Original Research Article https://doi.org/10.20546/ijcmas.2019.806.315

Assessment of Marine Litter along Four Sandy Beaches of Saurashtra Coast, Gujarat, India

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A B S T R A C T

This study aims to quantify the abundance and composition of marine litter found on four sandy beaches of Saurashtra coast, Gujarat during different seasons. The marine litter was collected on bimonthly basis from the coast and categorized into material and usage categories. The marine litter significantly varied temporally and spatially at *P<0.05*. The mean abundance of marine litter was found to be 66.76 ± 4.24 items m^{-2} (19–158 items m-2) and mean weight 22.47 ± 1.03 g m-2 (4.17–40.18 g m-2) per square meters. The results indicated that, Plastic litter occurs in greatest number in all four stations ranging from 59.71 to 76.98% of the items collected (Mean 66.82%). The temporal variation revealed that, the marine litter abundance varied significantly between the months (p<0.05). The highest abundance of litter was observed during the post-monsoon months. The major contributing factor for the accumulation of marine litter is the recreational activities which suggest that the land based source (78.50%) provides the major inputs to marine litter pollution along the coast. Management efforts, including frequent local waste and marine litter collection, are required to minimize the impacts of marine litter on the environment. The results of the study provide the baseline information about the marine litter pollution and assist the effective mitigation strategies.

Introduction

Marine litter is defined as "any persistent, manufactured or processed solid material discarded, disposed or abandoned in the marine and coastal environment" (National Academy of Sciences, 1975). Marine litter investigation has been an interesting issue for many researchers over the last few decades with its main focus being on its impact on marine life and human activities.

Accumulation of marine litter is complex, multidimensional and wide spread problem of the 21st century (UNEP, 2011; UNGA, 2012).

Trouwborst (2011) reported that, globally the land based sources contribute about 80% of the litter in the marine environment whereas almost 20% coming from the marine based sources. Land-based litter include items washed out in storm water entering the marine environment through rivers, municipal

drainage systems, ephemeral streams and sewage inputs, as well as items discarded by beach goers and windblown litter (Stefatos *et al.,* 1999; Galgani *et al.,* 2000; Moore and Allen, 2000; Katsanevakis and Katsarou, 2004). It can be transported long distances by ocean currents and tides, and can sink and accumulate on the seafloor (Watters *et al.,* 2010).

In the last few decades, marine litter has been recognized as an indicator of other forms of pollution that pose risks to marine organisms. The amount of marine litter produced is currently a matter of great concern in the developing nations especially in India, where waste management has been considered one of the most environmental problems. The severity of the impacts and growing amount of litter in the marine environment, efforts are currently underway to quantify the amount present in the beaches as a first step for understanding and alleviating the problems. In order to understand the influence the marine litter on beaches and aquatic organisms, many observations for abundance and composition of litter on the shore has been carried out (Golik and Gertner, 1992; Garrity and Levings, 1993; Corbin and Singh, 1993; Debrot *et al.,* 1999; Moore, 2009; Jayasiri *et al.,* 2013a; Jayasiri *et al.,* 2013b; Galgani *et al.,* 2014; Scisciolo *et al.,* 2016.,).

The coastline of Gujarat is sensitive ecosystems encompasses diverse coastal habitats like rocky shores, sandy beaches, mudflats, mangrove forests, coral reefs, sea grass meadows, coastal wetlands, estuarine regions etc. lying amid in the densely populated and highly industrialized region, with intense coastal and shipping activities. There is dearth of information available on litter quantities and distribution in the Gujarat coast and thus its impact on the sensitive marine habitats has not been addressed. There are very few studies with respect to plastic litter along Indian beaches specifically on

Gujarat coast except the one by Kaladharan *et al.,* (2017).

Therefore, the present study aims to assess the distribution, types, and amounts of marine litter among the four beaches along the Saurashtra coast, Gujarat. It is hoped that, this study can fill the gap in the data and knowledge, and thus support efforts to achieve better marine litter management along the coast.

Materials and Methods

This study was comprised of four beaches located along the coast of Saurashtra of Gujarat which are exposing to different coastal activities viz. tourist activities, fishing activities and environmental conditions. The four beaches (Porbanadar, Madhavpur, Chorwad and Veraval) selected for the present study represent a wide geographical coverage of Saurashtra region of Gujarat (Fig. 1). The four stations were surveyed for marine litter on monthly intervals during March 2017 to March 2018. The state of Gujarat accounts for 1600 km long coastline with 28% of sandy beaches and many of these are lying along Saurashtra coast. Four beaches were selected for study due to its ecological significance and religiously importance. The detailed of each beach is given in Table 1.

At each beach, three replicates measuring 100 × 1m of the strandline were sampled based on Jayasiri *et al.,* (2013a) and Silva-cavalcanti *et al.,* (2009, 2013) with 100m interval. In each replicates all the items of marine litter were visually collected, counted and classified according to their composition and grouped into six categories (Plastic, Metals, Rubeer, Glass, Natural and Others) (Fig. 2). Based on the Trouwborst (2011) all the marine litter was separated to identify the most likely source. The categories were land based and sea based categories

Table.1

Sr. No	Level of Urbanization	Beaches	Ecological Importance
1	High	Porbandar	It is an excellent rocky and sandy beach. Beach stretches for almost 10km. It is an hot tourist destination and sees about 5000-6000 tourist every holidays. The beach has pristine waters for swimming.
2	Low	Madavpur	The 6 km long stretch of the beach is among the most beautiful, sandy beaches of Gujarat. This beach enjoys international recognition as one of the best beaches in the world. Itis one of the major nesting sites for the endangered Green turtle.
3	Low	Chorwad	The 7km long stretch of the beach was once home to the royal palace of the Nawab of Junagadh. The beach is famous as idyllic beach destinations in Gujarat.
4	High	Veraval	The 6.5km stretch of Veraval beach is a beautiful stretch of crystal blue water. Veraval beach is very famous tourist destination owing to its religious importance and the pilgrims visiting the temple also visit the beach.

Statistical analysis

The analysis of variance (ANOVA) was carried out to determines for the effects of the months, beach and their interactions at the significance level of *p<0.05* for the abundance by weight and number of plastic litter along the four stations. Prior to conducting the analysis, a normality test was performed, and data transformation was performed for the non-normal variables. Post–hoc tests were performed if the ANOVA results showed a significant difference between the different sites. The abundance of marine litter in all the categorized is expressed in Mean ± SE. The overall percentage of each category contributing to the total abundance was estimated.

Results and Discussion

As per the objectives of the study, four commercially and religiously important sandy beaches of Saurashtra were surveyed between the periods of June 2017 to April 2018. A total of 4807 items were found on the four beaches within three transects from all the beaches surveyed in different seasons. The mean distribution of Marine litter (Mean ± SE) for number and weights from four beaches of was represented in Figure 2 and 3. The significant variations through one way ANOVA (Analysis of variance) revealed that the number (ANOVA, F=50.07, *P*=0.00) and weight (ANOVA, F=34.003, *P*=0.00) of items varied significantly between the stations (*p<0.05*).

The mean abundance of marine litter was found to be 66.76±4.24 items m^{-2} (19–158 items m-2) and mean weight 22.47±1.03 g m-2 (4.17–40.18 g m-2) per square meters. Although the same types of waste occurred on

all the beaches, the mean amounts varied significantly according to level of the urbanization and recreational activities. These mean litter values are in line with the finding obtained from the other study carried out in SW Black sea coast, Northern Turkey (1.70 – 197.25 items m^{-1}) Topcu *et al.,* (2013), Balearic islands, Spain (8-132 items m^{-1}) Martinez-Ribes *et al.,* (2007), Cassino beach of Brazil (0.3-60.7 items m^{-1}) Wetzel *et al.,* (2004), Bottless Bay, Papua New Guinea (1.2-78.3 items m^{-2}) Smith, (2012). In general, the values of marine litter accumulation in the present study showed that the beaches have high influences of the litter and the quantity is comparably higher than the other studies. It can be characterized by the floatation of litter towards the beach, high uses of coast by the tourist visiting for the recreational purpose hence persisting the litter over time.

The mean abundance of marine litter in Porbandar coast was found 95.16±6.28 items m^{-2} (36–140 items m^{-2}) by items and 24.94±1.37 g m^{-2} (13.99-33.19 g m^{-2}) by weight. The highest abundance of plastic litter was recorded in Veraval coast with 97.66±6.65 items m^{-2} (66–158 items m^{-2}) by items and 31.59±1.17 g m^{-2} (19.84–40.18 g m^{-2}) by weight. The lowest abundance of number of items m^{-2} was recorded in the Madhavpur coast with mean abundance of 34.88±2.25 items m^{-2} (19–54 items m^{-2}) whereas the lowest weight was recorded in the Chorwad coast with mean weight of 13.07±0.59 g m^{-2}(8.48–17.30 g m^{-2}) (Fig. 4).

During all the sampling months and all the four different stations, plastic litter was predominated in the marine litter collected (Fig. 5) ranging from 59.71 to 76.98% of the items collected (Mean 66.82%). Similar to other findings, Jayasiri *et al.,* (2003a. 2003b); Santos *et al.,* (2009); Zhou *et al.,* (2011); Liu *et al.,* (2013); Leite *et al.,* (2014); Adydin *et al.,* (2016) founds a higher abundance of plastic litter (50-90%) during their study period. The abundance of plastics along these beaches especially Porbanadar and Veraval can be attributed with beach visitors, coastal inhabitants and recreational activities contribute to the major sources of litter pollution on beaches in developing countries due to their littering behavior and high usage of plastics. The plastics categories of marine litter classification also include the Styrofoam which was found in high quantity in Veraval and Porbanadar coast which can be attributed to the fishing activities all along the coast. Most of the marine litter was discarded mainly by the locals and by the tourist, which explains high quantities among these two beaches. Marine litter in Madhavpur and Chorwad beach has less accumulation which can be considered as the reference for other two beaches. The quantity of Metals was found 3.27% (0.05 – 4.11%), Rubber 4.39% (3.39-4.78%) and Glass 4.18% (3.11-4.84%) respectively.

The temporal variation revealed that the marine litter (ANOVA, F=2.16, *P=0.05*) and weight (ANOVA, F=2.32, *P=0.05*) abundance varied significantly between the months (*p<0.05*). A comparison based on the number of items among all four stations indicated a consistent temporal trend. The highest abundance of items was observed in the month of August (88.50±14.86 items m^{-2}) and October (72.58±10.59 items m^{-2}) (Post-monsoon) months than that of other months while by weight also significantly highest abundance was observed in August (26.10 ± 2.41 g m^{-2}) and December (24.33 ± 2.65 g m^{-2}) than in other months (Fig. 6). The lowest litter density was observed in the months of summer (57.75 ± 7.72 items m^{-2}). A highest number of large sized litters were observed in post-monsoon for many sites compared to those in other seasons. A general trend was that stations on the eastern side of the study area seemed to receive more local than foreign litter. The high litter accumulation

during post-monsoon months can be attributed with monsoon and heavy onshore wind speeds that increases the wave heights resulting into the traps of plastics on the shores. The seasonal fluctuation in the litter accumulation can be explained by the resuspension and transport of plastics and other objects on to the shores during post-monsoon months.

Identification of sources of marine litter from the beaches is a primitive step towards the litter solution. In the present study, the overall 78.5% of marine litter was land based while the remains 21.5% were based from the sea-based sources was observed during the study

(Fig. 7). The ability to define the sources of marine litter based on the composition depends, at least partially, how the conservationist are assume for. The increased sources of land based litters increased during the post-monsoon season. Porbandar and Veraval beach represents an area with high beach usage as compared to Madhavpur and Chorwad beach, reason being that it is easily accessible through road and people visit these beaches frequently. The majority of the litter recovered emanates from domestic, recreational and fishing activities which indicate very high anthropogenic pressure on the beaches.
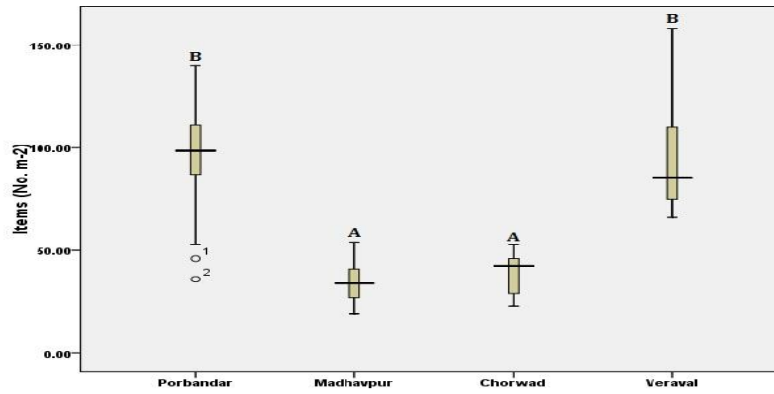
Fig.1 Sampling station
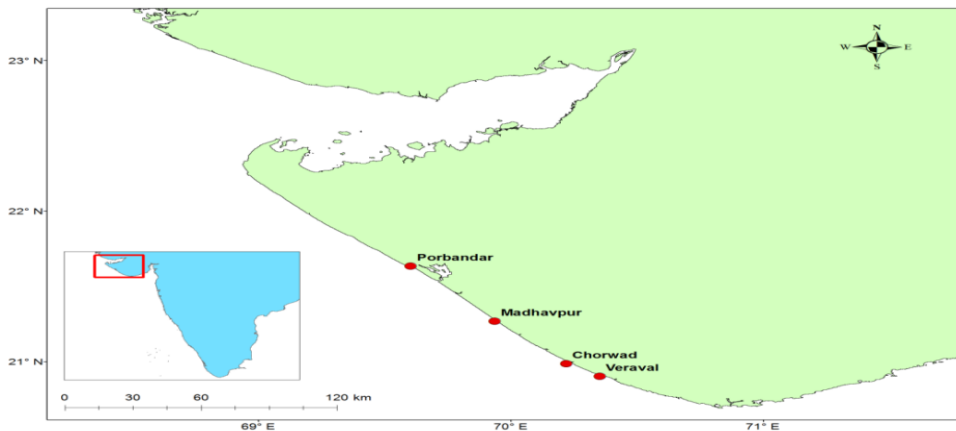
**Fig.2** Accumulation of marine litter along Porbanadar Coast

Fig.3 Spatial variations of marine litter abundance (Mean ± SE) by number of items in four sampling stations (*Bars with different letters in lowercase vary significantly among the beaches for the number of items in uppercase (P<0.05)*


Fig.4 Spatial variations of Marine litter abundance (Mean ± SE) by Weight of items in four sampling stations. (*Bars with different letters in lowercase vary significantly among the beaches for the number of items in uppercase (P<0.05)*
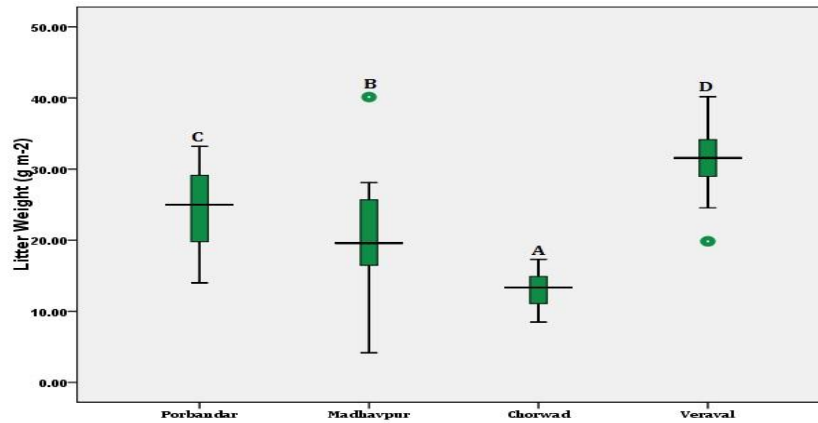

Fig.5 The average abundance of marine litter quantity in (Percentage) in the study area
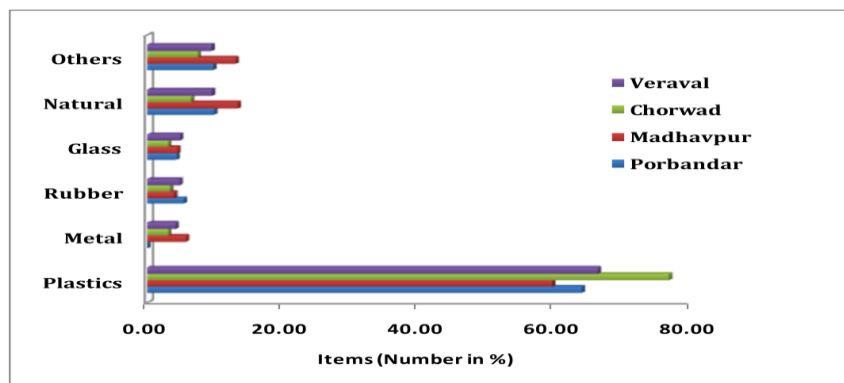
Fig.6 Temporal Variations in Marine litter abundance (Mean ± SE) by weight and number of items in four beaches of Gujarat coast from June 2017 to April 2018. *Bars with different letters in uppercase vary significantly* among the months for number and lowercase by the weight *(p<0.05)*
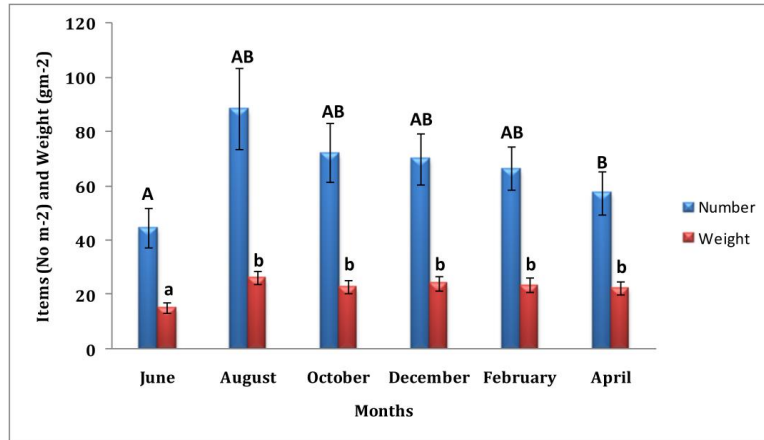
Fig.7 Land-based and sea-based sources of marine litter from the four important beaches of Gujarat coast
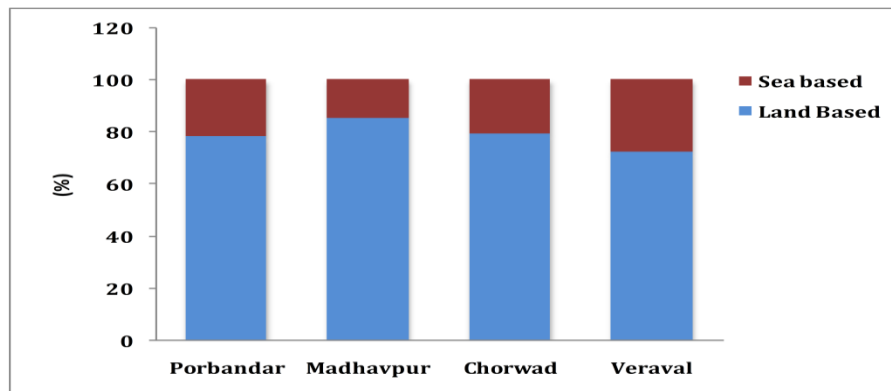
Conclusion of the study is as follows:

In present study, we have reported composition, quantities and distribution of marine litter along four important beaches of Gujarat. The observation of both - number and weight of items, characterized more precisely the contribution of Marine litter to the coastal zone pollution, which is essential for the improvement of Marine Litter management. Plastic was dominated items in the total marine litter from the coast. Majority of marine litter originates from land based

sources and activities, the primary emphasis should be given to controlling marine litter should focus on preventing the inflow of litter in to the sea. Taking into the account the absence of earlier study in these areas, our results can provide background information for future assessment and the implementation of management actions to mitigate the problems associated with marine litter. Management efforts, including public awareness and encouraging changes is attitudes related to marine litter management are very essential components in efforts to

mitigate the presence of marine litter in marine and coastal environments.

Acknowledgment

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