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EVALUATION OF WASTE MANAGEMENT FACILITIES THROUGH LAND-BASED MARINE LITTER DATA: CASE STUDY OF KENJERAN BEACH, SURABAYA

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Abstract

Marine litter surveys can be used to evaluate the effectiveness of policies to prevent litter pollution. This study aims to use land-based marine litter distribution data to evaluate the waste management facilities at Kenjeran Beach, Surabaya. The survey was carried out by systematically dividing 120 m length of the beach into five transects, with each transect having a length of 20 m. The litter was collected from the highest strandline, three times within three weeks. The collected litter was identified by count, weight, density, material, and object category. The waste management facilities at the beach, consisting of waste bins and collection services, were identified by direct observation. Both the litter and waste management facilities data were analyzed to evaluate the effectiveness of the facilities provided. The survey results showed that the northern side of the beach featured a high litter density. The major litter materials collected on each transect were plastic, wood, and cardboard, while the major litter objects were related to food, beverage, packaging, and others. The absence of waste bins on the northern side possibly caused the high land-based marine litter density. In terms of segregation, the waste bins must be segregated by litter material, prioritizing plastic waste, while the waste collection frequency must be increased. Thus, the waste management facilities at Kenjeran were less effective and not data driven. Based on the land-based marine litter survey data, improvements in waste bin segregation and distribution and waste collection frequency are needed.

Keywords: beach; facilities; marine litter; waste management.

1. Introduction

According to the World Health Organization, “solid waste” includes all nonliquid wastes generated by human activity and a range of solid waste materials resulting from disasters (Fernandez et al., 2018). The United Nations of Environment Programme (UNEP) refers to marine litter as any persistent, manufactured, or processed solid material discarded, disposed of, or abandoned in the marine and coastal environment (Chen, 2015). Approximately 6.4

million tonnes of marine litter enters the oceans every year (Deudero& Alomar, 2015). The pathways of litter introduction into the oceans include direct litter deposition, river run-off, and atmospheric deposition (Syakti, 2012). Around 80% of marine litter is derived from land (Gomiero et al., 2018).

Marine litter poses a threat to animals, economy and human (Schneider et al., 2015). The ingestion and entanglement of marine litter can kill marine animals (Farndon & John, 2013).Around28.5% of marine litter found entangled on corals in the benthic of Mediterranean Sea (Consoli et al., 2019). In 2015, Paraná state government paid the beach cleanup in the coast of Paraná, Brazil which created nearly 6.2% of the potential economic losses. The existence of marine litter also reduces the number of visitors led to lower local tourism income by 39,5% per year (Krelling, et al., 2017). Medical and sanitary wastes pose health hazard toward human and can cause injuries (UNEP, 2009). Plastic floating on the seas can be degraded by ultraviolet light, heat, microbes, and physical abrasion and then turn into smaller plastic fragments (microplastic). Microplastics lead to food safety problems, as they enter the food chains of marine animals and then into the human body through seafood consumption (Widianarko & Hantoro, 2018). Plastic fragments were found inside the guts of 28% edible fish which were sampled from markets in Makassar, Indonesia (Rochman et al., 2015).

The absence of science-based assessment and monitoring is one of the obstacles in combating marine litter. It is important to understand the types and sources of marine litter as well as the behavior that contribute marine litter pollution in order to effectively manage the impacts of marine litter. The survey of marine litter which presents on the beach is the initial method to measure the litter that enters the coastal area and marine environment (Cheshire et al., 2009). The waste management policy and regulation have been established in many countries as well as the marine litter survey. However, both policy and survey results were not often compared (Liu et al., 2013). Since most of the marine litter is sourced from land, so the policy in land must be integrated to reduce marine litter (Purba et al., 2019).

According to UNEP's Marine Litter Survey Guidelines on Cheshire et al. (2009), the basic beach selection criteria should include the following: the beach should have a minimum length of 100 m; the beach slope is relatively low or moderate; it should have clear access to the sea; it should be accessible to survey teams year-round; the beach is not routinely cleaned up; the survey activities must not pose the harm toward protected and endangered species. Under the same criteria, either sandy or pebble shoreline can be pointed out to be the survey site according to NOAA guidelines (Opfer et al., 2012).

The natural and anthropogenic debris that presents in the seas can be found stranded on the shore or the beach which creates a linear pile of debris (drift line) behind the uppermost limit of the wave swash. The high tide can be indicated by the position of drift lines (Pilkey, 2014). Studies regarding marine litter are needed to provide data on solid waste leakages from land to marine environment (World Bank, 2018). A study on marine litter sources conducted by Munari et al. (2016) on five beaches of the Adriatic coast showed that most of the litter was deposited by beach users and is thus categorized under land-based source. Meanwhile, in Biawak Island, Indonesia most of the marine litter found in the island was from fishing activities (Purba et al., 2017).

Solid waste management is systematic and comprehensive, and waste reduction and processing methods should involve sustainable activities (Pemerintah Republik Indonesia, 2008). According to UU No.18/2008, solid waste processing includes waste segregation, collection, transportation, treatment and landfill (Raharjo et al., 2017). According to SNI 19-2454-2002, waste storage is a method to temporarily contain the waste from its source, either by individual or communal programs (Arsyandi et al., 2019). Waste collection involves taking and moving the waste from its source to a container or a waste-processing site (Pemerintah Republik Indonesia, 2008).

The government of Surabaya along with volunteers carried out a beach cleanup in March 2019 and collected around 14 tonnes of garbage. The cleanup coverage was started from the west side of Suramadu Bridge and then straight to the coast of the Kenjeran Recreational Park (THP Kenjeran) (Ghinan, 2019). Moreover, the absence of adequate waste management facilities in the coastal residences of Kenjeran is becoming an issue in the waste management system of the area. It is one of the reasons communities in the Kenjeran coastal area dispose of their waste in the marine system (Mauludiyah et al., 2015).

Some studies regarding the general marine litter survey have been conducted, and a few of them discuss land-based marine litter distribution. One of the land-based marine litter studies, conducted by Portman and Brennan (2017), in the shoreline of Jisr, Israel, analyzed the dispersal of litter resulting from activities on the beach. The results showed that most of the litter was derived from beachgoers, and plastic was the dominant litter material found. Further study by Liu et al. (2013) which identify the land-based marine litter and national waste management policy on four beaches in Cijin Island Taiwan concluded that the reduce, reuse and recycle must be prosecuted to combat marine litter.Different from their study, the current study not only discusses land-based marine litter data but also uses the data to evaluate waste

management facilities, consisting of waste bins and collection services on Kenjeran Beach, to realize effective and data-driven improvements of waste management facilities.

2. Methods

The study area was located on Kenjeran Beach, or Cumpat Beach, Bulak, Surabaya (−7.22540, 112.78863). A transect survey was conducted by dividing 120 m length of the beach into five transects; each transect had a length of 20 m, and each gap was 5 m. The transects were adopted to give a clear land-based marine litter distribution along the beach. The litter collection was conducted above the highest strandline up to the beach posterior, which contained the litter generated by activities on the beach (land-based source). The highest strandline was indicated by the existence of the highest pile of litter stranded onshore, which was linear to the water edge, while the beach posterior was indicated by the existence of vegetation and a road.

To obtain high-quality data, the survey was conducted three times within three weeks: on August 26, September 1, and September 8, 2019. Each transect was cleaned by volunteers until no litter remained. The cleanup activity occurred on August 19, 2019, so the surveys started one week after litter accumulation. The litter collected from each transect was then quantified based on counts (item), weight (gram), density (item/m^2), percentage of material and object category, according to the UNEP Marine Litter Survey.

The waste management facilities identified in this study consisted of waste bins (shape, feature, volume, distribution, and segregation) and collection services (shape and volume of the waste cart, time, and frequency). In addition, the organizations that run waste management in the site were also considered. The waste management facilities were identified by direct observation, while the organization data were obtained by interviewing the officers. The identification results were then compared to the standard on the related regulations and references.

Figure 1. Study location on Kenjeran Beach, Surabaya

Source: Google Maps (n.d.)

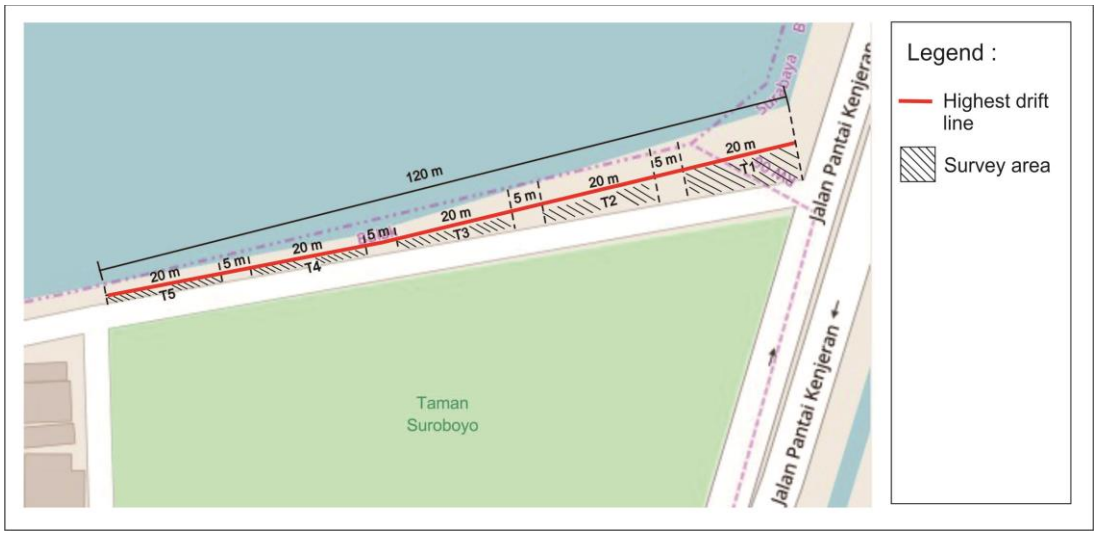

Figure 2. Transects and sampling site layout on the beach

Source: OpenStreetMap (n.d.)

The obtained data on land-based marine litter distribution were utilized to understand the effectiveness of the waste management facilities provided at Kenjeran Beach, Surabaya. Moreover, they also can serve as the baseline data to improve waste management facilities, create effective and data-driven waste management policies, and prevent the litter pollution resulting from human activities at the beach and marine environment.

3. Results and Discussions

3.1. Land-based Marine Litter

3.1.1.Counts, Weight, and Density

The position of the highest strandline was the same throughout the three surveys; therefore, the surface area of each transect remained the same during the surveys. The land-based marine litter distribution on Kenjeran Beach by counts, weight, and density can be seen in Table 1.

Table 1. Land-based marine litter distribution on Kenjeran Beach, Surabaya, by counts, weight, and density

Transect	Surface Area (m^2)	Average Land-Based Marine Litter		
		Counts (item)	Weight (g)	Density (item/m^2)
1	7,2	224	1629	11
2	6	583	2397	19
3	5	435	2212	22
4	3	558	2618	44
5	2,5	266	1691	34

Source: Authors (2020)

According to World Bank (2018), one of the causes of the dispersal of marine litter is the human activities occurring at the location. A study by Simeonova et al., (2017) showed that the increase of marine litter in Bulgarian Black Sea coast occurred in the summer when there were intense recreational activities.Increasing tourism or visitors in particular place leads to the greater solid waste generation (Singer et al., 2019).Based on the results, the high counts and weight distribution on transects 2, 3, and 4 were might be due to human activity. The beach entrance, which is located in transect 3, at the middle of the beach, and the existence of trees along transects 1 to 4 caused the occurrence of many human activities in those regions. The litter counts agreed with the weight. However, the high-density distribution on transects 4 and 5 (northern side) are affected by a smaller surface area with the high litter counts.

3.1.2.Material Category

The visual data of land-based marine litter distribution by material categories can be seen in Figure 3.

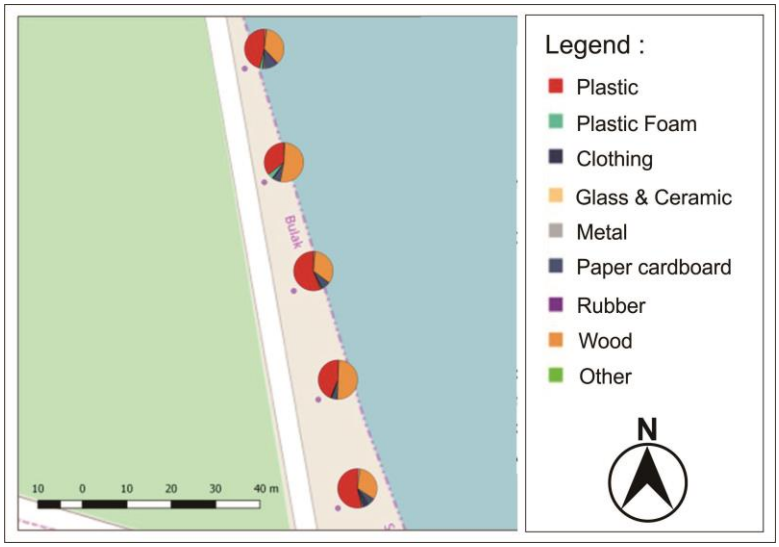

Figure 3. Land-based marine litter distribution by materials

Source: OpenStreetMap (n.d.)

Based on Figure 3, the majority of land-based marine litter materials on each transect were plastic, with an average of 120–255 items (35.5%–56%); wood, an average of 71–292 items (31.8%–52,4%); and cardboard paper, an average of 13–34 items (5.8%–10.9%). According to Raubenheimer & McIlgorm(2018), plastic is the major marine litter, making around 60%–90% of land-based marine litter. The International Coastal Clean Up 2017 Report by Ocean Conservancy stated that the top ten marine litter collected were dominated by plastic such as cigarette butts, food wrappers, plastic bottles, lids, plastic bags, etc. (Loizidou, Loizides, & Orthodoxou, 2018). Meanwhile, Indonesia is the country with the second-highest contribution of plastic litter into the ocean (Jambeck et al., 2015). Plastic is widely used due to its physical characteristic and low production cost (Andrades et al., 2018).

In line with the increase of urbanization and economic growth, the plastic production and consumption are also significantly increasing as well. The plastic waste recovery is relatively slow due to its low recycling value and there is still lack of adequate technology which can mitigate the plastic waste effectively. Those conditions create an environmental problem where most of the plastic waste is dumped into the ocean, disposed in the landfills and incinerated in the incinerator (Chow et al., 2017). Besides its wider use, the plastic pollution is emerged due to improper waste management (Lestari & Trihadiningrum, 2019).

Kenjeran Beach is a recreational resort visited by people who during their visits use multiple plastic-composed products, such as food wrappers, plastic bags, cigarette butts, straws, spoons, and forks. The major wood material found consisted of food sticks and processed lumber, while the cardboard was in the form of food wrappers and tissues. Similar

studies in Indonesia have also found plastic waste to be the dominant waste according to the marine litter survey results Djaguna et al. (2019) stated that plastic was the common litter found on Tongkaina and Talawan Bajo Beaches, accounting for 58.42% of litter collected. Plastic litter also dominated in the coastal area of Kuala Pesisir, Nagan Raya, according to Nasution (2019). Around 382 plastic items were found out of the 570 items collected on Penuaga Permai Beach, and 123 plastic items out of 192 items on Seunagan Beach.

3.1.3.Object Category

Figure 4 presents the visual data of land-based marine litter distribution by objects.

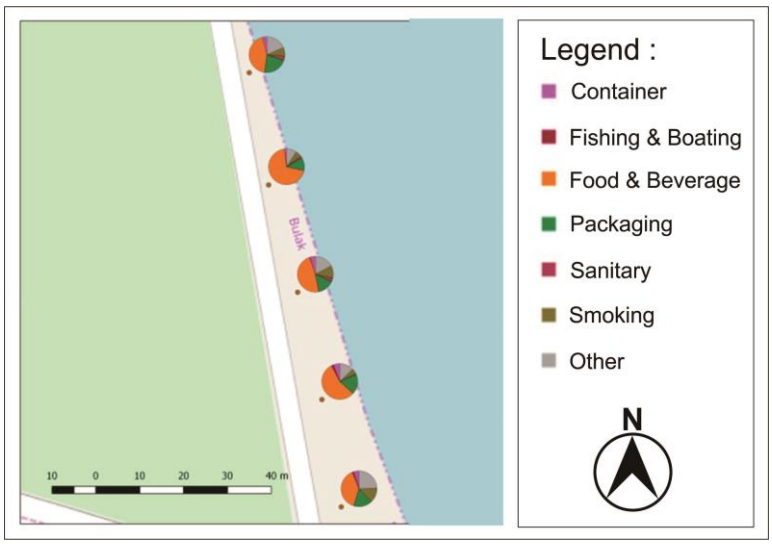

Figure 4. Land-based marine litter distribution by objects

Source: OpenStreetMap (n.d.)

Based on Figure 4, the majority of land-based marine litter objects on each transect were related to food beverage, with an average of 88–166 items (39.1%–69.7%); packaging, an average of 38–106 items (11.8%–21.9%), and others, an average of 49–55 items (9.2%–24.9%). According to UNEP (2009), the tourism sector represents one of the marine litter sources. Packaging- and food-and-beverage-related marine litter objects were included in the top 10 litter collected during the International Coastal Cleanup 2017 (Ocean Conservancy, 2018). Meanwhile, the use of plastic bags is rising. On average, Indonesian people use around 700 plastic bags/people/year. The Indonesian Ministry of Environment and Forestry stated that around 10.95 million plastic bags waste are generated every year (Ekawati, 2016).

Kenjeran Beach is a recreational park in which most people (tourists) engage in food-and-beverage-related activities, as food vendors are located at the beach posterior. The packaging-

related litter object was dominated by plastic bags, whose use is very common. In line with a study by Purba et al., (2018),food wrappers and plastic bags litter was mostly found in Savu Marine National Park Indonesia. The study on the influence of tourism in the southern Great Barrier Reef by surveying the litter from the drift line up to the foredune conducted by Wilson and Verlis (2017) revealed that visitors in the form of resort goers, campers, recreational boaters, and anglerswere identified to be the major contributor to marine litter on the southern Great Barrier Reef.

Moreover, the most dominant component of marine debris found from all research locations in the West Aceh coastal area was mostly related to food beverages such as plastic cup (26.10%), straws (17.36%), and food wrappers (14.95%) (Kusumawati et al. 2018). The "throwaway culture" might be a major cause of the dispersal of food-and-beverage-related waste (which were mostly plastic on Kenjeran Beach) based on the comparison of the study by Syakti et al. (2017). The authors studied the dispersal of plastic litter on the coast of Cilacap and concluded that most of the plastic litter, particularly packaging, originated from recreational parks and rivers.

3.2. Waste Management Facilities

3.2.1.Waste Bin

The waste containment in Kenjeran Surabaya is a communal system. According to Damanhuri and Padmi (2010), communal waste containment is adopted in low-income residential areas, city parks, roads, and markets. The waste bins condition on Kenjeran Beach as determined from the waste containment identification is presented in Table 2.

Table 2. Waste containment (Waste Bins) Identification Results on Kenjeran Beach, Surabaya

Criteria	Standards	Identification Results
Shape	Bucket-shaped	Cylindrical bucket-shaped
Features	Persistent, light and waterproof	Light, resistant, waterproof
Volume	30 L–40 L	±30 L
Distribution	Minimum distance of 100 m between bins	Total of 11 bins distributed on transects 1, 2, and 3, with the distance between bins <100 m

Criteria	Standards	Identification Results
Segregation	Segregated (organic, inorganic, hazards)	No segregation

Source: Badan Standarisasi Nasional (2002)

The waste containment facility provided at Kenjeran Beach, Surabaya, met the standard of SNI 19-2454-2002 according to Badan Standarisasi Nasional (2002) in shape, features, material, volume, and distribution criteria. Although the distance of each waste bins was less than 100 m, the distribution was not considered even, due to the absence of waste bins on transects 4 and 5.

3.2.2.Waste Collection Service

The waste collection on Kenjeran Beach was an indirect system. This means that the wastes are not directly transported to the landfill but placed in a transport site after the collection process. The identification results of the waste collection service at Kenjeran Beach are presented in Table 3.

Table 3. Waste Collection Service Identification Results on Kenjeran Beach, Surabaya

Criteria	Standards	Identification Results
Transport site	Provided	Provided at the side of beach
Tool	Non-machine waste collection tool: wheeled-waste cart	Wheeled-cuboid cart with a volume of ± 650 L
Rotation	1–4 times	1 time
Frequency	1–3 times per day	1 time per day

Source: Badan Standarisasi Nasional (2002)

The waste collection facility provided at Kenjeran Beach met the standard of SNI 19-2454-2002 according to Badan Standarisasi Nasional (2002) in terms of the transport site, waste collection tool, trip rotation, and frequency criteria. However, during the observation of waste management facilities, some waste bins were overloaded after the waste collection.

3.2.3.Waste Management Organization

The waste management at Kenjeran Beach is organized by the Agency of Cleanliness and Green Space of Surabaya or Dinas Kebersihan dan Ruang Terbuka Hijau (DKRTH) Kota

Surabaya. The beach region belonged to the work coverage of the North 1 Division of DKRTH Kota Surabaya, supervised by the head of division and the head of cleanliness department. The technical officers who handled the waste management (arranging the waste bins and collecting the waste) on Kenjeran Beach consist of one field coordinator and two waste officers.

All the management officers had a good understanding of municipal waste management, as their educational backgrounds were related to their work scopes. Moreover, the technical officers had good practical skills in handling the waste as they have been trained before given the jobs. However, the waste management officers had not been exposed to a workshop or training on marine litter or coastal waste management since they began working in DKRTH Kota Surabaya.

According to Damanhuri and Padmi (2010), the waste management process can be organized by governmental organizations or government-appointed private organizations. The waste management at Kenjeran Beach is run by a governmental organization with a good human resource structure and scope of work, but the workforce lacks the knowledge and practical skills in managing marine litter, as they have not been exposed to marine litter or coastal waste management training. Knowledge of marine litter is pivotal to prevent the litter flow and mitigate its impacts on the marine environment and human health.

3.3. Evaluation of Waste Management Facilities

3.3.1.Waste Bin

Figure 5 displays the visual data of land-based marine litter density and the waste bins distribution on Kenjeran Beach.

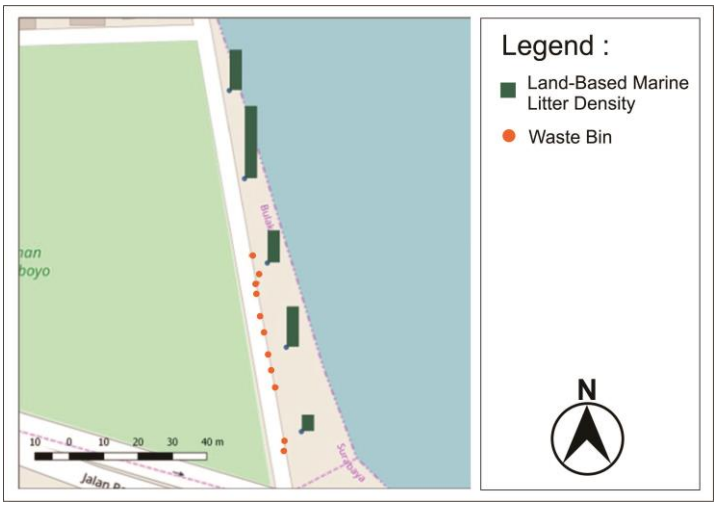

Figure 5. Land-Based Marine Litter Density and Waste Bins Distribution.

Source: OpenStreetMap (n, d)

Based on Figure 5, the land-based marine litter density was relatively low on transects 1, 2, and 3, where the waste bins were distributed, while transects 4 and 5, which had no waste bins, had high litter densities. Inadequate waste storage leads to litter production, which causes environmental problems (Afifaldi, 2019). One of the causes of littering is the lack of accessible waste facilities provided for the community in public places (Wibisono, 2014). The absence of waste bins on transects 4 and 5 contributed to the high land-based marine litter density, as the people could not properly dispose of their waste; instead, they left their waste on the beach environment. Moreover, some waste bins reached the maximum volume capacity during the observation; this may also affect the litter density, as people cannot discard their waste into the overloaded waste bins. According to Astuti (2019), the waste bins must be placed on an accessible open area. The even distribution of waste bins in public places as well as recreational sites is very important to prevent littering, as people can reach the waste bins and discard their waste properly; therefore, the waste bins must be distributed equally in every area.

According to the results of land-based marine litter material distribution, various types of litter materials were present on the beach, with the highest being plastic, wood, and cardboard on every transect. However, the waste bins provided at Kenjeran Beach were not segregated based on material type. This may affect the recycling process at TPA Benowo, as the waste needs to be sorted before the recycling process. In order to manage the plastic problem, there must be a role in individuals and authorities (Penca, 2018). The waste bins ought to ease the recycling process; therefore, it should be segregated according to material type (Damanhuri & Padmi, 2010). Darwati, S. (2019) recommended that waste management in beach regions must begin the segregation from the source and transport site by using segregated waste containment (bins), collection, and transport. The waste bins segregation at Kenjeran Beach did not meet the standard because the bins were not segregated. Such segregation is important in order to effectively manage the waste in further processes.

Based on the data and analysis, waste bins need to be placed on the northern side of the beach to reduce the land-based marine litter density. Moreover, the volume of the existing waste bins can also be increased to avoid overloading. The waste bins can be segregated by organic and inorganic materials to ease the recycling process at TPA Benowo, giving plastic waste more priority.

3.3.2.Waste Collection Service

Although waste bins were provided at transects 1, 2, and 3, which had a low marine litter density, some waste bins reached the volume capacity, and thus, the waste must be immediately collected or emptied to avoid littering. The collection frequency being only once per day, at 06.00 a.m., caused the overloaded waste bins, as the wastes were higher than the waste bins capacity and the bins were only emptied once per day.One of the considerations in the waste collection schedule is the accumulation of the waste (Ramdhani et al., 2018). The waste collection frequency should depend on the waste amount (Beatriex et al., 2017). Based on the data and analysis, the waste collection frequency must be increased to more than once per day, at least to twice per day, to avoid the overloading of waste bins, which can lead to littering.

3.3.3.Waste Management Organization

As being the database for policy makers to prevent and control the marine litter problems, both quantitative and qualitative knowledge of the marine litter are important to understand (UNEP, 2009). The waste management officers that run the waste management service at Kenjeran Beach have not been exposed to marine litter or coastal waste management knowledge by practical training or workshop. Waste management officers having sound understanding of marine litter and coastal waste management is important to mitigate and prevent the land-based marine litter produced by human activities on the beach. The source and the dispersal of marine litter knowledge can be a basis of waste managers to address marine litter problem so they need to be clear out about the knowledge (Portman & Brennan, 2017). By understanding the marine litter as well as the survey, they can determine the actions to control the litter pollution, for example, by implementing policies to reduce the litter from a specific source in targeted communities.

The effective response in term of intervention to address marine litter can be determined by looking the source of marine litter types. Cleanup efforts can be conducted to address sea-based marine litter while educational approach is the long-term solution to address land-based marine litter (Pasternak et al., 2017). The awareness raising combined with investment of waste management has been predicted to greatly reduce marine litter (Willis et al., 2018).The approaches to combat marine litter are not only relying on waste management but also the intervention of the beach users' behaviour (Rangel-Buitrago et al.,2019).Based on the survey results, the land-based marine litter was mostly related to food and beverage and packaging activities, which are produced by food vendors and beachgoers. The government as the waste

management organizer can impose policies to those prioritizes groups to not litter or limit the use of single-use food-and-beverage-related utensils and plastic bags and encourage the use of reusable options. The government can also raise marine litter awareness by educating the community around the beach or installing visual media on the beach.

4. Conclusion

A good waste management in land plays important role in combating land-based marine litter so its practice must be based on the waste generated in term of the dispersal, types and sources. Kenjeran beach is a recreational beach which is heavily polluted by litter with most of the litter was plastic, wood and paper-cardboard. Most of the litter was related to food and beverage, packaging and other activities. According to the survey data of land-based marine litter, the waste management facilities provided at Kenjeran Beach is less effective and not data-driven to prevent marine litter in the target area. Based on the survey data, improvements in waste bin distribution and segregation and waste collection frequency are needed in order to effectively manage the waste resulting from the activities on the beach, that is, land-based waste.

The waste management improvements include waste bins distribution on the area with higher litter density which was on the northern side, waste bins segregation prioritized in plastic waste and the collection service period increase are needed to prosecute in order to effectively manage the waste resulted by activities on the beach or land-based. Moreover, the authorities that run the waste management are expected to conduct the educational approach to raise the awareness and change the beach goers' and food vendors' behaviour in order to prevent the marine litter pollution.

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Author Contribution

Rizal Bahri conceived of the presented idea and developed the theory and performed the computations. Darjati verified the analytical methods. Rachmaniyah and Darjati encouraged Rizal Bahri to investigate the waste management facilities and organizer as well as supervised the findings of this work. All authors discussed the results and contributed to the final manuscript.

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