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Assessment of beached marine debris in the Green Island, Eritrea

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Abstract

Marine litters are one of the major environmental issues in the world's oceans and seas. Thus, this study quantified and assessed the beached marine debris in the Green Island, Eritrea. A survey has been conducted consecutively for five months (from September – 2019 to January – 2020), and the Clean Coastal Index (CCI) was applied to assess the quality of the Green Island, Eritrea. The results revealed that approximately 82% of debris collected was plastics and the remaining were glass and ceramics, cloth, paper and cardboard, rubber, metal, and other materials. The sources of pollutants in the Green Island were mainly from residential and business areas along the coast of Massawa port. In addition, the concentration of debris increased during holiday celebration and related activities. The CCI value was fluctuated monthly and with transects, where the first three transects detected as dirty quality in the first and the last month of sampling, however, the CCI of the total average marine debris was about 8.23. Therefore, based on the CCI assessment, Green Island is considered as a moderate quality.

Keywords: Eritrea; Red Sea; Green Island; Marine debris; CCI analysis.

1. Introduction

Marine environmental management, monitoring, and controlling are crucial for marine ecosystem as well as local developmental plan. Worldwide marine litter is one of the major concerns of environmental issues that may need an immediate action (Cauwenberghe *et al*., 2013). Marine litters are waste materials accumulated along the islands, costal area, beaches etc., including waste material used by local people, and intentionally or unintentionally deposited and set into the sea. Marine debris may enter into the sea

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through marine transportation from ships, boats and others or washed into the sea from the land through the system of rivers, wind, draining or sewage (Browne *et al.*, 2015; Galgani *et al.*, 2015). Then, these marine litters are washed farther into the beach by sea wave, ocean currents or ocean tides, and collectively, these items are called as beach marine debris (BMD). Browne *et al.* (2015) indicated that marine litters floating on the oceans or spread over the coastal area is accelerating climate change by altering solar radiation, sea wave, and rising and falling of sea level and others. In addition, the coastal water might be polluted from oil and waste material from different sources such as hospital or other medical centers (Ojaghi, *et al.,* 2021), wind and tidal forces may accelerate the spread and diffuse of oil pollution (Badri and Faghihifard, 2017).

Worldwide, the BMD are waste material such as manufactured products, where the durability and versatility depicts its status (Barnes *et al.*, 2009; Gregory, 2009). The increase of BMD, including plastic debris, foamed matter, glass and ceramics, rubbers, etc., in marine environment consider as a pressing global issue, similar to other environmental concerns like extinction of species, ocean acidification, global warming (Sutherland *et al.*, 2010). The BMD durability varies, some have very long durability (i.e. plastics) and others may have very short durability (i.e. papers). Plastics, especially causes marine environmental hazards, the physical abrasion and photo oxidative degradation lead to disintegration into fragments instead of transforming into chemicals (Ryan *et al.*, 2009; Cauwenberghe *et al.*, 2013; Eriksen *et al.*, 2014).

The source of BMD might be different but generally originated from sea or land (Tudor and Williams, 2004; Barnes *et al.*, 2009). However, some researchers in this area stressed that the main source of BMD are created from land (Coe and Rogers, 1997) and others such as Sheavly and Register (2007) argued that about 50% of BMD are originated from marine itself, including shells, dead organisms, such as fishes and birds and others. The BMD is very portable and can spread over large areas. Most of these materials are light in weight so as floating on the surface of the sea but others are might be heavy and sinking into the bottom of the sea (Morrison, 1999; Santos *et al.*, 2009; Carson *et al.*, 2013). Some BMD have a significant threat to the marine environment due to long durability, abundance and extensive spatial coverage (Thompson *et al.*, 2009) and these contributes about 40 – 80% (Kusui and Noda, 2003), and for all BMD accounts approximately 50–80% (Barnes *et al.*, 2009). BMD in the beach might be accelerated from rapid urbanization and increase in population along the coastal area (Oigman-Pszczol and Creed, 2007).

The BMD has an adverse impact over the marine ecology, and hindering local economic development (Zhou *et al.*, 2015). Some BMD (plastics) might have a permanent lodging in the digestive tracts of marine life, food may not pass properly and some may die because of starvation or infections. In addition, toxic chemicals used in manufactured plastics may leak in the beach area as it exposed to water surface, damaging marine biodiversity and marine ecology (Carson *et al.*, 2013). Moreover, enormous accumulation of BMD in the beach may reduce or affects tourism development and lead to decline in national or local income (Oigman-Pszczol and Creed, 2007). Therefore, the aim of this paper is to analysis the condition of BMD in the Green Island (also known as Sheikh Seid Island), in Eritrea. As this paper is the first study in the country about marine debris and coastal pollution, it may provide significant information about marine litters in the island. It can be also useful a source of reference in future and it may have a great role in tourism development.

2. Material and methods

2.1. The study area

Eritrea, a new country in the east Africa, has the longest coastal line (>1200km) along western coast of Red Sea, and it has more than 350 islands (Araya and Krishnan, 2012; Habtemariam and Fang, 2016; Ghebrezgabher and Yang, 2018), where only about 10 islands are populated. Eritrean islands are attractive sites for tourists. Eritrea has two important ports along this coastal line, namely, Massawa port and Asseb port. This study focuses on one of most significant island, called Green Island, located about one mile from Massawa port and covers about 12 hectares (Figure 1).

Green Island is a national park (Habtemariam and Fang, 2016), which is uninhabited and one of the most attractive tourist sites in Eritrea, enormous tourists, fishermen, researchers and divers are frequently visits the island. Most islands in Eritrea are deserts. However, Green Island is partially covered by sand land surface and large part is covered by mangrove evergreen forest, which is origin for its name (Figure 1). It is characterized by a layer of shells. The presence of this forest, leads the island rich in biodiversity, including seabirds, sea turtles, insects, crabs and so on. In addition, Halophyte plants and some grasses are also commonly occupied the island, it is also characterized with hot and less rainfall (Habtemariam and Fang, 2016). All the above mentioned factors make it unique from the rest of the islands in Eritrea. However, the Green Island is threatened by land pollution from virtuous sources, including wastes and debris (plastics, metals, glasses, and ceramics) either from tourists or litters that are washed by sea waves and currents.

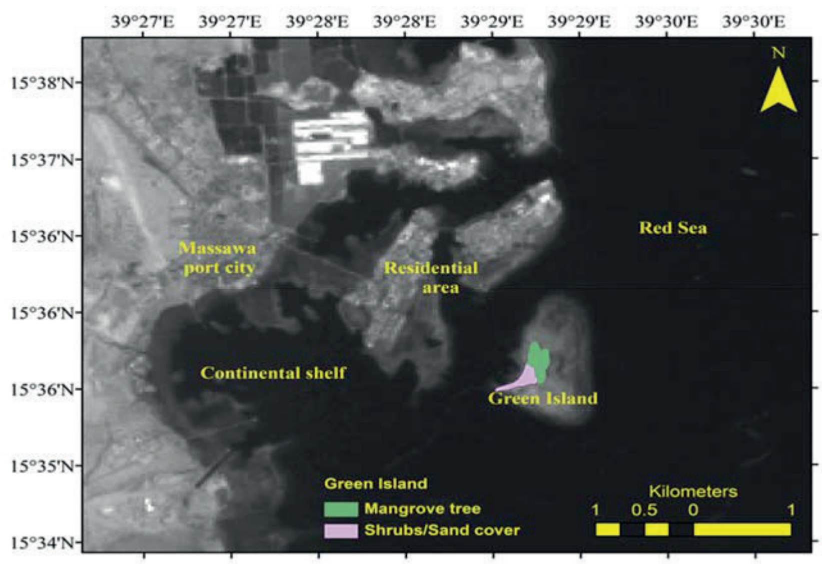

Figure 1. Geographical location of Green Island and Massawa port city from Land sat image

2.2. Data Collection

In this study, a survey data collection is exclusively applied, and a measuring tape is used to quantify the area coverage of each transect (t), and the Global Position System (GPS) is also used to detect the geographical location of the Green Island, transects, and direction and speed of wind. Land sat image and Google Earth map also applied to have a high resolution view of the study area. Here, 5 transects are randomly selected, each transect has an area of 5m by 5m (Figure 2). Since the Green Island is uninhabited, the source of marine debris should be outside the island. Therefore, transects are designed probably facing to the major source of marine debris, and toward the direction of the wind intentionally. The first three transects are selected along the coast facing close to the major residential area, hotels, and several governmental offices while the remaining two transects are facing toward distant small residential area like villages (Figure 2). Moreover, debris may reach the island from fishing and tourism activities. The time interval for data collection might be varied (monthly, bi-weekly, or three/four days or daily interval) (Smith and Markic, 2013) but in this study a monthly time interval is adopted. The study period ranges for five months (from September-2019 to January-2020), and data is collected at the end of each month and beached marine debris greater than 2cm within each transect are only collected. For convenience, transects and the months are indicated as 'ts' and 'm', respectively (i.e. September - m1, October-m2 ……and January – m5; and transects as ts1, ts2 …… and ts5).

2.3. Methodology

In this paper, a Cheshire *et al*. (2009) BMD classification technique is applied. The BMD data are classified as plastics, foamed plastics, cloths, glass, and ceramics, metals paper cardboard, rubber, wood and others. The collected BMD data from each transect and for each month is categorized based on the above classification, and registered in the data sheet. A data sheet serves as summary of information, including the surveyors detail, the weather condition (wind direction and speed) at the time of collection for each transect, and types and quantity of BMD. Rapid beach marine debris operational guidelines are used for sampling and assess litters (Cheshire *et al*., 2009). Generally,

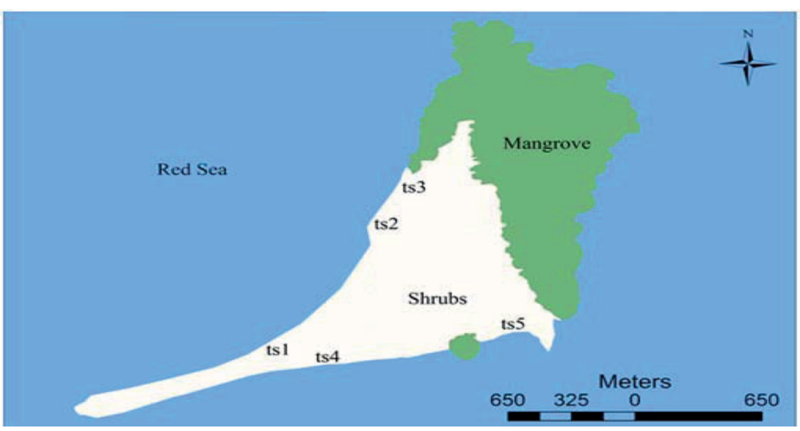

Figure 2. The site and direction of transects in the Green Island, Eritrea

Figure 3 the flow chart illustrates the survey design, including collecting and analyzing BMD in Green Island. In this study, Clean Coast Index (CCI) is applied to assess beach cleanliness (Alkalay *et al.,* 2007), and based on Table 1, the cleanliness of beaches ranges from very clean (CCI = 0 – 2) to extremely dirty (CCI > 20). CCI is defined as:

$$CCI = (\frac{D}{A})K$$

where, 'D' refers to the total debris within transect, and 'A' is the area of transect but K is a constant number equals to 20.

Table 1. Clean Coastal Index

Quality	CCI – Value	Definition
Very clean	0–2	No litter is seen
Clean	2–5	No litter is seen over a large area
Moderate	5–10	A few pieces of litter can be detected
Dirty	10–20	A lot of litter on the shore
Very dirty	>20	Most of the beach is covered with litter

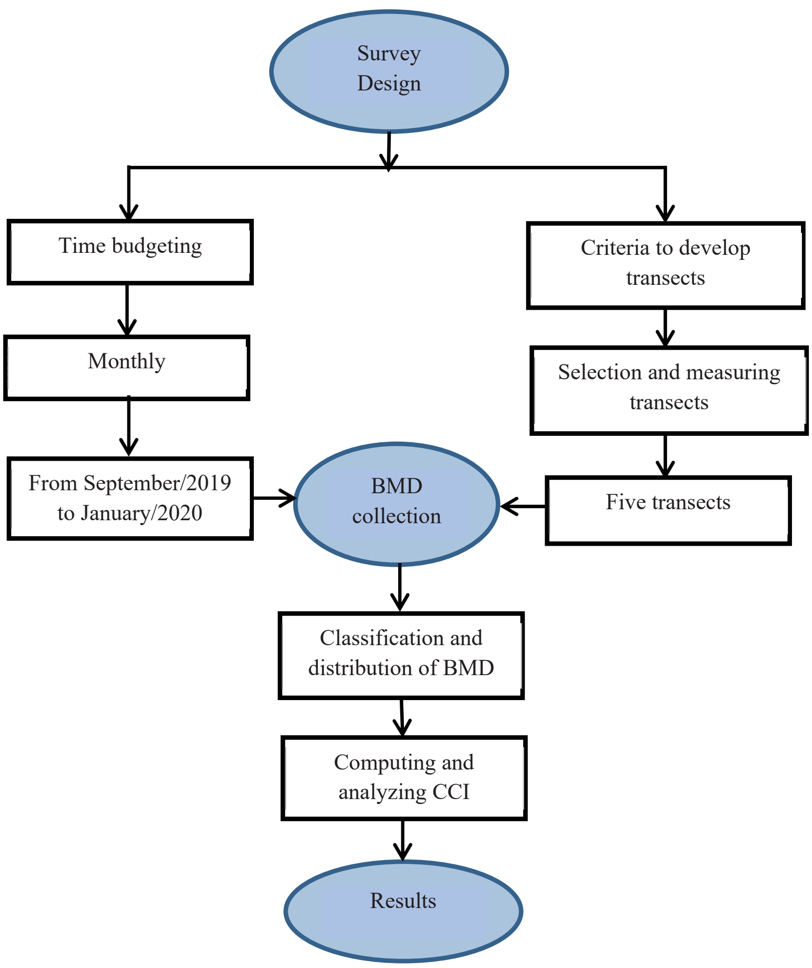

Figure 3. Survey design for this study

3. Results

3.1. Types of BMD

Table 2, explains the type of BMD in the Green Island. A total of 257 items were recorded, removed, and classified on the five sites surveyed. In this study, plastics are the dominant marine debris and followed by foamed plastics, approximately 151 and 60 items were collected, respectively. In addition, a considerable glass and ceramics were also found in the island. Plastics are such as bottles of plastics and food container plastics while foamed plastics are packaging pieces. In the first month of collection, the highest numbers of marine litters (101) are found where enormous number of plastics (74) and foamed plastics (14) items were collected. This is may be because of accumulated marine debris from previous months. In addition, large quantity of plastic (about 35) and foamed plastic (10) items also gathered in m5 of collection may be due to New Year eve celebration along coastal area. Relatively, the lowest amount of marine debris collected in m4, including 9 plastics and 18 foamed plastics are found. Figure 4 illustrates the TBMD in percentage, where plastics comprises about 58.8% of the total debris found, and followed by foamed plastics, accounted about 23.3%, the glass and ceramics (about 7.8%) are the third serious marine debris in the Green Island. Significant amount of metal and cloth debris were collected, about 1.2% and 3.1%, respectively. However, paper and cardboard, and rubber were found the lowest (each 0.8%), and the remaining about 4.3% referred to other types of marine debris.

3.2. BMD Distribution Assessment

Figure 5 shows the distribution of marine debris in each transect in a particular month. The result revealed that the highest marine litters were found in m1, especially in ts1 and ts3, where about 40 and 29 marine debris were collected, respectively. Generally, the highest BMD were found in ts1, ts2, and ts3 because their location is facing to residential and business areas. In m3, extremely high marine debris were collected from ts2 (about 31marine debris), but very few (only about 2 or 3 marine debris) were gathered from the other transects. Comparatively, large number of marine litters also collected in m5, may be due to New Year activities, in contrast, the lowest marine debris is found in m4, for example, no marine debris was found in ts2 in the same month. Generally, the highest

Table 2. TBMD for each type of debris by a month

Months	Plastics	Foamed Plastic	Cloth	Glass and Ceramic	Metal	Paper and cardboard	Rubber	Other	Total
m1	74	14	1	4	3	0	1	4	101
m2	13	5	1	14	2	0	1	1	37
m3	20	13	1	2	0	0	0	5	41
m4	9	18	0	0	1	0	0	0	28
m5	35	10	0	0	2	2	0	1	50
Total	151	60	3	20	8	2	2	11	257

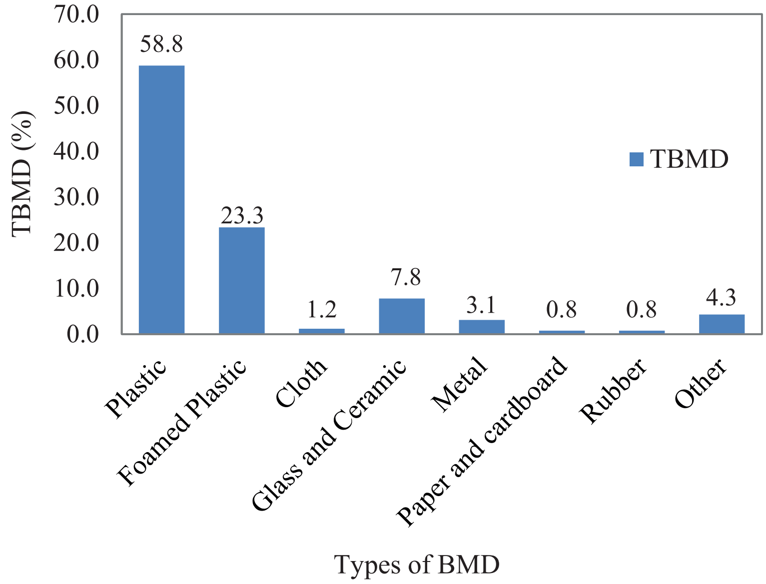

Figure 4. The percentage of TBMD in different types of BMD

total BMD were collected from the first three transects, where approximately 32%, 30%, and 24% of marine debris were found in ts1, ts2 and ts3, respectively, and the lowest TBMD was gathered in ts5 (only 5%) and followed by ts4, about 10% (Table 3). In addition, Table 3 also shows the TBMD detected in each month for all transects, as a result, in m1, the highest TBMD recorded (approximately 39%) and followed by m5 (about 20%), and relatively the lowest TBMD were recorded in m4.

3.3. Beach Cleanliness Assessment

The cleanliness of the Green Island of Eritrea is assessed using the CCI (Table 4). The results showed that the cleanliness of the island coastal area varies with the time of collection and transects. For instance, ts1 (CCI = 32) and ts3 (CCI = 23.2) in m1, and ts2 (CCI = 24.8) in m2 where very dirty, and a dirty index is recorded in m1 and m5 in the first 3 transects. The rest of the surveyed transects ranged from very clean

Table 3. The TBMD in Green Island by each transect and each month

Transect	TBMD	%	Months	TBMD	%
ts1	81	32	m1	101	39
ts2	78	30	m2	37	15
ts3	61	24	m3	41	16
ts4	25	10	m4	28	11
ts5	12	5	m5	50	20
Total	257	100		257	100

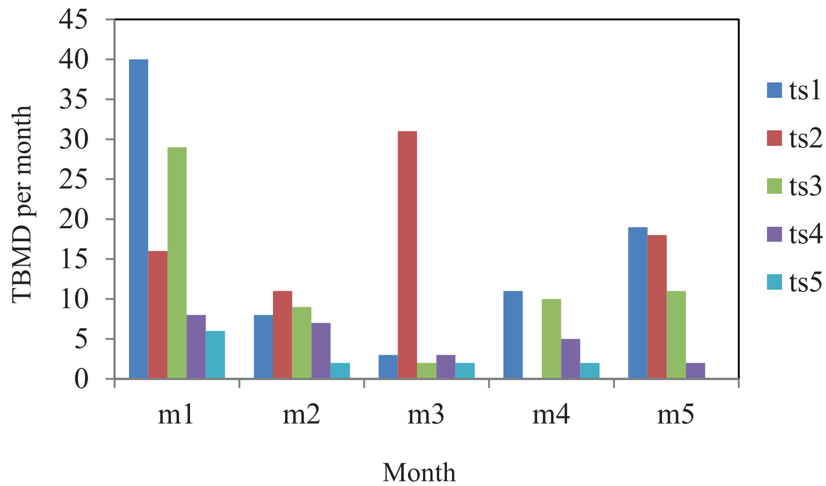

Figure 5. The distribution of TBMD in Green Island along the selected transects

Table 4. The CCI for each transect in each month

Transect	m1	CCI	m2	CCI	m3	CCI	m4	CCI	m5	CCI	Average CCI
ts1	40	32	8	6.4	3	2.4	11	8.8	19	15.2	12.96
ts2	18	14.4	11	8.8	31	24.8	0	0	18	14.4	12.48
ts3	29	23.2	9	7.2	2	1.6	10	8	11	8.8	9.76
ts4	8	6.4	7	5.6	3	2.4	5	4	2	1.6	4
ts5	6	4.8	2	1.6	2	1.6	2	1.6	0	0	1.92
Total	101	16.16	37	5.92	41	6.56	28	4.48	50	8	8.23

to moderate quality. The Green Island was considered as dirty quality in the first month of collection, where the CCI value is about 16.2, and the average CCI showed that the island falls under dirty condition in the first transects and very clean and clean in the fourth and fifth transects, respectively. However, the island has a moderate quality based on the total average cleanliness assessment (CCI = 8.23).

4. Discussion

This survey is conducted in Eritrea and it is the first of its kind as far as we know. Thus, it makes difficult to compare and contrast the results obtained in this research within the country. The selection of the area for the surveyed transect is consistent with some researchers (Manullang, 2019). Here, transects were selected (5m × 5m) deliberately with the direction wave, ocean tide and current, in addition to the direction of residential and economic activities, others may choose transects randomly (Martin *et al.*, 2019). Manullang (2019), selected transects (5m × 5m) randomly at the high tidal center to study marine debris along the Ambon Bay beaches, and Abu-Hilal and Al-Najjar (2009) designated transect location were randomly (12.5m × 12.5m). However, the area of transect to collect marine debris may vary, Vlachogianni (2019) used about 100m coastal length to analysis coastal cleanliness of several countries along the Mediterranean coast, similar transect also adopted by Cauwenberghe *et al.* (2013), and Eriksen *et al*. (2014). Al-Najjar and Al-Shiyab (2011) also applied 20m × 20m transect in his study and $100m^2$ of transect is used by Zhou *et al.* (2015) to study marine debris. Since the Green Island has two major land cover, the mangrove in the northern part and sand dominated area in the southern of the island, transects are selected intentionally in the sandy area of the island because marine litters are difficult to collect from forested land (Smith and Markic, 2013).

Marine debris may vary from coast to coast in the world, depending on human activities along the coast and wind direction and ocean movements, sometimes, marine debris might be drifted by tsunami (Matsuba *et al.*, 2020). In addition, beached marine debris differs in its type and effects, where most of marine debris investigated in this study are consistent with several researchers (Zhou *et al.*, 2015; Pawar *et al.*, 2016; Manullang, 2019). However, in most studies, plastics are the maximum available debris and have long duration, affecting adversely marine organism and coastal environment (Claessens *et al.*, 2011; Cauwenberghe *et al.*, 2013; Habtemariam and Fang, 2016). Critchell *et al*. (2015) stated six factors controlling the final destination of floating marine debris. Most of marine debris collected in this study is plastic bottles and foamed plastics, approximately 82%, which is constant with several researchers (Abu-Hilal and Al-Najjar, 2009; Galgani *et al.*, 2015; Alshawafi *et al.*, 2017; Hidalgo-Ruz *et al.*, 2018), for example, Cauwenberghe *et al.* (2013) showed that about 95% marine debris were plastics. However, in other studies, plastics might not be dominant litters, Al-Najjar and Al-Shiyab (2011), found that the cans debris to be the first major debris and plastics as the second dominant marine debris along the Gulf of Aqaba, Jordan, Red Sea. Cozar *et al.* (2014) stated that the concentration and size or weight of marine debris decreases toward inland, which is corresponding to the density of marine debris in the Green Island, where marine litters are highly concentrated close to the coastal area. In this study, considerable amount of glass and ceramics items also found.

The range of time for collection of marine debris varies among different studies, depending on several factors, including funding and marine rules and regulation policies. In this study, BMD are collected continuously for 5 months (from September 2019 to January 2020). The highest BMD are found in the m1, maybe due to accumulated debris from the previously months. Most researchers started to collect BMD immediately without removal of the previous accumulated debris, however, others removed all marine debris prior to the collection of marine litters begun (Smith and Markic, 2013). The accumulation of marine debris may vary monthly (Otley and Ingham, 2003), in the Green Island, the BMD density of the various types of marine litters varied from one month to the next month. The highest accumulation of debris observed when there are some holiday celebrations or other related activities, including recreational activities of fishing (Smith and Markic, 2013), where consumption and accumulation of marine debris increases and the reverse.

The cleanliness of islands may vary in the world, depending on location and source of litters. Vlachogianni (2019) investigated the CCI value of various islands along the Mediterranean beach ranged from very dirty (Zaglav - Island Vis (Croatia) and Bovo Marina (Italy)) to very clean (Boucanet and Espiguette from France). The results showed in this paper fluctuated monthly and in transects. The CCI indicated that the first two months (m1 and m2) termed as dirty quality while in the m4 and m5 collection the CCI showed the island as a clean quality and in the third month of collection the island measured as moderate quality. Overall, the Green Island considered as moderate quality, thus, the island could be attractive for tourism activities, where some countries economically rely on tourism activities (Zhou *et al.*, 2015). The cleanliness of islands depends on human activities along the coast or ports as well as natural factors. The concentration of debris in the islands also increases as economic activities growing in the port cities, including urbanization, industrialization, fishing activities, shipping and tourism (Abu-Hilal and Al-Najjar, 2009), as well as poor coastal environment management. The low concentration of marine litters in the Green Island is maybe related to insignificant fishing and tourism activities, and insufficient industrial activities in the Massawa port city.

Conclusion

This survey based study is analyzed the BMD on the Coast of the Green Island, is the first study to conduct survey along the coastal area of the country, making difficult to compare the results of this paper with any other researches. This work only showed the current abundance of the marine debris in the sampling areas and provides primary information. Most of marine litters in the Green Island are bottles of plastics, which are probably transported by ocean waves and currents from the residential area, hotels and governmental offices, the remaining types of debris are almost negligible compared to the plastics, however, the pattern and types of BMD are more or less remain similar throughout the coastline. Depending on several factors such as source of debris, direction of ocean movements, weight of litters, location of transects and fishing and tourism activities, the quantity and concentration of BMD items varies among the given transects. The first three transects discovered as the most polluted areas where about 220 items were collected and registered, however, the forth and the fifth transects are the least contaminated area where only total of 37 items were found. Although CCI value varies in terms of months and transects, the average CCI value of the Green Island showed a moderate quality. Therefore, this research provides an opportunity to evaluate the most common items that accumulate on the coastline of the island. It may help in future research on BMD in Eritrean coastal areas by applying a new methodology to compare the situation over time. The study also significant to promote marine environmental awareness to any part such as the government, ministry of marine and fishing or the local authorities who are interesting in the effect of marine litters in Eritrea.

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