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Solid Waste Transportation through Ocean Currents: Marine Debris Sightings and their Waste Quantification at Port Dickson Beaches, Peninsular Malaysia

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Abstract

Four beaches at Port Dickson, Peninsular Malaysia, namely Saujana Beach, Nelayan Beach, Bagan Pinang Beach and Cermin beach have been sampled for marine debris from 7th June 2014 until 26th July 2014, on every Saturday. These beaches face the Strait of Malacca with a coastline stretching 18 km each. Our observations revealed a total debris items of 13193 in those beaches. The top three items of highest frequency were cigarette butts, foamed fragments and food wrappers. Plastic debris scaled high upto 41% of the total debris. Compared to the ocean conservancy's 2013 report of marine debris in Malaysian beaches, which was 27,005 items with in 6.44 km, the current count is slightly low. However, Malaysia was ranked 14th place among the top 20 countries in International Marine Debris Watch program. Nelayan Beach is the dirtiest beach in Port Dickson. Around 50% of the total plastic items collected are found on those beaches. The marine debris items indicated that they arrived there by land-based and ocean-based activities. High energy conditions such as wind and waves in the beaches correlated well with less debris deposition on the beaches. With debris equivalent of 4193 items/km, Malaysia harvests less solid wastes compared to Croatia, USA, Singapore and Turkey. However, a nation wide survey is needed to assess the seriousness of marine debris problem in Malaysia.

Keywords: marine debris; plastic pollution; beach watch; solid waste; transportation

1. Introduction

Marine debris is an important pollution problem in the world's oceans and waterways today (Jambeck *et al*., 2015). Hence it is vital to compare debris sources, amounts, locations, movement, and impacts across Malaysia and nearby countries. Marine debris pose environmental, economic, health and aesthetic problems (Opfer *et al*., 2012) that are rooted in poor solid waste management practices, lack of infrastructure, indiscriminate human activities and behaviours and an inadequate understanding on the part of the public of the potential consequences of their actions (Jeftic *et al*., 2009; Agamuthu *et al*., 2013; Kadir *et al*., 2015). The marine debris's impacts on wildlife range from entanglement and drowning to increased transport of pollutants into food chains (Gall and Thompson, 2015; Lee *et al*., 2013). Researchers have identified some animal populations that are heavily impacted by marine debris, including several species of turtles in the northern and eastern marine bioregions of Australia and seabirds nesting on some offshore islands (Hardesty and Wilcox, 2011). Impacts may range from either ingestion or entanglement, and may result in reduced health, decreased reproductive output and mortality (Gall and Thompson, 2015). Marine debris hoards invasive species and transport them to new ecosystems (Barnes, 2002). In fact, very few studies have explored the economic impact of marine litter to world Governments, for example, UK municipalities spend approximately €18 million each year removing beach litter, which represents a 37% increase in cost over the past 10 years. Similarly, removing beach litter costs municipalities in the Netherlands and Belgium approximately €10.4 million per year (Mouat *et al*., 2010). Globally, ocean currents are the main waste transportation drivers (Howell *et al*., 2012). As a result, marine litter has attracted increasing attention in recent years from both policy makers and researchers. In terms of legislation, marine litter is specifically addressed as part of the UN Resolution A/RES/60/30 - Oceans and the Law of the Sea - and under the EU Marine Strategy Framework Directive (2008/56/EC) (Mouat *et al*., 2010).

In general, shoreline and recreational activities, smoking related activities, ocean or waterway related activities, dumping or discarding directly or indirectly contribute to the existence of debris in the beaches (ICC, 2013). Thus, there is a relationship between beach users and the quality of the coastline ecosystem. Public, beach users, and authorized parties have the ability to curb debris problem, as quoted by UNEP Executive

Director in International Coastal Clean-up report, 'Marine litter could be reduced by improving waste reduction, waste management, and recycling initiatives' (ICC, 2013).

Malaysia is surrounded by a long coastline exceeding 9323 km (including East Malaysia) with 98% of its population living within 100 km from the shoreline (Khairunnisa *et al*., 2012). In Malaysia, marine debris is not uncommon in most beaches (Khairunnisa *et al*., 2012; Hassan and Mobilik, 2012; Agamuthu *et al*., 2013; Mobilik *et al*., 2014; Kadir *et al*., 2015). However, there is no attempt to create a national marine debris map in Malaysia yet. Hence, it was decided to study the abundance and composition of marine debris in a few selected beaches especially in well-known Port Dickson area in Negeri Sembilan in order to enrich the sparsely available database. It was aimed to understand both in qualitative and quantitative terms the nature of marine debris in Malaysian beaches.

2. Materials and Method

Coastline locations in Port Dickson, Negeri Sembilan, Peninsular Malaysia have been chosen based on characteristics such as direct and clear year-round access to the beaches; no barriers or jetties in between the sea and the shoreline; a minimum of 100 m beach length parallel to the sea water; and do not have constant clean-up actions on the beach. Thus a standing-stock study as per NOAA Marine Debris Shoreline Survey Field Guide was conducted (Opfer *et al*., 2012). Port Dickson is the only coastal area in Negeri Sembilan state. It is a favourite weekend gateway for Malaysians. Due to active tourism activities, shipping, refineries, and coastal zone constructions, there is an academic concern on the deterioration of water quality in Port Dickson (Praveena *et al*., 2011; Khairunnisa *et al*., 2012).

In this study, waste quantification meant debris density and categorization of debris, which were carried out on the spot on data cards. The debris data card was based on the OSEAN (Our Sea of East Asia Network) /AMETEC (APEC Marine Environmental Training and Education Center) protocol, from The Korea Institute of Ocean Science and Technology (KIOST), Geoje, Korea. OSEAN/AMETEC protocol was chosen because it was amended in the year 2014. (Personal contact with Dr. Sunwook Hong, OSEAN - Korea Marine Litter Institute - http://koreamarinelitter.blogspot.my/) According to this protocol, the debris were divided into 10 categories, such as hard plastic and film plastic, fiber and fabric, foamed plastic, polymer, glass and ceramic, metal, paper and cardboard, wood and others.

At the site, the length and the width of the shoreline was measured by using a meter ruler according to the topography of the beach (Fig. 1). Each beach was different in size and area, thus, every beach was measured for sampling. The selected area was divided equally into two segments. Each section was labelled from left to right. Every quadrant started from the water's edge to the back of the shoreline.

Starting from water's edge to the back of the shoreline, each transect was traversed by foot, every debris item was collected in a plastic bag and later the categories were recorded by weight in the Debris Density Data Sheet. Snapshots of the debris items were taken in each transect. Sampling was carried out progressively for 8 consecutive Saturdays, in two months at different time zones, from morning till evening. Sampling started on the 5th of June and ended on 26th of July.

3. Results and Discussion

Table 1 summarizes the results obtained from four different beaches at Port Dickson. This includes the number of items, debris mass and debris density. The mass of debris is measured in kilogram (kg) while the density of debris is measured in kilogram (kg) over an area (m^2). The area of each beach depended on the beach's topography. For instance, the area taken in four beaches, Saujana, Nelayan, Bagan Pinang and Cermin were 2625 m^2, 750 m^2, 1500 m^2 and 900 m^2 respectively. The total mass of debris collected over 8 weeks period amounted to 169.8 kg.

Figs. 2 and 3 represent the pie charts of the total mass and the total density of debris collected at four different beaches over eight observations. Fig. 2 reveals the mass distribution at these beaches. Nelayan beach collected the maximum debris (79.8 kg) and Saujana beach had the least (21.9 kg). The mass distribution of marine debris at these beaches were in the following order: Nelayan>B.Pinang>Cermin>Saujana.

Fig. 4 is about the categories of total debris items collected. They are in this order: Hard and film plastics > Fabric and fibre > foamed plastic > polymer > paper/cardboard ≥glass/ceramic ≥ metal ≥ wood ≥ others.

The time trend in the collection of debris (mass) and their distribution (density) over the entire collection period at Port Dickson is presented in Figs. 5 and 6. The data revealed that debris varied in quality and quantity over the collection. This was possibly due to factors like weather, tides, wind amplitude, ocean topography, etc. For example, Nelayan Beach has the highest density of debris sighting compared to the other three beaches, especially on 28 June with heavy rain.

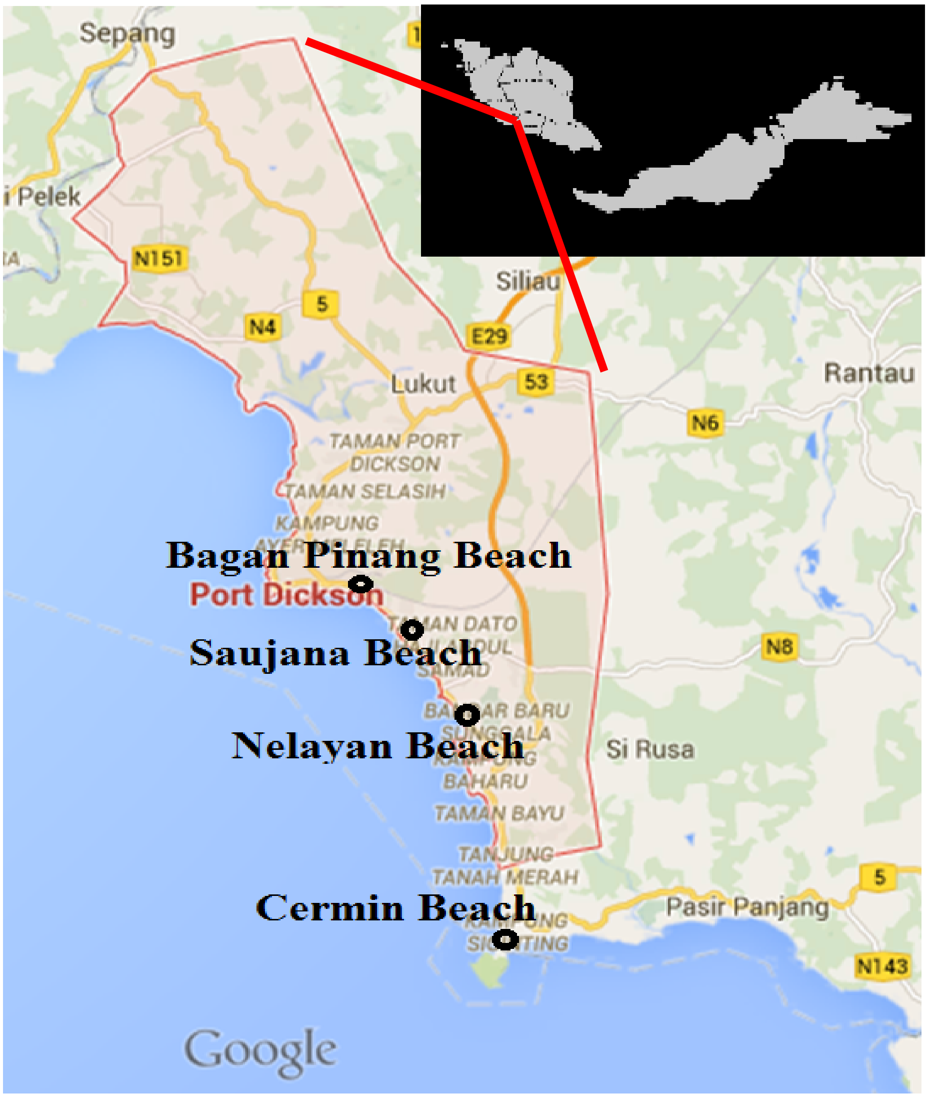


Figure 1. The sampling locations at Port Dickson, Malaysia

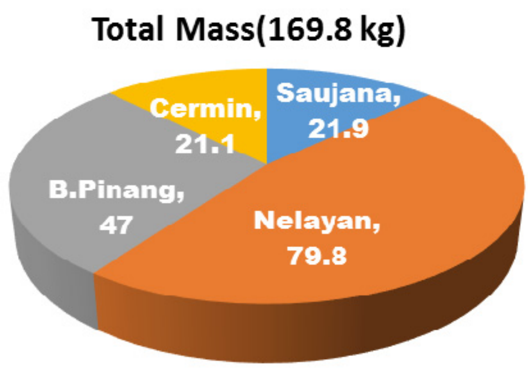


Figure 2. The distribution of total mass (169.8 kg) of debris in four beaches

Table 1. Wind amplitude, debris mass and debris density in Port Dickson beaches

Date	8.30am Saujana	10.30am Nelayan	2pm B.Pinanag	4pm Cermin
7 June	15km/h NW, P.C 1.0kg 0.0004 kg/m²	20km/h NW, P.C 3.8kg 0.0051 kg/m²	20km/h N, P.C 4kg 0.0027 kg/m²	19km/h N, P.C 1kg 0.0011kg/m²
14 June	4km/h W, P.C 2.2kg 0.0008 kg/m²	4km/h W, P.C 15kg 0.0200 kg/m²	6km/h N, P.C 8kg 0.0053 kg/m²	7km/h N, P.C 4kg 0.0044 kg/m²
21 June	4km/h NW, P.C 1.5kg 0.0006 kg/m²	11km/h N, P.C 7.1kg 0.0095 kg/m²	11km/h NE, P.C 4.7kg 0.0031kg/m²	13km/h NE, P.C 1.6kg 0.0018 kg/m²
28 June	2km/h W 2.6kg 0.0010 kg/m²	2km/h NE, P.C 17kg 0.0227 kg/m²	13km/h N, P.C 8kg 0.0053 kg/m²	11km/h NE, P.C 3.6kg 0.0040 kg/m²
5 July	6km/h W, P.C 3.5kg 0.0013 kg/m²	6km/h NW, P.C 12.8kg 0.0171 kg/m²	17km/h N, P.C 5kg 0.0033 kg/m²	9km/h NE, P.C 3.5kg 0.0039 kg/m²
12 July	7km/h W, P.C 4.7kg 0.0018 kg/m²	4km/h N, P.C 14.8kg 0.0197 kg/m²	13km/h N, P.C 5.7kg 0.0038 kg/m²	13km/h N, P.C 1.7kg 0.0019 kg/m²
19 July	2km/h W, P.C 2.6kg 0.0010 kg/m²	13km/h NE, P.C 5.6kg 0.0075 kg/m²	13km/h NE, P.C 6kg 0.0040 kg/m²	11km/h N, P.C 2kg 0.0022 kg/m²
26 July	6km/h W, P.C 3.8kg 0.0015 kg/m²	19km/h N, P.C 3.7kg 0.0049 kg/m²	15km/h N, P.C 5.6kg 0.0037 kg/m²	9km/h N, P.C 3.7kg 0.0041kg/m²
Total mass	21.9 kg	79.8 kg	47 kg	21.1kg
Total density	0.0083 kg/m²	0.1064 kg/m²	0.0313 kg/m²	0.0234 kg/m²
Total area	2625m²	750m²	1500m²	900m²

E=East, N=North, W=West, NE=North East, NW=North West, PC=Partly Cloudy

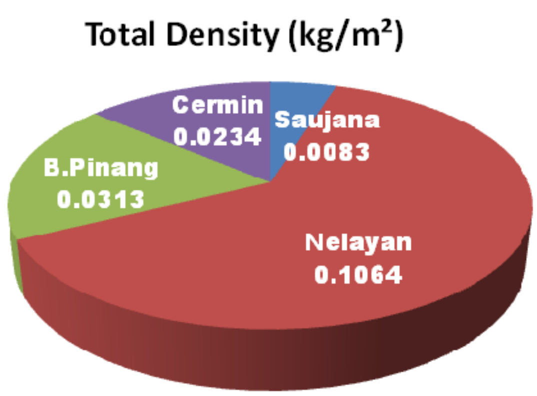


Figure 3. The density of debris in four beaches

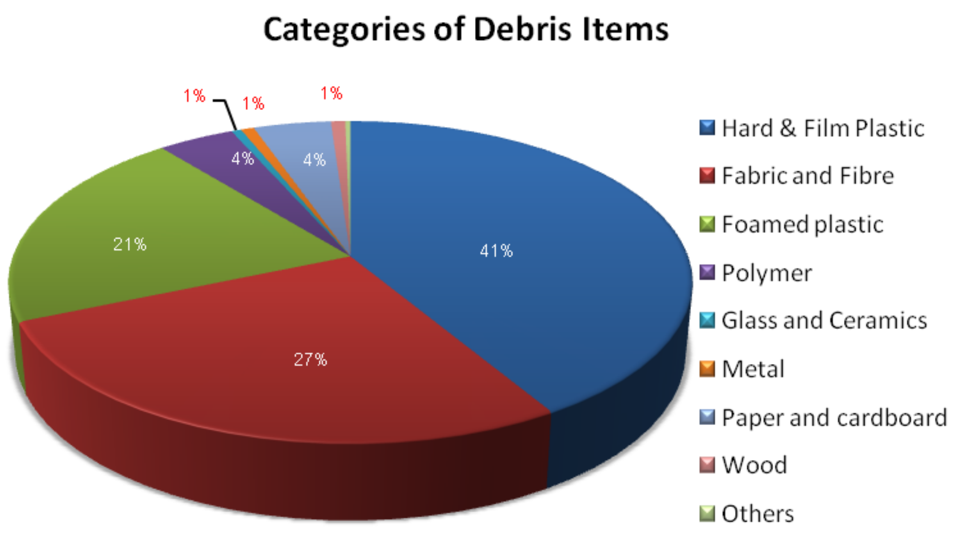
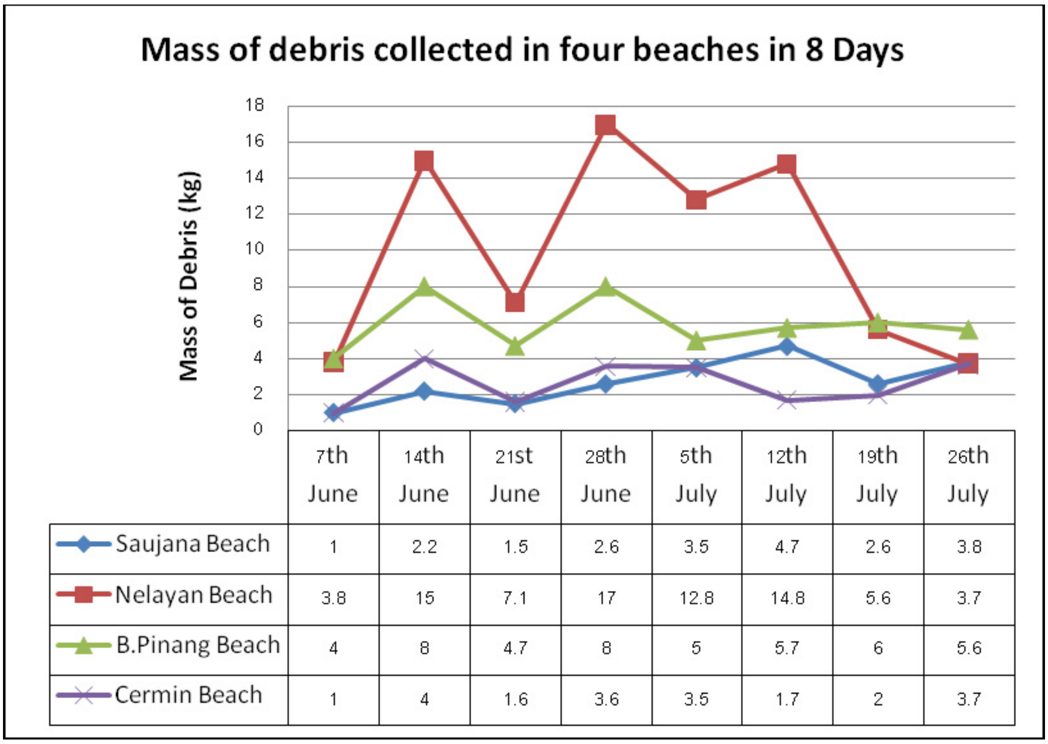
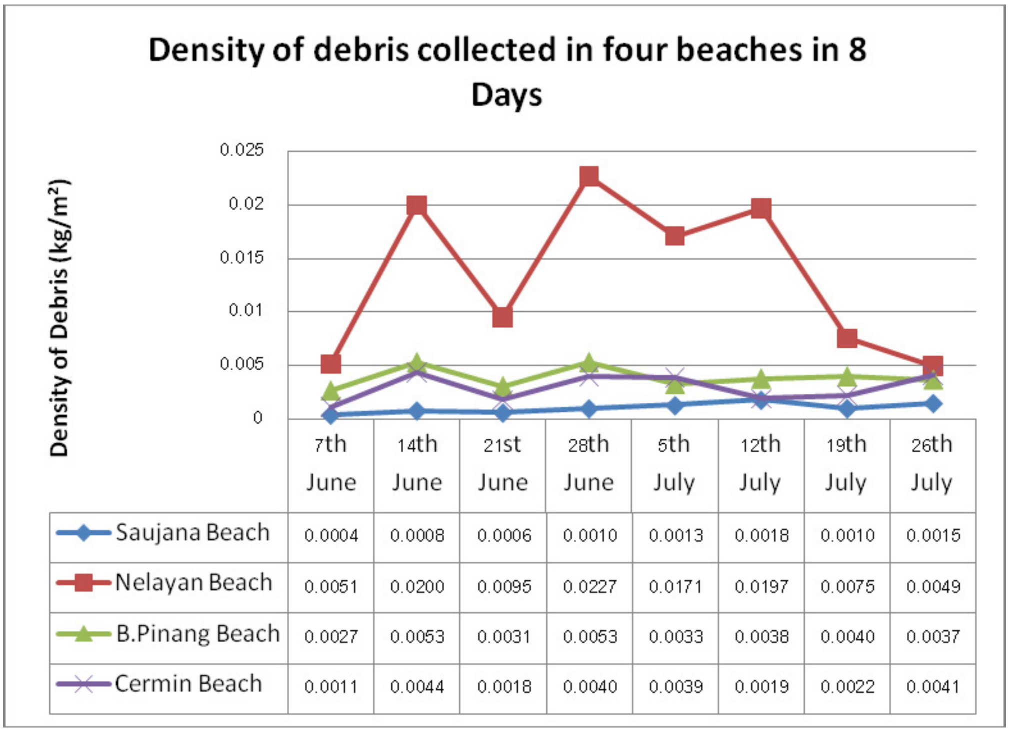


Figure 4. The categories of debris items from overall collections



	7th June	14th June	21st June	28th June	5th July	12th July	19th July	26th July
Saujana Beach	1	2.2	1.5	2.6	3.5	4.7	2.6	3.8
Nelayan Beach	3.8	15	7.1	17	12.8	14.8	5.6	3.7
B.Pinang Beach	4	8	4.7	8	5	5.7	6	5.6
Cermin Beach	1	4	1.6	3.6	3.5	1.7	2	3.7

Figure 5. Mass of debris recorded over the collection period at Port Dickson



	7th June	14th June	21st June	28th June	5th July	12th July	19th July	26th July
Saujana Beach	0.0004	0.0008	0.0006	0.0010	0.0013	0.0018	0.0010	0.0015
Nelayan Beach	0.0051	0.0200	0.0095	0.0227	0.0171	0.0197	0.0075	0.0049
B.Pinang Beach	0.0027	0.0053	0.0031	0.0053	0.0033	0.0038	0.0040	0.0037
Cermin Beach	0.0011	0.0044	0.0018	0.0040	0.0039	0.0019	0.0022	0.0041

Figure 6. Density of debris recorded over the collection period

It was noted during this study and in a pellet watch study earlier, that high energy beaches with heavy wind and wave action contained less marine debris including plastic pellets. This may be due to the fact that wind and waves drive away the lighter, floating materials from landing on the beaches. It was only during a quite weather the debris settle on the beaches due to tidal action. This hypothesis is supported in Fig. 7 where strong negative linear correlation was found between wind amplitude and debris density. Beach 2 namely, Nelayan and beach 4 namely, Cermin showed strong correlation, while beach 1 namely, Saujana and beach 3 namely, Bagan Pinang showed weak linear correlation, especially Saujana beach. This is because Saujana Beach is a popular sandy beach attracting visitors and hence clean-up activities were frequent. As a result, the debris density found at this beach did not correlate well with wind amplitude. On the other hand, results from less attended beaches such as Nelayan Beach, Cermin Beach, and Bagan Pinang Beach did support the hypothesis.

For a quarter century, Ocean Conservancy's ICC had been the world's largest volunteer action plan for ocean conservation. They have cleaned up to 145 million pounds per year of trash from beaches and waterways. Table 2 compares data from International Marine Debris Watch around the world. The top 10 countries ranked from the number of debris items collected in the year 2013 were shown. Malaysia ranked 14th internationally. Singapore, on the other hand was ranked three. Several factors could explain this: Singapore is a bigger economy than Malaysia, the rate of consumption per unit area in Singapore may be higher, the local sea currents may favour deposition of marine debris on Singaporean beaches. Whatever, relatively speaking Malaysia harvests less debris than Singapore on a global scale. However, a comprehensive comparison on the abundance and weight of debris collected in several beaches in Malaysia with Australian and Indonean beaches (Mobilik *et al.*, 2014) revealed that Malaysian beaches were dirtier than others. That also showed that beaches in Sarawak accumulated more debris than Port Dickson area. The paper postulated that Northeast monsoon was largely responsible for that transportation.

Table 3 shows the top 10 categories of marine debris collected from more than 90 countries including United States, New Zealand, Portugal, Japan, Indonesia, Hong Kong as well as Malaysia. Cigarette butts, food wrappers, plastic bottles, bottle caps, plastic cutlery and straws, grocery bags, glass bottles, plastic bags, paper bags and aluminium cans (soft drinks) were in the list. From this table, Ocean Conservancy had clearly stated that cigarette butts were the main debris (> two million pieces) among all, reaching the world beaches. It is easy to imagine the cancer risk it would cause to birds and other organisms that would ingest these cigarette butts which filtered all the toxic chemicals during smoking.

Table 2. International marine debris watch on the world beaches

	Country	Covered distance (km)	Items collected	Item/km
1	Croatia	0.161km	1,696	29,167
2	Alaska	0.48km	13,508	28,141
3	Singapore	9.17km	152,007	16,576
4	Bonaire	0.161km	2886	17,801
5	Turkey	0.8km	10,075	12,593
6	Mozambique	0.8km	8,787	10,983
7	Philippines	398.8km	2,390,047	5993
8	Dominican Republic	74.2km	423,396	5706
9	Taiwan	30.4km	151,867	5062
10	Jamaica	87.23km	421,399	4830
14	Malaysia	6.44km	27,005	4193

Data source: Ocean Conservancy's 2013 report

Table 4 shows the top 10 categories of marine debris collected in Malaysia (present study). Coincidentally, cigarette butts were the dominant debris in Malaysia as well. Cigarette smoking in roadside restaurants and in public places such as beaches is common in Malaysia. Thus our study vouches the previous observation that marine litter from smoking related activities accounts for 40 percent of total marine litter (higher than the global average) and constitutes a serious problem that has to be given priority in a Regional Strategy (Valavanidis and Vlachogianni, 2012).

From these top 10 items in Table 4, seven of them such as food wrappers, plastic cutleries, plastic fragments, bottle caps, food containers, beverage bottles, and grocery bags belong to plastic category. Derraik (2002) calculated that the proportion of plastics in marine debris on a global scale consistently varied between 60% and 80% of the total marine debris. While plastics typically constitute approximately 10% of discarded waste, they represent a much greater proportion of the debris accumulating on shorelines (Barnes *et al*., 2009; Lee *et al*., 2013; Mobilik *et al*., 2014). Plastic pollution threatens marine life (Gall and Thompson, 2015) and destroys the beauty of a beach (Moore *et al*., 2001). Additionally, plastic debris appears to act as a vector transferring PBTs, ie. persistent, bioaccumulative, and toxic substances, such as polychlorinated biphenyls (PCBs) and dioxins, from the water to the food web, increasing risk to the marine food web, including human consumption. Because of the extremely long lifetime of plastic and PBTs in the ocean, prevention strategies are vital to minimizing these risks (Engler, 2012). On the other hand, plastics do not biodegrade quickly. Ironically, some new biodegradable plastics might not break down in oceans at all. These products are designed to break

Table 3. Top 10 marine debris items found on the world's beaches

	Item	Number of pieces
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	Plastic cutleries	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	Aluminium tin cans	339,170

Data source: Ocean Conservancy's 2013 report

Table 4. Top 10 marine debris items found on the beaches in Port Dickson

	Item	Number of pieces
1	Cigarette Butts	3,421
2	Foam Fragments	2,645
3	Food Wrappers	1,384
4	Plastic Cutleries	1,049
5	Hard Plastic Fragments	948
6	Plastic Bottle Caps	419
7	Food Containers	405
8	Rubber Bands	322
9	Plastic Beverage Bottles	321
10	Plastic Grocery Bags	315

down when they heat up in a landfill or compost pile. Cooler ocean temperatures prevent these products from truly degrading and thus plastic should be considered a new source of chemical pollution in the ocean. (Barry, 2010). The total amount of plastic moving from land to ocean each year has been calculated (Jambeck *et al*., 2015) and that is 8 million metric tons. Eight million metric tons is the equivalent to finding five grocery bags full of plastic on every foot of coastline in the 192 countries examined in that study, including Malaysia.

The current study points out that Nelayan Beach was the dirtiest beach in Port Dickson (Fig. 3). Around 50% of the total plastic items collected were found on that beach. They arrived there via land-based and ocean-based activities, for example, recreational uses such as boating, swimming, surfing, sunbathing, and picnicking generate debris along the shoreline including food bags and wrappers, cups and utensils, trash bags, fast-food and other product containers, toys, fishing lures and floats, and plastic. Urban runoff (domestic waste) and maritime disposal (including accidental spills) are additional sources (Moore *et al*., 2001).Though beach clean-up is an important measure, production of waste should be prevented at the very source.

An ecosystem-based, environmentally sustainable management of the Malaysian beaches is needed in the future. Changes in climate may affect circulation patterns and marine debris movement, accumulation, and retention in space and time. Hence, it is important to conduct such studies on a regular basis in tropical Malaysia. Every year marine litter takes an enormous social and economic toll on people and communities around the world. The persistence of marine litter is the result of a lack of coordinated global and regional strategies and of deficiencies in the implementation and enforcement of existing programmes, regulations and standards at all levels - international, regional and national (Jeftic *et al*., 2009). It is high time that we balance multiple competing and potentially conflicting public goals towards marine resources (extracting food, visiting coastal areas, making a living, or continuing centuries-old traditions) and connect human development with the ocean's capacity to sustain progress (Halpern *et al*., 2012).

Reducing developmental stress and promoting public awareness will eventually achieve this. 2004 Nobel laureate for Peace, Wangari Maathai once said that, "It's very, very important for us to take action at the local level. Because sometimes when we think of global problems, we get disempowered. But when we take action at the local level, we are empowered."

4. Conclusion

Saujana, Nelayan, Bagan Pinang and Cermin beaches were sampled for marine debris in Malaysian west coast. Nelayan Beach was found to be the dirtiest beach in Port Dickson with > 50% of the total plastic items collected in all beaches were found on this beach. The top three items of highest frequency in all beaches were cigarette butts, foamed fragments and food wrappers. International Marine Debris Watch program list Malaysia in the 14th rank and the neigbouring Singapore as third in coastal debris deposition. High energy conditions such as wind and waves in the beaches correlated well with less debris deposition on the beaches. Urban runoff (domestic waste) and maritime disposal (including beach disposal) are the principal sources of marine debris in Malaysia. An ecosystem-based, environmentally sustainable management of the Malaysian beaches is needed in the future.

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