Marine Debris Assessment and Clean Coast Index of Pantai Navy Labuan, Wilayah Persekutuan Labuan, Malaysia

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Abstract Marine debris is described as any solid materials that are directly discharged into the marine and coastal ecosystems. Marine debris issues are recognized as a major stressor on the marine and coastal ecosystem around the world, including Malaysia. In this study, the coast cleanliness of Navi Beach, Labuan (coordinates of 5.2759, 115.2587) was assessed using Clean-Coast Index (CCI). The marine debris was collected for two days during northeast monsoon season at the same coastal area around using the transect survey method. Marine Debris Tracker application was used to record the type of debris found and categorized by type of material. The number of debris collected for Day 1 and Day 2 were 73 items and 288 items, respectively. 61.6% of the total debris found on Day 1 of the survey was categorized as plastic items. While for Day 2, 56.6% of the debris was categorized as lumber types, 24% was plastic and 18.8% was other items. The average value of CCI at the coastal area of Navi Beach, Labuan, was 0.64, considered as 'very clean according to the CCI index value.

Keywords Marine debris · Debris composition · Malaysia's beach · Navy beach · Clean-coastal index · Transect survey

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S. Harun et al. (eds.), *Proceedings of the 5th International Conference on Water Resources (ICWR) – Volume 1*, Lecture Notes in Civil Engineering 293,
https://doi.org/10.1007/978-981-19-5947-9_36

1 Introduction

Marine debris is described as any solid material that is manufactured or processed and directly or indirectly, intentionally or unintentionally, disposed of or abandoned into the marine environment. It is primarily the result of human activity due to poor or improper waste management, dumping and littering, or stormwater runoff [16]. Marine debris is known as a major stressor on the marine and coastal ecosystem around the world, with documented implications on marine biodiversity as well as negative social consequences, as debris can pose a health and safety risk, as well as wreak havoc on commercially valuable resources [8].

The marine debris can be broadly categorized as land-based (originating on land) or marine-based (originating at sea) sources [4]. The land-based source included recreational activity at the coast, public wastes, industrial wastes, and unregulated landfills areas (e.g., landfills near the shore). The ocean-based source comprises commercial shipping, ferries and liners, fishing vessels (recreational and commercial), leisure boats and offshore structures such as platforms, rigs and aquaculture sites. Previous studies found that land-based sources contributed a larger portion of the debris in the marine environment [9, 15, 17]. Plastic objects included plastic bags, cups and plates made from Styrofoam, food wrappers, plastic packaging products, plastic bottle caps, clear plastic bottles and coloured plastic bottles, contributing the largest portion of the total debris items. Plastic-based marine debris also makes up most of the marine litter worldwide. Approximately 80 per cent of debris is washed off from the land, blown by winds, or intentionally dumped from shore.

Beaches are one of the mainland-based sources of litter entering the marine environment due to poor waste management. Beaches in Malaysia are also experiencing threats from this solid pollution due to increasing population and rapid development. Marine debris Malaysia has been placed under the purview of local authorities. Solid trash management, on the other hand, was privatised in September 2011 under the Solid Waste and Public Cleansing Management Act 672 [5]. Various initiatives have been taken to keep Malaysian beaches clean and pristine.

Previous studies have also documented the presence of marine debris in Malaysian beaches. Abdul Kadir et al. [1] studied the presence of debris at two beaches, namely Sungai Lurus and Minyak Beku, in Batu Pahat district. Agamuthu et al. [2] studied the composition and abundance of marine debris at beaches in Peninsular Malaysia, namely Teluk Kemang, Pasir Panjang, Batu Burok, and Seberang Takir. Mobilik and coworkers studied the abundance of marine debris at Sarawak's beaches, namely Pandan beach, Pasir Pandak beach, Temasyah beach, and Tg. Lobang beach [7, 14]. Assessment of marine debris at Sabah beaches was conducted previously at Tg. Aru and Kosuhoi beaches [13]. They found the density of debris on these beaches were found to be comparable to other beaches worldwide in the range of 0.142–0.884 items/m.

Although these studies give an overview of debris pollution levels in Malaysia beaches, however, the data is still limited. This study was conducted to (i) assess the presence of marine debris and (2) evaluate the cleanness by using the Clean-Coast

Index (CCI) value of Navy Beach, Labuan, Sabah. The assessment of the type of marine debris in Malaysia is well discussed by the previous studies [1, 2, 7, 13, 14]. Maritime Institute of Malaysia (MIMA) conducted Clean Coast Index (CCI) for cleanliness assessment of coastal areas in Malaysia in 2010, and the results indicated plastic waste had been proven to be the major contributor of coastal litter in Malaysia beaches, with 66% of the overall litter collected (Hagir et al. 2013).

2 Materials and Methods

2.1 Study Area and Debris Sampling Method

In this study, the assessment of marine debris and cleanness index was carried out at Navy beach of Labuan Island. Labuan Island is located on the northwest coast of Borneo, north of Brunei and south of Kota Kinabalu, the capital of the state of Sabah. The Navy beach is located in the Southern part of Labuan Island, 5.2 km from Labuan town. The beach is not the main attraction for recreational activities; nevertheless, there are also people who visit the beach. There are two restaurants and a marine museum in the area of the beach.

The transect survey method is used for the debris collection. The sampling station is determined using a 100 m × 20 m transect. The Measure App that used the augmented reality (AR) technologies to show the length or measurement walking was used to determine the transect survey area (coordinates of 5.2759, 115.2587). Figure 1 shows the transection walking pattern for the transect area.

After the transect area was determined, all the visible debris was collected by walking within the transect area. In order to maximize the collection of the samples, the sampling process was conducted two times. The first survey was done on a weekday (March 19, 2021), and the second survey was conducted on the weekend (April 3, 2021). It must be noted that only debris that has a size larger than 2.5 cm were collected.

2.2 Classification of Debris Composition

The collected debris was then sorted and separated according to the material types. The number and type of material for each collected debris were recorded using the Marine Debris Tracker mobile application. From this application, the marine debris was categorized into nine types, namely plastic, metal, glass, rubber, cloth, paper and lumber, fishing gear, other items, and the amount of beach debris type was counted. After that, the debris was classified into various sub-categories listed as listed in the application. After separation and categorization, the amount of each type of debris

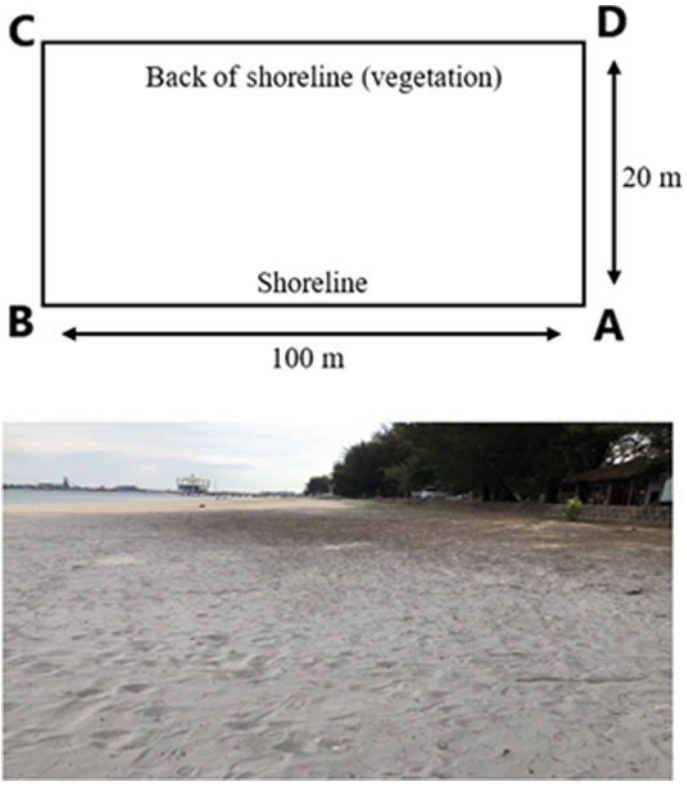

Fig. 1 Transect survey area for debris collection in navy beach, Labuan

was expressed as the number of items. The debris composition was counted and recorded in the Table in the worksheet classification of debris composition.

2.3 Clean-Coast Index (CCI)

The cleanness of the beach was measured by determining the clean-coast index (CCI) value. The index indicates how many plastics trash objects (man-made debris) were counted per square metre of the transect region, which is the product of the length and depth of the transect. The CCI uses a ranking system that ranges from "Very clean" to "Extremely Dirty" (see the range (from 0 to 20 +) mentioned in Table 1). The index is calculated as follows:

$$CCI = K\left(\frac{Total\ debris\ in\ transect}{Total\ area\ of\ transect}\right)$$

Table 1 CCI index categories

Numeric index	Coast index
0–2	Very clean
2–5	Clean
5–10	Moderate
10–20	Dirty
20+	Extremely dirty

where coefficient K = 20 was used as a multiplier to ensure that the value of the resulting index would not fall between 0 and 1.

3 Result and Discussions

3.1 Types of Debris Collected at Navy Beach

The number of debris collected from Day 1 was 73 debris while 288 of debris was collected on the second day. The debris was categorized into nine categories, namely plastic, metal, glass, rubber, cloth, paper and lumber, fishing gear and other items. Figure 2 shows some of the debris collected at Navy beach. Plastic and lumbar were the most abundant types of debris collected at the beach. There is only one item found for each type of debris, namely metals, glass, rubber and fishing gear. Figure 3 and Table 2 shows the number, percentage and categories of debris collected at the Navy beach for two days of sampling.

The total number of plastic debris from two days' collection was 114 items ranging from food wrappers, beverage bottles, other jugs or containers, plastic bags, hard plastic fragments, foam fragments, and film fragments. Table 3 shows specific plastic-type sub-categories as classified from the 'Marine Debris Tracker' application and the number of samples found during sampling activity. The number of foam and plastic fragments contributed a relatively larger portion as compared with other plastic sub-categories. Relatively big size plastic-based materials would transform into plastic fragments through the degradation process (O'Brine and Thompson, 2010) and remain to contaminate the beach environment. The polystyrene fragment, plastic bags, and beverage bottles debris might be contributed from the beachgoers, fishing, and picnic activities. Plastic debris is known as a major contributor to marine litter in Malaysia (Hagir et al. 2011b; [1]. By minimizing plastic intake, there will be lesser plastic waste produced.

Besides plastics materials, lumber in the form of wood sticks was also found in a large number. This lumber mainly contributed from the broken tree branches around the beach and was swiped to the transect area. Other items collected in this study shows the variety of organic debris types, such as fruit tree, seaweeds, plant stem

Fig. 2 Example of debris collected at navy beach, Labuan

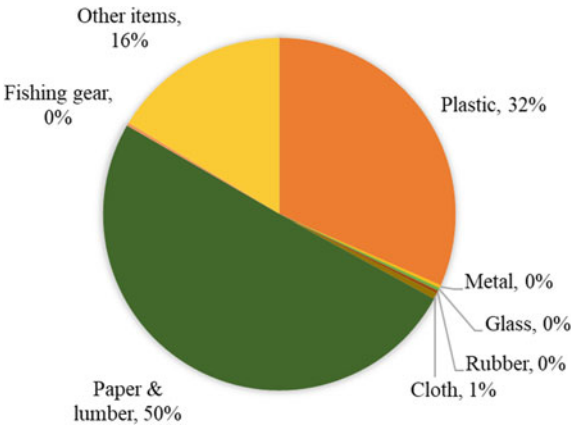

Fig. 3 Percentage of debris items collected from survey sites according to categories for two days of collection

with leaves, shell, birds' feather, stone, peanut shell, concrete piece, leaves, marine life and others. Rare items such as mop and washing machine parts were found on Day 1 of sampling. These items are believed to come from nearby restaurants. Types of other man-made debris collected during the survey are listed in Table 4.

The number of debris collected for the second day of the survey was 3.9 times higher than the first day. 56.6% of the debris was categorized as lumber types, 24.0% was plastic, and 18.8% was categorized as other items. Most of the lumber types were found in the form of wood sticks, and one item in the form of a wooden board was

Table 2 Types and number of marine debris collected at navy beach, Labuan

Categories	Day 1 (19 March 2021)		Day 2 (3 April 2021)	
	Number of items	Percentage (%)	Number of items	Percentage (%)
Plastic	45	61.6	69	24.0
Metal	1	1.4	0	0.0
Glass	1	1.4	0	0.0
Rubber	1	1.4	0	0.0
Cloth	1	1.4	1	0.3
Paper & lumber	19	26.0	163	56.6
Fishing gear	0	0.0	1	0.3
Other items	5	6.8	54	18.8
TOTAL	**73**	**100**	**288**	**100**

Table 3 Sub-categories of plastic debris collected at navy beach

Plastic item sub-categories	Day 1 (19 March 2021)		Day 2 (3 April 2021)	
	Amount	Specific items	Amount	Specific items
Food wrapper	1	Apple wrapper	6	
Beverage bottles	10		-	
Jugs or container	1	Bleach bottle	-	
Bottle/ container caps	-	-	7	
Cigar tips	-	-		
Cigarettes	-	-	6	
Disposable cigarette lighters	-	-	-	
Six-pack rings	-	-	-	
Plastic Bags	10		5	
Foam/ Plastic cups	-	-	2	
Plastic utensils	-	-	7	Lollipop stick
Straws	-	-	5	
Balloons-Mylar	-	-	-	
Personal care products	-	-	-	
Hard plastic fragments	7	Pail holders, pen, and plastic	10	Box tiers
Foam fragments	11	Polystyrene	6	Polystyrene
Film fragments	5	Plastic	15	Plastic
Other (Shotgun shells/wads)	-	-	-	-
Other (aquaculture debris)	-	-	-	-
Other plastics	-	-	-	-

Table 4 Other man-made debris collected at navy beach

Categories	Sub-categories	Day 1	Day 2
Metal	Metal Bottle Caps	1	
Glass	Glass fragments	1	
Rubber	Rubber fragments	1	
Cloth	Fabric pieces	1	1
Paper and lumber	Lumber	18	162
	Paper and Cardboard	1	
	Pallets		1
fishing gear	Fishing lures and lines		1
Others	Mop/ Washing Machine part and others	4	3

also found. These items are believed to be stranded at the area of the transect due to the rain and strong winds a day before the sampling was done. The number of plastic debris slightly increased as compared with the first day of collection. Most of the plastic debris was used for food packagings, such as food bottles or container caps, cigarettes, plastic bags, foam or plastic cups, plastic utensils, straws, hard plastic fragments, foam fragments, and film fragments. Since the time of collection was carried out on the weekend (Saturday), the high amount of food packaging is related to recreational activities such as picnic beachgoers who visited the beach after the working day of Friday.

Since the beach is not the main attraction for tourism industries, the main source of the debris is mainly associated with socio-economic activities from local people who live near the beach.

3.2 Clean Coast Index (CCI) for Cleanliness Assessment of Coastal Areas in Malaysia

The CCI is a metric used by the "Clean Coast" programme, which is a novel, long-term strategy to cleaner beaches involving a variety of activities such as increased public awareness and motivating the authorities to clean their beaches. The method is a simple, useful instrument for tracking progress and evaluating the effectiveness of operations such as public awareness campaigns, media coverage, and enforcement actions. The visual assessments appeared to have a high correlation with the index outcome.

In our study, we only considered man-made debris for the CCI calculation. As previously discussed, the CCI measures plastic debris or artificial waste made as a beach cleanliness indicator (Alkalay et al. 2006; [11]. Organic materials such as timber, lumbar, seaweeds, leaves, shells and other living organisms that can be counted were not included in the CCI calculation. Made-made organic materials such

Table 5 Value of parameters used for CCI calculation

Parameters		Values
Debris counts		
Day 1 Day 2	: :	54 items 72 items
Width of sampling area, *w*	:	20 m
Length of sampling area, *l*	:	100 m
Total area surveyed	:	2000 m^2
Constant K	:	20
CCI values		
Day 1 Day 2	: :	0.54 0.73
Average	:	0.64

as paper cups, board fragments and pallets are also not considered in the calculation. This method is in accordance with the procedure described by Hagir et al. [6] and MIMA [12], which only considered plastic pieces for the CCI calculation.

Out of 73 debris found on Day 1 of the survey, 54 items were considered as artificial debris, while only 72 items were found on Day 2 of the survey. The value of parameters used in this study and the calculated CCI are listed in Table 5. The average CCI value of Navy beach was 0.64, meaning that the Navy beach can be considered 'very clean' according to the scale presented in Table 1.

The CCI is seen to be an easy tool to help enforcement bodies and authorities in assessing and managing the cleanliness level of coastal areas in Malaysia. In 2010, the Malaysian Maritime Institute (MIMA) published a report on "Coastal Litter Management," using CCI values for assessing the cleanliness of Malaysian coastal areas. Malaysian coastal locations namely Pantai Morib and Kelanang (Selangor), Pantai Desaru (Johor), Pantai Cenang (Langkawi), Pantai Balok (Pahang), Pantai Puteri (Malacca), Tanjung Tuan and Pantai Cermin (Port Dickson), Pantai Puteri (Sarawak), Tanjung Aru (Sabah) were chosen for the sampling area. These locations are known as famous recreation areas in Malaysia. Pantai Cenang in Langkawi has the lowest score of 1.08 based on the defined baseline CCI for the sampled recreational areas, showing that the beach is very clean from plastic trash in the coastal area. Meanwhile, the highest index is 7.11 at Pantai Desaru, Johor. In 2017, another series of CCI assessments were carried out by MIMA presented the CCI values at Bagan Lalang, Pantai Remis, Pantai Morib, and Tanjung Harapan. It found that the CCI index for all the beaches was categorized as very clean. Table 6 shows the CCI values and status of Malaysian beaches from the survey [6, 12].

According to the previous research, there is no specific total area and no specific frequency for debris collection in CCI calculation. All the researchers used different total areas of sampling [9, 12], Munari et al. 2015; [3, 10]. According to MIMA [12], the larger the transect area or more transect are, the better the result. However, due to the technical difficulties with regard to the different beach types, the coverage area

Table 6 Clean Coast Index (CCI) and status of Malaysian beaches

Study site	CCI	Beach status	References
Pantai Morib and Kelanang (Selangor)	5.68	Moderate	Hagir et al. [6]
Pantai Desaru (Johor)	7.11	Moderate	Hagir et al. [6]
Pantai Cenang (Langkawi)	1.08	Very clean	Hagir et al. [6]
Pantai Balok (Pahang)	4.82	Clean	Hagir et al. [6]
Pantai Puteri (Malacca)	6.57	Moderate	Hagir et al. [6]
Tanjung Tuan and Pantai Cermin (Port Dickson)	4.62	Clean	Hagir et al. [6]
Pantai Puteri (Sarawak)	2.95	Clean	Hagir et al. [6]
Tanjung Aru (Sabah)	3.8	Clean	Hagir et al. [6]
Pantai Remis (Selangor)	0.5	Very clean	MIMA, [12]
Pantai Bagan Lalang (Selangor)	0.1	Very clean	MIMA, [12]
Pantai Tanjung Harapan	0.3	Very clean	MIMA, [12]
Pantai Morib	1	Very clean	MIMA, [12]
Pantai Navy, Labuan	0.64	Very clean	This study

differs. In addition, there is no limitation on how frequent the sampling is needed to show the level of cleanliness. For the Malaysia scenario, the CCI value was compared using a single day of sampling. Studies by Akalay et al. [3] show that there is no specific trend is recorded when comparing the CCI value measured every four weeks for six months. They found that drastic CCI value changes from not clean to clean basically due to the enforcement activities and cleaning activities conducted by local authorities. MIMA monitored the CCI value of Pantai Morib, where the CCI value in the years 2010 and 2017 were 5.68 and 1.0, respectively. The changing of level of cleanliness after seven years at Pantai Morib might be due to the awareness campaign and improvement provided by local authorities to maintain the cleanness of the beach, thus the motivate the general public for keeping the coast clean.

4 Conclusions

The CCI values of Navy beach indicate that the beach was categorized as ‘very clean. Made-made debris such as plastic materials contributes significant effect towards the cleanness index of the Navy beach. Plastic debris was the most abundant item found on the beach, among other man-made debris. This type of debris is mainly connected to the socio-economic activities done by local people near the beach. Besides plastic debris, a huge number of organic-type debris such as lumber, tree branches, and leaves are also present at the beach. These types of debris were mainly related to the weather before the debris was collected. In general, our results add up to increased evidence indicating that man-made plastic pollution is a significant problem for the marine environment in Malaysia beaches.

Acknowledgements This work was financially supported by the Universiti Teknologi Malaysia under the Industry/International Incentive Grant Scheme (IIIG) (Project No: J130000.3601.03M25 and J130000.3601.03M50).

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