PLASTIC POLLUTION AT PUBLIC BEACHES: A CASE STUDY IN TELUK LIKAS, KOTA KINABALU, SABAH

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Abstract. Human activities (urbanisation, tourism, fishing) and marine transport via rivers and currents are primary sources of beach plastics. A deeper examination of land-based management failures, such as collection inefficiencies or illegal dumping, has become a main factor in waste deposition in beach spaces. This study investigated plastic pollution at Teluk Likas Beach in Kota Kinabalu, Malaysia, to inform the development of a sustainable, eco-friendly waste management system. A convergent parallel mixed-methods design integrated quantitative transect sampling and structured visitor surveys with qualitative semi-structured interviews of local authorities and environmental NGOs, as well as non-participant observations of beachgoer behaviour. Results showed that polyethene terephthalate (PET) (34%), high-density polyethene (HDPE) (24%), and polypropylene (PP) (17%) are the most prevalent plastics in the debris profile. Visitor surveys confirmed that single-use beverage containers and disposable food packaging are the most common litter items. The principal pollution sources identified are tourism activities, insufficient disposal infrastructure, and upstream riverine inputs. Stakeholders advocate for biweekly beach cleanups, additional waste bins, and targeted public-awareness campaigns, while visitors propose deposit-return schemes and eco-volunteer guides during peak seasons. Future research should feature continuous sampling, unobtrusive behavioural observations, and comprehensive waste audits. The study concluded that mitigating coastal plastic pollution at Teluk Likas requires source reduction, enhanced collection infrastructure, and sustained community engagement to secure long-term environmental sustainability and a circular economy for the state.
Keywords: *coastal marine, plastic waste, sea pollution, Kota Kinabalu, Sabah*

Introduction

Solid waste that is not handled properly can pollute soil, water, and air, as well as cause health problems to humans and animals. With the amount of solid waste generation expected to increase every year, the country's environment will be indirectly affected if solid waste management is not carried out systematically and effectively. The presence of waste that is not handled properly also causes visual pollution or degrades the aesthetic value of the beach, making the area unattractive and unhealthy to live in (Adnan et al., 2015). Solid waste is categorised into various types, including household waste, public solid waste, and commercial solid waste. Additionally, waste is also categorised into two types: recyclable waste and non-recyclable waste. Plastic waste is recyclable waste, but some categories of plastics cannot be recycled. Indiscriminate

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disposal of plastic waste is a critical issue because undecomposed plastics remain in the environment for hundreds of years causing marine animals to die due to being entangled in marine debris or eating plastic waste that is thought to be food (Pawar et al., 2016) then humans will be exposed to microplastics through seafood and drinking water, which can lead to adverse health effects, including inflammation and chronic diseases (Khanna et al., 2024).

Plastic is defined as an organic synthetic material produced through chemical processing, possessing the property of being moldable without undergoing structural damage, such as breakage or cracking (Deanin and Mead, 2012). These materials consist of key elements such as carbon and hydrogen, which often combine with other elements, including oxygen, nitrogen, and chlorine, to create different types of plastics with varying physical and chemical properties (Govind and Nishitha, 2023). Plastics can be categorised as synthetic polymer materials that are not easily biodegradable and are typically derived from petroleum sources. It is formed through the polymerisation reaction of monomers, resulting in long chains of polymer molecules with high chemical stability (Padsalgikar, 2017). There are different types of plastics, each with specific characteristics tailored to their particular uses. The six most commonly used types are polypropylene (PP), low-density polyethylene (LDPE), high-density polyethylene (HDPE), polyvinyl chloride (PVC), polyethylene terephthalate (PET), polyurethane (PU), as well as other materials such as polyester and polystyrene (PS) (Muthuvairavasamy, 2022).Each type of plastic has its own unique characteristics in terms of heat resistance, chemical resistance, flexibility, and environmental impact, which influence the choice of materials for specific applications. Overall, plastic is a very useful material in many fields, but its effect on the environment and health.

Literature review

In plastic pollution, six main categories of plastics that are often found as pollutants along coastal areas have been identified such as polypropylene (PP), low-density polyethylene (LDPE), high-density polyethylene (HDPE), polyvinyl chloride (PVC), polyethylene terephthalate (PET), polyurethane, polyester, and polystyrene (PS). Hence, ineffective waste management not only pollutes the environment but also adversely affects ecosystems and human health. Raising awareness and implementing plastic waste reduction measures, such as recycling and the use of alternative materials that are more environmentally friendly, is very important. Therefore, cooperation between authorities, industry, and society needs to be strengthened to ensure that plastic waste is better handled to maintain a prosperous environment for future generations. Over the past seven decades, global plastic production has risen exponentially from approximately 2 million tons in 1950 to over 350 million tons by 2017 (Jambeck et al., 2015). A substantial fraction of this production becomes waste within a single-use cycle, particularly single-use plastics, such as bags, bottles, and packaging materials. It is estimated that 4.8 to 12.7 million tonnes of plastic waste enter the marine environment each year from land-based sources (Jambeck et al., 2015). Once in the ocean, plastics can travel hundreds of kilometres, fragment into microplastics, and persist for centuries, thereby threatening marine life through ingestion, entanglement and habitat alteration.

In urban environments, such as a recreational beach located in Halifax Harbour, Nova Scotia, it has been observed that over 86% of the collected debris comprises plastic materials, including items associated with recreational activities and municipal

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sewage disposal (Walker et al., 2006). Furthermore, global evaluations indicate that plastic represents a significant component of marine litter, occasionally constituting up to 100% of floating debris. These plastics frequently originate from both terrestrial and marine sources, including shipping and recreational activities (Galgani et al., 2015). Notably, rivers in Asia, particularly in nations such as Indonesia and Vietnam, are identified as major conduits for the introduction of plastic into the marine environment, transporting larger volumes of plastic to the oceans compared to rivers in Europe (Van Calcar and Van Emmerik, 2019). Malaysia, an emerging economy with extensive coastlines, has experienced rapid industrialisation and urbanisation over the past few decades. The proliferation of plastic packaging, low recycling rates, and inadequate waste management infrastructure have contributed to the significant volume of plastic waste entering Malaysian waters. A national survey conducted by the Department of Environment (DOE) in 2016 reported that plastics constituted approximately 13% of the municipal solid waste stream, with single-use polymers dominating the composition of the waste. Despite government initiatives such as the Roadmap Towards Zero Single-Use Plastics 2018–2030, challenges remain in implementation, public awareness, and enforcement of the ban.

Coastal regions in Malaysia receive plastic debris from urban runoff, riverine transport, and direct littering by visitors. Studies conducted in Peninsular Malaysia and Sabah has documented high densities of plastic litter on beaches, particularly near populated areas and river outlets. For instance, Pantai Morib in Selangor recorded an average of 1,200 plastic items per 100 m stretch, while surveys at Pantai Tanjung Aru in Kota Kinabalu revealed similar pollution magnitudes. These findings underscore the need for localised investigations to inform targeted intervention strategies. Various factors contribute to waste accumulation along coastlines, primarily due to human activities and poor waste management practices. Key contributors to this issue include the tourism sector, urbanisation, and a lack of public awareness regarding proper waste disposal. Many villages and residential areas struggle with effective solid waste management, which often leads to garbage being washed onto the beach during the rainy season (Sutrisnawati and Purwahita, 2018). Additionally, the presence of houses near the beach exacerbates the problem of garbage accumulation (Jayantri and Ridlo, 2021).

From a geographical perspective, villages located along riverbanks typically have a direct relationship with domestic waste, including plastics, food waste, and other materials that are dumped directly into the river. Much of the waste found on the beach is primarily composed of waste that flows down the river and ultimately reaches the shore (Sudiatmika, 2023). This indicates that residential areas near rivers often choose to dispose of their waste in the river, which then flows into the sea. As a result, the beaches near the river estuary frequently serve as major collection sites for marine litter. This study aims aimed to quantify the composition of plastic waste at Teluk Likas Beach. Additionally, the study seeks to identify the sources of plastic waste and the current practices of local authorities in managing plastic waste.

Materials and Methods

The research site is situated in Teluk Likas, Kota Kinabalu, Sabah (*Figure 1*). The beach constitutes a segment of the coastal region that faces the South China Sea and is recognised as a prominent recreational destination for both local inhabitants and

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tourists. This beach locale is situated near Tun Fuad Stephen Road, which serves as a conduit linking the urban centre of Kota Kinabalu to its peripheral regions. Its advantageous location facilitates easy access via private automobiles or public transportation. The distance from Teluk Likas Beach to the city of Kota Kinabalu is approximately 6 to 7 kilometres. Teluk Likas Beach, located in Kota Kinabalu, Sabah, serves as a public recreational area along the western coastline of Kota Kinabalu, the administrative capital of Sabah, Malaysia. The beach area is a recreational park equipped with facilities for leisure and recreation. Additionally, there is a flow of water from several adjacent rivers, including the Inanam and Likas rivers, into the shoreline (Adnan et al., 2015).

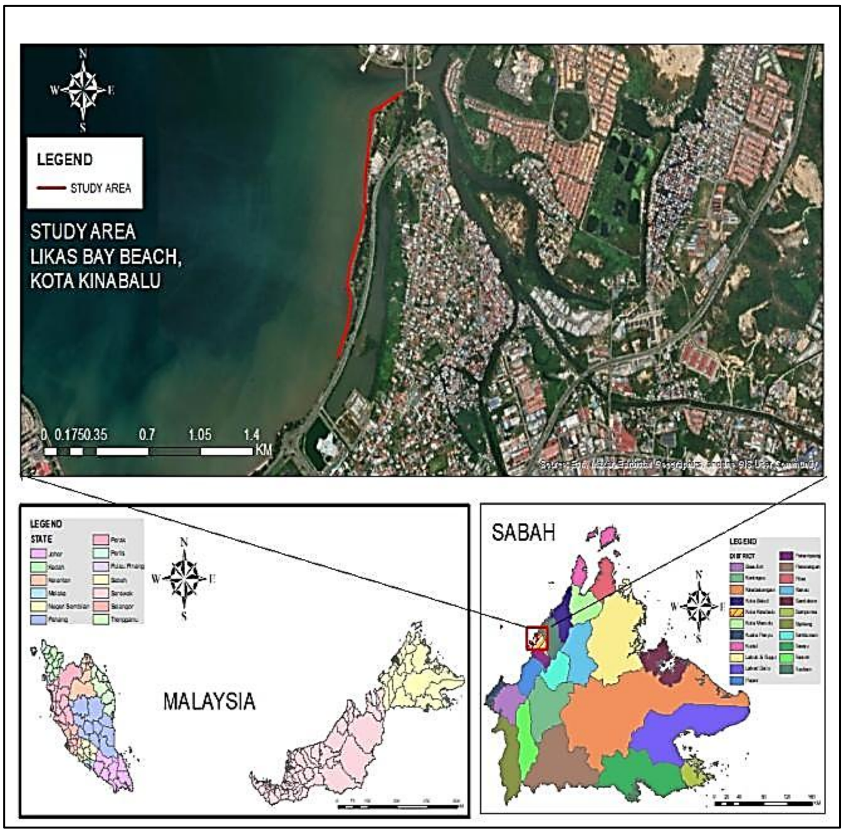

Figure 1. *Study area.*

Research design

A convergent parallel approach was adopted: quantitative transect sampling. Data were integrated at the interpretation stage to corroborate findings.

Transect preparation

Sample collection was conducted in two different types of soil, namely in rocky areas and sandy areas (Schuyler et al., 2018). This method is based on the guidelines in the Handbook of Survey Methodology for Plastics Leakage, developed for the CSIRO Global Plastic Pollution Baseline Project (Version 1.4). This method was only employed in this study once, on the same day. The size of each transects used in this study was 2 meters wide and 26 meters long (*Figure 2*). More specifically, beach transect sampling had a fixed width of 2 meters. In contrast, the transect length was determined based on the width of the shoreline, the distance from the waterline, and extended two meters into the vegetation area (Roman et al., 2024). Transect A is installed close to the mouth of the Likas River, which is connected to the sea of Likas Bay. Transect B is located approximately 150 metres from Transect A, while Transect C is 150 metres from Transect B, which leads away from the estuary. The arrangement of these transects enables comparisons to be made of the distribution of plastics along the coastline that are exposed to the influence of estuary flows and human activities on the coast. The distance between each transect was 150 meters (*Figure 3*). During the sampling, only plastic-based waste was collected to ensure the study focused on plastic pollution in the coastal area. Waste collection was limited to the designated transect area. Before the transect was installed, the area was first inspected to ensure that no existing waste was present. This step aimed to ensure that the collected samples were truly newly stranded plastic waste during the study period. The collection was carried out 24 hours after the transect was installed. All plastic objects found within the boundaries of each transect are carefully collected and then classified according to their specific polymer types. This classification may include, but is not limited to, polyethene terephthalate (PET), high-density polyethene (HDPE), and polypropylene (PP) (*Table 1*). After classification, each type is accurately counted to provide numerical data.

Table 1*. Resin Identification Code according to ASTM D7611/D7611M-20.*

Resin identification number	Resin	Resin identification code: Option A	Resin identification code: Option B
1	Poly(ethyleneterephthalate)	1 PETE	01 PET
2	High-density polyethylene	2 HDPE	02 PE-HD
3	Poly(vinyl chloride)	3 V	03 PVC
4	Low-density polyethylene	4 LDPE	04 PE-LD
5	Polypropylene	5 PP	05 PP
6	Polystyrene	6 PS	06 PS
7	Other resins	7 OTHER	07 O

Source: ASTM International (2013)

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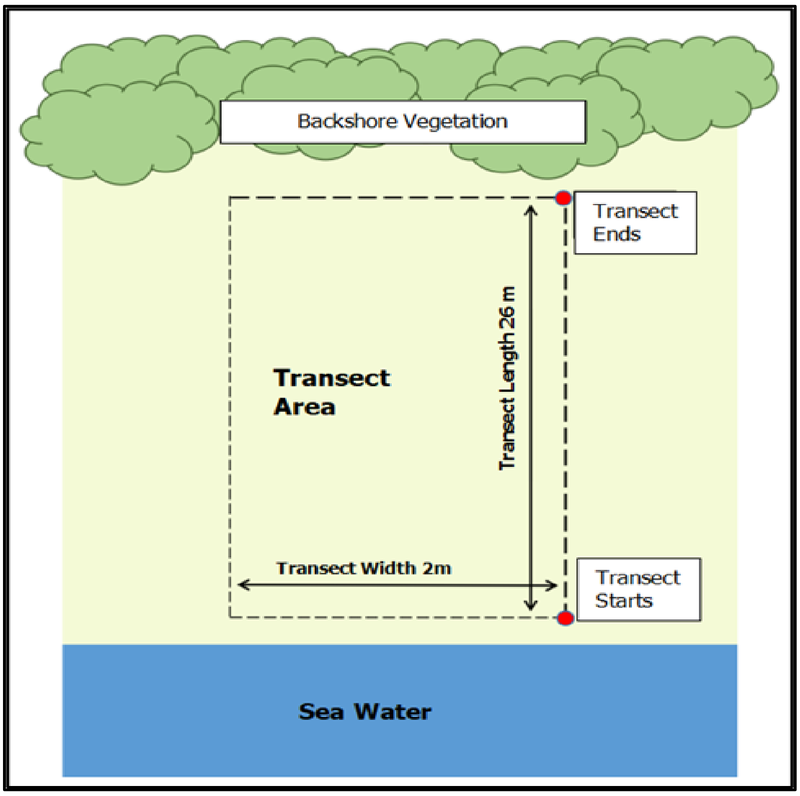

Figure 2. *Illustration of Transects in the study area.*
Source: Schuyler et al. (2018)

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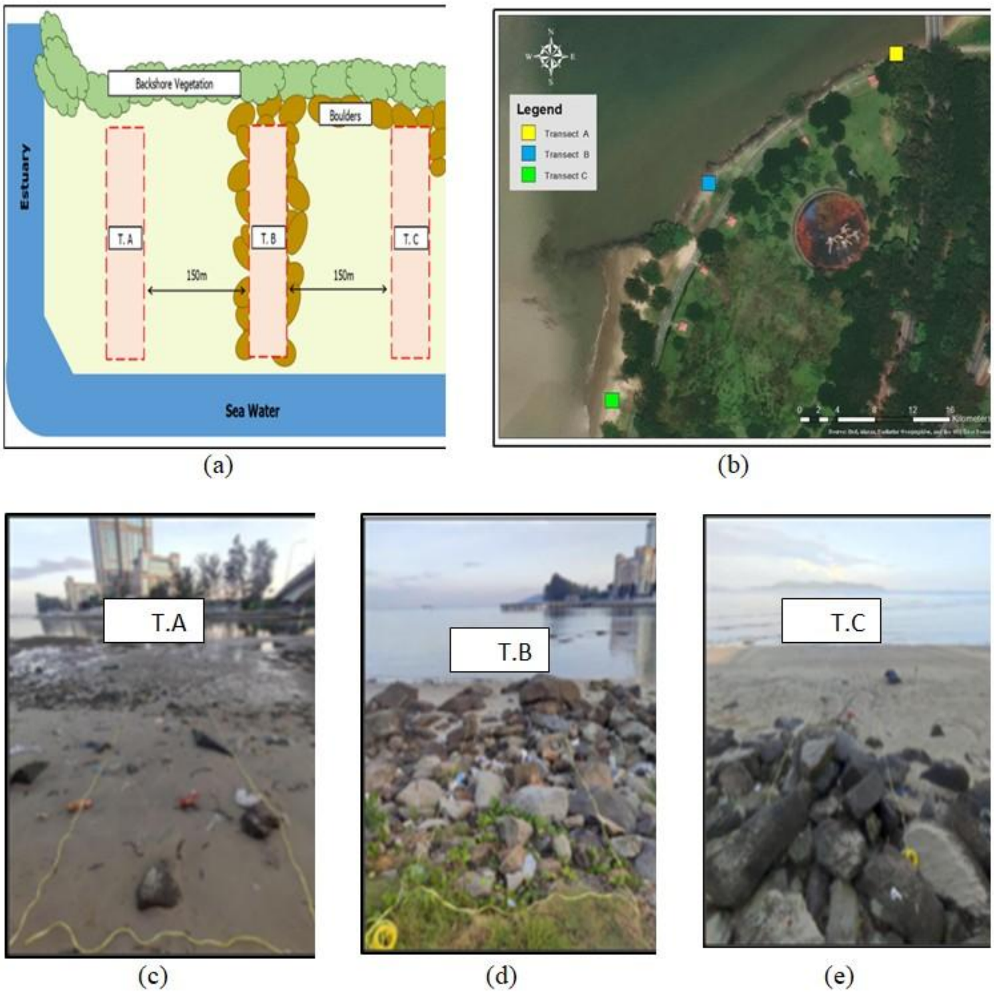

Figure 3. *Distance between the transect (a) and its installation in the field (b,c,d,e) T.A=Transec A, T.B=Transec B, T.C=Transec C.*
Source: Schuyler et al. (2018).

The sampling process is carefully conducted during low tide, and the tidal sea table referred to is from the Department of Survey and Mapping Malaysia (JUPEM). This approach aims to effectively capture and analyse the spatial variability that may exist within the various beach environments at these distinct times. During the sampling, only plastic-based waste will be collected to ensure the focus of the study on plastic pollution in coastal areas. Waste collection is carried out on a limited basis in areas within a predetermined transect. Next, the plastic waste was collected using a trash picker tool, and the collection position was along the transect line to prevent the waste from being buried or uncovered. With this systematic method, the study was able to provide a clearer picture of the composition of plastic waste in the coastal area. After the plastic waste sampling was conducted, the plastic waste was separated by type based on the Resin Identification Code, as specified in ASTM D7611/D7611M-20.

Results and Discussion

Analysis of the transect data revealed that the total plastic waste amounted to 13 units in Transect A, 30 units in Transect B, and 16 units in Transect C, totalling 59 units

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of plastic waste across the three transects. The plastic waste was examined based on the transect location, with particular attention to the quantity of waste units identified in each transect. The predominant types of plastics varied among the transects, with no single type being universally dominant. The composition of plastics demonstrated considerable variation between transects. The "OTHER (7)" category is particularly significant, especially in Transect A and Transect C, indicating the presence of other plastic types that are either uncategorized or serve as a general category for unidentified plastics. Certain plastics, such as PVC (3) and PS (6), were completely absent from Transect A and Transect B, while LDPE (4) was absent from Transect B. This absence suggests specific patterns of plastic accumulation or usage in these areas (*Figure 4*). The study identified that High-Density Polyethene (HDPE) plastic waste constituted the second-highest percentage at 23.08%. This category of waste pertains to single-use plastic bags. Polyethene Terephthalate (PET) and Polypropylene (PP) plastics each accounted for 7.69%. In contrast, Polyvinyl Chloride (PVC), Low-Density Polyethene (LDPE), and Polystyrene (PS) were present in negligible quantities. These findings suggest that the vicinity of the river estuary serves as a site for accumulating various plastic types, particularly those that may be indirectly introduced through urban drainage systems. In the Transect A region, situated near the river mouth, the predominant plastic type identified was "OTHER" (7), accounting for approximately 61.54% of the total sample. Plastics coded as resin 7 encompass mixed waste, including laminated and composite plastics, which are typically challenging to recycle. This category includes items such as snack and instant drink wrappers, as well as packaging materials. The presence of this type of plastic is attributed to the river flow that traverses the adjacent village area.

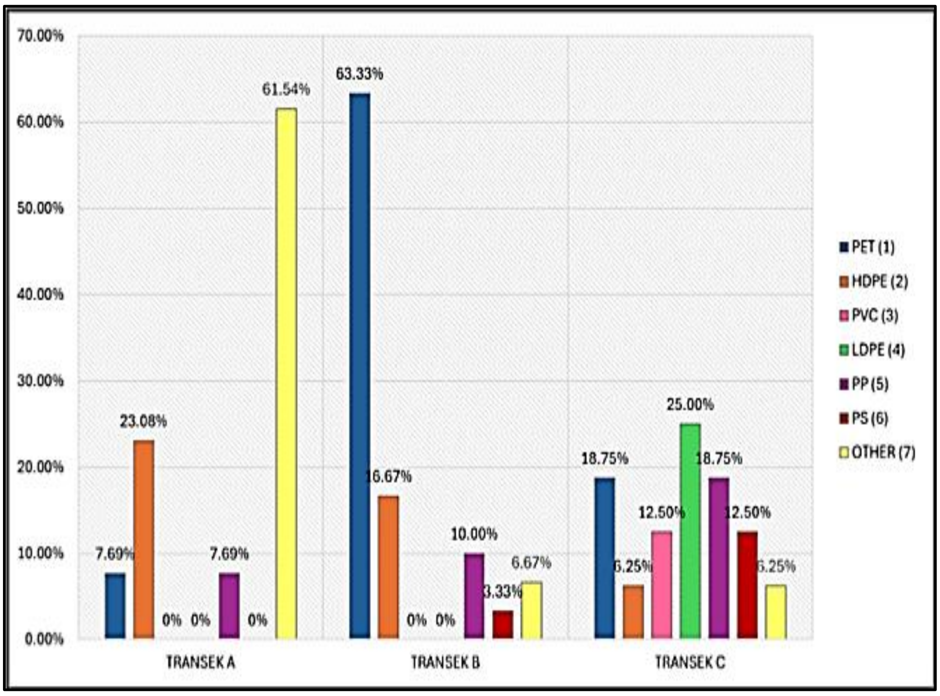

Figure 4. *Plastic waste composition analysis.*

Transect B, situated approximately 150 meters from Transect A near the estuary and closer to the open coastal area, revealed that polyethene terephthalate (PET) plastic (1) was the most prevalent, comprising 63.33% of the total plastic waste. PET is commonly utilised for manufacturing drinking water bottles and plastic cups. This substantial percentage may be attributed to recreational activities in the vicinity, where visitors frequently bring beverages in plastic containers. High-density polyethene (HDPE) (2) constituted the second highest percentage at 16.67%, followed by polypropylene (PP) (5) at 10.00%. Polystyrene (PS) (6) accounted for only 3.33%, while the category labelled as OTHER (7) represented 6.67%. Notably, no presence of polyvinyl chloride (PVC) (3) or low-density polyethene (LDPE) (4) was detected in this transect. The composition of plastics in Transect B suggests that the primary source of plastic waste in this area is attributable to human activities along the coast rather than waste transported via riverine systems. Transect C, located furthest from the estuary and extending towards the open sea, exhibits a more balanced and diverse distribution of plastic materials. The predominant type of plastic is LDPE (4), constituting 25% of the total. The LDPE plastic waste identified includes food wrappers, masks, and fruit nets. This is followed by PET (1) and PP (5), each accounting for 18.75%. Other plastic types, such as PS (6) and PVC (3), each represent 12.50%. Meanwhile, HDPE (2) and OTHER (7) each account for 6.25%. This diverse composition suggests that Transect C receives plastic waste from a variety of sources, including coastal visitors and potentially from seafood activities in the open sea, rather than being directly influenced by river flows as observed in Transect A.

Conclusion

In conclusion, the distribution of plastic composition along the coast of Teluk Likas Beach is significantly influenced by the location of transects, which vary in proximity to river mouths and areas of human activity. Transect A exhibited a high prevalence of mixed plastics (OTHER 7), indicative of the direct impact of river flows that transport diverse waste types from upstream regions. Conversely, Transect B was predominantly characterised by PET-type plastic (1), closely associated with recreational activities on the beach. Meanwhile, Transect C demonstrated a more balanced and diverse distribution of plastics, suggesting influences from multiple sources, including tourism activities and fishing from the open sea. The findings suggest that geographic factors and human activities are significant determinants of the type and distribution of plastic along coastlines. This study has furnished authorities with valuable insights into the sources and composition of waste deposited on the shores of Likas Bay. The results can serve as a reference for formulating policies regarding riverside settlements, which constitute a major issue in numerous cities across Malaysia and Southeast Asia. Nonetheless, the study has certain limitations that warrant attention. Notably, the study's duration may have impacted the comprehensiveness of the data. Despite this, the data obtained provides compelling evidence of pressing pollution concerns in the study area.

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Conflict of interest

This study has no conflict with any party.

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