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Microplastic Occurrence in Seaturtle Nesting Beach Sediments from Terengganu, Malaysia

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Abstract

Data on the microplastic abundance in sea turtle nesting beaches of Southeast Asia are limited. We sampled four sea turtle nesting beaches in the northern and southern coastal areas of Terengganu, Malaysia between October and November 2018, to investigate microplastic abundance, shape, and colour at both high tide swash zone and dry dunes. Using optical observation, we isolated 2,489 microplastic items, belong to four types: Fibres, fragments, foam, and films. We found more microplastics at the high tide swash zone (58%) compared to the dune zone. Fibres were the most common shape (96.18%). Of the nine recognised colours found, black was the most abundant (35.64%) followed by transparent (24.53%). Of the sites investigated, those on the northern beaches had a higher abundance of microplastics. The causes of this difference were discussed. This study provides baseline data on microplastic contamination in Terengganu turtle nesting beaches. It highlights the need for further research to identify the effects on sea turtle nesting in this region.

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Key words: Fibre microplastics, sediments, Sea turtle nesting, South China Sea

1 Introduction

In 2019, global plastic production increased to 359 million tonnes, posing a growing threat to marine and terrestrial ecosystems. Asian industries contribute half of this production (51%), with 30% from China and 21% from other Asian countries [1].

Microplastics (MPs) can be defined as any solid synthetic organic polymers with a particle size in the range of 0.001–5 mm [2]. Primary microplastics are manufactured for a specific product, such as microbeads for abrasives in cosmetics, toothpaste. Secondary microplastics are fragmented particles derived from organic, synthetic polymer products used in the environment [3].

MPs are detected worldwide within the marine habitats, including water column, beach, subtidal and deep sea-sediment, arctic ice, freshwater bodies [4]. Due to their size, MPs are ingested by most organisms in the food web; and transferred through successive trophic levels, from planktons [5] to molluscs [6], fish [7], birds [8], sea turtles [9], and humans [10].

Both the surface area and hydrophobic characteristics of MPs cause the sorption and transfer of persistent organic pollutants (POPs), Dichlorodiphenyltrichloroethane (DDT), dioxins, and Polychlorinated biphenyls (PCBs) [5, 11]. Waves deposit microplastics and other marine debris on sandy beaches after they were discharged from land-based sources into marine waters [12].

Marine and coastal areas in Asia are some of the most plastic-polluted regions globally [10]. The South China Sea is one of the most plastic contaminated seas, with microplastics (size < 0.3 mm) contributing to 92% of the total load [12]. Other plastic debris of 1-20 mm accounted for more than 60% of the total plastic contamination of tourist beaches on the South China sea [13]. The Asian continental slope is the largest reservoir of microplastics with an inventory of 295 tons, whereas the continental shelf and deep basin are estimated to store 156 tons and 234 tons, respectively [12]. Inputs of plastics from the land through riverine current, to the marine waters go through beaching, drifting, and settling pathways until they reach temporary reservoirs on beaches, tidal wetlands, and benthic marine sediments [14].

Peninsular Malaysia is located between the Strait of Malacca to the west and the South China Sea to the east [15]. Of the Asian countries, Malaysia is ranked eighth based on the total amount of plastic trash dumped into the seas. About 22.9 million Malaysians live on the coast and are estimated to produce 1.52 kg/person of waste daily, with plastics representing 13% [16]. The estimated annual marine debris in Malaysia ranges from 0.14 - 0.37 million metric tons/year [17].

Plastics were the most abundant type of trash in Port Dickson beaches on the west coast [18]. Similar results were found in Sabah beaches [19].

Kuala Terengganu is one of the most contaminated beaches in Peninsular Malaysia [20]. In this region, 38 beaches are known sea turtle nesting beaches. The Terengganu state government identified a high level of marine debris on or in these sandy beaches, which may pose a threat to both adult and incubating clutches of sea turtles.

Sea turtles are highly sensitive to pollution. In particular, plastic pollution [21] found that tracks of sea turtles that did not dig nests had the highest plastics concentrations. This heavy pollution can cause adverse effects, including sea turtle entanglement and entrapment for adult sea turtles and hatchlings. On the other hand, due to the high specific heat, plastic pollutants in sediments can increase temperature [22]. This increase in sand temperature can impact temperature-sensitive species, such as the temperature-dependent sex ratio in sea turtles, leading to female-biased hatchlings or increase embryo mortality.

This study aims to estimate the microplastics spatial distribution from northern and southern nesting beaches of sea turtles along the Terengganu state facing the South China Sea. Isolated microplastics will be classified according to type and colour, from the four sampled beaches. The different occurrence levels among northern and southern beaches was discussed in terms of marine currents, seasonal changes and contamination sources.

2 Materials and Methods

2.1 Description of Study Sites

From 13 October to 17 November 2018, just after Southwest Monsoons (May to September), we carried out beach sediment collection at the end of a sea turtle nesting season in Terengganu, represented the condition of the nesting habitat in the second half of the nesting season when eggs develop into hatchlings. Pantai Penarik Setiu and Pantai Pengkalan Atap represent the northern part of Terengganu beaches, whereas Pantai Rantau Abang and Pantai Ma' Daerah represent the southern part of Terengganu beaches (Figure 1). The description and status of each sampling site are:

a) Pantai Penarik, Setiu; secluded within the State Park, known as Setiu Wetland area (5˚37'05.0" N, 102º48'16.7" E). Green turtles (*Chelonia mydas*) are still nesting here in good numbers (range value), as the site has less human disturbance.

b) Pantai Pengkalan Atap, in Kuala Nerus; This site is an isolated beach, with some human activity, at 05˚27.444" N, 103˚02.474" E. Based on information from locals, green sea turtles are still nesting here.

c) **Pantai Rantau Abang**, in Dungun district, at 4°52' 9.26 "N, 103° 23' 33.11 "E. It was used to be one of the best nesting sites for the Leatherback sea turtle *Dermochelys coriacea* until 2010 when breeding halted.

d) Pantai Ma' Daerah, **Kerteh**; one of sea turtle sanctuaries in Terengganu state, at 4° 32'22.19 "N, 103°28'15.54"E in Kemaman District, established as a managed beach for turtle conservation since 1999 by the Department of Fisheries Malaysia, BP, and WWF-Malaysia.

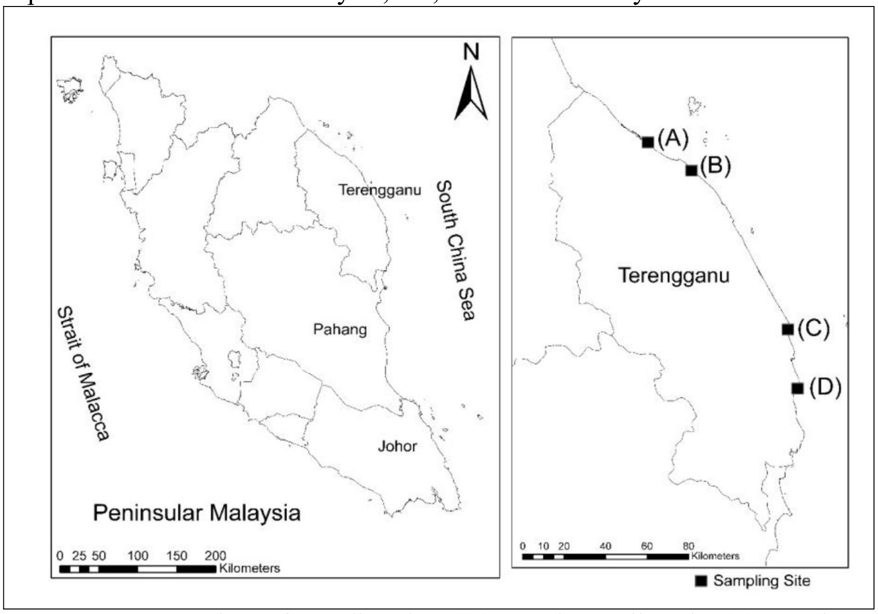

Figure 1: Locations of sampling sites: (A) Pantai Penarik Setiu, (B) Pantai Pengkalan Atap,(C) Pantai Rantau Abang, and (D) Pantai Ma' Daerah.

2.2 Sample Collection and Extraction

We placed one line of transect at each site's centre perpendicular to the shoreline. Quadrates of 0.25 m x 0.25 m set at high tide and dune zones. Sand samples scooped using metal shovels to 5–6 cm [22]. Two sample replicates were collected from each point (swash or dune zone). Sediment samples then transferred into a 2 L clean sample container covered with aluminium foil to avoid contamination and labelled, then stored in the fridge at 4 ºC until further analysis. Then samples were oven-dried for 24 hours at 40 ˚C to 60 ˚C, dry weight ranged from 3040 to 3058 grams. Sediment samples, then sieved using stainless steel sieves with the following mesh sizes: 125 µm, 250 µm, and 600 µm. We extracted microplastics from the sediment following [23]. Sand samples separated into labelled 500 ml glass beakers covered with aluminium foil. We left the mixture for a few minutes to settle down impurities.

2.3 Filtration

Water samples containing microplastics were filtered through 0.45 µm cellulose nitrate membrane filter paper using a vacuum pump. Filter papers kept in Petri dishes, covered with foil and dried overnight in a desiccator.

2.4 Contamination Control

Tools and glassware rinsed with deionised water to avoid airborne contamination. We used only metal and glass equipment during the sample preparation. One procedural blank was included alongside each set of samples, and no MPs were obtained from these samples, indicating that any background pollution resulting from the experimental treatment was negligible.

2.5 Physical Characterisation

Microplastic isolation was performed according to [24] Hidalgo-Ruiz *et al*. (2012). Under 40x Olympus SD30 Stereo Microscope (Olympus Optical Co., Japan), dried filter papers (containing microplastics) were examined and classified according to [2], as: beads, fragments (sheets, hard and soft granules, and flakes, including foam), or fibres (single and tangled or strands of fibres), and colours (black, blue, brown, green, white, transparent, red, yellow, and purple). Retrieved MPs were classified by colour for each sampling transect type (High tide mark or dune sediments), and the relative abundance of each MPs colour to the total MPs of that colour at each transect type for all beaches was calculated. In this study, all MPs were verified using the hot needle test. Although the hot needle test cannot be used to identify MPs with polymer type, it is accepted as an economical way to verify particles based on their response to a hot needle [25]. Microplastic pieces were transferred into a glass vial containing deionised water using soft, thin-tipped forceps.

2.6 Data Analyses

Relative microplastic abundance of shapes, colours and location, and charts were produced using Microsoft Excel®. Comparison of microplastic size classes abundance among sampled beaches was conducted using the R statistical environment version 2.11.1 [26].

3 Results

3.1 Distribution and Abundance of Microplastics at Study Sites

Two thousand four hundred eighty-nine microplastics items were isolated from all sampling sites combined. Pantai Penarik showed the highest overall microplastic abundance, 41.27%, followed by Pantai Pengkalan Atap, 35.11%, while it was 14.62% at Pantai Rantau Abang and 8.99% at Pantai Ma' Daerah. The combined distribution of microplastics between high tide and dune areas showed some differences too. 58% of microplastics were found at high tide mark, while the remaining 42% were in the dune area. All beaches contained all four size MPs classes (> 125, 250, 600 µm). The two northern beaches (Pantai Penarik and Pantai Pengkalan Atap) showed a relatively higher abundance compared to the two southern beaches (Pantai Rantau Abang and Pantai Ma' Daerah). Furthermore, about 55% of the MPs size class (>125 µm) were reported from dune sediments of Pantai Penarik (Figure 2). Comparing the relative abundance of each MPs size class among the four sampled beaches, showed no significant differences, Kruskal Wallis test $H(5) = 0.25$, $P > 0.05$.

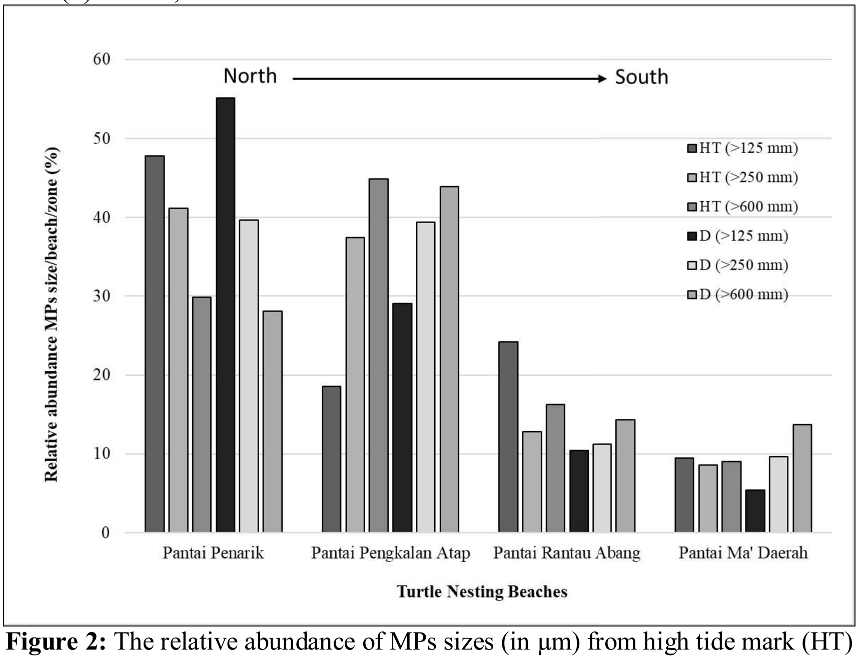

Figure 2: The relative abundance of MPs sizes (in µm) from high tide mark (HT) and dune (D) sediments of four turtle nesting beaches in Terengganu; notice the higher abundance within the two Northern beaches.

3.2 Microplastics Shapes

All sampling sites contained fibre and fragment microplastics. Most microplastics were fibres (96.18%) compared to other shapes (3.82%). Fibre MPs dominated the shape types at all beaches and ranged from 93.94% at Pantai Pengkalan Atap to 98.66 at Pantai Ma' Daerah. Fragment MPs also found at all beaches, with the highest abundance (2.92%) were found at Pantai Penarik, and lowest (0.91) was at Pantai Pengkalan Atap. The other two shape types (Foam and Film) were found only in Pantai Pengkalan Atap sediments, with an abundance of 4.92% and 0.23% respectively (Figure 3). We found no beads in any of the four beaches.

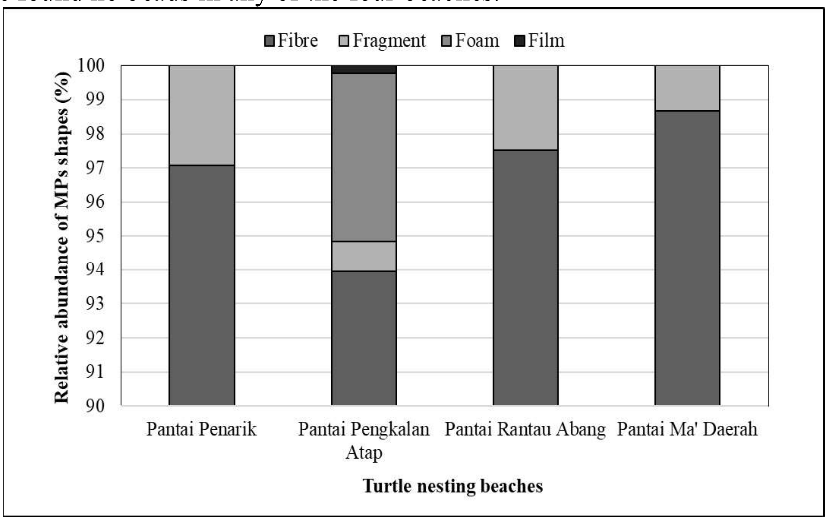

Figure 3: The MPs shape, composition in sediments of four nesting beaches in Terengganu.

3.3 The Relative Abundance of Mps Colours at High Tide Mark and Dune Sediments

Among the nine identified colours of microplastics found in this study, black was the most abundant with 35.68%, followed by transparent with 27.65% and Red 13.24%. Other colours ranged from 0.78% for Yellow to 10.34% for Brown. Figure (4) shows the relative abundance of each MPs colour at both high tide mark and dune sediments for each sampled beach.

At high tide mark samples, 21.2% (n= 1504) of black MPs were found in Pantai Penarik, followed by Pantai Pergkalan Atap 13.9 % (n= 984), while the lowest abundance was in Pantai Ma' Daerah with 5.9% (n= 416). A similar trend was found in dune transect sediments, 24.6% (n= 1744) of black MPs were found at Pantai Penarik followed by 17.4% (n= 1232) from Pantai Pergkalan Atap, and the lowest abundance was at Pantai Ma' Daerah 4.3% (n= 304).

The brown-coloured MPs were highest in high tide mark sediments of Pantai Pergkalan Atap with 24.6% (n= 504). It was lowest at Panati Ma' Daerah, 5.1% (n= 104), while at dune sediments it was highest at Pantai Penarik, 22.3 % (n= 456), and the lowest was at Pantai Rantau Abang, 2.3% (n= 48). The blue-coloured MPs were almost equally distributed at high tide mark sediments between Pantai Penarik, 19.7 % (n= 208), and at Pantai Rantau Abang, 18.9 % (n= 200). In comparison, it was 24.2 % (n= 256) from Pantai Penarik's dune sediments, and the lowest abundance was at Pantai Pergkalan Atap with 5.3 % (n= 56). Green MPs were found at Pantai Penarik high tide mark with 31.7 % (n= 264), while the lowest abundance was in Pantai Ma' Daerah with 1.9% (n= 16). Within dune sediments, it was highest at Pantai Penarik with 22.1 % (n= 184), and the lowest abundance was reported from both Pantai Rantau Abang and Pantai Ma' Daerah with 4.8% (n= 40) for each. The white MPs were found only in three samples, the high tide mark sediments of Pantai Penarik with 4.3 % (n= 16). The highest abundance reported at dune sediments of Pantai Pengakalan Atap, 93.5 % (n= 344) and the lowest were from Pantai Ma' Daerah, 2.3% (n= 8). The transparent MPs were found on all beaches in both high tide mark and dune sediments, the highest abundance was at Pantai Pergkalan Atap within the high tide mark sediments, with 21.4% (n= 1176), and the lowest from the dune sediments of Pantai Ma' Daerah, 3.6 % (n= 200). For red-coloured MPs, 26 % (n= 720) were found in Pantai Penarik high tide mark sediments, followed by Pantai Pergkalan Atap, 19.9 % (n= 552), and the lowest 3.5 % (n= 96) from Pantai Ma’ Daerah. Within the dune sediments, a similar trend was observed, and both Pantai Rantau Abang and Panti Ma' Daerah showed the lowest abundance, 4.3% (n= 8). The yellow MPs from high tide mark sediments were equally abundant for both Pantai Penarik and Pantai Rantau Abang, 21.4 % (n= 24) each. Similarly, between Pantai Pergkalan Atap and Pantai Ma' Daerah, 7.1 % (n= 8). At the dune sediments, yellow MPs were absent from Pantai Pergkalan Atap sediments, and it was highest at Pantai Rantau Abang, 21.4 % (n= 24), followed by Pantai Penarik, 14.3 % (n= 16), and the lowest reported from Pantai Ma' Daerah, 7.1 % (n= 8). Finally, the Purple MPs were highest at high tide mark sediments from Pantai Rantau Abang, 31.3 % (n= 40), followed by Pantai Penarik, 18.8 % (n= 24), while they were lowest at Pantai Pergkalan Atap with 6.3 % (n= 8). Purple MPs were absent from both Pantai Penarik and Pantai Pergkalan Atap dune sediments, and only found at Pantai Rantau Abang 18.8 % (n= 24), and at Pantai Ma' Daerah, 12.5 % (n= 16), Figure (4).

The above colour distribution shows variable results between the two sampled sediment transects, which indicates a sort of difference in some colours at each sediment type. It is likely that those found at high tide mark sediments and absent from dune sediment, indicating possible recent deposition.

The source of these MPs (from river driven debris or via other land-based sources), in addition to the beach geomorphology and the current system, controls the presence and abundance of each of the colour MPs.

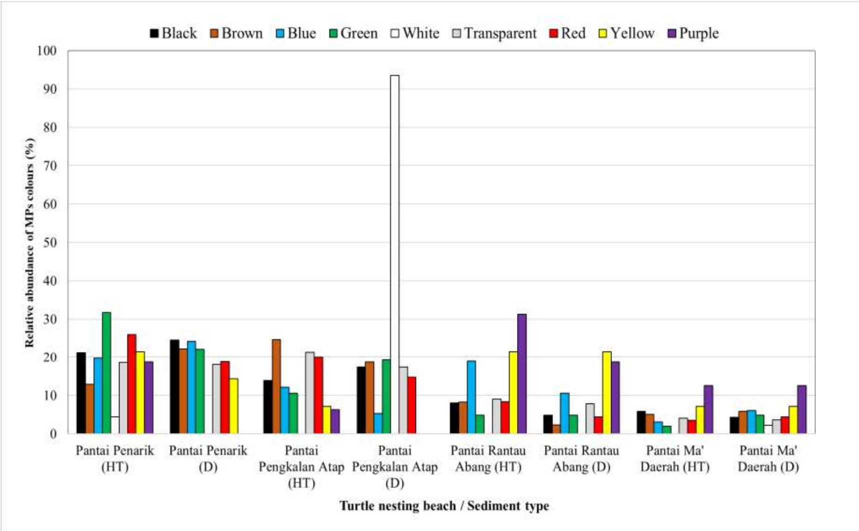

Figure 4: Colour distribution of microplastics from high tide mark and dunes of four turtle nesting beaches in Terengganu, Malaysia.

4 Discussion

4.1 Spatial Distribution

All four studied beaches were exposed various levels of microplastic contamination, with the northern beaches the worst affected (Figure 2). Our results are also in line with those of [27] in Kuala Nerus and Kuantan Rivers, as they found Kuala Nerus River waters carries more microplastic load to the sea than Kuantan River, which supports land based sources of microplastics.
The difference in grain size, current patterns, wave action, and wind exposure can affect microplastic accumulation in sediments [3]. The coastline of Terengganu is governed by the Northeast Monsoon (October to March) and the Southwest Monsoon (May to September) every year [28]. The monsoonal season transports the sediment and influences the sand characteristics and beach morphology [22]. Furthermore, seasonal change between the northern monsoon (October to March) and the southwest monsoon (May to September) controls the ocean currents along the Terengganu coastline [29]. The current flow along the Terengganu coast is southward during March-April and September-October [30]. Local winds can be very influential in the sedimentation process during both inter-monsoon and southeastern monsoon seasons.

The circulation and wind are both weak during that period, leading to limited mixing [31], which would slowly cause sediment accretion (building up) of suspended microplastics and other marine debris on the beaches. More recently [32] found that monsoon winds and effect from circulation in the Gulf of Thailand controls the current speed and direction in Terengganu waters. Southwest monsoon was also linked to higher marine debris sedimentations in East Malaysia [33]. These findings are in line with the results of the present study, as our sampling was conducted in early October, just after the end of the southwest monsoon.

4.2 Microplastics Form and Colours

Among the four identified shapes of microplastics from the study area, fibres were the most abundant shape type, followed by fragments. In contrast, the Pantai Pengkalan Atap was the only site with Foam and film shapes. Other research [34] found that the most common form of ingested microplastics in bivalves in Setiu Wetland (near Pantai Penarik) was the fibre. Similar results found in sediments from other countries in the Indian Ocean [35], the northwest Mediterranean Sea [36], and Scotland [37].

Using washing machines can cause the release of extensive amounts of microplastics (up to 1,900 fibres) by washing a single piece of clothing [38]. Microplastics are transported through sewage to treatment plants that release its waters in rivers, to reach beaches.

Black colour MPs have dominated identified microplastic colours (35.68%), followed by transparent (27.65%) and other colours (Figure 4). Similar trends reported from Kuala Nerus and Kuantan rivers, Malaysia [27], Jiaozhou Bay in China [39], and Bizerte lagoon, Tunisia [40]. Other colours ranged from Red (13.24%) and less than 1% of the yellow colour. White was absent in Pantai Rantau Abang beach, and it was the most common at Pantai Pengkalan Atap. The extensive usage of polystyrene foam, in fishing gear floats, can cause such dominance of white colour at Pantai Pengkalan Atap.
Diverse colours at all four sites reflect the full range of marine debris that contributes to the formation of microplastics in the study area.

4.3 Potential Sources

The results showed more accumulation of microplastics within the high tide mark zone compared to the dune zone. The high tide swash zone showed more contamination level (58%). [22] found opposite results, with more microplastics in the dune sediments and less in the swash zone. These differences could reflect differences in the number of transects, due to area, beach width, tide frequency, and differences in microplastic movement patterns and more debris from land-based sources compared to Malaysian sites.

Pantai Pengkalan Atap showed higher levels of larger microplastic particles (> 600 um), (Table 1), at both high tide zones (44.85%) and within the dunes (43.88%). The accumulated marine debris from fishing and other anthropogenic activities at this site can explain this [20]. While the other three beaches have a lower anthropogenic impact, marine debris can also be in the form of foam and film (both only reported from this site), with 4.95% and 0.23%, respectively (Figure 2), similar results were found by [41] in mangrove sediments of Malaysia, and [20] in beach sediments. The lack of land-based sources of pollution pathway (Rivers) can explain (with other factors) the lower level of microplastic contamination at the Ma' Daerah site. The nearest river mouth located to the south of this site, i.e., River Kerteh that opens at a small bay (Figure 1). This can limit the southward movement of drifted microplastics, especially when we consider the north-south direction of marine currents, before and during the study period. This site also showed the highest relative abundance of fibres among all study sites (98.66%) with a lower level of fragments (1.34%) with the other microplastic types absent (Figure 2).

River input and fishing activities and other maritime operations are the most contributing sources of microplastics in coastal waters [42]. The incomplete removal of microplastics during the water and wastewater treatment processes (released into rivers) cause the release of enormous quantities to the environment [43]. It is essential in future to assess the contribution of water, treatment of microplastic release in Malaysia. Other sources can include microplastics drifted from land masses to the north and east, during the NE monsoon, i.e. Vietnam, Philippines, Indonesia.

4.4 Ecological Implications

The increasing consumption and release of, plastic debris (of various sizes) into the marine environment, can cause severe effects for both the environment and biota. As microplastics washed up from the sea and accumulated at beaches, it could affect beach fauna. Birds [8], small mammals [44], sea turtles [9], and other reptiles are the vertebrates that use the beaches as their foraging, nesting, and breeding ground. Impacts on these animals can be in the form of direct ingestion, entanglement (of adults and young). Debris in the nest chamber can prevent sea turtle hatchlings, from emerging to the soil surface [45]. The microplastic content of sandy beaches can also alter temperature and humidity [22], introduce other toxicants to the sand [46]. Plastics have a higher specific heat compared to sand, especially dark microplastics [22]. High microplastic levels within turtle nests sand, can increase nest temperature, which would affect hatching success and cause female-biased hatchling sex ratios [45].

Unbalanced sex ratios in a population may lead to that population extinction due to the failure of individuals to find mates. The results of the present survey can add a factor to escalate the already proven female-biased hatchling production in Malaysia [47]. More in-depth research is needed to understand how microplastics types, colour, and abundance within the nest substrate, can influence the thermal profile of the incubating nest, and impact hatchlings fitness.

5 Conclusions

This study provides baseline data and a better understanding of microplastic occurrence in sea turtle nesting beaches. All studied nesting beaches found to contain microplastics.

Fibre type with dark and transparent colours was the most common. Microplastic contaminated water flows with rivers to the coast, and changes in seasonal marine currents both play a significant role in the movement and accumulation process of these contaminants on sandy beaches. Sites away from river mouths had lower contamination levels. We recommend the need for a more in-depth and rigorous study, including expanding the number of sampling sites, times and replicates and using more advanced methods of modelling microplastic movements at sea [48], and identifying plastics, polymer structure such as infrared or Raman spectroscopy.

6 Acknowledgements

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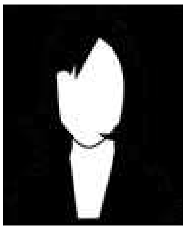

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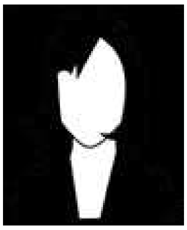

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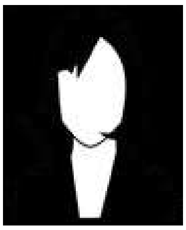

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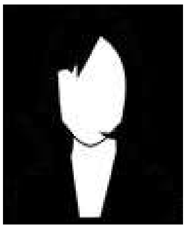

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