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Research Article

Microplastic contamination in *Nerita albicilla*: Implications for marine ecosystem health along Karachi coast

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Abstract

Microplastics (MPs) have become a significant environmental concern globally, with their pervasive presence in various ecosystems posing threats to marine life and human health. This study investigates the MPs contamination in a gastropod species *Nerita albicilla* found commonly along the Karachi coast. A total of 60 individuals of *N. albicilla*, 5 specimens from each site monthly were handpicked from the intertidal area of Hawksbay and Buleiji rocky shore from November 2022-April 2023. The shells were noted for morphometrics and visceral tissues were digested in 10% KOH solution in a ratio of 3:1. Each digested suspension was filtered using 0.45 µm organic filter paper and observed with the help of a compound microscope. A total of 64 MPs (1.4±0.244-3.6±0.678 item ind.$^{-1}$) were recorded from 30 *N. albicilla* specimens collected from Hawksbay and 59 MPs (1.4±0.4 - 3±0.632 item ind.$^{-1}$) from Buleji. The most dominant MPs types were microfibers, which made up to 84% and 88 % of total MPs at Hawksaby and Buleji, respectively whereas the most of MPs ranged in size range of 0-25 µm indicating anthropogenic pollution sources such as textiles, fishing gears, and synthetic materials commonly found in marine environments. The study underscores the ecological significance of gastropods in monitoring marine pollution and highlights the urgent need for mitigation measures to safeguard coastal ecosystems.

Article info

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Introduction

Microplastics (MPs) have become a major environmental concern due to their widespread presence in various ecosystems, including oceans, rivers, lakes, and even the air (Akdogan and Guven, 2019). MPs are small plastic particles that are less than 5 millimeters in size (Lim, 2021). They can be classified into two categories: primary microplastics, which are intentionally manufactured at small sizes for specific purposes (*e.g.*, microbeads in cosmetics), and secondary microplastics, which result from the breakdown of larger plastic items over time (Lots *et al*., 2017, Arshad *et al*., 2023). MPs are commonly transported through rivers and estuaries from terrestrial to aquatic environments, where they persist for extended durations, making them accessible to living organisms (Wright *et al*., 2013). MPs are widely found in marine environments and can be ingested by organisms with filter-feeding strategies, such as marine gastropods. This ingestion can lead to various detrimental effects, such as reduced feeding, internal injuries, blocked digestive tracts, and impaired reproduction (Ding *et al.*, 2022). MPs particles accumulate in the digestive tract, potentially causing obstructions that disrupt normal digestive processes and adversely affect the health and well-being of the gastropods (Li *et al*., 2021; Jeyavani *et al*., 2022). It can also disrupt the entire food chain (Gola *et al*., 2021) as MPs can be passed along from smaller organisms to larger predators. They contribute to nutrient cycling and are economically significant in the field of fisheries and aquaculture. Additionally, some species are known for their intricate and beautiful shells, making them popular in the shell trade and as collectibles (Moretzsohn, 2023).

The majority of gastropods species either exhibit limited mobility or are completely sessile as adults. These species, therefore, are ideal for studying contamination levels of their habitat (Lester *et al.*, 2009). Bioaccumulation of contaminants by shellfish is a human health issue and is indicative of poor water quality in the ecosystem (Larsen, 1979; Metian *et al*., 2009; Kumar *et al.*, 2021).

Nerita albicilla is an essential part of the food web and is consumed by other organisms, including humans. Examining the levels of MPs in gastropods offers valuable insights into their potential effects on higher trophic levels, including human health (Pastorino *et al.*, 2021; Multisanti *et al.*, 2022). *N. albicilla* has been chosen for this investigation owing to its ecological significance and abundance along the Karachi coast. This study aims to explore the contamination of microplastics in *N. albicilla* sampled from Hawksbay and Buleji beaches along the Karachi coast, thereby contributing to the ongoing monitoring efforts of MPs levels in gastropods.

Material and methods

Study location

Pakistan has a vast coastline that stretches from the province of Sindh in the south, to the province of Balochistan in the west. The largest and most populous city in Pakistan, Karachi, is endowed with a long beachfront along the Arabian Sea that stretches for around 64 kilometers (Arshad and Farooq, 2018). Because of the Port of Karachi, which is strategically located along this coast and is one of the busiest and most important ports in the area, a large amount of Pakistan's trade is facilitated. The Karachi coastline is a center of economic activity and trade (Hameed *et al*., 2012). The nation's maritime prominence has also been further elevated by the emergence of Gwadar Port in Balochistan as a hub for international trade and a key component of the China-Pakistan Economic Corridor (CPEC) initiatives (Khetran *et al*., 2017).The coastal area is particularly well-known for its marine life and provides chances for fishing, which contributes significantly to the livelihoods of the local populace. The coastline is distinguished by a blend of rocky outcrops, sandy beaches, and a busy urban setting (Inam *et al*., 2007). Two nearby rocky beaches on the Karachi coast, Hawksbay and Buleji, were chosen for the present study are shown in Figure 1.

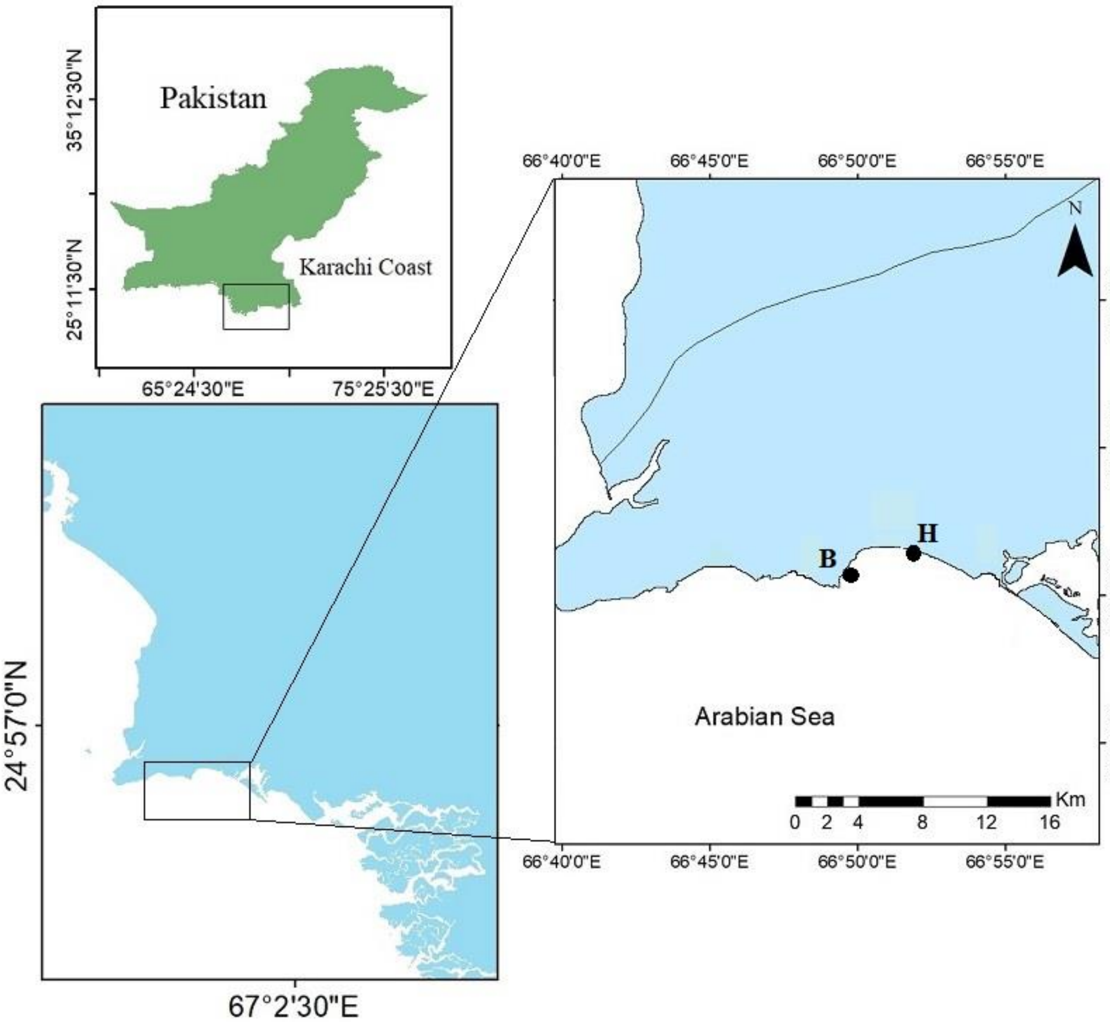

Figure 1: Study area map showing studied stations at Buleji (B) and Hawksbay (H) on the Karachi coast.

HawksBay

Hawksbay approximately covers an area of 990 Km and is characterized by a combination of rocky and sandy beaches. The rocky regions sustain a varied marine ecology by offering special habitats for a range of marine organisms. Crevices and tide pools are frequently found in the rocky terrain, where marine life like crustaceans, mollusks, and tiny fish can flourish. The sandy beaches, on the other hand, are crucial sea turtle breeding grounds and offer a natural backdrop for beachgoers and visitors looking to engage in leisure activities like beach sports and picnics.

Buleiji

Buleiji is an 800-meter-long rocky beach. The intertidal zone is made up of sporadic, slightly elevated, and depressed parts. Large and small boulders are mainly found in the high tidal zone. The rocks in the mid- and low-tidal zones are comparably smaller and more level. Mid- and low-tidal zones have rock ponds of various sizes (Zafar *et al*., 2018). The majority of the organisms in the high tidal zone are barnacles and gastropods. Gastropods, crustaceans (crabs, pistol shrimp, and amphipods), echinoderms (sea cucumber and sea urchin), bivalves (mussels and oysters), etc. live in the mid- and low-tidal zones. The algal vegetation on the shore is abundant.

Faunal sampling and MPs analysis

A total of 60 individuals of *N. albicilla* were randomly handpicked from the intertidal area of Hawksbay and Buleiji rocky ledge along the coast of Karachi. Five individuals of *N. albicilla* were collected from each station every month from both locations from November 2022 to April 2023. The months between November to February are referred to northeast monsoon (winter) whereas, March and April are referred to spring inter-monsoon. The samples were placed in aluminum foil to avoid contamination and brought to the laboratory, placed in the freezer at -20℃ to prevent deterioration till further laboratory procedures. The collected specimens were defrosted at room temperature in the clean laboratory, and analyzed using Bio protocol by Lusher *et al*. (2015, 2018). The molluscan species were identified using Shells, Dance (2002) and available literature. Digital weight balance (Akira, Tx-200) was used to calculate the weight whereas a Vernier caliper was used to measure the length and width of molluscan shells. After morphometrics for each sample, an iron hammer covered with clean sterilized aluminum foil was used to crack the shells, the visceral tissues were extracted carefully and weighed to get wet weight of the samples. The whole visceral tissue of every specimen was placed into pre-cleaned vials and digested with 10% KOH solution in a ratio of 3:1 (KOH: visceral tissue) as described by Lusher *et al*. (2018) and Arshad *et al*. (2023). The samples were kept in 10% KOH for 3 weeks to break down the living residues without heat (Foekema *et al*., 2013). Some of the samples which were turbid after 3 weeks of KOH digestion, were heated on a magnetic stirrer at 125 rpm till the suspension became transparent. Each digested suspension was filtered using 1.6 μm (pore size) GF/A filter papers. Filter papers were placed and covered with Petri dishes washed with Milli-Q water. After filtration, stereomicroscope (Micros Austria) was used to study the total number of MPs and their characteristics in each sample. MPs were evaluated according to size, shape, color, and abundance. The morphotypes of MPs were categorized into fibers and fragments (including irregular particles) and confirmed according to their physical characteristics. MPs were categorized into four size ranges in this study, including 0-25µm, 26-50µm, 151-175 and 176-200µm, respectively and eight different colors i.e. black, blue, brown, green, orange, pink, purple and red. Regression analysis was performed to find out the significant relation between the morphometrics and MPs count in the samples. Statistical analyses were performed using Statistical Package for the Social Sciences *(SPSS)* program for windows, version 26.0 *(IBM, America)*.

Results

Monthly microplastic abundance in molluscan Species at Hawksbay

A total of 64 MPs were recorded from 30 *N. albicilla* collected from Hawksbay from November 2022 to April 2023. The morphometric characteristics of all specimens are described in Table 1. MPs abundance differed significantly among months and ranged between 1.400±.244-3.600±0.678 item ind.$^{-1}$. The highest number of MPs (3.600±0.678 item ind.$^{-1}$, 2.420±1.489 MPs/g) was recorded in November with an average wet weight of 0.52 ± 0.062 g. The lowest number of MPs (1.4±0.244 item ind.$^{-1}$, 0.422±0.088 Mps/g) was recorded in March with an average wet weight of 0.508±0.041 g.

Table 1: Morphometric characteristics and microplastic (Mps) abundance in *Nerita albicilla* species collected from Hawksbay beach monthly (November 2022- April 2023).

S.No.	Months	Number	Avg. width	Avg. Height	Avg. wt. with shell	Avg. wt. without shell	Total MPs	Total MPs /g
1	Nov.	5	1.98±0.037	1.66±0.081	3.31±0.208	0.52±0.062	3.60±0.678	2.420±1.489
2	Dec.	5	1.78±0.156	1.36±0.067	2.78±0.172	0.58±0.054	1.40±0.600	0.891±0.288
3	Jan.	5	2.34±0.112	3.48±0.152	9.29±1.052	1.71±0.214	2.60±0.927	0.933±0.267
4	Feb.	5	2.00±0.044	1.00±0.031	2.53±0.145	0.45±0.038	2.60±1.077	1.710±0.315
5	Mar.	5	1.46±0.040	1.08±0.058	2.67±0.108	0.50±0.041	1.40±0.244	0.422±0.088
6	Apr.	5	1.50±0.031	1.08±0.020	2.87±0.115	0.60±0.020	1.80±1.067	0.383±0.139

Avg. = average; MPs = microplastics

Monthly Microplastic Abundance in Molluscan Species at Buleiji

A total of 59 MPs were recorded from 30 samples of *N. albicilla* collected from Buleiji from November 2022 to April 2023. Whereas, the morphometrics of all specimens are described in Table 2. MPs abundance differed significantly among months and ranged between 1.4±0.4 - 3±0.632 item ind.$^{-1}$ The highest number of MPs (3±0.632 item ind.$^{-1,}$ 0.448±0.095 MPs/g) were recorded in November with an average wet weight of 1.108±0.082 g. However, the lowest number of MPs (1.4±0.4 item ind.$^{-1}$, 0.456±0.144 MPs/g) was recorded in March with an average wet weight of 0.865±0.123 g. The results of regression analysis do not indicate any significant relationship among height, weight, and number of MPs in studied samples (Fig. 2).

Table 2: Morphometric characteristics and microplastic (Mps) abundance in *Nerita albicilla* recorded monthly (November 2022 - April 2023) from Buleiji beach.

S.No.	Months	Number	Avg. width	Avg.Height	Avg. wt. with shell	Avg. wt. without shell	Total MPs	Total MPs/g
1	Nov.	5	1.54 ± 0.04	1.86±0.067	2.99±0.384	0.48±0.038	2.20±0.374	0.25±0.049
2	Dec.	5	2.14±0.092	1.34±0.024	4.13±0.268	0.48±0.039	1.80±0.860	0.37±0.088
3	Jan.	5	1.98±0.109	1.30±0.054	3.69±0.208	0.65±0.034	2.40±0.509	0.34±0.087
4	Feb.	5	2.72±0.048	1.32±0.058	5.56±0.281	1.10±0.082	3.00±0.632	0.45±0.095
5	Mar.	5	1.84±0.024	1.28±0.048	5.39±0.447	0.86±0.123	1.40±0.400	0.46±0.144
6	Apr.	5	1.60±0.137	1.14±0.074	4.09±0.468	0.66±0.100	2.20±0.374	0.34±0.062

Avg. = average; MPs = microplastics

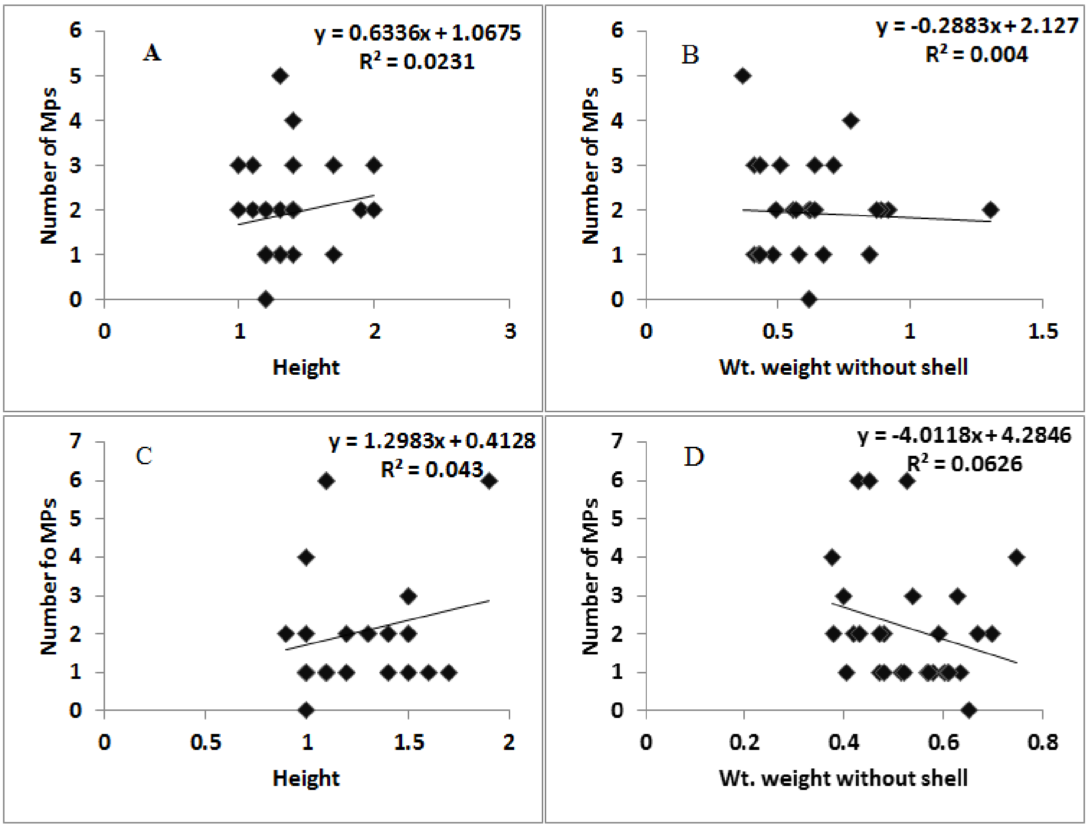

Figure 2: Regression analysis between height (A, C), wet weight without shell (B, D) of *Nerita albicilla* and number of microplastics (MPs) recorded from Hawksbay (A, C) and Buleiji (B, D), respectively.

Identified MPs were classified into eight size ranges, i.e., <0-25 µm >151-175µm. The most observed MPs size ranged from 0-25µm while the lowest particle sizes ranged from 76-100 µm, respectively. A negligible difference has been recorded in both sites. The highest number of MPs was recorded in November (18, 27%) followed by February (14, 23%), December (9, 19%) and January (7, 15%) at Hawksbay. At Buleiji, the highest Mps count was recorded in January (12, 31%) followed by November (11, 17%), December (10, 17%), February (9, 13%) and March (7, 9%) (Fig. 3A and B). A total of 129 MPs were examined from both sites, however, a negligible difference has been recorded the highest number of MPs (66, 51%) were recorded from Hawksbay whereas, (63, 49%) MPs were recorded from Buleiji. Black and Blue color MPs were dominant, followed by red, green, and orange from both sites (Fig. 3C and D).

Overall, two different morphologies of MPs were recorded. Fibers were the most dominant type in all samples (84%) followed by fragments (16%) from Hawksbay while 88% of fibers were recorded from Buleiji followed by 12% fragments (Fig. 4).

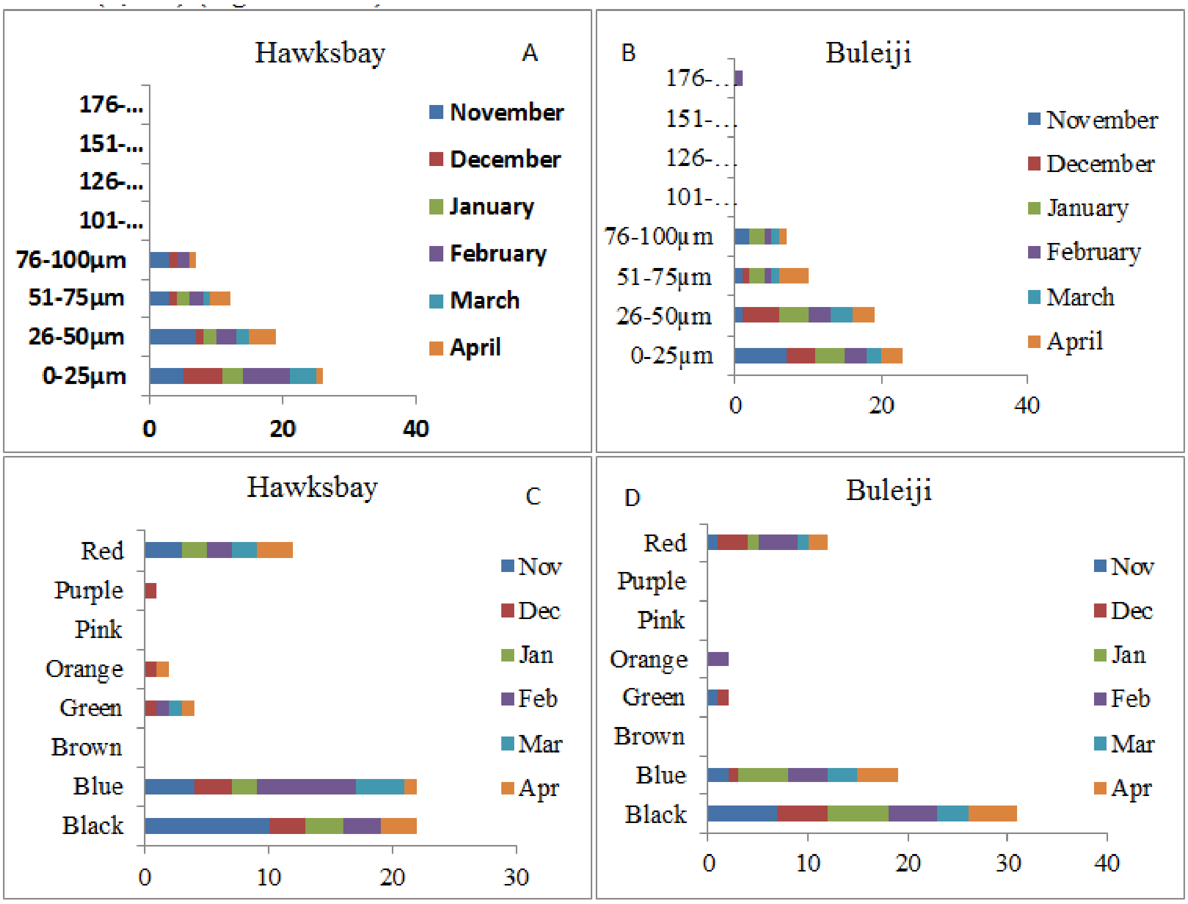

Figure 3: Size range of MPs particle (A, B), colors of MPs (C, D) in *Nerita albicilla* collected from Hawksbay (A, C) and Buleiji (B, D), respectively.

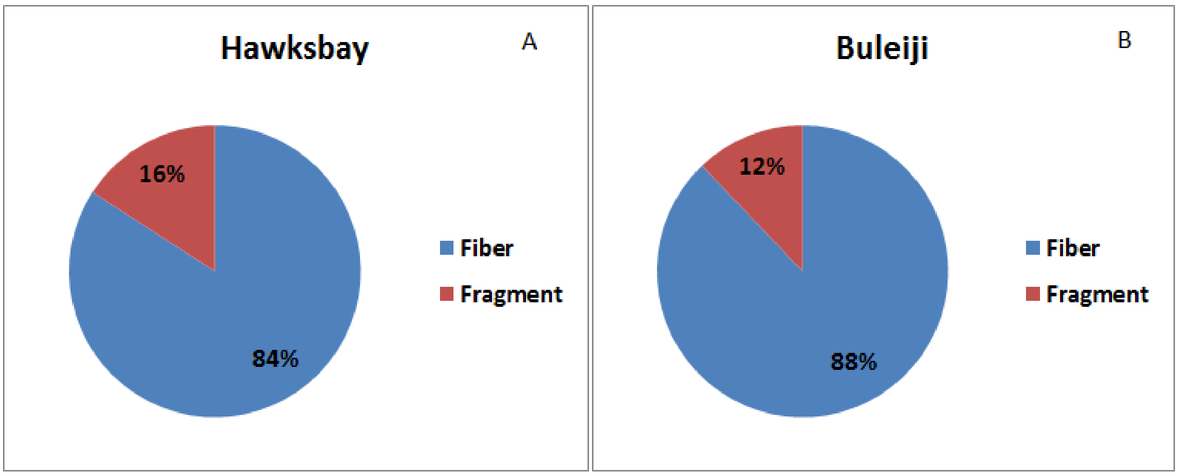

Figure 4: Types of MPs recorded from Hawksbay (A) and Buleiji (B) sites

Discussion

This is the first study investigating and confirming microplastics (MPs) contamination in *Nerita albicilla* from Karachi coast. Our findings indicate a lower number of MPs compared to other gastropod species from various regions, such as *Siphonalia subdilatata* from the Bohai Sea in China (Zhao *et al*., 2024), *Thais mutabilis* and *Cerithidea cingulata* from the northern Persian Gulf (Naji *et al*., 2018), *Babylonia spirata* from the southwest coast of India (Abisha *et al*., 2024), and *Telescopium telescopium* from East Java, Indonesia (Vidayanti and Retnaningdyah, 2024). Comparing the MPs abundance in mollusk species from different regions worldwide is difficult due to the lack of standardized methods (KOH digestion, H_2O_2 treatment, acid destruction) and units (microplastics per individual or gram tissue) to quantify MPs (Vandermeersch *et al*., 2015).

MPs contamination comparatively our finding has less number of MPs than in other gastropods species from different regions of the world such as *Thais mutabilis* from north part of the Persian Gulf (Naji *et al*., 2018), *Siphonalia subdilatata from Bohai sea China (* Zhao *et al*., 2024*), Thais mutabilis* and *Cerithidea cingulate* from north part of the Persian Gulf (Naji *et al.*, 2018), *Babylonia spirata* southwest coast of India (Abisha *et al*., 2024) and *Telescopium telescopium* East java Indonesia (Vidayanti and Retnaningdyah, 2024)

Comparing these results with other studies helps to highlight the global nature of MP pollution and the need for comprehensive strategies to mitigate its impact on marine ecosystems. The most dominant fraction of MPs were microfibers which were observed in an alarming number in all gastropod samples, made up 84% from Hawksbay and 88% from Buleiji, respectively. Similar results have been documented by many researchers. *i.e.*, 66.66% by Wang *et al*. (2021), 68.72%, Patria *et al*. (2020), 50.2%, and Nikhil *et al*. (2024). For microfibers with different colors, black stands out as the most prevalent hue, primarily attributed to its larger proportion within marine environments as reported by Abidli *et al.* (2019) at 99%, Expósito *et al.* (2022) at 74%, and Akindele *et al*. (2019) at 100%. Additionally, it has been suggested by Akindele *et al.* (2019) that near-shore ecosystems are predominantly characterized by these fibers. Microfibers, being degradable plastic waste in yarn or fiber form, typically originate from sources such as fishing lines, ship mines, and synthetic fibers (Pirc *et al.,* 2016). Hawksbay and Buleiji serve as an ecotourism spot for boating and fishing. Moreover, the fragments type of microplastics found in the sample could be from degradation and fragmented plastic debris such as plastic bottles, plastic bags, and plastic bowls. The fiber type of microplastic known could be released from textiles and garments such as clothes (Napper and Thompson, 2016). The fibers are known to remain for a longer period of time on the surface of the water because of their relatively low densities while fragments and granules with higher densities tend to sink (Priscilla and Patria, 2020). Ecologically gastropods are considered a valuable model for environmental biomonitoring of genotoxic pollutants (Radwan *et al*., 2020). They have been extensively studied for possessing therapeutically significant proteins and peptides which exhibit antiviral, antimicrobial, and antifungal activities (Cheung *et al*., 2014). This study underscores the ecological significance of gastropods in monitoring marine pollution and highlights the urgent need for mitigation measures to safeguard the coastal ecosystem.

Conclusion

This study found considerable microplastic (MPs) contamination in the gastropod species *Nerita albicilla* along the Karachi coast, with microfibers accounting for up to 84-88% of total MPs with the majority ranging in size from 0-25 µm. These findings provide valuable insights into the extent of MPs pollution and its potential impacts on marine life. The results highlight the critical need for actions to safeguard coastal ecosystems and the function of gastropods in monitoring marine pollution.

Confilicts of interest

The authors have no conflicts of interest to declare. All co-authors have seen and agree with the contents of the manuscript and there is no financial interest to report.

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