ORIGINAL PAPER

Abundance and distribution of macro- and micro-plastics at three different habitats along the Penang Coastline in the Northern Straits of Malacca

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Abstract. The abundance and distribution of Macro- (> 2.5 cm) and microplastics (1-5 mm) at three different habitats were documented. Particle size analysis on the sediment of each habitat were carried out to characterize the habitat. Macroplastics and microplastics were found at all study sites. Macroplastics were found only at the high tide line. Packaging, electrical and electronic, household, construction, agriculture and others plastics market sector were found. The highest amount of macroplastics were found at Pulau Betong (mudflat) which was 20.25 g/m^2. Fragment, film, foam, and filament type of microplastics were found. The highest average number of microplastics were found at the high tide line of all study sites. The highest total number of microplastics among the study sites found during the sampling time and within the quadrats employed was 72 items at Teluk Aling (fine sandy beach). The source of plastics pollution was from local activities and transportation of debris from other places by oceanic current and wind.

Keywords: Straits of Malacca, Malaysia, Penang, Macorplastics, Microplastics, Mudflat, Sandy beach

1. Introduction

World plastic production is 335 million metric tons in 2016 (The Statista 2018). When plastics is not managed properly, it will end up in the landfill and in the worst-case scenario, in the ocean becoming marine debris. It is estimated that 150 million metric tons of plastic are already in the ocean and by 2050, there will be more plastic than fish by weight (Ocean Conservancy and McKinsey Center for Business and Environment 2015; World Economic Forum 2016). It is now one of the pollutions in the world's water, which along with its different sizes, affecting different marine environment and different levels of the food chain including human at the top level of food chain (Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) 2015). Microplastics are plastics with size of lesser than 5 mm (Cole et al. 2011). They became a concern globally as they are exposed to wider range of organisms due to its small size, either manufactured intentionally for specific purposes, termed primary microplastics, or secondary microplastics, which are generated when fragmented from its larger counterpart, macroplastics (Van Cauwenberghe et al. 2015b).

Plastics were found in many different habitats. For example, hydrosphere environment includes sea surface layer, water column, and benthic of ocean, and estuaries, lagoon and others while terrestrial environment include intertidal zone of sandy beaches, mudflat, mangrove and others (Hidalgo-Ruz et al. 2012; Liebezeit and Dubaish 2012; Vianello et al. 2013; Barasarathi et al. 2014). To date abundance and distribution of macro- and micro-plastic had been studied on some sandy beaches and mangrove of Straits of Malacca and South China Sea (Ismail, et al. 2009; Noik and Tuah 2015; Barasarathi et al. 2014). In 2010, a total of approximately 868, 523 ton of plastic were disposed (National Solid Waste Management Department 2011) in Malaysia. Plastics also constitute 12%, the second highest of waste composition of Malaysia (Bavani 2016). Without proper management, that could end up in the river and ocean, contributing to the amount of plastics debris found in Malaysia. However, no survey had been done on Penang, in the vicinity of Straits of Malacca. During a study in 2012, Ryan (2013) found 578 floating items/km^{-2} at the Straits of Malacca where 98.9% of it are plastics. It is possible that those macro and microplastics been washed up on-shore by oceanic current and wind, affecting the ecosystem at the coastline of Penang, beside local ontribution of plastic waste (Ryan et al. 2009). This study aims to assess the current status of abundance and distribution of macro- (> 2.5 cm) and microplastics (1 – 5 mm) pollution at different habitats along Penang coastline at the northern Straits of Malaccaand to identify major category and type of macroplastics and microplastics found at these habitats. This study serves as a baseline study to assess the potential risk of the pollution to the habitat and future reassessment of the sites. The selected study sites were Pulau Betong (mudflat), Pasir Panjang (coarse sandy beach) and Teluk Aling, (fine sandy beach).

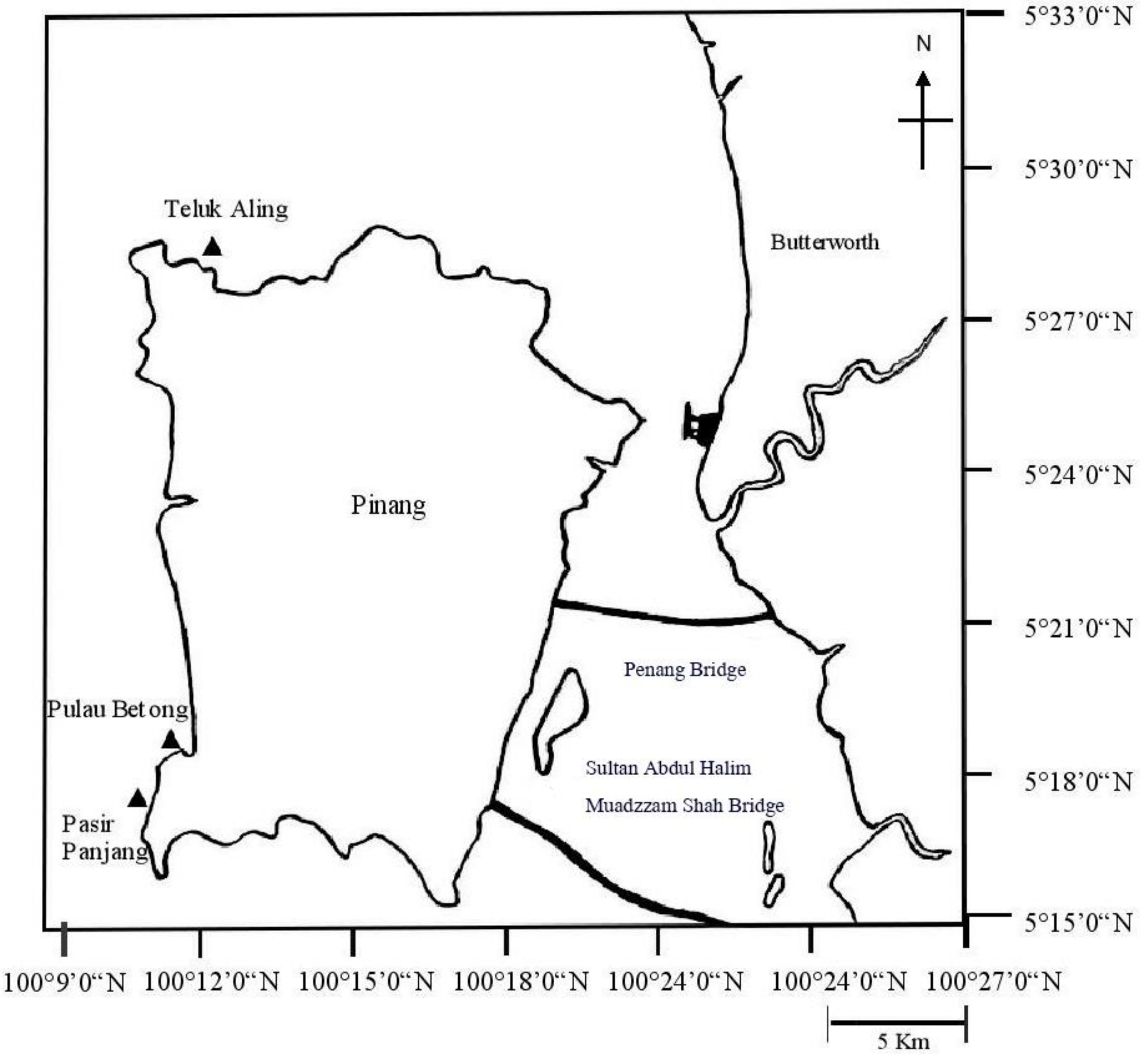

Figure 1. Location of study sites (▲) along the Penang coastline.

2. Materials and Methods

2.1 Site Selection

The study areas comprised three different habitats along the Penang island coastline in the Straits of Malacca, which are Pulau Betong (mudflat), Pasir Panjang (coarse sandy beach), and Teluk Aling (fine sandy beach) as shown in Figure 1. Preliminary survey found that each habitat has different sediment particle size. Sediment samples were sieved through tower sieves with 2000 µm, 500 µm, 250 µm, 125 µm, and 63 µm mesh size sieve. Each habitat is influenced by the local activities as described in Table 1.

2.2 Sample Collection

Samplings were carried out on 7th, 8th, and 20th of October 2017 during the spring low tide. Macroplastics and microplastics samples were collected at each habitat. High tide line, middle tide line and low tide line at each habitat were identified.

2.2.1 Macroplastics sample collection

Method by Lippiat et al. (2013) of NOAA was adopted with modification. Macroplastics are defined as larger than 2.5 cm following Lippiat et al. (2013). Macroplastics were first sampled to avoid contamination and obstruction of microplastics sampling. Suspected plastic debris that is larger than 2.5 cm were collected within a 100 m transect × 1 m width of area of the low tide line, middle tide line, and high tide line of the study site as illustrated in Figure 2. The collected samples were brought back to laboratory for further analysis as described in later section

2.2.2 Microplastics sample collection

Microplastics with size of 1-5 mm were considered in this study. Method by Besley et al. (2017) and Lippiat et al. (2013) of NOAA with modification were adopted. A stainless-steel quadrat with 50 × 50 cm frame size was randomly laid on the 0-20 m area of the 100 m transect laid for macroplastics sampling. The top 5 cm of the sediment within the quadrat was scooped with metal spoon and collected in the sample bag. The steps were repeated at the 20-40 m, 40-60 m, 60-80 m, and 80-100 m area of the transect as shown in Figure 3.

2.3 Laboratory Analysis

2.3.1 Macroplastics analysis

All macroplastics samples were air dried. Individual macroplastic was weighted and sorted to major market segment of Malaysia according to NSWMD (2011), which comprises of packaging, electrical and electronic, household, automotive, construction, agriculture and other sectors. The weights of all macroplastics sorted to same major market sector were added and expressed in g/m^2

Table 1. Description of study sites at Penang coastline

Location	Coordinate	Description
Pulau Betong	5°18'27.69" N, 100°11'41.98" E	• Sediment particle size range = < 63µm • Mudflat • Surrounded by fishing village and housing area • Separated by small patch of mangrove
Pasir Panjang	5°17'59.37" N, 100°11'04.67" E	• Sediment particle size range = 2 mm-500µm • Coarse sandy beach • Hotspot for fishing activities
Teluk Aling	5°28'03.49"N, 100°12'00.55"E	• Sediment particle size range = 1 mm-125µm • Fine sandy beach • Located in Penang National Park

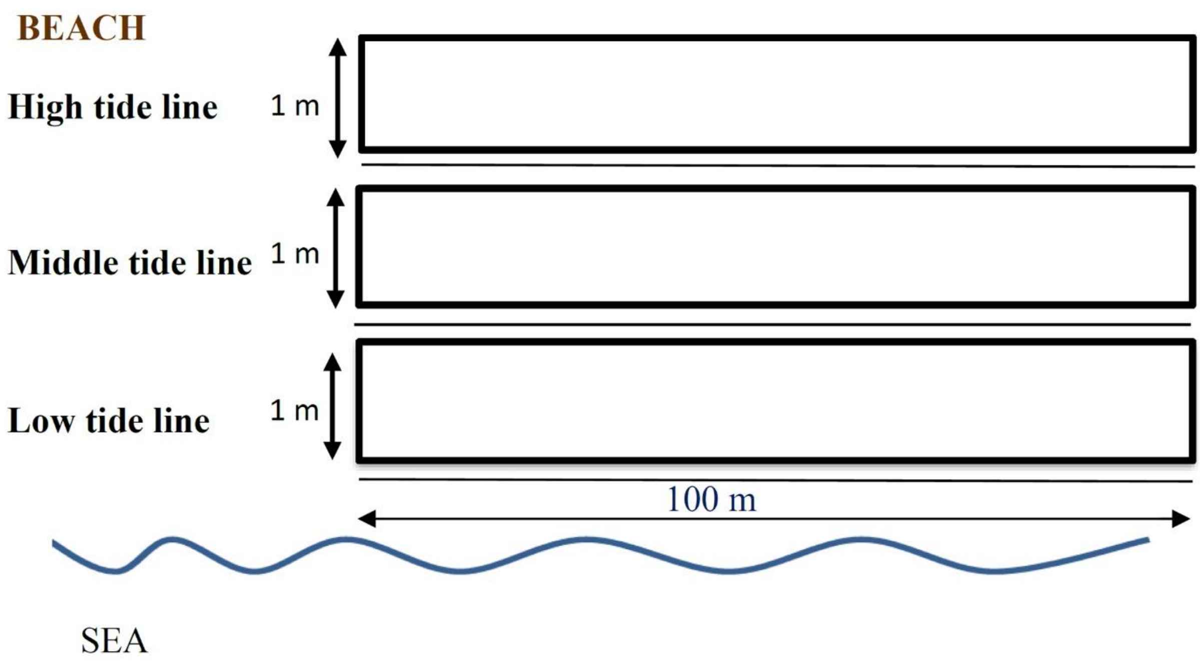

Figure 2. Schematic diagram of macrop

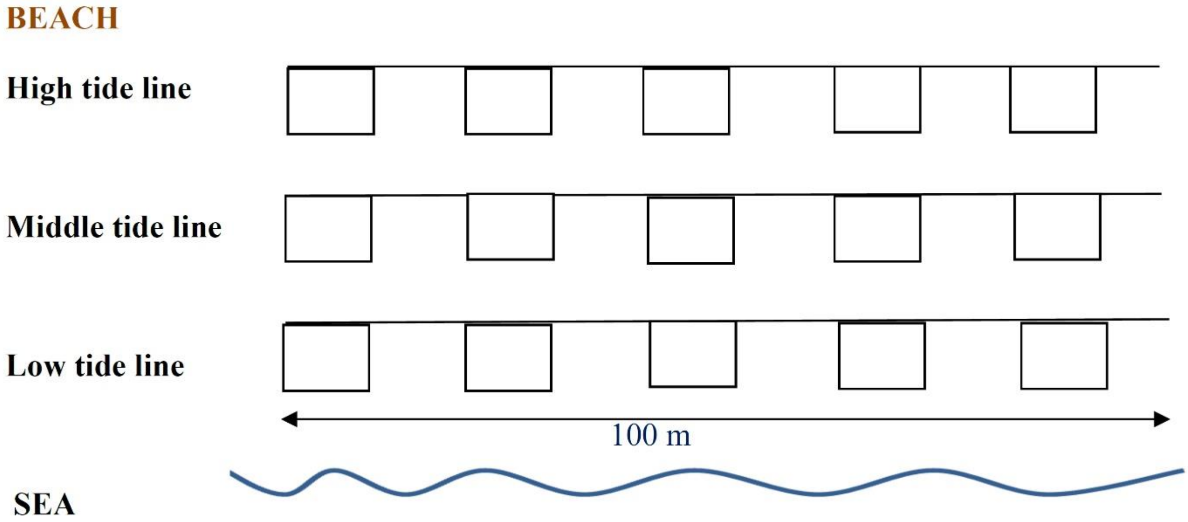

Figure 3. Schematic diagram of microplastics sampling using quadrat ( ) at intertidal zone of each study sites

2.3.2 Microplastics analysis

During the processing of sediment and microplastics, latex glove and laboratory coat were wore to minimize contamination. Samples were processed and kept at the area in laboratory with minimum disturbances, such as away from the door and not influenced directly by wind.

Sandy beach sediment were air dried. The dried sediment was sieved through a 1 mm mesh size stainless steel sieve. Samples retained on the sieve were inspected for possible microplastics following the method by Hidalgo-Ruz et al. (2012) rules. The remaining sample on the sieve was subjected to density separation. Calcium chloride of 1.3 g/mL density was mixed with the sediment in a cleaned beaker.

The mixture was vigorously stirred for two minutes and then allowed to settle until a clear solution between the meniscus and the denser matter at the bottom of the solution been formed. The floating samples were separated and examined for possible microplastics. The collected microplastics were stored in cleaned glass petri dish.

Mudflat samples were mixed with filtered fresh water in a container and stirred until the sediment was evenly mixed with the water. The mixture was then sieved through a cleaned 1 mm mesh size stainless steel sieve. Samples retained on the sieve were examined for possible microplastics and the microplastics were stored in cleaned glass petri dish.

All microplastics were classified according to types, which are fragment, filament, beads, pellet, films, and foam (Crawford and Quinn 2017). All data was expressed in average number of microplastics item/m^3 of sediment while the data on type of microplastics found at each study site was expressed in number of microplastics item.

2.4 Statistical analysis

Statistical analysis was done using Statistical Package for the Social Science (SPSS). Two-way analysis of variance (ANOVA) was used to test whether there was a significant interaction between study site and the average number of microplastics at each tide line. One-way ANOVA and independent sample t-test was used to test the differences between tide line within each study site. Significance level for all statistical analyses were 0.05.

3. Results

3.1 Abundance and distribution of macroplastics across tideline of different study site

All macroplastics were only found at high tide line of all study sites. The composite weight of macroplastics by area (g/m^2) sorted for each market sector for each study site were summarized in Table 2 and Figure 4. The highest abundance of macroplastics was found at Pulau Betong (mudflat), which was 20.25 g/m^2, with the second highest at Teluk Aling (fine sandy beach), 18.40 g/m^2 and the least among the sites at Pasir Panjang (coarse sandy beach), 17.62 g/m^2. All sites have macroplastics of packaging, household and other sector, while macroplastics of electrical and electronic were only found at Pulau Betong (mudflat) and macroplastics of construction were only found at Pasir Panjang (coarse beach). Packaging sector constitutes the highest abundance of macroplastics at Pulau Betong (mudflat), which was 13.50 g/m^2 and Pasir Panjang (coarse sandy beach), 7.63 g/m^2, with Pulau Betong (mudflat) bearing the highest amount of macroplastics found while for Teluk Aling (fine sandy beach) the agriculture sector constitutes the highest, which was 6.70 g/m^2. There were no macroplastics of automotive sector found at all sites.

Table 2. Abundance of macroplastics (g/m^2) at each study site by plastic major market sector of Malaysia.

Macroplastic Sector	Abundance of macroplastics, g/m²		
	Pulau Betong (mudflat)	Pasir Panjang (coarse sandy beach)	Teluk Aling (fine sandy beach)
Agriculture	1.50	0.00	6.70
Packaging	13.50	7.63	4.50
Household	2.00	2.72	2.50
Electrical and Electronic	1.50	0.00	0.00
Construction	0.00	3.30	0.00
Automotive	0.00	0.00	0.00
Other	1.75	3.97	4.50
Total	**20.25**	**17.62**	**18.20**

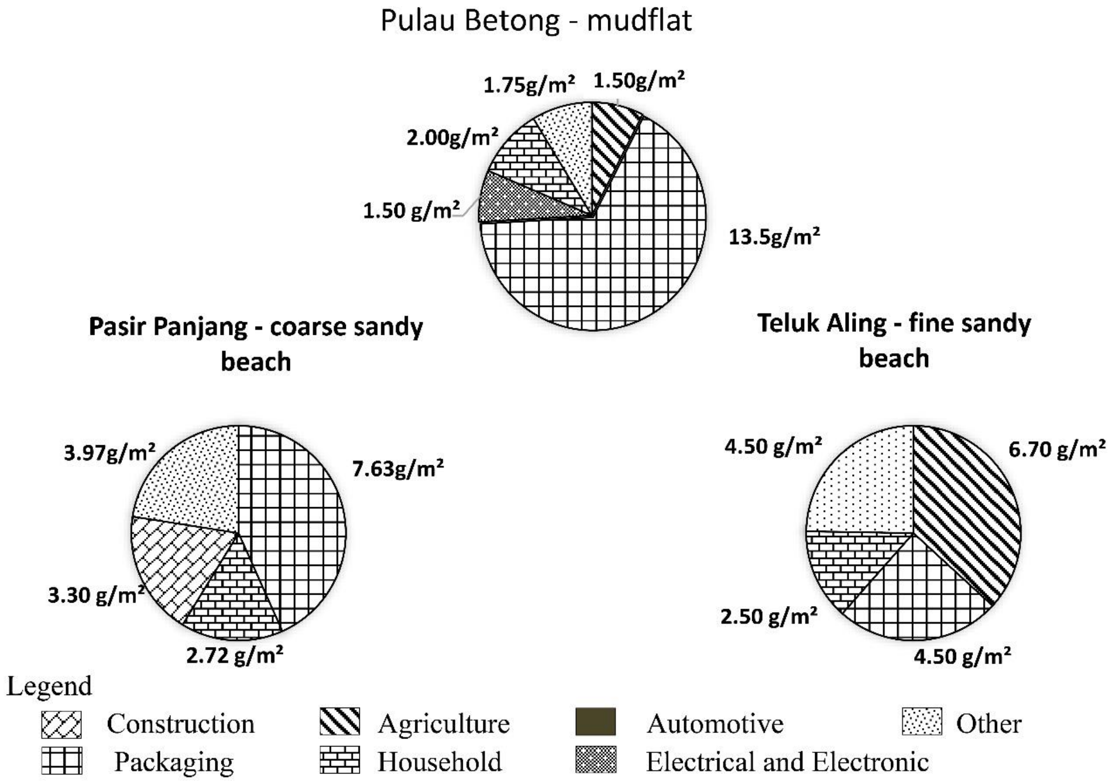

Figure 4. Abundance of macroplastics (g/m^2) at each study site by plastic major market sector of Malaysia represented in pie chart.

3.3 Particle Size Analysis

Table 3 shows the size range of particle and grain size classification at each study site. Pasir Panjang has the coarsest particle among the study site dominated its habitat, in the range of 500 µm to 2 mm, followed by Teluk Aling (fine sandy beach), in the range of 125 µm to 1 mm. The finest size of particle among the site was detected at Pulau Betong (mudflat), which is less than 63 µm. According to particle size classification by Wenworth (1922), Pulau Betong has at least silt and, or clay dominated its habitat. Pasir Panjang has very coarse sand to coarse sand and Teluk Aling (fine sandy beach) has coarse sand to fine sand.

3.4 Type of Microplastics

Fragment, foam, filament, and film type of microplastics were found in this study. Figure 5 shows the photographs of example of the type of microplastics found in this study.

3.5 Abundance and Distribution of Microplastics across Tide Line

The abundance and distribution of microplastics across high tide line, middle tide line, and low tide line at the three habitats were summarized in Figure 6. Samples of microplastics at low tide line of Pulau Betong (mudflat) were not collected as the tide line was hard to be determined during the time of sampling. There was an increasing trend of average number of microplastics from the low tide line towards the high tide line. The highest average number of microplastics microplastics was found at high tide line and the second highest was found at middle tide line for all the sites. Only Pasir Panjang (coarse sandy beach) had microplastics found at its low tide line among all the habitat during the study. The highest average of microplastics was found at the high tide line of of Pulau Betong (mudflat), which was 928.00 items/m^3 while the lowest average number of microplastics was found at low tide line of Pasir Panjang (coarse sandy beach) which had 128.00 items/m^3. There was no microplastics found at low tide line of Teluk Aling (fine sandy beach) during the study

3.6 Type of microplastics at different study site

The highest number of microplastics found during the sampling time among the study sites was found at Teluk Aling (fine sandy beach), which was 72 items, followed by Pulau Betong (mudflat), which was 68 items. The lowest number found during the sampling time among the study sites was found at Pasir Panjang (coarse sandy beach). Fragment, film , foam, and filament were the types of microplastics found at all study sites. Figure 7 shows the abundance of each type of microplastics at each study site. From the total number of microplastics at each location, fragment type constitutes the highest proportion of microplastics among other typefor mudflat and Pasir Panjang (coarse sandy beach), which was 52 and 30 items, respectively. For Teluk Aling (fine sandy beach), foam type constitutes the highest, which was 60 items. Film type constitutes the lowest number for Pulau Betong (mudflat) and Pasir Panjang (coarse sandy beach), which was 2 items and 1 item, respectively, while for Teluk Aling (fine sandy beach), filament constitutes the lowest which was 2 items.

Table 3. Size range of particle and grain size classification at each study site.

Study site	Size range	Type of particle
Pulau Betong (mudflat)	< 63µm	Silt and, or clay
Pasir Panjang (coarse sandy beach)	500 µm – 2 mm	Very coarse sand to coarse sand
Teluk Aling (fine sandy beach)	125 µm – 1 mm	Coarse sand to fine sand

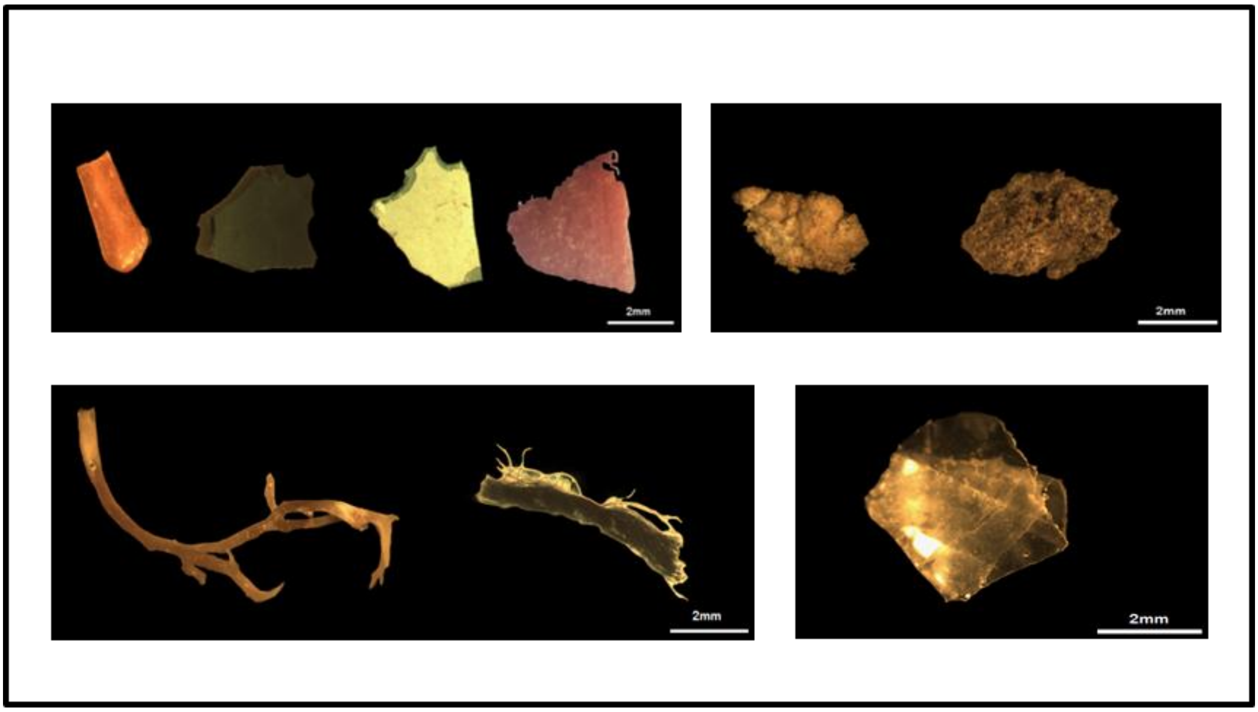

Figure 5. Photographs of example of different types of microplastics found in this study taken with stereomicroscope: (a) fragments, (b) foam, (c) filament, (d) film. Scale bar = 2.0 mm

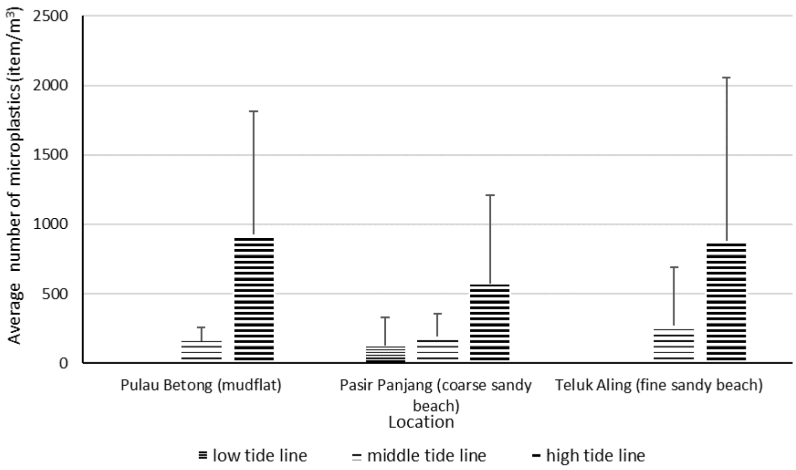

Figure 6. The average number (item/m^3) and distribution of microplastics across tide line at each habitat. The error bars are the standard deviation for each average number.

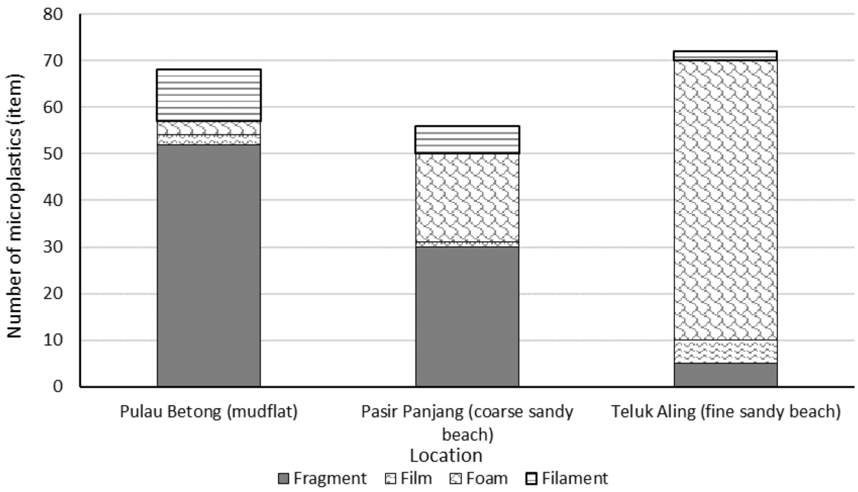

Figure 7. The number of microplastics (item) classified by type at each study site.

4. Discussion

4.1 Abundance and Distribution of Macroplastics

All the macroplastics were found at the high tide line for all the study sites. Due to various factors, such as wave action, wind and storm, the macroplastics were washed to the high tide line as observed in other study (Kunz el al. 2016). Furthermore, it is also where most beachgoers stay and nearest to the local activity which is not usually affected by wave (Fauziah et al. 2015). The highest amount of macroplastics by g per m^2 was found at Pulau Betong (mudflat). The likely contribution of the pollution maybe attributed to the high retention of the macroplastics due to the presence of the silt and, or clay particles which has high porosity, and retention of water allowing water to flow through between the particles thus increasing the thixotropic property compared to the other two habitats (Smith and Li 1966; Chapman 1949; UK Special Areas of Conservation n.d.; Zhang et al 2017). Wave and wind action can transport plastic debris at the sea onshore (Cole et al. 2011). When the macroplastics were in contact with the mud, the macroplastics may agitate and penetrate the mud causing them to stay at the habitat. However, more studies need to be done to test the relationship between thixotropic property and retention of plastics. Macroplastics were also found trapped between the aerial root and pneumatophore of the mangrove tree at the mudflat, which also prevented the tidal wave to wash the macroplastics back to the water. Pulau Betong (mudflat) is surrounded by housing area, which the local residents may dispose their waste including plastics at the mudflat contributing to the high amount of macroplastics, as in the case of Kampung Trombol at Sarawak, where the residents were suspected to dispose their waste on the beach in addition to lacking of solid waste management at the place (Tuah et al. 2015). Pulau Betong is also a habitat widely exposed to the incoming current.

Packaging sector constitutes the highest weight of macroplastics among other sector. From the collected sample, there were many weight of macroplastics among other sector. From the collected sample, there were many plastic bags, beverage bottles, food packaging and sachet. Most are daily common items which most likely came from the residential area.

The macroplastics presence at Teluk Aling (fine sandy beach) are likely to be intentionally or unintentionally littered by tourist visiting the beach as Teluk Aling is one of the beach surrounding the Penang National Park, one of the famous place for vacation in Penang. Tourism activity is one of the source of macroplastics (Cole et al. 2011). The daily activity of fisherman at the fisherman village situated near the entrance of Penang National Park may contributes to the macroplastics load, as stated in the study at fishing areas of Malaysian beaches (Fauziah et al. 2015). Agriculture sector was the sector that has the highest weight of macroplastics being allocated to, which comprises of fishing related tools such as ropes, net and surface buoy related fishing activity. Teluk Aling is also an exposed beach and susceptible to intense wave and wind action. Either disposed at the village and lost at sea or disposed on boat such as during shipping or fishing activity, the wave and wind may bring the macroplastics washed onshore of Teluk Aling.

Pasir Panjang (coarse sandy beach) maybe affected by fishing activities and the activity in the education centre, Kem Bina Negara Balik Pulau, which is adjacent to the beach. The fishing activity here is usually small in scale which the product is for individual consumption. Some individuals were observed fishing at the shoreline. However, no macroplastics of agriculture sector were found. Packaging sector constitutes the highest weight of macroplastics collected. The possibility of tourist coming to the beach for recreational purpose and left some wastes, such as the common plastic water bottle, plastic straw and tetrapak beverage as collected in this study.

Nevertheless, the wave and wind played a significant role, which can drive the accumulation of diverse plastic debris from other source on each of the habitat in this study other than local activity (Fauziah et al. 2015).

4.2 Abundance and Distribution of Microplastics

For each study site, there was an increasing trend of average number of microplastics from the low tide line towards the high tide line. Similar results were reported by Fauziah et al. (2015) at Teluk Kemang, Batu Burok, Tanjung Aru, Seberang Takir. Similar to macroplastics, the wave action and wind transported the microplastics together with the other flotsam such as wood to the high tide region by most recent high tide. Thus, the higher average number of microplastics was recorded at the high tide line (Browne et al., 2011). Further, the microplastics subsided at low tide line, the area which is most affected by tidal action, will be easily resuspended again in the water (Bangun et al. 2018). However, the presence of microplastics at the middle tide and low tide line still occured, the reason maybe wind blowing the light-weight microplastics such as foam found at Pasir Panjang (coarse sandy beach) and Teluk Aling (fine sandy beach) depending on the wind direction, as in study of Lee et al. (2015).

One-way ANOVA analysis shows that there were no significant difference in average number of microplastics between tide line at

Pasir Panjang (coarse sandy beach) (p = 0.195) and Teluk Aling (fine sandy beach) (p = 0.185). For Pulau Betong (mudflat), independent sample t-test shows that there was no significant different in average number of microplastics between middle and high tide line (P = 0.125). Although for all the study sites, the high tide line showed higher average number of microplastics than middle tide line, no significant difference was observed. This may due to the high standard deviation observed for high tide line. The high standard deviation of average number of microplastics on the tide line investigated in this study suggested that the microplastics might not be evenly distributed at the study site. Five quadrats were used on each tide line to estimate the average number of microplastics per m^3. On some of the tide line, for example, one of the quadrat on the high tide line of Pasir Panjang had no microplastics found. Even when microplastics were found at all the quadrat, the number varied. For example, the number of items found at high tide line of Teluk Aling (fine sandy beach) varied with only two items for a quadrat and up to 37 items for another quadrat. Similar observation was highlighted by Lee et al. (2015) at the beaches of South Korea. The authors found that the microplastics at the backshore had higher mean particles compared to high strand line surveyed in the study but some quadrats of high strand line had higher number of plastics found compared to some quadrats at the backshore. Their statistical test showed no significant different between the two lines they studied.

Two-way ANOVA analysis shows that there were no significant interaction between study site and position of tide line on the average number of microplastics found (p = 0.868). This could indicate that the geographical location or degree and type of activity may not influence the microplastics abundance, although differences were observed. From the total number of microplastics found during the sampling time, although the highest number of microplastics was found at Teluk Aling (fine sandy beach), the differences compared to Pulau Betong (mudflat) was only by four items. The microplastics can be sourced from local anthropogenic activity similar to the source of macroplastics. Considering anthropogenic activity, during the sampling time, the education centre of Pasir Panjang (coarse sandy beach) was closed and the beach has relatively less activity when comparing to other sites, where Pulau Betong (mudflat) has residents surrounding the site while Teluk Aling (fine sandy beach) is situated along the coastline of Penang National Park., opened to public accessing the beach.

The dominant type of microplastics found at Pulau Betong were fragment type. It can be most likely attributed to the daily activity of the local resident and fisherman, where, for example, accidental abrasion can break and produce fragment from its larger counterpart. For Teluk Aling, the activity of fisherman which may use foam type of insulator box for transporting of fresh sea food may explain the high abundance of foam similar to the case of Hong Kong where EPS insulator box was used to transport fresh food and take-away food between southern China and Hong Kong (Fok and Cheung 2015). A study at beaches of Mexican coastline shows that during festive or tourism season, the abundance of microfiber and other type of microplastics was higher compared to non-tourism season, which clearly indicates that tourism can be a source of microplastics (Retama et al. 2016). Hence, microplastics at Teluk Aling (fine sandy beach) maybe attributed by tourist bringing in macroplastics, the potential source of microplastics.

Other than local activity, wave of the Straits of Malacca may transport diversity of microplastics onshore of the study sites. Fauziah et al. (2015) proposed that the intense wave action of South China Sea could transport the plastic debris from the high degree of activity at the South China Sea to Seberang Takir and Batu Burok beaches at Kuala Terengganu. Mechanical abrasion by wave, storm, rain, organisms, and beachgoers and embrittlemend by UV radiation can fragmentize the macroplastics that were already subsided at there, generating microplastics (Song et al. 2017). The similar trend of macroplastics and microplastics found at the high tide line may support the fragmentation of macroplastics and subsequent deposition of its microplastics at the same tide line. The lack of proper management of waste at the study sites may also increases the residential time of macroplastics onshore and thus the time of exposure to the natural environment that could fragmentize it. Overall, the source of the microplastics may not be conclusive as it can be due to the results of combination of events mentioned.

4.4 Possible Implication and Solution

The lack of proper management of waste might increase the exposure time of the macroplastics to environmental stress, increasing the chance of generating more secondary microplastics. The presence of macroplastics and microplastics will certainly affect the organisms living at the habitat. A study conducted at French, Belgian and Dutch North Sea coast shows that lugworm *Arenicola marina* and blue mussel *Mytilis edulis* living at the natural habitat there had uptake microplastics from the sandy sediment and seawater (Van Cauwenberghe et al. 2015a). The microplastics may further broken down to even smaller size of microplastics, offering to more wide range of organisms, especially the smaller size of organisms (GESAMP 2015). The organisms feeding strategy may affect its likelihood of ingesting microplastics, For example, non-selective filter feeders have higher chance of ingesting microplastics (Scherer et al. 2017). Subsequent preying on the smaller prey may transfer the microplastics to the bigger predator, the occurrence of trophic transfer. Laboratory study shows that crab could contain microplastics in the mussels initially exposed to microplastics (Farrell and Nelson 2013). As example, mudskipper was spotted living at Pulau Betong mudflat, which they might ingest microplastics if they feed on prey which has ingested microplastics.

The plastic pollution problem is not unique to Penang state or Straits of Malacca. Studies show that even remote island has plastic pollution due to ocean current and wind that transport the plastics to the far coast (Herrera et al. 2018). Plastics deposited at beach has chance of being redistributed and backwashed to the ocean by wave action (Ballent et al. 2013). Hence, plastic debris generated by Penang which may ends up in the Straits of Malacca, will follow the current and flow to other continents. Vice versa, plastic wastes may also be transported to Penang or Malaysia through the Straits of Malacca if improperly managed. Beside cross boundary collaboration in research on macroplastics and microplastics need to be carried out, intergovernmental effort and the support of citizen are needed to mitigate this world problem (Zulfigar et al. 2017). The existing macroplastics need to be removed from the habitats where it subsided. Lee et al. (2015) found positive correlation between both number and weight of mesoplastics and large microplastics at beaches of South Korea. Since there is a correlation, clean-up and maintenance can be done to remove those macroplastics which included mesoplastics in this study from the habitats to indirectly reduce the source of microplastics input (Fok and Cheung, 2015). the law should be enforced to protect the habitats, such as enforcement of “no litter” at the beach. Penang state is taking several steps to reduce the possible impact or plastics pollution. Penang has enforced “Everyday is no free plastic bag’ in 2011 to reduce the usage and possible disposal of plastic bag (Penang State Government 2011). Enforcement of “Waste segregation at source” in 2017 aimed to reduce waste and help recycling process easier (Penang Green Council 2011). Penang government also plans to ban single-use plastics, such as plastic straws and cup (Chiam 2018). At the national level, the Ministry of Energy, Science, Technology, Environment, and Climate Change (MESTECC) Malaysia has drafted a roadmap to achieve Zero Single-use Plastic by 2030. Bioremediation in the form of mineralization is a promising alternative way of degrading microplastics in the environment (Auta et al. 2017; Yang et al. 2015). More research also need to be done to assess the status of plastic pollution in Penang and the Straits of Malacca to execute a suitable strategy in remediating the problem. Parameters such as wind direction and speed during the sampling time can also be measured to understand the abundance and distribution of the macro- and microplastics better. More study should be done on habitat such as mudflat and mangrove as they are the relatively less studied habitats. In addition, fourier-transform infared spectroscopy test can be done for future work to identify the molecular composition of the plastics and microplastics found.

5. Conclusion

The three sites representing three different habitat along Penang coastline in the Northern Straits of Malacca were polluted by macro- and microplastics on the surface Pulau Betong (mudflat) has at least silay particle while Pasir Panjang (coarse sandy beach) has very coarse to coarse sand and Teluk Aling (fine sandy beach) has coarse to fine sand. Macroplastics were distributed at the high tide line. The highest amount of macroplastics were found at Pulau Betong (mudflat) with 20.25 g/m^2, second highest at Teluk Aling (fine sandy beach) with 18.20 g/m^2 and the least at Pasir Panjang (coarse sandy beach) with 17.62 g/m^2. Packaging constitutes the highest portion of plastics at Pulau Betong, (mudflat) and Pasir Panjang (coarse sandy beach) while agriculture constitutes the highest at Teluk Aling (fine sandy beach). Fragment, film, foam, and filament type of microplastics were found. Microplastics were mostly distributed at the high tide line, followed by middle tide line and low tide line. The highest total number of microplastics among the study sites found during the sampling time and within the quadrats employed was 72 items at Teluk Aling (fine sandy beach). The second highest was 68 items at Pulau Betong (mudflat) and the least was 56 items at Pasir Panjang (course sandy beach). Mitigation strategies need to be planned and carried out to prevent exacerbation of the plastics pollution

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