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ASSESSMENT OF WASTE GENERATION, COMPOSITION AND REVENUE LOSS ESTIMATION DUE TO FLOATABLE RIVERINE LITTER AT LOG BOOM SUNGAI PINANG, KLANG, MALAYSIA

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Abstract

The presence of floatable riverine litter poses a significant environmental challenge, impacting both aquatic ecosystems and local economies. The purpose of this study is to quantify waste generation and composition based on two different seasons and estimate revenue loss from floatable litter at the log boom in Sungai Pinang. Using systematic waste sampling and analysis techniques, we categorised and measured the types and volumes of waste collected over a specified period. The data revealed substantial quantities of plastic, organic matter, and miscellaneous debris. To estimate the economic impact, we employed a revenue loss model that considers cleanup costs, damage to local fisheries, and the tourism sector. Our findings indicate that the accumulation of floatable riverine litter results in considerable economic losses annually. The study highlights the urgent need for effective waste management strategies and policies to mitigate the negative impacts of riverine litter on both the environment and the local economy.

Keywords: Waste, Environmental, Revenue Loss, Floatable Riverine Litter, Log Boom

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INTRODUCTION

The issue of floatable riverine litter has become an increasingly pressing environmental concern. Along with seriously endangering aquatic life, water quality, and human health, this floatable riverine litter affects the aesthetic value of riverine habitats (Ahmad et al, 2022). In the context of Sungai Pinang, a key waterway in the region, one of the biggest challenges facing local government and communities is the build-up of floatable riverine litter at the log boom (Eusoff et al, 2011).

Floatable riverine litter typically comprises a variety of waste materials, including plastics, organic matter, and other debris. These materials are often carried into rivers through stormwater runoff, improper waste disposal, and other human activities. Once in the river, they can travel considerable distances, eventually accumulating at structures like log booms designed to trap and remove such debris. The environmental implications of riverine litter are well-documented (Ahmad et al, 2022). Plastics, in particular, can persist in the environment for extended periods, fragmenting into microplastics that are ingested by aquatic organisms, thereby entering the food chain. Organic waste, while biodegradable, can contribute to oxygen depletion in water bodies, adversely affecting fish and other aquatic species.

Beyond the environmental impact, floatable riverine litter also has significant economic repercussions. The costs associated with cleaning up and managing this waste are substantial (Malik et al., 2020). Additionally, the presence of floatable riverine litter can detract from the natural beauty of riverine areas, negatively affecting tourism and recreational activities (Malik et al., 2020). Furthermore, local fisheries can suffer due to polluted waters, leading to a decline in fish populations and affecting the livelihoods of those dependent on fishing (Ahmad et al, 2022). With a systematic waste generation assessment and an estimation of the related revenue loss, this study seeks to solve these concerns at the Sungai Pinang log boom. In additions, it aims to provide an extensive overview of the kinds and quantities of litter collected by means of thorough waste sampling and analysis (Burillo et al, 2002). Futhermore, the financial impact of this riverine litter can be determined by using revenue loss model, taking into account factors like cleanup expenses, harm to nearby fisheries and the impact on tourists (Kim et al., 2009)

This study highlights the critical need for efficient waste management methods and regulations by illuminating the extent and consequences of floatable riverine litter (Galgani et al, 2024). It is envisaged that the results would guide the creation of focused actions to lessen the negative effects that riverine trash at Sungai Pinang is having on the environment and the local economy.

SIGNIFICANCE OF THE STUDY

The study of waste generation and revenue loss estimation due to floatable riverine litter at the log boom in Sungai Pinang holds critical significance for several reasons. Firstly, it addresses a pressing environmental issue that affects water quality, aquatic ecosystems, and public health. By systematically quantifying the types and volumes of waste collected, the study provides essential data that can be used to understand the extent of pollution and its sources. This information is crucial for designing effective waste management strategies and policies that target the reduction of litter at its origin, thereby improving the overall health of the riverine ecosystem.

Secondly, the economic dimension of this study is of paramount importance. The estimation of revenue losses associated with riverine litter highlights the financial burden borne by local communities and authorities. Costs related to the cleanup and management of floatable litter, as well as the negative impact on tourism, fisheries, and recreational activities, are significant. By quantifying these economic impacts, the study underscores the need for investments in preventive measures and infrastructure that can mitigate these costs in the long term. This economic analysis can also serve as a compelling argument for policymakers and stakeholders to prioritise and allocate resources for riverine litter management.

Finally, this study has broader implications for environmental sustainability and community engagement. By drawing attention to the tangible and intangible costs of riverine litter, it fosters greater public awareness and involvement in waste reduction initiatives. Educating the community about the environmental and economic impacts of litter can lead to more responsible behaviour and increased participation in local clean-up efforts. Moreover, the study's findings can contribute to global discussions on sustainable waste management practices, offering insights that can be adapted and applied in other regions facing similar challenges. In essence, this study not only aims to address immediate local concerns but also aspires to contribute to the global movement towards more sustainable and resilient environmental practices.

METHODOLOGY

Study Area

This study employs a comprehensive approach to quantify the waste generation and estimate revenue losses due to floatable riverine litter at the log boom in Sungai Pinang. The methodology is divided into several key components: site selection and sampling, waste categorization and analysis, revenue loss estimation, and data analysis. The log boom is located at Sungai Pinang, which is at the bottom of Sungai Klang, about twenty-five kilometres from the coast. Situated downstream along the Sungai Klang, the log boom is a considerable distance from the river mouth and the coast. The purpose of the log boom is to capture or control logs and debris that may be transported downstream by the river's flow, preventing them from reaching the sea and potentially causing navigational hazards or environmental issues. Figure 1 below, - shows the location of the log boom at Sungai Pinang

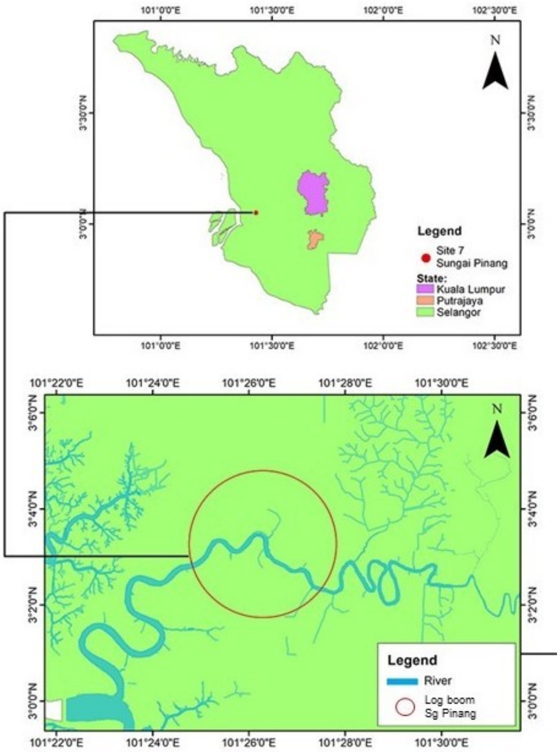

Figure 1: Study Area of Log Boom Sungai Pinang

Sampling Procedure

The waste generation study of floatable riverine litter was carried out during two different seasons: the dry season from March to the end of April 2020 and the wet season from September to October 2021. During the dry and wet seasons, 28 days of sampling were conducted to collect data on floatable riverine litter whereas 14 days during the dry season and another 14 days respectively during wet season. The collection took place at the log boom located at Sungai Pinang. The log boom serves as a barrier to capture and collect the litter that floats on the river's surface. The floatable riverine litter that gets accumulated at the log boom is then manually pushed into the river to be transported to a facility for further analysis. By conducting these data collection efforts, the study aimed to gather information on the seasonal variations in floatable riverine litter and gain insights into the effectiveness of litter management strategies in the studied area. However, during the data collection process, there were some technical problems encountered. The excavator arm breakdown and the time required to physically push the collected litter into the river caused variations in the rate at which the excavator transported the waste throughout the operating day. To address this issue, the researchers modified the equation used to measure the conveyor's rate. They weighed each of the n conveyors that brought the waste to the facility within a range of 30 minutes. This modification aimed to record the fluctuations in the conveyer's performance and provide a more accurate assessment of the litter collection process. The floatable riverine litter was weighed and documented when it arrived at the facility. This is a critical stage in determining the quantity of waste collected and the scope of the litter problem in Sungai Pinang, both in the rainy and dry seasons. The following equation has been used to determine the total amount of floatable riverine litter generated.

$$W = T1\,(w1/t1) + T2\,(w2/t2) + T3\,(w3/t3) + \ldots\ldots + Tn\,(wn/tn) \text{ ----- (equation 1)}$$

Where;

W = the total weight of waste transported by the excavator
T = the total number of excavators that transported waste
W = the total weight of the excavator that was weighed
T= the number of the excavators that were weighed

Floatable riverine litter composition describes the kinds of components that make up litter that can float on the water's surface, such as in rivers. Several factors, including geographic location, human activity in the area, and environmental features, might affect the composition of floatable riverine litter. The composition of unprocessed municipal solid garbage was examined using the ASTM D5231 standard test method, which is a tool used by the American Society for Testing and Materials, to determine the composition of floatable riverine litter. The ideal sample size, ranging from 200–300 pounds (91–136 kg), was manually selected at random from the waste samples.

$$n = (t * s/ex)^2 \quad \text{.......... (Equation 2)}$$

Where:
n = the required sample size,
t* = the confidence level and an estimate of the sample size needed,
s = the estimated standard deviation,
e = the level of precision, and
x = the estimated mean.

Once a sufficient number of samples had been collected for that categorization, the floatable riverine litter classification technique required basic sorting sequences for sample sampling. Following the sorting process, the following descriptions of floatable riverine litter were produced:

a) The sample of floatable riverine litter generated from the excavator was lifted onto the surface of the sorting area.
b) The floatable riverine litter was segregated manually and classified into 11 different types of floatable riverine litter compositions such as plastics, organic waste, metal, cardboard/paper/tetrapak (CPT), glass, polystyrene, bulky waste, aluminium, rubber, medical waste, and others.
c) Then, by using a 50 kg non-automatic weighing scale, each type of floatable riverine litter was sorted, weighed and recorded. Repeatability measurement for quality testing were used to calibrate non-automatic weighing scales. In order to determine repeatability, the same load was replaced on the load receptor at the same location under the same circumstances.

Rainfall Data

From March to April 2020 and September to October 2021, the Department of Irrigation and Drainage Malaysia (DID) provided a secondary dataset of total rainfall for 28 days of operation during the dry and wet seasons. In order to comprehend its impact on the creation and accumulation of floatable riverine litter at the log boom in Sungai Pinang, rainfall data was used as secondary data in this study. Debris from both urban and rural areas is transported into the river system by precipitation patterns, especially during heavy rain events that enhance surface runoff. The local meteorological department provided historical rainfall data for the study period, including daily precipitation amounts and the frequency of major storm events. The study sought to determine patterns and peaks in the buildup of litter by comparing rainfall data with rubbish collection records. This would provide further insight into the connection between environmental variables and riverine pollution. This analysis helped in determining the extent to which rainfall contributes to the influx of floatable litter, informing more targeted and timely waste management interventions.

Revenue Loss from the Potential Recyclables

Understanding the revenue loss of recyclable materials requires knowledge about the price list. The total weight of each possible recyclable material is multiplied by its corresponding market price per unit (e.g., per kilogramme or tonne) to determine the value of the recyclable materials. The price list for recyclable materials based on Alam Flora's current market price is displayed in Table 3.1. The entire weight of possible recyclable material is converted into Malaysian Ringgit (RM) to determine the projected value for recyclable material.

The calculation is done by using the following equation:

$$E_r = T_w \, x W_p$$

where
E_r = Estimated revenue
T_w = Total weight
W_p = Price of waste material

Table 1: Types of Waste that can be calculate as potential recyclables.

TYPE OF WASTE	PRICE PER KG (RM)
Plastic	0.40
Glass	0.10
Metal	0.20
Aluminum	2.00

Source: Alam Flora (2023)

ANALYSIS & DISCUSSION

Floatable Litter Generation and Composition

Analyses have been conducted on the observed data sampling at the log boom structure during two different seasons. The findings on the amount of floatable riverine litter collected at the log boom structure during the cleaning operation day are shown in Figure 4.1. The summary of the graphical presentation on the amount of floatable riverine litter collected at the log boom structure for each cleaning operation day revealed that the sixth cleaning operation for the wet sampling and the third cleaning operation for the dry sampling contributed the highest amounts of floatable litter generation, with 1140.00 kg/day and 1123.00 kg/day, respectively, because of the highly heterogeneous waste condition resulting from land-based source activities. On the eighth and fourth days of the cleaning operation, respectively, for the wet and dry season samples, the lowest floatable riverine litter weight was recorded, at 801.00 kg/day for the wet season and 889.00 kg/day for the dry season. This result has demonstrates the intricate relationship between environmental factors—such as high and low moisture content—and the creation of litter. High moisture conditions tend to accelerate the decomposition of organic matter and, consequently, the breakdown of waste products. Waste production may rise as a result of the decomposition of organic materials and the release of gases like methane. Excessive moisture levels might also make waste heavier, which could affect logistics and transportation expenses (Kasavan et.al, 2017). Conversely, low moisture levels can potentially reduce the amount of litter created by slowing down the breakdown process. On the other hand, low moisture content can also prevent some materials from breaking down, which can lead to an accumulation of non-biodegradable waste (Eusuff et al, 2011).

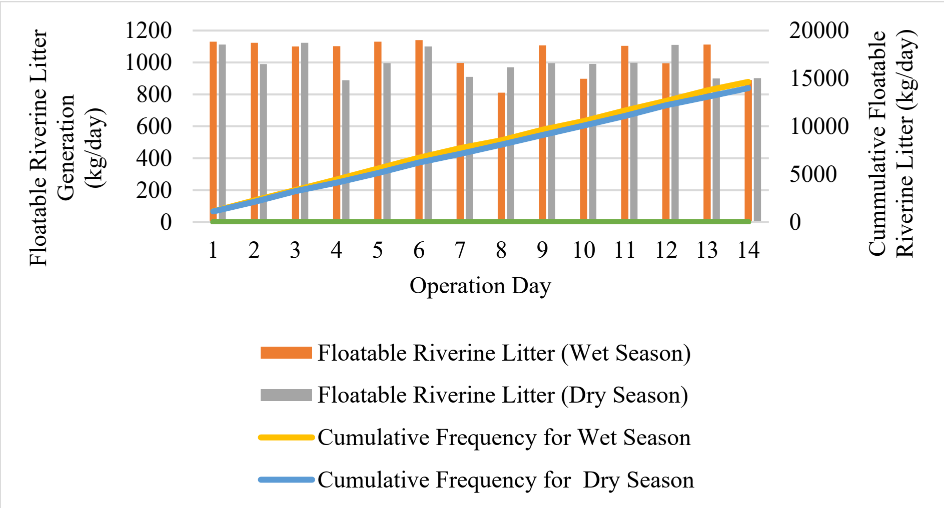

Figure 2: Floatable Riverine Litter Generation

It is important to conduct a systematic analysis of the formation of floatable riverine litter and its composition at log boom structures in order to ascertain the amount and composition of waste that is gathered in this manner. According to Crosti et al. (2018), there was a lack of monitoring data on the formation of floatable litter and its composition in river systems. The amount and composition of floatable riverine litter provided essential information for the planning and operation of the waste management systems (Beigl et al., 2008).

The wet sampling produced the highest cumulative amount of floatable riverine litter creation (15555.00 kg/day) compared to the dry sampling's 13628.00 kg/day of generated cumulative amount. Based on the actual conditions at the sample site, where the data was divided between dry and wet seasons, the study's overall conclusions about the formation of floatable riverine litter and its cumulative burden were made. Studies on hydrology and climate frequently deal with this since rainfall can fluctuate seasonally.

Additionally, changes in the amount of floatable riverine litter generated at the log boom structure were sometimes caused by technical issues with the excavator equipment that was employed to raise and move the litter to a facility. Consequently, the inability of the bucket conveyor machine to operate properly has affected time management, the frequency of bucket conveyors, and the amount of labour needed to manually transfer the floatable riverine litter. Due to the inability to elevate and transfer the floatable riverine litter from the log boom structure to the waste sample area, this has an indirect impact on the formation of floatable riverine litter and its cumulative weight.

An investigation and analysis have been conducted regarding the make-up of the floatable riverine litter that was gathered at the log boom structure within the river system. Floatable riverine trash, including plastic, organic, glass, metal, bulky, rubber, polystyrene, aluminium, and CPT (cardboard/paper/tetrapak), together with other materials, makes up the majority of the litter collected at log boom structures. Better results for each kind of floatable riverine litter composition load are shown in Figure 3.

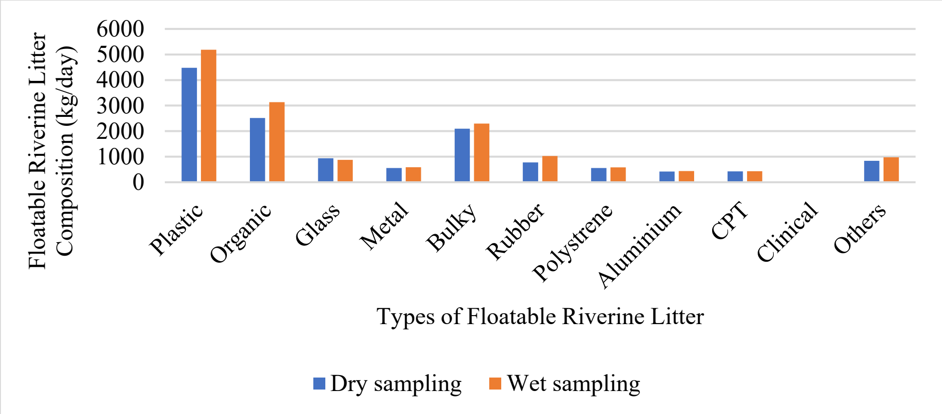

Figure 3: Floatable Riverine Litter Composition

Figure 3 illustrates that the majority of the different types of floatable riverine litter composition that was collected at the log boom structure was composed of household garbage from the residential and commercial regions along Sungai Pinang. The results unequivocally show that, during the wet season sampling, the plastic load at the log boom structure was reported to be 5684.20 kg/day, which is higher than the plastic weight during the dry sampling, which was 5596.00 kg/day. This indicates that the volume of garbage by composition varies significantly between the rainy and dry seasons. This is due to the fact that a number of variables, including consumption patterns, are reaponsible for the variation in waste volume between the dry and wet seasons (Sadri and Thompson, 2014). Plastic waste is a diverse range of materials that includes food packaging, water bottles, plastic bags, and other items. It is evident that illegal dumping and littering operations are the primary cause of much of this waste. The physical characteristics of plastic waste, such as its strength, light weight, electrical insulation, resistance to corrosion, and ability to float on the water's surface (Thompson et al., 2009); low cost, durability, and versatility (Sadri and Thompson, 2014); and disposable nature, make it an obvious source of pollution, particularly in the river system. Consumers can simply dispose of their waste in a number of situations and utilise it often as a result. Previous studies have concentrated on quantifying plastic debris in water bodies, such as rivers, because of the large volume of plastic garbage that has been disposed of in these studies (Gasperi et al., 2014; Sadri and Thompson, 2014; Di-Méglio and Campana, 2017; Tramoy et al., 2019). The majority of plastic waste in river systems has also been detected in different regions, according to Riverine and Marine Floating Macro-Litter Monitoring and Modelling of Environmental Loading (RIMMEL) from the European Commission-Joint Research Centre (2018). These include the Rhone River (77%), Tiber River (82%; Crosti et al., 2018), and Esperana Stream (8.7% to 17.3%) (Salles et al., 2012).

Furthermore, the term "polystyrene" in this study refers to polystyrene, which is easily accessible at log boom constructions in a range of forms, such as food packages and cups. It is widely used in a wide range of consumer product applications and is particularly useful for commercial packaging. Rigid foam and regular solid plastics are two forms of Polystyrene (PS), a naturally transparent thermoplastic. According to this study, it is evident that 569.23 kg of polystyrene were collected per day during the first sampling and 539.11 kg per day during the second sampling. This characteristic allows polystyrene to survive a long period in the natural environment and contributes to the litter problem because the material is typically discarded after a very short usable lifespan (Tony et al, 2015).

In addition, the elements most likely to be recyclable in the composition of floatable riverine litter gathered at the log boom structure were found to be plastic, aluminium, glass, and metal. Moreover, it supports environmental preservation and sustainability even in the event that the market value of some resources changes. Among the floatable riverine litter compositions collected at the log boom structure during both periods of floatable litter sampling on the cleaning operation day, these four types of materials were found to be the least abundant in numbers (Figure 3). Next, the quantity of organic waste collected at the log boom structure during the first sampling, which weighed 4437.66 kg per day, was compared to the second sampling's organic waste load of 12222.48 kg per day. Different cleaning operations were scheduled to correspond with different levels of rainfall and river water flow, which led to different volumes of organic waste being recorded during the floatable litter sampling at the log boom structure. The log boom structure's abundant organic waste, which included fruits, vegetables, and food items, was consistently in line with the findings of Saidan et al's (2017) investigation. According to Figure 3, medical waste contributes 25 kg of weight per day during the wet season and 20 kg per day during the dry season. The higher frequency of COVID-19 infections has been linked to an increase in the amount of medical waste. This is due to the fact that more disposable medical products, such as masks, coveralls, gloves, and other items, are being utilised to treat COVID-19 patients. The growing use of cleansers and disinfectants by hospitals and clinics has also resulted in an increase in the quantity of medical waste.

The Relationships between Floatable Riverine Litter Generation, Composition and Rainfall

There are consequences for environmental science and sustainable waste management techniques from the complex and ecologically significant relationship that exists between the production of floatable riverine waste and rainfall data. This complex relationship highlights the significance of comprehending, tracking, and reducing the effects of litter on our aquatic ecosystems in the context of shifting precipitation and weather patterns. It also reflects the complex interactions between natural processes, human activity, and climate variables.

Figure 4 illustrates the relationship between the development of cumulative rainfall data and the generation of cumulative floatable litter during a 14-day cleaning operation at the log boom for two distinct sampling seasons. The findings indicate a strong correlation between the two variables: cumulative rainfall data and floatable litter generation during dry sampling, with $R^2 = 0.9673$, $r = 0.9881$ ($p < 0.01$); and cumulative floatable litter generation and wet sampling, with $R^2 = 0.9816$, $r = 0.992$ ($p < 0.01$).

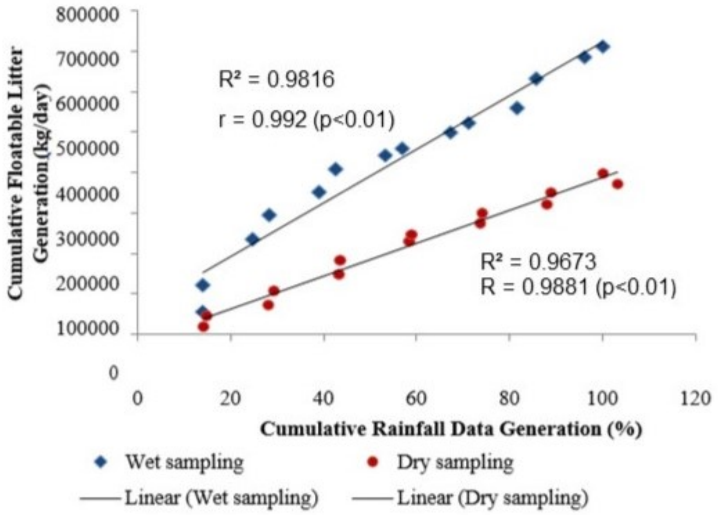

Figure 4: The Relationships Between Floatable Riverine Litter Generation, Composition and Rainfall Data Generation

Rainfall data can be presented as a percentage to indicate the likelihood of precipitation in a specific location or period of time. This percentage represents the probability that measurable rainfall will occur at a given place over a given time frame, usually one or more days. Because rainfall events generated runoff, which in turn readily carried and washed out the floatable trash from land-based sources into the main river system, they played a crucial role in the hydrology of this study. Furthermore, rainfall events have the ability to transport and introduce new floatable litter materials into the waterways system as well as reassemble the floatable litter that has been deposited along riverbanks, as Castro-Jimenez et al. (2019) have convincingly shown.

Estimation Revenue Loss from the Potential Recyclables

The materials that can be recycled the most from riverine litter are aluminium, glass, metal, and tetrapak (CPT), as well as plastic, cardboard, and paper. Observations made during data collection indicated that metals were mostly obtained from aluminium cans, while food packaging, such as drink and pizza boxes, accounted for the bulk of CPT. Aluminium cans are highly desirable materials because of their high cost and large recycling potential. The weight of all possible recyclables from the Sungai Pinang log boom that can be recycled is shown in the following statistics.

Table 2: Estimation Revenue from Potential Recyclables Floatable Riverine Litter

Types of Potential Recyclables	*Total Quantity (kg)*	*Unit price/kg (RM)*	*Revenue Loss Value (RM)*
Plastic	9663.00	0.40	3865.20
Glass	1817.00	0.10	181.70
Metal	1142.00	0.20	228.40
CPT	855.00	0.45	384.75
Aluminum can	858.00	2.00	1716.00

The entire amount of floatable riverine litter generated throughout both the wet and dry seasons has been used to calculate and summarise the weight of potential recyclables. Evaluating the number of recyclable materials in riverine trash can also be used to calculate the possible economic and environmental gains from recycling initiatives. It can also be used as a starting point to track changes in plastic pollution over time and assess how well conservation efforts are working. The estimated revenue was calculated using the most current litter collection prices from Alam Flora Sdn Bhd. Consequently, in light of the anticipated revenue mentioned above, the local government ought to support recycling initiatives. The community may reduce waste while earning money with these efforts. Trash minimization should be promoted because Malaysia's landfills are unable to handle the increasing amount of trash produced annually. To sum up, in order to tackle the issue of increasing waste generation and promote a sustainable and eco-friendly community, local authorities in Malaysia need to prioritise the promotion of responsible waste management practices, recycling initiatives, and waste reduction incentives. These initiatives have the power to promote social interaction and economic advancement in addition to improving the environment.

CONCLUSION

Overall, a comprehensive assessment of waste generation and its economic impacts was conducted at the log boom in Sungai Pinang. Through systematic sampling and categorization, we have identified significant quantities of plastic, organic matter, and other debris that contribute to the environmental degradation of the river. The correlation with rainfall data highlighted the influence of precipitation on the influx of litter, underscoring the need for targeted interventions during heavy rain events.

The economic analysis revealed substantial revenue losses attributable to the management of riverine litter. Cleanup costs, negative impacts on local fisheries, and reduced tourism revenue collectively illustrate the financial burden imposed by this environmental challenge. These findings underscore the importance of investing in effective waste management strategies, such as improved waste collection infrastructure, public education campaigns, and policies aimed at reducing litter at the source.

In the end, this study emphasises how critical it is to take a multipronged strategy to solving the problem of floatable riverine litter. Educating the public, policymakers, and local authorities about the scope and financial implications of this issue is intended to promote increased cooperation and dedication to long-term solutions. The knowledge acquired from this study can also be a useful guide for other areas dealing with comparable issues, supporting more extensive initiatives in environmental preservation and economic resilience.

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