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TYPE AND ABUNDANCE OF MARINE DEBRIS AT SELECTED PUBLIC BEACHES IN SARAWAK, EAST MALAYSIA, DURING THE NORTHEAST MONSOON

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Abstract: Different forms of debris pollute the marine environment. Due to lack of knowledge and awareness among the public on the negative impacts of marine debris, coastal areas such as beaches have been polluted and contaminated with waste. Existing knowledge on marine debris in Malaysia, especially in the state of Sarawak are limited. Therefore, a study was conducted at four beaches in Sarawak to document the types and abundance of marine debris. Marine debris items were collected and categorized during beach surveys at Pandan (Lundu), Pasir Pandak (Santubong), Temasyah (Bintulu) and Tg. Lobang (Miri) in October 2012. Plastic category was the most numerous (90.70%), followed by wood, rubber, glass, metal and cloth contributing 3.53%, 2.20%, 1.78%, 1.58% and 0.21%, respectively. Pasir Pandak beach received the highest quantities of debris (1,120 items/km or 44.1 kg/km). For sources of debris, 23.99% items collected were objects that were directly associated with marine sources. Items associated with terrestrial and common sources were 11.67% and 64.34% respectively. Out of the 21 objects identified as marine source debris, 86.91% comprised of ropes, oil bottles, packaging and cigarette lighters which were present in all study sites. Five highest number of items found in all the study sites for the terrestrial source debris were wrappers, shopping bags, cardboard cartons, aluminium cans and cloths which contributed a total of 97.98%. Clear and coloured plastic bottles represented 46.15% of the total objects in the common source debris. A total of 730 item/km of debris at 42 kg/km was collected from this study. The high number of plastic-based items contributed from the terrestrial and common sources indicates that continued efforts need to be made to reduce marine debris on those beaches.

KEYWORDS: Marine debris, beach pollution, MARPOL, plastic debris, marine debris source.

Introduction

Debris is known to enter the ocean both deliberately and accidentally from a number of sources including sea dumping by fishing, merchant, cruise and recreational ships and from land-based sources such as rivers and drains (Derraik, 2002). Anthropogenic debris poses a serious threat to wildlife, habitat, and human health and safety. The rapid increase of marine debris has impacted 267 species including sea turtle, seabird and marine mammal species (Laist, 1997). Marine debris not only represents a hazard to marine animals but may impact many human activities as well. Marine debris damages and fouls shipping operation (United Nations Environment Programme, 2009), degrades aesthetically wilderness values and multi-use of coastal habitat (Land Conservation Council, 1991), and poses a hazard to divers (Jones, 1995).

The International Convention for the Prevention of Pollution from Ships (MARPOL 73/78) (International Maritime Organization [IMO], 2012) is the main convention governing prevention of pollution of the marine environment by ships from operational or accidental causes. This convention contains 6 annexes, concerned with preventing different forms of pollution

from ship and to minimize pollution from ship activities. A country that becomes a party to MARPOL 73/78 is mandatory to accept Annex I (Regulations for the Prevention of Pollution by Oil) and Annex II (Regulations for the Control of Pollution by Noxious Liquid Substances in Bulk) of the convention. Annex V (Prevention of Pollution by Garbage from Ships) and the other annexes are to be accepted on a voluntary basis but are not compulsory. Since Annex V is not mandatory, the prohibition to discharge garbage into the sea has been largely ignored worldwide (Derraik, 2002).

Plastic-based marine debris makes up most of the marine litter worldwide and was reported to vary between 60% and 80% from the total marine debris (Derraik, 2002; Gregory & Ryan, 1997). Approximately 80 percent of debris is washed off from land, blown by winds, or intentionally dumped from shore, while 20 percent comes from vessels and offshore platforms (Group of Experts on the Scientific Aspects of Marine Pollution, 1991). Marine debris can travel long distance in the ocean because it is light weighted and it degrades slowly in the marine environment. According to Sheavly (2005), ocean-based activities including cruise ship operations, commercial fishing, recreational boating, commercial shipping, military vessel operations and offshore oil drilling, are significant sources of debris. Accumulation of marine debris can be critical especially in heavy maritime traffic area or where ocean currents can naturally accumulate surface material (Walker *et al.*, 1997). To reduce debris in the marine environment, the sources of the debris must be identified (Australian and New Zealand Environment and Conservation Council, 1996) and guidelines developed to increase awareness of the importance of the ocean environment.

Malaysia coastline represents a complex and dynamic system both in terms of human activities and biophysical conditions (Sabah Town and Regional Planning Department, 1998). Beaches in Malaysia are experiencing threats from pollution with increasing population and rapid development (Khairunnisa *et al.,* 2012; Hassan *et al.,* 2007). Sarawak being the largest state in Malaysia has approximately 1,035 kilometres of coastline facing the South China Sea stretching from Tg. Dato, Sematan to Merapok, Lawas (Department of Irrigation and Drainage Malaysia, 2012). This coastline has variable characteristics with valuable natural resources including lagoon, mangrove forest, mudflats, swamps, rocky cliffs, sandy beaches and coral reefs (Hassan *et al.*, 2007). Shipping traffic in the South East Asia region to which Sarawak belongs is relatively high and 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). However, studies on marine debris in Malaysia, in particular, the state of Sarawak are limited. Therefore, this study aimed to: (1) assess the amount of debris on selected public beaches, (2) categorize the debris by type of material and (3) determine the possible sources.

Methodology

Four public beaches were selected for the survey namely Pandan beach (Lundu), Pasir Pandak beach (Santubong), Temasyah beach (Bintulu) and Tg. Lobang beach (Miri) as shown in Figure 1. Pandan and Pasir Pandak beaches are located on the southwest, whereas Temasyah and Tg. Lobang beaches are located on the northeast of Sarawak. Pandan beach is located 12.3 km from Lundu town and 97.4 km from Kuching city. The Pasir Pandak beach is located 15.5 km from Santubong village and 24.8 km from Kuching city. Temasyah and Tg. Lobang beaches are within proximity of Bintulu town (5.6 km) and Miri city (5.1 km) respectively. Pandan and Pasir Pandak beaches are adjacent to village land with only one public entrance to the beach. The livelihood of the older generation in those beaches is fishing. On the other hand, Temasyah and Tg. Lobang beaches are adjacent to town area, housing area, hotel and privately owned land. The local councils and people from nearby

Figure 1: The Four Sampling Sites of This Study

villages take initiatives to conduct beach cleanup at least twice a year in Pandan beach since there is no scheduled rubbish collection. Pasir Pandak, Temasyah and Tg. Lobang beaches have public amenities and are maintained by the local authority appointed contractor for the regular rubbish collection of at least twice a week. This is due to the location of the beaches which is within the urban areas.

All the study sites are exposed to swells and wind waves between 2-3 m during the northeast monsoon from the South China Sea. The shoreline of the survey sites stretches between 1.0 to 6.0 kilometres in length and between 20 to 60 meters in width. Surrounding these beaches are shallow coastal waters which support fisheries activity such as razor clam or 'ambal' harvesting (Rahim & Tan, 2008; Pang, 1992), as a source of food and income to the locals; and also as an attraction for shore fishing activity. Surrounding the shorelines especially at 10 m of water depth at the survey sites, are home to the Irrawaddy dolphins (*Orcaella brevirostris*) and finless porpoises (*Neophocaena phocaenoides*) (Minton *et al.*, 2011). Beach surveys have been conducted on 22, 24, 26 and 28 October 2012 at Pandan beach, Pasir Pandak beach, Temasyah and Tg. Lobang beaches respectively. Identification of the starting point of the beach surveyed was marked by hammering a PVC pipe into the sand above the high tide mark. On the PVC pipe it was indicated the starting point with an arrow pointing to the end point. Then, the distance of one kilometre along the beach was measured using a Global Positioning System (GPS), and marked with a PVC pipe indicating the end point. GPS coordinates of the points are then recorded (Table 1).

Table 1: Study Sites with Their Respective GPS Coordinates Corresponding to Starting and End Points

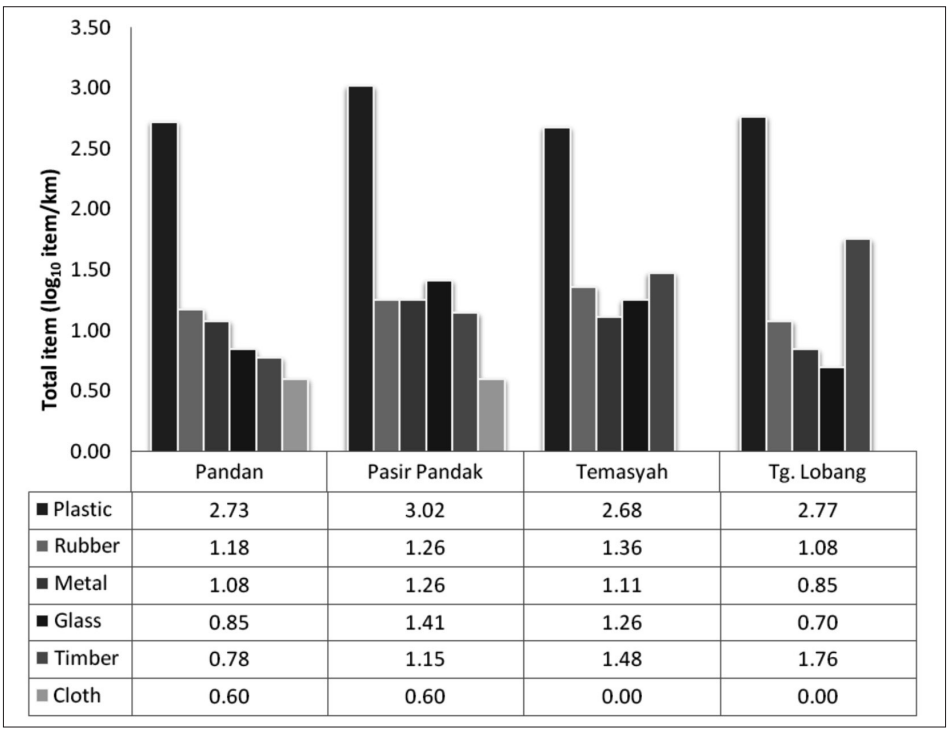
Study Site	Starting Point	End Point	Beach Characteristics
Pandan Beach	$01^0$45' 48.7" N 109^0 51' 53.2" E	01^0 45' 42.8" N 109^0 52' 11.2" E	- 12.3 km from Lundu town - 97.4 km from Kuching city - Public beach with one entry - Length 6.0 km - Width 90 m
Pasir Pandak Beach	01^0 41' 30.0" N 110^0 18' 11.1" E	01^0 41' 38.9" N 110^0 18' 27.8" E	- 15.1 km from Santubong village - 24.8 km from Kuching city - Public beach with one entry - Length 1.2 km - Width 50 m
Temasyah Beach	03^0 12' 51.5" N 113^0 02' 59.9" E	03^0 12' 37.3" N 113^0 02' 47.0" E	- 5.6 km from Bintulu town - Public/Recreational beach with two entries - Length 1 km - Width 20 m
Tg. Lobang Beach	04^0 22' 22.2" N 113^0 58' 08.5" E	04^0 22' 05.1" N 113^0 57' 59.8" E	- 5.1 km from Miri city - Public beach with one entry - Length 1 km - Width 30 m

During low tide, all anthropogenic debris other than fragments smaller than 0.25 cm^2 covering from the high tide mark to the low tide mark at each survey sites were collected and then classified into six main categories: plastic (24 objects); rubber (3 objects); metal (5 objects); glass (3 objects); wood (4 objects); and cloth (2 objects), based on Ribic *et al.,* (1992). Total weight of all items was recorded. Each category was further sorted into objects. Plastic category included plastic shopping bags, cups and plates, made from Styrofoam. Packaging materials including Styrofoam packaging, food wrappers plastic packaging products, plastic bottle caps, clear plastic bottles and coloured plastic bottles were also collected. Debris collected was then classified according to debris sources; marine source (21 objects), terrestrial source (11 objects) or common source (8 objects) following Ribic (1998). 'Common source' refers to objects that could be originating from either terrestrial or marine sources. Objects classified under debris sources were extracted from the debris categories. Plastic-based items categorized in marine source included nets, lures, oil bottles, ropes, packaging, buckets and cigarette lighters. Plastic-based items for terrestrial source included plastic shopping bags and food wrappers. Clear and coloured plastic bottles, cups, plastic bottle caps and toothbrush are plastic-based items for the common source.

Results and Discussion

Amount of Debris

From this study, the mean total item of debris was 729±265 item/km weighing at 41.5±3.8 kg/km. The greatest amount of debris collected was from Pasir Pandak beach at 1,120 item/km (44.1 kg/km). Tg. Lobang, Pandan and Temasyah beaches accumulated 665 item/km (35.8 kg/km), 570 item/km (43.5 kg/km) and 559 item/km (42.6 kg/km) respectively. Pasir Pandak beach also received the most debris from the plastic category which contributed 1,045 item/km or 35.86% from the total amount of debris collected (Figure 2). Objects contributing to the largest amount of total debris items were from



	Pandan	Pasir Pandak	Temasyah	Tg. Lobang
Plastic	2.73	3.02	2.68	2.77
Rubber	1.18	1.26	1.36	1.08
Metal	1.08	1.26	1.11	0.85
Glass	0.85	1.41	1.26	0.70
Timber	0.78	1.15	1.48	1.76
Cloth	0.60	0.60	0.00	0.00

Figure 2: Total Number of Debris Items Collected from Survey Sites According to Categories

Table 2: Ten Most Numerous Objects Found at the Survey Site and Total Items/km

Objects	Pandan	Pasir Pandak	Temasyah	Tg. Lobang
Clear plastic bottle	139	114	167	131
Cups	13	303	46	92
Packaging	74	265	34	31
Pragmnet of plastic	127	87	53	87
Plastic bottle caps	68	107	31	108
Colour plastic bottle	51	37	82	35
Food wrappers	0	46	30	42
Cardboard cartons	5	13	29	56
Thongs and footwear	12	14	22	11
Cigarette lighters	5	32	10	7
Total number of items/km	570	1120	559	665

the plastic category. The plastic objects were cups and packaging objects amounting to 568 items at Pasir Pandak beach as compared to 87 items at Pandan, 80 items at Temasyah and 123 items at Tg. Lobang beaches (Table 2). Prior to the beach survey at Pasir Pandak beach, a family day was conducted on the beach on 21st October 2012 that most likely caused the difference especially the presence of cups and other objects. Similar studies that investigated the quantity of debris in the marine environment reported that debris is ubiquitous throughout the oceans and shores (Rosevelt *et al.*, 2013; Khairunnisa *et al.*, 2012; Taffs & Cullen, 2005; Willoughby *et al*., 1997). Total debris item found at present study was relatively high but the weight was lower as compared to beaches in other countries (Table 3).

Table 2 shows the most numerous objects collected at the survey sites. Clear plastic bottles contributed 551 items (18.91%) from the total items collected in this study with Temasyah beach accumulating the highest (167 items; 5.73%). Pandan and Tg. Lobang beaches accumulated 139 items (4.77%) and 133 items (4.50%) respectively. Pasir Pandak beach was the lowest in clear plastic bottles collected at 114 items (3.91%). The five most numerous objects collected were clear plastic bottles, cups, packaging, fragment of plastic and plastic bottle caps.

Table 3: Comparisons of the Abundance and Weight of Debris on Beaches in the Present Study with Literature Values

Objects	Number of items (item/km)	Weight of items (item/km)	References
Pandan	570	43.5	Present study
Pasir Pandak	1,120	44.1	Present study
Temasyah	559	42.6	Present study
Tg. Lobang	665	35.8	Present study
Pandan	1,594	46	Hassan & Mobilik, 2008
Pasir Pandak	3,565	152	Hassan & Mobilik, 2008
Temasyah	862	41	Hassan & Mobilik, 2008
Tg. Lobang	1,178	65	Hassan & Mobilik, 2008
Anxious Bay, Australia	21	9.7	Edyvane *et al*., 2004
Illaroo Beach, NWS Australia	228	n/a	Taffs & Cullen, 2005
Indonesia (23 Islands)	742	83	Willoughby *et al*. 1997
Marmion Marine Park, Australia	3660	123.1	Jones, 1995

When compared to a study conducted at the same location in February 2008 by Hassan & Mobilik (2012), it was found that the amount of debris in this study decreased by 147% from 1,800 item/km in 2008 to 730 item/km in the present study (Table 3). The decrease of debris collected from this study indicates the effectiveness of the Malaysian government's effort in controlling solid waste through the Solid Waste and Public Cleansing Management Act (2007). Solid waste management has been one of the Malaysian government's priorities under the 9th Malaysian Plan (2006-2010) (Ministry of Housing and

Local Government Malaysia [MHLG], 2005) whereby new concessions on domestic waste management, as well as recycling, and handling of specific types of solid waste like plastic and paper were introduced.

Categories of Debris

A total of 2,914 items of debris weighing 166 kilograms were collected during the survey in October 2012. Out of the 41 objects collected in this study, the plastic category contributed 2,643 (90.70%) ranging from clear plastic bottles, plastic bags, cups, packaging, food wrapper, plastic bottle caps, clear plastic bottles to coloured plastic bottles objects (Table 4). Rosevelt *et al.,* (2013), Khairunnisa *et al.*, (2012) and Otley & Ingham (2003) also recorded that plastic-based objects were dominant. In this study, 24 objects (57%) were present at all survey sites which included ropes, disposable diapers, thongs, aluminium cans, tin cans, aerosol cans, glass bottles, cardboard cartons (e.g. Tetra Brik, laminated dairy product carton) to footwear. Such plastic-based objects were reported to pose a real threat to the health of marine mammals and seabirds found in Falkland waters (Laist *et al.*, 1999) and they could increase the probability of invasion of marine organisms (Barnes, 2002).

Sources of Debris

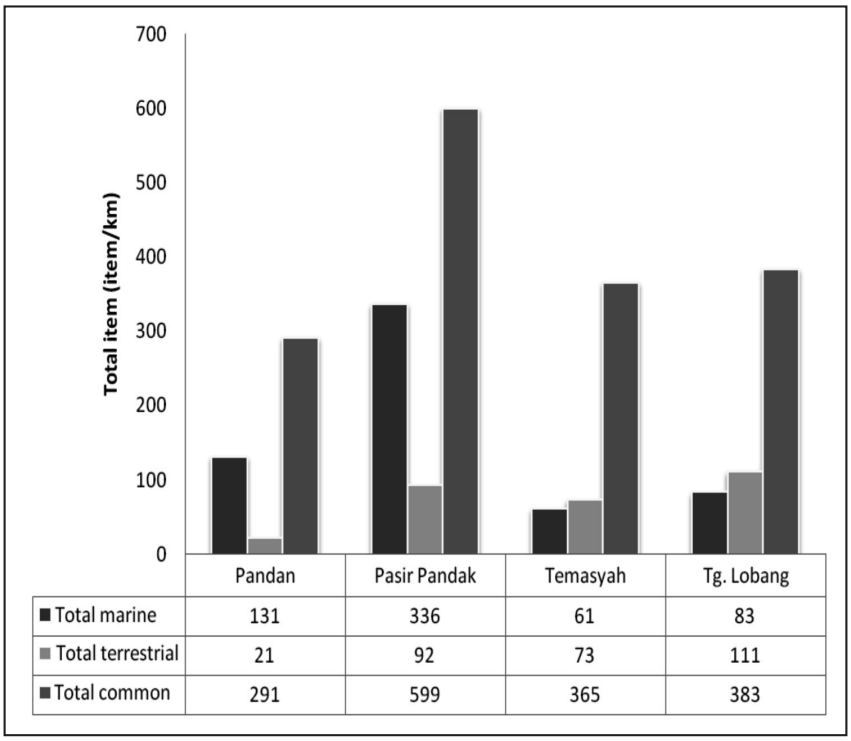
As for sources of debris categories, Pasir Pandak beach accumulated the most items from marine and common sources (Figure 3). In this study, a total of 611 items (23.99%) collected were objects associated directly with marine source debris. Out of the 21 objects identified in marine source debris category; packaging (66.12%), cigarette lighters (8.84%), ropes (8.35%) and oil bottles (3.60%), were found on all survey sites. The high amount of packaging objects in Pasir Pandak (265 item) and Pandan (74 item) beaches (Table 2) contributed to the high percentage in marine source debris. Observation shows that some Styrofoam packaging items collected were attached with fishing nylon line used during shore fishing. Styrofoam was used because it is cheap and easily available. This indicates that these objects could have been from the terrestrial source.

Table 4: Total Number of Objects and Items According to Debris Categories

Category	No. of objects	% of total	No. of Item	% of total
Plastic	24	58.54	2,643	90.70
Rubber	3	7.32	64	2.20
Metal	5	12.20	46	1.58
Glass	3	7.32	52	1.78
Wood	4	9.76	103	3.53
Cloth/Fabric	2	4.88	6	0.21
Total	41		2,914	

Objects associated with terrestrial and common source debris was 297 items (11.67%) and 1,638 items (64.34%) from the total items collected respectively (Figure 3). Overall, terrestrial source debris items found at the survey sites were food wrappers, cardboard cartons, plastic shopping bags, aluminium cans and tin cans. These items contribute 39.73%, 34.68%, 12.79%, 7.07% and 3.70%, respectively from the total items in the terrestrial category. The highest items found from the common source were clear and coloured plastic bottles. Those item contributed 33.64% (551 items or 35.5 kg) and 12.52% (205 items or 16.6 kg), respectively from the total items in the common source category.

Factors influencing the types and amount of debris present in the marine environment include proximity to urban centres, a development area, industrial and recreational areas (Khairunnisa *et al.,* 2012; Hassan *et al.,* 2007; Sheavly, 2005). Seven objects from the terrestrial and common sources debris that were plastic-based were plastic shopping bags, food wrappers, clear plastic bottle, coloured plastic bottles, cups, plastic bottle caps and toothbrushes and they contributed 66.42%. With respect to terrestrial and common sources debris, available evidence strongly indicates that most debris on the study sites were from very local sources. This indicates



	Pandan	Pasir Pandak	Temasyah	Tg. Lobang
Total marine	131	336	61	83
Total terrestrial	21	92	73	111
Total common	291	599	365	383

Figure 3: Results Assigning Debris Items to Marine, Terrestrial and Common Categories at the Four Beaches

a strong need for local authority solutions in the quest for keeping local beaches clean and safe.

The study of sources of debris has given a better understanding of the origin of debris landed on the beaches. The present study shows that 24% of the total debris originated from marine source debris and this is lower than the amount (46%) reported by Otley & Ingham (2003) but higher compared to 18% reported by Sheavly (2007). Linking the Indian and Pacific Oceans, the Straits of Malacca is the shortest sea route and gateway passage to and from East and West of Asia. Malaysia Marine Department (2009) recorded more than 70,000 vessels transited the 621 mile long Strait of Malacca. With this high volume of vessel using this strait, the concentrations of debris in shipping lanes could be high (Galgani *et al.*, 1995). Since vessel in the shipping lanes navigate from this strait to Japan or China is within Malaysia Territorial Water, those vessels likely contributed to the marine debris collected when navigating through Sarawak Territorial Water. The MARPOL 73/78 (IMO, 2012) which have been revised and adopted on 15 July 2011 through resolution MEPC.201 (62) has been in forced since 1 January 2013. The revised convention requires all discharges of ship waste into the sea to be totally prohibited, especially all types of plastics, cooking oil and incinerated ashes. The effectiveness of this new resolution is yet to be known.

Conclusion

A total of 2,914 items (730 item/km) of debris at 166 kilograms (42 kg/km) were collected from the beaches surveyed in this study. The most abundant objects found at all study sites were clear plastic bottles, cups, packaging, fragment of plastic, plastic bottle caps, coloured plastic bottles, food wrappers, cardboard cartons, thongs/footwears and cigarette lighters. Those objects contributed 86.92% of the total debris

collected. Plastic category contributed 90.70% in the total items collected. Pasir Pandak beach (1,120 item/km) received substantially greater quantities of debris compared to Pandan, Tg. Lobang and Temasyah beach. The main source of debris was from the common source which contributed 64.34%. Marine and terrestrial source debris contributed 23.99% and 11.67% respectively. The high percentage of terrestrial and common sources debris, indicates that a continue effort needs to be made to reduce marine debris in those beaches.

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