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Evaluating marine debris pollution: A study of Sandspit and Clifton beaches in Karachi coast

Anila Kausar[1,2*], Usama Hussain[2,3], Hassaan Fahimuddin Siddiqui[2], Afsheen Ashraf[1], Marianna Goroneskul[4], Florentin Ouiya[5*], Amrin Hina Khan[1], Maha Malik[2], Vitalii Borysenko[4], Oksana Sivik[6]

[1] Department of Geography, University of Karachi, Karachi, Pakistan
[2] Institute of Environmental Studies, University of Karachi, Karachi, Pakistan
[3] WWF, Pakistan
[4] Department of Physical and Mathematical Sciences, National University of Civil Protection of Ukraine, Kharkiv, Ukrain
[5] African Organization for Sustainable Development, Burkina Faso
[6] Department of Aviation Engineering Support, Ivan Kozhedub Kharkiv National Air Force University, Kharkiv, Ukraine
* Corresponding author's e-mai: anilak@uok.edu.pk

ABSTRACT

Marine debris poses a significant threat to the coastal environment and marine life as a whole. This study examines the presence, quantity, and composition of marine debris on Sandspit and Clifton beaches (commonly known as Sea View) in Karachi, Pakistan, as well as the impact of debris on marine ecosystems and sea turtle nesting sites. During the study, samples of various types of debris were collected and analyzed using a random sampling method at different points along each beach. According to the results, plastic was found to be the most common type of debris on both beaches, representing a substantial portion of the total waste. Other common types of debris included paper waste, tetra packs, wood, Styrofoam, medical waste, and other materials. The study revealed that beach pollution poses a serious threat to sea turtles, particularly due to entanglement in fishing nets and ingestion of plastic waste. Based on the findings, recommendations are proposed to improve waste management and reduce pollution along the coastline.

Keywords: marine debris, coastal pollution, plastic waste, waste management, marine ecosystem, environmental impact.

INTRODUCTION

The survival of humanity is closely linked to the Earth's environment and its natural resources. At present, frequent ecological crises affect our planet, impacting humans, animals, and ecosystems alike. These issues, ranging from acid rain and air pollution to global warming and urban sprawl, have far-reaching concerns (Tahir, M., 2017). Including these challenges, the explosion of marine debris poses a substantial threat to both developed and developing nations (Sheavly, et al., 2007). Marine debris comprises a wide range of materials, including plastics, glass, metals, and organic matter, which not only endanger marine life but also disrupt marine ecosystems and coastal mangroves worldwide (Rochman, et al., 2016). Solid waste pollution along coastlines has emerged as a major global environmental concern, exacerbated by exponential population growth and its impact on mangroves and aquatic life (Ariza, et al., 2008). Marine debris, primarily composed of non-biodegradable materials like plastics, poses physical threats to aquatic life and often leads to entanglement and ingestion, resulting in awful injuries and casualties (Laist, et al., 1997 ; Wilcox, et al., 2015).

Furthermore, the incorporation of marine debris by marine creatures can cause inside damage, decreasing their food utilization competence (Cole, et al., 2011). Formerly in the ocean, plastics

can endure for long periods, destructively impacting marine ecosystems and associations (AL, 2011). Furthermore, plastics in the marine environment can act as shippers of organic waste products, presenting additional risks to marine life and personal health (Blanchette, et al., 1991). Examine conducted in Karachi emphasizes the harshness of the concern, with plastic waste encompassing a substantial serving of waste located on coasts.

Shoreline sections like Sandspit Beach, known for their environmental implication and turtle nestling locations, are remarkably susceptible to plastic pollution (Neelam, et al., 2018). Subsequently, there is an insistent need to focus on marine debris through thorough organization and justification strategies to safeguard marine ecosystems and coastline cooperation (Barbier, et al., 2011).

This study assesses the occurrence, sizable quantity, and components of marine debris along the Sandspit coastline in Karachi, Pakistan. The main objective is to investigate the extent of coastal pollution and the type of marine debris to understand the risks to marine ecosystems and, in particular, for sea turtle nesting sites. Although many examines have determined visible debris found on beaches, only a limited number have inspected the plenty of material in the seawater stake (Lattin, et al., 2004).

MATERIALS AND METHODS

Area of study

Two beaches were studied: Sandspit Beach (Fig. 1) and Clifton Beach (Fig. 2).

Karachi, situated along the Arabian Sea coast, is Pakistan's largest metropolitan city, displaying a coastline widening around 60 km. (Alamgir, et al., 2024). The city's shoreline contains numerous common beaches, including Hawks Bay, Clifton Beach, Paradise Point, Sandspit, and French Beach, which are frequented by locals and tourists for spare time events (Suhail, et al., 2024; Durranee, et al., 2008).

Sandspit Beach (Fig. 1 and 2), famous for its substantial turtle nesting sites, distances about 5.5 km and is specifically fundamental for Green Turtle nesting (Firdous., 2001). Sandspit and Hawks Bay beaches are recognized worldwide as the foremost nesting locations for Green Sea Turtles (*Chelonia mydas*) (Hany, et al., 2018).

Clifton Beach (Fig. 1 and 2), Karachi, commonly known as Sea View, distances nearly 10 km of coastline and is renowned as one of Karachi's most frequented seaside objectives. Despite its actual beauty, modern years have observed a surge in profit-making activities, leading to beach ruin and an increase in waste gathering (Ali et al., 2015; Neelam et al., 2018). This premier attraction along the Arabian Sea coastline draws significant visitation from locals and tourists alike. However, the beach's popularity has brought about environmental hazards for both marine life and human visitors, as documented by (Rafique, et al., 2019).

Sampling procedure

In February 2024, an extended study was assumed to measure marine debris along Sandspit Beach and Seaview in Karachi, Pakistan. The sampling area encompassed 2.5 km at Sandspit

Figure 1. Study area-beaches of Karachi

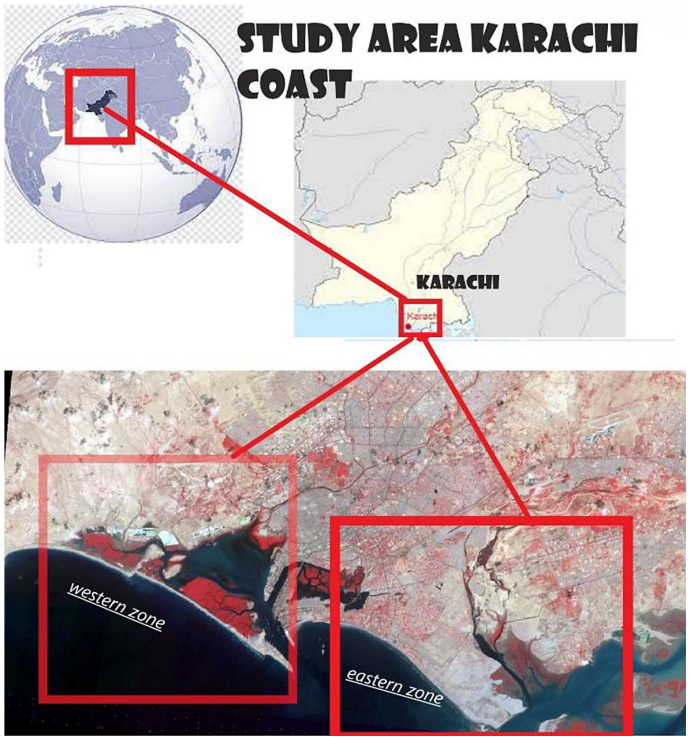


Figure 2. Karachi coastal zones

Beach and 3 km at Seaview. Utilizing a random sampling method, the study aimed to determine the presence, abundance, and composition of marine debris along the coastline. Surveys were conducted at intervals of 300 m at both locations, following the recommended timing proposed by Hanke et al. in 2013. The study adopted a "standing stock" survey approach to assess the accumulated litter in a single visit, intending to document the composition and sources of pollution in the marine ecosystem (Aslam et al., 2022). All coordinates are listed in the tables.

Macroscopic objects larger than 2.5 cm within a quarter of 150 × 10 m (i.e., a transect area of 1500 m²) were assessed. Things that could be lifted from the beach were removed, while larger objects such as fishing lines, fishing nets, ropes, and wooden logs were weighed approximately. Along Seaview, various waste products were encountered, with plastics being the most prevalent, including plastic shoppers, disposable cups, plates, straws, water bottles, and hazardous medical waste such as syringes, medicinal glass bottles, blood collection tubes, and latex gloves (Delgado et al., 2004). A cost-effective single-visit method was adopted to collect the quantities of marine debris. Natural organic waste, such as dead leaves, animal bones, fruit and vegetable coverings/seeds, animal waste, and seaweed, were excluded from the study. All objects were identified and sorted by category, including plastic, single-use plastics, metal, clothing, glass, rubber, paper, Styrofoam, fishing nets/fishing lines/ropes, tetra packs, and cigarette butts. After sorting, each sample was counted, weighed, and placed in separate labeled containers.

GPS coordinates (Table 1, Fig. 3, 4, 5) were recorded from the start point (Fig. 3) to the end point where litter was collected for future analysis and study of debris on the surveyed beach.

RESULTS AND DISCUSSION

Sandspit Beach

A total of 1565 items were collected and categorized into nine predefined types. These items were gathered from 10 sampling points at each beach along the sandbar. In February 2024, random sampling was conducted on the sandspit beach. Each sample was collected at intervals of 300 meters. During the sampling process, it was discovered that out of 1565 items, 700 (44.73%) were plastic-made material, 313 items were packaging waste, accounting for 20%, and 281 items of tetra pack waste were also found, making up approximately 17.96%. A small number of syringes were discovered, totaling 25 items, which

Table 1. Coordinates along Sandspit and Clifton Beach

S. No.	Sandspit Beach		Clifton Beach	
	Longitude	Latitude	Longitude	Latitude
1	66°53'52.60"E	24°50'37.30"N	67° 3'6.71"E	24°46'43.16"N
2	66°53'43.73"E	24°50'42.63"N	67° 2'59.69"E	24°46'50.36"N
3	66°53'35.15"E	24°50'48.29"N	67° 2'53.10"E	24°46'58.59"N
4	66°53'26.00"E	24°50'53.15"N	67° 2'46.61"E	24°47'6.85"N
5	66°53'16.51"E	24°50'57.70"N	67° 2'39.95"E	24°47'14.91"N
6	66°53'7.40"E	24°51'2.74"N	67° 2'33.05"E	24°47'22.71"N
7	66°52'58.31"E	24°51'7.76"N	67° 2'25.78"E	24°47'30.15"N
8	66°52'48.72"E	24°51'11.88"N	67° 2'18.24"E	24°47'37.45"N
9	66°52'39.14"E	24°51'16.05"N	67° 2'10.18"E	24°47'44.11"N
10	66°52'29.89"E	24°51'20.65"N	67° 2'1.62"E	24°47'50.27"N

Figure 3. GCP (ground control points) of Surveyed Area

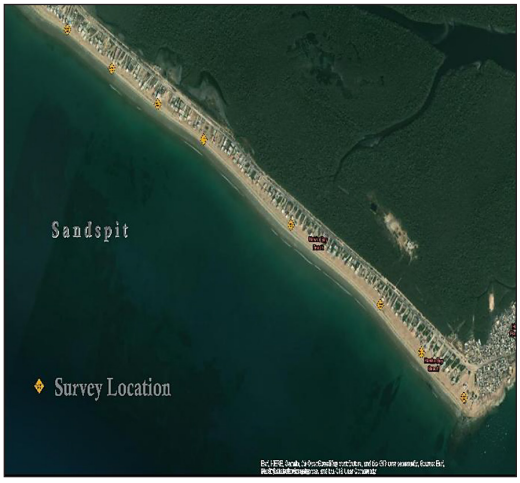


Figure 4. Sandspit Beach

Figure 5. Clifton Beac

accounted for 1.60% overall. Additionally, 100 Styrofoam items were found, representing 6.39% of the total, along with several other items, such as deflated footballs, cardboard cartons, fishing nets, brooms, gunny bags, toothpaste tubes, broken helmets, cotton ropes, safety razors, metal pieces.

Plastic was the most abundant type of debris on the beach, followed by packaging waste and tetra pack waste (Fig. 6).

However, in terms of weight, Entangled Debris was the most abundant debris on the beach, followed by Plastic waste, wood, and tetra pack.

Figure 6. Debris on Sandspit Beach, Karachi

Entangled Debris accounted for 102 kg (51% of the total weight), followed by, plastic (12%), and the weight of wood was found to be 23 kg (11.5%). Lesser weight of glass was observed i.e. 3 kg which makes up only 1.5%. Meanwhile, packaging wrappers weighed 18kg which makes up a total of 9% while light-weight sponges accounted for 4% and were of 8 kg (Fig. 7).

Clifton Beach

An identical study was conducted at Clifton Beach as Sandspit Beach, consuming a similar arbitrary selection technique. A total of 1533 items were detected at 10 sampling points on the beach. Plastic was the most common type of rubble found that made up (47.33%), followed by medical waste, wood, and Styrofoam. Hospital waste was found to be relatively high, with a

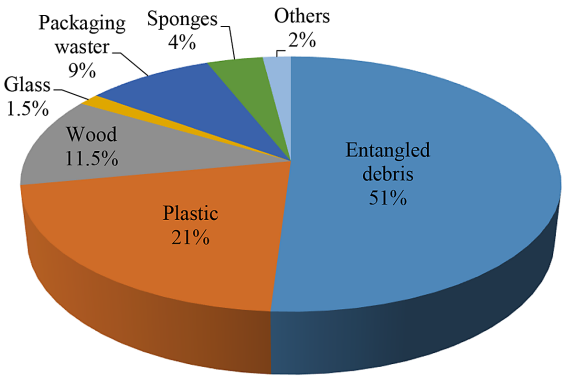


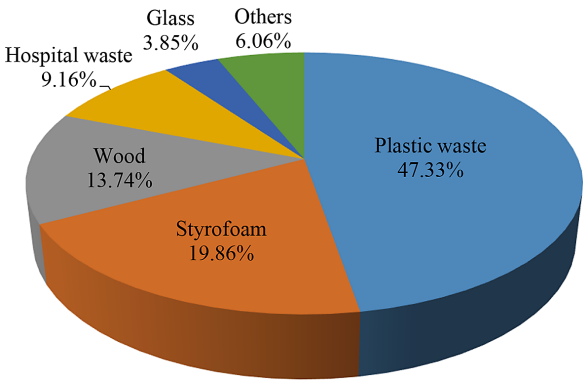
Figure 7. Percentage of waste types by weight (kg) at Sandspit Beach, Karachi

total of 155 hospital-related items observed, including broken bottles and syringes which comprised 10.11% of the debris. A substantial amount of wood pieces was also observed, totaling 205 items (13.37%), including both large and small wood chips and logs. The study also found many Styrofoam plates, cups, and boxes, which made up about 19.24% of the debris. Other items observed included safety razors, metal pieces, fishing nets, matchboxes, glass bottles of medicines, wine bottles, and glass bottles of juices.

While considering the weight of these items, it was revealed that plastic was the most abundant form of debris on the beach, followed by medical waste (Fig. 8). In terms of weight, plastic waste accounted for 47.33% of the total weight, which included items such as plastic shoppers, plastic water bottles, mobile screen protectors, detergent bottles, disposable plastic cups, and plates. Styrofoam came in second, accounting for 19.86% of the weight, followed by wood at 13.74%. Hospital waste weighed 12 kg, equivalent to 9.16% of the total weight. Glass was the least rich material, weighing only 5 kg, a little higher than the 3.85% of sandspit beach. Other items found on the beach included balls, cartons, fish traps, slippers, cigarette butts, dead small organisms, wrappers, sandpapers, and brooms (Fig. 9).

Different species of flora i.e. Avicennia marina, manzanitas, etc, and fauna like Crabs, snails, and fishes of different families (Fig. 10) were also discerned in the chosen area. Marine pollution poses a serious threat to marine biodiversity, ecosystems and socio-economic conditions

Figure 8. Debris on Clifton Beach, Karachi



Figures 9. Percentage of waste types by weight (kg) at Clifton Beach, Karachi

of coastal communities in Pakistan. Driven by industrial, agricultural and plastic pollution, increasing levels of marine pollution are significantly leading to habitat destruction, loss of biodiversity (Sheikh, et al., 2024).

For some marine species, plastic debris can pose a significant threat due to entanglement, ingestion, and habitat degradation and loss. Sea turtles are among the most sensitive species, as their migratory behavior and multifaceted life cycles make these reptiles particularly vulnerable to the negative impacts of plastic debris. Plastic elements can persist in the digestive tract for more than 64

Figure 10. Snail (left) crab (right)

days before being excreted (Solomando et al., 2022). Ingestion of marine debris is an established threat to sea turtles (Clukey et al., 2017).

According to World Wide Fund for Nature – Pakistan, the most serious threats to marine turtles include habitat degradation, entanglement in fishing nets, and pollution of popular beaches with garbage, primarily consisting of single-use plastics and microplastics. Additionally, the impact of diesel and petrol on hatchlings, which can cause deformities, poses a significant threat to their survival (wwfpak).

Industrial pellets and plastic fragments were the most common type of marine debris found in the turtles' fecal material. In AlMusallami's study (AlMusallami, et al., 2024) plastic fragments made up the largest proportion of marine debris in the faecal material and were relatively well represented in dissected individuals.

Ingestion of debris by sea turtles can occur in four ways: it can be mistakenly swallowed due to visual similarity to prey; sea turtles can be attracted to the odor produced by biocontaminated plastic debris; debris can be accidentally ingested while consuming prey; debris can be transferred from contaminated prey. Most studies show that sea turtles directly ingest plastic, mistaking it for prey. This implies that some characteristics of the plastic resemble the prey of sea turtles (Noh, et al, 2024).

As the data (Fig. 11) shows, coastal development has reduced the space available for turtle nesting, while rising temperatures associated with global climate change are killing the coral reefs that provide their food source (Fig. 12).

Figure 11. Temporal change of LULC at Nesting Pits Areas

Figure 12. Coastal development density near turtle nesting sites in 2002 (top) and 2024 (bottom)

The nesting procedure begins) when the turtles leave the sea (Fig. 13) to choose an area to lay their eggs (Fig. 14).

They dig a pit in the sand, fill it with 130 to 160 eggs, and then cover it. At this stage the turtles retreat to the sea, leaving the eggs, which will hatch in about 60 days (Fig. 15).

The most dangerous time of their lives comes when hatchlings make the journey from their nests to the sea (Fig. 16). Crabs and flocks of gulls voraciously prey on the young turtles during this short scamper. The orientation of the Huts in the Sandspit is out of the way, but it's near to the nesting point and it disturbs turtles and their environment (Fig. 17).

The current state demonstrates that the beaches under study need protection to maintain their biological state. Since these beaches are active recreational areas, i.e. places of active recreation for the population and tourists, the following actions should be the simplest and most immediate:

- To reduce coastal pollution; sign boards and dust bins should be placed along the coastline.
- To encourage awareness, programs should be organized in terms of walks, seminars, etc.
- An organized solid waste management system should be introduced by the Karachi Metropolitan Corporation (KMC) for the daily removal of pollution from the coast.
- To introduce fines for the visitors who are involved in creating pollution at the beaches.

In addition, continuous monitoring of the environmental conditions in the area of the beaches, as well as monitoring of the population of turtles living on the studied beaches should be organized for prompt response in the event of a threat of extinction of turtles.

Figure 13. Turtle Nest at Sandspit Beach

Figure 14. Turtle Nest-Layed Egges

Figure 15. A turtle has dug a nesting pit

Figure 16. Huts orientation in sandspit, Karachi

Figure 17. The nesting pit where the turtle laid its eggs and its tracks back to the sea

CONCLUSIONS

The current study demonstrates the adverse effects of coastal development and the popularity of Clifton Beach (Sea View) as a tourist destination on marine ecosystems, specifically on the natural habitats of sea turtles and other marine species.

The findings revealed that plastic waste, including single-use items and packaging, is the most prevalent type of litter on both Sandspit and Clifton beaches, accounting for a significant portion of the total waste. This aligns with global trends, where plastic pollution is a major concern due to its persistence in the environment. In addition to plastic, other common types of debris included paper waste, tetra packs, wood, Styrofoam, glass bottles, and syringes, which pose health risks to marine life.

The study underscores the vulnerability of sea turtles to marine debris, particularly through entanglement in fishing nets and ingestion of plastic. The accumulation of debris on nesting beaches, such as Sandspit, poses a direct threat to sea turtle nesting sites and leads to a decline in the survival rates of turtle hatchlings.

The implementation of effective waste management systems, public awareness campaigns, and the installation of trash containers along the coastline are essential to reduce the harmful effects of environmental contamination on marine ecosystems and protect vulnerable species such as sea turtles.

Future research should continue to monitor the dynamics of marine debris and its impact on coastal environments to inform ongoing conservation efforts.

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