MACRO AND MICROPLASTICS ABUNDANCE ON BEACHES OF SELECTED ISLANDS IN PENINSULAR MALAYSIA

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MACRO AND MICROPLASTICS ABUNDANCE ON BEACHES OF SELECTED ISLANDS IN PENINSULAR MALAYSIA

ABSTRACT

The rapid development and heavy anthropogenic activities near the beach are believed to contribute to the abundance of plastic debris, which results in an array of negative effects to marine biota. This study discussed the macro and microplastics abundance on beaches of Malaysian islands namely, Pulau Besar, Langkawi Island, Sibu Island and Perhentian Island. The objectives of this study are to determine the current waste management and evaluate the cleanliness index (BCI) of the beach. It is also aimed to determine the composition of marine waste and abundance distributions of macro and microplastic as well as to determine their correlations. The BCI scores on each beach sites was evaluated by using a five point Likert scale ranged from 0 (very negative responses) to 4 (very positive responses). For the waste composition studies, debris on each beach sites were collected, weighed and counted after the segregation into 27 predetermined types. As for the microplastic quantification, a triplicate of 12.5 L of sediment samples was collected using 50 x 50 cm quadrat to a depth of approximately 5cm, at different tidal zones. The sediment samples were sieved to group them according to their respective sizes. Results indicated that, beach of Pulau Besar that faces the open sea was the cleanest with the highest BCI value (3). Recreational, fishing and shipping activities are the anthropogenic activities conducted on all the beaches studied. Marine waste found on these beaches includes hard plastic, film, polystyrene, paper, aluminium cans, and drinking packs. The distributions of macro and microplastic debris in this study are dependent of the economic activities of the respective beaches. The quantity of macroplastics was highest in Pinang Seribu Beach (103 items/m^2), followed by beach of Sibu Island that faces the mainland (76 items/m^2) and Tanjung

Butong Beach (60 items/m^2). The highest quantity of microplastics were collected at Pinang Seribu Beach with 2517 items/m^2 and followed by beach of Sibu Island that faces the open sea with 401 items/m^2. While fishing beaches have abundant quantities of plastic line, foam and film, recreational beaches accumulated more plastic film, fragment and foamed plastic. Remote beaches on Perhentian Island had the highest quantity of plastic foam, fragment and line. In general, a positive correlation (0.917) with R^2 = 0.841 was found between the abundance of macro and microplastics on the selected beaches of Malaysian islands. This demonstrates that continued cleaning efforts are crucial to reduce the plastic debris pollution on beaches of Malaysian islands.

Keywords: anthropogenic, cleanliness index, marine waste, macroplastic, microplastic

TABURAN MAKRO DAN MIKROPLASTIK DI PANTAI-PANTAI PULAU TERPILIH DI SEMENANJUNG MALAYSIA

ABSTRAK

Pembangunan yang pesat dan aktiviti antropogenik berdekatan kawasan pantai dipercayai menyumbang kepada timbunan sisa plastik, yang turut memberi kesan negatif kepada ekosistem marin. Kajian ini membincangkan mengenai taburan makro dan mikroplastik di pantai- pantai pulau terpilih di Malaysia iaitu Pulau Besar, Pulau Langkawi, Pulau Sibu dan Pulau Perhentian. Kajian ini bertujuan untuk menentukan pengurusan sisa di kawasan pantai dan untuk menilai indeks kebersihan pantai. Kajian ini juga bertujuan untuk menentukan komposisi sisa-sisa marin dan taburan serta jumlah makro dan mikroplastik yang terdapat di pantai-pantai tersebut selain menentukan korelasi di antara taburan makro dan mikroplastik. Indeks kebersihan di setiap pantai dinilai dengan menggunakan skala Likert lima titik bermula dari skor 0 (tindak balas yang sangat negatif) kepada skor 4 (tindak balas yang sangat positif). Kesemua sisa di setiap pantai dikumpul, ditimbang dan dikira selepas diasingkan kepada 27 jenis sisa yang telah ditetapkan. Bagi kajian mikroplastik, triplikasi sampel pasir sebanyak 12.5 L diambil menggunakan kuadrat bersaiz 50 x 50 cm dengan kedalaman kira-kira 5 cm di kawasan pasang surut yang berbeza. Sampel-sampel pasir ini diayak untuk mengasingkan sisa mikroplastik mengikut saiz. Keputusan menunjukkan bahawa, kawasan pantai yang menghadap laut terbuka di Pulau Besar merupakan pantai yang paling bersih dengan nilai indeks kebersihan pantai yang paling tinggi (3). Aktiviti rekreasi, perikanan dan perkapalan merupakan aktiviti antropogenik yang terdapat di pantai-pantai kajian. Antara sisa-sisa marin yang terdapat di pantai kajian ialah plastik HDPE, filem, polistirena, kertas, tin aluminium dan kotak minuman. Taburan sisa makro dan mikroplastik dalam kajian ini bergantung kepada aktiviti ekonomi di pantai-

pantai kajian. Pantai Pinang Seribu mencatatkan jumlah makroplastik tertinggi (103 item/m^2), diikuti oleh kawasan Pantai Pulau Sibu yang menghadap tanah besar (76 item/m^2) dan Pantai Tanjung Butong (60 item/m^2). Pantai Pinang Seribu juga mencatatkan jumlah mikroplastik yang paling tinggi (2517 item/m^2) dan diikuti oleh kawasan pantai Pulau Sibu yang menghadap laut terbuka (401 item/m^2). Kawasan pantai yang terkenal dengan aktiviti memancing dan petempatan nelayan mencatatkan jenis-jenis mikroplastik seperti tali, buih dan filem, manakala pantai rekreasi mencatatkan lebih banyak mikroplastik filem, pecahan dan buih. Pantai terpencil di Pulau Perhentian memperolehi jumlah buih, pecahan dan tali yang tinggi. Secara umumnya, terdapat korelasi positif (0.917) dengan R^2 = 0.841 di antara taburan makro dan mikroplastik di pantai-pantai pulau terpilih di Malaysia. Hal ini menunjukkan bahawa usaha pembersihan pantai yang berterusan adalah sangat penting untuk mengurangkan pencemaran sisa plastik di pantai-pantai pulau di Malaysia.

Kata kunci: antropogenik, indeks kebersihan, sisa marin, makroplastik, mikroplastik

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LIST OF SYMBOLS AND ABBREVIATIONS

$<$	:	less than
$>$	:	more than
%	:	percentage
cm	:	centimetre
m^3	:	cubic metre
E	:	East
g	:	gram
kg	:	kilogram
km	:	kilometre
L	:	litre
m	:	metre
m^2	:	metre square
µm	:	micrometer
mm	:	millimetre
N	:	North
AA	:	Anthropogenic activities
AB	:	Availability of waste bins
BC	:	Beach cleaning activity
BCI	:	Beach Cleanliness Index
BP	:	Best Practice
BPA	:	Bisphenol-A
DMPM	:	Department of Marine Park Malaysia
DOFM	:	Department of Fisheries Malaysia
EEA	:	European Environment Agency

EPA	:	Environmental Protection Agency
EU	:	European Union
F	:	fishing
FS	:	facilities and services
GNP	:	Gross National Product
GPA	:	Global Programme of Action for the Protection of the Marine Environment from Land-based Activities
GPS	:	Global Positioning System
GESAMP	:	United Nations Group of Experts on the Scientific Aspects of Marine Pollution
HDPE	:	high-density polyethylene
HELMEPA	:	Hellenic Marine Environment Protection Association
ICC	:	International Coastal Cleanup
IMO	:	International Maritime Organization
IUCN	:	International Union for the Conservation of Nature and Natural Resources
LDPE	:	low density polyethylene
LLDPE	:	linear low density polyethylene
MARPOL	:	International Convention for the Prevention of Pollution from Ships
MEA	:	Millennium Ecosystem Assessment
META	:	Marine Education and Training Academy
MMHLG	:	Malaysian Ministry of Housing and Local Government
MOCAT	:	Ministry of Culture, Arts and Tourism in Malaysia
MPA	:	Marine Protected Area
MPB	:	Marine Parks Trust Fund Management Committee
MSW	:	municipal solid waste
NAC	:	National Advisory Council for Marine Park

NAMEPA	:	North American Marine Environment Protection Association
NF	:	Natural factors
NGOs	:	non-government organizations
NMDMP	:	National Marine Debris Monitoring Program
NOAA	:	National Oceanic and Atmospheric Administration
NOWPAP	:	Northwest Pacific Action Plan
NRE	:	Ministry of Natural Resources and Environment
PAHs	:	polycyclic aromatic hydrocarbons
PB	:	Penarak Beach
PBM	:	Pulau Besar Mainland
PBS	:	Pulau Besar Open Sea
PCBs	:	polychlorinated biphenyls
PE	:	Polyethylene
POPs	:	persistent organic pollutants
PP	:	Polypropylene
PS	:	Pinang Seribu Beach
PS	:	Polystyrene
PVC	:	Polyvinyl chloride
R	:	recreational
RSP	:	Regional Seas Programme
S	:	Shipping
SIM	:	Sibu Island Mainland
SIS	:	Sibu Island Open Sea
STAP	:	Scientific and Technical Advisory Panel
SWM	:	Solid Waste Management
TB	:	Tengah Beach

TBG	:	Tanjung Butong Beach
TRBP	:	Tourism and Recreation Best Practice
UK	:	United Kingdom
UNEP	:	United Nation Environmental Programme
UNESCO	:	United Nations Educational, Scientific and Cultural Organization
USA	:	United State of America
USEPA	:	United States Environmental Protection Agency
UV	:	ultraviolet
WWF	:	World Wide Fund

LIST OF APPENDICES

CHAPTER 1: INTRODUCTION

1.1 Plastic Usage

Plastic is one of the most prevalent and multipurpose materials in the world. Due to their lightweight properties, durable and inexpensive, plastic products were widely used in our daily applications. According to PlasticsEurope (2016), the various industries produced 322 million tonnes of plastics in 2015 against 230 million tonnes in 2005, meaning that the production quantity increased 1.4 times between those ten years. The acceleration in the demand of plastics production leads to the characterization of the present era as the "Plastic Age" (Thompson *et al.,* 2009). When more people rely on plastic, the production rate will continue to grow rapidly which inevitably result to a higher disposal rate. Although plastics bring many societal and technological benefit, the acceleration of plastic usage should be given more concern as plastic has the potential to cause greater pollution problem to the environment.

Plastic is a material derives from petrochemicals produced from crude oil and natural gas (Thompson *et al.,* 2009). The global production is commonly dominated with four types of plastics namely, polyethylene (PE, high and low density), polypropylene (PP), polyvinyl chloride (PVC), and polystyrene (PS). The varieties of polymer types offer versatile usage because of its own attractive characteristics. According to Allahvaisi *et al.* (2010), PE and PP are mainly used as packaging materials for products that have a relatively short useful lifetime. Meanwhile, PVC is a hard rigid material which is extensively used in building construction as thin sheeting, gutters and irrigation pipes (Brent Strong, 2005).

Not surprisingly, plastic is the second most commonly used material for automotive manufacturers in the world. Plastics are used as substitution for aluminium and metals in the car‛‛s interior such as steering wheels and electronics components. In the car‛‛s exterior, ultra lightweight wheel trims made of plastics contributed to weight reduction without affecting the safety of the vehicles (VTO, 2016). Overall, using more plastic materials in automotive could help to optimize the power usage, minimize the operation cost and reduce carbon emissions into the air (Andrady & Neal, 2009). In addition, PE, PP, and PVC are the beneficial plastic materials used in agricultural sector. These practices are referred to as „plasticulture‟. Nowadays, majority of farmers prefer to use plastic irrigation pipes to prevent loss of water and nutrients (Ingman, 2015). In many developing countries, the usage of plastic has grown progressively over the years, replacing traditional materials such as glass to cover greenhouse and paper or straw for soil mulching (Scarascia *et al.,* 2011). The extensive and expanding use of plastic materials in agriculture has helped farmers to increase crop production, improve food quality and reduce their ecological footprint.

The use of plastic materials in buildings continues to increase, particularly as architects, designers and builders appreciated their advantages in construction and decoration (Appiah *et al.,* 2016). Plastic materials are often more economical than traditional materials and it can be reused or recycled. Today, plastics are used as insulation materials in green buildings due to their low conductor of heat (Kruger & Seville, 2012). Currently, different types of plastic are used in construction industry such as expanded PS, PE, PP and PVC. Therefore, due to the wide range of plastics product, no doubt that the building and construction industry consumed around 9.6 million tonnes of plastics, making it the second largest plastic application after packaging (PlasticEurope, 2015). As a consequence, the frequent use of plastic material generates large amounts of post-consumer material that need to be properly managed.

Plastic offers a great benefit to commercial and industrial users in packaging industry (Andrady & Neal, 2009). Plastic packaging is ideal for most frozen food, fresh perishable food items and snack foods. Apart from that, plastics are better suited in the health and medical sector, where they possesses a unique set of properties such as lightweight and lower cost of production (Rustagi *et al.,* 2011). According to North and Halden (2013), plastics are widely used to replace metal instruments and medical devices including disposable syringes, catheters, cannulas and intravenous blood bags.

Plastic are used extensively in personal care and cosmetics products such as toothpaste, facial cleanings and exfoliating body scrubs (Andrady, 2011; Wright *et al.,* 2013). Most of the cosmetic manufacturers choose to use tiny pieces of plastic known as „micro-beads‟ due to its low production cost and easy reproducibility (Cosmetics Ingredient Review, 2012). Yet, their negative impact to the environment is somewhat ignored (Derraik, 2002).

In manufacturing industry, plastic are used regularly for circuit boards, chips, coffee makers, microwave ovens, hair dryers and even refrigerators. Furthermore, plastic is also used to make optic fibers that are laid under the sea to provide high speed internet connections to the users (Koike & Asai, 2009). Thus, the presence of plastics allows humans to have a convenient lifestyle, while passing along cost-savings to the various stakeholders in manufacturing industry. As global industrialization continues to evolve, it is very important to monitor the usage of plastic material because most of them are non-biodegradable and will remain as waste in the environment. In fact, plastic has become a serious threat to the marine environment due to their inert nature as marine debris. Marine debris which mainly comprised of plastic waste is getting more and more attention at the global level (Stofen-O‟Brien, 2015).

1.2 Plastic Debris Pollution

Plastic debris pollution is ever increasing in the marine environment which eventually becomes the second most important global environmental issue after climate change (Barnes *et al.,* 2009; Moore, 2008; Ryan *et al.,* 2009). The increase of plastic debris found at sea, on the ocean floor and along the shore poses a serious emerging threat to the environment, human health and marine biota (Barnes & Milner, 2005). However, the knowledge on the adverse effects on human health due to the consumption of marine organisms containing microplastic is very limited, difficult to assess and still controversial. Thus, research is urgently needed, especially regarding the potential exposure and associated health risk to micro-sized plastics.

Plastic debris is usually associated with anthropogenic activities. Locations, types of beach usage and influences from anthropogenic activity are the most important factors controlling abundance of beach debris (Storrier *et al.,* 2007). This also includes indirect input from natural beach physiographic, slope, exposure and environmental factors (prevailing winds and ocean currents) (Galgani *et al.,* 2015). Studies by Jambeck *et al.* (2015), have shown that once on the beach, plastic debris may be buried resulting in the underestimation of the total amount of plastic litter reaching the shore which accidentally lost, carelessly handled or left behind by beachgoers. Among plastic litter, microplastics are of special concern due to their small size, the lack of technology available to quantify the presence of the smallest microplastics in the environment, and their potential to cause adverse effects on the marine biota and humans.

Existing in a variety of sizes and shapes, plastics debris has significant impacts to the marine organisms such as sea turtles, fishes, plankton and seabirds (Derraik, 2002; Ryan *et al.,* 2009). Large plastic debris, known as "macroplastics" present an aesthetic problem with economic repercussions for tourism (Jang *et al.,* 2014), pose a risk to various marine industries (Sheavly & Register, 2007) and threaten marine life through entanglement and ingestion (Teuten *et al.,* 2009). Another emerging environmental issue associated with plastic debris in recent years is the present of microplastics, commonly derived from degrading macroplastics as a result of chemical, biological and physical breakdowns (GESAMP, 2015).

The coastline of Malaysia represents a complex and dynamic system both in terms of human activities and biophysical conditions (Mobilik *et al.,* 2014). With the increasing population and rapid development, Malaysian beaches experience tremendous threats from plastic debris pollution (Khairunnisa *et al.,* 2012; Hassan *et al.,* 2007). Although the serious concern of the plastic pollution problem has grown in Malaysia, comprehensive studies are still lacking to document the pollution. Furthermore, there are deficiencies in waste management causing some of the waste end up in the ocean (UNEP, 2009a; Lytle, 2010; PlasticsEurope, 2010). Lack of enforcement systems and improper human behaviour frequently lead to the accumulation of plastic debris on Malaysian beaches.

Previous studies on marine debris in Malaysia found plastic materials as the most abundant type of marine debris in Port Dickson (Khairunnisa *et al.,* 2012), Sarawak (Hassan & Mobilik, 2012) and Terengganu beaches. Although these studies gave an overview on debris pollution level on Malaysian beaches, however it might not be sufficient to generalize the level of contamination and the subsequent impacts of plastic debris to the marine environment. Therefore, it is highly essential to have further studies on plastic debris pollution and adopt improved measures towards the reduction, prevention and management of marine plastics.

1.3 Objectives of the Research

This present study focused on the macro and microplastic abundance on selected beaches of Malaysian islands. The data from this study is needed since not much research has been carried out in Malaysia. It is very important to monitor and reduce the impacts of plastics debris to the marine environment, so that appropriate and timely actions can be implemented. Therefore, the objectives of this study are:

1. To determine current waste management on beaches of selected islands in Peninsular Malaysia.
2. To determine the cleanliness index of the beach.
3. To determine the composition of marine waste discarded on the beach.
4. To determine the types and distributions of macro and microplastics.
5. To correlate the distribution of macroplastics with microplastics abundance.

1.4 Salient Features of the Research

The accumulation of plastic debris across the environments is overwhelming with the rapid increase in their production and subsequent disposal. In the most studies conducted, major contributor to marine debris is land based sources including surface runoff and human activities (Silva-Iniguez & Fischer, 2003). Natural exposure such as wind and wave also caused the presence of debris on the beaches (Liyana, 2012). Thus, it is essential to understand the sources of marine debris, so future changes on waste management can be predicted and managed.

Moore (2008) reported that plastic debris pollution is not commonly addressed by researchers as compared to other environmental marine issues such as water quality and toxicology (Agusa *et al.,* 2005; Sultan *et al.,* 2011). To date, most of the existing research and monitoring has focused on beach surveys of stranded macrosized plastic debris (Ryan *et al.,* 2009). Considering that macroplastics are more visible and easier to sample than microplastics, it was getting more and more concern by scientists and the general public. Pollution to the marine environment by microscopic plastic particles may be regarded as a relatively new environmental problem since this field of study is still at an early stage of development. Hence, this study presents the first ever findings on the type and distributions of both macro and microplastics from beaches of selected islands in Peninsular Malaysia. Besides, the composition and abundance of marine waste discarded on the beach can also be determined.

To our knowledge, there is no specific index concerning the real cleanliness of Malaysian beaches. The only measure was the amount of waste removed from the beach during cleanup event. Thus, this study also would provide the beach cleanliness index (BCI) which helps to measure the actual cleanliness of the beach. BCI is an important parameter which helps to increase public"s awareness on beach cleanliness and motivate the local authorities to clean their beaches. On overall, it is hoped that the data obtained from this study can be used as a baseline for further assessment and monitoring of plastic debris in the marine environment.

CHAPTER 2: LITERATURE REVIEW

2.1 Marine Environment

According to Orams (1999), the marine environment is defined as those waters that are saline and tide-affected. Approximately, about 71% of the Earth's surface is covered in water and the oceans containing about 96.5% of the world‟s water (Haefner, 2003). By having its own rich natural and cultural heritage, marine environment is one of the most precious asset that must be protected in order to achieve sustainable development in the marine area (Duxbury *et al.,* 2000). Due to their transboundary nature of oceans, large coastal population in every region depends on them for their livelihood and prosperity.

Owing to their size and complexity, marine environment is divided into more manageable arbitrary subdivisions (Figure 2.1) (Hedgepeth, 1957). Spatially, the division is based on the characterization of ecological features, the associated plants and animals known as a pelagic realm and a benthic realm representing organisms and zones of the sea bottom (Duxbury *et al.*, 2002). Horizontally, the pelagic realm can be divided into two zones where the neritic zone encompasses the water mass that overlies the continental shelves while the oceanic zone includes all other open waters (Subramanian, 2015). Progressing vertically, the pelagic realm can be further subdivided into photic and aphotic zone. The layer of water that is exposed to the sufficient sunlight for photosynthesis to occur is known as the photic zone. The most bottom zone is called the aphotic zone where most deep sea ocean waters belong to this zone (Kunich, 2006).

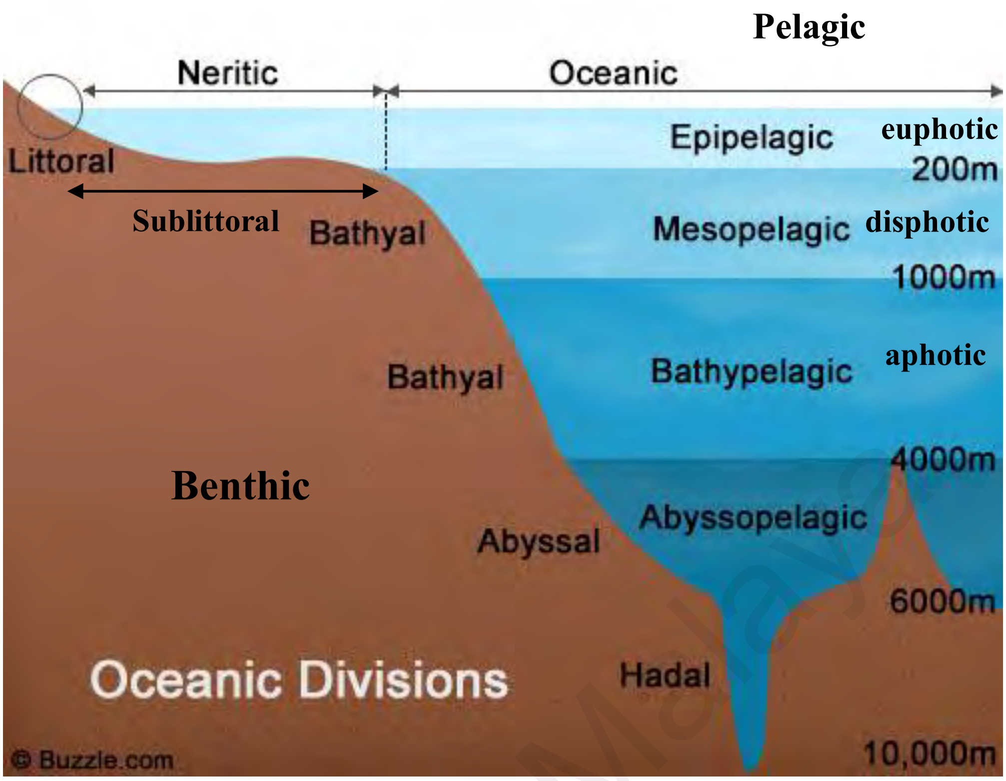

Figure 2.1: Divisions of the oceans (Image reproduced with permission from Hedgepeth (1957))

The marine environment contains a range of ecosystems, from the shoreline to the deepest trenches that harbor great biological diversity of marine life (Duxbury *et al.*, 2002). There are 230,000 marine flora and fauna species in the ocean which ranges from microscopic organisms to the largest fish and whales (Hickman, 2010). Due to the great depths of the oceans, this estimation could be higher (Fautin, 2012; Manivasagan *et al.,* 2013).

In addition, marine environment are known to provide a large number of ecological services. These includes cycling and storing of nutrients, accumulation and distribution of solar energy, filtering pollutants, maintaining biological control and regulating planetary balances in hydrology and climate (Egoh *et al.,* 2012; Liquete *et al.,* 2013). Furthermore, the marine environment is a great storehouse of major protein source from fish and other marine products of value to human (Bollmann, 2010). Considering the marine environment‟s vast size in comparison to land, it is easy to assume that we could never deplete it resources.

Although only occupy less than 15% of the earth‟s land surface, coastal areas are regions that represent a very important resource base for societal, economic, and cultural activities (Mimura, 2008). Because of these features, most countries recognize the coastal zone as a distinct region with resources that require special attention (Moreno-Casasola, 2004). However, an issue to bear in mind is that human activities affect the coastal environment and in the environmental in turn affect the lives of human.

2.1.1 Marine Ecotourism

Ecotourism defined by the International Union for the Conservation of Nature and Natural Resources (IUCN) (Ceballos-Lascurain, 1993) and endorsed by Ministry of Culture, Arts and Tourism in Malaysia (MOCAT) to be "environmentally responsible travel and visitation to relatively undisturbed natural areas, in order to enjoy and appreciate nature, that promotes conservation, has low visitor impact and provides the beneficially active socio-economic involvement of local populations" (MOCAT, 2000). Ecotourism is an effective way for businesses in a tourism destination to have a positive impact on their host community.

According to Ainul Raihan (2000), the objectives of the Marine Parks are the same with the concept of ecotourism which is enjoying and appreciating the nature. Marine ecotourism is about attempting to establish and maintain a symbiotic relationship between tourism and the natural marine environment (Hoctor, 2001). Halpenny and Elizabeth (2002) stated that marine ecotourism should include five essential elements which are (i) travel to a marine or coastal setting (this may include some cultural attractions) that benefits local communities, including involvement and financial returns; (ii) travel that helps to conserve the local environment (both cultural and natural); (iii) travel that minimize its negative impact on natural environments and local communities; (iv) travel that emphasizes learning and interpretation of the local environment to visitors, and (v) travel that motivates visitors to re-examine how they impact the earth and how they can aid local communities and the environment.

Gunnar Myrdal, one of the Swedish economists first outlined backwash effects in his Theory of Circular and Cumulative Causation in 1957 (Ho, 2004). This concept can also be usefully applied in marine ecotourism. Figure 2.2 illustrates the scales of spread (positive) and backwash (negative) effects between the various sectors, levels and interests which will dictate the prospects for sustainable outcomes (Cater, 2002).

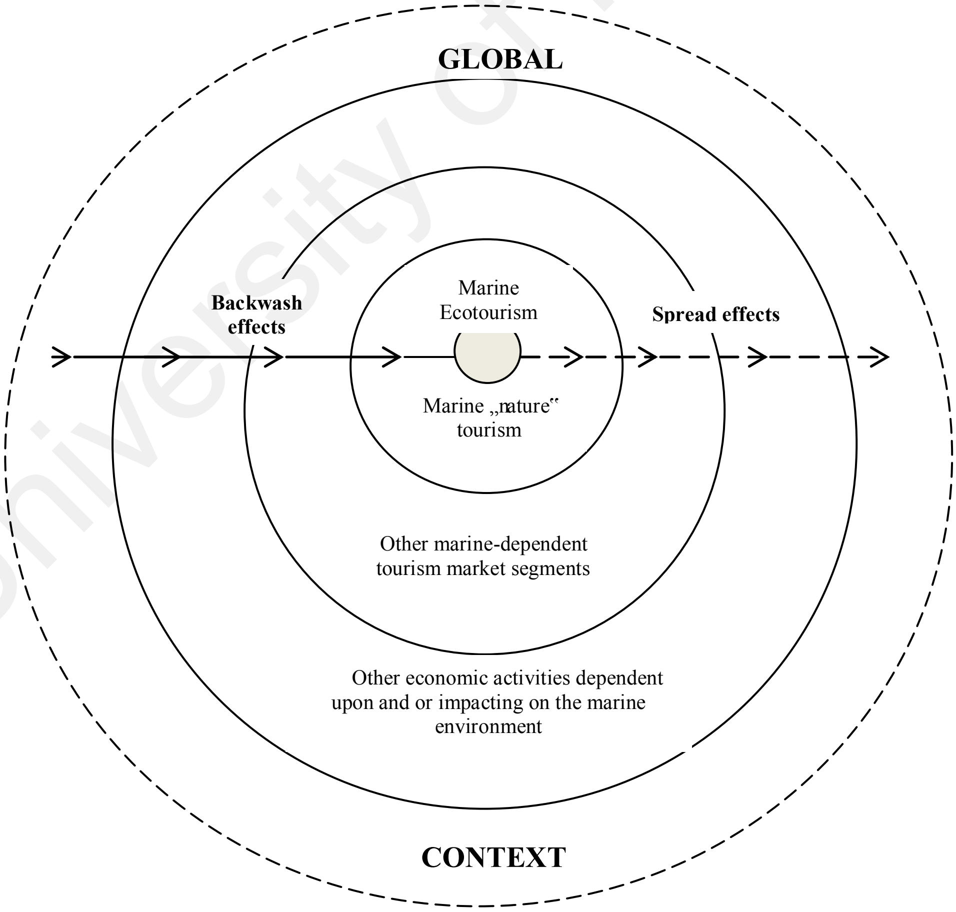

Figure 2.2: Spread and backwash effects in marine ecotourism (Adapted by permission from Cater (2002))

The spread effects from marine ecotourism include the raising of environmental awareness and the disseminating of understanding on the coincidence of good environmental practice which would be advantageous to business. Simultaneously, there are significant backwash, which occurs if the adverse effects dominate and the level of economic activities in the peripheral communities declines (De Haas, 2010).

Currently, marine ecotourism is the fastest growing sector within the tourism industry (Yeung & Law, 2005). The development of marine ecotourism may be perceived as an opportunity to overcome economic hardship and regenerate coastal communities that are experiencing the decline in agriculture, commercial fishing and seaside tourism (Garrod *et al.,* 2001). Marine ecotourism can also generate positive outcomes, for example by raising funds that can be used for environmental protection, by providing economic alternatives to activities which cause deterioration to the marine environment and by more widely propagating eco-awareness and the principles of sustainable development (Kandari, 2004). Local participation in planning and management as well as the collaboration of stakeholders will ensure that the ecotourism benefits local people economically as well in other ways. The subsequent sections discuss the management of Marine Park in Malaysia.

2.1.2 Marine Park in Malaysia

A Marine Park is defined as a sea area zoned as a sanctuary for the protection of marine ecosystem especially coral reef community, which is considered possibly as the most productive ecosystem in the world, with its diversity of flora and fauna (Chiau, 2005). Even though parks and reserves were established in Malaysia in 1925, they were confined to mainland areas (Jasmi, 1996). When the country started to realize that marine fishery resources had experienced a decline in the early 1980s, appropriate steps were taken to initiate the conservation of the natural marine habitats (Ch'ng, 1990;

Department of Fisheries Malaysia (DOFM), 1996a; Lim, 1998; Ridwan & Syarifah, 1996). The initial establishment of Marine Protected Area (MPA) was made in 1983, where islands in Terengganu, Kedah, Pahang and Johor were gazetted as Fisheries Protected Area (Ahmad & Hanley, 2009).

The management and conservation of the Marine Parks in Malaysia are subjected to the National Advisory Council for Marine Park (NAC) and Marine Reserve and the Marine Parks Trust Fund Management Committee (MPB), which was established to determine the governmental policy on any development project in a Marine Park and coordinates development planning by the federal agencies (Cheryl, 2005). There are 42 islands in Malaysia which has been gazetted as Marine Parks (Figure 2.3) which are Pulau Payar Marine Park in Kedah (4 islands); Pulau Redang Marine Park in Terengganu (13 islands); Pulau Tioman Marine Park in Pahang (9 islands); Mersing Marine Park in Johor (13 islands) and Labuan Marine Park in Labuan Federal Territory (3 islands) (Islam *et al.,* 2013).

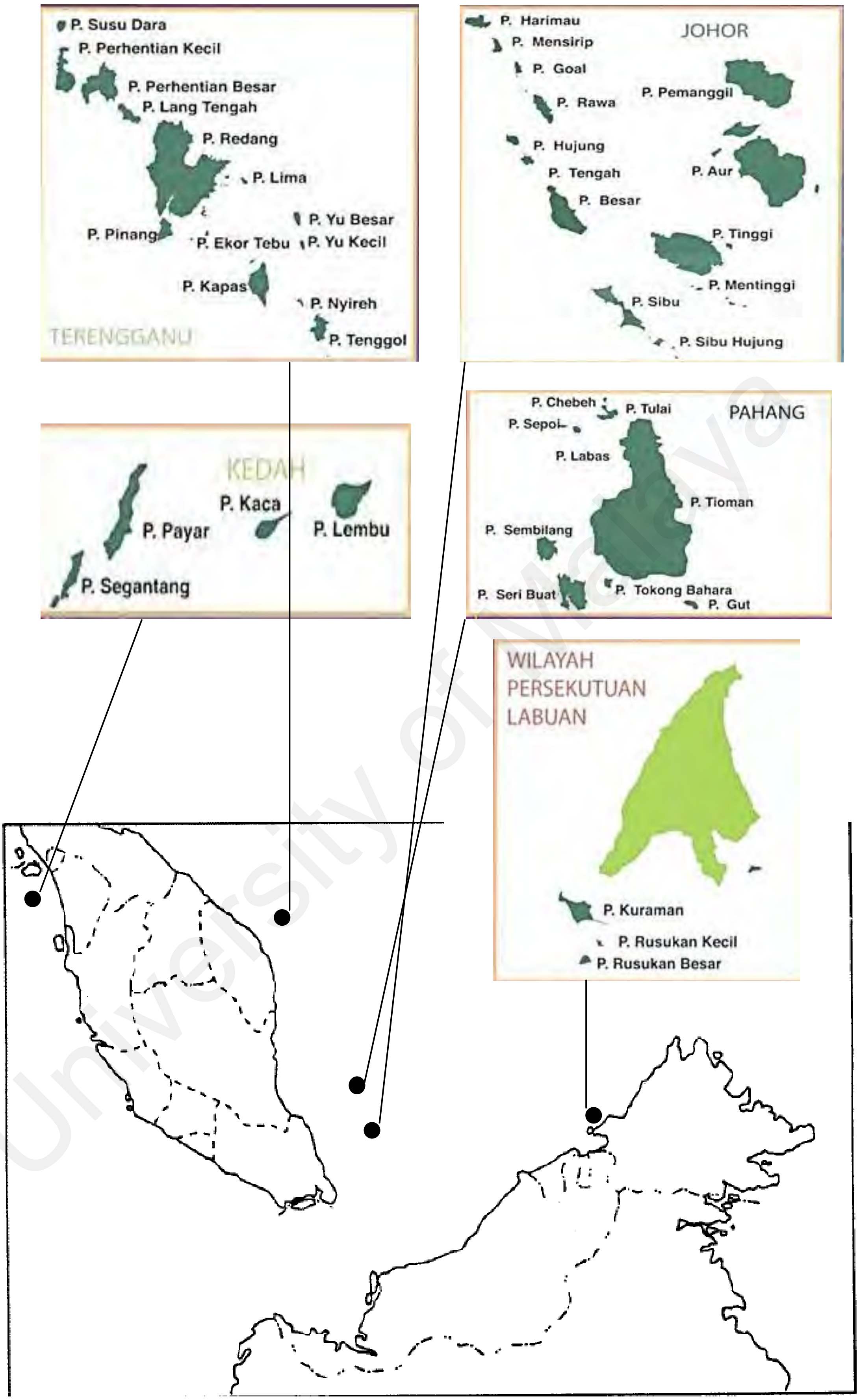

Figure 2.3: Marine Parks in Malaysia (Image reproduced with permission from Department of Marine Park Malaysia (2013))

The objectives of the Marine Parks in Malaysia are (i) to conserve and protect biological diversity of marine community and its habitats; (ii) to upgrade and conserve the natural habitats of endangered aquatic species; (iii) to establish zones of recreational use consistent with the carrying capacity of the area (Ramli, 2002) and (iv) to manage and protect natural marine ecosystems for biodiversity research, educational purposes and sustainable development of recreational and ecotourism activities (Kiper, 2013). Because of the peculiar situation in Malaysia, where land management is under the jurisdiction of the State Government, ensuring development on the islands does not jeopardize the marine ecosystem is an important issue.

Each Marine Park has a centre which serves as a focal point for the administration and management of the area concerned. Department of Fisheries Malaysia (2000) had reported that another Marine Park centre was built in Perhentian Island which started operating in 2002. All visitors to Marine Park in Malaysia are obliged to pay the Conservation Fee. All Conservation Fee collection was credited to the Marine Park and Marine Reserve Trust Fund. This trust fund is used to carry out rehabilitation activities such as beach cleanup, to organize and participate in awareness programmes as well as to provide basic facilities and accommodations for the tourists and maintain the cleanliness of the Marine Park Centre (Department of Marine Park Malaysia, 2012). Although initially the Department faced some resistance from the private sector, especially the tour operators and chalet/hotel operators on this charge, the teething problems have now been solved and the Department is getting almost full cooperation from them.

Malaysia is blessed with beautiful sandy beaches, corals colonies, fish species and sea turtles nesting activities (MOCAT, 2000; Mohd Rusli *et al.,* 2009). Nonetheless, the combination of all these marine resources has become the main attraction among tourists (MOCAT, 2000). The development of tourism industry in Marine Park has become one of the major interests which help to generate foreign exchange earnings to the country (Mosbah & Saleh, 2014). According to Department of Marine Park Malaysia (2014), the total number of visitors to the Marine Park in Kedah, Terengganu, Pahang, and Johor was doubled from 423,229 in 2000 to 793,359 in 2013, thus contributing revenues and incomes to the Malaysian economy.

The establishment of Marine Parks in Malaysia is an important step forward in protecting valuable coastal marine resources and promoting sustainable development. Also, it will help to facilitate the implementation of targeted conservation measures to benefit both the environment and local communities. The protection and conservation of the marine environment is significant in order to keep them undamaged for future generations and to inculcate public understanding, appreciation and enjoyment of marine heritage in Malaysia (Hashimi *et al.,* 2000).

(a) Tourism and Recreation Best Practice (TRBP)

According to Ching and Gayathri (1999), Tourism and Recreation Best Practice (TRBP) was formulated at Pulau Redang in 1999 by Department of Fisheries Malaysia, WWF Malaysia, Marine Park researchers and operators, environmental policy analyst and conservation policy unit.

Tourism and Recreation Best Practice refer to the best practice for tourism and recreation operations so that a high level of enjoyment is achieved but only minimal impact to the coastal resources and environment occurs (Hendry & McGill, 2001). The concept of TRBP is suitable for tourist service operators in marine parks, to increase awareness among tourists in protecting the environment and to lead to a better business operation, mainly by reducing the consumption of water and electricity (Hendry & McGill, 2001). Direct impacts from the tourism and recreation operation include from anchoring, boat groundings, as well as poor diving and snorkeling practices (Hendry &

McGill, 2001). Indirect impacts are resulted from building material and construction, site planning, emission of sewage and solid waste, soil erosion, and sedimentation. The guiding principles for Best Practice (BP) in the tourism and recreation industry are listed in Appendix 1.

(b) Problem and Issues of Marine Ecotourism Sites

Many anthropogenic activities cause adverse environmental effects that ecotourism has the potential to gradually degrade and destroy the environment. This situation occurs when the number of visitors is greater than the limits of acceptable change or carrying capacity in the marine parks (McCool, 2013). Studies by Ahmad and Hanley (2009) on carrying capacity assessment in Pulau Payar found that majority of visitors feel crowded when they visited the island. Lack of control in terms of the number of tourists, many tour operators seem to offer unlimited snorkelling trips, sometimes surpassing the carrying capacity of the site. As a result, overcrowding of snorkelers at the snorkelling areas has become a major concern.

The overwhelming presence of tourists also causes a huge impact to the marine habitats and species (MEA, 2005; Warnken & Byrnes, 2004). Tourist activities such as recreational boating, diving and snorkeling have serious consequences for coral reefs in many parts of the world. Tourists could accidentally kill corals, simply by touching, polluting or break off parts of them (Diedrich, 2007). Marine animals such as whale sharks, turtles, seals, and dolphins are also disturbed by increased number of boats and by people approaching too closely (Erbe *et al.,* 2018). Also, the fish feeding activities may cause significant impacts on fish behavior such as growing reliance on food sites and increased aggressive behavior (Dobson, 2008). As consequences, marine ecotourism can have a direct impact on the behaviour of marine species causing unnecessary disturbances and stress to these species.

The growing number of tourists every year will lead to increase in demand of fresh water (Kotios *et al.,* 2009). In some areas, water demand during peak tourism months can be much higher than the demand of local population in a whole year (Kotios *et al.,* 2009). The solid waste pollution is also one of the challenges faced by marine parks. This not only affects the cleanliness of the beach but also the growth of coral reefs and aquatic life, such as turtle species (Spait, 2001). Development of infrastructure such as hotels and chalets to promote ecotourism can result in long term detrimental changes to the environment (Rinzin *et al.,* 2007).

The other problematic issue with the marine park in Malaysia is the overlapping and poor coordination between the Federal and the State government agencies (Gopinath & Puvanesuri, 2006). Also, there are often conflicting targets and mandates within State government and the managing body of the marine parks, formerly the Fisheries Department and presently under the Ministry of Natural Resources and Environment (NRE) (Islam *et al.,* 2017).

Lack of environmental responsibility among visitors, tourist‟s service operators and stakeholder are the primary season for the destruction of the unique value and physical beauty of the coastal area (Ghosh, 2012). There are shortages numbers of staff to carry out enforcement in the marine parks especially during school holidays or public holidays (Kaur, 2007). Due to lack of continuous monitoring in the marine parks, it is difficult to enforce ecotourism guidelines and prevent illegal encroachments (Kaur, 2007). Thus, local authorities will need to discuss the urgency of this matter as they have a definite role in handling issues concerning marine parks.

The environmental consequences of ecotourism should be addressed in the design and implementation of policies related to the protection of the marine environment in Malaysia. Studies by Spait (2001) highlighted that there are three ways in which the marine park resources can be improved, namely by strengthening the enforcement capacity, gazetting additional marine parks, and developing and implementing education programmes. Therefore, coordination between the Federal and State Government .is highly recommended for effective management of the marine parks.

2.1.3 Anthropogenic Disturbance to Marine Environment

Land reclamation, development of resorts, aquaculture and agriculture activities are among the major problems which can cause modification and deterioration to the marine ecosystem (Jiao, 2000). It has been estimated that more than 70% of natural habitats in the world are completely loss due to anthropogenic exploitation to the coastal area (Airoldi & Beck, 2007).

The rapid increase in the number of tourists equates to the increase in wastewater emissions from hotels surrounding the beaches (Ramdas & Badaruddin, 2014). Improper treatment of wastewaters could result in contaminants being discharged into the sea. Recreational boating is the main cause to water pollution due to release of chemical pollutants such as mercury and lead (Ramdas & Badaruddin, 2014). The improper disposal of solid waste from construction and transportation activities may directly cause adverse impacts to water quality (Davies & Cahill, 2000; Reopanichkul, 2000). The excessive littering by beachgoers as well as oil spillage and leakage from recreational activities has deeply reduced the quality of waters in the islands.

The use of off-road vehicles by tourists on beaches has been identified to have effects on flora and fauna (McLachlan *et al.,* 2013; Silva & Ghilardi-Lopes, 2012). Apart from that, the illegal fishing and unsustainable harvesting are more likely to decrease the fish populations (Ramdas & Badaruddin, 2014). Fishing which were once served as source living to the local communities has turned into a tourist recreation spot.

Some other obvious impacts include collection of corals, shells and other marine souvenirs by tourists and local people which could lead to the imbalance in the ecosystem (Davies & Cahill, 2000; McLachlan *et al.,* 2013; Silva & Ghilardi-Lopes, 2012; Vousdoukas *et al.,* 2009). Excessive admittance of tourist to the island with unmonitored activities could also bring possible damage to the environmental attributes of islands.

On overall, anthropogenic activities have visible impacts to the marine environment (Ramdas & Badaruddin, 2014). It is believed that tourists with high knowledge and awareness towards the environment may display tendencies that favor more responsible environmental behaviors than others (Deidrich *et al.,* 2011). Therefore, an effective solid waste management is urgently needed in order to prevent further deterioration of the ecosystem including marine environment.

2.2 Clean-Coast Index (CCI)

A clean-coast index (CCI) was developed and is suggested as a tool for evaluation of the actual coast cleanliness (Alkalay *et al.,* 2007). It measures plastic debris as a beach cleanliness indicator, in an easy way precluding bias by the assessor. The CCI proved to be a useful tool for measuring the progress and success of different actions that are aimed to improve beach cleanliness, such as the Clean Coast programme (Alkalay *et al.,* 2007). The aim of the programme is to maintain beach cleanliness at all times, while generating a change in public awareness of the importance of the subject of coast cleanliness (Chiappone *et al.,* 2002). The programme includes several complementary components such as routine cleaning of the coast by local authorities, enforcement against authorities and polluters of the coasts, educational activities in the schools as well as public relations regarding the programme (Alkalay *et al.,* 2007).

For many years, there was no accepted index of whether a beach was clean or dirty. The only measure was the amount of waste removed from the beach (The Ocean Conservancy, 2005). Success of every cleaning operation was measured by the tonnage of litter cleared from the beach or the number of trash bags collected at the end of the operation (UNEP, 2003). With no systematic studies to ensure the cleanliness of beaches, no national coordinated marine litter survey and monitoring programme, and a lack of data on the extent and nature of the problem, efforts to assess the level of beach cleanliness and to ensure that it is adequately monitored have mostly been in vain (Rouwen, 2011).

2.3 Marine Debris Pollution

Marine debris includes any form of manufactured or processed material discarded, disposed of or abandoned in the marine environment either directly through human or natural exposure (Galgani *et al.,* 2010). Marine debris pollution has received increased international attention in recent years since early eighties when the first international marine debris conference was held (van Sebille *et al.,* 2016). In order to address the growing problem of marine debris pollution, extensive research and monitoring programme ranged from international legislation, education and public awareness campaigns and beach cleanup operations have been conducted (UNEP, 2015). Despite these initiatives, there are still large gaps in our knowledge of marine debris, regarding inputs and potential impacts, especially at the local level and many questions still to be answered regarding the implementation of effective mitigation actions.

2.3.1 Composition of Marine Debris

A beach survey is one of the established monitoring techniques to determine the accumulation, composition and abundance of marine debris in the environment (Ryan *et al.,* 2009). Table 2.1 depicts the most common type of marine debris found during beach clean-up by International Coastal Cleanup (ICC) in 2013.

Table 2.1: Top fifteen marine debris item worldwide (ICC, 2013)

Rank	Debris item	Number of debris item
1	Cigarette butts	2,043,470
2	Food wrappers	1,685,422
3	Plastic beverage bottles	940,170
4	Plastic bottle caps	847,972
5	Straws/stirrers	555,007
6	Plastic grocery bags	441,493
7	Glass beverage bottles	394,796
8	Other plastic bags	389,088
9	Paper bags	368,746
10	Beverage cans	339,170
11	Plastic lids	312,996
12	Metal bottle caps	304,638
13	Plastic cups and plates	282,743
14	Plastic takeout containers	234,692
15	Other plastic/foam packaging	233,595

This type of litter appeared to be derived from beach users (Taffs & Cullen, 2005). Cigarette butts were recorded as the most dominant item found throughout the beach profile (ICC, 2013). A study on beaches of the Balearic Islands, recorded that cigarette butts comprised up to 46% of the total debris during the holiday seasons (Martinez-Ribes *et al.,* 2007). Another study on Milnerton beach showed that more than half of the non-plastic marine debris consisted of cigarette butts (Oigman-Pszczol & Creed, 2007). Cigarette butts are carelessly discarded by smokers onto beaches and carried to streams and waterways leading directly to the aquatic environment.

Many studies have enumerated the composition and amount of marine debris found on worldwide beaches. The overwhelming majority of debris found on beaches was derived from plastic materials (Cunningham, 2000; Edyvane *et al.,* 2004). According to Moore *et al.* (2001), pellets, foamed plastics and hard plastic accounted for 99% and cigarette butt, paper, wood, glass and rubber with less than 1% in Orange Country beach. In South Africa, debris mostly consists of single use items and packaging materials such as paper and plastic food wrapping, cans, plastic bottles, cigarette packets and cigarette butts (Armitage & Rooseboom, 2000). In Obhur coastline, Saudi Arabia, more than 75% of the marine debris was plastic materials and the rest are wood, metal, glass and paper (Kitto *et al*., 2011). Most of the litter appeared to be from local land-based sources, although there were some regional influences as well. Public education and awareness on waste disposal was found essential to protect marine environment.

2.3.2 Distribution of Marine Debris

Marine debris is usually present in highly populated regions, and also in isolated regions located far away from any kind of human activity (Claro & Hubert, 2011). This is due to their durability and buoyancy which allows them to float on the sea surface and can be carried far from their sources (UNEP, 2016). Many studies have been carried out in different nations and oceans to estimate the quantity of marine debris in the environment. Figure 2.4 shows that Canada and many other nations have problems of persistent debris in the marine environment.

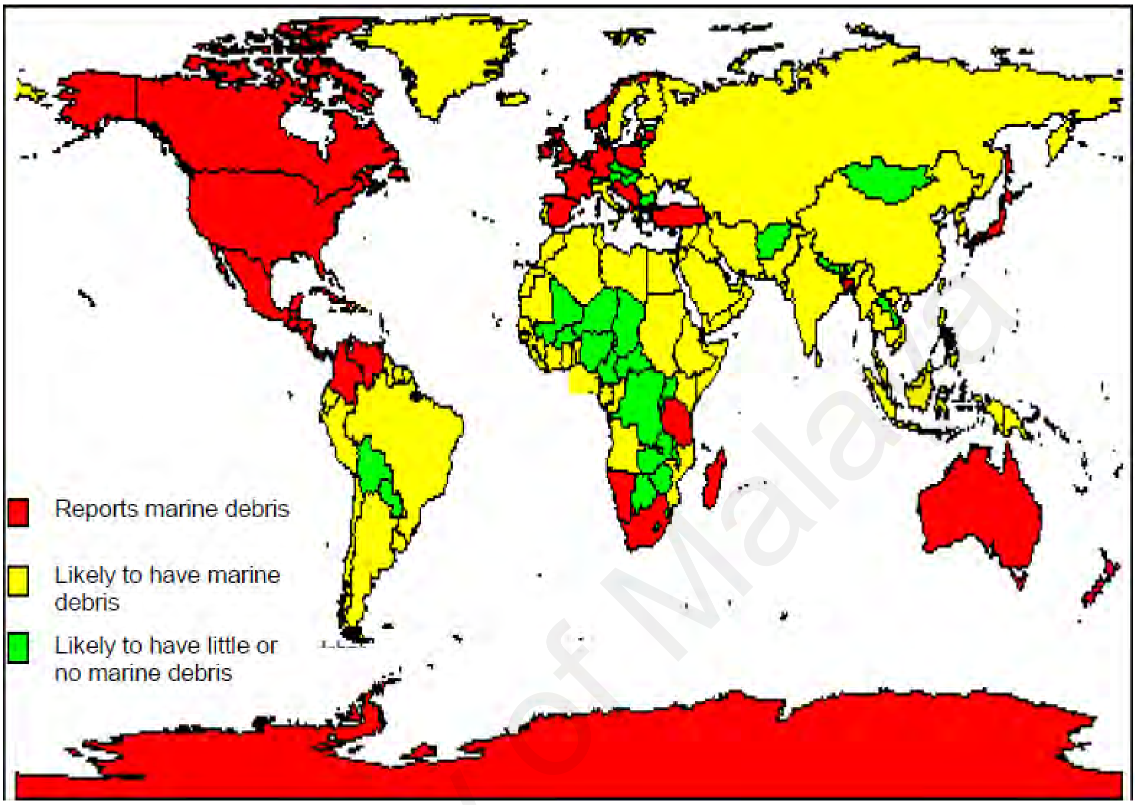

Figure 2.4: Distribution of marine debris in the world's coastal zones (Adapted by permission from Topping (2000))

The distribution of marine debris is affected by multiple factors, including anthropogenic activities, hydrographic and geomorphological factors, prevailing winds and entry points (Barnes *et al.,* 2009; Derraik, 2002; Galgani *et al.,* 2000). Generally, the distribution of marine debris depends largely on near shore circulation patterns (Aliani *et al.,* 2003). Pelagic marine debris can be found near the water surface or suspended vertically in the upper water column, while benthic marine debris is found near or on the seabed (NOAA, 2016).

Accurate estimation on the distribution of marine debris in the global ocean remain elusive, but the presence of marine debris is generally agreed to be ubiquitous (Ivar do Sul & Costa, 2007; Ribic *et al.,* 2011; Woodall *et al.,* 2015). In 2009, volunteers collected a total of 10.24 million tonnes of marine debris on beaches of 108 different countries (ICC, 2009). This situation concluded that the amount of marine debris remains high and is not reducing (OSPAR Commission *et al.,* 2009). A lack of research on marine debris pollution makes it difficult to evaluate the degree of pollution as well as the effects that are occuring at present. The consecutive sections discuss the possible sources of marine debris found in the marine environment.

2.3.3 Sources of Marine Debris

Marine debris enters the ocean from a variety of sources, which are mainly divided into land-based and sea-based (Williams *et al.,* 2005; Sheavly & Register, 2007). Land-based sources account for 80% of the total marine plastic debris, while the rest of them (20%) are sea-based sources (Schuyler *et al.,* 2014). However, due to the dynamic nature of the ocean surface, the large area involved, it is also difficult to know where the debris accumulates, and thus where it will cause the greatest impacts.

(a) Land-based Sources

Landfills are one of the major land-based sources of marine debris (Valavanidis & Vlachogianni, 2012). Poor management of landfills are the main means that marine debris may find their way into the oceans (European Commission, 2010; Lytle, 2010; UNEP, 2011). It has been noted that many estuaries around waste treatment sites in United States suffer from severe waste contamination (Nollkaemper, 1994). It is also possible that plastics may be lost during collection and transportation in the marine environment (Sheavly & Register, 2007; Barnes *et al.,* 2009). This litter is then blown by the wind or washed away by rains into nearby waterways or directly into the ocean.

Untreated sewage and storm water drains are one of the continuous and massive sources of marine debris (Nollkaemper, 1994; UNEP, 2011; Hammer *et al.,* 2012). During heavy rain events, storm water drainages collect runoff water and directly discharged into nearby ocean, rivers or streams (USEPA, 2002; NOAA, 2007).

Tourism, agriculture, and fishing activities along the coast are serious causes of marine debris (UNEP, 2005). Beachgoers and recreational fishermen may carelessly discarded litter on beaches or at the coast, which can easily enter the aquatic environment (Allsopp *et al.,* 2006; NOAA, 2007; Lytle, 2010; Sheavly & Register, 2007). For example, recreational activities along shorelines of Baltic Sea region and Japan generate 58% and 50% of marine debris, respectively (Lytle, 2010).

Industrial and construction activities are other factors that generate marine debris (Davis-Mattis, 2005; UNEP, 2005; UNEP, 2011). For example, plastic pellets enter the marine environment from outfalls of plants which transport them via rivers, or spillage from truck and ships during loading, transport or unloading (Eerkes-Medrano *et al.,* 2015). Nevertheless, identifying the root cause and introducing solutions to mitigate each marine debris categories and sources are essential to ensure totally eradicate illegal discharge at sea.

(b) Ocean-based Sources

The main ocean-based sources of marine debris are fishing vessels, military or research ships, merchant shipping, ferries and cruise liners, pleasure craft, offshore oil and gas platforms and aquaculture installations (UNEP, 2005; Allsopp *et al.,* 2006; European Commission, 2010; Gordon, 2011). Large vessels may generate solid wastes which are deliberately or accidentally released into the marine environment (Hammer *et al.,* 2012). It has been estimated that 6.5 million tonnes of marine debris are generated from vessels in a year (Lytle, 2010). Therefore, it imposes a general ban or discharges of all garbage from ships at sea.

Commercial fishing also contributed to marine debris (UNEP, 2011). Some researchers reported that plastic items were more abundant in area with prosperous fishing activities (Fujieda & Sasaki, 2005; Hinojosa & Thiel, 2009). Fishing buoys, broken nets and associated fishing gears are possible items which may deliberately thrown overboard by fishermen (Astudillo *et al.,* 2009).

Activities on oil and gas platforms are recognized as one of the sources of marine debris (UNEP, 2005; Sheavly & Register, 2007). As these platforms are usually located in the middle of sea, large amount of marine debris including gloves, storage drums, hard hats and personal waste will directly enter the ocean (Sheavly, 2005; Allsopp *et al.,* 2006). For this reason, the debris may be washed ashore on remote mid-ocean islands far from source.

The presence of marine debris from different sources will result to the deterioration of the environment, health implications and public nuisance (Thompson *et al.,* 2009). At a larger scale, marine debris pollution will disrupt the ecological balance thus eventually led to the destruction of the entire ecosystem. Subsequent sections discuss the impact of marine debris on the marine wildlife and its chain reaction to human.

2.3.4 Impact of Marine Debris

2.3.4.1 Harm to Marine Organism

(a) Entanglement

Entanglement is one of the most direct and visible impacts posed to wildlife. Marine debris have either killed or injured mammal species such as pinnipeds, sea turtles and seabirds due to their becoming entangled with it (Hanni & Pyle, 2000; Moore *et al.,* 2009). The most problematic debris which can lead to entanglement are fishing nets and ropes (Figure 2.5), monofilament lines, six-pack rings and packing strapping bands (Sheavly, 2005; UNEP, 2009; Lytle, 2010). Boren *et al.* (2006) suggest that high entanglement rates are mostly found where marine animal populations reside in close proximity to human settlements or fishing activities. To date, monitoring the accumulation of stranded debris is useful because it identifies the main sources of plastic debris entering the sea and can direct mitigation efforts.

Entanglement may also cause death by strangulation. For instance, plastic debris usually wrapped around the neck of victims (Figure 2.6) which in time, this plastic collar tightens and may eventually severs their arteries (Derraik, 2002). It is known that juvenile animals have been found to be more susceptible to entanglement (Raum-Suryan, 2009). Compared to ingestion, entanglement is more likely to cause death (Laist & Liffmann, 2000). In Scotland, 21% of all minke whales (*Balaenoptera acutorostrata)* were died (OSPAR Commission *et al.,* 2009) while 40,000 of seals in the Bering Sea were killed every year as a result of entanglement (Derraik, 2002).

Although entanglement is the most obvious impacts caused by marine debris, the impacts are still far to be fully clarified and estimated. The incidences of entanglement of marine species are harder to predict and know the exact cases as marine debris is carried across the ocean by following the winds and currents (Hammer *et al.,* 2012).

Figure 2.5: A sea turtle trapped in a broken fishing net (Adapted by permission from Sheavly (2007))

Figure 2.6: Blue striped grunt fish caught in a red plastic band in Caribbean Sea (Adapted by permission from Doody *et al.* (2017))

Figure 2.7: Young seal entangled in a plastic beverage rings (Adapted by permission from Butterworth *et al.* (2012))

(b) Ingestion

Many types of animals such as sea turtles and seabirds experienced other effects from marine debris, through the ingestion of plastics (Tourinho *et al.,* 2009; Mascarenhas *et al.,* 2003). Research indicates that 56% to 80% of sea turtles have suffered from plastic ingestion (Figure 2.8) (Bugoni *et al.,* 2001; Tomás *et al.,* 2002). Lytle (2010) reported that plastic debris has been found in the stomach of 80% to 96% of investigated marine birds (Figure 2.9).

It is thought that the ingestion of marine debris occurs mainly because animals might accidentally feed on plastic items, often confusing them as prey or food (Moore, 2008). Due to the greater amount of plastic debris in the ocean, it is believed that plastics may mix with natural food sources which are floating on the layer of sea surface. For example, sea birds dive from height and mistaken floatable plastics as their food such as jellyfish (Figure 2.10) (Allsopp *et al.,* 2006). Whether debris is confused with, or accidentally ingested alongside, preferred food sources, debris is ingested by what is increasingly appears to be nearly all types of marine organisms.

Figure 2.8: Debris recovered from the stomach, small intestine, large intestine, and rectum of a small turtle (Adapted by permission from Schuyler *et al.* (2014))

Figure 2.9: Small plastic debris found in the stomach of marine birds (Adapted by permission from Moore (2008))

Figure 2.10: A seabird ingested plastic bag mistakenly identified plastic as a jellyfish (Adapted by permission from Sverdrup and Armbrust (2009))

Once plastics have been ingested, it is possible that the digestive system may be damaged, including the oral cavity, digestive tract, stomach and intestines (Derraik, 2002; NOAA, 2011a). Because oceanic plastic debris contain high levels of hydrophobic toxins (Endo *et al.,* 2005; Rios *et al.,* 2010), ingestion of plastic debris may also increase toxic exposure (Teuten *et al.,* 2009). Therefore, it is clearly seen that the effects of marine debris are not only aesthetic and environmental, but that it is also a cause of significant, large-scale and wholly avoidable animal suffering.

2.3.4.2 Spread of Invasive Species

The introduction of large quantities of plastic debris into the marine environment has consequently facilitated the transport of exotic and invasive species to other areas (Barnes, 2002; Barnes & Milner, 2005). For example, a biological invasion of the American comb jellyfish *(Mnemiopsis leidyi)* into the Black Sea resulted to a huge population explosion of the jellyfish and poses negative impact to finfish fisheries in the area (Oliveira, 2007).

The surface of plastics can act as a new habitat for some marine creatures, including sessile species, polychaete worms, molluscs and even small crabs (Barnes, 2002; Bax *et al.,* 2003; Astudillo *et al.,* 2009; Waterman, 2012). Some species may live and lay eggs on the plastic debris (Aliani & Molcard, 2003). As a result, both species and eggs are able to transport to a new communities and coastlines. It is also possible that invasive species may compete with the local species, and even result in their extinction (Sheavly & Register, 2007).

Combined, new and sound information on floating trajectories, raft persistence, and performance of associated organisms will help to estimate the potential of marine litter for the transport of invasive species or entire rafting communities, and therefore add to our understanding of the hazardous characteristic of marine litter beyond the immediate effects of ingestion and entanglement.

2.3.4.3 Damage to Coral Reefs and Other Habitats

The presence of marine debris in the ocean may block sunlight that is needed by coral reefs to produce food and energy (Figure 2.11) (NOAA, 2011b). Plastic items may suffocate the coral reef by cutting off the supply of oxygen (Lytle, 2010). As a result, the deterioration of coral reefs may affect associated flora and fauna and even lead to an increase in mortality (European Commission, 2010).

Figure 2.11: Derelict fishing gears tangle on coral reef (Adapted by permission from NOAA (2011b))

Marine debris can pose severe impact to the benthic environments by smothering, abrading, and changing the sea bottom structure (Gilardi *et al.,* 2010; Katsanevakis *et al.,* 2007). Ultimately, 300 million of plastic items are found on the seabed of Mediterranean Sea (UNEP, 2001). Plastic items are also found within mangrove ecosystem where they becomes trapped amongst the aerial roots, which may block mangrove tidal channels and prove detrimental effects to the near shore habitats and their associated species (UNEP, 2009; Davis-Mattis, 2005). Hence, establishing counter measures to protect mangrove forests of Malaysia from marine debris is imperative.

2.4 Plastic Debris Pollution

Plastic debris in the marine environment is considered as one of the most significant issues around the world (Sheavly, 2005). Thompson (2006) estimated that about 10% of plastic debris would finally accumulate and persist in the oceans. Since plastic debris may enter the ocean via different pathways and transported over thousands of miles, it is difficult to determine their exact origins (Lee *et al.,* 2013). Therefore, variety of approaches is urgently required in order to address the omnipresent plastic debris pollution in the oceans (Derraik, 2002).

2.4.1 Distribution of Plastic Debris

Plastic debris has been documented in all marine environments, from densely populated area to small remote islands (Allsopp *et al.*, 2006). Beach, tributary, and seafloor throughout the world are becoming polluted with plastic debris (Corcoran *et al.,* 2015). Currently, it was estimated that more than five trillion pieces of plastic debris are floating in the oceans (Eriksen *et al.,* 2014).

The geographies of countries play an important part in their contribution to plastic debris pollution (Pawar *et al.,* 2016). It occurs in many regions with up to 68% in California (Rosevelt *et al.,* 2013; Moore *et al.,* 2001), 77% in the south east of Taiwan (Liu *et al.,* 2013), 86% in Chile (Thiel *et al.,* 2013), and 91% in the southern Black Sea (Topçu *et al.,* 2013). Galgani *et al.* (2015) also reported that 19 out of 27 studies in the different regions worldwide showed that plastic debris make-up more than 50% of debris items (Table 2.2).

Table 2.2: Plastic proportion among marine debris worldwide (per number of items) (Galgani *et al.,* 2015)

Region	Litter type	% of debris items represented by plastics	Sources
SW Black Sea	Beach	91	Topçu *et al.* (2013)
Costa do Dende, Brazil	Beach	75	Santos *et al.* (2009)
Monterey, USA	Beach	68	Rosevelt *et al.* (2013)
Bootless Bay, Papua New Guinea	Beach	89	Smith (2012)
Kaosiung, Taiwan	Beach	77	Liu *et al.* (2013)
Midway, North Pacific	Beach	91	Ribic *et al.* (2012a)
North Sea	Sea surface	70	Thiel *et al.* (2011)
Belgian coast	Sea surface	95	Van Cauwenberghe *et al.* (2013)
Mediterranean Sea	Sea surface	95.6	Suaria and Aliani (2014)
Chile	Sea surface	>80	Hinojosa and Thiel (2009)
British Columbia	Sea surface	92	Williams *et al.* (2011)
South China Sea	Sea surface	68	Zhou *et al.* (2011)
Thyrenian Sea	Seafloor	76	Sanchez *et al.* (2013)
Spain- Mediterranean	Seafloor	37	Sanchez *et al.* (2013)
Malta	Seafloor	47	Misfud *et al.* (2013)
Turkey / Levantin Basin	Seafloor	81.1	Güven *et al.* (2013)
US west coast	Seafloor	23	Keller *et al.* (2010)
Japan, offshore Iwate	Seafloor	42.8	Miyake *et al.* (2011)
Fram Strait, Arctic	Seafloor	59	Bergman and Klages (2012)
Monterey Canyon, California	Seafloor	33	Schlining *et al.* (2013)
ABC islands, Dutch Caribbean	Seafloor	29	Debrot *et al.* (2014)

2.4.2 Degradation of Plastic Debris

Plastics deteriorate into fragments as a consequence of photo-oxidative (UV induced), thermo-oxidative (temperature induced), and mechanical degradation (Hopewell *et al.,* 2009). According to Webb *et al.* (2012), prolonged exposure to UV radiation and physical abrasion may cause embrittlement in plastic materials that wave action can readily cause the material to break into smaller pieces in the marine environment. Hence, degradation of plastics is a complex process.

After the breaking down of large plastic debris by photo-degradation, thermo-oxidative degradation take place rapidly when heat and oxygen accelerate the breaking of the polymer chains of plastic (Shah *et al.,* 2008; Zheng *et al.,* 2005). However, the degradation process is more efficient on beaches as the plastic material is exposed to high levels of oxygen and UV radiation (Andrady, 2011). As compared in the marine environment, degradation processes are extremely slow, such that particles persist for long periods of time (Hidalgo-Ruz *et al.,* 2012). Photodegradation is retarded due to the cold temperatures and the lower oxygen concentration of the oceans (Andrady, 2011; Gregory & Andrady, 2003).

The rates of degradation have been calculated for some debris items found on the beach. Plastic bags can degrade in 20-30 years while plastic beverage bottles need 450 years, and monofilament fishing line is expected to take as long as 600 years for its degradation in the ocean (Mouat *et al.,* 2010; Ten Brink *et al.,* 2009; Cheshire *et al.,* 2009). The subsequent sections discuss the category of macroplastic and microplastic debris in more detail.

2.4.2.1 Macroplastic

Macroplastics are usually recognized as the most predominant type of debris in the world‟s ocean. Macroplastics refers to plastic particles with diameter larger than 10mm (Collignon *et al.,* 2013). Macroplastics can be in their original, full shapes or they can exist as pieces. It consists of plastic bottles, plastic bags, food packaging, cigarette butts, buoys, plastic toys, fishing gears, nets and lines (Figure 2.12) (Leslie, 2014). Macroplastics is a serious issue with serious consequences. These large plastic items tend to accumulate on the sea surface, seabed, beaches and other coastal areas (Barnes, 2005; Thompson *et al.,* 2009).

Figure 2.12: The Big Island of Hawaii has become a trap for macroplastic debris (Adapted by permission from Leslie (2014))

2.4.2.2 Microplastic

Since there is no international agreement upon the plastic size classes, microplastics generally refers to plastic particles less than 5mm (Collignon *et al.,* 2013). Microplastics occur in a variety of shapes (Figure 2.13) from fibres to fragments, and made up from different types of polymers, such as polystyrene and polyethylene (Browne *et al.,* 2008).

Microplastics have become a major concern over the last few decades (Andrady, 2011). Browne *et al.* (2011) reported that large quantities of plastic debris found in the oceans are present in the microscopic size. These tiny sizes of plastic tend to float and accumulate in the ocean to form garbage patches in gyres (Lytle, 2010). The sources of microplastic debris in the marine environment will be discussed in the consecutive sections.

Figure 2.13: Garbage patches are mostly made up of microplastic debris (Adapted by permission from Yonkos *et al.* (2014))

(a) Sources of Microplastic

i Primary Sources

Primary microplastics are used for plastic production and directly released to the marine environment in the form of small particulates (Browne *et al.,* 2007; Arthur *et al.,* 2009; Costa *et al.,* 2010). Microplastics can be a voluntary addition to natural product as scrubbing agents in hand cleansers and facial scrubs (Derraik, 2002; Fendall & Sewell, 2009).

Furthermore, microplastics are also used in air blasting technology (Derraik, 2002). This technology is applied to remove rust and paints during the cleaning of engines and boat hulls (Browne *et al.,* 2007; Derraik, 2002; Cole *et al.,* 2011). According to Browne *et al.* (2007), microplastics serve as a vector for drug delivery in the medical sector. Microplastics are widely used in the dental tooth polish, and acts as carriers to deliver active pharmaceutical agents (Lassen *et al.,* 2015; Sundt *et al.,* 2014). Patel *et al.* (2009) reported that delivery process of medicine into the brain is improved by using microplastic particles. Primary microplastics are globally responsible for a major source of plastics in the ocean.

ii Secondary Sources

Secondary microplastics refer to microplastics generated from the breakdown of larger plastic debris through photodegradation and weathering process in the marine environment (Andrady, 2011; Wagner *et al.,* 2014). Apart from that, they can also originate from the abrasion of synthetic textiles during washing (Browne *et al.,* 2011). Recent studies indicated that more than 700,000 pieces of fibres were released from washing of 6 kg of laundry (Napper & Thompson, 2016). Consecutive sections discuss the types of microplastic commonly found in the environment.

(b) Types of Microplastic

i Film

Plastic film is a thin continuous polymeric material. The majorities of plastic films are made up from polyethylene resin such as high-density polyethylene (HDPE), low density polyethylene (LDPE), and linear low density polyethylene (LLDPE) (Abdel-Bary, 2003). Plastic film appear in irregular shapes, but in comparison with fragments, they are thin, flexible and usually transparent (Figure 2.14) (Kovač Viršek, 2016).

Plastic films are used as packaging materials for food and beverages items, cosmetics, pharmaceuticals, toiletries and textiles (Kriswan *et al.,* 2011). As for non-packaging applications, films are commonly used as horticultural and agricultural film, construction film, health care film, household wrap and musical instruments (Kriswan *et al.,* 2011).

Plastic films such as plastic bags will eventually breaking down into smaller pieces in the marine environment under certain condition (Moore, 2008). Due to their similar size as plankton, films pose severe threats to the marine animals. Other types of plastic which are commonly found on the beaches are foam.

Figure 2.14: Example of films microplastic (Adapted by permission from Kovač Viršek (2016))

ii Foam

Foam is a porous plastics which originated from large particles of styrofoam (Figure 2.15) (Kovač Viršek, 2016). They are soft, irregular shape and white to yellow in color. The density of plastic foams is determined by the volume ratio of gaseous pores to the solid polymer (Liu & Chen, 2014). Plastic foams include vinyls, polystyrene, polyethylene, phenolics, silicones, cellulose acetate and urethanes (Piergiovanni, 2009).

There are many advantageous properties of foam, such as lightweight, excellent insulators and good barriers to the air and moisture (Lewis, 2000). Foams are used in a wide range of products including cushioning materials, thermal insulation, sponges, air filters, furniture, plastic boats, panels for buildings, and even lightweight beams (Suh, 2000).

Nearly all beaches are contaminated with plastic foams. Foam is believed to be discarded by fishermen and beachgoers which might lead to the deposition of foam on beaches (Browne *et al.,* 2010; Gregory & Andrady, 2003). Similar problem is also reported from the presence of fragment plastic.

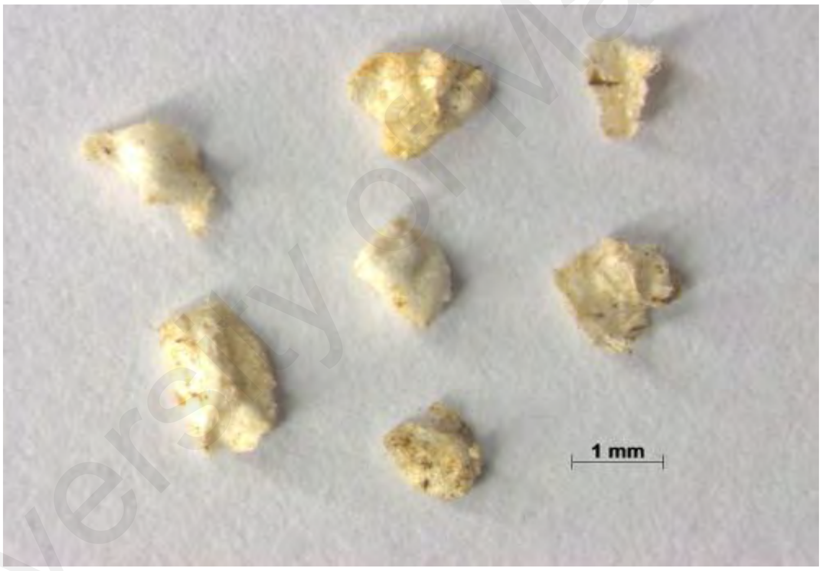

Figure 2.15: Example of foams microplastic (Adapted by permission from Kovač Viršek (2016))

iii Fragment

Fragment is a tiny microplastic with sizes smaller than 1 mm (Ng & Obbard, 2006; Costa *et al.,* 2010). Plastic fragments have various surface features, such as sharp edges with cracks, rounded shapes with smooth surfaces, or degraded rough surfaces (Figure 2.16) (Kovač Viršek, 2016). Aside from plastic fragments, plastic line is also commonly found on beaches.

Figure 2.16: Example of fragments microplastic (Adapted by permission from Kovač Viršek (2016))

iv Line

Monofilament line is a single strand of material which are strung from multiple strands that are fused, braided or bundled together (Johnlewis, 2017). The most common and popular monofilament line is nylon (Gait & Hancock, 1970). Monofilament lines are manufactured in a various colours including white, blue, green and fluorescent (Figure 2.17) (Kovač Viršek, 2016). Monofilament line is widely used for fishing purposes and extremely difficult to spot when they submerged in water (Gait & Hancock, 1970). Due to their durability and longevity in the ocean, they are become a particular concern for animal welfare (Butterworth & Simmonds, 2017). Also commonly found in the marine environment is pelletized plastic.

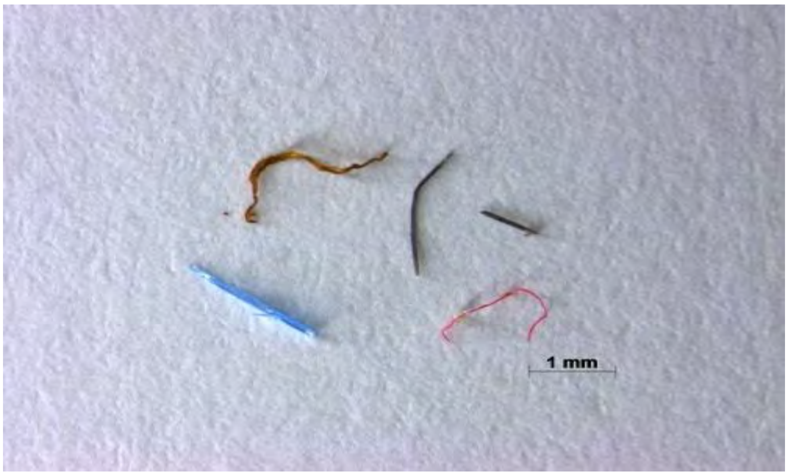

Figure 2.17: Example of lines microplastic (Adapted by permission from Kovač Viršek (2016))

v Pellet

Pellets are small cylindrical granules of about 2-7 mm in size (Figure 2.18) (Kovač Viršek, 2016; Andrady, 2011). Plastic pellets consist of various types of polymers such as polypropylene, polyethylene, and polystyrene with different surface structures (Hisham, 2016). According to Goettlich (2005), plastics pellet can be shaped into cylindrical or disk with most regularly clear, white or off-white in colours. Plastic pellets are industrial raw material which is heated and chemically treated to mould into wide range of plastic products such as plastic bags, bottles, toys and packaging (Australian Marine Debris Initiative, 2013).

Pellets are commonly found throughout the world‟s oceans (Ogata *et al.,* 2009). Antunes *et al.* (2013) reported that the most dominant class of plastic debris along the Portuguese coastline was resin pellets, which represents 53% of the total marine debris collected. These pellets are potentially lost during industrial production, processing or handling and finally end up into the oceans (Turner & Holmes, 2011). Therefore, this clearly indicated that growing production of plastic resin pellets lead to a measurable increase in microplastic pollution in the marine environment. Consecutive sections discuss the impact of microplastic debris to the marine environment.

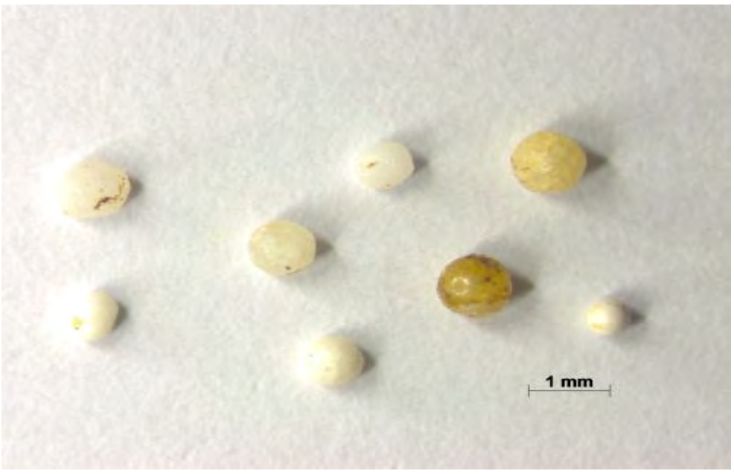

Figure 2.18: Example of pellets microplastic (Adapted by permission from Kovač Viršek (2016))

(c) Impacts of Microplastic

i Adsorption and Transportation of Pollutant

Microplastics are susceptible to the adsorption of hydrophobic pollutants, such as polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs) and this is likely the greatest threat that microplastics pose to marine life (Rios *et al.,* 2007; Teuten *et al.,* 2007; Hammer *et al.,* 2012). Hydrophobic pollutants are usually concentrated on the upper surface of water with 500 times of that in the deeper oceans (Teuten *et al.,* 2007).

Because of the nature of microplastics, they could act as vectors for the transport and release of toxic substances into the marine organisms (Browne *et al.,* 2008; Zarfl & Matthies, 2010). Once microplastics have been contaminated, they may be transported across the oceans or be ingested by marine organisms through bioaccumulation (Gorycka, 2009).

Since data is still inadequate to show how significant the problem is, further research and analysis are required to determine the source of chemicals and the significance of correlated impacts to the marine ecosystems.

ii Release of Plastic Additives

Bisphenol-A (BPA), phthalates, alkylphenols and polybrominated diphenyl ethers are among the most common additives found in plastic items to extend their resistance to heat, oxidative damage and microbial degradation (Latini *et al.,* 2004; Vandenberg *et al.,* 2007).

Additives can acts as endocrine-disrupting chemicals that can mimic, compete or disrupt the synthesis of endogenous hormones (Talsness *et al.,* 2009). These additives are hazardous to the marine animals (Gouin *et al.,* 2011; Koelmans *et al.,* 2016; Bakir *et al.,* 2016; Paul-Pont *et al.,* 2016). According to Oehlmann *et al.* (2009), the presence of additives may impact the movement of invertebrates and the sexual condition of fishes. Although microplastics are revealed to release additives to organism after ingestion, their quantity and effects are still underestimated (Gouin *et al.,* 2011; Tanaka *et al.,* 2013; Bakir *et al.,* 2014). Despite how useful these additives are in the functionality of polymer products, their potential to contaminate soil, air and water is widely documented. Thus, sound recycling has to be performed in such a way as to ensure that emission of substances of high concern and contamination of recycled products is avoided, ensuring environmental and human health protection, at all times.

2.5 Actions to Address the Issue of Marine Debris

2.5.1 Global Conventions and Agreements

Annex V of International Convention for the Prevention of Pollution from Ships (MARPOL) had been ratified by 139 countries and specifically concerned to prevent ships from disposing of their garbage overboard (Sheavly, 2005; Derraik, 2002). Annex V must also ensure garbage reception facilities are provided by ports and terminals to meet the needs of boats and ships (Andrady, 2003b). MARPOL has designated “Special Areas” where these areas are provided with a higher level of protection than other areas of the sea (Weidemann, 2014). This include include the Mediterranean Sea, Baltic Sea, Black Sea, Red Sea, Persian Gulf, Gulf of Aden, North Sea, Antarctic area and the wider Caribbean (IMO, 2014).

Cartagena Convention is a regional legal agreement for the protection of the Caribbean Sea which aims to prevent, control and reduce pollution caused by discharges from both ships and land-based activities (Sheavly, 2005). The International Council of Cruise Lines is an association to promote zero discharges of solid waste products from cruise ships (Allsopp *et al.,* 2006). This is achieved by using comprehensive waste minimization practices, re-use and recycling waste strategies (UNEP, 2005).

Furthermore, the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA) is the global intergovernmental mechanisms in Washington that directly address the connectivity between terrestrial, freshwater, coastal and marine ecosystems. GPA recognized marine litter as one of the nine pollution categories to be addressed (UNEP, 2005).

The Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) has recommended the improvement of land-based waste recycling, port facilities and education as well as the development of more degradable packaging materials (UNEP, 2005). Since 1980, the Barcelona Convention has dealt with pollution from land-based sources, ships and aircraft in the Mediterranean region (UNEP, 2005). Northwest Pacific Action Plan (NOWPAP) is one of the regional seas programme aims at preserving the marine environment of the Sea of Japan and the Yellow Sea (UNEP, 2005). The protection and preservation of the marine environment has become primary goal for the international community as it is widely acknowledged that a healthy coastal and marine environment is essential to human wellbeing, sustainable development and economic security.

2.5.2 Clean-up Activity of Marine Debris

Local authorities, non-government organizations (NGOs) and volunteers have been playing an important role towards coastal clean-up operations (Allsopp *et al.,* 2006). The Ocean Conservancy which began with a small group of volunteers in Texas in 1986 has since grown into the International Coastal Cleanup (ICC) (Hanley, 2017). The ICC is of the world"s largest volunteer effort to remove trash from local waterways, beaches, lakes and rivers in the United States and in over 100 countries. The ICC also gathers information on the types of debris collected for the purpose of its global database (Sheavly, 2005).

The National Marine Debris Monitoring Program (NMDMP) was developed to standardize the data collection of marine debris in the United States by using a scientifically valid protocol (Sheavly, 2005). Volunteers are used to conduct monthly marine debris surveys on the designated beaches for over a five year period (Philpott, 2015). NMDMP is a significant step forward in the continuing fight to understand and control marine debris pollution.

"Clean-Up the World" program which is supported by UNEP encouraged people to show their commitment to protect the environment. It is estimated that more than 40 million people from 120 different countries are engaged in the beach cleanup operations (UNEP, 2005). In United Kingdom (UK), NGOs called the Marine Conservation Society has set up programmes to cleanup beaches and protect marine organisms and their habitats (UNEP, 2005).

Hellenic Marine Environment Protection Association (HELMEPA) in Greece has organized voluntary annual beach clean-up and provides materials on environmental education for schools (UNEP, 2005).

Regional Seas Programme (RSP) which is launched in 1974, is also one of the most significant achievements by UNEP. RSP aims to address the rapid degradation of the world‟s oceans and coastal areas through sustainable resource management, by engaging neighbouring countries (Nadim *et al.,* 2008). This has been accomplished by organizing regional cleanup day within the framework of the ICC campaign (Sheavly, 2005).

The Texas Adopt-A-Beach program, founded in 1986 is a public awareness and cleanup campaign designed to preserve and protect Texas beaches from marine debris pollution. Over the past 30 years, 489,000 volunteers have pickup more than 9200 tonnes of trash from the beaches (Stephanie, 2016).

2.5.3 Education

One important way to reduce marine debris in the ocean is to educate people to be more conscious about the importance to protect the marine environment (Gelcich *et al.,* 2014).

Environmental education programmes in schools, academic institutions, local communities and industrial sector can be very effective tools to raise environmental awareness among children and adults (Derrraik, 2002). For example, The TeachWild programme in Australia was organized to build knowledge, skills and attitudes to protect the environment by engaging more than 5000 students, teachers and industrial employees in one-day research and training projects (Hardesty *et al.,* 2014). North American Marine Environment Protection Association (NAMEPA) also promotes education to seafarers and port communities to help them make responsible decision in order to maintain a healthy and sustainable marine environment (UNEP, 2005). These programmes were developed as a means to educate people and the next generation about marine debris and most importantly, how we all can prevent it.

2.5.4 Zero Waste Strategy and Biodegradable Plastic Initiatives

Zero waste is a concept aims to guide people in changing their lifestyles to emulate sustainable natural cycles, where all discarded materials are designed to become resources for others to use (Zero Waste International Alliance, 2004). This concept includes waste reduction, reuse, and recycling (Welsh Assembly Government, 2002).

Zero waste concept will requires a concerted effort and coordination between all level of government as well as industry, businesses and consumers (Townend, 2010). It will also ensure that products are designed to be reuse, repair, recyclability and decreased toxicity (Snow & Dickinson, 2001). Currently, most of the developed countries are practicing zero waste concepts to promote waste prevention and reduction. For examples, USA, Canada, Australia, Lebanon, Taiwan and China are implementing zero waste concepts to change their current waste management practices to a more sustainable methods (Greyson, 2007).

The use of biodegradable plastic is one of the alternatives to combat the problem of marine debris in the world (Kubota *et al.,* 2005). Certainly, biodegradable plastics are used for a wide variety of application such as food packaging, fishing lines and fishing nets. Biodegradable plastic have a great potential to contribute to material recovery, reduction of landfill and the use of renewable resources (Song *et al.,* 2009). Thus, there is a need for improved promotion by local government to raise awareness about biodegradable plastics and their proper use.

CHAPTER 3: METHODOLOGY

3.1 Study Area

For the purpose of this study, the study areas are divided into islands along the west coast of Peninsular Malaysia and islands along the east coast of Peninsular Malaysia. West coast of Peninsular Malaysia faces the Straits of Malacca while the east coast of Peninsular faces the South China Sea. In this study, four islands were selected. The chosen islands are Pulau Besar, Malacca and Langkawi Island, Kedah from the west coast of Peninsular while Sibu Island, Johor and Perhentian Island, Terengganu represented the east coast of Peninsular Malaysia.

For each islands, two beaches that face the mainland and open sea were selected. Hence, eight sampling sites were selected for this study. Marine debris including macroplastic and microplastic from these selected beaches were collected from May, July, September and November 2016. The site locations were recorded with a portable Global Positioning System (GPS) during the sampling in order to ensure the same and exact area was sampled during all sampling events. The location of the sampling sites is shown in Figure 3.1 and the coordinates of the sampling sites is shown in Table 3.1.

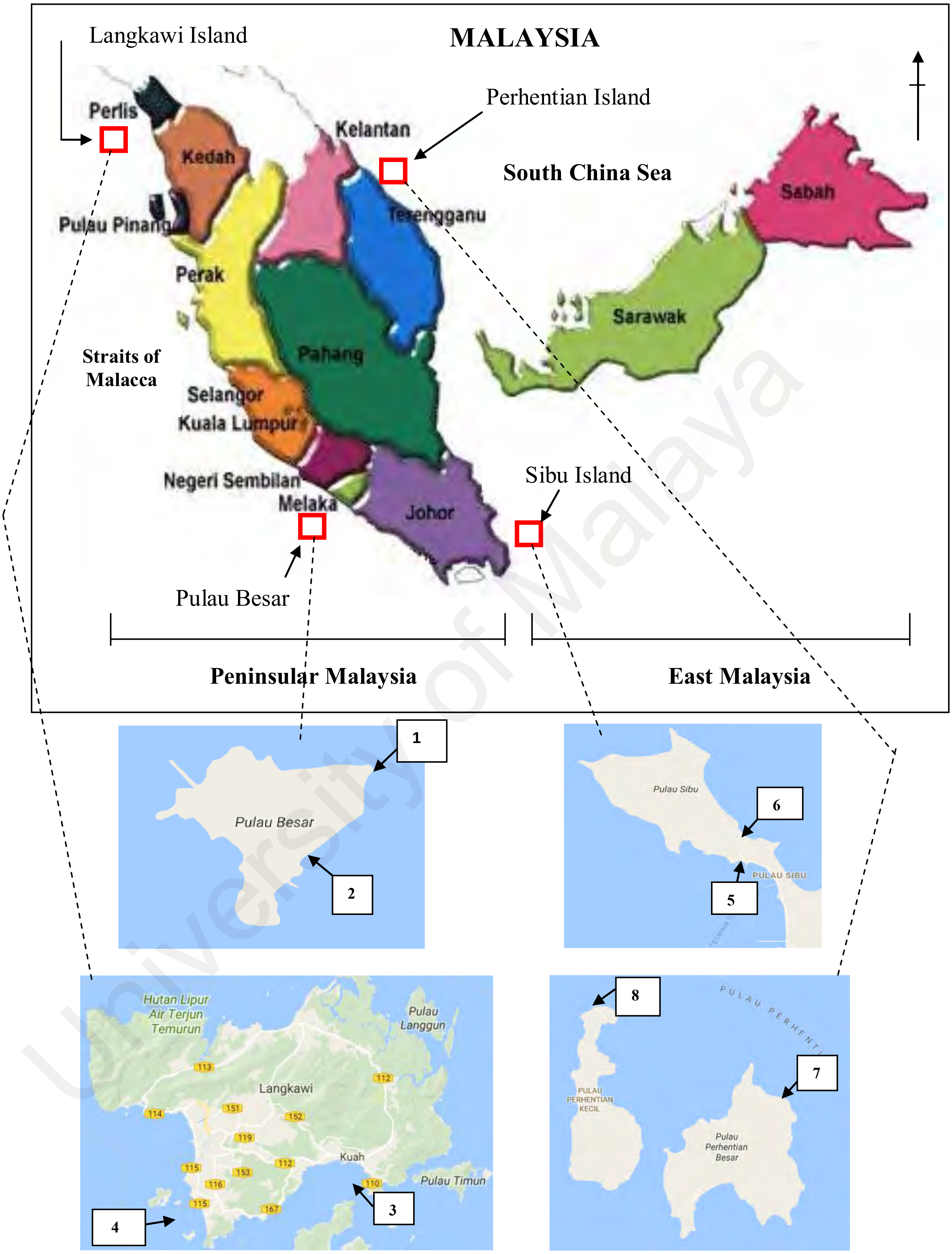

Figure 3.1: Location of sampling sites. Numbers correspond to location in Table 3.1 (Image reproduced with permission from Liyana (2012))

Table 3.1: Coordinates of the sampling sites

Sampling Sites	Coordinates	
	Latitude	**Longitude**
Pulau Besar, Malacca		
1. Mainland (PBM)	2º06'56.9" N	102º20'05.7" E
2. Open sea (PBS)	2º06'37.2" N	102º19'55.9" E
Langkawi Island, Kedah		
3. Penarak Beach (PB)	6º18'30.6" N	99º51'47.9" E
4. Tengah Beach (TB)	6º16'53.3" N	99º43'46.2" E
Sibu Island, Johor		
5. Mainland (SIM)	2º13'01.2" N	104º04'10.9" E
6. Open sea (SIS)	2º13'16.0" N	104º04'11.4" E
Perhentian Island, Terengganu		
7. Pinang Seribu (PS)	5º56'16.9" N	102º43'14.4" E
8. Tanjung Butong (TBG)	5º54'46.8" N	102º46'11.1" E

3.2 Determination of Waste Management Practices on the Beaches

3.2.1 Survey and Interviews

This study consists of public survey, discussions with local authority staff involved in waste management and observation on current practice in the management of marine wastes on the beaches. Interview was conducted one-to-one basis to obtain waste management contractor feedback on island waste management including waste collection efficiency, waste management facilities and issue related to waste management.

3.3 Determination of Beach Cleanliness Index (BCI)

3.3.1 Survey (Observations)

Data were collected by observing the existing anthropogenic activities conducted along the beaches. Observations on how the management of marine wastes on the beaches and the general cleanliness of the beach were conducted. This can be done by talking to the local authorities and public about the waste management on the beach. Also, the occurrence of natural factor during the sampling period on each beach sites was noted.

3.3.2 Data Analysis

A beach cleanliness index (BCI) was developed to suggest a tool for the evaluation of the actual cleanliness of the beaches in Malaysia. In order to achieve optimal characterization of beach cleanliness, the BCI were evaluated by considering the following elements:

1. Beach cleaning activity (BC)
2. Availability of waste bins (AB)
3. Anthropogenic activities (AA)
4. Natural factors (NF)

The higher the BCI value, the cleaner the beach. The calculation of the BCI is presented based on the following proposed formula:

$$BCI = (BC + AB) - (AA + NF) \qquad \text{(Eqn. 3.1)}$$

This study used descriptive statistics in assessing the BCI. The BCI score of each beach sites were evaluated by using a five point Likert scales ranged from 0 (very negative responses) to 4 (very positive responses) as indicated in Table 3.2 - Table 3.5. This five point Likert scale was adapted from Brown (2010).

BC was evaluated by considering the frequency of beach cleaning activities conducted on the beaches. Local authorities, local people and volunteers are among the responsible organizations that help in managing the marine waste found on beaches.

Table 3.2: Value given (based on Likert scales) of the frequency of beach cleaning activities

Numerical value	Beach Cleaning Activities (BC)		
	Responsible authority	**Local people**	**Volunteers**
0	None	None	None
1	Once / month	Once / month	Once / month
2	Once / weeks	Once / weeks	Once / weeks
3	Once / day	Once / day	Once / day
4	Twice / day	Twice / day	Twice / day

AB is one of the important elements which contribute to the BCI. The availability of waste bins on the beaches can help to prevent beach littering.

Table 3.3: Value given (based on Likert scales) for the availability of waste bins

Numerical value	Availability of Waste Bins (AB)
0	Unavailable
1	Low availability (<2)
2	Moderately available (2<x<5)
3	Available (5<x<10)
4	Highly available (>10)

AA is the existing anthropogenic activities conducted on the beaches. It was obtained by calculating the numerical value of these activities as proposed:

$$AA = (R+F+S+FS) \quad \text{(Eqn. 3.2)}$$

where R = recreational activities

F = fishing activities

S = shipping activities

FS = facilities and services

Table 3.4: Value given (based on Likert scales) for the presence of anthropogenic activities

Numerical value	Number of anthropogenic activities (AA)
0	None
1	Low (< 5)
2	Moderate (5<x<10)
3	High (10<x<20)
4	Very high (>20)

NF was evaluated by considering the different types of natural factors taken place during sampling period on the beaches. The value given (based on Likert scales) were calculated based on the observation of weather condition such as winds, waves, rainfall, storm and monsoon season that has occurred during sampling events. The natural exposure may determine the marine debris abundance that was present on the beach (Garcon *et al.,* 2010).

Table 3.5: Value given (based on Likert scales) of the different type of natural factors

Numerical value	Frequencies of occurrence of natural factors (NF)
0	None
1	Low (<1)
2	Moderate (1<x<3)
3	Strong (3<x<5)
4	Very strong (>5)

3.4 Sampling of Marine Waste on the Beaches

3.4.1 Sampling Design

The samplings were conducted before beach clean-up by the local authority to maximize collection of the samples. The method used was adapted from Opfer *et al.* (2012). All visible marine waste was collected from the low tide shoreline to the berm area. They were then stored in a large plastic bag before separated into 27 predetermined type of wastes as shown in Table 3.6. After that, marine waste were counted manually, weighed and recorded in the marine waste composition worksheet.

Table 3.6: Category of marine waste (Agamuthu & Nagendran, 2018)

	Type of waste	Examples
1	Food waste	Consumed and non consumed food waste
2	Mixed paper	Coloured and heterogenous paper
3	Newspaper / newsprint	-
4	Phone directory	Telephone books, non-glossy mail catalogs
5	Magazine	Glossy paper
6	White paper	Computer or printing paper
7	Box paper	Corrugated paper, carton
8	Hard plastic (HDPE)	Drinking bottle, toys, plastic container
9	Film	Plastic bag, food wrapper
10	Polystyrene	Food packaging material, disposable cups and plates
11	Disposable diapers	-
12	Textile	Clothes, bags
13	Rubber	Shoes, tyres
14	Wood	Furniture wood, wooden crates
15	Garden waste	-
16	Non-coloured glass	Clear glass
17	Coloured glass	Dark or amber glass
18	Metal	Plumbing part, electrical appliances
19	Non-metal	Rope
20	Tin	Food cans
21	Aluminium cans	Drink cans
22	Other aluminium	Aluminium foil
23	Hazardous waste	Light bulb, oil containers
24	Sand/dirt/dust	-
25	Other organic waste	Non-food material
26	Other inorganic waste	Ceramic, cigarette
27	Bulky waste	Furniture, electrical appliances

3.4.2 Data Analysis

Data obtained in this study was presented in two different units, namely weight/area (g/m^2) and number of items/area (number of items/m^2). For the purpose of this study, the average data obtained from the four months sampling were calculated to determine the abundance of marine waste on each beach. The averaged number from all debris types were also calculated to compare debris abundance between selected beaches.

Example: Abundance of marine waste in Pinang Seribu Beach (weight/area)

$$\text{Type of marine waste, } x = [A + B + C + D] \div 4 \qquad \text{(Eqn. 3.3)}$$

$$= (0.609 + 0.520 + 0.918 + 0.724) \div 4$$

$$= 0.693 \text{ g/m}^2$$ A, B, C, D are number of sampling

3.5 Sampling of Microplastic on the Beaches

3.5.1 Sampling Design

The sampling was carried out along three shorelines namely low tide shoreline, high tide shoreline and the berm area. The first quadrat was randomly established and was 50 m away from the sea while second and third quadrat spaced 10 m apart from each other. At each site, nine sampling points (Figure 3.2) were marked using measuring tapes, stakes and nylon cord. GPS coordinate were noted at each sampling points. Within each 50 cm x 50 cm quadrat (Plate 3.1), a triplicate of 12.5 L sediment was scooped to a depth of approximately 5 cm (Liyana, 2012). Before scooping the sediment samples, all leaves and woody debris was removed. The collected sediment was then subsequently placed into a plastic bag for further analysis (Plate 3.2).

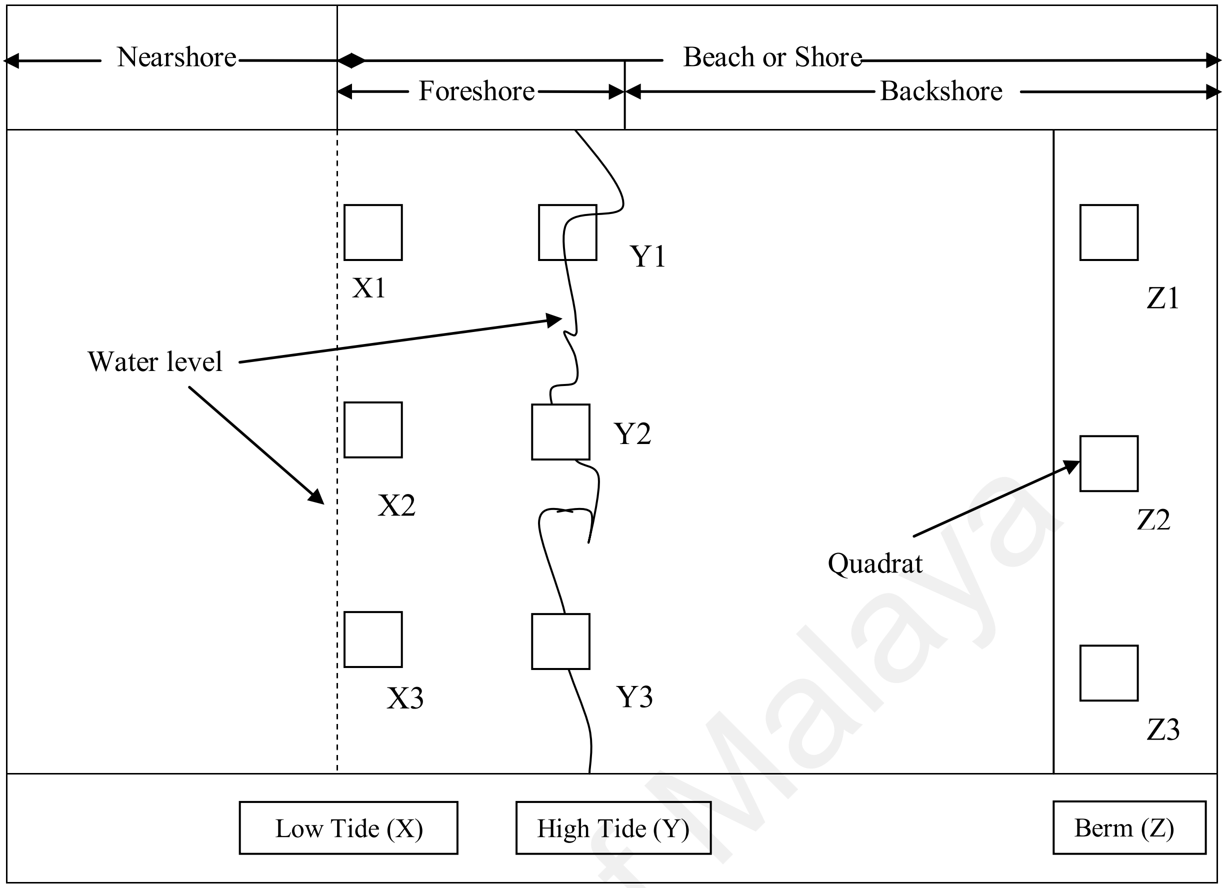

Figure 3.2: Nine sampling points on each beach sites (Image reproduced with permission from Liyana (2012))

Plate 3.1: 50 cm x 50 cm sampling quadrat (Image reproduced with permission from Liyana (2012))

Plate 3.2: Sediment samples were placed into plastic bags

3.5.2 Sieving of Samples

The sand was placed into a container filled with seawater. The sample was stirred and then sieved through 2 mm, 1 mm, 0.5 mm, 0.1 mm and 0.05 mm sieves. This step was done in portions, so that the sieves were not clogged with the sand particles. After that, the collected particles from each nested sieves was placed into separate labeled ziplock bag and brought to the laboratory for sorting purpose.

3.5.3 Sorting of Samples

The methods were adapted from McDermid and McMullen (2004) and Liyana (2012). After the sample was separated by different size classes, it was sorted using wet sorting method. The collected particles were then rinsed to pick out non floatable items that might be mistaken for plastics. By initially pouring the small amounts of sand into a container of freshwater, the sample was swirled using metal spatula to float out any portion of the sample that had a low specific density which was mostly plastic. Then, the plastic samples in each size classes were collected using forceps and stored.

3.5.4 Classification and Quantification of Samples

Plastic particles within each size classification were separated and classified into five types of plastic; namely foam, film, fragment, line and pellet (Table 3.7). These samples were counted and stored in separate labeled ziplock bags. All plastics items were then recorded onto appropriate data sheet in terms of number of items (items/m^2).

Table 3.7: Definitions and potential sources of microplastic types (Free *et al.,* 2014)

Microplastic type	Definition	Potential Sources
Fragment	Hard, jagged plastic particle	Bottles; hard, sturdy plastics
Line	Thin or fibrous, straight plastic	Fishing line/nets; clothing or textiles
Pellet	Hard, rounded plastic particle	Virgin resin pellets; facial cleansers
Film	Thin plane of flimsy plastic	Plastic bag, wrappers, or sheeting
Foam	Lightweight,sponge-like plastic	Foam floats, styrofoam, cushioning

3.5.5 Data Analysis

All the data collected from laboratory works were statistically calculated and analyzed using the Microsoft Excel software. In this study, two units of comparison applied which were number of items/area (items/m^2) and weight/area (g/m^2).

Other than that, Microsoft Excel software was also used as a statistical tool to generate a Two-Way Analysis of Variance (ANOVA) of the samples, as well as, correlation between the distribution of macroplastics with microplastics abundance. To evaluate potential relationship between distribution of macroplastics with microplastic abundance, the quantity of macro and microplastics was determined from the average data obtained from four months sampling on each beach.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Background Study of Selected Beaches

(a) Islands along the West Coast of Peninsular Malaysia

Sampling locations along the west coast of Peninsular Malaysia are in Kedah and Malacca. This region faces the Straits of Malacca and is dotted with a number of popular island destinations and beautiful beaches (Mapjabil *et al.,* 2015). However, this has been tarnished with debris and pollution which washed ashore as these coastlines is one of the world‟s busiest shipping lanes (Ayob & Masron, 2014). In addition, the beaches along this region are more heavily touristed and known among local and foreigners. In this study, Pulau Besar in Malacca and Langkawi Island in Kedah were selected to represent the islands from the west coast of Peninsular Malaysia.

i Pulau Besar, Malacca

Pulau Besar (Plate 4.1 and Plate 4.2) is located about 15 km south east of Malacca and approximately 40 km from the Petronas largest refinery complex in Sungai Udang. It is a fine sandy beach with lush green vegetation. Pulau Besar is surrounded with ancient shrines which scattered around the island that most visitors come to visit. Restaurants, a guesthouse and a public toilet can be found near the beach area. In addition, snacks and cold drinks are also sold at the jetty. Other attractions that can be seen nearby the beach area are the museum and camping site. Most activities here are non-water sports such as jogging, strolling, jungle trekking, and beach volleyball. Adjacent to the beach is a grilled fish restaurant which may also contribute to marine debris problem in this island. Thus, the great number of people in Pulau Besar might have resulted into the presence of plastic debris that can be found buried in the sand.

Plate 4.1: The beautiful view of Pulau Besar that face the mainland

Plate 4.2: Camping sites nearby the beach that face the open sea

ii Langkawi Island, Kedah

Penarak Beach (Plate 4.3) is located at the south of Langkawi Island. The scenic beauty of Penarak Beach was due to the natural landscape and man made structures. There are fishing village adjoining the beach. This beach area becomes a strategic port for fishing and the jetty is located in a secluded area. Local fishermen usually spend their leisure time on the beach before going off to the sea. Other than carrying fishing activities like setting nettings, most of the villagers are also involved in small business such as selling fish at the night market near the beach. Therefore, fishing activities and night market are the main contributor of debris to Penarak Beach.

Plate 4.3: Fishing boat harbor at Penarak Beach

Tengah Beach is one of the most beautiful beaches in Langkawi. Stretched over 700 m long, the beach has very fine sandy beach, fringed with palm and coconut trees. Located on the western coastline of Langkawi, Tengah Beach is basically a continuation of Cenang Beach, but separated by a rocky cliff. There are numerous seaside chalets and hotels along the beach including spas, restaurants and shops along the road that runs parallel to the beach. In addition, there are also small kiosks to offer all sorts of water sport activities (Plate 4.4) like parasailing, jet skiing, banana boating and water scooting during day time. Thus, Tengah Beach normally is crowded on weekends and during holidays. Nevertheless, swimming is not suitable at the northern end of the beach because this area is not well maintained. Some building material and trash from the resorts are dumped into this area. Due to different types of anthropogenic activities conducted here, this sandy beach area also had abundant of microplastic regardless of the daily cleaning activities.

Plate 4.4: Watersports kiosk at Tengah Beach

(b) Islands along the East Coast of Peninsular Malaysia

The East Coast of Peninsular Malaysia faces the South China Sea and highly acclaimed for its peaceful fishing village, beautiful coral islands, acres of tropical rainforest and small townships which had never failed to attract tourist from all over the world. Furthermore, this region is affected by North-East Monsoon season that strikes between November and February with rainfalls and severe floods. Monsoon season can disrupt boat crossings thus most of the resorts along the East Coast of Peninsular Malaysia will be closed during November to February and re-opened in March. In this study, Sibu Island in Johor and Perhentian Island in Terengganu were selected to represent islands on the East Coast of Peninsular Malaysia.

i Sibu Island, Johor

Sibu Island which is located in Mersing, Johor consists of cluster of islands, namely Sibu Besar Island, Sibu Tengah Island, Sibu Kukus Island and Sibu Hujung Island. The beach stretched over 6 km long with spectacular sunset view. There are also two main resorts which offer a private bay with views of Tioman Island to the north (Plate 4.5). It is very well-known for its panoramic sea views and golden sandy beaches. Towards the southern tip of Sibu Island that face the mainland, there is a small fishing village namely Kampong Duku with about 40 families (Plate 4.6). On top of that, there are many interesting activities which can attract more visitors to the beach such as snorkeling, diving, scuba diving, jungle trekking, fishing, beach volleyball, and island hopping. Thus, the presence of visitor at the beach and nearby fishing villages might have contributed to the occurrence of plastic debris in this area.

Plate 4.5: The calm and relaxing view of beach that face the open sea

Plate 4.6: Fishing village along the beach that face the mainland

ii Perhentian Island, Terengganu

Pinang Seribu Beach (Plate 4.7) is one of the nesting beaches for sea turtles in Perhentian Island. It is located on the eastern coast of Perhentian Besar. This beach remains relatively untouched because of its remoteness and away from other beaches. Facing the South China Sea, it is only about 50 m long but caters for more than 150 turtle"s nests per year. The beach experiences strong waves and winds during the monsoon. The most special attraction in Pinang Seribu Beach is to view the sunset. Other water sport activities such as snorkeling are also available. Although beach clean-up activity were taken by local villagers and volunteers, microplastic is still inevitable since they are buried in the sand.

Plate 4.7: Abandoned fishing net in Pinang Seribu Beach

Tanjung Butong (Plate 4.8) or known as Curtain Rock is located at the north of Perhentian Kecil with an extended rocky cape. The name Curtain Rock comes from the way the waves hit these rocks as the wind blows. There are a variety of marine life can be found hidden amongst the hard corals within this area including scorpion fish, pipe fish, nudibranchs and many coloured tropical fishes. Swimming and other water-sport activities are not recommended here as the wave is very strong during monsoon season. Thus, this beach area is rather clean.

Plate 4.8: Extended rocky headland of Tanjung Butong Beach

4.2 Waste Management on Selected Beaches in Malaysian Islands

Table 4.1 lists the waste management on selected beaches in Malaysian islands. From this study, it clearly shows that waste management on beaches affect the presence of marine debris on beaches but that is also contributed by the natural factor such as flood, wind and rainy season.

In general, the beach management is better in recreational beaches than other beaches. The recreational beaches are regularly cleaned since these types of beaches play a significant role in attracting tourist to the areas. As a result, Pulau Besar, Tengah Beach and Sibu Island that face the open sea are maintained by contractors appointed by the local authority to conduct regular waste collection, as well as, maintaining the landscape. On the other hand, in Penarak Beach, the local people from Penarak Fishing Village take the initiatives to conduct beach cleanup at least once a month since there is no proper waste collection by the local authority. This is in contrast with Pinang Seribu Beach and Tanjung Butong Beach, where both of these beaches are in isolated area. Blue Temple Conservation, an organization with focus on research and community outreach usually carry out beach cleaning in this study area.

Basic facilities such as signage and dustbin are only found at recreational beaches. Although fishing beaches are of lesser value and less attended by tourists, it should not be a factor to neglect its cleanliness. Hence, this highlights the importance of effective waste management system by the local authorities to ensure the cleanliness of the beach. Plate 4.9 - 4.11 illustrate activities conducted on the beaches.

Table 4.1: Waste Management on Selected Beaches in Malaysian Islands

Sampling Site	Beach function / Major activities	Local authority / Responsible body	Issues related to waste management
Pulau Besar (Mainland)	Recreational	Malacca Municipal Council	- Waste is collected twice daily - Dustbin provided - Signage available
Pulau Besar (Open Sea)	Recreational	Malacca Municipal Council	- Waste is collected twice daily - Dustbin provided - Signage available
Penarak Beach	Fishing village	Langkawi Municipal Council but only focused on most popular beaches	- Waste is collected once a month - No dustbin provided - No signage - Beach cleaning dependant to locals
Tengah Beach	Recreational	Langkawi Municipal Council and Environment Idaman	- Waste is collected twice daily - Dustbin provided - Signage available - High intensity of beach usage
Sibu Island (Mainland)	Fishing village	Mersing District Council	- No waste collection - No dustbin provided - No signage - Household waste washed ashore
Sibu Island (Open Sea)	Recreational	Mersing District Council	- Waste is collected once daily - Dustbin provided - No signage
Pinang Seribu	Fishing, boating	Besut District Council	- No dustbin provided - No signage - Beach cleaning dependant to volunteers
Tanjung Butong	Recreational, dive sites	Besut District Council	- No waste collection - No dustbin provided - No signage

Plate 4.9: Beach clean-up activities in Tengah Beach

Plate 4.10: Tractor is used to collect waste in Tengah Beach

Plate 4.11: Waste bin in Pulau Besar

4.3 Determination of Beach Cleanliness Index (BCI)

In order to determine the beach cleanliness index (BCI) of selected beaches in Malaysian island, the value for each element was evaluated based on Likert scales. BCI data collected throughout the sampling period are presented in Table 4.2-Table 4.8.

(a) Beach Cleaning Activity (BC)

Table 4.2 lists the value given (based on Likert scales) of the frequency of beach cleaning activity conducted in the study area.

Table 4.2: Value given (based on Likert scales) of the frequency of beach cleaning activity among the selected beaches

Types of beach cleaning	Name of the beaches studied							
	PBM	**PBS**	**PB**	**TB**	**SIM**	**SIS**	**PS**	**TBG**
Responsible authority	4	4	0	4	0	3	0	0
Local people	0	0	1	0	0	0	0	0
Volunteers	0	0	0	0	0	0	1	0
Total	4	4	1	4	0	3	1	0

Pulau Besar and Tengah Beach scored the highest value as the most frequently cleaned beaches. From the observation, these beaches are maintained by contractors appointed by the authority to conduct regular waste collection. These beaches were cleaned twice a day. This is in contrast with areas of Sibu Island that face the mainland and Tanjung Butong Beach as there is no beach cleaning activity conducted. Due to their location in rural areas with low tourism value, the cleanliness of the beach was often neglected by fishing villagers and local authorities. Thus, marine wastes were trapped and got buried over years. Hence, it should be noted that regular clean-up event play a vital role to reduce the amount of marine debris on the beach.

(b) Availability of Waste Bins (AB)

Table 4.3 lists the value given (based on Likert scales) for the availability of waste bins in the study areas.

Table 4.3: Value given (based on Likert scales) for the availability of waste bins among the selected beaches

Numerical values	**Name of the beaches studied**							
	PBM	**PBS**	**PB**	**TB**	**SIM**	**SIS**	**PS**	**TBG**
0			/		/		/	/
1								
2	/					/		
3		/		/				
4								
Total	2	3	0	3	0	2	0	0

For the availability of waste bins, the beach in Pulau Besar that face the open sea and Tengah Beach scored the highest value. From this study, it was observed that waste bins are only provided on recreational beaches. In addition, waste collection in other beaches is not under supervision by the authority and due to the reason there is no waste bins provided in the study area. Lack of waste management facilities and behaviors of beachgoers will lead to the accumulation of litter on beaches (Lozoya *et al.,* 2016).

(c) Anthropogenic Activities (AA)

Table 4.4 lists the different types of anthropogenic activities conducted on the beach.

Table 4.4: Type of anthropogenic activities conducted among the selected beaches

Types	Name of the beaches studied							
	PBM	**PBS**	**PB**	**TB**	**SIM**	**SIS**	**PS**	**TBG**
Recreational activities								
Kayaking				/				
Snorkeling				/		/	/	
Jet skiing				/				
Scuba diving				/		/		
Parasailing				/				
Island hopping				/		/		
Swimming		/						
Recreational boating	/	/	/		/		/	/
Camping		/						
Picnicking	/	/	/	/		/		
Beach volleyball		/		/		/		
Sunbathing				/		/		
Strolling	/	/		/		/		
Fishing activities								
Fishing village			/		/			
Fishing boat			/		/			
Pre-fishing activities			/		/			
Leisure fishing	/		/				/	
Shipping activities		/	/	/			/	
Facilities and services								
Resorts / chalets		/		/		/		
Restaurants / food stalls	/	/	/	/		/		
Toilets		/		/				
Gazebo	/		/			/		
Total	6	10	9	14	4	10	4	1

Tengah Beach recorded the highest number of anthropogenic activities. This is followed by areas of Pulau Besar and Sibu Island that face the open sea. From the observation, it was found that most of the beach users enjoy water sport activities, picnicking, sunbathing, playing volleyball and swimming along the beach. Thus, it can be indicated that these study areas have high tourism value and receive high number of beach users especially during weekend and public holiday. Khairunnisa (2012) had reported that beach activities were the most important aspect considered by beach users for holiday destination.

The lowest numbers of anthropogenic activities were recorded in Sibu Island beach that face the mainland, Pinang Seribu Beach and Tanjung Butong Beach. These beaches always receive less number of beach users due to their remoteness and they are away from other beaches. However, a high number of fishing activities was recorded in area of Sibu Island that face the mainland and Penarak Beach. There are a small fishing village and fishing boats along these study areas. In addition to that, fishermen usually conducted pre-fishing activities such as building of artificial reefs and anchors, and fixing boats and fishing nets. Eventhough Pulau Besar that face the mainland is not a fishing beach, small number of beachgoers can be seen to have leisure fishing on the beach.

All the beaches studied recorded the presence of shipping activities along their coast except for Pulau Besar beach that face the mainland, Sibu Island and Tanjung Butong Beach. During the sampling periods, a number of ships can be seen along the coast. Pinang Seribu Beach is one of the main stopovers for ships plying the trade to Southeast Asia. Also, it might be used as a shelter for ships during strong winds and huge waves in Perhentian Island. Meanwhile, the presence of a port which is located about 10 km from Tengah Beach and approximately 13 km from Penarak Beach makes this area a busy shipping route.

Most of the beaches in this study have a wide variety of facilities and services for visitors. From the observation, Tengah Beach, Pulau Besar and Sibu Island that face the open sea are surrounded with resorts and restaurants. In addition to that, many gazebo and snack stall line the beach area in Pulau Besar that face the mainland. Since many facilities and services are available, tourists tend to spend long hours on these beaches (Ariza *et al.,* 2008). Table 4.5 lists the value given (based on Likert scales) for the presence of anthropogenic activities conducted in the study areas.

Table 4.5: Value given (based on Likert scales) for the presence of anthropogenic activities among the selected beaches

Numerical values	**Name of the beaches studied**							
	PBM	**PBS**	**PB**	**TB**	**SIM**	**SIS**	**PS**	**TBG**
0								
1					/		/	/
2	/	/	/			/		
3				/				
4								

Based on Likert scales, Tengah Beach scored high value on the presence of anthropogenic activities, with recreational activities being the most frequently conducted. Tengah Beach is one of the most well maintained beaches with sufficient basic facilities. Pulau Besar, Penarak Beach and the beach of Sibu Island that face the open sea recorded the moderate value of anthropogenic activities with five to ten activities conducted on the beach. Most of these beaches offer non water sport activities such as volleyball and picnicking. Therefore, it can be concluded that diverse types of anthropogenic activities conducted on the beach might have influence by the tourist preferences for nature based attractions for any given destination. Plate 4.12 - 4.23 illustrate anthropogenic activities conducted on the beaches.

Plate 4.12: Boating activities at Pulau Besar that face the mainland

Plate 4.13: Gazebo at Pulau Besar that face the mainland

Plate 4.14: Boating activities at Pulau that face the open sea

Plate 4.15: Camping sites at Pulau Besar Besar that face the open sea

Plate 4.16: Resorts at Pulau Besar that face the open sea

Plate 4.17: Small cafe at Pulau Besar that face the open sea

Plate 4.18: Boating activities at Penarak Beach

Plate 4.19: Pre-fishing activities at Penarak Beach

Plate 4.20: Chalets at Tengah Beach

Plate 4.21: Watersports kiosk at Tengah Beach

Plate 4.22: Fishing boat at Sibu Island that face the mainland

Plate 4.23: Picnicking activities at Sibu Island that face the open sea

(d) Natural Factors (NF)

Table 4.6 lists the natural factors that take place in the study areas.

Table 4.6: Natural factors that influence the condition of the selected beaches

Types	**Name of the beaches studied**							
	PBM	**PBS**	**PB**	**TB**	**SIM**	**SIS**	**PS**	**TBG**
Winds	/	/	/	/	/	/	/	/
Waves	/	/	/	/	/	/	/	/
Rainfall season							/	/
Storm				/			/	
Monsoon season					/	/	/	/
Total	2	2	2	3	3	3	5	4

Table 4.7 lists the value given (based on Likert scales) of different types of natural factors taken place during sampling period.

Table 4.7: Value given (based on Likert scales) of different types of natural factors that influence the condition of the selected beaches

Numerical values	**Name of the beaches studied**							
	PBM	**PBS**	**PB**	**TB**	**SIM**	**SIS**	**PS**	**TBG**
0								
1								
2	/	/	/	/	/	/		
3							/	/
4								

From the results, Pinang Seribu and Tanjung Butong beach scored the highest value on the occurrences of natural factors throughout the four samplings. Based on the observations, it was revealed that strong waves and winds that usually occur heavily during the sampling period are one of the factors that affect the accumulation of marine debris in this study area. In addition, the presence of assorted plastic types ashore may be contributed by the occurrence of the North-Eastern monsoon.

4.3.1 Calculation of the Beach Cleanliness Index (BCI)

The calculated BCI is presented in Table 4.8 based on the following proposed formula:

$$BCI = (BC + AB) - (AA + NF) \qquad \text{(Eqn. 4.1)}$$

Table 4.8: Beach cleanliness index among the selected beaches

BCI	Elements	Name of the beaches studied							
		PBM	PBS	PB	TB	SIM	SIS	PS	TBG
	BC	4	4	1	4	0	3	1	0
	AB	2	3	0	3	0	2	0	0
	AA	2	2	2	3	1	2	1	1
	NF	2	2	2	2	2	2	3	3
BCI Value		2	3	-3	2	-3	1	-3	-4

The results in Table 4.8 show that areas of Pulau Besar that face the open sea was the cleanest with the highest BCI value at 3. This is due to the routine beach cleanups that are conducted twice a day by appointed contractors while monitoring was done by the Malacca Municipal Council. In addition to that, a large numbers of waste bins are provided by the local authority along the beach area which are regularly emptied. The moderate value of anthropogenic activities conducted on the beach also might contribute to their cleanliness as lesser amount of marine waste discarded by beachgoers and local communities. Moreover, this study area is not highly influenced by extreme weather events such as storm which might brought in marine debris onto the beach. Though abundance of marine debris is not critical in areas of Pulau Besar that face the open sea, it becomes the most popular spots for tourists especially during weekend and public holiday. Ballance *et al.* (2000) highlighted that cleanliness is recognised as the most important factor in influencing choice of beach, especially for foreign tourists.

Tengah Beach, areas of Pulau Besar that face the mainland and areas of Sibu Island that face the open sea are being considered as moderately cleaned beaches. Tengah Beach receives heavy burden of anthropogenic activities conducted such as water sport and picnicking activities. Daily beach cleaning are conducted by Environment Idaman to maintain the cleanliness of the beach. However, this might not be sufficient to prevent the beach from being contaminated with marine debris. Stronger wave movement and heavy storm may have transported some debris onto the beach area.

Penarak Beach, areas of Sibu Island that face the mainland, Pinang Seribu Beach and Tanjung Butong Beach are recorded as being the dirtiest beach with low BCI value. From the observation, Penarak Beach has moderate exposure to anthropogenic activities such as fishing activities and the presence of fishing villages near the beach. Lack of extensive solid waste management and facilities including waste bins are the major problem in this study area. Since there is no proper waste collection, beach clean-up were only depending on the initiatives of the local villagers. Due to this reason, the greatest abundant of marine debris was found in Penarak Beach.

In contrast, low anthropogenic activities are conducted in areas of Sibu Island that face the mainland, Pinang Seribu Beach and Tanjung Butong Beach. In addition to that, these beaches receives rough weather during monsoon season, thus, most debris was possibly transported to the beach by waves, winds and sea current. Therefore, it can be indicated that the deposition of marine debris in this study area are highly influenced by natural factors rather than human influences.

4.4 Marine Waste on Beaches of Selected Islands

4.4.1 Composition of Marine Waste

The composition of marine debris along the beaches of Malaysian islands is shown in Table 4.9. Debris collected in each beach sites were weighed and counted after the waste segregation. The amount of each type of debris is expressed in terms of weight and number of items.

Table 4.9: Three main types of debris on each study sites

Name of beaches	Marine debris types based on weight (g/m^2)	Marine debris types based on number of item
Pulau Besar (PBM)	Ceramics, hard plastic, food waste	Hard plastic, film, polystyrene
Pulau Besar (PBS)	Newspaper, hard plastic, food waste	Film, hard plastic, newspaper
Penarak Beach (PB)	Tyres, other aluminium, film	Tyres, film, other aluminium
Tengah Beach (TB)	Hard plastic, ceramics, film	Cigarette, box paper, hard plastic
Sibu Island (SIM)	Hard plastic, film, hazardous waste	Hard plastic, film, non-metal
Sibu Island (SIS)	Aluminium cans, hard plastic, polystyrene	Hard plastic, polystyrene, aluminium cans
Pinang Seribu (PS)	Hard plastic, polystyrene, aluminium cans	Hard plastic, polystyrene, aluminium cans
Tanjung Butong (TBG)	Hard plastic, non-metal, polystyrene	Hard plastic, polystyrene, non-metal

Out of 27 categories, hard plastic was highly predominant on nearly all of the beaches studied, followed by film, polystyrene, paper, aluminium cans, ceramics and food waste. Other wastes are tyres, cigarette, hazardous waste, non metal and other aluminium. This is in line with other studies that also recorded high abundance of plastic debris worldwide (Bravo *et al.,* 2009, Claereboudt, 2004; Derraik, 2002). The results indicated that composition of marine debris is highly dependable on the different types of anthropogenic activities on the relevant beaches.

(a) Pulau Besar, Malacca

Figure 4.1 and Figure 4.2 show the average percentage of debris found in Pulau Besar.

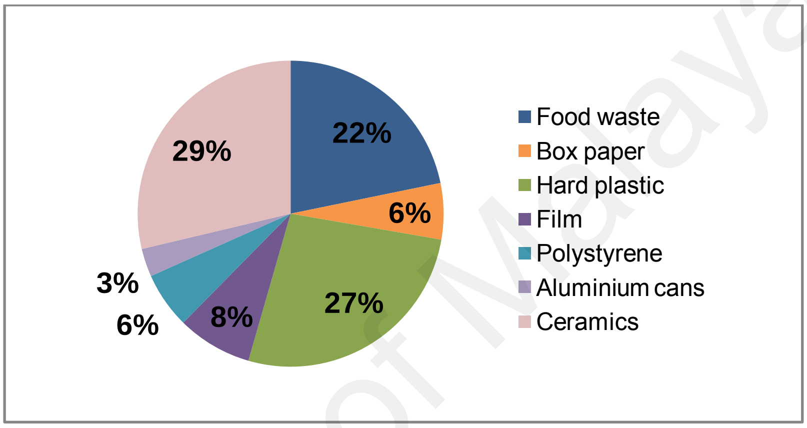

Figure 4.1: Average percentage of debris (fresh weight) collected from Pulau Besar that face the mainland

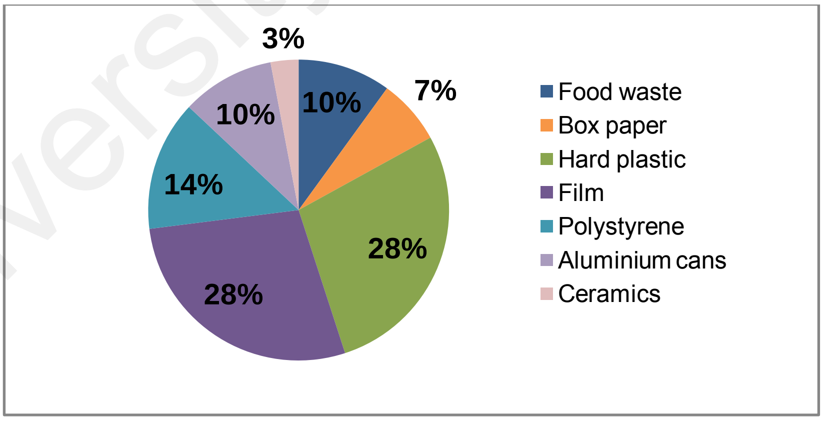

Figure 4.2: Average percentage of debris (number of item) collected from Pulau Besar that face the mainland

Ceramics recorded the highest percentage of the total weight (29%) followed by hard plastic (27%). Ceramics found in the study area could possibly originated from construction activities which were conducted near the beach or brought in by wave. Besides anthropogenic activities, natural factors can also contribute to the abundance of debris found on the beach. Somerville *et al.* (2003), also had reported that debris can accumulate temporarily or permanently on the beaches due to transportation by wind, tide and current.

A high percentage of hard plastic (drinking bottles) and film (plastic bag and food wrapper) were recorded in terms of number (56%) in this study area. Thus, it clearly showed that these types of marine debris are mostly generated by beachgoers in Pulau Besar that face the mainland. Plastic items are also abundant since they are lightweight, strong and cheaply available (Derraik, 2002; Jayasiri *et al.,* 2013).

Besides ceramics and plastic items, food waste which probably contributed from picnicking activities by beachgoers in this study area was recorded at 22% in weight and 10% in number. Beachgoers especially picnickers usually bring food with them. In addition, food waste can also originated from the disposal of products sold by food and beverage stalls at the jetty.

On the other hand, box papers which includes carton and corrugated paper were also found with 6% in weight and 7% in number which mostly are picnic debris. Other debris in Pulau Besar that face the mainland was polystyrene. Polystyrene was probably originated from styrofoam packaging items that were attached with fishing nylon line during leisure fishing at the jetty, as well as, disposable food wares from picnicking activities. Other type of waste found includes aluminium cans. The result indicated that beach activities influence the generation of marine debris as well as contributing to the different amount of debris found on the beach.

Basically, the composition of marine debris in Pulau Besar that face the open sea is quite similar with the beach that face the mainland. The average percentage of debris found in beaches that face the open sea is shown in Figure 4.3 and Figure 4.4. The result indicated that the highest percentage of marine debris are newspaper and hard plastic (31% by weight), and film (28% by number).

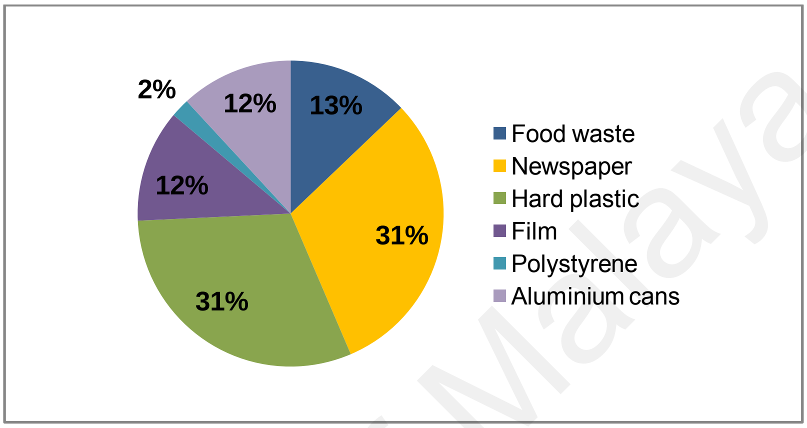

Figure 4.3: Average percentage of debris (fresh weight) collected from Pulau Besar that face the open sea

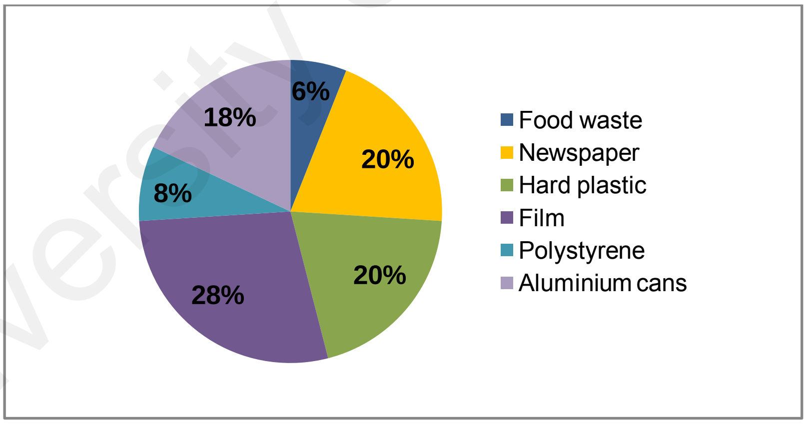

Figure 4.4: Average percentage of debris (number of item) collected from Pulau Besar that face the open sea

From this study, it was found that newspaper, hard plastic and film were the main types of debris collected in every sampling occasion. Other type of debris includes food waste, polystyrene and aluminum cans. Newspaper is believed to be used by beachgoers during picnicking activities. The left-overs and debris abandoned by irresponsible beachgoers pollute the beautiful view of the beach.

Apart from that, a high number of hard plastic (31%) in weight and (20%) in number collected may be contributed by the campers in this study area who discarded different types of personal items such as toiletries, detergent bottle and shampoo along the beach. Furthermore, the presence of high number of film waste (12% by weight and 28% by number) was probably due to the abundance of plastic bags, confectionary and convenience plastic foods wrapping that were normally discarded casually by people at beach. Besides plastic items, food waste was also found to dominate Pulau Besar that face the open sea. 13% in weight and 6% in number of food waste were collected possibly was attributed by the presence of restaurants near the beach area. Ariza *et al.* (2008), reported that the availability of food stalls along the beach may affect the composition of debris.

Polystyrene contributed around 2% in weight and 8% in number of debris found on beaches that face the open sea. This is similar to study by Moore *et al.* (2001), where polystyrene was found to be the second most abundant type of beach debris (88%) along the Orange Country coast. From the observation, abundant pieces of polystyrene were scattered in this study area which are believed to originate from food and drink containers that were disposed carelessly by beach users. Therefore, a timely action should be implemented in order to prevent the use of polystyrene as it takes a longer time to degrade in the marine environment.

(b) Langkawi Island, Kedah

Figure 4.5 and Figure 4.6 show the average percentage of debris found in Penarak Beach.

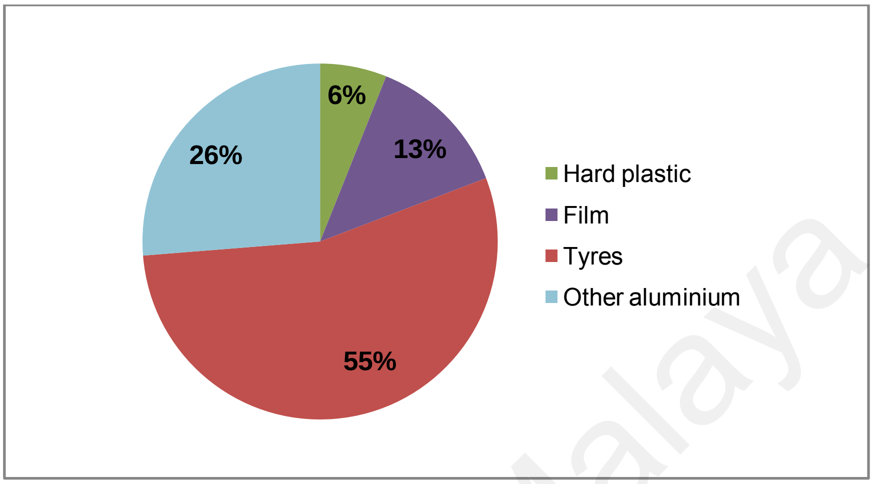

Figure 4.5: Average percentage of debris (fresh weight) collected from Penarak Beach

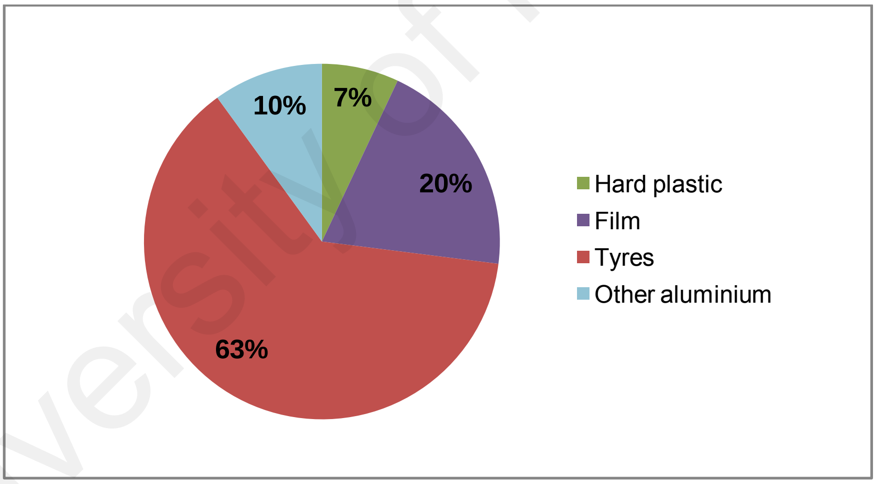

Figure 4.6: Average percentage of debris (number of item) collected from Penarak Beach

The most common items found in Penarak Beach are tyres, hard plastic, film and other aluminium. The highest percentage (55% in weight and 63% in number) is tyres which can be attributed to fishing activities within the study area. Penarak Beach is undoubtedly the most popular fishing village in Langkawi Island. Tyres were collected to be used as artificial reefs which are dropped into the sea to attract fish. In addition to that, fishermen that fix boat and fishing nets are likely to contribute to the high quantity of marine debris in the Penarak Beach. Other aluminium recorded 10% of the total number of debris. Besides that, plastic namely hard plastic and film constitute 39% in weight and 30% in number of the total amount of debris found. This may be contributed by the abundance of sweets wrappers, plastic bag and drinking bottles brought by local villagers to the beach.

Another beach studied in Langkawi Island is Tengah Beach. Tengah Beach is a recreational beach which receives high number of tourists as compared to Pulau Besar. This beach offers diverse type of anthropogenic activities, thus contribute to the different types of marine debris. Figure 4.7 and Figure 4.8 show the average percentage of marine debris in Tengah Beach.

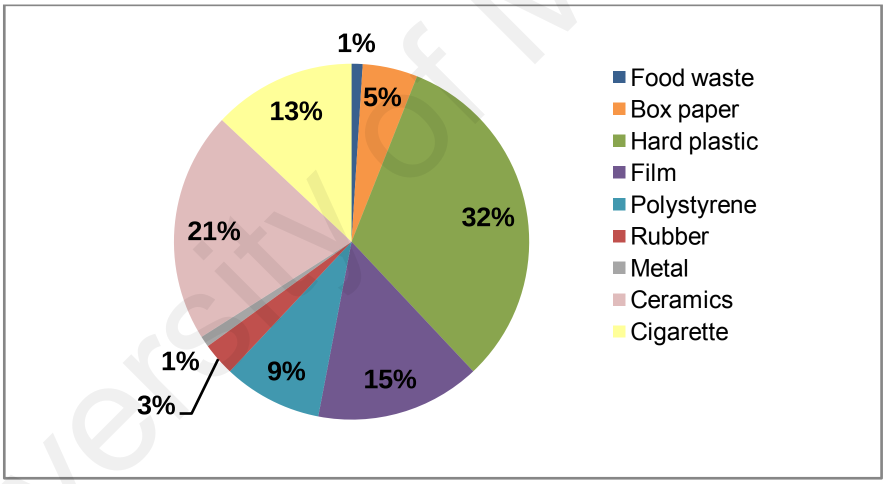

Figure 4.7: Average percentage of debris (fresh weight) collected from Tengah Beach

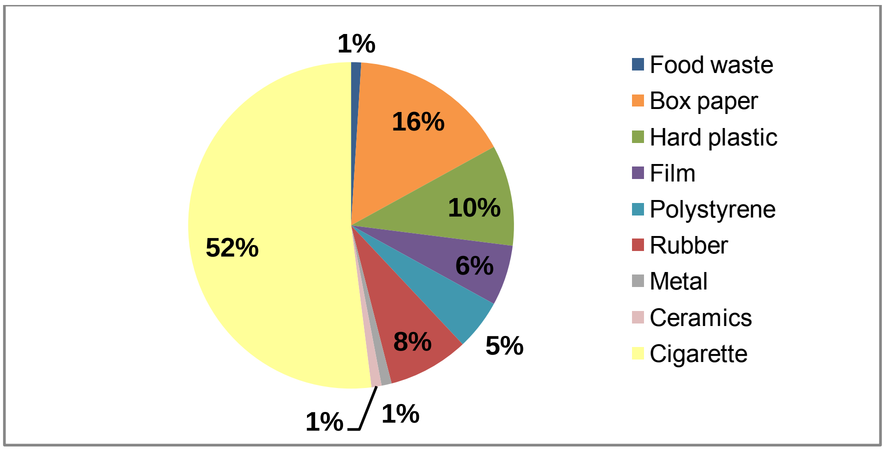

Figure 4.8: Average percentage of debris (number of item) collected from Tengah Beach

From this study, plastic (hard plastic and film) was the most abundant type of debris found on beaches in terms of weight (47%). Plastic bag, food container and drinking bottles were mostly generated by beachgoers. Plastic waste has been proven to be major contributor of coastal litter in Malaysian beaches with 66% of the overall litter collected (Hagir *et al.,* 2013). In contrast, cigarette buts were recorded as the most abundant type of debris in terms of number (52%). The significant amount of cigarette buts was probably due to its small size, therefore left unattended by the waste collectors in Tengah Beach.

Furthermore, Tengah Beach was also polluted with other types of debris such as food waste, box paper (cigarette box and drinking box), polystyrene, rubber, metal, and ceramics. Rubber which includes beach sandals was also found in Tengah Beach with 3% in weight and 8% in number of items. However, the amount of food waste, ceramics and metal are low. Based on the observations during the sampling event, it was revealed that most of the marine debris found in Tengah Beach was contributed from the picnicking activities carried out on Tengah Beach.

(c) Sibu Island, Johor

Another beach studied was Sibu Island which is located in East Johor, along the East Coast of Peninsular Malaysia. The average percentage of debris found in terms of weight and number of items in Sibu Island that face the mainland is shown in Figure 4.9 and Figure 4.10.

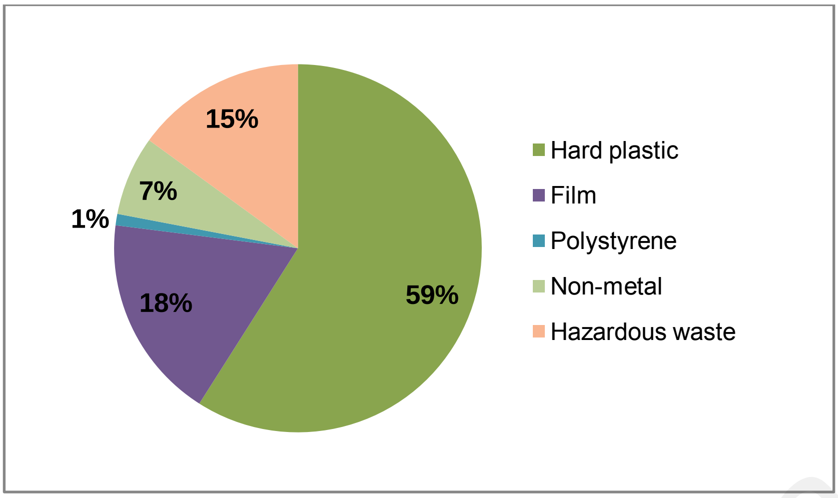

Figure 4.9: Average percentage of debris (fresh weight) collected from Sibu Island that face the mainland

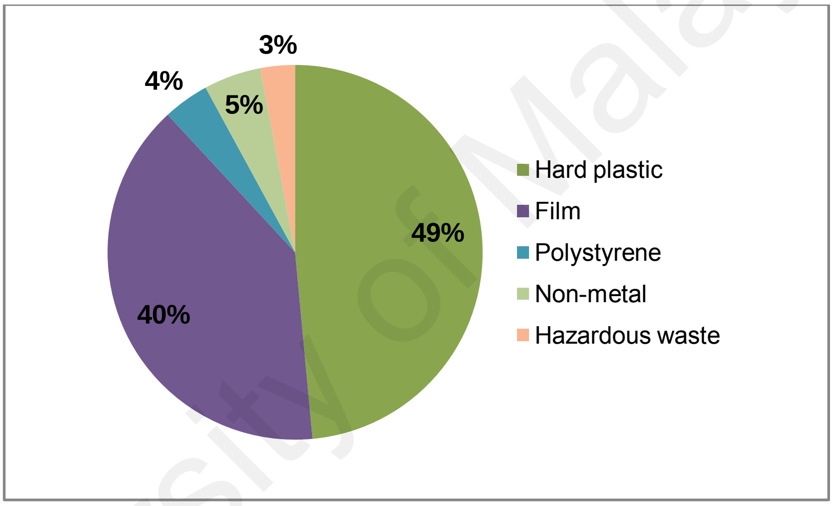

Figure 4.10: Average percentage of debris (number of item) collected from Sibu Island that face the mainland

Hard plastic, film, hazardous waste, non metal (rope) and polystyrene are the most numerous items found in Sibu Island side that face the mainland. Plastic items recorded more than 70% of the total amount of debris, both in terms of weight and number of items. They were mostly plastic bags, food wrappers, plastic bottles, straw and some household items, such as detergent bottles. Most of these items are believed to originate from the small fishing village adjoining the beach.

On the other hand, rope was 7% in weight and 5% in number during the sampling events. However, this is contradicting with study by Bilkovic *et al.* (2014) where plastic bait jars, fishing lines and crab pots were more abundant on beaches than plastic lines. Debris such as rope can also lead to entanglement of marine organisms (Sheavly & Register, 2007). In addition to other common item found on the beaches, some hazardous items such as used light bulbs were also found contributing 5% in number, which probably sourced from fishing village near the beach. Besides that, some of these household items might also get washed ashore during rainy season.

Polystyrene including disposable food containers were also found. Like most plastics, polystyrene is lightweight that it floats. It has been reported that when polystyrene is littered, it can be carried far away from its origin through storm drains out to the ocean (Miriam, 2006). Based on this study, it suggests that debris in Sibu Island beach that face the mainland was possibly from sources other than fisheries. However, this may only represent the condition during monsoon period where fishing activity area at minimum while flood pulled the household wastes ashore.

Sibu Island that face the mainland is considered as a fishing beach, while another study area that face the open sea is a private recreational beaches. The weight of marine debris collected from this area is shown in Figure 4.11, while Figure 4.12 illustrates the number of item. This beach was generally clean with only some dried leaves scattered along the beach. Aluminium cans, hard plastic and polystyrene are the common debris found in Sibu Island that face the open sea. It is similar to other recreational beach worldwide (Bravo *et al.,* 2009).

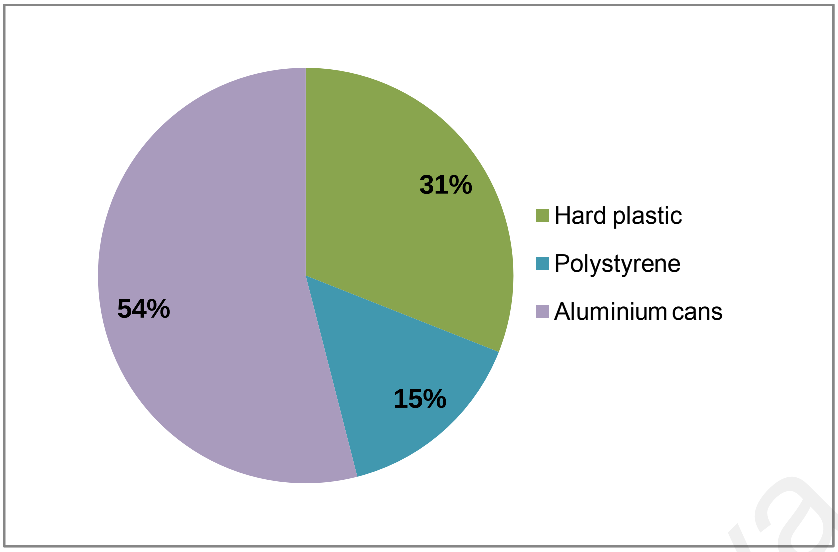

Figure 4.11: Average percentage of debris (fresh weight) collected from Sibu Island that face the open sea

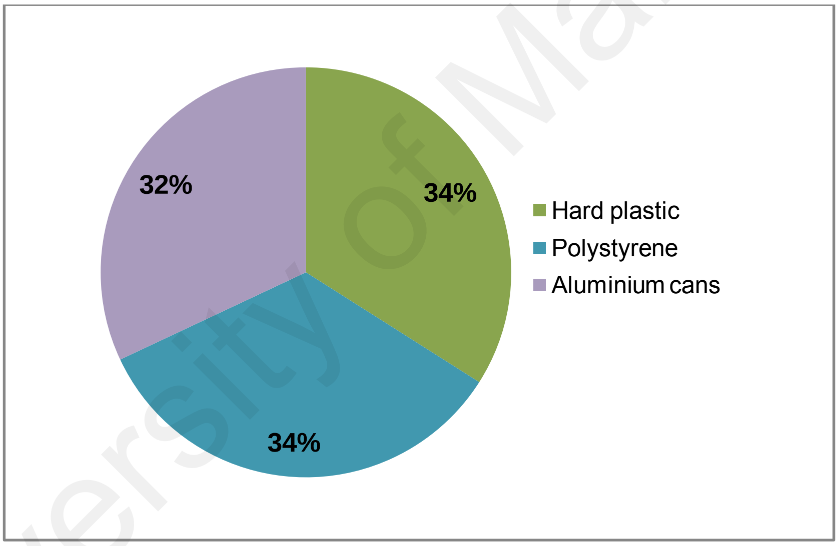

Figure 4.12: Average percentage of debris (number of item) collected from Sibu Island that face the open sea

Figure 4.11 illustrates that aluminium cans was the largest category of debris with 54% in weight in Sibu Island that face the open sea. Aluminium cans found in the study area probably were left behind by tourists or simply washed ashore from the sea. Furthermore, hard plastic such as drinking bottles which was possibly discarded by picnickers constitute a notable weight of 31%. Polystyrene which was lesser than 20% of the total weight is believed to originate from disposable food and drink containers by beachgoers.

Figure 4.12 illustrates the composition of debris based on number of item found in Sibu Island that face the open sea. Hard plastic and polystyrene are the highest percentage (34%) of debris in every sampling event. Lightweight debris such as polystyrene can be easily blown to the sea with the aid of winds.

(d) Perhentian Island, Terengganu

The average percentage of debris found in Pinang Seribu Beach is shown in Figure 4.13 and Figure 4.14.

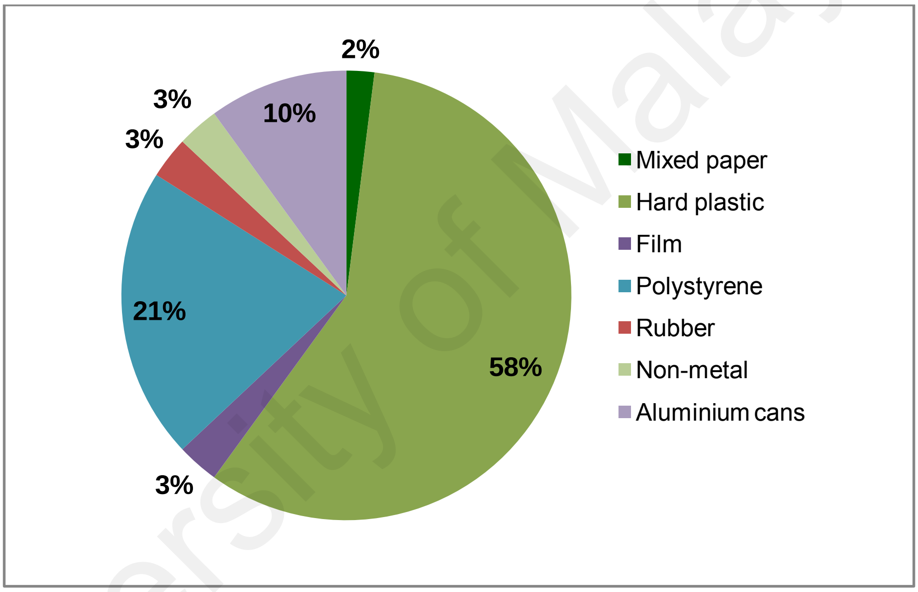

Figure 4.13: Average percentage of debris (fresh weight) collected from Pinang Seribu Beach

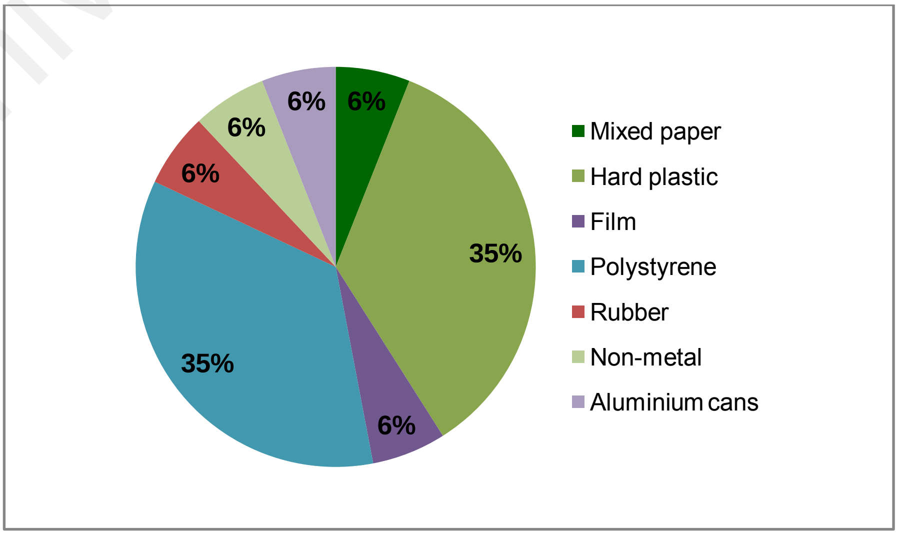

Figure 4.14: Average percentage of debris (number of item) collected from Pinang Seribu Beach

From this study, it can be seen that Pinang Seribu Beach were polluted with large amount of debris. Due to its location that was isolated from other main attraction in Perhentian Island, most marine debris accumulated in this study area is believed to be brought in by wind, wave and sea current. Some water sports activities such as snorkeling may probably generate debris such as hard plastic which consists of plastic drinking bottles and detergent bottles, polystyrene and aluminium cans.

On overall, plastic constituted 61% of the total weight of debris found on Pinang Seribu Beach. This is followed by 21% polystyrene and 10% aluminium cans, 3% rubber, 3% non metal (rope) and 2% mixed paper. There are similar types of debris found in terms of number. Plastics represent 41% of the total number of items found within the study area followed by polystyrene at 35% and aluminium can, rubber, non metal (rope) and mixed paper at 6% each. On top of that, fishing related debris including plastic rope, small net pieces and buoys were also found in Pinang Seribu Beach. Abandoned nets which were already half buried made the removal difficult.

This study revealed that most of the debris collected in Pinang Seribu Beach was plastic. Plastic have low density that they can float and get transported over long distance by winds and currents (Galgani *et al.,* 2015; Kubota *et al.,* 2005). Low windage debris such as fishing nets and plastic bottle caps probably were transported to the site by the sea currents. In contrast, high windage debris such as fishing buoys will float on the water surface and blown by winds. This is agreeable to report by Eriksson *et al.* (2013) that ocean currents, wind and wave affects the distribution of debris items onto the beach.

Another beach studied in Perhentian Island is Tanjung Butong Beach. The average percentage of debris found within this study area is shown in Figure 4.15 and Figure 4.16. The result indicated that the most common items found in Tanjung Butong Beach are hard plastic (59%), polystyrene (20%), and non metal (12%) in terms of number. It can be noted that hard plastics are tend to accumulate on rocky shores (Moore *et al.*, 2001).

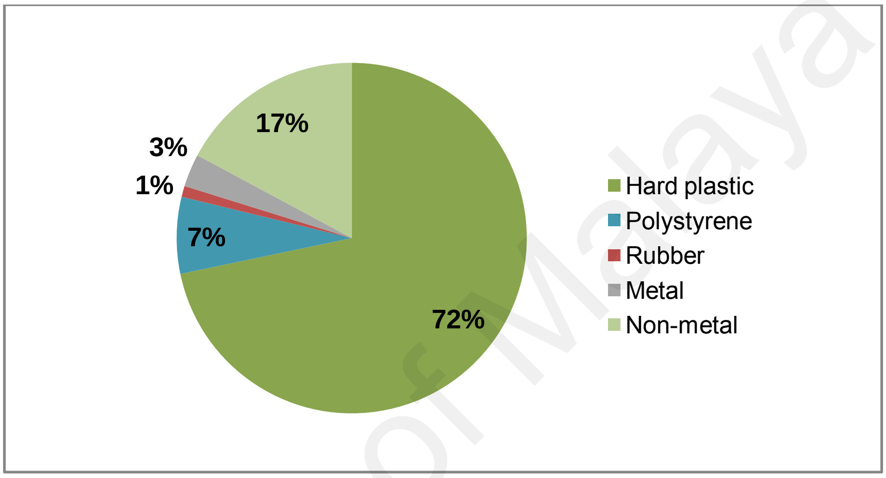

Figure 4.15: Average percentage of debris (fresh weight) collected from Tanjung Butong Beach

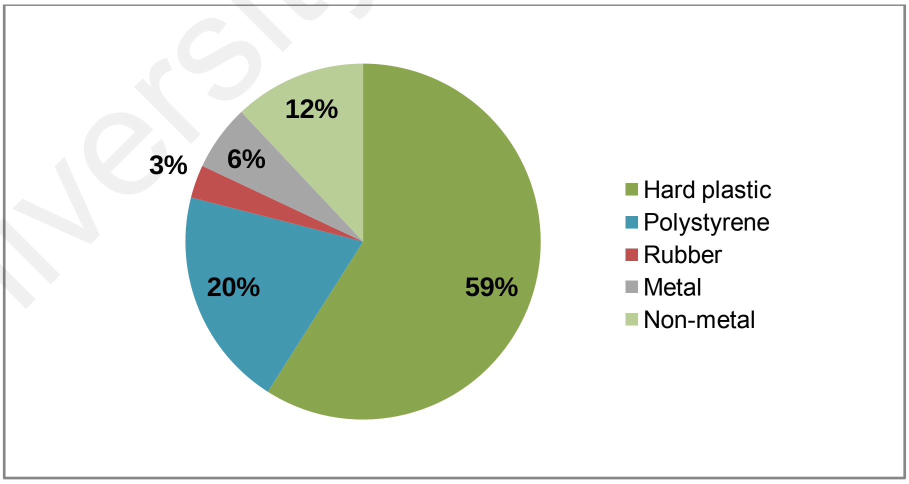

Figure 4.16: Average percentage of debris (number of item) collected from Tanjung Butong Beach

Hard plastic constituted the highest percentage (72%) of the total weight of debris followed by 17% non metal, 7% polystyrene, 3% metal and 1% rubber (Figure 4.15). As for the total number of debris, hard plastic recorded 59% followed by polystyrene at 20%, non metal at 12%, metal at 6% and rubber at 3%. The composition of marine debris on the beach shows that similar types of debris were found as that of other beaches.

Furthermore, it was noted that during the study period, Tanjung Butong beach has less debris as compared to Pinang Seribu beach. This may be due to the reason that this study area receives heavy wind and wave action which might drive away the marine debris into the sea or from deposited on the beaches.

4.4.2 Abundance of Marine Waste

Table 4.10 and Table 4.11 show the type of marine debris collected from selected beaches. The abundance of marine debris is presented in weight/g/m^2 and number of item/m^2.

Table 4.10: Amount of debris collected from selected beaches based on fresh weight

	Fresh weight, g/m^2			
Type of waste	**PBM**	**PBS**	**PB**	**TB**
Food waste	0.160±0.104	0.090±0.008	-	0.003±0.001
Newspaper	-	**0.217±0.009**	-	-
Box paper	0.041±0.051	-	-	0.031
Hard plastic	0.197±0.036	0.216±0.094	0.008±0.001	**0.190±0.037**
Film	0.056±0.002	0.083±0.006	0.016±0.002	0.090±0.009
Polystyrene	0.046±0.023	0.015±0.002	-	0.055±0.002
Rubber	-	-	**0.068±0.016**	0.016±0.006
Metal	-	-	-	0.001±0.0008
Aluminium cans	0.024±0.006	0.081±0.046	-	-
Other aluminium	-	-	0.033±0.008	-
Ceramics	**0.209±0.121**	-	-	0.124±0.023
Cigarette	-	-	-	0.079±0.031
Total	**0.733**	**0.702**	**0.125**	**0.589**
	Fresh weight, g/m^2			
Type of waste	**SIM**	**SIS**	**PS**	**TBG**
Mixed paper	-	-	0.041±0.005	-
Hard plastic	**0.570±0.036**	0.053±0.006	**1.294±0.144**	**0.753±0.058**
Film	0.173±0.017	-	0.068±0.006	-
Polystyrene	0.007±0.002	0.025±0.006	0.461±0.028	0.070±0.006
Rubber	-	-	0.071±0.008	0.015±0.001
Metal	-	-	-	0.033±0.008
Non metal	0.067±0.004	-	0.069±0.005	0.183±0.031
Aluminium cans	-	**0.091±0.011**	0.224±0.103	-
Hazardous waste	0.148±0.015	-	-	-
Total	**0.965**	**0.169**	**2.228**	**1.054**

In terms of weight, the highest amount of marine debris was found in Pinang Seribu beach weighing 2.228 g/m^2. This is followed by Tanjung Butong beach (1.054 g/m^2) the beach in Sibu Island that face the mainland (0.965 g/m^2). The presence of household items and fishing related debris in these areas are the main contributing factors to the high amount of marine debris in terms of weight. These study area are highly influenced by the North Eastern Monsoon season. Studies by Schulz *et al.* (2013) shown that deposition of debris items increased with storms and rain events. In addition, these beaches can be considered to have low tourism value due to their remoteness from other beaches. Thus, the removals of solid waste were often neglected by the local authorities. On the other hand, areas of Sibu Island that face the open sea recorded the lowest amount of marine debris in terms of weight (0.169 g/m^2) among other beaches along the East Coast of Peninsular Malaysia. This beach have high tourism value and receives high number of beach users everyday. Daily clean-up activity was done by appointed contractors in order to maintain the cleanliness of the beaches. Beach signage and waste bins were also provided in this area, thus littering by beach user is much lesser.

As compared to the beaches which are located along the West Coast of Peninsular Malaysia, areas of Pulau Besar that face the mainland constituted the highest amount of marine debris in terms of weight (0.733 g/m^2), may be due to the presence of ceramics or construction debris which were discarded onto the beach.

Table 4.11: Amount of debris collected from selected beaches based on number of item

	Number of item/ m²			
Type of waste	**PBM**	**PBS**	**PB**	**TB**
Food waste	0.003±0.001	0.003±0.002	-	0.001±0.0005
Newspaper	-	0.010±0.002	-	-
Box paper	0.002±0.001	-	-	0.025±0.001
Hard plastic	**0.008±0.006**	0.010±0.004	0.003±0.001	0.015±0.007
Film	**0.008±0.005**	**0.014±0.008**	0.008±0.004	0.009±0.003
Polystyrene	0.004±0.002	0.004±0.003	-	0.007±0.002
Rubber	-	-	**0.026±0.006**	0.013±0.009
Metal	-	-	-	0.002±0.001
Aluminium cans	0.003±0.002	0.009±0.002	-	-
Other aluminium	-	-	0.004±0.001	-
Ceramics	0.001±0.0008	-	-	0.002±0.001
Cigarette	-	-	-	**0.081±0.003**
Total	**0.029**	**0.050**	**0.041**	**0.155**
	Number of item/ m²			
Type of waste	**SIM**	**SIS**	**PS**	**TBG**
Mixed paper	-	-	0.008±0.006	-
Hard plastic	**0.038±0.027**	**0.011±0.006**	**0.044±0.003**	**0.039±0.022**
Film	0.031±0.020	-	0.007±0.002	-
Polystyrene	0.003±0.001	**0.011±0.008**	**0.044±0.002**	0.013±0.005
Rubber	-	-	0.008±0.005	0.002±0.001
Metal	-	-	-	0.004±0.002
Non metal	0.004±0.002	-	0.008±0.001	0.008±0.004
Aluminium can	-	0.010±0.004	0.008±0.005	-
Hazardous waste	0.002±0.001	-	-	-
Total	**0.078**	**0.032**	**0.127**	**0.066**

The abundance of marine debris in terms of number of items was the highest in Tengah Beach at 0.155 item/m^2 followed by Pinang Seribu (0.127 item/m^2) and the beach in Sibu Island that face the mainland (0.078 item/m^2). From the observation, cigarette butts are the most abundant (0.081 item/m^2) in Tengah Beach since it was less visible to waste collectors during beach cleaning due to their lightweight properties and smaller size. According to the Ocean Conservancy (2009), over 230,000 cigarette butt were collected from Californian beaches making it the most littered item in the world.

Among all types, plastics recorded as the highest number of items at all the beaches except Penarak Beach and Tengah Beach. This is possibly due to the fact that plastics are low density materials and easily transported long distances from source areas (UNEP, 2005). Rubber contributes to the highest amount of marine waste in terms of number in Penarak Beach which was possibly used for fishing activities. Hard plastic tends to dominate the quantity of marine waste in Pinang Seribu beach (0.044 item/m^2) and area of Sibu Island that face the mainland (0.038 item/m^2). The high number is due to the presence of household items, plastic bags, and drinking bottles along the beach.

4.5 Macroplastic Abundance on Beaches of Selected Islands

Table 4.12 shows the type of macroplastics collected from the beaches of Malaysian islands. Hard plastic, film and polystyrene are the most dominant macroplastics items recorded in the study area. This is similar to study by Zhou *et al.* (2011), where plastic was found to dominate the composition of marine waste on the beach.

Table 4.12: Type of macroplastics on each study sites

Name of beaches	Type of macroplastics
Pulau Besar (PBM)	Hard plastic, film and polystyrene
Pulau Besar (PBS)	Hard plastic, film and polystyrene
Penarak Beach (PB)	Hard plastic and film
Tengah Beach (TB)	Hard plastic, film and polystyrene
Sibu Island (SIM)	Hard plastic, film, polystyrene and rope
Sibu Island (SIS)	Hard plastic and polystyrene
Pinang Seribu (PS)	Hard plastic, film, polystyrene and rope
Tanjung Butong (TBG)	Hard plastic, polystyrene and rope

From Table 4.12, it was clearly shows that the beaches along the West Coast of Peninsular Malaysia recorded different type of macroplastic debris which mainly originated from recreational activities by beachgoers and land based sources. In contrast, most remote and unpopulated beaches along the East Coast of Peninsular Malaysia tend to be littered with macroplastic items from fishing and domestic activities, such as household waste from rivers and onshore, as well as disposal from shipping activities. Lavers and Bond (2017) reported that uninhabited islands in South Pacific region act as sinks and sources for macroplastic debris. Table 4.13 shows the monthly differences between the abundance of macroplastic in selected beaches.

Table 4.13: Quantity of macroplastic collected on beaches studied for monthly intervals

Sampling sites / Months	May 2016 (items/m^2)	July 2016 (items/m^2)	September 2016 (items/m^2)	November 2016 (items/m^2)
Pulau Besar (Mainland)	5	3	7	5
Pulau Besar (Open Sea)	10	13	3	2
Penarak Beach	2	3	3	3
Tengah Beach	3	9	12	7
Sibu Island (Mainland)	12	16	20	28
Sibu Island (Open Sea)	8	10	3	1
Pinang Seribu Beach	15	31	25	32
Tanjung Butong Beach	12	10	18	20

The quantity of macroplastics was the highest in Pinang Seribu Beach at 103 items/m^2 followed by areas of Sibu Island that face the mainland (76 items/m^2) and Tanjung Butong Beach (60 items/m^2). The present findings also showed that there are slightly increase in the total quantity of macroplastic collected from these beaches in November. This is because most of the macroplastic might be washed ashore during monsoon season. Besides that, these beaches are unknown to public hence low human activities. The low presence of anthropogenic activities on the beach might also explain the high number of macroplastics at the shore during wetter months (Noik & Tuah, 2015).

On the other hand, it was found that the beaches along the West Coast of Peninsular Malaysia did not record notable differences in the quantity of macroplastic collected between the four months sampling. Unlike in areas of Pulau Besar that face the open sea, huge reduction was recorded from July until November 2016. This may probably due to the presence of tourists during weekend and public holidays in early years. In addition, the low quantity of macroplastic was found on beaches which are located along the West Coast of Peninsular Malaysia. These beaches have regular clean-up activity conducted by contractors appointed by the local authority, fishing villagers and volunteers. As a result, macroplastic found during each month are those accumulated for the same time period. Thus, a comprehensive plan of action should be implemented in order to protect Malaysian beaches from macroplastic pollution.

4.6 Microplastic Abundance on Beaches of Selected Islands

4.6.1 Pulau Besar (Mainland)

(a) Classification of Microplastic

Figure 4.17 shows the number of film, foam, fragment, line and pellet (item/m^2) collected from beach of Pulau Besar that face the mainland.

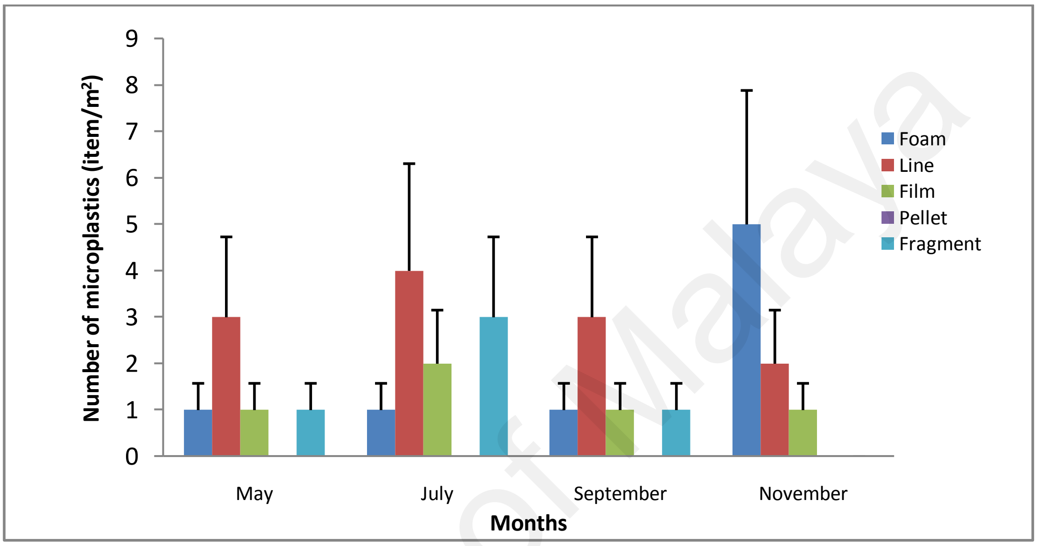

Figure 4.17: Quantity of microplastics from beaches that face the mainland

The most dominant type of microplastics found in this area is line plastic, followed by foam, film and fragment. No pellet plastics were found in this area. However, more foam was recorded at the year end as compared to other months. This may probably due to the strong wind and waves which may have transported this lightweight debris onto the beach after the monsoon.

Line was found to be the highest number of microplastics (15 items/m^2) in Pulau Besar that face the mainland and it was assumed to have originated from leisure fishing. Broken fishing line and ropes contribute to the greater quantity of microplastic in this study area. These larger plastics debris are derelict on the beach which then got buried in the sands. In addition, line plastics might have drifted from nearby local villager where nets line was discarded into the sea. According to Law (2017), abundance of fishing lines used for fishing activities had resulted in large amount of persistent marine debris drifting in the world‟s ocean and washing ashore. Besides that, plastic film from plastic bags and food wrappers were also found littered by irresponsible people at the beach.

On top of that, the presence of high number of foam plastics (8 items/m^2) is believed to originate from polystyrene food and beverage containers that were discarded carelessly by beachgoers during picnicking activities. Foam plastics can be broken into tiny pieces after certain period of time (Santos *et al.,* 2009). These types of plastics are derived from the degradation of larger plastic waste in the marine environment (Ng & Obbard, 2006).

Furthermore, microplastic such as foam, film and fragment arguably posed a serious threat to the marine environment since it can easily got buried in the sand, or mistakenly ingested by animals (Macrae, 2011). Thus, it is crucially important to ban the use of plastic bags and polystyrene before it become litters on the environment and find their way to the ocean.

(b) Abundance of Microplastic According to Tidal Zones

Figure 4.18 shows the quantity of microplastic according to the tidal zones.

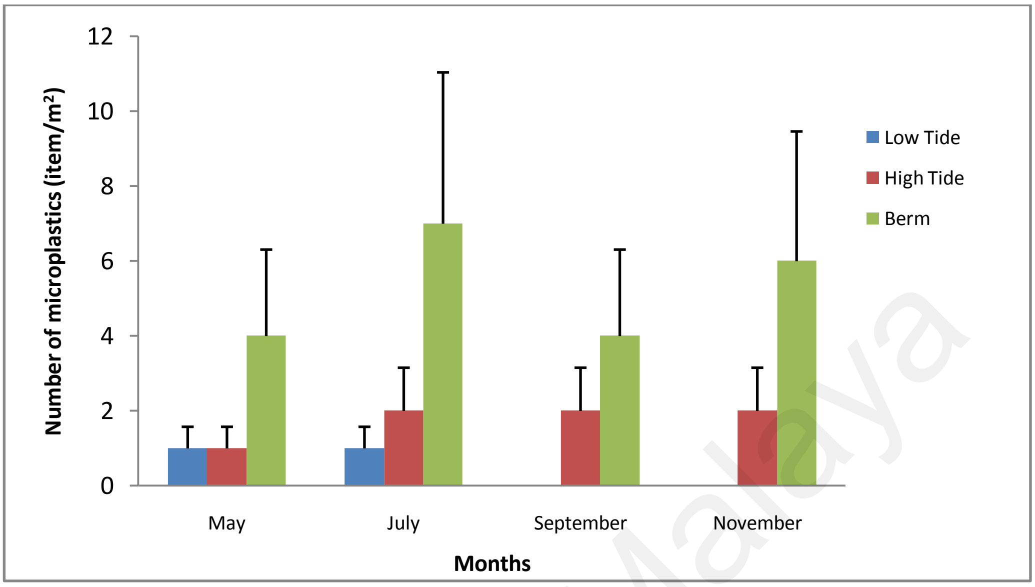

Figure 4.18: Quantity of microplastics according to the tidal zones collected from beaches that face the mainland

The results indicate that the microplastic is the highest along the berm area of Pulau Besar that face the mainland (21 items/m^2) followed by high tide and the low tide areas.

Berm area accumulates more microplastic than high tide and low tide shoreline. Commonly, the berm is heavily used by beachgoers during picnicking activities as it composed of vegetated backshore. In November, the higher quantity of microplastic were buried along the berm area. Lightweight debris especially foam were blown by wind from water‟s edge to the beach surface before gotten buried in the sands. Also, the abundance of microplastic along the low tide shoreline in May and July might be due to the presence of heavy-weight debris such as line and fragment on the beach surface. According to Thornton and Jackson (1998), heavier debris is usually deposited at the low tide and high tide shoreline. It can be noted that characteristics of plastic debris also influence the transport of debris items in the study area (Thiel *et al.,* 2013).

(c) Abundance of Microplastic According to Size

Figure 4.19 shows the quantity of microplastic (items/m^2) according to size.

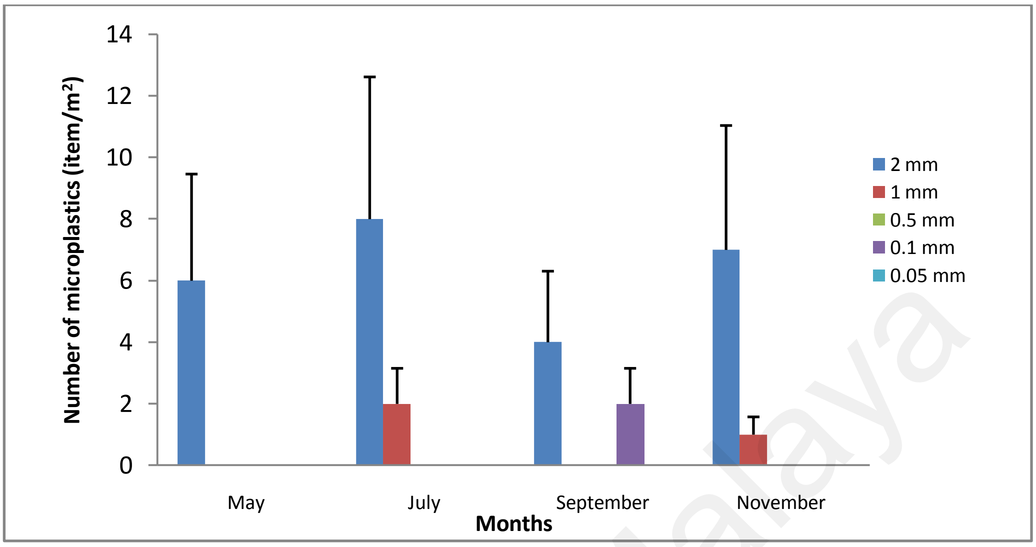

Figure 4.19: Quantity of microplastics according to size collected from beaches that face the mainland

The results showed that the most predominant size of microplastic on this beach was 2.00 mm, followed by microplastic at 1.00 mm and 0.1 mm. It is believed that the large amount of plastic waste undergo degradation process on the beach after certain period of time thus reduced the physical size of plastic (Santos *et al.*, 2009; Gregory & Andrady, 2003). Therefore, due to its smaller particle, it has been receiving increased attention because of the hazards posed to marine organism (Weinstein *et al.,* 2016). Hence, further action should be taken to reduce the amount of plastic waste on the beach.

4.6.2 Pulau Besar (Open Sea)

(a) Classification of Microplastic

Figure 4.20 shows the number of film, foam, fragment, line and pellet (item/m^2) in areas of Pulau Besar that face the open sea.

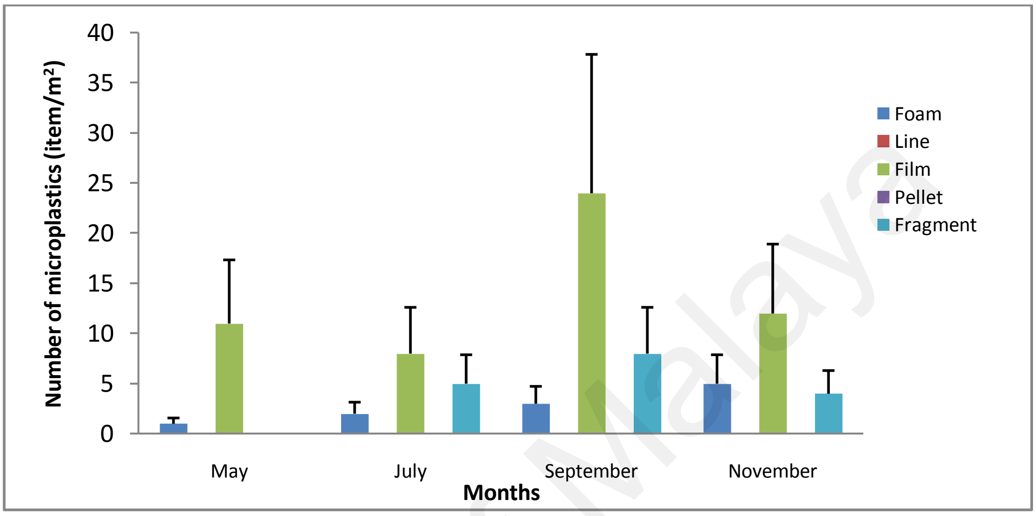

Figure 4.20: Quantity of microplastics collected from beaches that face the open sea

Film, fragment and foam were accounted as the most abundant types of microplastic found in Pulau Besar that face the open sea. The quantity of these microplastic were 55 items/m^2, 17 items/m^2, and 11 items/m^2, respectively. No line and pellet plastics were found.

Recreational and picnicking activities may be the reason for the abundance of microplastic found in Pulau Besar that face the open sea. These observations are supported by previous study by Sarafraz *et al.* (2016), who attributed the presence of beach debris to tourism and recreational activities. The main reason for the pronounced presence of fragments may be attributed to indiscriminate use of hard plastic components such as drinking bottles, detergent bottles and toys. Plastic film is believed to originate from plastic bags that were discarded by beachgoers. These types of plastics may originate from restaurants and food stalls nearby the beach that often care less about proper waste disposal.

Another source of microplastic in this study area might be contributed by the speed boat from mainland to Pulau Besar. It is estimated that the boaters may discard plastic debris overboard which will continue to float till washed ashore by the wave and sea current. As a result, this plastic debris may be degraded into smaller pieces and got deposited on the beach. Other study also had reported that boating activities within the study area may be the source of microplastics like film as similarly found in Pulau Semakau and Pulau Ubin (Mohamed Nor & Obbard, 2014).

Littering of plastic waste by visitors is one of the contributing factors to the abundance of microplastic on beaches that face the open sea. Hence, there is an urgent need to find ways to reduce the abundance of microplastic in these beaches. The most significant strategies to mitigate this problem are to scale down the use of plastic materials, and to implement mandatory and smart recycling system for the beach users.

(b) Abundance of Microplastic According to Tidal Zones

Figure 4.21 shows the quantity of microplastic according to the tidal zones.

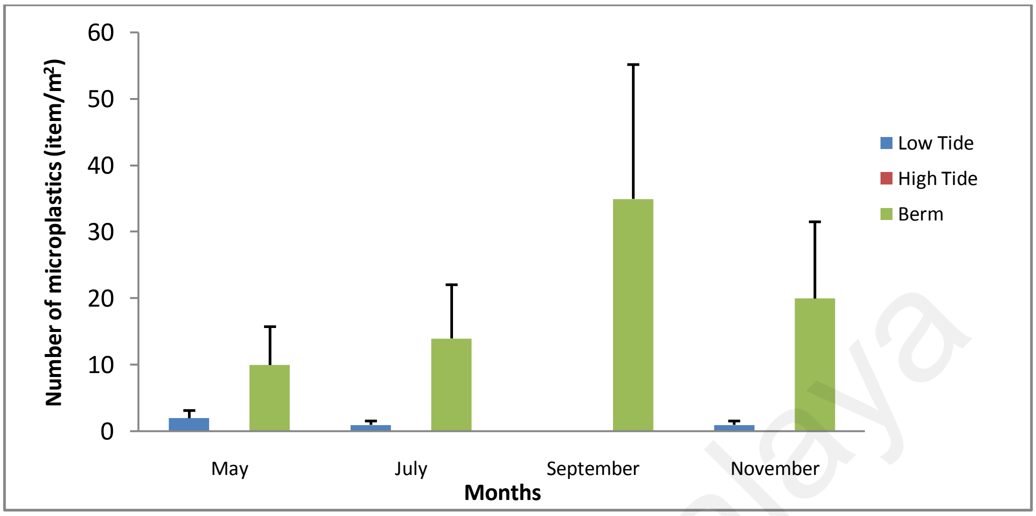

Figure 4.21: Quantity of microplastic according to the tidal zones collected from beaches that face the open sea

Based on the result, microplastic along the berm area on beaches that face the open sea is the highest, followed by low tide area. However, there was no microplastic found along the high tide shoreline. This situation was similar to previous study area that face the mainland where berm area recorded the highest abundance of microplastic.

The lightweight debris such as foam can be easily transported with the aid of winds before being deposited at the berm. This phenomenon was also reported in Cape Town beaches in South Africa (Thornton & Jackson, 1998). Some of heavier debris such as fragment was found accumulated at the low tide shoreline where movement of debris will be reduced once trapped in the sands (Liyana, 2012).

(c) Abundance of Microplastic According to Size

Figure 4.22 shows the quantity of microplastic (items/m^2) according to size.

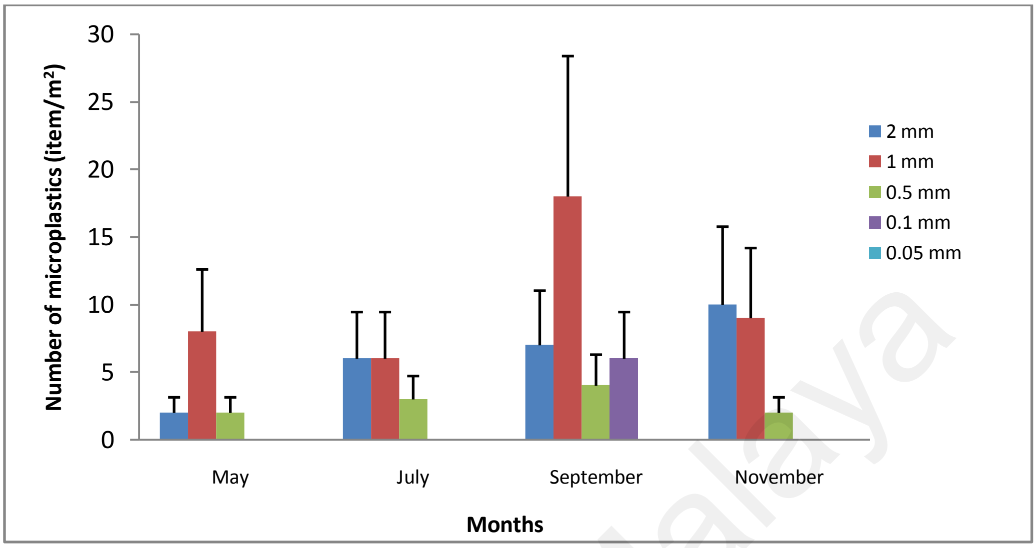

Figure 4.22: Quantity of microplastic according to size collected from beaches that face the open sea

On the beach of Pulau Besar that face the open sea, 1.00 mm microplastic was the most abundant, followed by 2.00 mm, 0.5 mm and 0.1 mm microplastic.

When plastic waste is exposed to environmental conditions, it begins to degrade slowly (Tosin *et al.,* 2012). Degradation process is believed to make larger plastic items more brittle to fragment into microplastic on beaches that face the open sea. These microplastics are potentially the most dangerous for the environment (Andrady, 2011; GESAMP, 2015).

4.6.3 Penarak Beach

(a) Classification of Microplastic

Figure 4.23 shows the number of film, foam, fragment, line and pellet (item/m^2) in Penarak Beach.

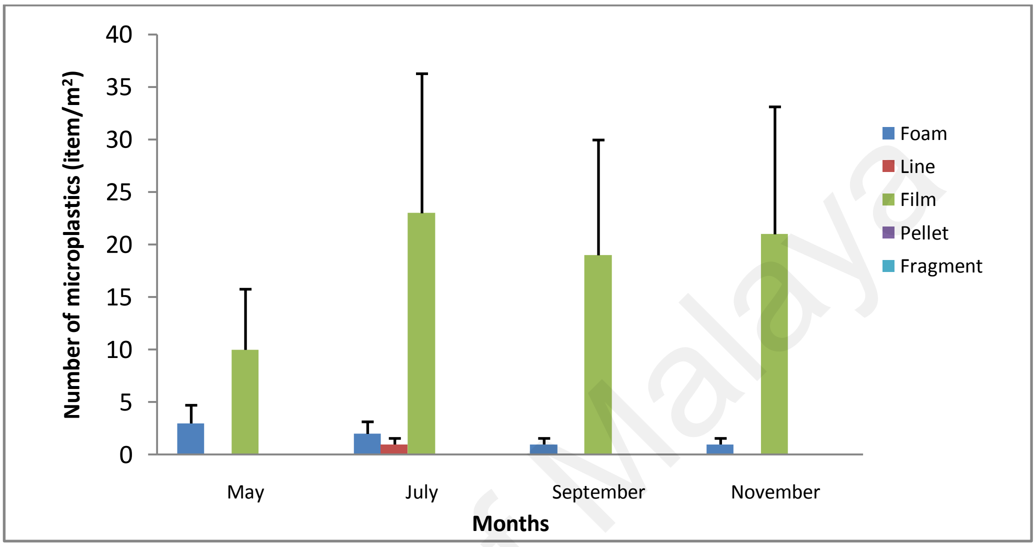

Figure 4.23: Quantity of microplastics in Penarak Beach

The most common types of microplastic found throughout the sampling events were film, foam and line plastics. No fragment and pellet were found in this study area. Film was dominant (73 items/m^2), followed by foam (7 items/m^2), and line plastics (1 items/m^2).

Eventhough Penarak Beach is a popular fishing beach in Langkawi Island, plastic line was the least abundant microplastic found in this study area. The collection of larger plastic waste especially fishing line, nets and ropes during clean-up activity reduce the possibility of these line plastic from being fragmented into microplastic size.

Styrofoam fishing crates and styrofoam bait boxes is believed to be discarded by fishermen once they are damaged. These styrofoam items were then broken down into smaller pieces of foam in the sea before being deposited onto the beach. In addition, some household items such as plastic bags and food wrapper were also discarded by fishing villagers along the beach area and were carried onto the beach via drainage system. Hence, it can be indicated that plastic waste found in Penarak Beach may have been generated from different sources such as fishing activities, recreational activities, and waste disposal by local villagers along the beach.

(b) Abundance of Microplastic According to Tidal Zones

Figure 4.24 shows the quantity of microplastic according to the tidal zones.

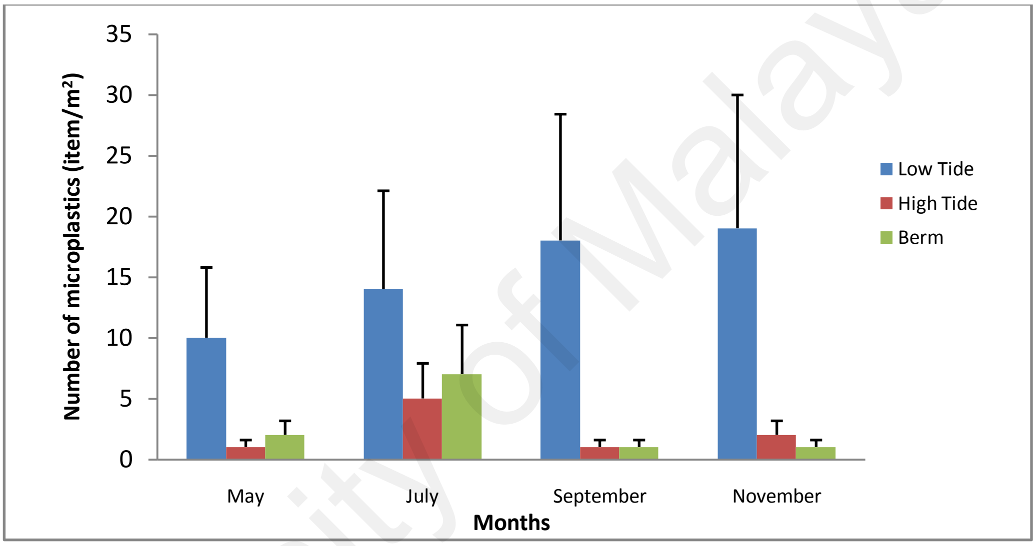

Figure 4.24: Quantity of microplastic according to the tidal zones in Penarak Beach

The most abundant microplastic was recorded at the low tide shoreline (61 items/m^2), followed by berm area (11 items/m^2), and high tide shoreline (9 items/m^2).

Low tide shorelines of Penarak Beach recorded the highest amount of microplastic perhaps due to the presence of lightweight debris such as film. Besides that, plastic debris along the low tide shoreline tends to accumulate and trap in the sand during tide if these plastic items are not washed out into the sea. Beach *et al.* (1998) reported that at high tide shoreline, debris moved by waves is commonly stranded along the low tide shoreline. The debris will continue to accumulate unless stronger current occur and relocate the debris to another place.

(c) Abundance of Microplastic According to Size

Figure 4.25 shows the quantity of microplastic (items/m^2) according to size.

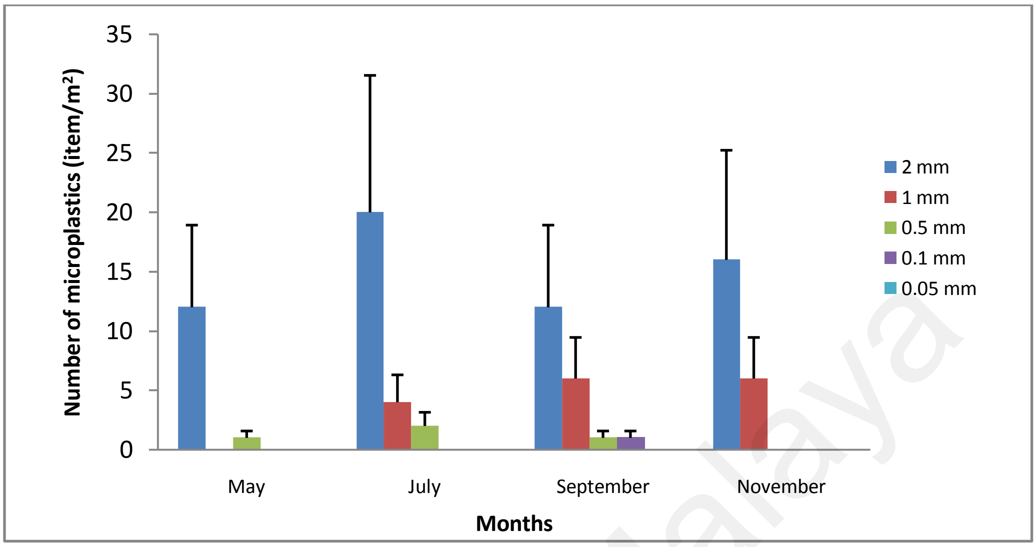

Figure 4.25: Quantity of microplastics according to size in Penarak Beach

The results showed that in Penarak Beach, 2.00 mm microplastic was the most abundant size of microplastic followed by 1.00 mm, 0.5 mm and 0.1 mm. Similar result was recorded in Pulau Besar where the largest size classes (>2.00 mm) was recorded as the most abundant.

Microplastics in this study area were mainly from the breakdown of larger plastic debris. This larger plastic debris will gradually lose its mechanical integrity when it undergoes weathering and degradation. The degradation of plastic debris on the beach is believed to be much faster that than in water mainly due to the high temperature and strong UV radiation on the beach surface (Andrady, 2015).

4.6.4 Tengah Beach

(a) Classification of Microplastic

Figure 4.26 shows the number of film, foam, fragment, line and pellet (item/m^2) in Tengah Beach.

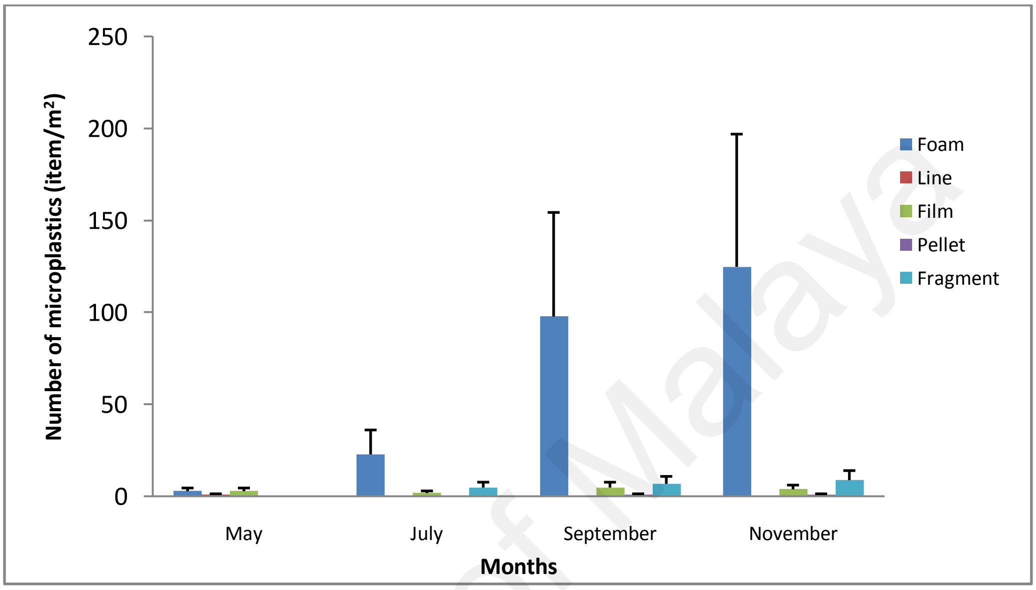

Figure 4.26: Quantity of microplastic in Tengah Beach

Foam was the dominant type of microplastic found in Tengah Beach (249 items/m^2). This is followed by fragment (21 items/m^2), film (14 items/m^2) and pellet (2 items/m^2). Line plastics only make up a small number (1 items/m^2) in Tengah Beach.

The presence of assorted type of microplastic in Tengah Beach is believed to be originated from picnicking activities by beachgoers. Beachgoers often discarded large plastic debris such as plastic bag (film), polystyrene food container (foam), and drinking bottles (fragment) along the beach. This is supported by the study by Mehlhart and Blepp (2012), that microplastics appeared to be sourced from shoreline and recreational activities such as general littering or beach-picnicking.

In addition, the varieties of microplastic found in this study area may have resulted from stronger wave movement which may have brought in plastic debris from the sea onto the beach. Although Environment Idaman is the responsible authority to ensure the cleanliness of Tengah Beach and other popular beaches in Langkawi Island, microplastic buried in the sand may not be collected during the clean-up activity. According to Fauziah *et al.* (2015), regular cleaning alone might not be sufficient to rid the beach from plastic contamination because plastic waste travels from one continent to another by the sea. Similar finding was also found in Kauai beach, Hawaii where small pieces of plastic waste still exist even after clean-up event was regularly conducted (Cooper & Corcoran, 2010).

As for the presence of plastic pellet which was found in the third and fourth sampling, it was noted that this study area may probably be influenced by strong waves and sea current that transported these microplastic onto the beach. This is supported by the observations of Takada *et al.* (2010) which highlighted that pellets tend to accumulate on beaches due to the action of waves and currents.

(b) Abundance of Microplastic According to Tidal Zones

Figure 4.27 shows the quantity of microplastic according to the tidal zones.

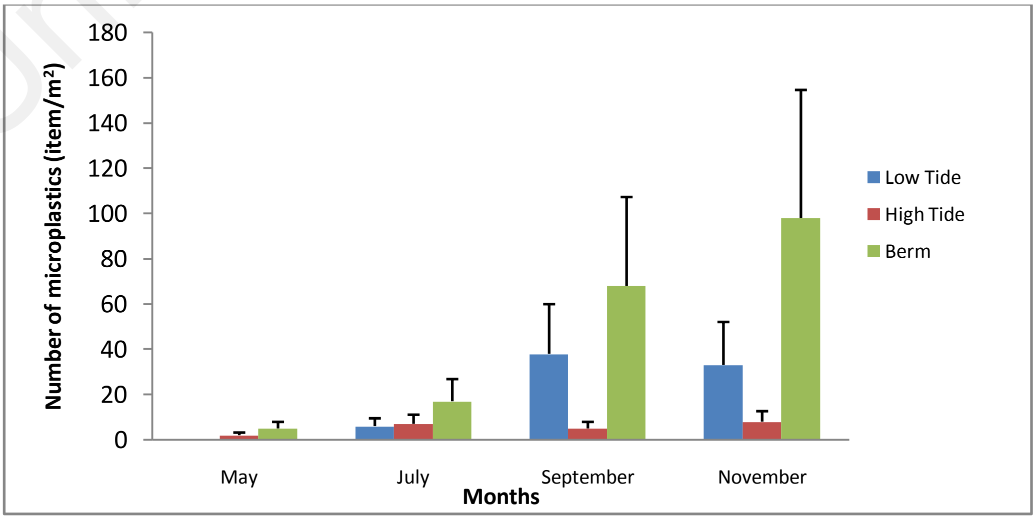

Figure 4.27: Quantity of microplastic according to the tidal zones in Tengah Beach

The results indicate that the microplastic buried along the berm area in Tengah Beach is the highest (188 items/m^2), followed by low tide and the high tide areas.

The most crucial zone where visitor spend their time is the berm area which would be the site for them to discard plastic waste carelessly (Liyana, 2012). Similar observation was found in this study area where beachgoers often spend their leisure time and enjoy picnicking along the berm area. In addition, berm area usually receives lower wave thus microplastic tends to accumulate in the sands. However, in the third and fourth sampling events, the greater quantity of microplastics was found perhaps due to the strong waves which move them to the upper part of the beach.

(c) Abundance of Microplastic According to Size

Figure 4.28 shows the quantity of microplastic (items/m^2) according to size.

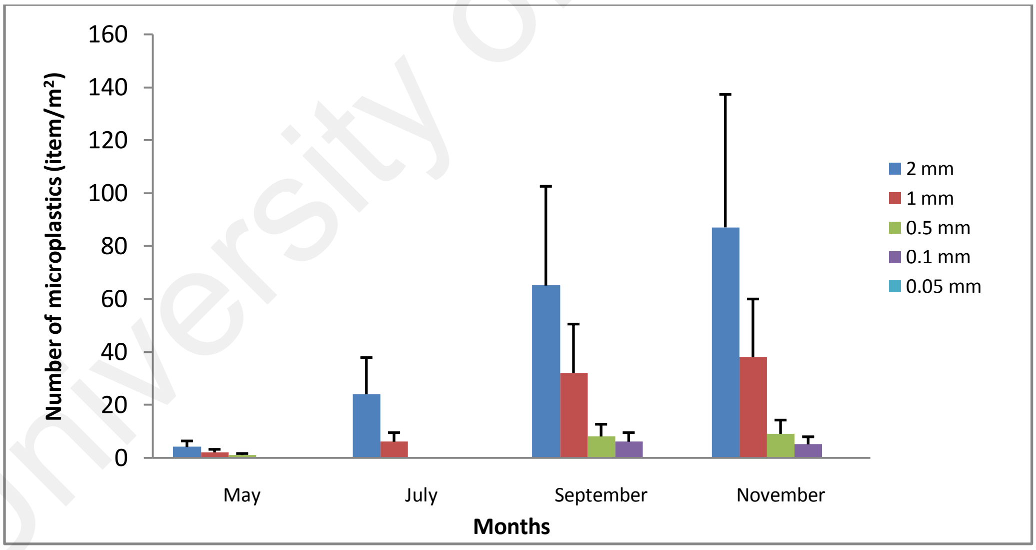

Figure 4.28: Quantity of microplastic according to size in Tengah Beach

The results showed that the most predominant size of microplastic in this study area was 2.00 mm, followed by microplastic at 1.00 mm, 0.5 mm and 0.1 mm.

The degradation of larger plastics caused the occurrence of various size of plastic debris due to the physical and mechanical degradation of plastics as found in Tengah Beach. As microplastics are often in the same size range as some plankton, it risks serious threat to marine biota. As a result, marine organisms are particularly susceptible to microplastic ingestion with indirect consequent effect on organism at higher trophic levels (Bond *et al.,* 2013). Therefore, it is possible that the abundance of microplastic in Tengah Beach can also pose dangerous effect to marine organisms as it is less visible on the beach surface.

4.6.5 Sibu Island (Mainland)

(a) Classification of Microplastic

Figure 4.29 shows the categories of film, foam, fragment, line and pellet (item/m^2) in areas of Sibu Island that face the mainland.

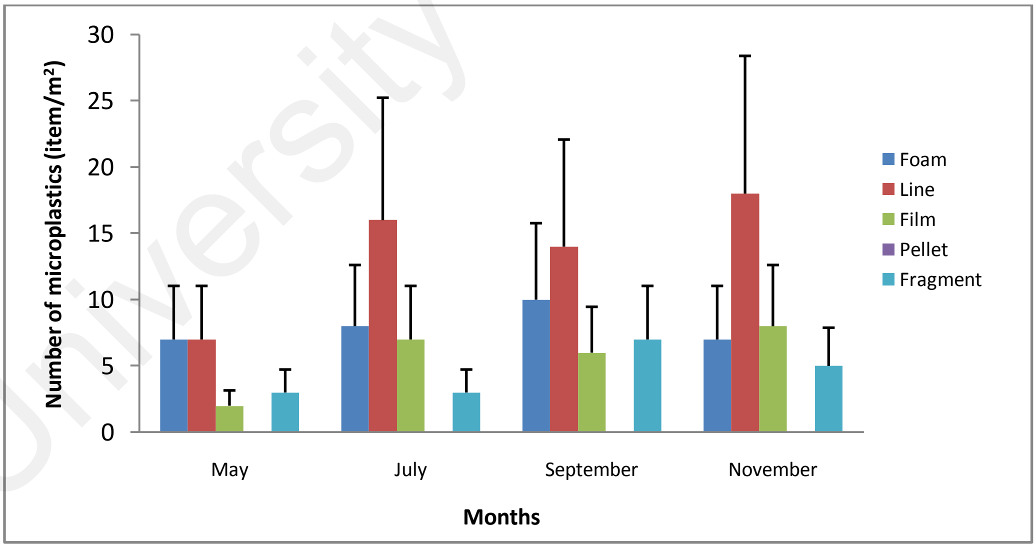

Figure 4.29: Quantity of microplastic collected from beaches that face the mainland

Line, foam, film and fragment were the most commont types of microplastic found in the side of Sibu Island that face the mainland. The quantity of these microplastic were 55 items/m^2, 32 items/m^2, 23 items/m^2 and 18 items/m^2, respectively. The amount of microplastic in the study area will increase after rain events as a result of runoff from urban area where rubbish eventually flow into the river and sea.

The greater number of line plastics found in this study area is believed to originate from fishing equipments such as nets and ropes. This is due to the fact that Sibu Island that face the mainland is known as fishing beach and increased level of line reflects the frequent beach activity. Furthermore, plastic foam may have originated from section of baits or fish boxes discarded by fishermen and fragments of foam packaging material littered by beach users. From the observation, abundance of film and fragment may be attributed by the presence of plastic bags and some household items that were discarded by local villagers along the beach. Similar studies by Mobilik *et al.* (2014), indicates that microplastic may originate from surrounding activity within the beach vicinity or introduced by beachgoers or from local villagers. Thus, larger plastic items may be broken down into smaller pieces before gotten buried in the sands in this study area.

Apart from this, another possibility for the greater abundance of microplastic found in this study area is the natural event. Sea currents and tides also play a significant role to the abundance of microplastic in this study area as Sibu Island receives strong wind and sea current from the South China Sea.

(b) Abundance of Microplastic According to Tidal Zones

Figure 4.30 shows the quantity of microplastic according to the tidal zones.

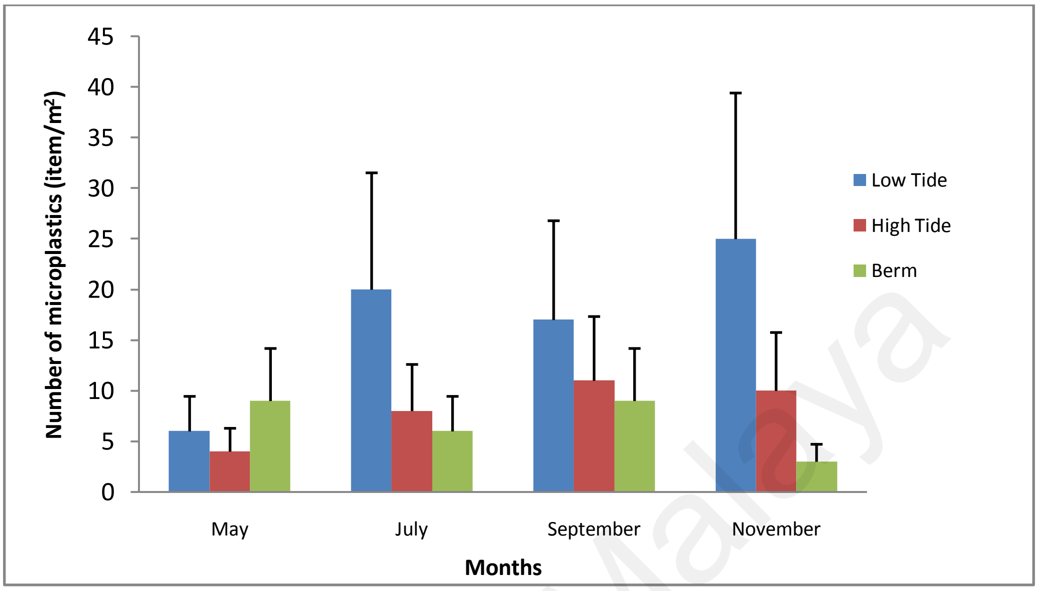

Figure 4.30: Quantity of microplastic according to the tidal zones collected from beaches that face the mainland

The highest number of microplastic in areas of Sibu Island that face the mainland was found at the low tide shoreline (6-25 items/m^2). However, in the first sampling event, the highest abundance of microplastic was found at the berm area (9 items/m^2). This probably is due to the strong wave and winds which move plastic debris to the berm area. Thornton and Jackson (1998) had reported that with the strong wave surges, plastic debris will move to higher places. While in the second, third and fourth sampling events, the presence of heavy weight debris such as line plastic and household items that cannot be transported to the berm area were more abundantly deposited in low tide sands.

(c) Abundance of Microplastic According to Size

Figure 4.31 shows the quantity of microplastic (items/m^2) according to size.

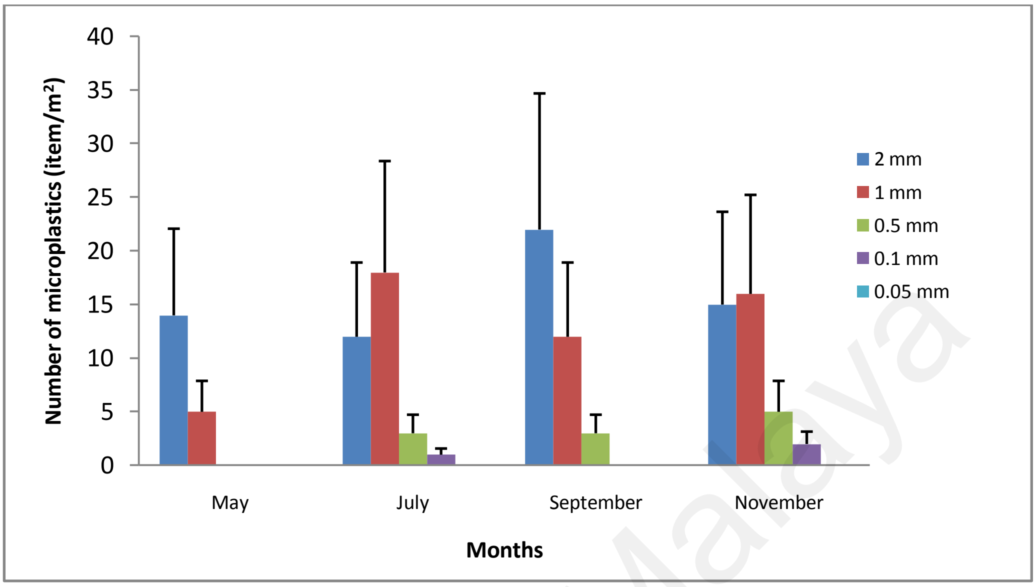

Figure 4.31: Quantity of microplastic according to size collected from beaches that face the mainland

In Sibu Island that face the mainland, microplastic with a size of 2.00 mm was the most abundant, followed by 1.00 mm and 0.5 mm, while 0.1 mm was the least abundant.

The greater abundance of different size of microplastic in Sibu Island that face the mainland might be due to the combination of chemical weathering and mechanically eroding of plastic. The exposure of these plastic wastes to waves after certain period of time results in their degradation, embrittlement and fragmentation (Andrady, 2011). As the size of plastic debris decreases, they can be ingested by wide variety of marine organisms such as sea birds and fishes. Thus, beach clean-up event is important to reduce plastic debris pollution (Agamuthu & Fauziah, 2011).

4.6.6 Sibu Island (Open Sea)

(a) Classification of Microplastic

Figure 4.32 shows the categories of film, foam, fragment, line and pellet (item/m^2) in areas of Sibu Island that face the open sea.

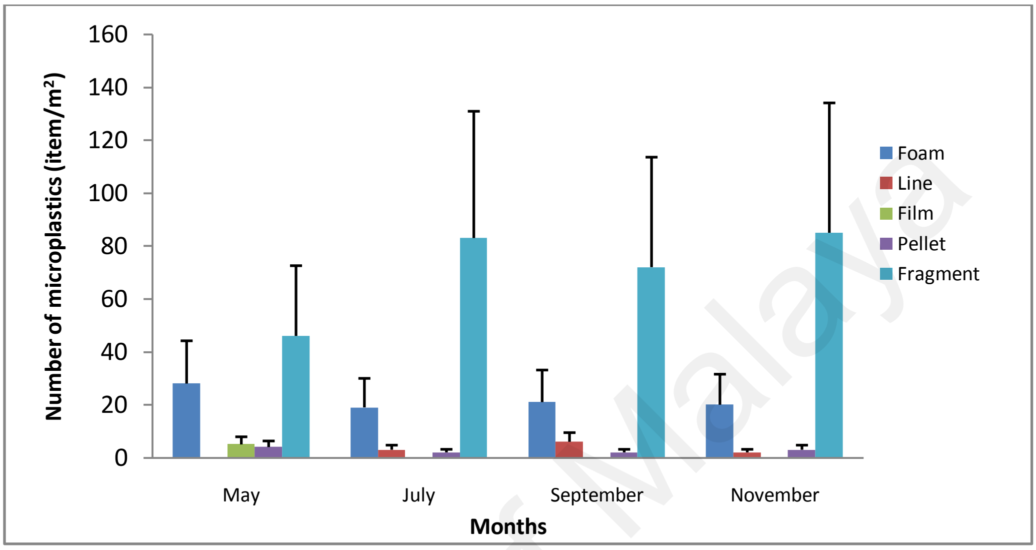

Figure 4.32: Quantity of microplastic collected from beaches that face the open sea

The most dominant type of microplastics found in this study area was fragment plastic (286 items/m^2), followed by foam, pellet and line. In this study area, film plastics were only found during the first sampling events.

The results obtained from the present study show that fragment were the highest component of plastics found in this study area. Due to its heavy weight debris, these plastic fragments may not be transported by waves into the sea thus continues to undergo degradation in the sands. Furthermore, plastic fragments could be originated from hard plastic which comprises of drinking bottles and food container that were disposed by visitor at the beach. Therefore, it can be suggested that recreational activities may be the source of other microplastics like film, line and foam found in this study area.

The quantity of microplastic found during fourth sampling event was the highest (110 items/m^2). Heavy rainfall during monsoon season might have resulted to the high presence of microplastic deposited in the sands. Moreover, this study area is directly facing the sea thus may probably receive floating debris during tides and rough sea. This is in line with other study which reported that the monsoon season acts as an effective carrier of floating debris from the neighbouring country to the Malaysian marine environment (Personal communication with Captain Abdul Malik Hashim, 2012).

Approximately 11 items/m^2 of pellet was found in this study area. These plastic pellets may end up in the oceans from accidental release during ocean transportation. Another important factor to be considered is that, due to the low density of pellets and their small size, high energy events such as monsoon can distribute them onto the beach which is located far from their origin (Pawar *et al.,* 2016). As fronting one of the busiest shipping lanes in South China Sea, the presence of plastic pellets is unavoidable in this study area. Similar studies by Takada *et al.* (2010), reported that the coast along busy shipping routes are more likely to have pellets on its beach due to the heavy shipping activities along the shoreline.

(b) Abundance of Microplastic According to Tidal Zones

Figure 4.33 shows the quantity of microplastic according to the tidal zones

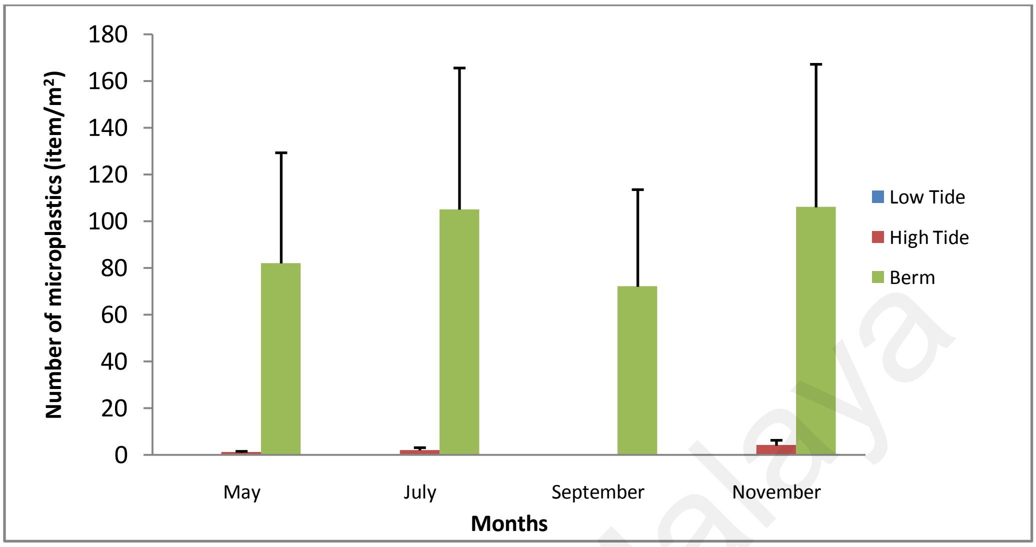

Figure 4.33: Quantity of microplastic according to the tidal zones collected from beaches that face the open sea

In this study area, the most abundant microplastic was recorded at the berm area (365 items/m^2) followed by the high tide shoreline (7 items/m^2).

The greater quantity of microplastic along the berm of this study area probably is due to the littering of plastic wastes by beachgoers. Nevertheless, it can be noted that the amount of microplastic buried along the berm of this study area is not influenced by wave movement but it may probably attributed by human influences. High tide shoreline also contains microplastic buried in the sand due to the abundance of fragment plastics that were left onshore during every receding tide.

(c) Abundance of Microplastic Debris According to Size

Figure 4.34 shows the quantity of microplastic (items/m^2) according to size.

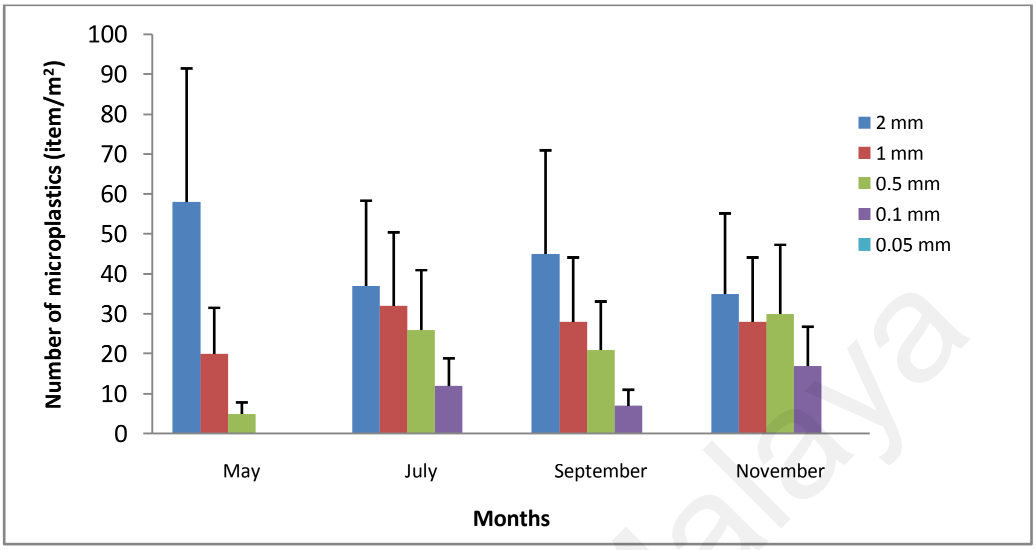

Figure 4.34: Quantity of microplastic according to size collected from beaches that face the open sea

Based on the study conducted, the results showed that microplastic size 2.00 mm was the most abundant followed by 1.00 mm, 0.5 mm, and 0.1 mm.

As macroplastics breaks down into smaller particles, their quantification becomes more difficult. Plastic items in this study area might be subjected to UV radiation, as well as mechanical stress, thus fragmentation processes is likely to occur. Much of the microplastics in the ocean in thought to have been yielded on beaches (Andrady, 2011). Unfortunately, microplastic can also affect marine animals. It is common to find marine birds, turtles and sea mammals died from starvation after ingesting plastic items (Gall & Thompson, 2015). Hence, is it important to develop an effective solution in order to protect Malaysian beaches from being contaminated with plastic debris.

4.6.7 Pinang Seribu Beach

(a) Classification of Microplastic

Figure 4.35 shows the categories of film, foam, fragment, line and pellet (item/m^2) in Pinang Seribu Beach.

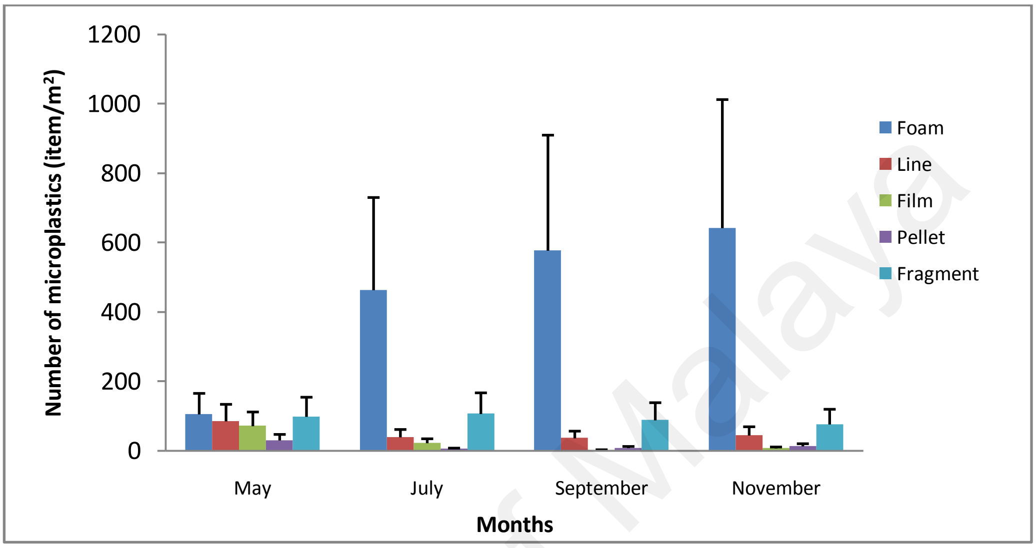

Figure 4.35: Quantity of microplastic in Pinang Seribu Beach

The most common type of microplastic found was foam plastics (1787 items/m^2), followed by fragment (368 items/m^2), line (204 items/m^2), film (102 items/m^2) and plastic pellets (56 items/m^2). More foam was found probably contributed by the North-Eastern monsoon which occur in November. During this season, this study area receives huge wave with incredibly rough sea. Thus, lightweight plastic such as foam can be easily transported onto the beach.

The presence of microplastic in this study area may also be contributed by ocean based sources. These results demonstrate the presence of microplastics in Pinang Seribu Beach even when there are minimum impacts from anthropogenic activities. The presence of microplastic in remote area is due to the oceanic currents, which lead to high dispersion patterns (Martinez *et al.,* 2009). It is most likely that plastics came from adjacent marine area, where ships and fishing boats generate pelagic plastics, which then cast ashore towards the beach by the sea current.

It was found that Pinang Seribu Beach recorded among the highest number of microplastics collected as compared to other beaches. Hence, relative remoteness is not a predictor for lower microplastic concentration. Moreover, Ogata *et al.* (2009) claimed that remote areas of the world‟s shores are becoming site for the preproduction of resin pellets. Therefore, the presence of plastic pellets of different size in this study area could be from accidental spillage from shipping activities which will then get accumulated in the sands.

(b) Abundance of Microplastic According to Tidal Zones

Figure 4.36 shows the quantity of microplastic according to the tidal zones.

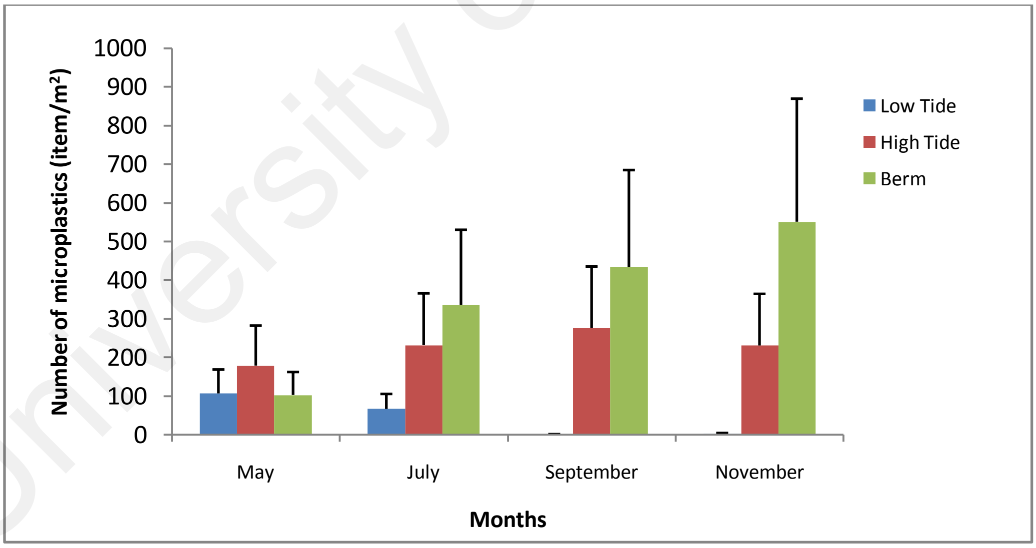

Figure 4.36: Quantity of microplastic according to the tidal zones in Pinang Seribu Beach

The highest number of microplastic in Pinang Seribu Beach was recorded at the berm area (336–551 items/m^2). However, in May, the highest abundance of microplastic was found at the high tide shoreline. This may be due to stronger wave movement during high tide that most of the microplastics are washed onto the beach and left buried. Furthermore, foam plastic was the highest at the berm area since it can move easily with wind and tidal actions. Browne *et al.* (2010) had reported that low density debris may move to the berm area due to the action of wind.

(c) Abundance of Microplastic According to Size

Figure 4.37 shows the quantity of microplastic (items/m^2) according to size.

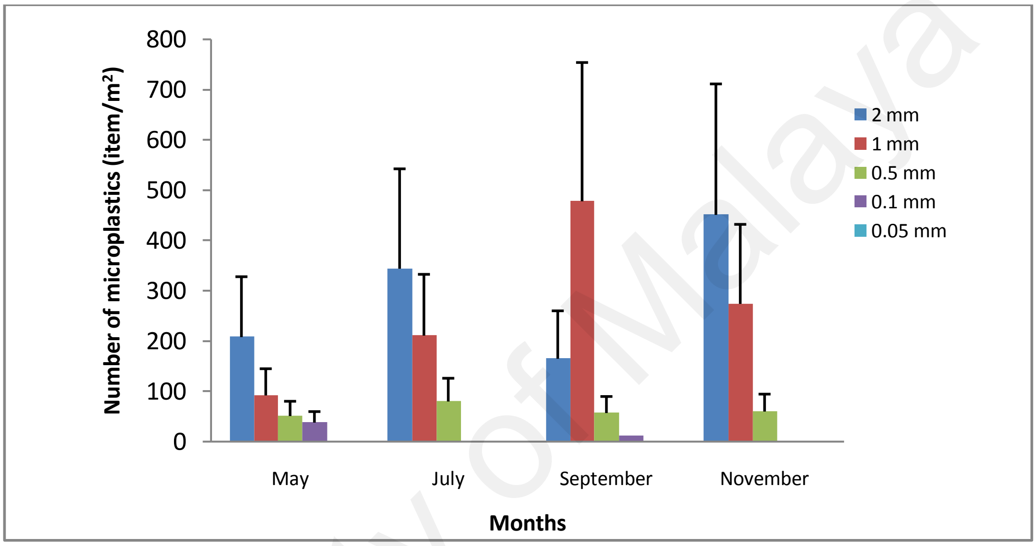

Figure 4.37: Quantity of microplastic according to size in Pinang Seribu Beach

The results showed that the most predominant size of microplastic in this study area was 2.00 mm, followed by 1.00mm, 0.5mm and 0.1mm. However, the largest size of microplastic obtained in September was 1.00 mm. This is believed that microplastic from different size were transported from the sea and deposited in this study area. Photodegradation, oxidation and mechanical abrasion is a great combination that helps to enhance the breakdown of plastic items (Andrady, 2003). Except for polystyrene, plastic take much longer to degrade in water due to lower UV exposure and temperatures.

4.6.8 Tanjung Butong, Beach

(a) Classification of Microplastic

Figure 4.38 shows the categories of film, foam, fragment, line and pellet (item/m^2) in Tanjung Butong Beach.

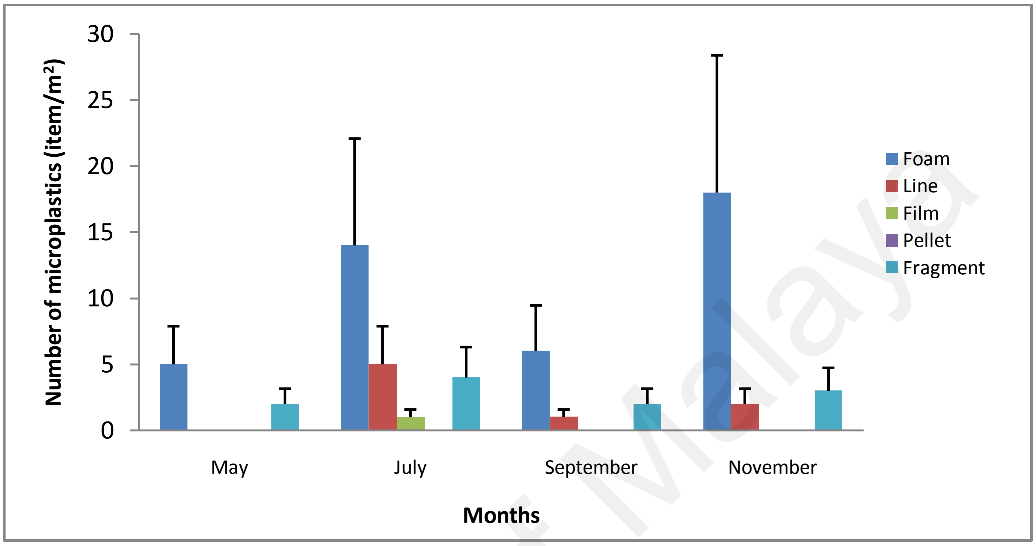

Figure 4.38: Quantity of microplastic in Tanjung Butong Beach

Foam, fragment and line were accounted as the most abundant types of microplastic collected in Tanjung Butong Beach. Plastic film only made up a small number in this study area (1 items/m^2). Eventhough Tanjung Butong Beach is facing the South China Sea which is one of the busiest shipping routes, there was no plastic pellet collected in this study area.

The abundance of various plastic types in this study area might be due to the strong waves that occur heavily during monsoon season that drags the trashes from inland into the sea. Ocean currents spread large amounts of debris from industrialized and densely populated areas to even the most remote and unpopulated coastal regions (McDermid & McMullen, 2004; Barnes *et al.,* 2009; Santos e*t al.,* 2009; Hirai *et al*., 2011).

From the observation, Tanjung Butong Beach was dominated with shell debris. This may be due to the natural strong wave after the monsoon season. Waves moving towards the beach produce a current in the surf zone that pushes the water onshore. This onshore current transports sediments and dead shell in the sediment towards the shore, as well as along the beach (Sverdrup & Armbrust, 2009).

(b) Abundance of Microplastic According to Tidal Zones

Figure 4.39 shows the quantity of microplastic according to the tidal zones.

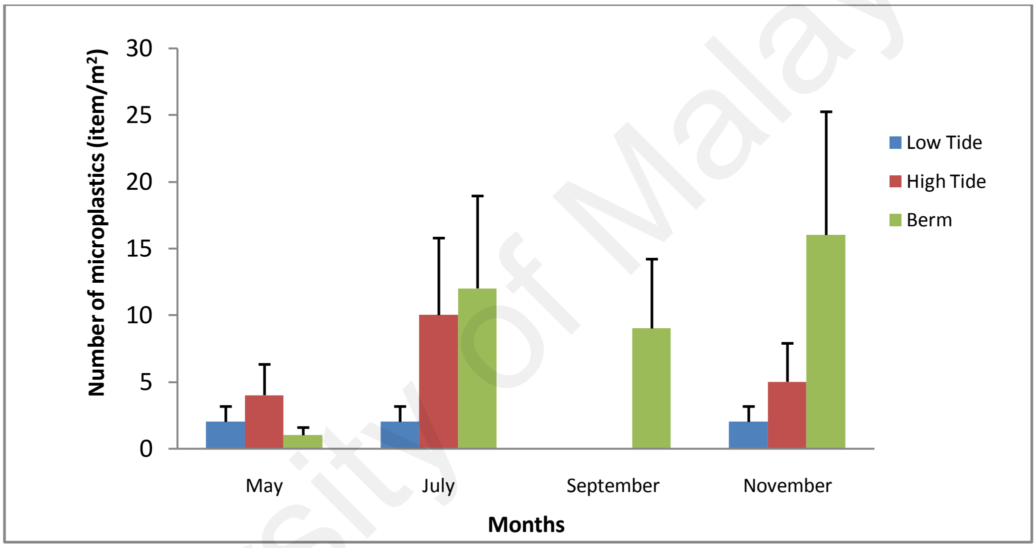

Figure 4.39: Quantity of microplastic according to the tidal zones in Tanjung Butong Beach

Tanjung Butong Beach was dominated with greater number of microplastic at the berm area. However, in the first sampling event, the highest number of microplastic was found from the high tide shoreline as compared to the berm. Similar findings in Pinang Seribu Beach were reported where both of these beaches experienced strong wave during the first sampling event. From the observation, this study area was dominated with shell at the low tide and high tide shoreline. Dead shell and microplastic were transported onto the beach due to the onshore current and wave actions (Liyana, 2012).

(c) Abundance of Microplastic According to Size

Figure 4.40 shows the quantity of microplastic (items/m^2) according to size.

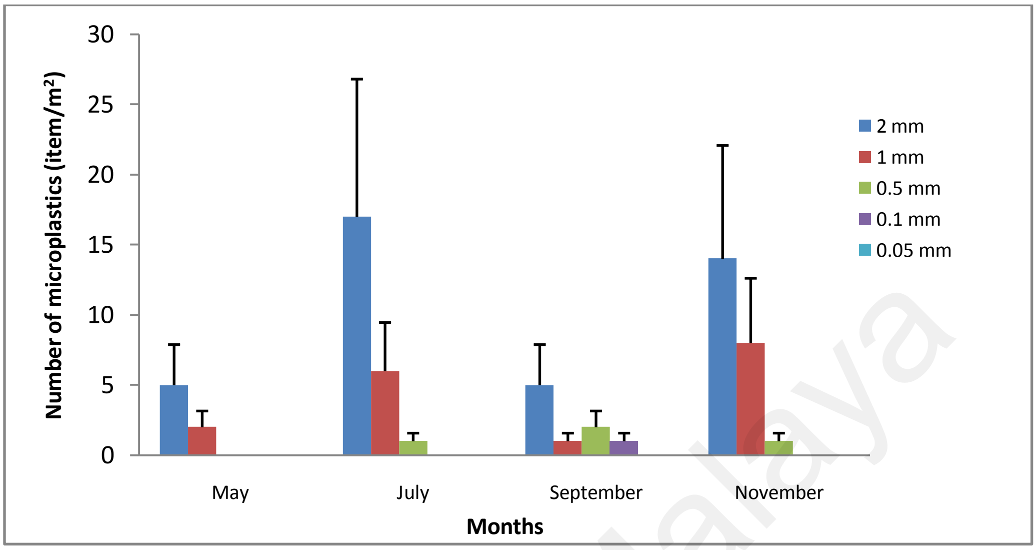

Figure 4.40: Quantity of microplastic according to size in Tanjung Butong Beach

In Tanjung Butong Beach, microplastic namely those at 2.00 mm was the most abundant, followed by 1.00 mm, 0.5 mm and 0.1 mm. Plastic debris in this study area can be smaller in size due to the degradation process that caused losses in useful physical and mechanical properties. Owing to their small size, microplastics can be easily accumulated by planktonic and invertebrate organisms, and being transferred along food chains and finally to human. Since microplastic have the potential to affect marine organism and humans, remediative actions should be taken to reduce the amount of microplastics that are deposited in this study area.

4.7 Comparative Study of the Beaches

Figure 4.41 shows the average quantity of different types of microplastic collected from selected beaches of Malaysian islands (items/m^2).

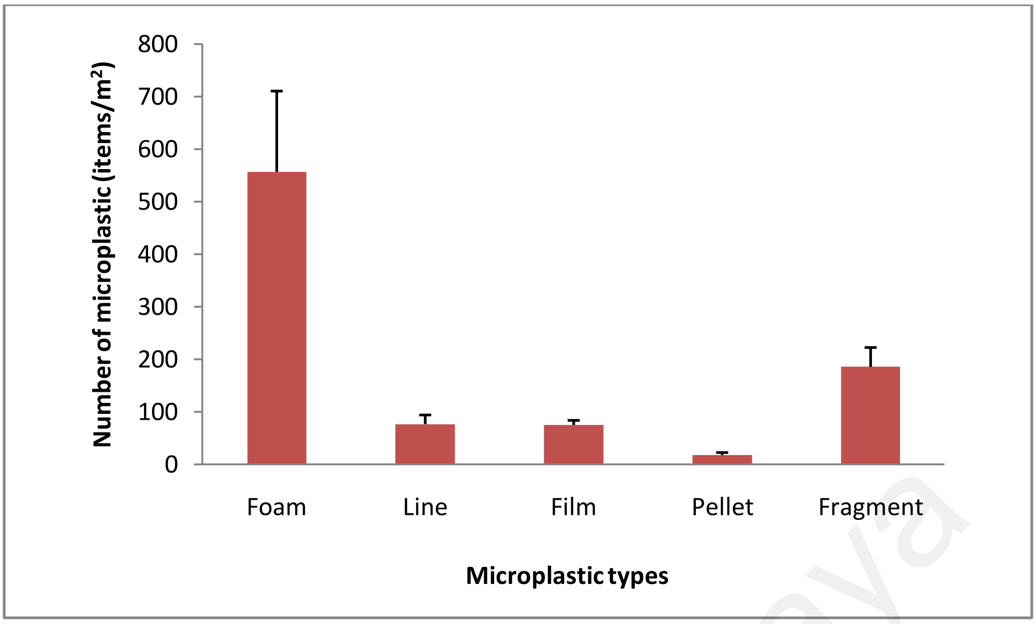

Figure 4.41: Average quantity of different types of microplastic collected from beaches of selected islands

Foam accounted as the most abundant types of microplastic collected (557 items/m^2) from the study areas. Consequently, recreational activities such as beach-picnicking contribute to the greater number of discarded polystyrene food and beverage container along the beach. Besides that, abundant of foam plastic on beaches may also be contributed from fishing activities where styrofoam fishing crates and styrofoam bait boxes may be discarded carelessly by fishermen. In addition, styrofoam has lower density, which can break down more readily than other plastics, accounting for its dominance among the microplastics. Thus, they are more abundant in most beaches.

Fragment was also found to dominate the beaches of Malaysian islands, where 186 items/m^2 were collected. The presence of high number of fragment plastics was assumed to have originated from recreational activities. The indiscriminate use of hard plastic components such as drinking bottles, food container, toys and some household items during picnicking activities had resulted to the deposition of plastic fragment in the sands.

As for the presence of line, this highlight the fact that line plastics were normally found on beaches that are largely dominated by fishing activities. A total of 77 items/m^2 of line plastics were collected from the study area. The use of fishing equipments such as nets and ropes are likely to contribute to the high quantity of plastic line on the beach. Apart from that, the quantity of film plastics collected was 75 items/m^2. The presence of high number of film plastic was believed to originate from plastic bags and food wrapper which were discarded by irresponsible beachgoers during recreational activities.

The least abundant types of microplastic were plastic pellets with only 18 items/m^2 were collected from three study areas namely Tengah Beach, Sibu Island that face the open sea and Pinang Seribu Beach. The distributions of plastic pellets on these beaches depend on the shipping activities where pellets might be accidentally release during ocean transportation. From this study, it can be seen that microplastic are highly exposed to different types of anthropogenic activities (recreational, fishing and shipping) conducted on the beaches.

4.7.1 Comparison between Quantities of Microplastic on Beaches that Face Mainland and Open Sea

Figure 4.42 shows the average quantity of microplastic collected from beaches that face the mainland and open sea.

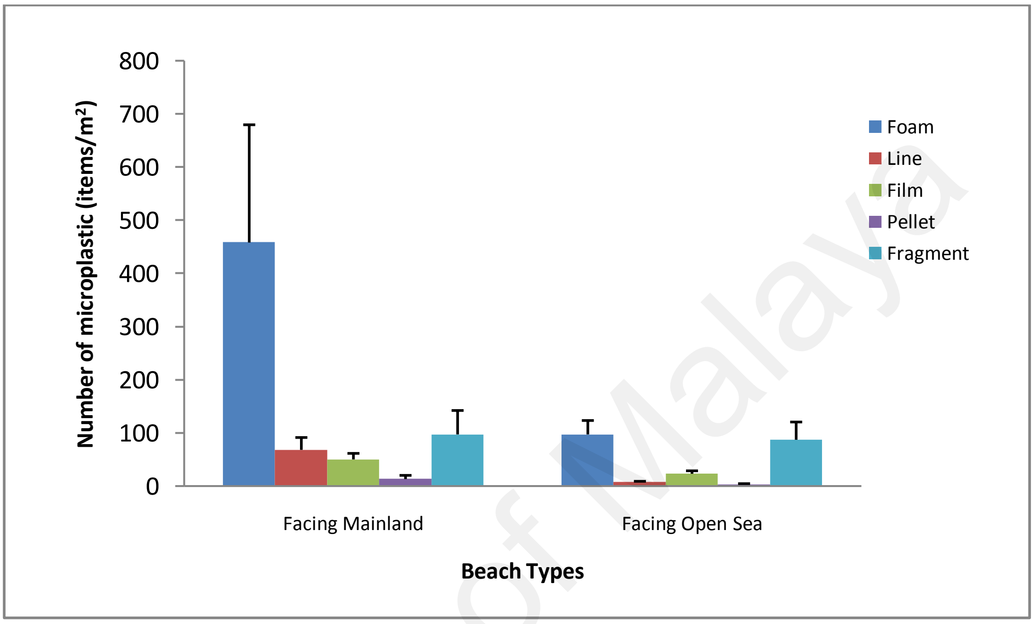

Figure 4.42: Average quantity of microplastic collected from beaches that face the mainland and open sea

The result showed that the highest quantity of microplastic was found on beaches that face the mainland (691 items/m^2) as compared to the beaches that face the open sea (222 items/m^2). The most dominant type of microplastic found in this area is foam plastic, followed by fragment, line, film and plastic pellets. On the other hand, on beaches that face the open sea, more foam and fragment plastics were recorded as compared to other types of microplastics. Plastic pellets only makes up a small number in this study area.

The presence of high number of microplastic on beaches that face the mainland might be from different type of anthropogenic activities on the mainland. The rapid development of housing area, jetty and restaurant which is located adjacent to the beach may also be contributing to the abundance of microplastic in this study area. In addition, the use of fishing nets and ropes by nearby local villagers on the mainland could possibly attribute to the high number of line plastic deposited in the sands. Eventhough most of the beaches that face the mainland were not located along the busy shipping routes, it is unavoidable to have pellets on the beaches (Turra *et al.,* 2014). Besides that, debris from inland sources may possibly be transported with the aids of wind and storm water runoff into the drainages system (Armitage & Rooseboom, 2000). This debris have a high potential to travel long distances via river and sea current which then eventually deposited onto the beaches (Derraik, 2002).

The result showed a least number of microplastic buried on beaches that face the open sea. This is due to the location of the beaches which are exposed to more intense wave current and tides (Fauziah *et al.,* 2015). As a result, it is expected that most of plastic debris that were accumulated on the beaches will be washed ashore onto the sea. As in the case of these beaches, disposal of waste from inland may not influence the deposition of debris since most debris deposited on the beaches are transported by the waves. For examples, Pinang Seribu Beach and Tanjung Butong beach experienced strong wave and wind during the sampling events.

4.7.2 Comparison between Quantities of Microplastic on Beaches along the West Coast and East Coast of Peninsular Malaysia

Figure 4.43 shows the average quantity of microplastic collected from beaches along the West Coast and East Coast of Peninsular Malaysia.

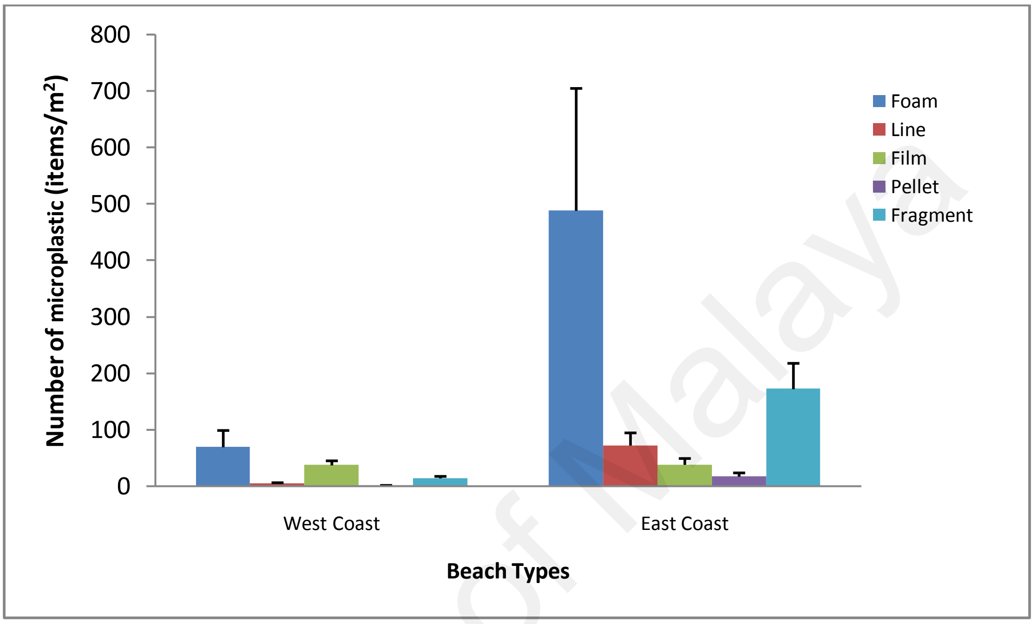

Figure 4.43: Average quantity of microplastic collected from beaches along the West Coast and East Coast of Peninsular Malaysia

Based on this study, a total of 787 items/m^2 of microplastic were collected from beaches at the East Coast of Peninsular Malaysia and 126 items/m^2 of microplastic were collected from the beaches at the West Coast of Peninsular Malaysia. Foam (488 items/m^2), fragment (172 items/m^2) and line plastics (72 items/m^2) were accounted as the most abundant types of microplastic on beaches along the East Coast of Peninsular Malaysia. This is followed by film (38 items/m^2) and plastic pellets (17 items/m^2). Meanwhile as for another study area which located along the West Coast of Peninsular Malaysia, the most common types of microplastic debris collected on beaches were foam (69 items/m^2), film (37 items/m^2) and fragment (14 items/m^2). Plastic line and pellets only makes up a small number in this study area with 14 items/m^2 and 2 item/m^2, respectively.

The highest number of microplastic collected at the East Coast of Peninsular Malaysia is probably contributed by the North-Eastern monsoon season that occurs yearly. Ribic *et al.* (2010) had reported similar findings where plastic debris can be found after period of rough weather such as storms and rain. Since all the study areas along this coast are exposed to the South China Sea which is one of the busiest shipping lanes, the distribution of plastic pellets could be high. As a result, it can be noted that the abundance of microplastic collected on beaches along the East Coast of Peninsular Malaysia depends on natural factor such as monsoon season, sea currents, wind and wave, as well as, recreational and fishing activities in the study areas.

Unlike the beaches which are located along the West Coast of Peninsular Malaysia, these beaches often receive a high number of visitors as compared to the beaches located along the East Coast of Peninsular Malaysia. From the observation, the number of microplastic in the study areas were associated with varieties types of anthropogenic activities took place on the beaches. However, it can be seen that proper waste management such as regular clean-up programme by responsible authorities and villagers contribute to the lower number of microplastic collected in the study areas. Pasternak *et al.* (2017) also had reported a similar finding on beaches along the Israeli Mediterranean coast.

4.7.3 Comparison with Literature Studies

Findings from Malaysian beaches indicated that the research exploration related to the issue of microplastics is still limited. To the best of our knowledge, there are several studies documenting the occurrence of microplastic in Malaysia such as in mangrove sediment (Barasarathi *et al.,* 2014), sandy beaches (Noik & Tuah, 2015; Liyana, 2012), bivalves (Ibrahim, 2016), marine waters (Khalik *et al.,* 2018) and estuary fishes (Yusof *et al.,* 2017). Indeed, there have been no studies documenting the microplastics on beaches of Malaysian island. Extensive and in-depth studies are urgently needed to bridge the knowledge gaps to enable a more comprehensive risk assessment of microplastics in island beaches and to support the development of policy addressing this issue.

Since this study is considered as the first report for island beaches, the occurrence of microplastic was compared with previously documented literature. These studies suggest island beaches are facing similar microplastic accumulation problems as found in the oceans. Many island beaches are habitats for marine species that have important ecological and economic value as well as provide services for recreation, aquatic products and water resources. Therefore it is important to understand the occurrence, fate and effects of microplastics in the island beaches.

The literature reporting the occurrence of microplastics in Malaysia is summarized in Table 4.14. A comparison of data from different study areas can be challenging due to the difference in sampling methods used, size ranges studied and the reporting units that are employed. Therefore, it is urgently needed to adopt universal criteria for sampling and reporting microplastics occurrence data to facilitate a comparison (Phuong *et al.,* 2016).

Additionally, the abundance of microplastics from different study area differs by several order magnitude. This uneven distribution pattern can be related to their relatively low density, which means that they can be transported easily with the waves, wind and current. Previously, Yonkos *et al.* (2014) demonstrated that the abundance of microplastic was positively correlated with anthropogenic activities. However, researchers also demonstrated that microplastics were also found at relatively high concentration from remoted area with limited human activities (Zhang *et al.,* 2016). This is likely due to a lack of proper waste management measures in those areas. This might explain the very high abundance of microplastics in Pinang Seribu Beach. Therefore, island beaches deserve more attention in the future.

Furthermore, it is a great concern about the potential risks that microplastics may pose to organism via ingestion, which is then transferred to food chain and ultimately poses risks to human health. According to Ibrahim (2016), the abundance of microplastics is higher in wild species as compared to the cage-cultured species, which is linked to the dynamic of habitat and feeding activity. Similar situation has been reported by Ibrahim (2016), where the presence of microplastic particles in the lower trophic level organisms such as bivalves is remarkably high. Thus, the ubiquity of microplastics in the upper trophic level was studied to understand the translocation, which could further be found in human body (Yusof *et al.,* 2017).

Table 4.14: Abundance of microplastics in different study area in Malaysia

Study area	Sample type	Size (mm)	Abundance	Main type	References
Sementa Mangrove Forest, Kapar, Selangor	Mangrove sediments	4.75 2.80 1.00 0.5	418 items/m^2	Line, pellet film, foam fragments	Barasarathi *et al.* (2014)
Santubong Beach, Kuching, Sarawak Trombol Beach, Kuching, Sarawak	Beach sediments	1.00	N=100 N=132	Polysytrene Polypropylene Polyethylene Polyethylene terephtalane Nylon, polyurethane	Noik & Tuah, 2015
Teluk Kemang, Pasir Panjang, Batu Burok, Seberang Takir, Tanjung Aru and Teluk Likas Beach	Beach sediments	1 - 30	2542 items/m^2	Line, pellet film, foam fragments	Liyana (2012)
Setiu Wetland, Terengganu	Bivalve tissue	0.12 - 9.5	880 individual	Filaments	Ibrahim (2016)
Kuala Nerus and Kuantan	Marine waters	Not specified	Kuala Nerus (1713 items/m^2) Kuantan (621 items/m^2)	Fragment type, black or grey colour	Khalik *et al.* (2018)
Setiu Wetland, Terengganu	Estuary fishes	4.3 to 15.7µm	4,498 pieces	Threadlike, fragment, spherical	Yusof *et al.* (2017)
Beaches in selected islands in Peninsular Malaysia	Beach sediments	2.00 1.00 0.5 0.1 0.05	3590 items/m^2	Line, pellet film, foam fragments	This report

4.8 Correlation between Distributions of Macroplastics with Microplastics Abundance

Table 4.15 shows the quantity of macroplastic collected from beaches of selected islands in Peninsular Malaysia, while Table 4.16 shows the quantity of microplastic collected in the study area from the four sampling events.

Table 4.15: Quantity of macroplastic (items/m^2) in May, July, September and November 2016 collected in four selected islands

Sampling sites / Months	May 2016 (items/m^2)	July 2016 (items/m^2)	September 2016 (items/m^2)	November 2016 (items/m^2)
Langkawi Island, Kedah	5	12	15	10
Pulau Besar, Malacca	15	16	10	7
Sibu Island, Johor	20	26	23	29
Perhentian Island, Terengganu	27	41	43	52

Table 4.16: Quantity of microplastic (items/m^2) in May, July, September and November 2016 collected in four selected islands

Sampling sites / Months	May 2016 (items/m^2)	July 2016 (items/m^2)	September 2016 (items/m^2)	November 2016 (items/m^2)
Langkawi Island, Kedah	20	56	131	161
Pulau Besar, Malacca	18	25	41	29
Sibu Island, Johor	102	141	138	148
Perhentian Island, Terengganu	396	659	720	805

Based on Table 4.15 and Table 4.16, the quantity of microplastic seemed to be more abundant than the quantity of macroplastics in each islands studied. The distribution of macroplastic and microplastics were found predominant in islands which are located along the East Coast of Peninsular Malaysia as compared to the islands along the West Coast of Peninsular Malaysia. This is because the accumulation of macroplastic and microplastic was influenced by several factors including monsoon season and anthropogenic activities in the study areas. The correlation between the distributions of macroplastics (items/m^2) with microplastics (items/m^2) abundance in Malaysian islands is shown in Figure 4.44.

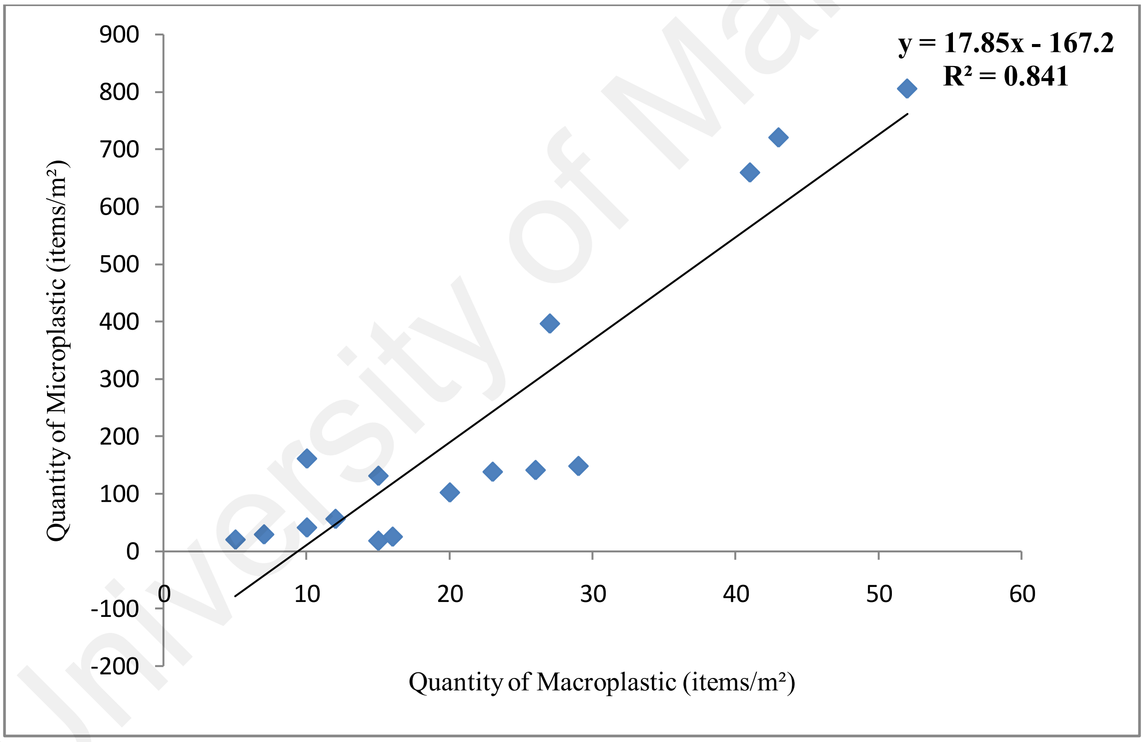

Figure 4.44: Correlation between the distributions of macro-plastics with micro-plastics abundance in Malaysian islands

Based on the results, a positive correlation (0.917) with R^2 = 0.841 was found between the abundance of macro and microplastics on beaches of selected islands in Peninsular Malaysia. This suggests that microplastics were abundant in areas where the macroplastics abundance was high. This is in contrast with Lee *et al.* (2013) who reported that there was a stronger correlation between the abundances of macro- and mesoplastics than that in macro- and microplastics. Langkawi Island and Pulau Besar recorded the lower quantity of macro and microplastic as compared to the beaches in Sibu Island and Perhentian Island. This may be attributed to the availability of waste bins and regular beach clean-up activities conducted along the beach. In contrast, beaches which are located in Sibu Island and Perhentian Island were more prominent with macro- and microplastic debris which might be due to their low tourism value and their remote location. Most of these beaches do not have regular beach clean-up activities except in areas of Sibu Island that face the open sea.

Once deposited on the beach via anthropogenic and natural factors, these large macroplastic will undergo fragmentation process to form tiny microplastic after certain period of time. Studies by Corcoran *et al.* (2009) and Andrady (2015) reported that plastic debris on the beach is exposed to UV radiation and the effects of wind, currents, waves, and tides which will lead to the chemical or mechanical weathering and eventually result in plastic embrittlement. Therefore, it can be indicated that the abundance of microplastic may possibly depend on the distributions of macroplastic discarded on the beach. The issue of marine waste must be addressed urgently in order to prevent the continuous degradation of macroplastic on beaches of Malaysian islands.

4.10 General Discussion

Plastic debris in marine environment is increasingly recognized as an international pollution problem. The impact of anthropogenic activities may pose a serious threat to the marine environment. Thus, this study is important to determine type, distributions and abundance of macro-plastics and micro-plastics on beaches of Malaysian islands. This study revealed that the beaches in Malaysia were fouled with abundance of macro- and microplastic buried in the sands.

From this study, it was found that among all type of marine debris, plastic items which consist of hard plastic, film plastic and polystyrene is obviously the most abundant in almost all study areas. The distribution of plastic debris was found to contribute around 60% to 80% of the total debris in many other studies worldwide (Derraik, 2002). Plastic debris found in the study areas include detergent bottles, drinking bottles, candy wrappers, plastic bags, straws and food packaging items, which were disposed off by beach users.

A total of 3590 items/m^2 of microplastic were collected from all eight beaches from Malaysian island. The greatest quantity was found in Pinang Seribu Beach with 2517 items/m^2, followed by areas of Sibu Island that face the open sea with 401 items/m^2. Other six beaches had lower quantities which ranged from 30 items/m^2 to 287 items/m^2.

From the visual observation, some of the beaches studied have high exposure to anthropogenic activities such as picnicking and water sport activities, where restaurants and chalets are located too. This is illustrated in the high quantity of plastic debris recorded in Tengah Beach, and beach of Pulau Besar and Sibu Island that face the open sea. Although regular clean up event was conducted, the accumulation of microplastic still happens. Therefore, it can be concluded that the beach management may dictate the composition and abundance of plastic debris on beaches. Similar findings were also reported by Liyana (2012), Bravo *et al.* (2009), and Claereboudt (2004).

Furthermore, fishing activities which involve the maintenance of fishing gears such as fishing nets and boats were also expected to be a major affecting factor towards the abundance of macro-and microplastic. A similar situation can be found in areas of Penarak Beach and Sibu Island that face the mainland where most of plastic debris collected are believed to originate from fishing activities. Other types of anthropogenic activities which influence the distribution of plastic debris are shipping activities. Microplastic especially plastic pellet which is believed to be released during transportation were found on the beach.

In addition to that, natural factors such as wind, wave, sea currents and rainy season may also contribute to the greater number of plastic items in the study area. This is in accordance with study by Liyana (2012), where sea currents and tidal waves play an important role in determining the amount of plastic debris. Thus, this study is hoped to be useful as references for future researchers to develop more effective strategies in order to protect the beaches of Malaysian islands from plastic debris pollution.

CHAPTER 5: CONCLUSION

This study was designed to investigate the macro and microplastics abundance on selected beaches in Peninsular Malaysia. The abundance of plastic debris in these study areas were originated from anthropogenic activities (mostly fishing, recreational and shipping) which are land-based and sea-based.

Tengah Beach, areas of Pulau Besar and Sibu Island that face the open sea have a lot of recreational activities such as water sport activities, picnicking and swimming. Fishing activities can be found in areas of Sibu Island and Pulau Besar that face the mainland, and Penarak Beach. Most beaches have shipping activities along their coast except for Pulau Besar beach that face the mainland, Sibu Island and Tanjung Butong Beach. Due to their remoteness from other beaches, Pinang Seribu Beach and Tanjung Butong Beach have low exposure to anthropogenic activities.

In terms of cleanliness, areas of Pulau Besar that face the open sea is the cleanest with the highest BCI value. Tengah Beach, areas of Pulau Besar that face the mainland and areas of Sibu Island that face the open sea are moderately cleaned beaches. However, Penarak Beach, areas of Sibu Island that face the mainland, Pinang Seribu Beach and Tanjung Butong Beach have low BCI value, to be categorized as dirty beaches.

The composition of marine waste on selected beaches in Malaysian islands includes hard plastic, film, polystyrene, paper, and other anthropogenic items, such as aluminium cans and drinking box. The results indicated that composition of marine debris is highly dependable on the different types of anthropogenic activities on the beaches. The highest abundance of marine waste in terms of weight was found in Pinang Seribu Beach (2.228 g/m^2) whereas Tengah Beach recorded the highest abundance of marine waste in terms of number of items (0.155 item/m^2). Pinang Seribu Beach was dominated with high amount of household items and fishing related debris whereas cigarette butts are the most abundant type of marine waste collected in Tengah Beach. The regular beach clean-up activity is important in reducing the abundance of marine waste on these beaches.

From this study, a total of 351 items/m^2 of macroplastic were collected. The quantity of macroplastics was the highest in Pinang Seribu Beach at 103 items/m^2, followed by areas of Sibu Island that face the mainland (76 items/m^2) and Tanjung Butong Beach (60 items/m^2). Pulau Besar, Tengah Beach, areas of Sibu Island that face the mainland and Pinang Seribu Beach have abundant distribution of hard plastic, film and polystyrene. Hard plastic and polystyrene were commonly found in Sibu Island that face the open sea and Tanjung Butong Beach. Penarak Beach has abundant hard plastic and film. Plastic rope were present only in three study areas namely Sibu Island that face the mainland, Pinang Seribu Beach and Tanjung Butong Beach.

A total of 3590 items/m^2 of microplastic were collected from all eight beaches. The greatest quantity was found in Pinang Seribu Beach with 2517 items/m^2, followed by areas of Sibu Island that face the open sea with 401 items/m^2. Other six beaches had lower quantities which ranged from 30 items/m^2 to 287 items/m^2. Pulau Besar that face the mainland, Penarak Beach and areas of Sibu Island that face the mainland have abundant distribution of plastic line, foam and film, whereas film, fragment and foam were accounted as the most abundant types of microplastic collected in areas of Pulau Besar that face the open sea and Tengah Beach. Pinang Seribu Beach and Tanjung Butong Beach had the highest quantity of plastic foam, fragment and line while fragment, foam and pellet are abundantly found in areas of Sibu Island that face the open sea.

Based from this study, a positive correlation (0.917) with R^2 = 0.841 was found between the abundance of macro and microplastics on the selected beaches of Malaysian islands. This suggests that microplastics were found abundant in areas where the macroplastics abundance was high.

Data indicated that the presence of plastic debris would continue to pose serious threat to the human health and marine biota if no immediate action taken to reduce macroplastic and microplastic on beaches of Malaysian islands.

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APPENDICES

Appendix A: Guidelines Principle for Tourism and Recreation Best Practice

Sitting and Development Facilities

1) Areas to avoid

(a) No development should occur on beaches, area where turtle and other endangered species nest or roost,

(b) No development should occur in water catchment area,

(c) Limit facilities to highland areas, well away from sensitive habitats and resource component such as turtle nesting beaches,

(d) Establish buffer zones at beach areas, with ideal minimum setback of 100m from high watermark beyond which building construction may take place,

(e) If development is long term, establish additional buffer zones that will consider the effects and range of influence for sea level rise and storm events,

(f) Avoid development on the very small island or rugged coasts with caves, headlands and high cliffs, and

(g) Avoid breaching cultural and social norms (limit nuisance such as noise).

2) Erosion control

a) Use hard and soft soil erosion control measures,

b) Leave beach strand vegetation as it important for shore stabilization,

c) Maintain and replant vegetation as practical erosion control measures,

d) Avoid cutting down any significant trees, and

e) Consult with the relevant authorizing agency and other experts before designing or commencing any coastal development.

3) **Type of development**

a) Develop low density and low rise tourist accommodation, while providing adequate services and amenities for tourist. For example, frame huts, single storey chalet, and

b) Develop unobtrusive structure that do not dominate their natural surrounding or detract from the intrinsic natural values of the area. Building should be screened by trees.

Facilities and Management

1) **Landscaping**

a) Avoid the use of exotic or introduced new species for landscaping instead of indigenous species.

2) **Use of building materials**

a) Use locally available materials, recycled and non toxic materials as possible, and

b) Construction methods and materials should be design to minimize the impact on the environment.

3) **Energy conservation**

a) Promote the habit of saving electricity among guests. For example, use stickers on the switches to remind guests to switch off lights and equipment when not in use,

b) Use fluorescent lamps or energy saving bulbs for lightning,

c) If air conditioning is used, setting it at a higher thermostat setting while running a ceiling fan,

d) Use natural cross ventilation and ceiling fans and try to avoid air conditioning,

e) Used solar energy and wind energy,

f) Switch off refrigerators when they are not needed, and

g) Ensure all batteries are safely and cleanly disposed off after use.

Freshwater Management

1) Water conservation

a) Provide low flow toilets and low flow showerheads,

b) Catch and recycled rainwater and seawater,

c) Use water efficient showerheads,

d) Check for leaky faucets or leaky tap washers regularly to prevent wastage,

e) Provided proper water treatment system before discharge to sea, and

f) Do not leave taps running when cleaning or washing.

Sewage and Wastewater Management

1) Sewage treatment

a) Use self contained sewage treatment system and treat sewage appropriately, if possible up to tertiary level which would remove all organic matter and nutrients,

b) Make sure septic tanks are placed at appropriate distances, gradients away from source of freshwater and surface runoff,

c) Monitor septic tanks for efficiency and ensure sludge is pumped out at intervals,

d) Utilize a central system and do not allow discharge of sewage into the sea,

e) Keep grey water (effluent from washing operations) and black water (effluent from toilets) streams separate, and

f) Recycled and reuse grey water after it is filtered and disinfected, for non consumption purpose.

Solid Waste Management

1) Waste minimization

a) Minimise waste at source – reduce, reuse, recycle and repair whenever possible. Reducing waste volume makes treatment and disposal easier,

b) Avoid styrofoam and other disposable products such as disposable napkins, cutlery or crockery,

c) Use biodegradable or recycled product packaging, such as paper bags and cardboard or use products need minimal packaging,

d) Provide incentives for guest to return used glass, plastic bottles and cans. For example, by offering small rewards or discounts, and

e) Provide bulk dispensers for shampoo, coffee and sugar rather than packaged single serves.

2) Waste separation and recycling

a) Separate and sort waste into paper, other biodegradable materials, aluminium cans, plastics and glass which that can be sold for reuse and recycling to obtain revenue,

b) Compost organic wastes that can be used as fertiliser – make sure that it is actively managed as compost because it will be smelly and generates methane,

c) Invest or take part in appropriate recycling schemes, and

d) Use products made from recycled materials.

3) Waste removal

a) Take all trash and debris back to shore after visiting reefs and dispose of it in an environmentally sound manner.

4) Litter control

a) Collect litter regularly and provide enough litter bins that are secure,

b) Issuance of fines should be enforced,

c) Make sure guests do not litter and never throw garbage in the water,

d) Encourage visitors to also pick up litter left by other people – a bounty system can be introduced to encourage this. For example, give discounts at souvenir shops or restaurants,

e) Organize beach and underwater cleanups, and

f) Place staff patrol on beaches, especially during peak seasons.

Appendix B: Categories of marine waste

	Type of waste	Weight (g)				Number of item			
		M	J	S	N	M	J	S	N
1	Food waste								
2	Mixed paper								
3	Newspaper / newsprint								
4	Phone directory								
5	Magazine								
6	White paper								
7	Box paper								
8	Hard plastic (HDPE)								
9	Film								
10	Polystyrene								
11	Disposable diapers								
12	Textile								
13	Rubber								
14	Wood								
15	Garden waste								
16	Non-coloured glass								
17	Coloured glass								
18	Metal								
19	Non-metal								
20	Tin								
21	Aluminium cans								
22	Other aluminium								
23	Hazardous waste								
24	Sand/dirt/dust								
25	Other organic waste								
26	Other inorganic waste								
27	Bulky waste								

Appendix C: ANOVA Stastistical Analysis

Table 1: ANOVA Stastistical Analysis of Classification of Microplastic with Months at Pulau Besar that Face the Mainland

Quantity (items/m^2) of debris with months

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
May	5	6	1.2	1.2
July	5	10	2	2.5
September	5	6	1.2	1.2
November	5	8	1.6	4.3
Foam	4	8	2	4
Line	4	12	3	0.666667
Film	4	5	1.25	0.25
Pellet	4	0	0	0
Fragment	4	5	1.25	1.583333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	2.2	3	0.733333	0.508671	0.683711	3.490295
Columns	19.5	4	4.875	3.381503	0.045113	3.259167
Error	17.3	12	1.441667			
Total	39	19				

Table 2: ANOVA Stastistical Analysis of Abundance of Microplastic According to Tidal Zone with Months at Pulau Besar that Face the Mainland

Quantity (items/m^2) of debris with months

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
May	3	6	2	3
July	3	10	3.333333	10.33333
September	3	6	2	4
November	3	8	2.666667	9.333333
Low Tide	4	2	0.5	0.333333
High Tide	4	7	1.75	0.25
Berm	4	21	5.25	2.25

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Rows	3.666667	3	1.222222	1.517241	0.303257	4.757063
Columns	48.5	2	24.25	30.10345	0.000744	5.143253
Error	4.833333	6	0.805556			
Total	57	11				

Table 3: ANOVA Stastistical Analysis of Abundance of Microplastic According to Size with Months at Pulau Besar that Face the Mainland

Quantity (items/m^2) of debris with months

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
May	5	6	1.2	7.2
July	5	10	2	12
September	5	6	1.2	3.2
November	5	8	1.6	9.3
2 mm	4	25	6.25	2.916667
1 mm	4	3	0.75	0.916667
0.5 mm	4	0	0	0
0.1 mm	4	2	0.5	1
0.05 mm	4	0	0	0

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	2.2	3	0.733333	0.715447	0.561479	3.490295
Columns	114.5	4	28.625	27.92683	5.35E-06	3.259167
Error	12.3	12	1.025			
Total	129	19				

Table 4: ANOVA Stastistical Analysis of Classification of Microplastic with Months at Pulau Besar that Face the Open Sea

Quantity (items/m^2) of debris with months

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
May	5	12	2.4	23.3
July	5	15	3	12
September	5	35	7	101
November	5	21	4.2	24.2
Foam	4	11	2.75	2.916667
Line	4	0	0	0
Film	4	55	13.75	49.58333
Pellet	4	0	0	0
Fragment	4	17	4.25	10.91667

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	62.55	3	20.85	1.95928	0.174009	3.490295
Columns	514.3	4	128.575	12.08222	0.00036	3.259167
Error	127.7	12	10.64167			
Total	704.55	19				

Table 5: ANOVA Stastistical Analysis of Abundance of Microplastic According to Tidal Zone with Months at Pulau Besar that Face the Open Sea

Quantity (items/m^2) of debris with months

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
May	3	12	4	28
July	3	15	5	61
September	3	35	11.66667	408.3333
November	3	21	7	127
Low Tide	4	4	1	0.666667
High Tide	4	0	0	0
Berm	4	79	19.75	120.25

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	104.25	3	34.75	0.806576	0.53456	4.757063
Columns	990.1667	2	495.0833	11.4913	0.008872	5.143253
Error	258.5	6	43.08333			
Total	1352.917	11				

Table 6: ANOVA Stastistical Analysis of Abundance of Microplastic According to Size with Months at Pulau Besar that Face the Open Sea

Quantity (items/m^2) of debris with months

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
May	5	12	2.4	10.8
July	5	15	3	9
September	5	35	7	45
November	5	21	4.2	24.2
2 mm	4	25	6.25	10.91667
1 mm	4	41	10.25	28.25
0.5 mm	4	11	2.75	0.916667
0.1 mm	4	6	1.5	9
0.05 mm	4	0	0	0

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	62.55	3	20.85	2.953955	0.075459	3.490295
Columns	271.3	4	67.825	9.609209	0.001011	3.259167
Error	84.7	12	7.058333			
Total	418.55	19				

Table 7: ANOVA Stastistical Analysis of Classification of Microplastic with Months at Penarak Beach

Quantity (items/m^2) of debris with months

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
May	5	13	2.6	18.8
July	5	26	5.2	99.7
September	5	20	4	70.5
November	5	22	4.4	86.3
Foam	4	7	1.75	0.916667
Line	4	1	0.25	0.25
Film	4	73	18.25	32.91667
Pellet	4	0	0	0
Fragment	4	0	0	0

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	17.75	3	5.916667	0.840237	0.497615	3.490295
Columns	1016.7	4	254.175	36.09586	1.34E-06	3.259167
Error	84.5	12	7.041667			
Total	1118.95	19				

Table 8: ANOVA Stastistical Analysis of Abundance of Microplastic According to Tidal Zone with Months at Penarak Beach

Quantity (items/m^2) of debris with months

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
May	3	13	4.333333	24.33333
July	3	26	8.666667	22.33333
September	3	20	6.666667	96.33333
November	3	22	7.333333	102.3333
Low Tide	4	61	15.25	16.91667
High Tide	4	9	2.25	3.583333
Berm	4	11	2.75	8.25

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Rows	29.58333	3	9.861111	1.044118	0.438574	4.757063
Columns	434	2	217	22.97647	0.00154	5.143253
Error	56.66667	6	9.444444			
Total	520.25	11				

Table 9: ANOVA Stastistical Analysis of Abundance of Microplastic According to Size with Months at Penarak Beach

Quantity (items/m^2) of debris with months

SUMMARY	Count	Sum	Average	Variance
May	5	13	2.6	27.8
July	5	26	5.2	71.2
September	5	20	4	25.5
November	5	22	4.4	48.8
2 mm	4	60	15	14.66667
1 mm	4	16	4	8
0.5 mm	4	4	1	0.666667
0.1 mm	4	1	0.25	0.25
0.05 mm	4	0	0	0

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Rows	17.75	3	5.916667	1.339623	0.307711	3.490295
Columns	640.2	4	160.05	36.23774	1.31E-06	3.259167
Error	53	12	4.416667			
Total	710.95	19				

Table 10: ANOVA Stastistical Analysis of Classification of Microplastic with Months at Tengah Beach

Quantity (items/m^2) of debris with months

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
May	5	7	1.4	2.3
July	5	30	6	94.5
September	5	111	22.2	1803.7
November	5	139	27.8	2964.7
Foam	4	249	62.25	3422.25
Line	4	1	0.25	0.25
Film	4	14	3.5	1.666667
Pellet	4	2	0.5	0.333333
Fragment	4	21	5.25	14.91667

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	2399.75	3	799.9167	1.212225	0.347422	3.490295
Columns	11542.3	4	2885.575	4.372912	0.020688	3.259167
Error	7918.5	12	659.875			
Total	21860.55	19				

Table 11: ANOVA Stastistical Analysis of Abundance of Microplastic According to Tidal Zone with Months at Tengah Beach

Quantity (items/m^2) of debris with months

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
May	3	7	2.333333	6.333333
July	3	30	10	37
September	3	111	37	993
November	3	139	46.33333	2158.333
Low Tide	4	77	19.25	362.25
High Tide	4	22	5.5	7
Berm	4	188	47	1902

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	3999.583	3	1333.194	2.842464	0.127831	4.757063
Columns	3575.167	2	1787.583	3.811253	0.085444	5.143253
Error	2814.167	6	469.0278			
Total	10388.92	11				

Table 12: ANOVA Stastistical Analysis of Abundance of Microplastic According to Size with Months at Tengah Beach

Quantity (items/m^2) of debris with months

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
May	5	7	1.4	2.8
July	5	30	6	108
September	5	111	22.2	721.2
November	5	139	27.8	1313.7
2 mm	4	180	45	1428.667
1 mm	4	78	19.5	329
0.5 mm	4	18	4.5	21.66667
0.1 mm	4	11	2.75	10.25
0.05 mm	4	0	0	0

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	2399.75	3	799.9167	3.233075	0.060716	3.490295
Columns	5613.8	4	1403.45	5.672415	0.008438	3.259167
Error	2969	12	247.4167			
Total	10982.55	19				

Table 13: ANOVA Stastistical Analysis of Classification of Microplastic with Months at Sibu Island that Face the Mainland

Quantity (items/m^2) of debris with months

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
May	5	19	3.8	9.7
July	5	34	6.8	36.7
September	5	37	7.4	26.8
November	5	38	7.6	43.3
Foam	4	32	8	2
Line	4	55	13.75	22.91667
Film	4	23	5.75	6.916667
Pellet	4	0	0	0
Fragment	4	18	4.5	3.666667

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	46.8	3	15.6	3.135678	0.065448	3.490295
Columns	406.3	4	101.575	20.41709	2.75E-05	3.259167
Error	59.7	12	4.975			
Total	512.8	19				

Table 14: ANOVA Stastistical Analysis of Abundance of Microplastic According to Tidal Zone with Months at Sibu Island that Face the Mainland

Quantity (items/m^2) of debris with months

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
May	3	19	6.333333	6.333333
July	3	34	11.33333	57.33333
September	3	37	12.33333	17.33333
November	3	38	12.66667	126.3333
Low Tide	4	68	17	64.66667
High Tide	4	33	8.25	9.583333
Berm	4	27	6.75	8.25

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	78	3	26	0.920354	0.485748	4.757063
Columns	245.1667	2	122.5833	4.339233	0.068299	5.143253
Error	169.5	6	28.25			
Total	492.6667	11				

Table 15: ANOVA Stastistical Analysis of Abundance of Microplastic According to Size with Months at Sibu Island that Face the Mainland

Quantity (items/m^2) of debris with months

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
May	5	19	3.8	37.2
July	5	34	6.8	61.7
September	5	37	7.4	90.8
November	5	38	7.6	55.3
2 mm	4	63	15.75	18.91667
1 mm	4	51	12.75	32.91667
0.5 mm	4	11	2.75	4.25
0.1 mm	4	3	0.75	0.916667
0.05 mm	4	0	0	0

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	46.8	3	15.6	1.507246	0.26281	3.490295
Columns	855.8	4	213.95	20.6715	2.59E-05	3.259167
Error	124.2	12	10.35			
Total	1026.8	19				

Table 16: ANOVA Stastistical Analysis of Classification of Microplastic with Months at Sibu Island that Face the Open Sea

Quantity (items/m^2) of debris with months

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
May	5	83	16.6	390.8
July	5	107	21.4	1243.3
September	5	101	20.2	906.2
November	5	110	22	1304.5
Foam	4	88	22	16.66667
Line	4	11	2.75	6.25
Film	4	5	1.25	6.25
Pellet	4	11	2.75	0.916667
Fragment	4	286	71.5	321.6667

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	87.75	3	29.25	0.362791	0.781068	3.490295
Columns	14411.7	4	3602.925	44.68744	4.11E-07	3.259167
Error	967.5	12	80.625			
Total	15466.95	19				

Table 17: ANOVA Stastistical Analysis of Abundance of Microplastic According to Tidal Zone with Months at Sibu Island that Face the Open Sea

Quantity (items/m^2) of debris with months

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
May	3	83	27.66667	2214.333
July	3	107	35.66667	3606.333
September	3	72	24	1728
November	3	110	36.66667	3609.333
Low Tide	4	0	0	0
High Tide	4	7	1.75	2.916667
Berm	4	365	91.25	287.5833

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	342	3	114	1.291785	0.359975	4.757063
Columns	21786.5	2	10893.25	123.4363	1.34E-05	5.143253
Error	529.5	6	88.25			
Total	22658	11				

Table 18: ANOVA Stastistical Analysis of Abundance of Microplastic According to Size with Months at Sibu Island that Face the Open Sea

Quantity (items/m^2) of debris with months

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
May	5	83	16.6	602.8
July	5	107	21.4	230.8
September	5	101	20.2	314.7
November	5	110	22	194.5
2 mm	4	175	43.75	108.9167
1 mm	4	108	27	25.33333
0.5 mm	4	82	20.5	120.3333
0.1 mm	4	36	9	52.66667
0.05 mm	4	0	0	0

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	87.75	3	29.25	0.420863	0.741415	3.490295
Columns	4537.2	4	1134.3	16.32086	8.5E-05	3.259167
Error	834	12	69.5			
Total	5458.95	19				

Table 19: ANOVA Stastistical Analysis of Classification of Microplastic with Months at Pinang Seribu Beach

Quantity (items/m^2) of debris with months

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
May	5	389	77.8	882.7
July	5	635	127	36747.5
September	5	711	142.2	60233.2
November	5	782	156.4	74447.3
Foam	4	1787	446.75	57381.58
Line	4	204	51	524.6667
Film	4	102	25.5	992.3333
Pellet	4	56	14	124.6667
Fragment	4	368	92	168

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	17553.75	3	5851.25	0.438789	0.729393	3.490295
Columns	529222.8	4	132305.7	9.921687	0.000878	3.259167
Error	160020	12	13335			
Total	706796.6	19				

Table 20: ANOVA Stastistical Analysis of Abundance of Microplastic According to Tidal Zone with Months at Pinang Seribu Beach

Quantity (items/m^2) of debris with months

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
May	3	389	129.6667	1829.333
July	3	635	211.6667	18400.33
September	3	711	237	48013
November	3	785	261.6667	75781.33
Low Tide	4	178	44.5	2675.667
High Tide	4	918	229.5	1573.667
Berm	4	1424	356	36172.67

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Rows	29564	3	9854.667	0.644784	0.614015	4.757063
Columns	196346	2	98173	6.423393	0.032266	5.143253
Error	91702	6	15283.67			
Total	317612	11				

Table 21: ANOVA Stastistical Analysis of Abundance of Microplastic According to Size with Months at Pinang Seribu Beach

Quantity (items/m^2) of debris with months

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
May	5	389	77.8	6377.2
July	5	635	127	22153
September	5	711	142.2	39493.7
November	5	785	157	39708
2 mm	4	1168	292	17056.67
1 mm	4	1055	263.75	26096.25
0.5 mm	4	248	62	158
0.1 mm	4	49	12.25	321.5833
0.05 mm	4	0	0	0

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	17738.4	3	5912.8	0.627025	0.611255	3.490295
Columns	317768.5	4	79442.13	8.424471	0.001779	3.259167
Error	113159.1	12	9429.925			
Total	448666	19				

Table 22: ANOVA Stastistical Analysis of Classification of Microplastic with Months at Tanjung Butong Beach

Quantity (items/m^2) of debris with months

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
May	5	7	1.4	4.8
July	5	24	4.8	30.7
September	5	9	1.8	6.2
November	5	23	4.6	57.8
Foam	4	43	10.75	39.58333
Line	4	8	2	4.666667
Film	4	1	0.25	0.25
Pellet	4	0	0	0
Fragment	4	11	2.75	0.916667

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	48.55	3	16.18333	2.214367	0.139133	3.490295
Columns	310.3	4	77.575	10.6146	0.00065	3.259167
Error	87.7	12	7.308333			
Total	446.55	19				

Table 23: ANOVA Stastistical Analysis of Abundance of Microplastic According to Tidal Zone with Months at Tanjung Butong Beach

Quantity (items/m^2) of debris with months

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
May	3	7	2.333333	2.333333
July	3	24	8	28
September	3	9	3	27
November	3	23	7.666667	54.33333
Low Tide	4	6	1.5	1
High Tide	4	19	4.75	16.91667
Berm	4	38	9.5	40.33333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	80.91667	3	26.97222	1.724689	0.260791	4.757063
Columns	129.5	2	64.75	4.14032	0.074167	5.143253
Error	93.83333	6	15.63889			
Total	304.25	11				

Table 24: ANOVA Stastistical Analysis of Abundance of Microplastic According to Size with Months at Tanjung Butong Beach

Quantity (items/m^2) of debris with months

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
May	5	7	1.4	4.8
July	5	24	4.8	52.7
September	5	9	1.8	3.7
November	5	23	4.6	38.8
2 mm	4	41	10.25	38.25
1 mm	4	17	4.25	10.91667
0.5 mm	4	4	1	0.666667
0.1 mm	4	1	0.25	0.25
0.05 mm	4	0	0	0

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	48.55	3	16.18333	1.909538	0.181907	3.490295
Columns	298.3	4	74.575	8.79941	0.001479	3.259167
Error	101.7	12	8.475			
Total	448.55	19				

Table 25: ANOVA Stastistical Analysis of Quantities of Microplastic on Beaches that Face Mainland and Open Sea

Quantity (items/m^2) of debris with locations

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
Facing Mainland	5	691	138.2	33086.7
Facing Open Sea	5	222	44.4	2036.8
Foam	2	557	278.5	65160.5
Line	2	77	38.5	1860.5
Film	2	75	37.5	364.5
Pellet	2	18	9	50
Fragment	2	186	93	50

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	21996.1	1	21996.1	1.934174	0.236676	7.708647
Columns	95004.6	4	23751.15	2.0885	0.246617	6.388233
Error	45489.4	4	11372.35			
Total	162490.1	9				

Table 26: ANOVA Stastistical Analysis of Quantities of Microplastic on Beach along the West Coast and East Coast of Peninsular Malaysia

Quantity (items/m^2) of debris with locations

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
West Coast	5	126	25.2	794.2
East Coast	5	787	157.4	37692.8
Foam	2	557	278.5	87780.5
Line	2	77	38.5	2244.5
Film	2	75	37.5	0.5
Pellet	2	18	9	128
Fragment	2	186	93	12482

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	43692.1	1	43692.1	2.965021	0.160189	7.708647
Columns	95004.6	4	23751.15	1.611794	0.327531	6.388233
Error	58943.4	4	14735.85			
Total	197640.1	9				