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Macroplastic Waste Management Strategies in Palembang City

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ABSTRACT

The Musi River in Palembang City plays an important role in meeting human needs, such as food, drink, and clean water. The high level of activity of the community around the river has led to an increase in macroplastic (MP) waste pollution. This study aims to (1) determine the condition of macroplastic waste pollution in the Musi River; (2) determine sustainable macroplastic waste management strategies; and (3) sustainable plastic waste reduction participation. The method uses a qualitative description of semi-structured interviews. Data collection used documentation and interviews. Data analysis used descriptive to describe the current condition and analysed using SWOT. The research results showed that the source of macroplastic waste pollution came from community activities such as domestic activities, industry, markets and tourism. The strategy for capturing macroplastic waste involved placing waste containment devices (trash booms and waste containment fences) in the streams of densely populated tributaries. To reduce the amount of macroplastic waste entering the environment, all parties, including the government, the community, and non-governmental organisations, must participate and work together. The implication of this research is that preventing macroplastic waste from entering the sea and effective management can reduce the threat to shrinking endemic river populations.

1. INTRODUCTION

Rivers in urban areas often become dumping grounds for community waste. The indifference of the local community causes the river to become increasingly polluted. The amount of macroplastic waste in Palembang City has increased every year. It is clearly seen that the condition of the Musi River or tributaries is covered with rubbish. Waste that enters the river environment comes from household waste, industrial waste and macroplastic waste [1].

The increase in the amount of waste is certainly influenced by the increase in population. The increase in population causes plastic production to increase. Plastic is used to facilitate human life every day. Almost every item used comes from plastic and the remaining results of anthropogenic activities inevitably produce plastic waste. This fact causes plastic production to increase. An increase in the amount of plastic production can increase the amount of macroplastic waste. Macroplastic waste that enters the environment is influenced by human factors that dispose of waste on land, on riverbanks, or into river channels [2]. Macroplastic waste that is found in many tributaries is a threat to the local and global environment, considering that rivers are transport routes for macroplastic waste from land to the sea. The Musi River in Palembang City is one of the largest rivers in Indonesia and has an important role in the social, economic and cultural life of the surrounding community. The Musi River is also used as a transport route for ships transporting crops to be traded widely both in Sumatra and outside Sumatera [3]. This has caused the condition of the Musi River to have a higher level of pollution.

The condition of the Musi River, which is quite alarming, can have many negative impacts on the environment and cause pollution of the environment, both water, soil, and air [4, 5]. When macroplastic waste enters the river, it can disrupt the river's aesthetics, jeopardize the ecosystem, endanger accidentally swallowed or entangled aquatic animals, lead to their death, and jeopardize the economic sustainability of river-dependent communities [6, 7]. When macroplastic waste remains in a waterway, settles in the sediment, and is exposed to sunlight, it degrades into microplastics, posing a risk to human health if swallowed. The problem of macroplastic waste requires appropriate handling [8-10].

The Musi River is filled with macroplastic waste, leading to a high level of pollution in the river. The main sources of pollution in the Musi River are industrial waste from both large and small industries, household waste, and plastic waste. Each of these activities is directly related to the river, and it is this tendency that causes the Musi River to become increasingly polluted. This condition is quite concerning

considering that the Musi River is very important for fulfilling the needs of the people of Palembang City. Plastic itself is non-biodegradable, making it one of the largest contributors to environmental waste [11, 12]. Although river cleaning has been carried out, the condition of the Musi River has not shown any improvement. In the smaller tributaries, a lot of macroplastic waste is still found, causing these tributaries to become shallow due to the accumulation of macroplastic waste in the river sediments.

The Palembang City Government has made various efforts to reduce the amount of macroplastic waste. The Palembang City Government, in this case the mayor, sub-districts and agencies in the Palembang City area conduct river clean-ups which are carried out regularly every week. In addition, every year on National Waste Day and Environment Day, macroplastic waste is captured centered in the Musi River area.

The biggest environmental challenge today is to reduce the amount of plastic waste entering the environment. An effective and sustainable countermeasure strategy is needed to reduce macroplastic waste. The amount of waste in Palembang City cannot be reduced by itself, it requires cooperation from all parties. Both government agencies, the private sector, and communities as well as local communities conduct waste collection in the Musi River area of Palembang City. The Musi River in Palembang City is one of the largest rivers in Indonesia and has an important role in the social, economic and cultural life of the surrounding community. The Musi River is also used as a transport route for ships transporting crops to be traded widely both in Sumatra and outside Sumatra [3].

The urgent need to create a sustainable and efficient plan for managing macroplastic garbage near the Musi River is what makes this research so urgent. Considering the significant negative impact caused by macroplastic waste, coordinated and science-based efforts are needed to reduce this pollution. This research is expected to contribute in the form of a comprehensive waste capture strategy, which is not only effective in the short term but also sustainable in the long term.

This research aims to (1) determine the condition of macroplastic waste pollution in the Musi River; (2) determine a sustainable macroplastic waste management strategy; and (3) determine sustainable plastic waste reduction participation.

The research questions are (1) what are the conditions of macroplastic waste pollution in the Musi River; (2) what is the strategy for sustainable macroplastic waste management; and (3) what is the participation in sustainable plastic waste reduction.

2. METHODS

The research area was conducted in Palembang City, especially in the Musi River basin. The selection of this location was based on the consideration that the research area is a residential area associated with the Musi River body and tributaries, which are environmental crisis points of macroplastic waste pollution (Figure 1).

This research will explore and describe macroplastic waste pollution, macroplastic waste capture and management strategies, and collaborative efforts related to susainable macroplastic waste reduction. The method used is descriptive qualitative semi-structured interview. Semi-structured interviews were conducted flexibly, structured around open-ended questions exploring information related to methods of capturing macroplastic waste and participation that had been carried out. Interviews were conducted with 20 informants, with interview durations ranging from 30 minutes to 100 minutes.

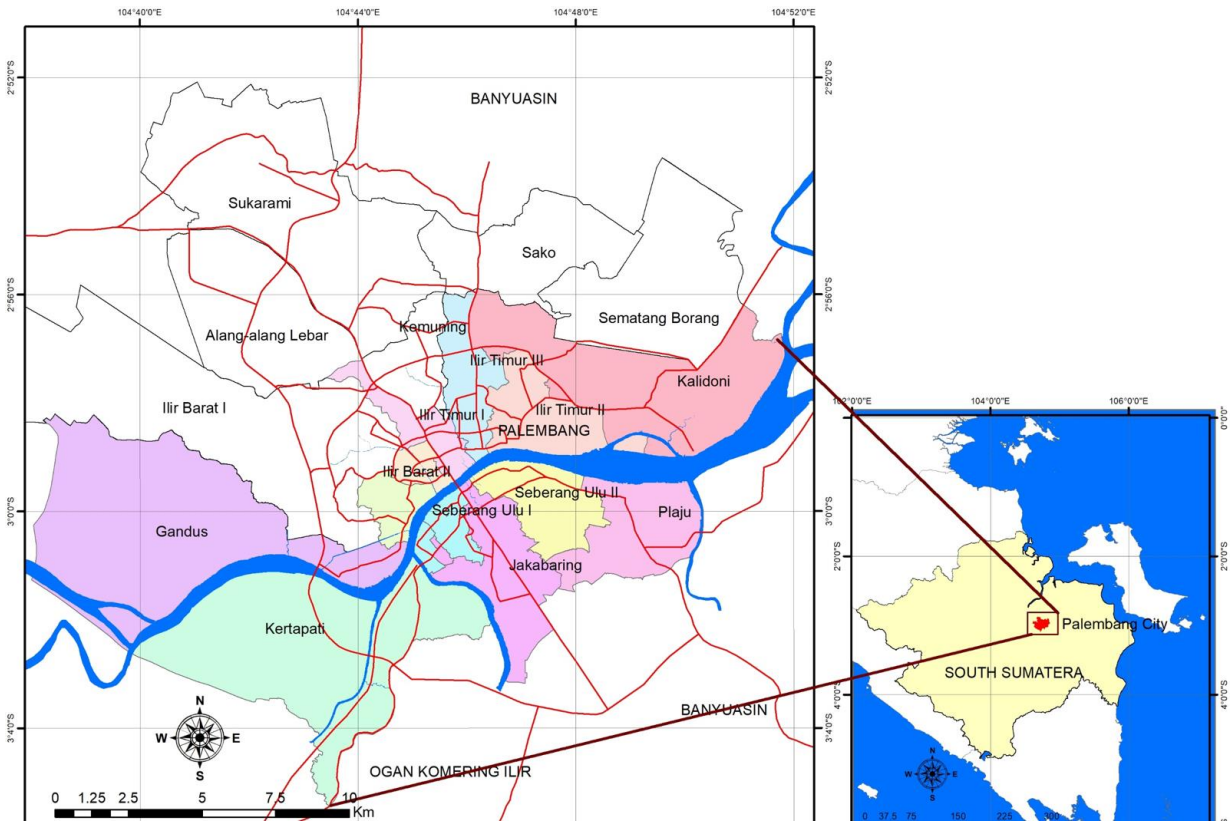


Figure 1. Research location

The subjects/informants of this study were people living around the Musi River, government agencies such as the Environment and Cleanliness Office, the Palembang City Public Works and Housing Office, and 6 non-governmental organisations (NGOs) that manage waste banks. Informants were purposively selected with certain considerations (purposive sampling). The criteria for selecting informants for this study were that they were considered to be the people who knew the most about the problem of macroplastic waste in Palembang City and were directly involved in handling macroplastic waste. They were also required to have knowledge of the technology for capturing macroplastic waste. The object of observation in this study is the capture and management of macroplastic waste in the Musi River, the performance of the waste handling system, the volume and type of macroplastic waste, and related policies and regulations.

Data collected in the field in the form of technology used to capture macroplastic waste in the river, the effectiveness of macroplastic waste capture methods, community involvement and collaboration carried out to capture macroplastic waste, the location of the installation of waste fishing gear, and macroplastic waste management (Table 1).

Table 1. Research indicators

Dimensions	Indicators
Capture Technology	• Type of tool used • Effectiveness of the tool
Community Involvement	• Direct participation • Frequency of participation
Collaboration	• Stakeholders • Non-governmental organization • Society

Data collecting methodologies employ documentation and interviews. Documentation comprising data recordings and field pictures. Interviews are performed in a semi-structured, in-depth manner. The assembled questions may evolve based on the informants' responses. The acquired data is further categorized by themes and examined.

The data analysis employs descriptive analysis to elucidate the current situation of the distribution of macroplastic trash in the Musi River and the community's reaction to plastic pollution. SWOT analysis is used to formulate strategies for capturing macroplastic waste by identifying the strengths, weaknesses, opportunities, and threats related to the implementation of various waste capture methods. The information that has been collected is then summarized and analyzed using the SWOT matrix. This matrix clearly illustrates the strengths, weaknesses, opportunities, and threats regarding the management of macroplastic waste (Table 2).

Table 2. SWOT analysis matrix

		Internal Factor	
		Strength	Weakness
External Factor	Opportunity	S-O	W-O
	Threat	S-T	W-T

The results of this SWOT analysis will serve as the basis for designing effective and efficient strategies. In the meantime, the interview results are sorted, described, and examined in accordance with the study's goals.

3. RESULTS AND DISCUSSION

3.1 Condition of macroplastic waste pollution in the Musi River

The Musi River in Palembang City is the longest river on the island of Sumatra, with a length of 720KM, dividing Palembang City into two regions. This has also led to the city of Palembang being nicknamed the River City. The Musi River, besides serving as a water transportation route, is also directly utilized by the surrounding community for both water and riverine endemic organisms.

The waste produced by the people of Palembang City and successfully transported by the Cleanliness Service consists of organic and non-organic waste. Organic waste comes from food scraps, wood and twigs. Meanwhile, non-organic waste consists of macroplastic, paper/cardboard, metal and other waste. Based on recorded annual waste data, in 2019 waste production was 424,869.16 tonnes/year, in 2020 it produced 426,390.66 tonnes/year, in 2021 it produced 430,791.65 tonnes/year, and in 2022 it produced 439,815.66 tonnes/year. Residual waste from community activities that are successfully transported is recorded every day.

However, the fact is that waste (macroplastics) is still found that is not properly recorded and is still found around people's homes. This can be seen from the condition of the Musi River, which is filled with waste from anthropogenic activities. The large amount of waste filling the river causes a high level of pollution in the Musi River. The waste that enters the Musi River comes from various activities such as domestic activities, industrial activities, market and trade activities, and tourism activities. The domestic activities of humans that contribute waste to the river are household waste. Almost every human activity inevitably produces plastic waste. The lack of human care and awareness in protecting the environment leads to more severe environmental damage. Most of the people living in the areas around the river throw their trash directly into the river. This condition causes the river to be filled with macroplastic waste due to the actions of the community (Figure 2).

Figure 2. Condition of the Musi River tributary

In Figure 2, it can be seen that the Musi tributaries are filled with waste generated by the activities of the surrounding community. The majority of the waste generated consists of

macroplastic. The most common macroplastic waste found in the tributaries are plastic bags, beverage bottles, food packaging, straws and industrial packaging. Even other types of waste were found in the Musi River, such as tree trunks, food scraps, and leaves. This condition causes the environment to become slum-like and the river water to be contaminated with macroplastics. Macroplastic waste that remains in water for a long time can degrade into smaller sizes such as mesoplastic (5-2.5 mm) and microplastic (<5 mm) [13]. Animals contaminated with macroplastic waste have been found in fish, seabirds, turtles, and mammals. Even macroplastic waste has been accidentally ingested by aquatic animals, leading to death, as evidenced by the stomach contents of animals found dead at sea containing macroplastic waste. Macroplastic waste is also very dangerous if it degrades and enters the human body, causing health issues for humans [10, 14, 15].

Industrial activities around the Musi River often exacerbate the river's environmental conditions. The activities of this industry produce macroplastic waste and can contribute to river pollution if the macroplastic waste is directly disposed of into the river. This also contributes to the entry of macroplastic waste into the river. If this continues, it will have a more serious impact on the aquatic ecosystem and could eliminate the native aquatic animals in the river. Proper and serious measures are needed to reduce the environmental damage to the river.

One of the community activities that contributes to macroplastic waste is market and trade activities. Commercial activities that take place in the market can generate waste. The amount of waste generated from these activities can cause waste if the infrastructure is inadequate [16, 17]. The location of traditional markets near the Musi River can contribute significantly to the entry of macroplastic waste into the river. This is because the buying and selling activities carried out in traditional markets often produce macroplastic waste. The macroplastic waste can enter the river either intentionally or unintentionally. The condition of the Musi River tributaries is filled with macroplastic waste, even accumulating in the river sediments. This causes the river to become shallow and narrow (Figure 3).

Figure 3. Silting up of rivers in the surrounding trading area

The condition of the Musi River, which is currently filled with macroplastic waste. This is caused by the activities of the community. The activity of the community throwing garbage directly into the river has been going on for a long time. This condition disrupts the ecosystem in the river. This is evident, as the plastic waste has accumulated for quite some time in the river sediment. This condition causes the river water to turn dark black and emit an unpleasant odor.

Another activity that contributes to macroplastic waste is tourism. Tourism activities also contribute to the plastic waste that enters the Musi River, as the city of Palembang is a river city. The Musi River itself is the largest river on the island of Sumatera, which is why several tourist attractions are located around the river, such as Pulau Kemarau, Kampung Arab, Kampung Kapitan, Benteng Kuto Besak, and the Ampera Bridge, which has become the mascot of the city of Palembang. The lack of care and awareness among tourists in maintaining the environment causes them to throw macroplastic waste directly into the river. The macroplastic waste commonly found at tourist spots includes drink bottles and food wrappers. These activities, whether consciously or unconsciously, can contribute to the environmental damage of the Musi River.

3.2 Sustainable macroplastic waste management strategy

The purpose of this research is to determine sustainable macroplastic waste management strategies, where the observations include the methods of capturing macroplastic waste in the Musi River, the locations for installing waste barriers, community involvement, and the collaborations that have been carried out.

The analysis of data related to macroplastic waste capture strategies has been conducted by examining strengths, weaknesses, opportunities, and threats. The results obtained are as shown in the Table 3:

Table 3. Strengths, weaknesses, opportunities, threats

Strengths	Weaknesses
• Trash-catching tools such as trash booms and trash fences • The installation locations of the tools are placed in strategic areas, such as densely populated river regions. • Increased public awareness after education and socialization efforts • Government support in reducing and maintaining the river environment from macroplastic waste	• Financial and resource constraints • Some equipment usage is still less effective due to the unique characteristics of the Musi River compared to other rivers (tidal) • Community participation is not yet optimal, as not all community members are actively involved in maintaining the river
Opportunities	**Threats**
• Support from local government regarding waste management • Macroplastic waste is recycled into reusable items and implements the concept of a circular economy • Funding from external parties such as private and international entities	• Lack of long-term public awareness and dependence on tools • Lack of law enforcement

The data analysis reveals the strengths, weaknesses, opportunities, and threats in sustainable macroplastic waste management strategies. According to our observations, the strength of this strategy is the use of appropriate waste capture

devices placed in strategic locations. The waste capture devices used can be trash booms placed floating in densely populated rivers. Meanwhile, the trash retaining fence is placed downstream. The installation of macroplastic waste capture devices in rivers aims to prevent macroplastic waste from entering the sea [18-20]. In addition, the importance of increasing public awareness of the cleanliness of the river environment and government support to reduce and protect it. These factors are the strengths of the macroplastic waste management strategy in Palembang City, so that macroplastic waste does not enter the sea.

The weakness of this macroplastic waste management strategy lies in the limited budget and resources. The number of trash catchers placed in rivers near residential areas is still limited. In addition, the resources for maintaining the installed devices are inadequate. The characteristics of the Musi River flow cause the installed devices to be less effective. The effectiveness of installing trash booms must be adjusted to river conditions [21]. Also, suboptimal community participation causes macroplastic waste, much of which is still being disposed of in their living environment.

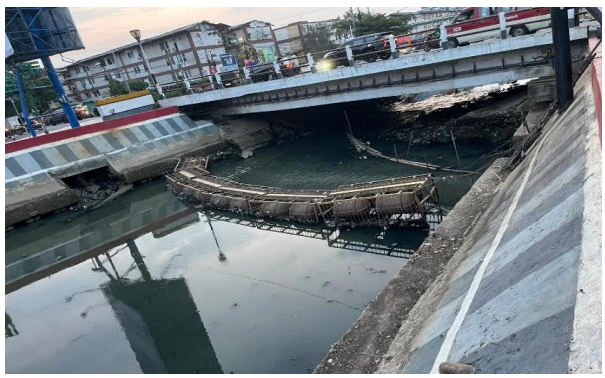
The macroplastic waste management strategy presents an opportunity to establish cooperation and support from local governments to be actively involved in waste management, recycling and reusing macroplastic waste. So that it is able to implement the concept of a circular economy, and can then establish cooperation and collaboration from outside parties in waste management. The threat arising from this strategy is that in the long term, public awareness will decrease due to the devices installed in the river, as well as the lack of law enforcement regarding macroplastic waste and sanctions for those who dispose of waste directly into the environment.

The Musi River plays an important role in fulfilling the needs of the people of Palembang City. Local residents directly utilize both the water and animals of the Musi River; they use the river water for bathing, washing, and cooking, and they directly consume the local river animals. However, the issue of plastic waste pollution, particularly the presence of macroplastics, has emerged as a significant concern, endangering both environmental health and aquatic ecosystems. To address this issue, the Palembang City government, along with the Public Works Department (PU) and the Environmental and Sanitation Department, is installing trash booms and waste barriers in several strategically considered areas.

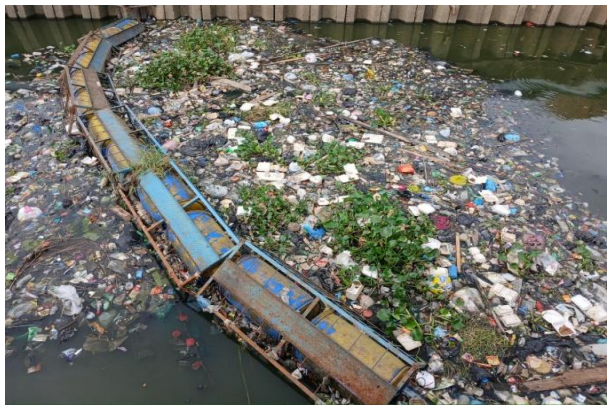
The efficiency of capturing macroplastic waste depends on how it is captured and placed. The use of tools will be more effective if placed in the Musi River tributaries/canals that are considered strategic, namely densely populated areas (Figure 4). The proper use and placement of the tool can reduce the amount of macroplastic waste, preventing it from entering the river and eventually flowing into the sea.

The location for the installation of the trash boom is placed in strategic spots scattered along the Bendung River (Sekip Canal), Sekanak River, Aur River, and one on Radial Road. We expect the installation of this tool to capture waste entering the Musi River. We expect the installation of the trash boom and trash trap to reduce the macroplastic waste entering the Musi River.

Trash boom installation is one of the effective strategies and trash booms were installed at several strategic points in the Musi River, especially near the Ampera Bridge and downstream areas. This trash boom successfully retained most of the macroplastic waste floating on the water's surface, making the waste collection process easier (Figure 4 (b)). Considering the river as one of the transportation routes for macroplastic waste from land to sea or from upstream to the ocean [22-27]. The installation of this device is quite effective in reducing macroplastic waste entering the Musi River. However, when entering the dry season, the installation of trash booms and trash traps becomes less effective due to the reduced water flow in the tributaries (Figure 4 (a)). This is due to the different characteristics of the Musi River tributaries. The Musi River tributary is also referred to as a periodic river, where the river's water flow is high during the rainy season, but conversely, the water flow is low during the dry season. Because of this, during the rainy season, macroplastic waste can be swept away and caught by the trash boom. In the dry season, the lower water discharge causes macroplastic waste not to be carried away by river water currents and settles in the river. This seasonal trend undoubtedly influences the shift in the transportation of macroplastic waste [28].



(a)



(b)

Figure 4. Installation of trash boom

If this continues, it will cause damage to the river ecosystem. The accumulated macroplastic waste can cause the environment to become slum and the condition of river water turns black, causing an unpleasant odour. The Palembang City Government, in an effort to reduce macroplastic waste entering the main river, installed a waste-retaining fence between tributaries to the Musi River. This is because the river serves as an important pathway, transporting macroplastic waste from the land into the river and ultimately to the sea [29-34]. The installation of this waste-retaining fence aims to reduce the amount of macroplastic waste entering the Musi River, which will then flow into the sea. The installation of this waste-retaining fence is quite effective in holding back macroplastic waste entering the Musi River (Figure 5).

The condition observed in the area where the trash barrier fence is installed shows that macroplastic waste has been successfully trapped by the fence, preventing it from entering the large river. The installation of this fence is quite effective in holding back and reducing macroplastic waste originating from land or small rivers. The installation of the trash barrier fence is placed at strategically considered points, namely densely populated residential areas. The trash boom was installed at Canal 10 Ulu, 12 Ulu, Jalan Pedatuan Laut.

Figure 5. Installation of the rubbish retaining fence

In general, installing trash booms and fences in streams to hold back trash is quite effective. The effectiveness of waste capture using trash booms and waste fences is influenced by several factors, namely river currents, population density, and maintenance and cleaning. The Musi River is a permanent river with a significant and stable water flow throughout the year. Meanwhile, the tributaries of the Musi River can be classified as periodic rivers, where the water flow is high during the rainy season and low during the dry season. This is why the collection of macroplastic waste in the tributaries is quite effective during the rainy season and less effective during the dry season.

Densely populated residential areas can lead to higher accumulation of macroplastic debris, requiring more regular and routine cleaning. The equipment that has been installed requires regular maintenance and cleaning. Macroplastic debris that has been netted must be picked up immediately, if left for too long, it will be less effective because the debris will accumulate and hinder its function. The use of trash booms and retaining fences has had a positive impact on reducing macroplastic waste entering the Musi River. In addition to the use of appropriate tools, a strategy is also needed to reduce macroplastic waste.

A sustainable and effective strategy is needed to properly reduce macroplastic waste in the Musi River. Firstly, the Palembang City Government needs to raise public awareness through education and campaigns about the dangers of macroplastic waste through various media and involving local communities. Environmental education must start early in order to raise public awareness and concern about macroplastic waste in the environment. In addition, environmental campaigns are also needed to raise public awareness of the dangers of macroplastics. Creative and participatory campaigns involving local communities, such as plastic waste recycling competitions, river clean-up actions, and the use of social media, can be an important first step.

Secondly, the Palembang City Government needs to provide more recycling facilities that are adequate and easily accessible in public areas. The provision of plastic waste dropboxes can encourage people to be more aware and care about the environment. Dropboxes can be placed in government areas or educational areas (schools or universities), this is the first step in public awareness of macroplastic waste. The collected macroplastic waste can be used as a learning resource by students by knowing the types of plastics and macroplastic waste can be reprocessed [35].

Third, there is a need to increase supervision and law enforcement for people who illegally dump waste into the Musi River, whether it is done by individuals, groups, or companies. Strict law enforcement against violators includes imposing fines on violators, this is expected to have a deterrent effect on the community. Additionally, the government can reduce plastic waste by promoting the use of environmentally friendly items. The government can also implement plastic policies, such as a ban on the use of single-use plastics that can be started from offices, schools, universities, and hotels in Palembang City.

Fourth, collaboration between various parties is needed to support the reduction of plastic waste. The reduction of plastic waste involves all elements, including the government, the community, environmental practitioners, and academics. This collaboration will increase the effectiveness of waste management efforts and accelerate the achievement of plastic waste reduction goals in society.

Participation in Sustainable Plastic Waste Reduction

The current condition of the Musi River is extremely concerning due to the significant amount of macroplastic waste found in its tributaries. In addition to macroplastic waste, household waste is also found in the river. Musi River tributaries located around densely populated settlements; the condition of these tributaries has been filled with macroplastic waste (Figure 2). This condition raises concern and concern for some groups/people. Reducing plastic waste in Palembang City requires a holistic and sustainable approach, involving various stakeholders including government, industry, communities, and non-governmental organizations. The river cannot be cleaned by itself, active participation from every group is needed in order to create a clean and healthy river environment free from macroplastic waste.

The lack of concern among some people in Palembang City for the cleanliness of the Musi River has led the government to issue regulations related to plastic waste. Palembang City Regional Regulation Number 27 of 2011 and Mayor Regulation Number 72 of 2018 explicitly address waste management. The Palembang City Government also has a slogan ‘Palembang Zero Waste 2030’ which aims to reduce the use of single-use plastics and improve waste management. The government plays a role in regulating the use and management of waste in Palembang City. Socialization, education, and environmental campaigns are necessary in addition to the regulations implemented to reduce macroplastic waste.

Socialization, education, and campaigns to reduce the use of plastic waste involve academics and practitioners in Palembang City. Academics conduct education in the form of socialization conducted in schools and practitioners conduct education related to macroplastic waste management for the community. Socialization, education, and campaign activities that have been carried out by academics and practitioners related to environmental issues can create a pro-environmental society [36, 37]. There have been many efforts and actions taken by academics and practitioners to reduce macroplastic

waste in the environment by processing macroplastic waste into useful items. Through education that is applied from an early age to the community, it is hoped that it can instill an attitude and concern for the environment [38-40].

The mayor of Palembang City, together with government staff-in this case, the Department of Environment and Hygiene and related sub-districts-carried out river cleaning activities. The government also invites the community to actively participate in macroplastic waste cleanup activities in the Musi River. River cleaning activities are carried out every week to clean up macroplastic waste that has accumulated in river sediments. Additionally, the community contributes both labor and material assistance by providing drinks and snacks during the collection and cleaning of macroplastic waste around the river. The government also invites the community to reduce the usage that contributes to macroplastic waste. Reuse items that can still be used, and invite people to use environmentally friendly products.

Every year, on National Waste Day, the Palembang City Government, the Department of Environment and Hygiene, BPBD South Sumatera, Waste Banks, and environmentally conscious communities come together to clean up the river. In addition, community groups that collect macroplastic waste include WALHI South Sumatra, Rumah Relawan Peduli, and students from Palembang City.

The waste that has been collected will be taken directly to the landfill to be weighed. Then the landfill officers together with the community living around, sort the macroplastic waste. In addition, non-governmental organizations also process macroplastic waste. They convert the macroplastic waste into reusable items and turn it into gas, paving blocks, and handicraft items.

While the macroplastic waste management strategy has various strengths and opportunities, this SWOT analysis reveals significant weaknesses and threats that require attention. Achieving effective macroplastic waste management requires improved infrastructure, public awareness, and more intensive cooperation between the government, private sector, and communities. In addition, stricter law enforcement and innovation in the use of alternative materials can help reduce the negative impact of plastic waste on the environment.

4. CONCLUSIONS

Based on the results of the study, it can be concluded that the source of macroplastic waste pollution in the Musi River in Palembang City comes from community activities such as domestic, industrial, market and tourism activities. The strategy for capturing macroplastic waste involves placing waste containment devices in densely populated tributaries. Waste capture devices such as trash booms in streams and waste retaining fences are located downstream. To reduce the amount of macroplastic waste entering the environment, all parties, including the government, the community, and non-governmental organisations, must participate and work together. The implication of this research is that preventing macroplastic waste from entering the sea and effective management can reduce the threat to shrinking river endemic populations.

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