (enrichment) of the waters and subsequently trigger the growth of algae and aquatic plants rapidly (blooming) [36].

At Station I, the content of the phenol compound (C$_6$H$_5$OH) was 0.682 mg/l and the oil and fat content of 1.862 mg/l exceeded the quality standard. High levels of oil and fat are influenced by several factors, namely the presence of oil spills on shipping and the currents that carry it towards the coast [37]. The number of fishing vessels in the observation location has increased the oil and fat in this location. High oil and fat in water can endanger marine biota by damaging fish gills and being toxic to another biota [38].

3.6. Impact of Plastic Trash for Kendari Bay Maritime Tourism Area

One of the causes of waste generated every day from tourism activities is, directly and indirectly, carried out between tourists and tourism actors. The results of a United Nations Environment Program (UNEP) study which states that tourists produce an average of six times as much waste when they are on vacation [21]. Increasing the number of tourist visits to a tourist destination in line with the increase in the volume of waste. Improper waste management will disrupt tourist comfort in tourist areas [20]. In the Kendari Bay tourist destination, when garbage is not managed properly, it will result in a decrease in tourist visits both local and foreign to the place. This is according to the data of the Kendari City Tourism and Culture Office which states in the last 5 years there has been a decrease in tourist visits by 56%.

Currently, there are no policies issued by the government regarding the Plastic Waste Management Policy and Efforts to Support Tourism. The policy issued by the government is KLHK Circular No. S.1230/PSLB3-PS/2016 concerning the Price and Mechanism of the Application of Paid Plastic Bags to reduce plastic waste. This policy has been tested but is considered imperfect so the government has re-issued Circular No. 8/PSLB 3/PS.PLB.0/5/2016 concerning Reducing Plastic Waste through the Application of Disposable Plastic Shopping Bags Not Free. These two rules confuse the local government and business actors [39]. Such a policy on reducing plastic waste is not yet effective, because not all regions in the tourist destinations implement it. Also, plastic bags are ranked 9th out of 10 types of trash that dominate the world's coastline. Based on the International Coastal Cleanup Report, ten types of trash that dominate the world's coast are cigarette butts (1,030,640), food wrappers (314,649), plastic bottle caps (276,483), plastic drink bottles (205,687), beverage cans (127,764), straws and plastic stirrers (125,973), glass drink bottles (105,929), metal bottle caps (99,740), plastic shopping bags (85,079), and other plastic packaging (77,014) [40].
3.7. Mitigation of Microplastic Pollution in Kendari Bay
Microplastic is a big threat to the whole ecosystem by entering the food chain through aquatic organisms [41]. Given the high consumption patterns of sea products by the population in Kendari City and the potential for marine tourism which are also threatened, it is necessary to address this problem immediately to prevent and reduce worse risks in the future. There are at least five ways that can be done as an effort to mitigate the occurrence of pollution or accumulation of plastic waste in Kendari Bay, namely:

- Change habits: 6 R (Reduce, Reuse, Recycle, Repair, Refuse, Rethink)
- Separating waste from the beginning.
- Encouraging the role of government through education and regulation.
- Research and technology support. Other alternative materials are needed that can replace the use of plastic but with environmentally friendly properties such as the development of bioplastic.
- Clean beach action. This action is mostly done in tourism areas such as Bali, Pangandaran, Belitung, and others. In addition to having a direct impact on beautifying the beach, and increasing the comfort of the local community and visitors, this activity also supports the improvement of the coastal and marine environment.

4. Conclusion
From the results of the study it can be concluded:

- Microplastic types found in Kendari Bay are types of films, fragments, and fibers. The average abundance of microplastics at Station I (Mata Village, Kendari City) and Station II (Kendari Archipelago Harbor) at a depth of 0-5 cm ranged from 426.82-424.92 particles/kg. This value is higher than microplastic abundance at 5-10 cm depth, which is between 276.50 to 363.74 particles/kg. The average abundance of film-type microplastics and fragments at 0-5 cm depth was higher at Station I (203.75 particles/kg and 359.90 particles/kg). Microplastic categories of fragments/debris at a depth of 5-10 cm, found at Station II (409.06 particles/kg).
- Biota found in Station I sediments were blood shells (Anadara Sp.) With microplastic fragment type (1 particle) and fiber type (2 particles) with an average abundance of 0.12 particles/ind. Fiber-type microplastics are found in tofu shells (Maretrixmaretrix) of 5 particles with an average abundance of 0.5 particles/Ind. and the Violin Crab (Uca), as many as 1 particles with an average abundance of 0.04 particles/Ind.
- Water quality in the area of microplastic abundance found NH3, BOD, Phosphate (PO4\(^{3-}\)), Nitrate (NO\(_3^{-}\)), Phenol (C\(_6\)H\(_5\)OH), detergent and fat oil content have exceeded the quality standard.
- Mitigation efforts that can be done are 6R, separating the types of waste from the beginning, encouraging the role of government through education and regulation, research and technology support as well as bay clean action so as to beautify the bay and increase the comfort of the local community and visitors so that the function of Kendari Bay as a mainstay beach tourism area Southeast Sulawesi remains sustainable.

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