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RIVERINE LITTER ASSESSMENT AND RECYCLING POTENTIAL ALONG SUNGAI KELANTAN AT KAMPUNG PASIR ERA, KELANTAN, MALAYSIA

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Abstract

Nowadays in Malaysia, riverine litter has become a major environmental problem. Knowledge of solid waste generation, composition and recyclability is necessary for accurate decision making in the management strategy of municipal solid waste. This study is conducted to assess riverine litter and its recycling potential along Sungai Kelantan at Kampung Pasir Era Kelantan. The objectives are to determine the generation and composition of riverine litter and to evaluate the recycling potential of the litter. The waste samples are collected over a 14-day period at three different zones within the study area. Through quantification method, composition, proportion and the average daily total weight of the litter were determined. Findings show that the total weight of waste collected for all zones throughout the 14 days operation was found to be 70.912 kg out of which the upper-bank generated 25.9 kg. The result also shows that plastic has the highest contribution to riverine litter with 68.20%. Additionally, estimated revenue from potentially recyclable litter generated in 14 days was RM33.96. This study provides the local authority and relevant agencies with baseline information for effective management of riverine litter based on recycling potentials.
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Keywords: riverine litter, quantification method, recycling, riverbank, solid waste, revenue estimates

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INTRODUCTION

The term riverine litter refers to litter present in rivers and on river bank referred to it as solid waste being disposed or washed away into the river (Malik & Manaf 2018). Small urban rivers are thought to be major sources of riverine litter, especially macro-plastics, into the ocean (Tramoy et al., 2022). The study of riverine litter is very important as it is not only protecting the direct usage of freshwater, but also the merits of protecting riverine ecosystems (Owens et al., 2020). Even though marine debris are often discussed as the threat to the environment, riverine litter issues are very important as it can threaten the environment, human health and socio-economic activities. Estimates show that between 1.15 and 2.41 million tonnes of plastic waste currently enters the ocean every year from rivers, with over 74% of emissions occurring between May and October (Lebreton et al., 2017). There are many activities that lead to riverine litter issues such as illegal dumping and improper solid waste management by people in communities. The attitude of the people plays a vital role in influencing riverine litter. For instance, many rural areas in Malaysia are not provided with solid waste collection service due to the budget limitation by the local authorities. This makes most of the community members to throw their wastes into rivers. While most communities in urban area receive solid waste collection services, only 66% coverage is found in rural areas (Ya'acob et al., 2019).

Kampung Pasir Era is located outside the service area of Kuala Krai Municipal Council. Hence, members of the community are responsible for the disposal of the solid waste they generate. Usually, they manage and dispose their solid waste by open burning and dumping on the ground. Without a proper management, most of the solid waste gets into the river system when there is rainfall or settle on the riverbank. Storms and huge floods can transport solid waste between riverbanks and dump it far away from the water's edge, where it gathers until being washed away by another high flood (Roebroek et al., 2021). In this community, people are getting aware of the implications of riverine litter, however they tend to continue throwing their waste carelessly. For instance, despite ten years of "clean river" programmes, 700kg of trash is thrown every day into the Sungai Klang, the main river that runs through downtown Kuala Lumpur and Greater Kuala Lumpur (The Straits Times 2022). In addition, the people tend to ignore the negative effects arising from their actions and no mitigation measures are taken by all parties.

An efficient means of managing wastes is by recycling but the potential for recycling riverine litter is quite challenging. Recycling is an important part of municipal waste management and resource efficiency strategies, as well as industrial processes (Abd Rauf et al., 2021). Daily, Malaysians produce roughly 38,699 tonnes of solid garbage, or about 1.17 kilogrammes per person (Malaysia Versus Waste Features the Chemical Engineer, 2022). Recent record shows that

this year's National Recycling Rate increased to 31.52 percent, up from 30.7 percent previous year, with recyclables totalling 4.3 million tonnes (The Sun Daily, 2022). However, the recycling rate is still low as the National Recycling Rate is targeted at 40% by 2025. Therefore, by assessing the potential recyclable material from riverine litter, recycling rate can be increased thereby reducing the waste disposal at the landfills.

According to Malik and Manaf (2018), quantifying the types and abundance of riverine litter not only provides baseline data for the waste reduction programmes, but it can also describe the potential of recyclable materials from the waste stream. There is not enough data to provide solutions to riverine litter as there are only a few studies on riverine litter especially on plastic materials (Sadri & Thompson 2014). It is vital to have a sufficient data on riverine litter materials so that it can be assessed for recycling purposes after the litter collection from the river is done.

Thus, this study is conducted to assess riverine litter and its recycling potential along Sungai Kelantan at Kampung Pasir Era Kelantan. The objectives are to determine the generation and composition of riverine litter and to evaluate the recycling potential of the litter. Riverine litter quantification and composition are very important in understanding the attendant problems associated with it and recommending solutions to solve such issues. This study anticipates that quantifying the types and abundance of riverine litter will help organisations involved with waste management to provide proper management solutions and baseline data for waste reduction programmes.

MATERIAL AND METHODOLOGY

Study Area

Sungai Kelantan is a major river in Kelantan (Figure 1). Its drains a catchment area of about 11,900 km^2 in north-east Malaysia including a part of Kuala Koh National Park and flows northward to South China Sea. For this research, Sungai Kelantan along Kampung Pasir Era in Kuala Krai district was selected as the study area. Kampung Pasir Era is situated in Kuala Krai, Kelantan. Its geographical coordinates are 5° 32' 2" North, 102° 11' 58" East and with about 1.3 km length. It consists of 700 people with various background. Kampung Pasir Era was selected as the study area being a non-serviced residential area and transportation centre that connect the river to the other sides of Sungai Kelantan.

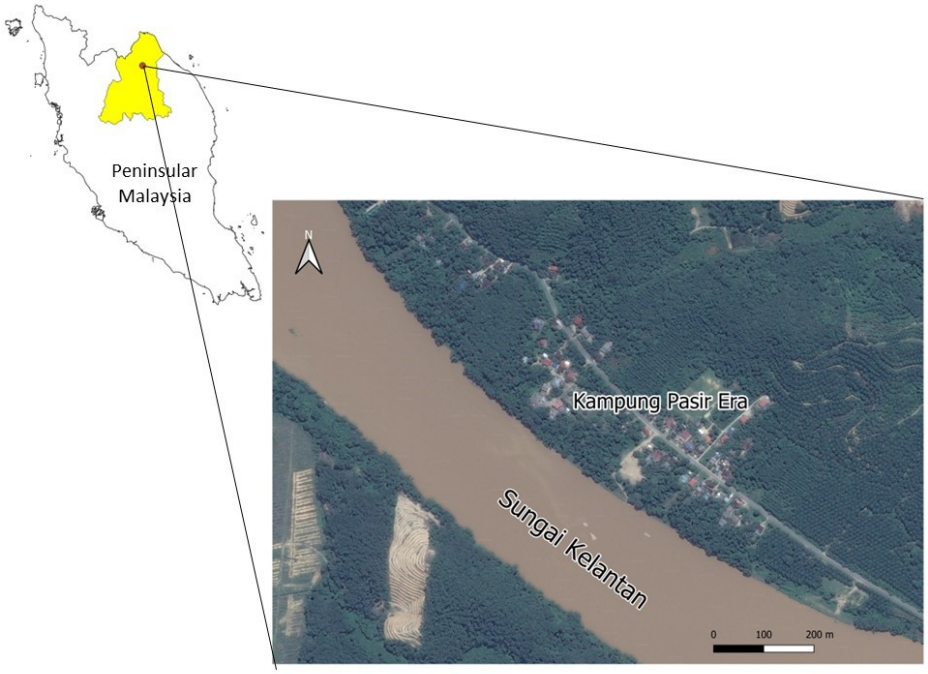

Figure 1: Study area along Kelantan River in Kampung Pasir Era.
Source: Google Map, 2023

Sampling Procedure

For litter sampling, only the river bank was considered and no litter was sampled from the river bed. The study area was divided into three zones namely the river shore, mid bank and upper bank. For each zone, three circles with 2-meter radius were sampled. Being an uneven riverside ground, with rocks and vegetation, it is often difficult to mark the sampling area with standard quadrats. Therefore, sample in circle was chosen, which was defined by fixing a line with the length of the radius in the center of each circle, and marking the outer edge of the circle along the tightened rope. Everything visible within the given area that is attributable to human activity was collected. 14 days of sampling for riverine litter collection was conducted within the months of August to October as per Malik and Manaf (2018). These months are usually rainy seasons in Malaysia.

Secondary Data for Maximum Wind Speed and Total Rainfall

A secondary data of maximum wind speed and total rainfall for 14 days of operation day was obtained from World Weather Online. The data for both parameters is shown in Table 1.

Table 1: Maximum Wind Speed and Total Rainfall for 14 Days

Day	Rainfall (mm)	Wind Speed (kmh)
1	1.6	6
2	0.9	5
3	0	3
5	0.1	3
5	1.4	4
6	0	4
7	0.1	4
8	0.1	4
9	0.6	5
10	1.1	4
11	0.8	4
12	0.9	5
13	4	4
14	1.9	8

Source: Kuala Krai, Kelantan, MY Historical Weather Almanac

Quantification Method

Quantification method is used for determining the sorts of things dumped in a waste stream and the proportions in which they are disposed (Alias et al., 2019). This study employed quantification at the waste collection point. Sorting was carried out on the same day after the waste was collected. After every session of waste sampling, the waste was analysed by sorting and weighing according to its type. The sample of waste was segregated manually into eight different components and placed in containers. In this study, the riverine litter composition was classified into eight different types of waste (plastics; metal; cardboard/paper/tetrapak (CPT); glass; bulky waste; napkins; rubber; textiles; and others). The weight of each sorted composition was measured with a weighing balance and recorded. At the end of every sorting, the individual weights were summed together to give the average daily total weight of riverine litter collected. Finally, the percentage composition of each of the components was then calculated.

Revenue estimation for recyclable litter

Recycling is an important part of municipal waste management and resource efficiency strategies, as well as industrial processes (Hotta et al., 2015). Differentiating the solid wastes among recyclable and non-recyclable categories was done after obtaining the weight percentage of each individual component. Among the waste materials found, only plastics, glasses, CPT and aluminium were considered for recycling, hence, how much they cost was sought for. Table 2 shows the price list for recyclable materials based on current market price from

Alam Flora. The estimated value for recyclable material is calculated by converting the total weight of potential recyclable material into Malaysian Ringgit (RM). The calculation is done using the following equation adapted from revenue estimation described in Samah et al., (2015).

$$E_r = T_w \, xW_p \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots... \quad \text{Eq 1}$$

Where:
ER = Estimated revenue
Tw = Total weight
Wp = Price of waste material

Table 2: Price list for recyclable materials

Litter type	Price per kg (RM)
Plastic	0.40
Glass	0.10
CPT	0.45
Aluminum	2.00

Source: (Oon,2022)

Data Analysis
The study utilised both descriptive and inferential statistics to analyse the data obtained. Descriptive analysis was used to describe the characteristics of the collected samples along the Sungai Kelantan in Kampung Pasir Era. It is very useful to collect information on the total weight of riverine litter during the sample collection and the weight of different types of waste composition; the means, standard deviation (SD) and range of minimum and maximum value for each variable; and others relevant information. For the inferential statistics, one way analysis of variance (ANOVA) was conducted to compare the mean between variables and to identify the significant difference between variables (i.e., between the litter collected at the river shore, middle-bank and upper-bank)

ANALYSIS AND DISCUSSION
Composition of riverine litter
Figure 2 shows the percentage composition of waste collected at the riverbank along Sungai Kelantan at Kampung Pasir Era. Plastic has the highest contribution to the riverine litter with 68.20% while textiles had the least contribution with only 0.92%. The mean and SD of the composition of the collected waste is also shown in Table 3. Most of the plastic waste come from various sources such as food packaging, water bottle, plastic bag and polystyrene. Since Kampung Pasir

Era is within the non-service area of Kuala Krai District Council (KKDC), there was no bin provided at the area. Hence, the people tend to litter instead of throwing it at a designated area. Similar composition or riverine litter was reported in Malik and Manaf (2018) and was attributed to illegal dumping and littering activities and subsequently transported into the river by water surface runoff.

Additionally, Schirinzi et al 2020 studied two rivers the Llobregat and Besòs located in Catalonia, to analyse the riverine anthropogenic litter load. Results showed similar waste composition in both rivers, mostly represented by plastic material: 67.7% and 50.5% respectively. Plastic pollution in aquatic environments is one of the most fatal environmental issues in the world (Battulga et al., 2019).

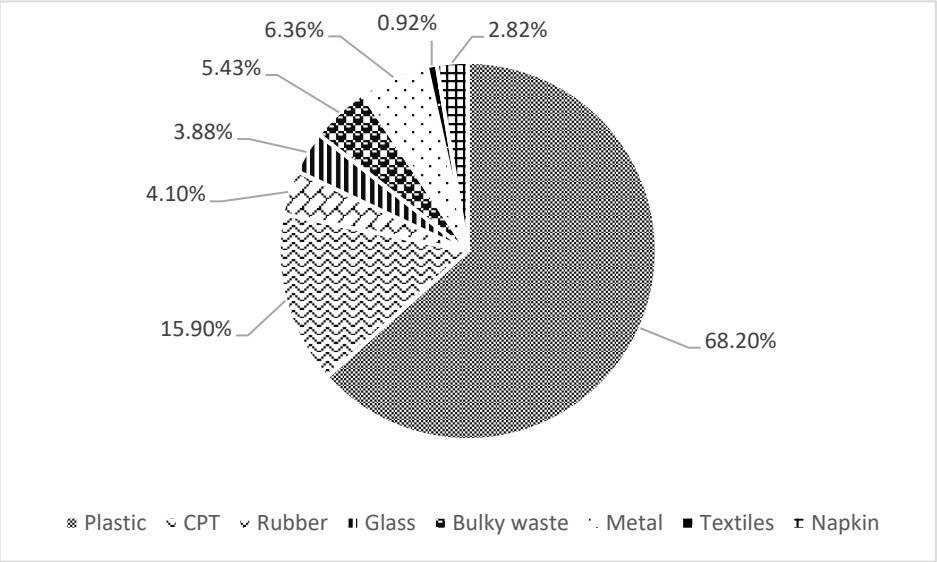

Figure 2: The proportion of riverine litter (% by weight)

Table 3: Riverine litter composition (Mean ± standard deviation)

Litter type	N	Minimum	Maximum	Mean	Standard deviation
Plastic	14	2.26	4.93	3.4564	0.67041
CPT	14	0.52	1.13	0.8100	0.18322
Rubber	14	0.00	0.59	0.2086	0.20501
Glass	14	0.00	0.880	0.1964	0.30631
Metal	14	0.00	0.86	0.3221	0.31445
Napkin	14	0.00	1.00	0.1429	0.36314
Bulky waste	14	0.00	2.00	0.2500	0.64301
Textile	14	0.00	0.65	0.0464	0.17372

Daily Riverine Litter Generation by zones

At the river shore, day 14 recorded the highest total weight collected at the river-shore (2.69 kg) as indicated in Figure 3. This is due to the maximum wind speed and total rainfall during Day 14 which is higher compared to other days as earlier shown in Table 1. The lowest waste generated at the river shore was during Day 2 as the total rainfall and wind speed on that day was moderate. Wind plays a vital role as a transportation agent to transport litter to the riverbanks compared to precipitation and water level. High wind speed will transport the litter from upper- bank to middle-bank and river-shore. Runoff from precipitation, has been proposed as a major factor in litter transport (Roebroek et al., 2021).

At the middle-bank, the pattern of riverine litter generation was similar to that of the river shore on some operation days and differed on others as observed in Figure 2. Day 14 shows the highest amount of riverine litter at the middle-bank while Day 12 recorded the lowest amount of riverine litter. The variations in wind speed recorded on both days may have contributed to the trend. Eventually the litter from the upper-bank will be transported to the middle-bank.

For the upper-bank, the riverine litter generated peaked on Day 9 while Day 1 recorded the lowest amount of riverine litter. Low wind speed and minimum total rainfall influence the movement of the litter at the riverbank as the litter tend to stay at the upper-bank. Also, human activities could have led to the higher riverine litter generation based on the high the number of vehicles parked at the upper-bank. Studies have reported that the major source of riverine litter is recreational activity near the riverbank (Gasperi et al., 2014) and high urban activities in that area (Carson et al., 2013).

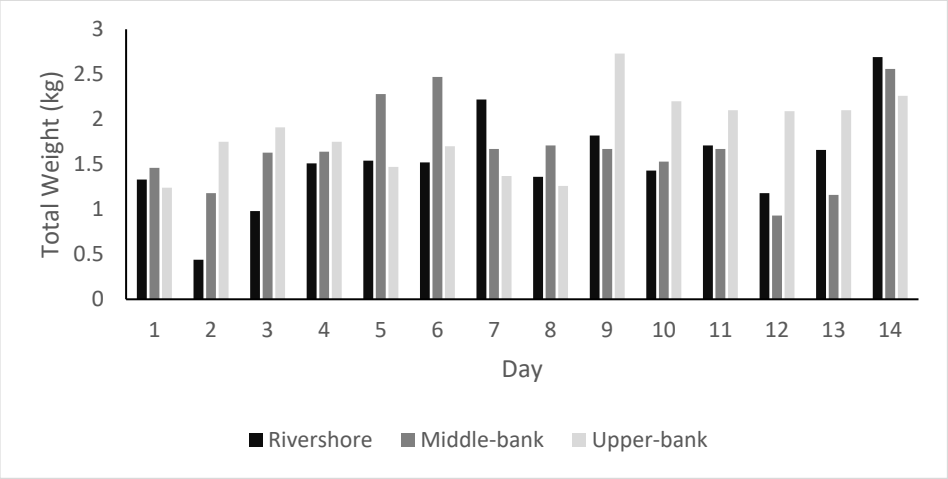

Figure 3: Daily riverine litter collected during 14 days by zones.

Total weight of riverine litter for each zone of riverbank

The result in Figure 4 shows the total weight of riverine litter for each zone of riverbank. As indicated, the upper-bank generated 25.9 kg of litter which is the highest total weight of riverine litter collected during 14 days operation. On the other hand, the operation at the river shore contributes the lowest amount of riverine litter which is 21.4 kg. Also, Table 4 shows the weighted average amount and SD for total weight of riverine litter at the upper-bank was 1.5821 ± 0.4286 (kg/operation day) while it was 1.5279 ± 0.5297 (kg/operation day) at the river shore. One-Way ANOVA test was conducted to identify whether there is significant difference between total weight of riverine litter at the river shore, middle bank and upper bank. Based on the results in Table 5, there is no significant difference between each zone as $p = 0.214$ is larger than 0.05. Even though there is high waste accumulated at the upper bank, the presence of wind speed and rainfall will redistribute the waste to the other part of riverbank.

The upper-bank contributed the highest amount of riverine litter due to its location near the main road. Besides, as Kampung Pasir Era is a transportation centre for the people to go to the other side of the river, several parking lots are provided for the vehicles. Most of the people park their vehicle at the upper-bank of the river. The frequency of illegal trash along riversides is thought to be influenced by the land use and accessibility of the area, particularly to vehicles (Samah et al., 2015). The river shore has the lowest amount of riverine litter because it is located near the water. According to Rech et al (2015), river shore is located at the edge of water with maximum three meter away from water. It is

permanently in contact with the water. Therefore, the litter at the river shore will be carried away constantly into the river compared to upper bank which is located further away from the water body.

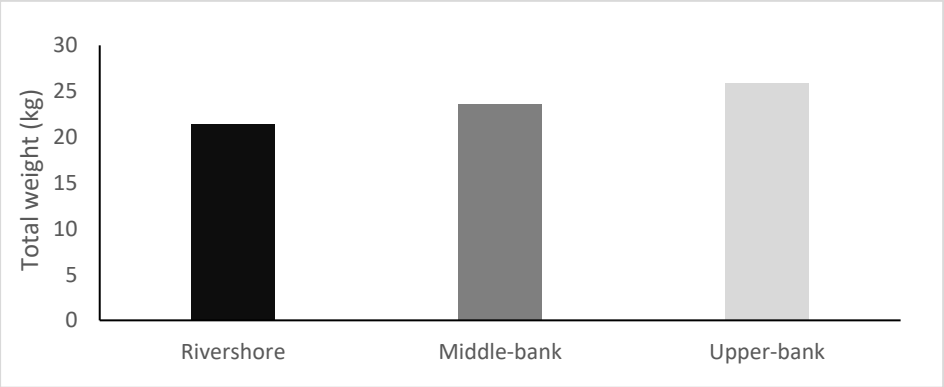

Figure 4: Total weight (kg) of riverine litter collected for each zone

Table 4: Descriptive analysis for total weight of riverine litter for each zone

Zones	N	Minimum	Maximum	Mean	Standard deviation
River shore	14	0.44	2.69	1.5279	0.52970
Middle bank	14	0.93	2.56	1.6829	0.47373
Upper bank	14	1.24	2.73	1.5821	0.42865

Table 5: ANOVA for waste generation at different zones.

Source of variation	Sum of squares	df	Mean squares	p-value
Between groups	0.737	2	0.368	0.214*
Within groups	8.954	39	0.230	
Total	9.690	41		

**Not significant*

Total Riverine Litter Collected per operation day at Kampung Pasir Era

The result of the total weight of waste collected for all zones per operation day at the study area from August until October 2021 is shown in Figure 5. Overall, the combined weight throughout the 14 days operation was 70.912 kg. Specifically, the result shows that Day 14 contributed the highest amount of riverine litter collected during operation days at 7.51 kg/operation day due to the high heterogeneous nature of the waste. However, the operation during Day 2 contributed the lowest amount of riverine litter at 3.37 kg/operation day due to the small amount of plastic waste collected on that day with 2.26 kg/day compared to other days. In addition, there was no glass and metal waste collected on Day 2, leading to small amount of riverine litter. In this situation, even though

there are a variety of possible causes of litter along rivers, such as boats, sewage, and rainwater runoff, illegal dumping appears to be a substantial source of litter along the rivers surveyed, as observed in Malik et al (2018). Alternatively, it may be caused by the poor solid waste management and the lack of awareness among the community.

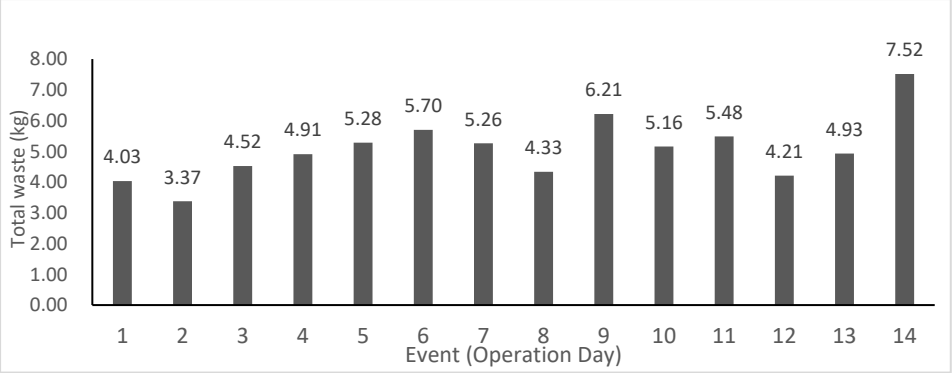

Figure 5: Total weight(kg) of riverine litter during 14 days of operation day.

Many people do not know about the implication of littering, especially at the riverside. The accumulation of floating litter, particularly plastic garbage, has been linked to a lack of recycling, waste management, and littering behavior on a global scale.

Potential recyclables material from riverine litter composition

The most potentially recyclable materials from riverine litter are plastic, cardboard, paper, tetrapek (CPT); glass, and metal. As found in this study, the composition of plastic is 68.20% (3.456 ± 0.6704), CPT; 15.9% (0.81 ± 0.1831), metal; 6.36% (0.3221 ± 0.31445) and glass; 3.88% (0.1964 ± 0.3063). Based on the observation during data collection, most of CPT were derived from the food packaging like pizza boxes and drink boxes meanwhile metals were mostly derived from aluminium cans. Aluminium can is one of the most sought-after materials with high potential to be recycled due to its high price. Table 6 shows the estimates of potential revenue that can be generated from the sale of riverine litter collected at the riverbank in Kampung Pasir Era for the purposes of recycling. The estimated revenue was calculated based on the current prices of litter obtained from Alam Flora Sdn Bhd. Going by the results, revenue generated for litter in 14 days was RM33.96. It implies that the average revenue per day will be RM2.43 and approximately RM75.33 in a month if the same quantity of litter is generated.

Therefore, based on the estimated revenue recorded, recycling activities should be encouraged by the local authority. The villagers can reduce their waste and earn money from these activities. Waste minimisation should be promoted as the landfills cannot support more waste in the future as the waste generation in Malaysia is increasing rapidly by the year.

Table 6: Estimated revenue from litter collected at the riverbank

Litter type	Quantity (kg)	Unit price/kg (RM)	Value (RM)
Plastic	48.93	0.40	19.57
Glass	2.75	0.10	0.27
CPT	11.34	0.45	5.10
Aluminum can	4.51	2.00	9.02
Total			33.96

CONCLUSION

In conclusion, there is high abundance of riverine litter along Sungai Kelantan at Kampung Pasir Era with the total weight collected for 14 days is 70.912 kg (5.0651±1.1097 kg/operation day). Event 14 contributes the highest amount of riverine litter collection which is 7.51 kg/operation day. Upper-bank recorded the highest waste collected compared to other zones with the total weight 25.9 kg 1.8521±0.4286 (kg/operation day). For the waste composition, plastic dominantly contribute to the riverine litter with 68.2%. The estimated revenue for high potential recyclable material is RM 33.96. Based on this study, the data on waste generation and composition can be used for the knowledge contribution regarding the solid waste management to solve the riverine litter issue in Malaysia. Other than that, the government should make a new policy about the service collection in the rural area as there are improper solid waste management in that particular area. Besides, awareness campaign for the villagers should be held so that they are more responsible of their actions and improve their attitude.

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