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MARINE DEBRIS COMPOSITION AT THE UMS OUTDOOR DEVELOPMENT CENTRE BEACH USING THE TRASH ANALYSIS METHOD

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Abstract: Marine debris is a ubiquitous pollutant due to its persistence, durability, and flexibility. Many negative environmental and economic impacts of marine debris have been studied, including habitat destruction, diseases, and mortality, which can jeopardise ecosystem services. It has become a major concern, especially since Malaysia has adopted the United Nations' Sustainable Development Goals (SDGs). This study aims to quantify the composition of debris collected from the UMS Outdoor Development Centre beach through trash analysis. On average, 5111 items/day with a total weight of 356.8 kg were collected during the 3-day sampling period. Based on the analysis, the most abundant type of debris at the beach is plastic (88.6%), which comprises plastic bags, food wrappers, and plastic bottles, followed by paper (8.4%). Findings from this study provide insights into the severity of marine debris, especially plastic materials and their origin in the study areas. This can be valuable evidence to raise the urgency for the local government and the policymakers to enforce stricter laws and better solid waste management strategies in the affected areas. Further studies on the composition of debris during seasonal changes to understand the transportation pattern of debris by water currents and wind movement are recommended.

Keywords: Marine debris, trash analysis, plastic, sustainability, pollutants.

Introduction

Marine debris is, by definition, artificial waste that is persistent in water bodies that are intentionally or accidentally released into the ocean or the waterways (Fauziah *et al*., 2021). Marine pollutants, especially plastic debris, have become a major concern over the years as plastic production and consumption increase significantly. According to Chen *et al.* (2021), people have relied on plastic products in all facets of their everyday lives since the 1940s due to their durability, persistence, and versatility, making plastic manufacturing the fastest-growing industry. Currently, the packaging industry holds the largest market of plastics in the world, where the production of single-use plastics is at the forefront.

Debris that accumulates in the ocean can come from a multitude of sources. Fauziah *et al.* (2021) mention that "numerous researchers have concluded that 85% of marine debris is sourced from land-based activities and only 15-20% comes from sea-based activities". This shows that debris from anthropogenic sources, mainly from land-based activities such as construction, illegal dumping, and domestic runoffs, while sea-based activities such as fishing, aquaculture, and nautical activities make up a major fraction of debris in the environment. Since aquatic and terrestrial ecosystems are interconnected, shifts in any ecosystem will influence changes in the other (Thushari & Senevirathna, 2020). This includes the transport of anthropogenic marine debris from land-based activities by wave and wind, ocean currents, tidal movements, and animal movements (Fauziah *et al.,* 2021).

Undoubtedly, stressors from anthropogenic activities inflict serious physical damage and stress on the environment, as well as its

inhabitants. Excessive ingestion of plastic pollutants of various sizes puts them in danger of suffocation and blockage (Ryberg *et al.,* 2018). Other harmful effects of plastic ingestion include changes in feeding and predatory behaviour, reduced sensitivity, and decreased reproduction ability (Thushari & Senevirathna, 2020; Amelia *et al.,* 2021). Marine animals are also at risk of entanglement, which can cause suffocation and injuries. Marine debris could also destroy coastal seascapes that provide fundamental services to their inhabitants and humans (Sambrook *et al*., 2019). These implications can be lethal, which raises concerns about maintaining biodiversity and species richness.

The severity of marine plastic pollution reflects the mentality and awareness of the local community on waste management. In Sabah, littering and mismanagement of waste seem to be the biggest contributor to debris input into the environment, which puts the state under threat of environmental degradation. Additionally, many islands in Sabah, for instance, Pulau Gaya and Pulau Sepanggar, are home to the Bajau Laut community. Complications related to solid waste management are also amplified by illegal immigration and squatting (Girl *et al.,* 2020), where most settlements are built on the water. Established garbage disposal and collection systems do not exist in illegal settlements, resulting in waste littering into river basins or directly into the ocean.

Located within the Sulu-Sulawesi Marine Ecoregion alongside Indonesia and the Philippines, Sabah is recognised as part of the Coral Triangle, the world's centre of marine biodiversity (Santodomingo *et al.,* 2021). Plastic debris pollution causes devastating impacts on the marine environment and its biodiversity. As the rest of the world progresses into a more environmentally conscious lifestyle, Malaysia has adopted the 17 Sustainable Development Goals, which provide a blueprint for sustainable growth, encompassing health and education, social equality, and economic growth. Such initiatives are a great way to redirect the future of Malaysia towards green growth.

Materials and Methods

Study Area

The private beach area of the UMS Outdoor Development Centre (ODEC) is located on the west coast of Sabah, where it stretches over 650 m along the Kota Kinabalu coastline (Figure 1). The ODEC beach can accommodate 300 people at a time and features an archery range and a kayak course. It also has a spacious land area perfect for recreational activities, such as picnics, retreat programs, and beach clean-ups (Zahari *et al.,* 2022). Despite being isolated from other public beaches, the beach has become a well-known leisure spot among UMS students and some local residents.

In addition to that, the ODEC beach is directly opposite Pulau Sepanggar and Pulau Gaya (Figure 2), which have become home to many island communities living in houses on stilts. Kampung Pulau Sepanggar is one of the water settlements of the Bajau Ubian community in Pulau Sepanggar, and Kampung Kesuapan and Kampung Lok Urai are two of the water settlements in Pulau Gaya.

Trash Analysis

Trash analyses were conducted along the ODEC beach (Figure 3). They were done when the tide was low, which exposed the debris washed up on shore. The first round of sampling was done in conjunction with the Ocean Celebration Beach & Underwater Clean Up 2022, organised by the Marine Borneo Research Institute (BMRI), Universiti Malaysia Sabah, where 100 participants volunteered. Meanwhile, another two rounds of clean-up activities were joined by five postgraduate students.

Most of the debris within the beach area was collected from beach clean-up activities, where the sampling site extended vertically from the vegetation area to the water edge (Windari *et al*., 2022). Any debris that was visible within the sampling site was collected. Those embedded within the sand were dismissed as permanent debris. After collection, the debris was segregated and quantified through trash

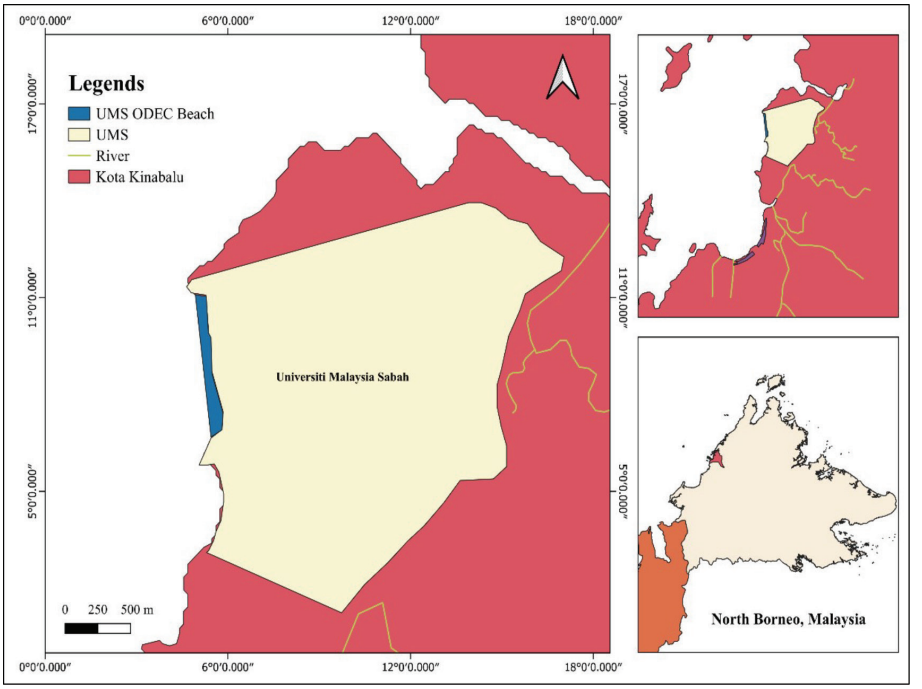


Figure 1: The map of the study area, UMS ODEC Beach

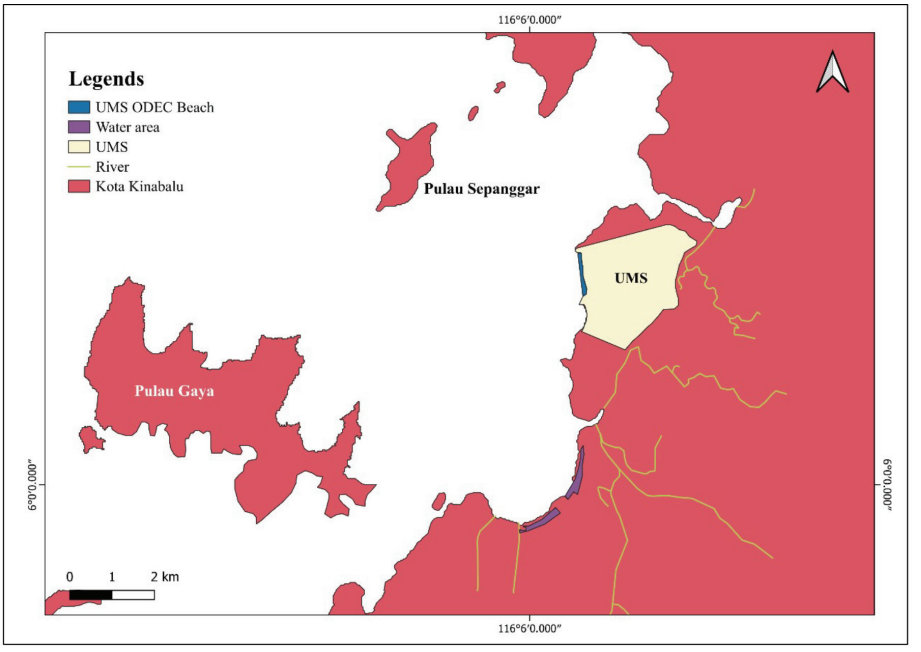


Figure 2: Location of Pulau Gaya and Pulau Sepanggar

Figure 3: Beach clean-up activities at UMS ODEC beach during Ocean Celebration Beach & Underwater Clean-Up 2022

analysis. The total weight of the collected debris was measured using a portable weighing scale.

During the segregation process, the debris was classified into six categories: Plastic, fabric, paper, metal, rubber, and glass (Azam *et al.,* 2018; Santodomingo *et al*., 2021). The coordinates, weather conditions, description of sampling sites, and types of collected debris were recorded in the survey sheet (Appendix A), and only one person was put in charge of the notation to avoid confusion and inconsistency. All volunteers involved in the clean-up and analysis were well-informed of related knowledge. A few criteria included for segregating the collected debris were described in the trash analysis survey form (Appendix A).

All data obtained from the sampling activities were analysed using SPSS Statistics. The debris composition, total amount, and weight were computed using the formula in Appendix B. The beach cleanliness was determined using the Clean Coastal Index (CCI), where the equation used is as follows:

$$CCI = \left(\frac{total\ number\ of\ plastic\ parts}{area\ of\ sampling}\right) \times K \quad (1)$$

K coefficient value = 20

The values were compared to the ranking (Marin *et al*., 2019), which is "very clean" (≤ 2); "clean" (2–5); "moderate" (5–10); "dirty" (10–20); or "extremely dirty" (≥ 20).

Results and Discussion

This study examines the composition and quantification of debris accumulated at the ODEC beach. On average, 5,111 items/day with a total weight of 356.8 kg were collected during the 3-day sampling period. Based on the analysis, the most abundant type of debris at the beach is plastic (88.6%), as shown in Figure 4, followed by paper (8.4%). The plastic debris is dominated by plastic bags, food wrappers, and plastic bottles, all of which come from human activities. The lowest type of debris collected was glass, at 1.4%.

The collected plastic debris was further categorised based on its macro-sized or

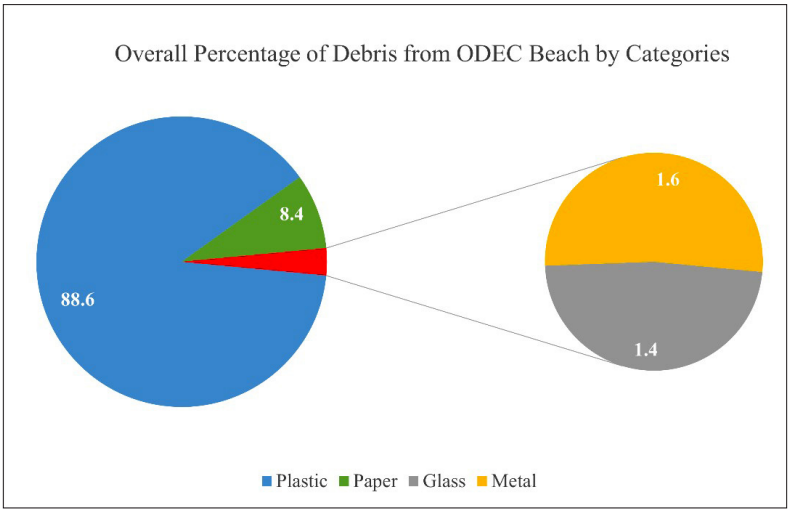


Figure 4: The overall percentage of debris collected along ODEC beach by categories

meso-sized size. As expected, the amount of macroplastics collected during all the sampling days was significantly high, with the third sampling day having the highest amount at 6,095 items (Figure 5). Meanwhile, the amount of collected mesoplastics was the highest during the first sampling day at 2,250 items. On average, the amount of macroplastics collected was 5,878 items/day, while the amount of mesoplastics was 2,057 items/day.

Based on Figure 6, plastic packaging makes up most of the plastic debris collected on every sampling day at an average of 3,994 items/day, followed by mesoplastics of unidentified origin at an average of 2,057 items/day. Plastic packaging, such as beverage bottles, food wrappers, and plastic bags, is the most abundant. Diapers, personal care and beauty products, and fabric items, categorised under household items, were collected at an average of 954 items/day. Miscellaneous debris items, categorised under

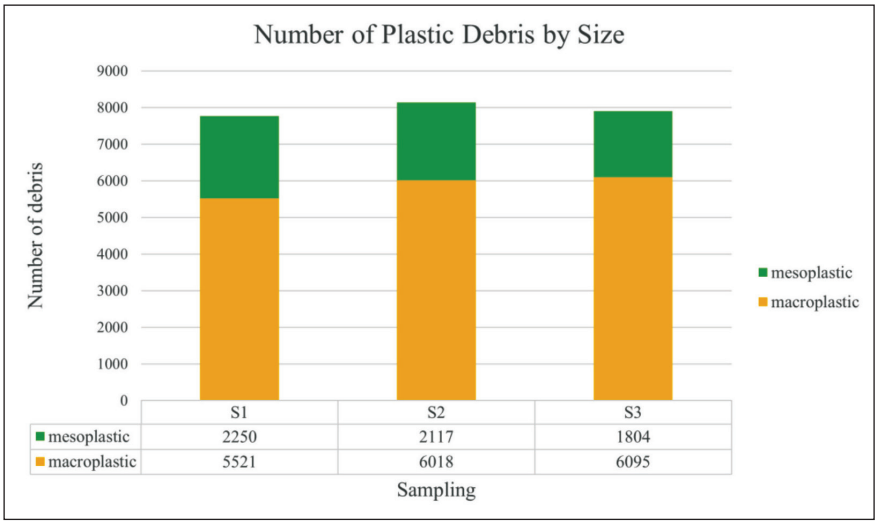
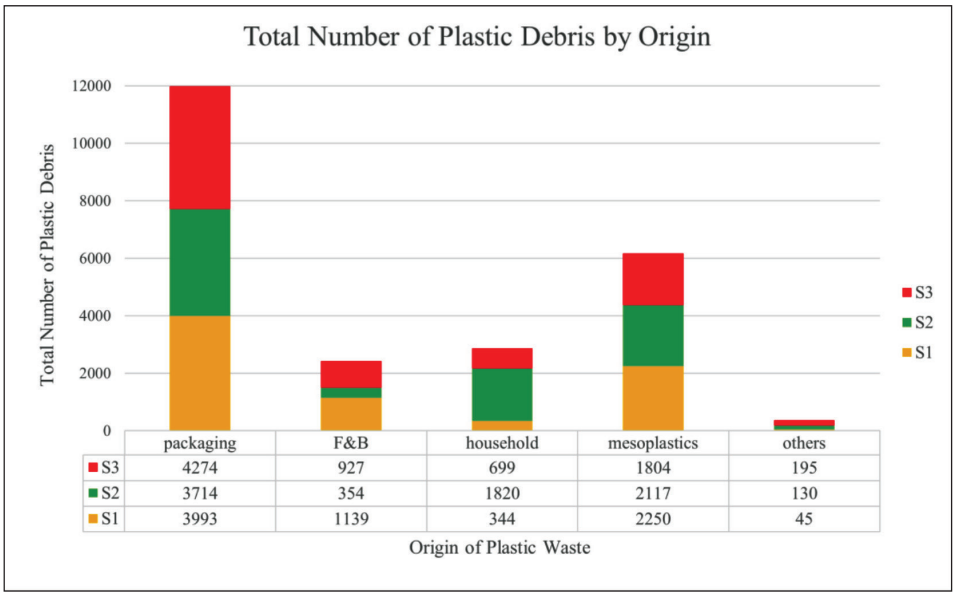


Figure 5: The number of plastic debris categorised by size



	packaging	F&B	household	mesoplastics	others
S3	4274	927	699	1804	195
S2	3714	354	1820	2117	130
S1	3993	1139	344	2250	45

Figure 6: The total number of plastic debris grouped by origin and photographs of debris (a) packaging, (b) household, and (c) others

"others", consist of ropes, plastic gloves, and fishing nets, which were collected at a total average of 123 items/day.

Regarding cleanliness, the ODEC beach falls into the "extremely dirty" category, as shown in Table 1. The CCI value is consistent for all sampling days, indicating severe plastic pollution at the beach.

It is important to note the weather and tidal conditions as limiting factors of this study. The 3-day sampling exercise was done sporadically from June to October due to unpredictable weather conditions as the monsoon season began. Nonetheless, comparisons between seasonal changes cannot be made as there is not enough data to confidently conclude how they affect the composition or transport of debris.

Table 1: The Clean Coastal Index, which determines the cleanliness of the ODEC beach

Sampling Day	Clean Coastal Index	CCI Category
S1	24	Extremely dirty
S2	25	Extremely dirty
S3	24	Extremely dirty

Composition of Debris

This study has successfully analysed the composition of marine debris and evaluated the cleanliness of the study area. On the third day of sampling, the beach recorded the highest abundance of debris compared to the previous days because it was done during monsoon season in Sabah, where it had been raining since the night before the sampling commenced. As the water level rises due to the high precipitation, the water runoff from land into rivers and streams increases. Poor disposal of debris from residential, industrial, and commercial areas is the main cause of the abundance of debris in runoffs in the ocean. Besides that, the transport of debris into the ocean is also caused by strong monsoon winds and currents carrying litter into the ocean. Frequent flooding during this season also increases the debris influx from landfills, coastal areas, and waterways. A study on the spatiotemporal distribution of debris by (Mugilarasan *et al.,* 2021) proved that debris is significantly abundant during monsoon season compared to post-monsoon season.

The results of this study have a similar pattern to previous studies, where plastic was the most dominant type of debris found in the marine environment. Such findings are ordinary since plastic materials are widely used in all facets of our everyday lives, as they are versatile and, most importantly, more cost-effective than other materials. Besides that, plastics are highly persistent, durable, and lightweight, making it impossible for them to degrade naturally and allowing them to disperse widely (Van Sebille *et al*., 2020). In fact, the bigger plastic debris, known as microplastics, will be broken down into smaller pieces called mesoplastics or microplastics after long exposure to nature. As plastic items become small, the impact of plastic pollution on biodiversity and the environment can be adverse.

Based on the debris composition, household activities are the primary source of plastic waste collected at the ODEC beach. Since human activities at the ODEC beach are limited and the beach area is isolated from urbanisation, the transport of debris by tidal movements and surface currents is responsible for the accumulation of debris along the shore. This is supported by the study by (Zahari *et al.,* 2022), where most plastic items collected in the same study area came from household goods and packaging. The debris collected during the 3-day sampling period was consistent as fewer beachgoers on weekdays than on weekends. This shows that the recreational activities at the ODEC beach were not the main cause of the accumulation of marine debris.

In addition to that, a few settlements were spotted opposite the ODEC beach in Pulau Gaya and Pulau Sepanggar (Figure 2). The main issue brought about by these settlements on the water is the improper management of household waste, leading to residents littering directly into the ocean. This explains the abundance of domestic waste stranded along the coast of Kota Kinabalu, including the ODEC beach. Though land-based activities are assumed to be the main culprits of the accumulation of domestic waste in the ocean, sea-based activities should also be considered (Van Sebille *et al.,* 2020). Facing the South China Sea, shipping activities could be a plausible cause of pollution as it is recognised as a high-traffic shipping route. The release of ballast water tanks within the Kota Kinabalu waters, where shipping activities were observed, has indirectly polluted the area with marine debris.

Cleanliness of Pantai ODEC

From the CCI value stated in Table 1, the ODEC beach faces severe plastic pollution. This is concerning, considering it is the least visited beach compared with other neighbouring beaches, like Pantai Teluk Likas and Pantai Tanjung Aru. However, fisheries and shipping activities along the beach are high because it is located within the proximity of a few island settlements, like Pulau Gaya and Pulau Sepanggar, in addition to Sepanggar Bay Container Port, which explains the abundance of macro-debris along the ODEC beach. The CCI for UMS ODEC beach is comparable to

those observed at a few northeast beaches of India (Mugilarasan *et al*., 2021) and Indonesian beaches (Cordova *et al*., 2022), considering the tropical monsoon season.

Many institutionalised initiatives have been introduced by Universiti Malaysia Sabah (UMS), including the establishment of the EcoCampus Management Centre. Through this initiative, routine clean-up at the ODEC beach is performed by UMS contractors, but marine debris is still reoccurring. This study provides insights into the progression of plastic pollution in the study area, where it can be useful in monitoring programs. Though seasonal changes were deemed influential in the distribution and composition of debris, this study is still considered important as publications related to marine debris at the ODEC beach are scarce. Continuous monitoring of marine debris and plastic pollution should be implemented to ensure effective waste management and contain the concerning issues. Also, permanent solutions to this recurring problem are yet to be found.

Conclusion

Overall, the most abundant type of marine debris in quantity and weight were plastic items, which were dominated by plastic bags, food wrappers, and water bottles. The CCI indicates that ODEC beach is extremely dirty. Even so, the CCI evaluation does not represent the overall pollution as it only accounts for plastic materials. This study provides insights into the severity of plastic pollution in the study area and can be further evidence for action by any related party. However, further studies on debris composition influenced by seasonal changes are recommended to better understand the transport pattern with changing wind movements and surface currents. Besides that, further studies could also take a closer look into residents' perspectives and habits of waste management and plastic pollution using the Knowledge, Attitude, and Practices model to further understand the mindset of the common people on said issues and to find common ground on where these issues could be mitigated.

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APPENDIX

Appendix A

Trash Analysis Form

Survey Form for Beach Cleanup

Name of surveyor: Date/Time:

Group Number: Location:

Items/debris	No. of items (n)	Personal hygiene	
Typical solid waste materials		Condoms	
Beverage bottles (glass)		Diapers	
Beverage bottles* (plastic)		Face tissue/wet wipes/cotton pad	
Cigarette butts		Sanitary napkins	
Drinking cans		Syringes	
Food wrappers*		**Total (N)**	
Metal bottle caps		Other debris items	
Paper bags		Appliances* (whole)	
Plastic bags		Balloons	
Plastic bottle caps		Cigarettes lighters	
Plates & cups (foam)		Construction materials*	
Plates & cups (paper)		Fireworks	
Plates & cups (plastic)		Shoe/slippers	
Straws/stirrers		Tires (whole)	
Take away containers (plastic)		Toys	
Utensils* (plastic)		**Total (N)**	
Total (N)		Tiny debris (<2.5 cm)	
Packaging materials		Foam pieces	
6-pack holders		Glass pieces	
Cigarette packaging/wrappers		Metal pieces	
Other plastic bottles*		Plastic pieces	
Other plastic/ foam packaging*		**Total (N)**	
Total (N)		Unlisted/unknown items	
Fishing gear			
Buoys & traps			
Fishing line (1 m=1 piece)			
Fishing nets			
Rope (1 m=1 piece)			
Total (N)		**Total (N)**	

Summary of survey
Estimated distance cleaned (km):
Number of sacks filled:
Total weight of debris(kg):

Beach condition:
a) Substrate
b) Slope
c) Weather condition

Specification (*):
Beverage bottles – water, soft drinks, alcohol
Food wrappers – condiment sachets, candy, chips, biscuits, premix sachets etc.
Utensils – forks, knives and spoons
Appliances – TV, radio, computer, toaster etc.
Construction materials – wood, bars, nails, brush etc.
Other plastic/foam packaging – soap, detergent, shampoo, toothpaste, fruit net, styrofoam from appliances etc.
Other plastic bottles – bleach, detergent, body wash, motor oil, milk, oil/soy/vinegar etc.

Legends:

Substrate
01 – sand
02 – boulders
03 – combination

Slope
01 – low
02 – moderate
03 – steep

Weather condition
Cloud coverage – <50%, 50%, >50%
Wind – slow, moderate, strong

Appendix B

The total amount of debris collected at Pantai ODEC (Windari *et al*., 2022) were quantified using the formula stated below:

$$\sum D = D_{T1} + D_{T2} + D_{T3} \quad (2)$$

$\sum$D = total amount of debris (items)
D_{Tn} = amount of debris in respective transect

The abundance of debris will be calculated (Windari *et al*., 2022) using equation as follows:

$$K = \frac{n}{w \times l} \quad (3)$$

K = abundant of waste (items/m^2)
n = number of debris (items)
w = width of sampling area (m)
l = length of sampling area (m)

The percentage abundance of debris (Windari *et al*., 2022) will be computed using equation as follows:

$$\%K = \frac{n}{a}( ) \times 100\% \quad (4)$$

$\%K$ = percentage abundance of waste
n = number of debris (items)
a = area of sampling (m^2)