CHAPTER 3: QUANTITATIVE STUDY OF MARINE DEBRIS ON MALAYSIAN BEACHES

3.1 Introduction

Malaysia has a coastline area which exceeds 9323 km with 98% of its population lives within the 100 km from the shoreline ("Malaysia - Coastal and Marine Ecosystem Factsheet (WRI)", 2010). Coastal areas in Malaysia are mostly comprised of mangrove-fringed mud flats and sandy beaches which covers about 4.43 million hectares or 13% of the total land area of Malaysia (Department of Irrigation and Drainage Malaysia, 1993). Thus, a lot of issues arise due to improper management of this area.

Among the issues is the management of marine debris. Marine debris study in Malaysia is relatively few and new. However, it does not reflect that Malaysian beaches are free from debris. Apparently, studies on other aspect of marine pollution were given more attention due to the seriousness of the problem such as heavy metal toxification (Agusa et al., 2005; Yap et al., 2002). Currently, there is no specific legislation on marine debris in Malaysia. It is regarded as solid waste which falls under the Local Government Act 1976.

Tourism is the third largest contributor to Malaysian economy after manufacturing and oil and gas industry (Department of Irrigation and Drainage Malaysia, 1993). The total fish landing in Malaysia is as large as 1,394,531 tons in 2008 (Department of Fisheries, 2008). Despite their economic significance, these two industries also contribute to a significant amount of marine debris found on Malaysian beaches. This chapter generally aims at

determining the composition, abundance, rate of accumulation and sources of marine debris found on recreational and fishing beaches.

3.2 Materials and Methods

3.2.1 Selection of beaches

Generally, Malaysian beaches can be divided into three, namely beaches at the West Coast of Peninsular Malaysia, beaches along the East Coast of Peninsular Malaysia and beaches of the East Malaysia. Therefore, in this study three areas were chosen to represent the different parts of Malaysia. The chosen areas are Port Dickson, Kuala Terengganu and Kota Kinabalu representing West Coast of Peninsular Malaysia, East Coast of Peninsular Malaysia and East Malaysia, respectively.

Other characteristic considered in this selection is the existence of a popular beach destination within the area. All selected beaches are located in big cities with vast housing area, administrative buildings and industries. Therefore, these beaches receive the most number of users. In each chosen area, two beaches with different function namely recreational and fishing activities were selected. The location of the selected beaches is shown in Figure 3.1.

Figure 3.1: Area of study (Note: (R) recreational beaches, (F) fishing beaches)
Source: http://www.statistics.gov.my

3.2.2 Debris sampling on the beaches

Debris from six beaches namely Teluk Kemang, Pasir Panjang, Batu Burok, Seberang Takir, Tanjung Aru and Teluk Likas, were sampled monthly from January to March 2010. Three different sites with 20m x beach width (low tide line to first vegetation/ concrete) were sampled on each beach to give a total area of 60 m x beach width.

This is applied to all beaches except Pasir Panjang beach. For Pasir Panjang, the whole area was sampled because the length of the beach is less than 60m. All visible debris in the sampling area was collected. They were then sorted and categorized into 12 predetermined type of waste (Appendix A). These wastes were disposed after the analysis. In order to avoid sampling error, the following procedures were practiced:

1. Same and exact area was sampled for every sampling event.
2. Excess dirt and water were removed from the waste before weighing.
3. Sampling was done during low tide to sample widest possible area.
4. Sampling was done before the clean-up by the local authority
5. Only wastes littered on beach were collected. Wastes disposed in rubbish bins were not included.

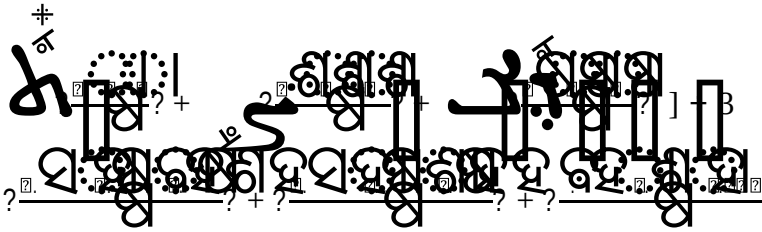
3.2.3 Data analysis

In this study, two units of comparison were used. This includes the weight/ area (g/ m^2) and number of item/ area (number of item/ m^2). Number of item was often used to compare amount of marine debris found (Bravo et al., 2009; Claereboudt, 2004; Madzena & Lasiak, 1997). This unit was also used in the biggest cleanup program worldwide i.e. Ocean Conservancy's International Coastal Cleanup event (ICC, 2010). However, the large difference of sizes between debris may contribute to errors. For example, a candy wrapper may not cause a same impact as one large plastic bag. Therefore, weight is also considered for this comparison study.

Due to some differences in total area sampled and the management of each beach, data were treated with cautions. Data were revised and shown in m^2 unit area. Besides that, the amount of debris sampled on the beaches also covers the aspect of abundance and rate of accumulation.

A**bundance** of debris refers to amount of debris found on each sampling events. These data is also known as 'standing stock' values. It may not be very effective to generate comparison between beaches. However, data on waste abundance is still necessary. This is to allow the comparison with other studies which adopt similar method (Ryan et al., 2009). In this study, the abundance of debris was determined from the average of three sampling areas on each beach. The averaged numbers from each month was then accumulated to find the mean value of debris for each beach. The averaged numbers from all debris types were accumulated to compare debris abundance between selected beaches.

Example: Abundance of **plastic** in Teluk Kemang (weight/ area)

Plastic, x = [] ÷ 3

= [? + ? + ?] ÷ 3

= (0.438 + 0.383 + 0.908) ÷ 3

= **0.576** g/ m^2 , A,B,C are replicates

Rate of accumulation is used to generate comparison between all beaches within this study. As selected beaches do not have similar background, standing stock data of the first sampling (January) will not be comparable with data for the coming months (February and March). Despite discarding data of the first month, data for January is used to represent amount of debris found for unknown period (initial). The amount collected during second and third sampling was then added to the amount of debris found in the previous month. Linear equations (y = mx +c) were made as to compare the rate of accumulation between selected beaches using the gradient.

Example: Rate of debris accumulation in Teluk Kemang (weight/ area/ time)

Initial weight = **0.724** g/ m^2

Accumulation after 1 month = 0.724 + 1.483 = **2.207** g/ m^2

Accumulation after 2 months = 2.207 + 1.150 = **3.357** g/ m^2

Linear equation from the three points, **y = 1.316x – 0.537**

3.3 Results and Discussions

3.3.1 Background study of selected beaches

(a) West Coast of Peninsular Malaysia

West Coast of Peninsular Malaysia includes Kedah, Penang, Perak, Selangor, Negeri Sembilan and Malacca faces the Straits of Malacca. Commonly, beaches on this region are muddy and relatively narrower compared to beaches in East Peninsular. These beaches are exposed to pollution from the busy shipping activities along the Straits of Malacca. In addition, the beaches receive influence from the high population along the rapidly developing west coast of Peninsular Malaysia. Plate 3.1 and Plate 3.2 show the beaches of Teluk Kemang and Pasir Panjang that represent the recreational and fishing beach, respectively for the West Coast of Peninsular Malaysia.

Plate 3.1: Surrounding area of Teluk Kemang in the evening

Plate 3.2: Rocky and muddy beach of Pasir Panjang

Teluk Kemang is one of the most popular spot among the eight main beaches in Port Dickson. It is a wide sandy beach with casuarina and palm trees. Teluk Kemang is the tourist's choice for holidays because it provides lots of water activities such as canoeing, parasailing, yachting and speed boat rides. Besides, it is the most well maintained beach in Port Dickson with sufficient toilets, public bathroom and free car parks. As a result, about 20,000 to 30,000 of visitors visit this beach every week (Personal communication: MPPD).

There is a concrete wall built along the beach to prevent erosion thus narrows the beach compound. The beach is quite flat and wide reaching 20 meters during low tide. The sand is yellowish in colour and the water is brownish.

Pasir Panjang is situated about 21 km from Teluk Kemang. The beach is very narrow; less than 10 meters during low tide. The sand is reddish/ brownish. Rocky areas and mangroves line the shoreline. Located on the border of Negeri Sembilan and Malacca, it is rich with sea catch such as snapper, grouper and other fishes. Locals in this area depend on the sea products for their livelihoods. Therefore, fishing activities and restaurants become the main contributor of debris to Pasir Panjang. Housing and small industries may also contribute a significant amount of waste especially through storm drains, river and inland washed. In addition, there are also hotels and chalets around the area namely Tiara Beach Resort and Palm Spring Golf Resort, and a forest reserve which is a known tourist's attraction.

(b) East Coast of Peninsular Malaysia

Kelantan, Terengganu and Pahang are the states that make up the East Coast of Peninsular Malaysia. These three states are known with traditional fishing villages, small towns and resort islands. This area is relatively less populated, conservative and quiet compared to the West Peninsular. Facing the South China Sea, beaches in this region are larger with high amount of fish landings. Sea within this region is affected by seasonal factors namely winds and heavy rains during monsoons between November and February. Plate 3.3 and Plate 3.4 show Batu Burok and Seberang Takir beaches which represent recreational and fishing beach, respectively for the East Coast of Peninsular Malaysia.

Plate 3.3: Wide beach and strong waves in Batu Burok beach

Plate 3.4: Strong waves deposit debris on Seberang Takir beach

Batu Burok in Kuala Terengganu is one of a major tourist attraction for picnicking. The sand is cream in colour and very fine in texture. Casuarina trees are also planted along the coastline. The intertidal zone is about 10 m width while another 30-40 m sandy area is for picnics and other recreational activities. In general, the area is kept in their natural form with very few man-made structures. The activities here are mostly non-water sports such as

volleyball and beach soccer. Kite flying is also popular since the area is always windy. Swimming can be dangerous as the wave is very strong especially during the monsoon.

Similar to Batu Burok, Seberang Takir beach experiences strong waves and winds where swimming and water sports activities can be dangerous. Monsoon occurs from November to the end of February every year. Although the main activity in Seberang Takir is fishing, there are also recreational activities. Recently, there is a land reclamation activity for the refurbishment of Terengganu airport nearby this beach. This may also contribute to marine debris found on the beach. Other than that, the most significant activity that may contribute to marine debris problem in the area is from the fishing village and the fishing activities.

(c) East Malaysia

East Malaysia consists of Sabah, Sarawak and the Federal Territory of Labuan. The states within East Malaysia are relatively larger to other states in Malaysia but are less populated with slower development. The total area covers 200,565 km^2 of land areas, known with their richness in natural resources. It is a popular tourism area in Malaysia with the natural heritage sites including World Heritage Site Kinabalu Park and Sipadan Island. Sabah coastline stretches from 1440 km where many beautiful sandy beaches can be found. Plate 3.5 and Plate 3.6 show the beaches of Tanjung Aru and Teluk Likas that represent recreational and fishing beach, respectively for the East Malaysia.

Plate 3.5: The calm and relaxing view of Tanjung Aru

Plate 3.6: Teluk Likas with abundant half-buried debris

Tanjung Aru is one of the famous beaches in Kota Kinabalu. It is located at a walking distance from the Kota Kinabalu Terminal 2 Airport. Few popular islands within Tunku Abdul Rahman Marine Park (consists of 5 small islands) can be seen from this beach. Stretched over 2 km long, the beach is wide with fine white sand. Casuarina and palm trees add the amazing scenery of the beach. It is a popular weekend destination for locals and foreign tourists. Every evening it will be crowded with visitors to view the sunsets or to

carry out other beach activities such as playing kites and volleyball. Other water sport activities such as diving and water skiing are also available. In general, the area is quite clean.

On the other hand, Teluk Likas is situated on the east of Kota Kinabalu. The width of the beach is less than 20 m. The sand is very fine thus trapped waste easily. Waste from inland is washed ashore from Sungai Likas thus pollutes the area. Besides inland sources, other possible contributor to the pollution is from ships and adjacent islands. Adjacent to the beach are small islands occupied by few village, and the presence of a port nearby makes Teluk Likas a busy shipping area.

3.3.2 Comparison of beach management on selected beaches

Many factors may contribute to the presence of marine debris on beaches including biophysical aspect, weather, wind and waves. Another factor that affects the amount of marine debris found on beaches is the waste management in the area. Table 3.1 and Table 3.2 illustrate the management of the beaches studied.

Table 3.1: Management issues on the three recreational beaches studied

	Teluk Kemang	**Batu Burok**	**Tanjung Aru**
Beach function/ Major activities	Recreational	Recreational	Recreational
Estimated number of users/ day	>1000	>500	>50
Local authority/ Responsible body	MPPD and SWM Sdn. Bhd.	MBKT	DBKK
Frequency of waste collection	8 hours continuously during weekdays (rotate workers)	2 times daily	Once/ day
Number of workers for waste collection	5-8	>7 including facilities maintenance	4-6
Availability of waste facilities (dustbin)	Available	Available	Available
Availability of signages (Do not litter)	Available	Available	Available
Programs to promote beach cleanliness	'Adopt a beach' Tax exemption for private companies that include beach cleaning activities in their event	Not available	Not available
Issues related to waste management	High intensity of beach usage	Household waste washed ashore following flooding during monsoon season	Medium intensity of beach usage

Table 3.2: Management issues on the three fishing beaches studied

	Pasir Panjang	**Seberang Takir**	**Teluk Likas**
Beach function/ Major activities	Fishing	Fishing village	Fishing village, shipping
Estimation number of users/ day	>20	<10 during sampling event due to monsoon	>20
Local authority/ Responsible body	MPPD but does not include waste collection on beach	MBKT but does not include waste collection on beach	DBKK and a private company
Frequency of waste collection	Not relevant	Not relevant	Once/ day
Number of workers in waste collection	Not relevant	Not relevant	4-6
Availability of waste facilities (eg:dustbin)	Not available	Not available	Not available
Availability of signage (eg:Do not litter)	Available	Not available	Not available
Special programs to promote beach cleanliness	Not available	Not available	Not available
Issues related to waste management	Beach cleaning is dependent to locals	Beach cleaning is dependent to locals	Buried waste since long time ago

In general, the beach management is better in recreational beaches than fishing beaches. This is probably due to the beach users demand to have cleaner beaches. The cleaning of the beaches by the local government depends on the number of beach users and the function of the beach. From Table 3.1 and Table 3.2, it is shown that the number of beach users in recreational beaches is much higher as compared to fishing beaches. Local authorities are responsible on all six studied beaches but regular clean-up events are only available on the three recreational beaches and Teluk Likas. Dustbin and signage are available only on recreational beaches. Different management between two function groups is believed to contribute amount of debris found, among other factors. Plate 3.7 – 3.9 illustrate the activities carried on the beaches.

Plate 3.7: Mechanical beach cleaner used in Batu Burok and Teluk Kemang

Plate 3.8: Signage available on well-maintained beaches including Batu Burok

Plate 3.9: Regular clean-ups on Tanjung Aru beach

3.3.3 Marine debris composition

Debris collected was categorized into 12 categories (Appendix 1). For this study, the debris composition is reported as wet weight, and total number of items, for each debris types. Table 3.3 shows the three main types of debris on each beach in general.

Table 3.3: Three main types of debris on each study sites

Type of beaches	Name of beaches	Main debris types based on weight (g/ m^2)	Main debris types based on number of item
Recreational beach	Teluk Kemang	Plastic, paper, polystyrene	Plastic, paper, polystyrene
	Batu Burok	Plastic, food waste, wood	Plastic, paper, polystyrene
	Tanjung Aru	Plastic, glass, food waste	Plastic, paper, polystyrene
Fishing beach	Pasir Panjang	Bulky waste, plastic, rubber	Plastic, polystyrene, paper
	Seberang Takir	Plastic, glass, rubber	Plastic, glass, polystyrene
	Teluk Likas	Plastic, food waste, rubber	Plastic, polystyrene, rubber

Plastic is the main type of debris found on all beaches. This is followed by paper, polystyrene, glass, rubber and food waste. Plastic is always the most abundant type of debris found on studied beaches. Paper and polystyrene are common debris found on recreational beaches, while glass and rubber are common on fishing beaches. This is probably contributed by the nature of activities conducted on the beaches.

(a) West Coast of Peninsular Malaysia

The general percentage of debris found in Teluk Kemang beach throughout three months study is shown in Figure 3.2 and Figure 3.3.

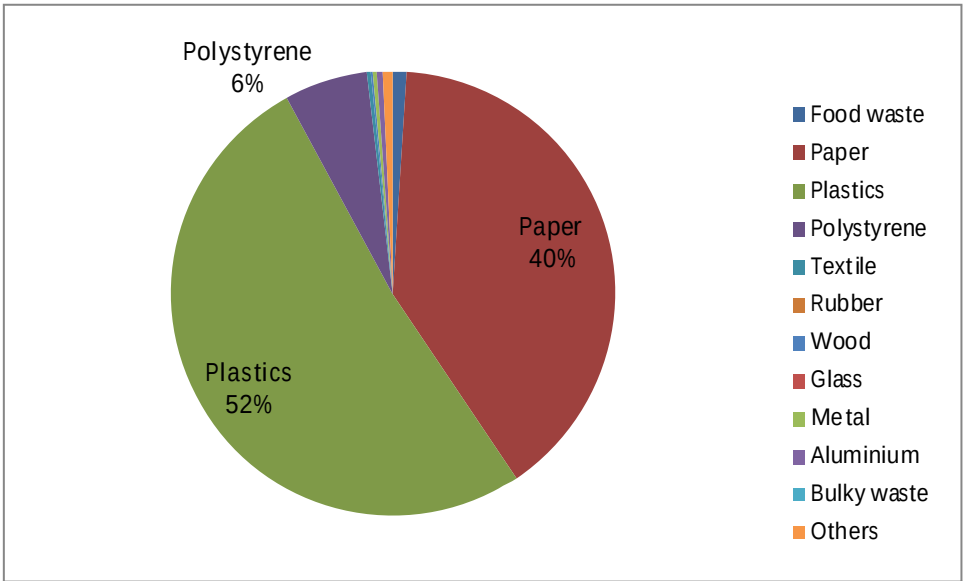


Figure 3.2: Debris in % (fresh weight) collected from Teluk Kemang beach

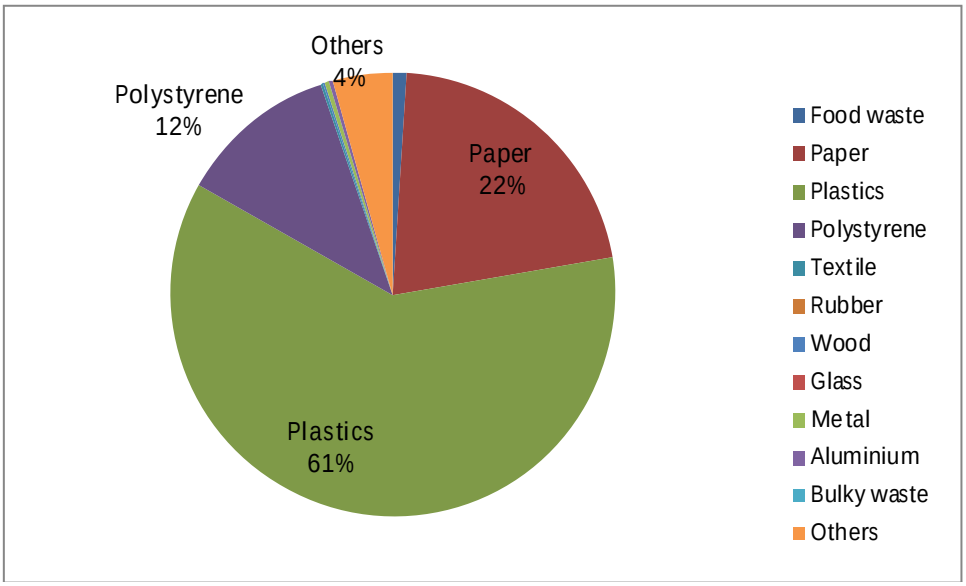


Figure 3.3: Debris in % (number of item) collected from Teluk Kemang beach

The most common items found in Teluk Kemang beach are plastics, papers and polystyrenes. Plastic constitutes more than 50% of total amount of debris found regardless of the unit. This may be contributed by the abundance of plastic bags, food containers and wrappers, and plastic bottles brought by the beachgoers every day. It is comparable to other studies carried out on recreational beaches worldwide (Bravo et al., 2009; Claereboudt, 2004; Derraik, 2002).

A high percentage of paper was also found on Teluk Kemang beach in terms of weight (40%) and number (22%). This is probably contributed by the presence of wet newspapers found which were used as picnic mats. Besides paper, polystyrene was also recorded among the abundant type of debris found on Teluk Kemang with 6% in weight and 12% in number. Both were contributed from the picnicking activity carried out on Teluk Kemang beach.

Other type of wastes found on Teluk Kemang beach such as food waste, aluminium, wood and metal constitute less than 1% of the total weight and number of item. Although most of these items are relatively high in density, it is not as abundant as other type of debris such as plastic and paper. Other study on a recreational beach in Orange County, California recorded a percentage less than 0.01% for wood and metal (by number) and about 15% by weight (Moore et al., 2001).

Plastics and polystyrene recorded a higher percentage in terms of number (61% and 12%, respectively) while paper was recorded with higher percentage in terms of weight (40%). This is because plastic and polystyrene have lower density than paper. The lightweight of

plastic and polystyrene is one of the characteristics that contribute to users' preference and the high production of the items (Derraik, 2002). Thus, plastic and polystyrene were found abundant on the beach.

Composition of debris in the recreational beach of Teluk Kemang is different from the nearby fishing beach of Pasir Panjang. The average percentage of debris found on Pasir Panjang beach during the three months study is shown in Figure 3.4 and Figure 3.5. It is indicated that the largest portion consist of bulky waste (86% by weight) and plastic waste (60% by number).

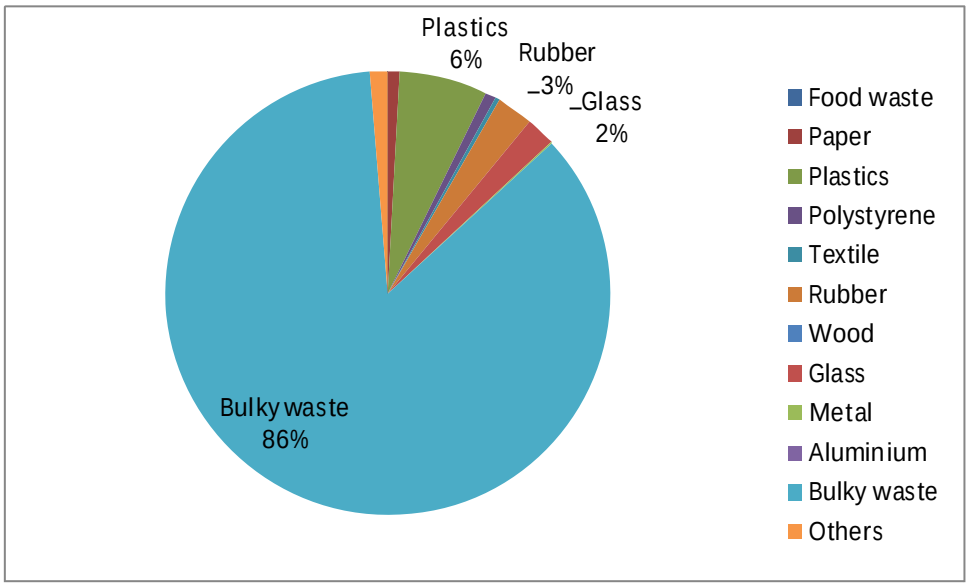


Figure 3.4: Debris in % (fresh weight) collected from Pasir Panjang beach

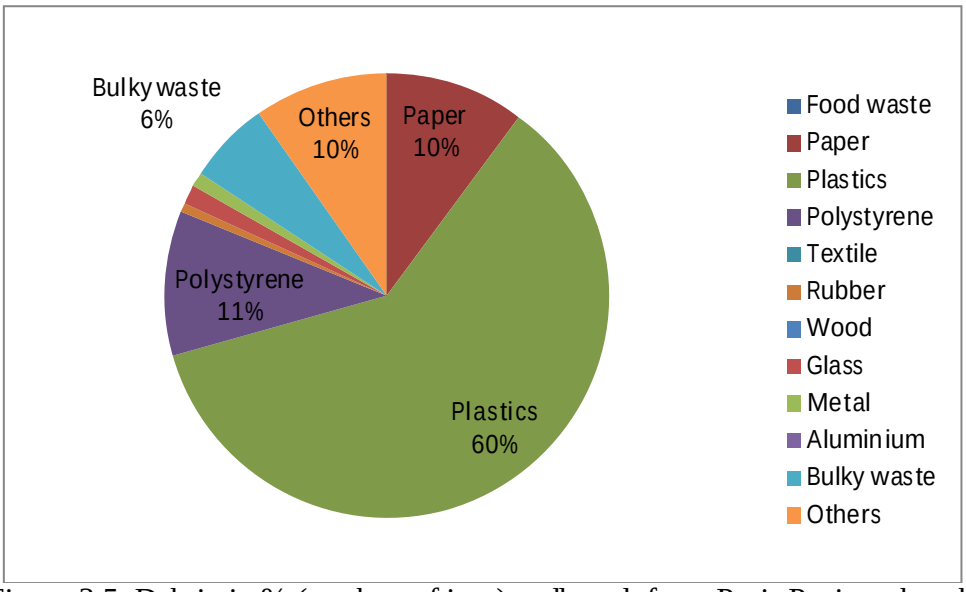


Figure 3.5: Debris in % (number of item) collected from Pasir Panjang beach

Figure 3.4 illustrates that bulky waste was the highest contributor (86%) of debris on Pasir Panjang beach while plastic which is the most common type of debris found on other beaches only contribute 6% of the total weight. Bulky waste contribute large weight due to the presence of fishing nets. Vehicle tyres (rubber) which was also possibly used for the fishing activities constitute a notable weight of 3%. Glass and other type of debris was only less than 2% of the total weight.

The massive amount of fishing-related debris found in Pasir Panjang beach shows that fishing activities is the main contributor of debris in Pasir Panjang beach. As reported in a study comparing the weight, nets, wood and other huge fishing-related debris tends to dominate the waste composition even with the presence of just one particular item (Claereboudt, 2004).

Figure 3.5 illustrates the debris composition based on number of item. It shows that type of waste found is more diverse and the percentage among different type of debris is more even. Plastic constitutes the largest proportion of debris which is 60%. A high number of plastic namely plastic bags, plastic bottles and some household items may be contributed by the village nearby. This is possible as suggested by Jones (1995) that debris may also be sourced from storm water drains or washed from inland.

Following plastic, other debris types found include 11% polystyrene, 10% paper and 6% bulky waste. Other items which is not within the major categories of debris found, contribute 10% of the total amount (Figure 3.5). Although most of these items are household waste, there are also a few disposable plates and disposable glass, food containers and newspaper that are similar to those found on recreational beach of Teluk Kemang. It suggests some similarity between the two beaches even with different functions.

(b) East Coast of Peninsular Malaysia

On the East Coast of Peninsular Malaysia, Batu Burok beach in Kuala Terengganu has similar debris composition as that of Teluk Kemang, Port Dickson. This is due to the similarity of their function and management. The general percentage of debris found in Batu Burok beach throughout the three months study is shown in Figure 3.6 and Figure 3.7.

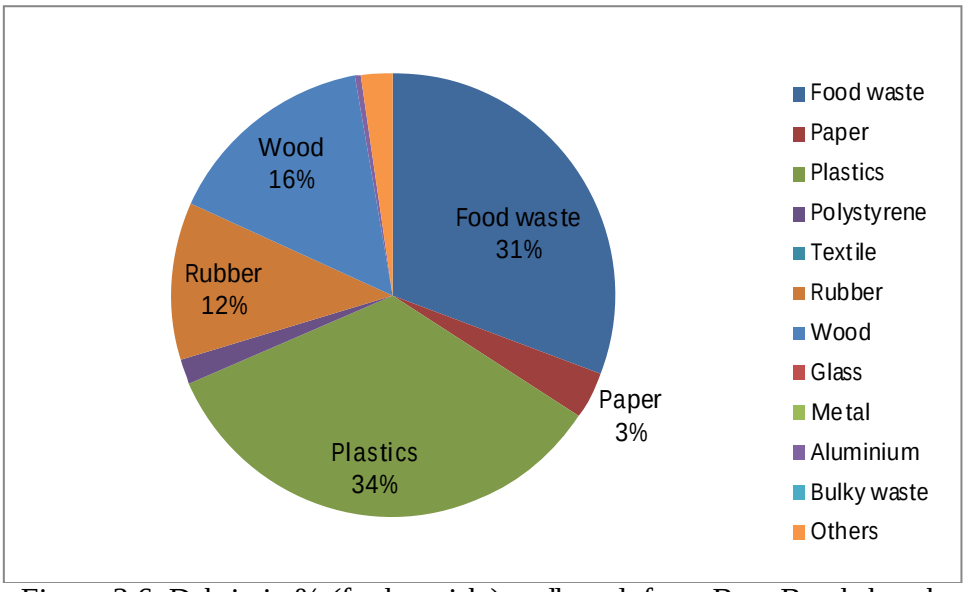


Figure 3.6: Debris in % (fresh weight) collected from Batu Burok beach

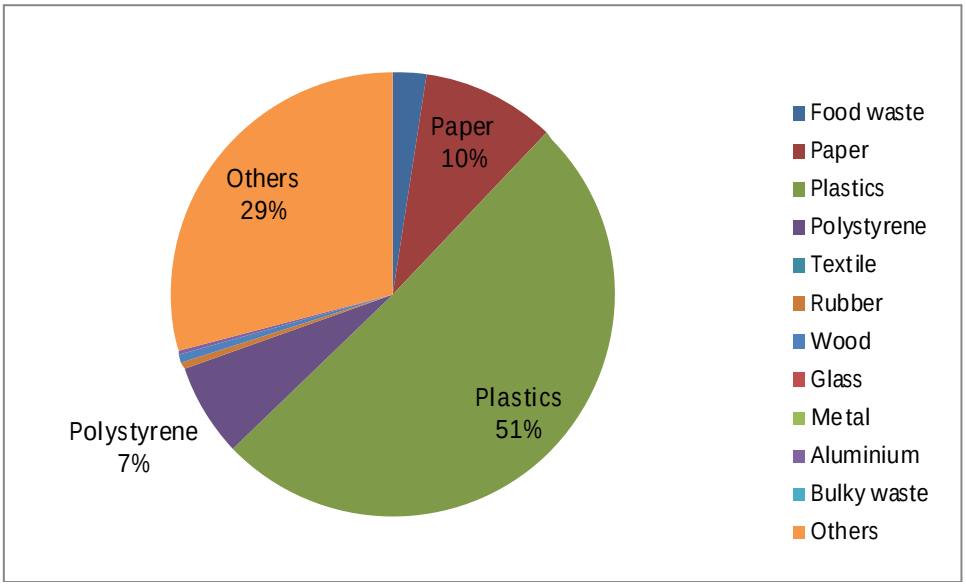


Figure 3.7: Debris in % (number of item) collected from Batu Burok beach

Figure 3.6 and Figure 3.7 show the types of waste found on Batu Burok beach. It is similar to other recreational beach worldwide (Bravo et al., 2009; Willoughby et al., 1997). Plastic constitute the highest weight of debris found (34%) followed by food waste (31%). Food waste found on Batu Burok beach is represented by leftovers, especially corn stalks which were sold every evening along the beach. This type of waste is mostly generated by the

beach users. It has been reported that beachgoers contribute significant amount of beach debris on recreational beaches in other country such as in Chile (Bravo et al., 2009).

Other debris found in Batu Burok beach includes wood (16%) and rubber (12%). Both have high density. Dead plant, twigs and branches found along the beach was not included in this study. Wood debris (16%) consisted of plywood and broken furniture could possibly originate from the nearby construction activity or generated by beachgoers, or floated from offshore. Rubber debris collected includes rubber 'flip-flop', pipes and other unrecognizable items.

Figure 3.7 also illustrates that types of debris found in Batu Burok beach is similar to Teluk Kemang beach where plastic recorded the highest percentage (51%) followed by paper (10%) and polystyrene (7%). Similarities between the two recreational beaches show the influence of beach function to the debris composition.

Another beach studied to represent fishing beach in the East Coast of Peninsular Malaysia is Seberang Takir beach. This beach was polluted with large amount of debris during the study period. This is caused by the monsoon. Figure 3.8 and Figure 3.9 illustrate the debris composition in Seberang Takir beach throughout the three months study. Types of waste found in Seberang Takir were similar in terms of weight and number of item. Plastics, polystyrene, rubber and glass were found in every sampling occasion. Other types of waste found include paper and metal.

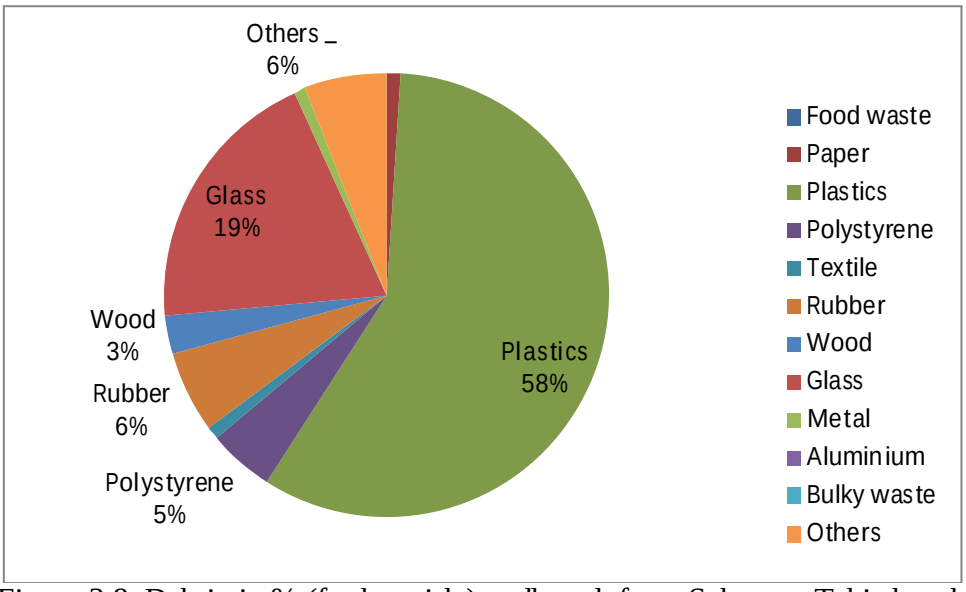


Figure 3.8: Debris in % (fresh weight) collected from Seberang Takir beach

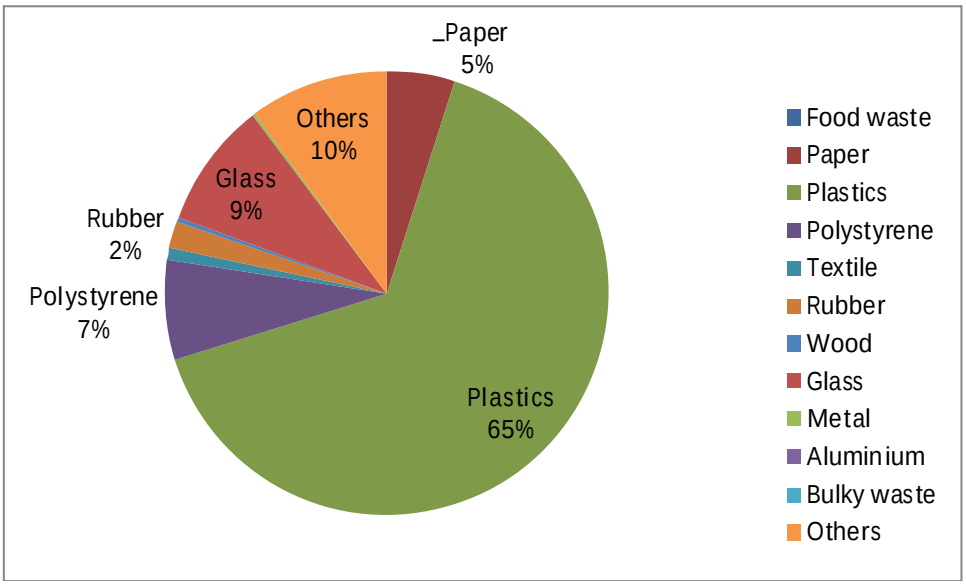


Figure 3.9: Debris in % (number of item) collected from Seberang Takir beach

Plastic constitute 58% of the total weight of debris found on Seberang Takir beach. This is followed by 19% glass, 6% rubber and 5% polystyrene (Figure 3.8). Similar types of debris were found in terms of number (Figure 3.8). Plastics represent 65% of the total number of items found followed by glass at 9%, polystyrene at 7% and rubber at 2%.

Plastic recorded the highest percentage of debris found on Seberang Takir beach due to the abundant of household item. They were mostly in the form of household utensils, detergent bottles, water bottles, and so on. Glass and rubber found were also comprised of household items. It suggests that debris found in Seberang Takir was possibly from sources other than fisheries. However, this may only represent the condition during monsoon period where fishing activity are at minimum while flood pulled the household wastes ashore.

(c) East Malaysia

In East Malaysia, Tanjung Aru beach is located in Kota Kinabalu, Sabah. Type of debris found on this beach area is similar to other recreational beaches. Interestingly, a large number of cigarette butts, categorized as 'others' within this study, was also found. Figure 3.10 and Figure 3.11 illustrate the composition of debris on Tanjung Aru beach based on weight and number of items, respectively.

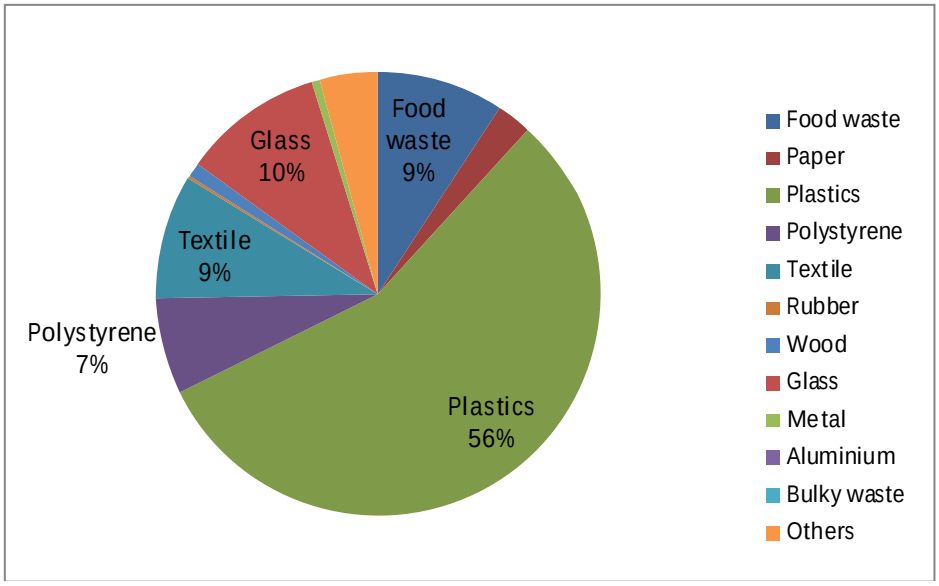


Figure 3.10: Debris in % (fresh weight) collected from Tanjung Aru beach

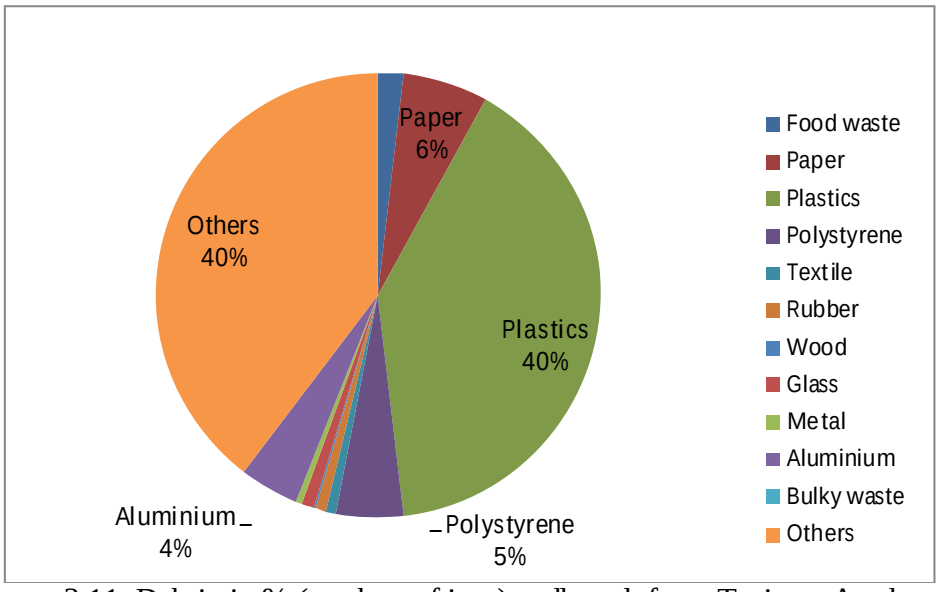


Figure 3.11: Debris in % (number of item) collected from Tanjung Aru beach

Plastic constitute the majority (56%) of the total debris weight followed by 10% glass, 9% textile, 9% food waste and 7% polystyrene (Figure 3.10). Type of waste found on Tanjung Aru beach is similar to other beaches in this study especially to fishing beach like Seberang Takir (Figure 3.8 and 3.9). Although the two beaches play different functions, the similarity in the debris composition can be due to the influence of household wastes washed ashore.

Plastic and 'Others' debris each recorded 40% of the total number of debris. This is due to the abundance of cigarette butts that were categorized as 'Others' within this study. Papers represent 6% of the total number of debris found followed by polystyrene at 5% and aluminium at 4% (Figure 3.11). The presence of papers and polystyrene in Tanjung Aru is similar to other beaches within this study.

While Tanjung Aru represent recreational beach, Teluk Likas beach in Kota Kinabalu is selected to represent fishing beach in East Malaysia. The weight of debris in Teluk Likas beach is shown in Figure 3.12 while Figure 3.13 illustrates the number of item.

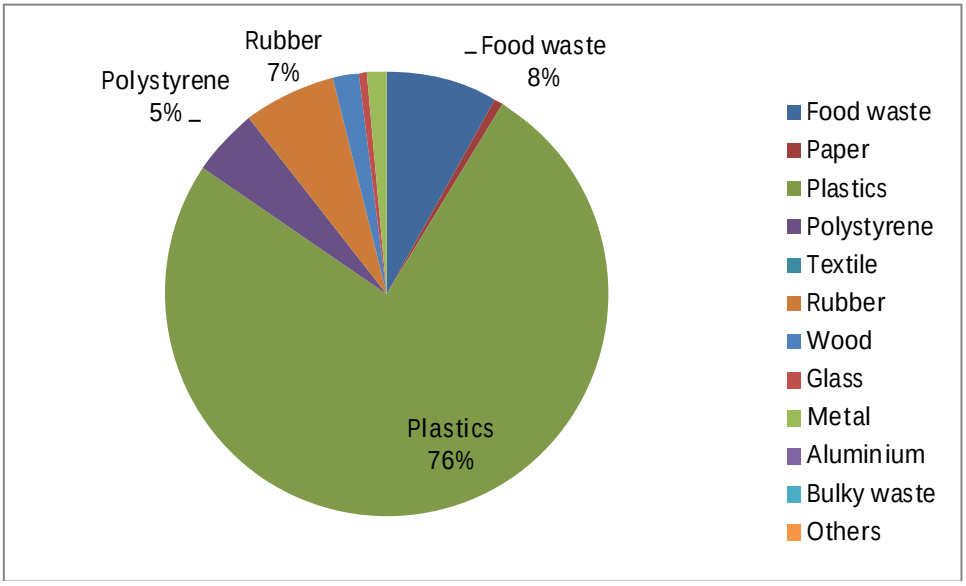


Figure 3.12: Debris in % (fresh weight) collected from Teluk Likas beach

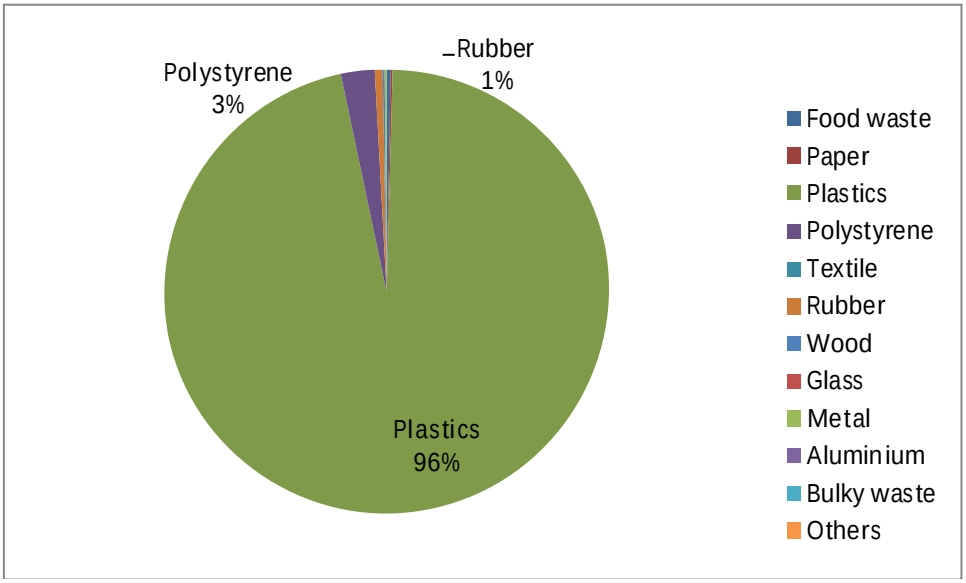


Figure 3.13: Debris in % (number of item) collected from Teluk Likas beach

Based on weight, the highest portion of the debris found on Teluk Likas beach was plastic (76%), followed by 8% food waste, 7% rubber and 5% polystyrene (Figure 3.12).

Plastic accounted for 96% of total number of debris recorded on Teluk Likas beach (Figure 3.13). This large amount of plastic was contributed by the abundant of plastic bags, bottles, household utensils, food wrappers and containers. The extremely high percentage of plastic in Teluk Likas is comparable to 5 Mediterranean beaches, 50 South African beaches and Bird Island of Southern Ocean as listed in a plastic debris review (Derraik, 2002).

Other type of debris with notable percentage in terms of number was polystyrene (3%). Most of the polystyrene are made up by disposable food wares and containers. It was found in large number since most of these items are floatable. Since most of the debris found on Teluk Likas beach was buried, polystyrene and other floatable material is expected to be more abundant.

Rubber constitute 1% of the total number of debris recorded on Teluk Likas beach followed by other debris such as food waste, metal, glass and wood in relatively lower amount (<1%). Type of waste found on Teluk Likas beach is similar to other beaches worldwide (Morishige et al., 2007; Thornton & Jackson, 1998).

In general, plastic constitute the highest amount of debris found on all beaches except in Pasir Panjang beach. Besides plastic, other highlighted debris are paper, polystyrene and cigarette butts. It shows the importance to find alternative to plastic in public activities in order to tackle marine debris problem.

Composition of debris on a beach may suggest which debris type should be concerned, but the abundance of each debris type may illustrate the seriousness of the problem.

3.3.4 Abundance of marine debris

Since the study was conducted in three consecutive months, the amount of debris found on the second and third sampling is expected to be lower. This is because the sampled debris was disposed from the beaches. Therefore, the determination of marine debris abundance in this section is based on the 'standing stock' value. This is to enable a comparison with other beaches in other parts of the world. Table 3.4 and Table 3.5 illustrate the debris abundance on each beach throughout the three months study. The abundance of debris is presented in number of item/ m^2 and weight/ g/ m^2.

Table 3.4: Amount of debris on Malaysian beaches based on number of item

Type of waste	Number of item/ m^2					
	Teluk Kemang	Pasir Panjang	Batu Burok	Seberang Takir	Tanjung Aru	Teluk Likas
Food waste	0.002	0.002	0.003	0.000	0.001	0.003
Paper	0.045	0.019	0.014	0.059	0.004	0.001
Plastics	**0.129**	**0.227**	**0.072**	**0.904**	**0.025**	**1.045**
Polystyrene	0.024	0.038	0.009	0.102	0.003	0.028
Textile	0.000	0.003	0.000	0.009	0.000	0.000
Rubber	0.000	0.002	0.001	0.029	0.000	0.006
Wood	0.000	0.000	0.001	0.003	0.000	0.001
Glass	0.000	0.007	0.000	0.137	0.001	0.001
Metal	0.001	0.003	0.000	0.006	0.000	0.001
Aluminium	0.001	0.001	0.000	0.000	0.003	0.000
Bulky waste	0.000	0.011	0.000	0.000	0.000	0.000
Others	0.009	0.019	0.041	0.129	**0.025**	0.000
Total	**0.211**	**0.333**	**0.142**	**1.379**	**0.062**	**1.086**
SD	±0.031	±0.157	±0.029	±0.883	±0.015	±0.309

Table 3.5: Amount of debris on Malaysian beaches based on fresh weight

Type of waste	Fresh weight, g/ m^2					
	Teluk Kemang	Pasir Panjang	Batu Burok	Seberang Takir	Tanjung Aru	Teluk Likas
Food waste	0.011	0.044	0.606	0.000	0.022	0.406
Paper	0.443	0.053	0.065	0.144	0.006	0.030
Plastics	**0.576**	1.153	**0.674**	**9.472**	**0.130**	**3.773**
Polystyrene	0.068	0.094	0.035	0.760	0.017	0.244
Textile	0.003	0.600	0.000	0.113	0.021	0.000
Rubber	0.000	2.861	0.225	1.233	0.000	0.333
Wood	0.001	0.000	0.306	0.242	0.003	0.094
Glass	0.000	0.356	0.000	2.597	0.024	0.034
Metal	0.003	0.014	0.000	0.119	0.001	0.068
Aluminium	0.006	0.033	0.007	0.000	0.000	0.000
Bulky waste	0.000	**5.556**	0.000	0.000	0.000	0.000
Others	0.008	0.178	0.047	0.844	0.010	0.000
Total	**1.119**	**10.942**	**1.963**	**15.525**	**0.233**	**4.983**
SD	±0.381	±7.868	±0.718	±10.743	±0.097	±0.522

The highest amount of debris was found in Seberang Takir where the number of item was 1.379 item/ m^2 and weighed 15.523 g/ m^2. This is followed by Teluk Likas (1.086 item/ m^2, 4.983 g/ m^2) and Pasir Panjang (0.333 item/ m^2, 10.942 g/ m^2). The higher amount of debris on all three fishing beaches may due to the presence of certain type of debris such as abandoned nets in Pasir Panjang. It may also caused by the lack of attention given by the authorities in managing the fishing beaches which is often in rural area with low tourism value.

Lower amount of debris were collected from the recreational beaches compared to fishing beaches. Lower amount of debris on recreational beaches is believed to be caused by the daily clean-up activity. Among the three recreational beaches, the highest abundance was recorded in Teluk Kemang, based on number of item (0.211 item/ m^2), and Batu Burok

based on weight (1.963 g/ m^2). Lowest amount of debris was found in Tanjung Aru (0.062 item/ m^2, 0.233 g/ m^2). Although these beaches are in urban areas with more beach users, it did not generate as much waste as fishing beaches that are located in rural areas. This is in contrast with a study in Curaçao, West Indies where public beach recorded 36.5 item/ $100m^2$ while rural beaches recorded lower amount of debris with 1.0 item/ $100m^2$.

In other study in the Gulf of Oman, debris was more abundant on recreational beaches in terms of number of item, and only recorded a higher amount of debris in fishing beaches in terms of weight (Claereboudt, 2004). However, the differences between fishing and recreational beaches were lower in terms of number (range: 0.062 – 1.379 item/ m^2), compared to the differences in terms of weight (0.233 – 15.523 g/ m^2).

Besides the function and management of the beaches, amount of debris can also be influenced by seasonal factor. Thus the amount of debris between monthly intervals is also important to be noted. Table 3.6 illustrates the monthly differences between debris abundance in selected beaches throughout the three months study.

Table 3.6: Amount of debris collected on beaches studied for monthly intervals

		Number of items (items/ m^2)				Weight (g/ m^2)			
		Jan	Feb	Mar	**Avg.**	Jan	Feb	Mar	**Avg.**
Recreational beaches	Teluk Kemang	0.178	0.238	0.218	**0.211**	0.724	1.483	1.150	**1.119**
	Batu Burok	0.175	0.121	0.130	**0.142**	2.194	1.158	2.538	**1.963**
	Tanjung Aru	0.079	0.058	0.050	**0.062**	0.312	0.262	0.125	**0.233**
Fishing beaches	Pasir Panjang	0.512	0.268	0.218	**0.333**	19.017	10.508	3.300	**10.942**
	Seberang Takir	2.083	1.666	0.388	**1.379**	24.871	17.917	3.788	**15.525**
	Teluk Likas	1.345	1.169	0.740	**1.086**	5.218	5.349	4.385	**4.983**

The amount of debris on Seberang Takir beach recorded a huge reduction from January till March. From observation, waste found in Seberang Takir was mostly from household item such as drinking bottles, kitchen wares and toiletries. It is believed that this debris originated from the nearby fishing village when they were cast ashore during flood event that was common during monsoon season. Consequently, the amount of debris during January and February sampling that was within the monsoon season recorded a very high number and weight. This is in accordance to other study where more debris can be found after periods of rough weather such as storms and rain (Ribic et al., 2010). It is also an example of the seasonal impact of marine debris abundance such as La Nina and El Nino events (Morishige et al., 2007). According to the villagers, Seberang Takir beach will be completely cleaned after the rough weather.

Unlike in Seberang Takir, other beaches did not record notable differences in the amount of debris collected between the three months. This is especially true to recreational beaches. These beaches have regular clean-up activity, thus the debris found during each month are those accumulated for the same time period. It shows that regular clean-ups play an important role in beach management especially in recreational beaches with higher rate of debris accumulation.

In order to determine the quality of the Malaysian beaches, other beaches globally are also compared. Table 3.7 illustrates the abundance of debris on other beaches worldwide.

Table 3.7: Debris abundance on selected beaches worldwide

	Area/ beaches	Number of item	Weight	Author
		Items/ m^2	g/ m^2	
1	Malaysian coast	0.062 – 1.379	0.233 – 15.525	*This study*
2	Gulf of Aqaba (Red Sea)	3 – 5	-	Abu-Hilal & Al-Najjar, 2004
3	SE Pacific, Chile	1.8	-	Bravo et al., 2009
4	Sea of Japan			Kusui & Noda, 2003
	- Japan	0.034	0.214	
	- Russia	0.002	0.0341	
5	Curaçao, West Indies	0.004	1.87	Nagelkernen et al., 2001
6	Ensenada, Baja California, Mexico	1.525	-	Silva-Iñiquez & Fischer, 2003

Due to different sampling protocol, comparative studies between two different marine debris studies can be difficult. Therefore, only studies which have similar sampling method are included in this comparison. All the studies are 'standing-stock' studies, where debris collection was either once for each beach, or a few times within a time period.

Amount of debris found on Malaysian beaches is similar to other beaches worldwide. The number of debris found in six studied beaches is neither the lowest nor the highest amount among the listed beaches. However, this study had also recorded a much higher debris weight (15.525 g/ m^2) than the listed studies. This is recorded from the fishing beach of Pasir Panjang and Seberang Takir (Table 3.5). The differences between local beaches and others depend on many factors including beach management, biophysical aspects and weather. Therefore, study on the debris accumulation rate is necessary, as 'standing-stock' value may not be sufficient.

3.3.5 Rate of accumulation

In this study, rate of accumulation was determined due to the differences in beach management. Some of the beaches were cleaned every day (Teluk Kemang, Batu Burok, Tanjung Aru and Teluk Likas), while the others were left as it is (Pasir Panjang and Seberang Takir). Therefore, the total amount of waste found on these beaches may not represent the actual amount of waste discarded. The total amount of waste generated in a day is what will be sampled on beaches with daily cleaning. Yet, for other beaches, the amount of waste collected during sampling represents the accumulation.

Unit used to represent rate of accumulation of marine debris on these selected Malaysian beaches are 'g/ m^2/ month' and 'number of item/ m^2/ month'. Beach with higher accumulation rate may illustrate higher intensity of usage, or higher frequency of waste generation from certain activities. Figure 3.14 and 3.15 show the debris accumulation rate on the studied beaches.

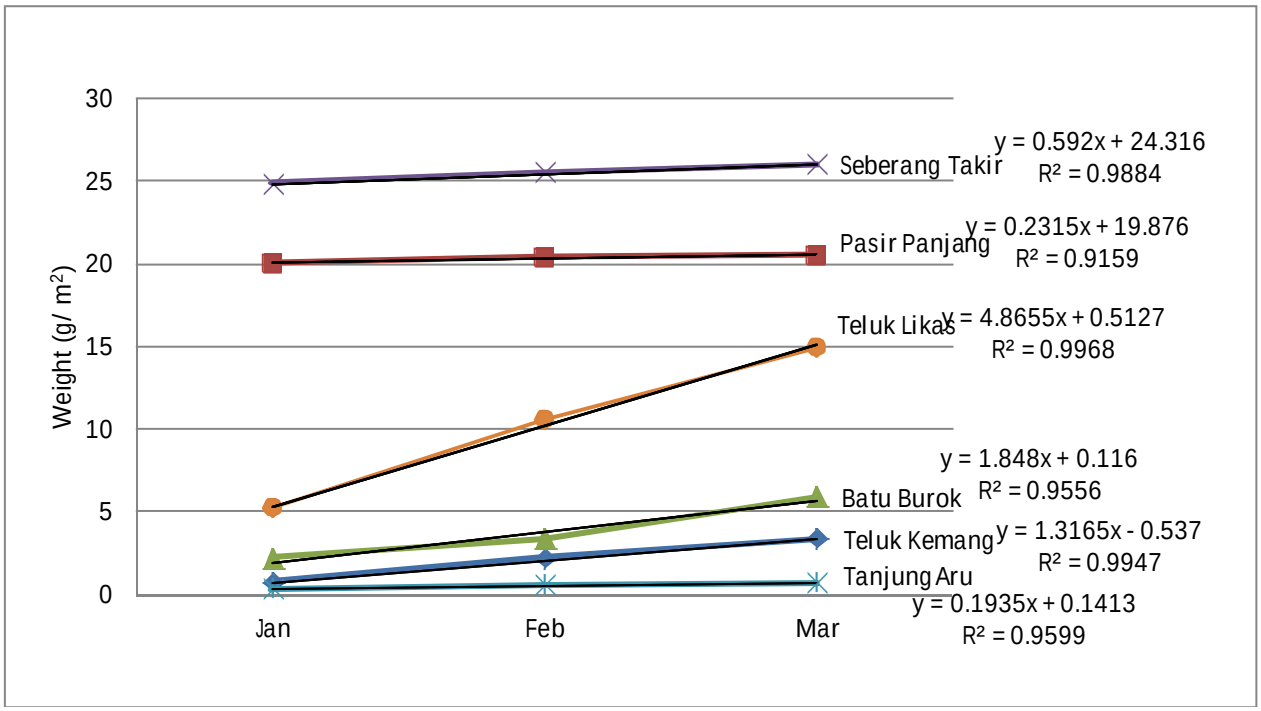


Figure 3.14: Rate of accumulation of marine debris on beaches based on fresh weight

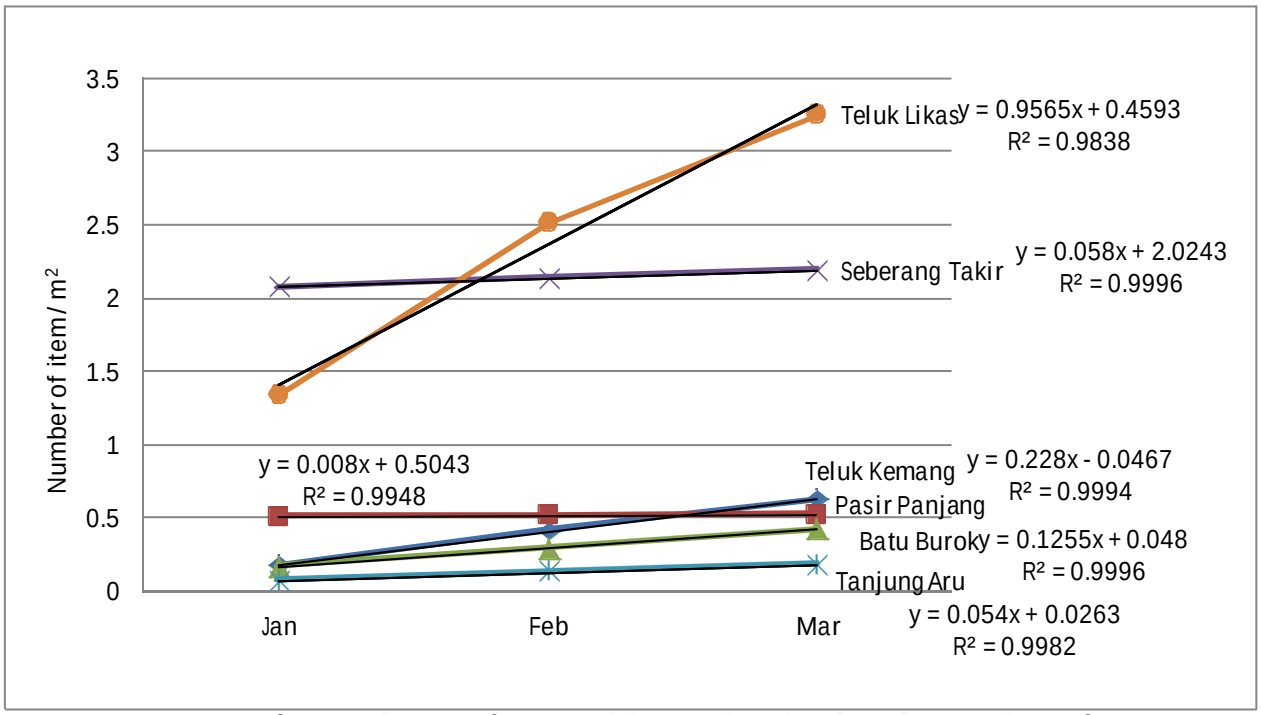


Figure 3.15: Rate of accumulation of marine debris on beaches based on number of item

Based on both figures, all three fishing beaches namely Pasir Panjang, Seberang Takir and Teluk Likas indicated the highest amount of marine debris but it does not reflect the highest accumulation rate among the beaches.

The rate of marine debris accumulation can be determined from the linear equation ($y = mx + c$). Higher gradient (m) illustrate higher accumulation rate. From the graphs, the rates of accumulation of studied beaches are within the following order:

Based on weight:

Teluk Likas (m=4.865) > Batu Burok (m=1.848) > Teluk Kemang (m=1.3165) > Seberang Takir (m=0.592) > Pasir Panjang (m=0.2315) > Tanjung Aru (m=0.1935).

Based on number:

Teluk Likas (m=0.9565) > Teluk Kemang (m=0.228) > Batu Burok (m=0.1225) > Seberang Takir (m=0.058) > Tanjung Aru (m=0.054) > Pasir Panjang (m=0.008).

Teluk Likas has the highest accumulation rate (m=4.865 and m=0.9565). Although, the beach is cleaned daily, new layer of waste will be unburied every day. It is believed that waste found on this beach had been accumulated years before the authority implement clean-up programs. According to the local workers, waste removal has begun since seven years ago. Beside trapped waste, the workers collected all wastes within their reach. However, the waste removal may take some time as buried waste will be out to the surface gradually.

Following Teluk Likas, other beaches with relatively high rate of marine debris accumulation are Teluk Kemang (m=1.3165 and m=0.228) and Batu Burok (m=1.848 and m=0.1225) beach. Both are recreational beaches with regular clean-up activities. The high accumulation rate of debris on these beaches is contributed by the high intensity of recreational activities.

Seberang Takir beach with no regular clean-up event has relatively lower accumulation rate (m=0.592 and m=0.058). It shows that debris generation on the beach is not as frequent as other beaches like Teluk Likas, Teluk Kemang or Batu Burok. The high abundance of debris on the first sampling was due to the flood event and may not be common throughout the year.

Tanjung Aru (m=0.1935 and m=0.054) and Pasir Panjang (m=0.2315 and m=0.008) recorded the lowest rate of marine debris accumulation. Tanjung Aru has relatively the lowest accumulation rate in terms of weight because it does not have high number of visitor as that of other recreational beaches like Teluk Kemang and Batu Burok. This is probably due to the lack of amenities provided near the area.

In terms of number, Pasir Panjang beach recorded the lowest accumulation rate (m=0.008). This is due to the facts that the abundance of debris in this beach is constituted by abandoned nets. These nets is not thrown or left frequently. For this study, nets recorded during the first sampling were not counted in the consecutive samplings. Thus, the rate of debris accumulation becomes lower. It shows that, once the abandoned nets are removed, debris abundance on this beach may become very low.

3.3.6 Sources of marine debris

The identification of exact sources of debris is difficult. Therefore, the determination of marine debris within this study is estimated based on the author's perspective and visual inspection. This section also aims to list other factors that contribute to the presence of debris, besides major activities held.

Plates 3.10-3.13 show the type of debris found on Teluk Kemang beach.

Plate 3.10: Drinking bottles, food packaging and wrappers found on Teluk Kemang beach

Plate 3.11: Plastics, papers and polystyrene are among the most common debris found on Teluk Kemang beach

Plate 3.12: Types of waste found on Teluk Kemang beach

Plate 3.13: Picnicking area is where most debris can be found

Drinking bottles, food wrappers and plastic bags are the common plastic items found. Most of the wastes found on the beach were at higher ground (Plate 3.13). From visual observation, this anthropogenic debris is most likely caused by the picnicking activity by the beachgoers. The availability of food stalls and the time spent by the beachgoers may affect the composition of debris (Ariza et al., 2008). Since many stalls are available at Teluk Kemang beach while wide range of water activities are provided, tourist tend to spend long hours on this beach. Therefore, the major contributor of anthropogenic marine debris (AMD) in Teluk Kemang is probably from beachgoers. This is in accordance with other studies of debris on recreational beaches around the world (Bravo et al., 2009; Ariza et al., 2008).

Paper wastes found include box paper, drinking box and newspaper which mostly are picnic debris. Newspaper found was also used as picnic mats besides as a reading material during picnicking. Besides plastic and paper, other visible contributor of debris on Teluk

Kemang beach is polystyrene. Polystyrene found are in the form of food packaging material and disposable cups and plates. Other types of waste found on Teluk Kemang beach include food waste, wood, metal and aluminium. These are the common items found on recreational beach throughout the world (Morishige et al., 2007; Thornton & Jackson, 1998).

On the whole, anthropogenic marine debris (AMD) from picnic activities is the most possible contributor of marine debris in Teluk Kemang. It is expected since the beach has many recreational activities. Recreational beach in Orange County, California recorded similar result where most of the items found were from food and beverages items (Moore et al., 2001) while approximately, 74% of total submerged debris in Curacao, West Indies was food-related item from recreational activities (Nagelkernen et al., 2001).

While most of the debris found on Teluk Kemang beach sourced from recreational activities, debris such as abandoned nets from fishing activities were found abundant in Pasir Panjang beach. Plate 3.14 - 3.17 illustrate the marine debris on Pasir Panjang beach.

Bulky waste make-ups the largest portion of debris found on Pasir Panjang beach. Fishing-based debris found on Pasir Panjang was mainly nets and ropes. This is contradicting with other areas where plastic bait jars, fishing lines and crab pots were more abundant (Hess et al., 1999). Most of the abandoned nets are already half-buried and badly entangled making its removal almost impossible without the use of large machineries.

Plate 3.14: Hazardous and dangerous wastes are among other debris found on Pasir Panjang beach

Plate 3.15: Abandoned net

Plate 3.16: Plastics found abundantly on the beach

Plate 3.17: Large amount of net make removal difficult

Besides fishing-based debris, other common debris such as drinking bottles and plastics can also be found. Additionally, there were also few floating bottles suggesting that the debris found on beach may also be marine-based item. It is based on a study that

categorized floatable item as marine-based debris and non-floatable material as land-based debris (Frost and Cullen, 1997).

In addition to abandoned nets and other common item found on the beaches, some hazardous and dangerous items such as oil containers, chipped glass and ceramics, and scissors were also found. It can injure the beach users (Plate 3.15). These hazardous and dangerous items are mostly household items which probably were washed ashore from inland. It is believed that litter can reach a beach area from rivers or municipal drainage system (Derraik, 2002).

Based on the visual inspection, debris on Pasir Panjang beach probably are from fishing activities, washed inland by waves and wind, or urban runoff. Therefore, management of debris for this area in future should consider all these possible sources.

While many of the debris found on the fishing beach of Pasir Panjang sourced from other activities than fishing, debris on Batu Burok beach sourced mainly from recreational activities there. Plate 3.18 and 3.19 illustrate types of waste found on Batu Burok beach.

Plate 3.18: Drinking bottle, drink packets and other debris on Batu Burok beach

Plate 3.19: Various plastic debris on Batu Burok beach

Plate 3.20: Chips of polystyrene on Batu Burok beach

Plastics contribute towards 34% of weight and 51% of the total number of debris found on Batu Burok. It consists of plastic bags, food and drink containers, straws, and bottles. Paper wastes found on Batu Burok beach mostly were comprised of food packets and drink boxes. Abundant scraps of polystyrene were also found. It probably originated from food and drink containers (Plate 3.20) from picnicking activities. As in accordance to International Coastal Cleanups (ICC, 2010) that usually conduct clean-up events on recreational beaches, shoreline and recreational activities are the contributor to 64% of marine debris found worldwide.

Besides shoreline activities, few household items made from plastic such as shampoo bottles and cloth pegs were also found. It was assumed that these items were washed ashore from housing area or other nearby buildings. This finding is similar to study by Bravo et al. (2009). Food waste, rubber and wood were also present. However, the number of these items is much lower.

While most of the debris found on Batu Burok beach came from recreational activities, it was found that the presence of marine debris on Seberang Takir beach is contributed by various factors besides fishing activities. Plate 3.21 – Plate 3.25 illustrate the high abundance of debris on the beach.

Plate 3.21: Plastic scraps on Seberang Takir beach

Plate 3.22: Torn plastics on Seberang Takir beach

Plate 3.23: Condition on Seberang Takir beach before waste collection

Plate 3.24: Large amount of debris to be sorted

Diverse type of debris was found scattered on Seberang Takir beach. This affects the scenery and the function of beach. In general, debris found on Seberang Takir beach is not typical as that of other fishing beach worldwide (Otley & Ingham, 2003; Walker et al. 1997; Jones, 1995).

From observation, debris found on the study area was mostly from household item such as drinking bottles, kitchen wares and toiletries. Most of the debris was originated from the nearby fishing villages when the wastes were cast ashore during the flood that was common during monsoon season. This is in accordance to other study where more debris can be found after periods of rough weather such as storms and rain (Ribic et al., 2010).

Plate 3.25 – 3.27 shows types of waste found on Tanjung Aru.

Plate 3.25: Food and drink packages and other debris on Tanjung Aru beach

Plate 3.26: Cigarette butts on Tanjung Aru beach

Plate 3.27: Debris on Tanjung Aru beach

In general, type of waste found on Tanjung Aru beach was similar to other recreational beach globally (Morishige et al., 2007; Thornton & Jackson, 1998). Plastic was the common item found. It includes plastic bags, bottles, wrappers and food containers. Beside plastic, one specific item found in significant number is cigarette butts. This is in

accordance to International Coastal Cleanup report, that listed cigarette butts/ cigarette filters as the most prevalent debris item found worldwide, which is 2,189 252 in number or 21% (ICC, 2010).

It is believed that most of the item found are from beachgoers. However, amount of items such as drinking bottles and food containers are not as much. This is because, waste collection in the beach area is frequent and dustbins are provided everywhere. The high number of cigarette butts found is probably due to its small size, therefore left unattended by the waste collectors.

As for Teluk Likas beach, there are various factors that contribute the presence of debris besides fishing activities. Although it is a fishing beach, no fishing village is located directly towards the beach. Most of the fishermen live within mainland and going to the sea through Sungai Likas (Plate 3.28).

Plate 3.28: Sungai Likas

Teluk Likas beach has seafood stalls, port and few villages on the island adjacent to the beach. Possible sources of marine debris to this beach are fishing activities, inland based, port and also from some recreational activities. Plate 3.29 – 3.32 illustrate Teluk Likas beach.

Plate 3.29: Polluted beach of Teluk Likas

Plate 3.30: Ships are possible contributor to debris on Teluk Likas beach

Plate 3.31: Buried wastes are visible during low tide

Plate 3.32: Wastes buried over time

The condition of Teluk Likas beach is severe. All water activities cannot be conducted here. From visual observation, the amount of solid waste on the beach is uncountable. The whole area was filled with plastic bags and other type of wastes. Most of the plastic bags

found were full of waste creating a 'landfill-like' condition. It is most likely that the wastes were thrown directly to the water body as they consist of household items and food waste.

During the study period, the debris was not weighed because most of the waste was trapped among the wet sand and waste removal was almost impossible. Therefore, data collected from this area involve few assumptions and estimation from the number of item visible and weight of few items available, of a same material.

Visually, the most abundant waste found on Teluk Likas beach is plastic bags. Other types of plastic seen are bottles, household items and utensils. Other than plastics, wood (furniture fractures, plank, etc.), textile (clothes, bags, etc.) and polystyrene are also visible and become an eyesore.

The natural scenery around the area is spectacular. This is because a lot of big trees line along the beach while few islands and well known 'Tun Fuad Stephen' building are within the view. However, the presence of huge amount of waste had spoiled the view and hinders any recreational activities.

On the whole, among other sources of debris on Malaysian beaches are recreational and fishing activities, shipping, and household item washed ashore. These are important sources need to be noted in order to eliminate debris presence at source.

3.4 Conclusions

From this chapter, it can be concluded that,

1. Debris on the selected beaches ranged from 0.06-1.38 items/ m^2, weighing 0.23-15.525 g/ m^2. In this study, debris is more abundant on fishing beaches compared to recreational beaches.

2. Plastic is the most abundant item found on all studied beaches, both recreational and fishing beaches. Other types of debris found in abundant on recreational beaches are cigarette butts, paper, polystyrene, glass and metal. On the other hand, one particular debris that is worth mentioning is the abandoned nets found on Pasir Panjang beach.

3. In general, the rates of debris accumulation on recreational beaches are higher as compared to fishing beaches. However, there is exception for one fishing beach which is Teluk Likas that recorded the highest rate of debris accumulation with approximately 0.9641 items or 4.8740 g of debris accumulated in every square meter in a day.

4. From the study, it was also found that the sources that contributed to the presence of debris on Malaysian beaches are recreational and fishing activities, shipping activities, and wastes washed from inland. Beach management and seasonal occurrences are the factors for abundance of debris on beaches.