Article

Coastal Community Perspective, Waste Density, and Spatial Area toward Sustainable Waste Management (Case Study: Ambon Bay, Indonesia)

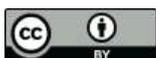**Herdis Herdiansyah** [1,*] **, Halvina Grasela Saiya** [1] **, Kunny Izza Indah Afkarina** [1] **and Tito Latif Indra** [2]

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Abstract: The coastal area has experienced significant changes of waste problems over the past few years. To resolve the waste problems in coastal areas, an understanding of community perception is needed to support government efforts. Therefore, this study aims to review people's perspectives on the dynamics of waste in the coastal areas. Community perception data were compiled through semi-structured interviews with the surrounding communities in coastal areas. ArcGIS and load count analysis were used to analyze the waste density. Waste was collected from the coastal area in Ambon Bay and analyzed using waste density calculation and spatial analysis. The results show that the total waste density obtained at the coastal area of Ambon Bay is 0.249 kg/m^2, of which 0.078 kg/m^2 is the density of plastic waste, and 0.171 kg/m^2 is the density of non-plastic waste. Communities in coastal areas have made efforts to deal with waste problems, but the efforts made are still ineffective in overcoming these problems. That problem happens because there is a lack of knowledge of the community and lack of infrastructure in coastal areas. The research results have the potential for replication in other coastal areas and are used as the basis of decision making for waste management improvement.

Keywords: coastal community; community perspective; marine waste; spatial analysis; waste density

1. Introduction

Waste problem in the sea is a very complex problem and solution. Waste in the sea can be from direct marine disposal waste from fishing industries, waste from fishermen, or waste from travelers [1–3]. The sea also can only collect and transfer waste through ocean currents from one beach location to another beach location. Some countries with long coastlines have a high priority for their coastal waste problems, and community participation developed as a result [4]. Those problems resulted in issuing in various regulations regarding the prohibition of using disposable plastic packaging, waste repurchase programs, and making rules for recycling waste to strengthen the prevention and mitigation of coastal pollution [4]. This method should be used because if people are not mobilized to see positive opportunities from waste management activities, then the impact can be severe. As a result, this article focuses on waste management activities in coastal areas. Those activities are important because waste can move to the sea and become marine waste.

Marine waste is generally defined as material wasted, discarded, or left in the marine and coastal environment as a result of human and natural activities that do not have an economic value yet [5,6]. Sea trash is found on the coast, which is closest to the center of human activity. The marine waste found mostly includes plastic waste (plastic packaging, plastic bags, straws, bottle caps, ropes, diapers, foam), fishing equipment (nets,

hooks, fishing lines), metals (canned cans, paints, bottle caps), cigarette butts and cigarette lighters, glass cups (light bulbs, glass bottles), processed wood, rubber, cloth, and electronic waste [7–9]. Most of the marine trash entering the sea comes from land waste carried by runoff rivers, inadequate sewerage and waste management, floods, storms, beach visitors, industrial activities, construction, and illegal waste disposal [10].

In 2010, researchers estimated that 11% of the 2.5 billion metric tons of waste produced by 6.4 billion people from the coastal areas of 192 countries is plastic waste [9]. East Asia is the region with the highest growth of waste products in the world. Of the 192 coastal countries, there are five countries from East Asia that are responsible for more than 50% of the total plastic waste in the oceans, namely China, Indonesia, Vietnam, the Philippines, and Thailand [11]. The entire marine waste heap is closely related to population size and waste production that is not well managed [12]. The accumulation of coastal waste pollution is also influenced by the geographical conditions of a country. The accumulation of pollution is dominated by countries with a long coastline [7]. The waste is made up of passive particles carried by wind and water currents until it accumulates in the coastal area [13]. It is predicted that 1.7–10% of plastics waste that is classified as waste that is mismanaged in a coastal area will enter into the marine ecosystem [9,14].

Marine waste is one of the global pollution problems that, if it is not handled correctly, will continue to get worse every year. Marine waste from various sources can cause negative impacts on the ecosystem, health, social, and economic environment of the community [15]. In Indonesia, the content of debris from human activities was found in 28% of a sample of consumption fish purchased at the market. This pollution was also found in 25% of fish sampled originating from the market in the United States. The difference is that all the debris found in Indonesia are plastic, while the sample from the United States is organic litter fibers. The difference in types reflects the different waste treatment strategies of the two countries [16]. In short, there are different waste management strategies between United Stated as a high-income country and Indonesia as a developing country. Even though the types of waste are different, the biological, ecological, and negative aesthetic impacts arising from marine trash pollution have the potential to affect various economic sectors, including fisheries, tourism, shipping, and public health so that the impact of marine trash pollution results in economic imbalances in the global marine ecosystem exceeding 13 billion dollars per year [14].

Pollution that occurs on the coast can cause damage to the marine ecosystem [4], which includes plastic debris and heavy metal. Plastic can be degraded into micro-sized debris that is harmful to marine organisms and poses risks to bodily physiological functions such as disturbance to growth, organ dysfunction, and impaired reproduction rate of marine biota [17–19] due to the microplastic substances as well as accumulation of harmful hydrophobic substances from the surrounding water before they can be swallowed by marine animals [10,14,20]. Likewise, the increase in heavy metals in sea waters has a severe impact on ecosystems because it has a high level of toxicity, is persistent, and can cause bioaccumulation and biomagnification in the food chain [21,22]. Pollution also harms the metabolism of marine biotas, causing stress, organ damage, abnormalities in blood circulation, tumors, and even death [23].

However, the impact of both types of pollution can be seen in the marine ecosystem. There are at least 50% different species that become entangled or trapped in plastic debris, ingest the plastic debris, or incur injuries due to plastic debris [10,24,25], which can make the population of that species decrease [25]. Likewise, the heavy metal concentrations such as As, Cd, Cr, Cu, Hg, Ni, Pb, and Zn have been accumulating in marine biotas such as mollusks, crustaceans, and fish [26]. There is an increase in the toxicity of organic compounds that accumulate in first-level consumers in the food chain. Organic compounds that are degraded and metabolically activated in first-degree consumers can be more dangerous than parent compounds from ingested food. This toxicity can affect all levels of the food chain [20].

Waste accumulated along coastlines, estuaries, and oceans is a significant global problem [6,7]. Due to its high buoyancy and durability in marine waters, marine waste can travel quite far away due to ocean currents, winds, and ocean storms, especially plastic waste. Therefore, due to the impact on the area along the coastline, marine waste can also have a long-term impact on the high seas [27]. If this condition is not immediately addressed, it is estimated that the amount of waste entering the waters will continue to increase by up to 45% by 2025 [9].

Barriers to overcome the problem of marine waste are caused by unsustainable production and consumption patterns. This pattern is indicated by the fact that there are still many product designs and marketing that do not consider environmental aspects, such as effective and efficient recycling facilities of product packaging waste, inadequate waste management, and disposal infrastructure [27]. There is also a lack of effective strategies from regional to global governance institutions for implementing international programs, regulations, and standards. The discussion on the issue of marine waste has been directly or indirectly alluded to in various international agreements [28]. Several countries have designed national policies to address the problem of marine waste through waste management laws such as the provision of marine sewage treatment facilities and beach cleaning, fisherman assistance, supported by information, education, and community awareness programs carried out with the principle of sustainability [15,28]. However, the improvement of the marine waste management infrastructure also requires a lot of time and cost. Therefore, the main focus of handling marine waste in developing countries such as Indonesia can shift into increasing efforts to collect and manage solid waste [12].

Interdisciplinary analysis is essential to resolve the problem of waste [29,30]. One of the requirements that should be addressed is community participation. Many studies in the literature have been claiming that community participation is important to solve the coast waste problem [31–33]. Based on that framework of community participation, we argue that community participation can be developing if the waste management with regard to the waste facilities and community perspective is evaluated at the ground level. This evaluation is needed to improve the decision-making process related to waste management activities. That statement is in line with Vince and Stoett [30]. They emphasized that effective prevention in the long-term process of waste management must begin at the ground level. As a result, this article is about the evaluation of the condition and the community perception of waste management especially waste disposal and collection. As a representative of the developing country, Indonesia was used as a study area, and the specific case study is Ambon Bay City.

This study is important because Indonesia as a developing country, which has a center of government, education, trade, and services, has direct implications for increasing and varied wastes. One of the activities that has implications for the waste problem is waste transportation services. Inadequate transportation infrastructure and service result in an insufficient capacity to transport waste to the landfills. That also has an impact on the limited ability to transport waste in coastal areas [34]. Some of coastal area in Indonesia are considerably damaged [35,36]. This damage is proven by the amount of waste in the waters. People who lived in rivers dump trash directly into rivers that flow into the sea. The location of settlements on the edge of the river makes it easy for people to do these activities, and it becomes a harmful habit. People often consider the coast and the sea to be the last dump or large trash can that will have little effect on the coastal and marine resources [34]. Therefore, this paper aims to review people's perspectives on the dynamics of waste in the coastal areas, with the case studies in Ambon Bay.

2. Materials and Methods

2.1. Case Study Area

The island of Ambon, in which the city of Ambon located, is part of the Maluku islands, which are arc volcanic islands, so in general, the city of Ambon has a region that mostly large consists of hilly and sloping steep areas [37].

The state topography of Ambon City, in general, can be grouped as follows [38,39]:

(1) Within 300 m of the coastline, the topography is relatively flat with a height of 0–100 m and slope of 0–10%.
(2) Within 100 m toward the mainland, the topography is sloping up with a height of 0–100 m and slope of 10–20%.
(3) In the hills area, the topography is undulating, rocky, and steep with a height of 0–100 m and slope of 20–30%.
(4) In the mountains area, the topography is steep with a height of >100 m and slope of >30%.

The Ambon City climate is strongly influenced by the ocean and takes place simultaneously with the seasonal climate, namely the west or north season and the east or southeast season [40]. Substitution of the season is always punctuated by the transition season that is a transition from the second season of the west season, which generally lasts from December until March, and April is a period of transition to the east season, while the east season lasts from the month of October, where the month of November is the period of transition to the west season [40]. The waste sampling for this research was carried out during the east monsoon in 2019.

The main reason this area was chosen, besides the Maluku province being an island province that has a high complexity in the problem of coastal waste, was the movement of seawater flow patterns that are very varied and difficult to predict, which become a challenge for coastal cities in Maluku, especially in Ambon City [37,41]. For this reason, this study will use the term 'burden of waste received by the coast'. This is done to avoid the justification that waste only originates from trash sent by the ocean currents, or only from community activities. Since the source still needs a more in-depth study, this scope does not identify the source but rather the burden of waste received, which will then be analyzed to assess its density.

2.2. Data Collection

The method used in this study is a combination of qualitative and quantitative methods [42,43]. The qualitative method is used for the community perception data; the data collection techniques are interviews with the surrounding communities in coastal locations. The quantitative method is used to calculate the density of waste collected by the coast where the presentation of the data is done spatially. The sampling of waste is carried out in a day from 8:00 a.m. to 12:00 p.m. (Eastern Indonesia time), with cloudy weather conditions in the morning and sunny in the afternoon. Sampling is done by taking every type of garbage found along the coast.

The interview techniques used to collect data on community perception are semi-structured interviews, because the type of information to be obtained is already known with certainty: people's perceptions of the problem of coastal rubbish in Ambon Bay, especially in the coastal areas near their homes, namely in Rumah Tiga Village, Ambon District, Ambon City. However, besides that, it also does not rule out the possibility of various opinions or information related to coastal waste issues to be conveyed by the community, which is in line and can be studied in the results of the study [44]. In carrying out this interview technique, it is essential to note that the informants chosen are those who know not only the surface issues of this problem but the essential details so that they can provide in-depth information with consistent answers, even though the same question was repeatedly confirmed [44]. Another stage that is also carried out in exploring public perception information is by setting some basic questions that become the initial benchmark in the interview. Then, the interview material can continue to evolve by the reciprocity of the answers given by informant [45].

Waste data collection techniques were measured based on SNI 19-3964-1994 standards on the method of taking and measuring sample generation and the composition of urban waste. Load count analysis was used to calculate waste generation. An example of a generation is waste taken from a selected pick up location to measure volume, composition,

and weight. Meanwhile, the composition of waste is physical components of waste such as food scraps, paper, wood, plastic, metal, glass, rubber, and others. In this study, examples of the waste generation that will be used are the weight of the waste and the composition of the waste, where the composition of the waste is divided into plastic waste and non-plastic waste (wood, glass, rubber, metal).

2.3. Data Analysis

Data analysis in this study was divided into two, namely data analysis for public perception and analysis of waste load density received. These two analyses were combined in order to be able to process two different types of data in this study: namely, qualitative and quantitative. Descriptive analysis flow used the method of Miles and Huberman [46], i.e., after the data are collected, the data are reduced first to be selected and focused on the core problem, and to abstract field notes.

The focus of community perception is on several important points, namely:

- How they felt about the condition a few years ago compared to the present situation when the beach has received a lot of daily waste.
- What efforts have been made or are being pursued or planned to overcome the waste problem in their area.
- What practical handling efforts have been carried out so far.
- What other solutions they would like to bring up regarding this waste problem.
- Their perception about the sources of the problems that affected the waste burden in Ambon Bay.
- As coastal communities and fishers, how they feel and what they see regarding the increase in pollution in the gulf and coast.
- According to their perception, what is the most dominant waste composition (plastic, metal, rubber, and others).

We selected the respondents who have lived or settled in the area for a minimum of ten years. This decision was made in order to ensure that the answers given are answers derived from what they experienced, not those from temporary assumptions because they have not lived too long in the area. Certain respondents, such as community leaders and village heads, were prioritized in sampling.

Waste density analysis was performed using ArcGIS 10.5 ESRI license, which was begun by digitizing the coastal areas of Rumah Tiga Village, using a map base on GeoEye satellite imagery data; then, the results of plot coordinates were entered. Then, the area was calculated using geometry. This calculation is also done to confirm the results of the area calculation using GPS when collecting waste and weighing the waste in the field. Next, we entered the data regarding weight and type of waste on an attribute table in a shapefile worksheet. After that, the waste density calculation was done with the field calculator. Furthermore, after the results were obtained, the following data were classified and laid out to produce a map of waste density.

3. Results and Discussion

3.1. Physical Condition Changes of Ambon City Bay

The Ambon City Bay area experienced significant changes in the physical elements of coastal ecosystems over the past few years, due to several forms of development on other coastal locations during that period. At this chosen coastal location, there has been a change in elements in the form of periodic shoreline changes. This change is a result of development in the coastal area, which is carried out in other coastal areas so that the physics style of waves and ocean currents finally place more weight on the other coast, and most are on the coast at the location. Changes in the shoreline are more dynamic for the coastal location of Ambon City Bay (Figure 1), which can be seen through the results of the coastline digitization from several satellite images time-series for this location, namely, 2007, 2014, 2016, and 2018. Another reason for this is the pattern of ocean currents, which naturally makes this coastal area more vulnerable to shoreline changes especially at a

threshold location separating the Inner Ambon Bay area (TAD) and the Outer Ambon Bay area (TAL).
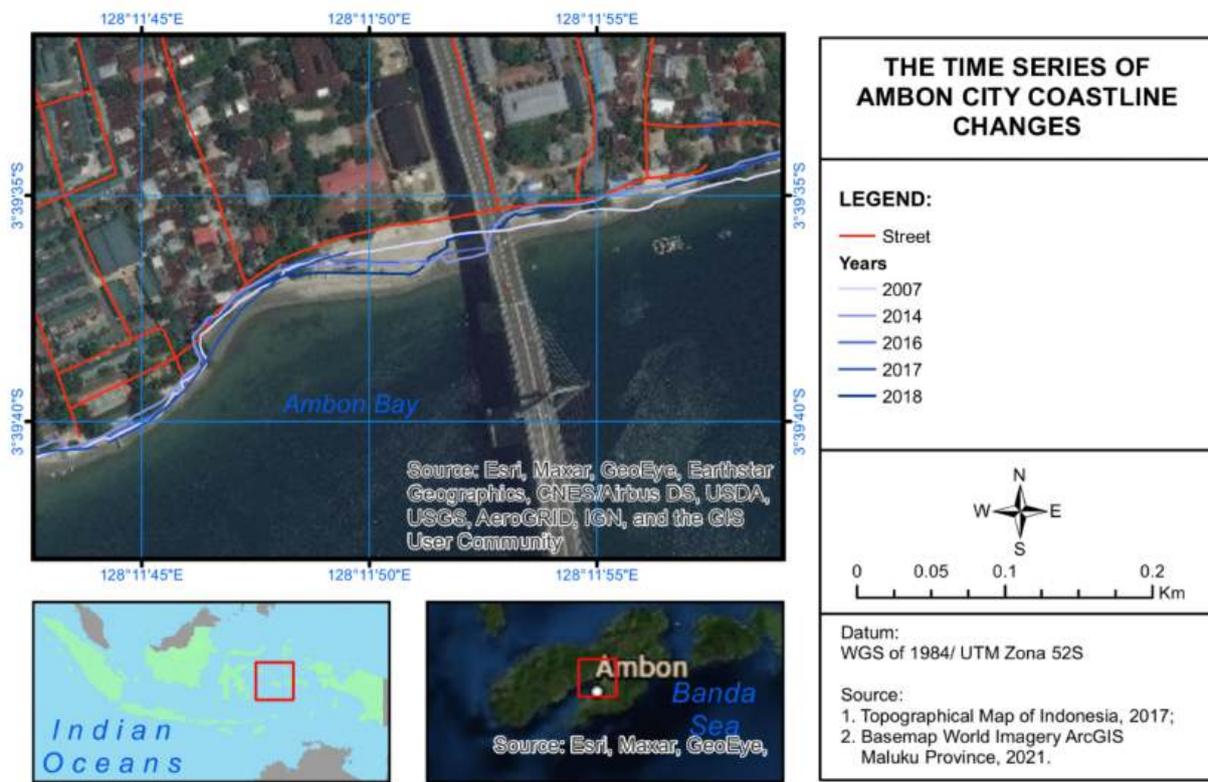

Figure 1. Change of coastline in the sill area, Ambon Bay.

This threshold area always receives a different current speed from the direction of the TAL, which is directly a stream from the Banda Sea; and also at the same time, it receives different current speeds from the direction of the TAD. So, in the coastal area of the threshold area, there is a split of seawater energy mass from the Outer Ambon Bay and the Inner Ambon Bay. In addition, there is also a process of water circulation and mass transfer between TAL and TAD [41,47,48]. This series of energy transfers occur every day, and the coast of the threshold area receives the energy burden every day so that the coastline in this area is never stable. Moreover, when upwelling is occurred—namely, the exchange and mixing of seawater masses vertically, which occurred in February, April, August, and November [48]—the threshold area must be prepared to receive high seawater mass energy as a result of the mixing of upwelling in Ambon Bay. Those geographical positions will affect the waste characteristics and will help select appropriate waste management plans in that area [49].

Based on the study of marine physics, the threshold area in the coastal area was chosen as the study area, with the hypothesis that with such a significant movement of seawater occurring around this area, the waste carried by the seawater circulation could not be avoided. This area must be prepared to accept a higher load of shipment waste than other coastal areas along Ambon Bay because this area receives waste from the direction of the TAD and TAL. However, it does not rule out the possibility that the waste received is partly a result of the activities of the surrounding community. Moreover, appropriate waste management in coastal areas can help to minimize marine pollutions [50]. Then, the impact of waste pollutants on the ecosystems, social, and economic resources of the coastal area community can be minimized.

3.2. Waste Management Developed in Ambon City

The amount of waste in Ambon City continues to increase each day according to data submitted by the Department of Environment and Solid Waste; the handled waste total amount of Ambon City reached 269 tons per day in 2019. This number continues to increase when compared to the amount of waste in 2016, which only reached 136 tons per day. Based on that, the total amount of waste in 2019 reached 98,029 tons. The Office of Environment and Waste Management of the City of Ambon has worked hard and seriously made a variety of breakthroughs and innovations to overcome the increasing number of waste problems with the implementation of the Regional Strategic Policy (Jakstrada). Jakstrada is a policy pursued by the Mayor of Ambon in the form of a Regional Strategy Policy in the Reduction of Household Waste and Household Trash. This was taken because Ambon City is a medium-sized city on a small island with an area of 377 km with a land area of 359.45 km, which is inhabited by approximately 400,000 people with a relatively high level of community routine. After all, as the capital of Maluku Province, Ambon also becomes the center of government, education, and economic activity of the Kota district in Maluku.

The problem of waste in Ambon City is getting more complicated because waste has not been considered as an economically valuable resource. The public's view of waste is only disgusting useless goods and must be discarded. This is where scavengers have potential for participation, and their activities can help waste management. The performance of waste management in Ambon City according to normative standards is quite good. Judging from the priority of waste services, it is also appropriate, namely in commercial areas, markets, and residential areas with densities of 50 to 100 people/ha. The results of the performance of waste management based on community perceptions are good enough, but they are not entirely satisfactory yet according to community expectations. Several factors influence the performance of waste management:

1. The number of personnel and infrastructure is still limited;
2. Transportation operations are not optimal;
3. There is low retribution income, so it needs subsidies for operations;
4. Operational costs are minimal;
5. The community has not adequately supported waste management;
6. There is a lack of enforcement for violating waste management regulations.

The government needs to increase the reach of waste services, personnel, and equipment and provide information on waste management to the public. Regulations related to waste management in Ambon City have been issued the Regional Regulation of Ambon City Number 11 of 2015 concerning Waste Management, which explains the definition, duties, principles, and functions of each Dinas in charge and how waste management is carried out. Inappropriate waste management will make the coastal area deteriorate over time [33] either in the study location or other islands in Indonesia.

3.3. Qualitative Description Analysis, Observation, and Interview Results

The condition of waste in the areas of Ambon Bay is increasingly alarming. The waste does not come from the local community, but the activity of Mardika, Wailela, and other places outside this area. That waste is carried by rivers and tides, which accumulates in the coastal area. This pollution is caused by the lack of awareness of the people who are still littering. If it rains, all the waste will drift into the sea and damage the sea. The leading producer of marine waste is estimated to be the population living within 50 km of the coast [9]. The high production of waste originating from coastal communities is caused by inadequate infrastructure, the low economic conditions of people living in the region, and lack of public knowledge and awareness about the environment and waste management. Based on the results in the study, in developing and island countries such as Indonesia, there is limited public knowledge about waste, especially marine waste problems. This statement was also supported by research done by Phelan et al. [51], where there was evidence that the low-level knowledge of communities in the coastal areas

was influenced by gender, age, and education. One step that is needed is increasing the knowledge of communities to increase the positive community perception. The bad habits of the community exacerbate this by throwing waste directly into the sea or into a river body [52]. In addition to originating from land, plastic waste can also come from human activities carried out at sea, such as fisheries, shipping, tourism, mining, military, and research activities [7].

Pollution that occurs on the coast can cause damage to the marine ecosystem [4]. The most dominant rubbish in the surface area of the Ambon Bay coastal waters is plastic waste, while much other rubbish with heavier masses collected on the seabed such as rubber, cloth, cans, and other rubbish. One type of marine pollutant is plastic, with a percentage of 60% to 80% of the total global sea pollution, so that plastic pollution affects all marine ecosystems ranging from the sea level to the ocean floor, including along the coastline. This is a threat to marine biota and also human health [14].

Damage to coastal aquatic ecosystems also affects the productivity of fishers because the piles of waste disturb the ecosystems of the coastal areas. According to fishers in Ambon City, sea pollution due to waste affects the quantity and quality of fish caught by fishers. Fish in Ambon Bay have been contaminated with waste, so many fish are no longer suitable for consumption. Rubbish caught in the reefs causes damage to the fish habitat and thus affects fish populations. As a result of the pollution, Ambon Bay fishers have to go to further catching areas to catch fish. In addition, sea pollution has resulted in some fishermen already switching jobs.

Communities in the Ambon Bay region have made efforts in dealing with waste problems such as installing boards that prohibit littering, taking rubbish from every house with waste carts, which will be disposed in waste collection basins, and cooperative efforts between students and the army have made efforts to clean up the bay area from waste once a week. The rubbish is collected by the community and transported to the waste bin. The local government has assisted in the form of four speedboats to transport waste from the waters. This effort has shown that the communities in coastal areas have been supporting the government to minimize the waste in the coastal area. This action is also seen in other coastal areas in other islands in Indonesia, such as Pari island [53] and South Sulawesi [51]. The local communities have been involved in waste collection and waste management. Various forms of community involvement and awareness raising of the community are important and effective steps in addressing the waste problem and achieving sustainable waste management [33]. Community involvement has a strong correlation with environmental co-creation [54]. Those forms of involvement can be in form of financial and technical cooperation in term of built infrastructure, waste services, technology implementation, green practices, and coastal and marine ecosystems programs [54]. However, these efforts are still considered ineffective in overcoming the waste problem because of the large number of waste generation in the coastal areas in Indonesia, especially in the Ambon Bay Area, every day.

Another solution that can be implemented in waste management in the coastal area of Ambon Bay is to increase public awareness of waste management and the importance of protecting the environment, as well as the existence of sanctions for people who are still littering. In addition, efforts were made to install nets in rivers and estuaries so that waste did not enter the bay area. With the installation of nets, transporting netted rubbish by using speed boats will be more effective. The government must provide more waste bins and encourage early control and socialization from parents for children from an early age by providing concrete examples.

The absence of a waste bank is an obstacle in waste management and recycling in the region because there is no appropriate location for a waste bank to be established. Waste management with waste banks has been carried out in several areas in Ambon City. From the secondary data of the Ambon City Environment and Solid Waste Department in 2018, the number of waste banks managed by the Ambon City government is good condition, but there are also some that are not recorded. These data are presented in Table 1.

Table 1. Number of Ambon City waste banks.

No.	Sub-District	Building Name	2015	2016	2017
1	Sirimau	Waste Bank SDN 2 Ambon	Good	Good	Good
		Waste Bank Sehat Lestari	Good	Good	Good
2	Ambon Baguala Bay	Waste Bank SMAN 4 Ambon	no data	Good	Good
		Waste Bank BTN Passo Ambon	no data	Good	Good
3	Ambon Bay	Waste Bank Becamber	no data	Good	Good
		Waste Bank Taheng	no data	Good	Good
4	South Leitimur	no data	no data	no data	no data

This study shows that the lack of supporting infrastructures, such as waste and landfills, is another problem faced by developing countries and archipelagic countries such as Indonesia. This problem was also raised by Phelan et al. [51] in their research. Supporting infrastructure cannot be lacking because it will affect people's behavior in the long term because they do not have the right location to dispose of their waste. Then, they will immediately throw waste into the sea or ignore the waste that people find on the bay. Therefore, building an adequate waste infrastructure is also a solution step to deal with waste in coastal areas.

Some environmental activists have also done a lot of socialization and training on waste recycling to schools, communities, and other agencies. Environmental activists work with children in the surrounding area to sort out plastic waste. The plastic waste can be used to make ecobricks [55,56] where all plastic waste will be put into used plastic bottles of the same size and then solidified fully in the bottle. After all the bottles have been filled, they will be bound using nylon straps so that they are not separated; later, the results of the craft can be used as a seat or table. Plastic waste cannot be broken down easily. When compared to ordinary seating that can only last one to two years, plastic waste can last twelve to fifteen years. The community can use various management techniques to utilize all the waste in the waste management program, but it will be optimal and most effective if the government also supports the program [33].

3.4. Spatial Analysis, Waste Density

Waste collection involves residents of the threshold area in Ambon City, with the waste collection time being carried out when the seawater conditions are receding, i.e., at 09:00–12:00 a.m. Eastern Indonesia Time. The collected waste is divided into two types of compositions, namely plastic waste and non-plastic waste (mixed). After being collected and separated into plastic waste and mixed waste, the waste is weighed. After being weighed, the waste is transported and taken to a waste disposal bin that has been provided. At the time of this activity, there were 13 rubbish transport trips to the reservoir with different weight variations of the waste, as shown by the data presented in Figure 2. From the data in Figure 2, it can be seen that the total weight of plastic waste collected is 234 kg, while that of non-plastic waste is 510 kg, so that the total waste collected is 744 kg. From the 13 waste transport trips, only three had a greater mass of plastic vs. non-plastic waste, which are the 3rd, 11th, and 12th waste transport trips. The dominant waste type is non-plastic waste, with a ratio between non-plastics and plastic waste of 85/39. This is in line with the results from other literature, which stated that a developing country mostly produces organics waste more than plastics waste [57]. The small amount of plastics found in this study can be because due to geographic reasons, such as tidal waves. Tidal upwelling in Ambon Bay is more frequent and intense in easterly monsoon [58].
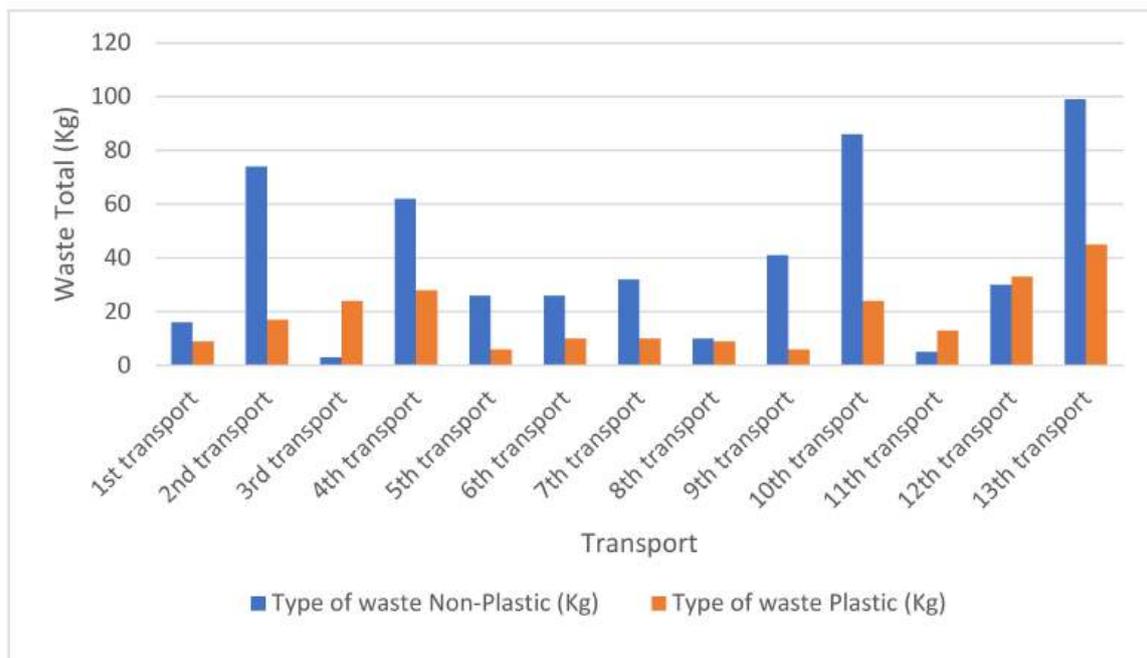
Figure 2. Amount of waste weight collected per transportation.

Then, these field data are included as attribute data at the coastal locations of the threshold area in Ambon city, which have been digitized in ArcGIS (see Figure 3).
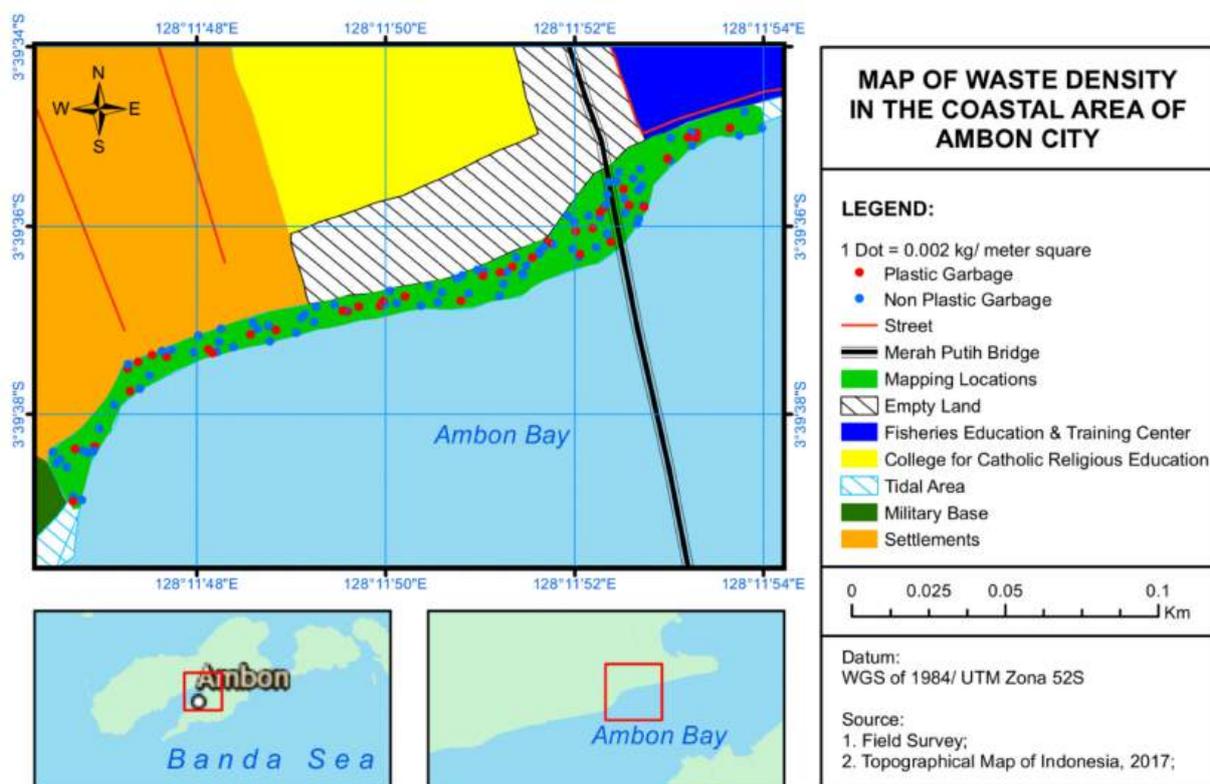

Figure 3. Waste density map.

The result of the field measurements and spatial measurements show that the length of the coastline at this location is 275.9 m, with the tidal area of the waste collection location amounting to 2982 m^2. So, the total waste density obtained at this location is 0.249 kg/m^2,

of which 0.078 kg/m^2 is the density of plastic waste, and 0.171 kg/m^2 is the density of non-plastic waste (mixed). Other research in the Ambon Coastal Area stated that the plastics waste that dominates the composition of marine debris in Ambon Bay is plastics packaging [59]. That waste density will affect the cost reduction that is needed to manage the waste in Ambon City Bay [60,61]. However, Thushari [62] stated that the accumulation, density, and size of the waste in coastal areas is dependent on the beach characteristics, seasons, and anthropogenic activities.

Based on the spatial analysis carried out, the presence of waste in the residential and school environment will create uncomfortable environmental conditions because it is reviewed based on the direction of the blowing wind, which will have an impact on the settlement and school environment. In addition, there is no Waste Disposal Site (TPS) in the Teluk Ambon Subdistrict. All waste transported from the Ambon Bay Subdistrict is taken to the TPS in Toisapu, which is located in the South Leitimur Subdistrict. This TPS handles almost all of the rubbish in Ambon Island. So, it is very likely that the rubbish that cannot be accommodated by Toisapu TPS or cannot be transported to Toisapu TPS will be left, burned, or even thrown into the sea. Hence, it is necessary to revitalize the TPS development program in this region. The impact of the existing landfill in this area will affect the changes in the coastline that will occur accretion events, i.e., the coastline is increasingly growing toward the sea due to sedimentation of landfill results. Therefore, infrastructure building and land utilization are required to be the considerations by the government [63,64], which can support the coastal community toward waste management and environmental sustainability. To make this economically feasible, regional cooperation through collaboration with surrounding areas [57] can be beneficial to reduce any financial burden. In addition, good governance [58] and the educational approach to raise awareness and change behavior [65] are further required to effectively manage the entire waste management system [58].

4. Conclusions

This study identified that the most dominant rubbish in the surface area of the Ambon Bay coastal waters is non-plastic waste, while other rubbish with denser masses collected on the seabed such as rubber, cloth, and cans. Communities in the Ambon Bay region have made efforts to deal with waste problems such as installing signs that prohibit littering, taking rubbish from every house with waste carts that is disposed in waste collection basins, and cooperating with students and the army to clean up the bay area once a week. Moreover, several areas in the Ambon Bay region have a waste bank, which is one of the efforts to manage the waste with good condition. However, some of them are not yet recorded. This study recognizes that there is community participation in managing the waste in coastal communities in Indonesia. Still, inadequate infrastructures, economic conditions, and lack of knowledge make the current efforts ineffective at overcoming the waste issue. Given the potential to resolve the waste management problem, especially to increase community participation, the government needs to increase the reach of waste services, personnel, equipment, and provide information on waste management. Another solution that should be done in waste management in the coastal area of Ambon Bay is to increase public awareness of waste management and the importance of protecting the environment. Such awareness needs to be owned by the younger generation [66,67].

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