BEACH MACRO-LITTER MONITORING ON MONASTIR COASTAL SEA (TUNISIA): FIRST FINDINGS

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Abstract – Monastir city is considered as one of the most important commercial capital in Tunisia. During the last decades, it has reported an increase in urban density and industrial activities (textile, agri-business industry, fishing activity offshore fish farm, etc.). The aim of this study is to provide information on the types, quantities, and distribution of marine debris and increasing public awareness of the coastline condition. The macrolitter monitoring activities was investigated on three beaches (Palmier, Marina, Karaia) and on Kuriat Island during four seasons (Winter, Spring, Summer, and Autumn). The operational toolkit used in this study was developed within the Interreg MED Plastic Busters MPAs Project and capitalized in the ENI CBC Med Common Project.
The highest abundance and density of macrolitter were recorded on Marina and Karaia beaches with respectively (13540 items/100 m; 8.49 items m^{-2}) and (6842 items/100 m; 6.11 items m^{-2}) during the spring season. According to the Clean Coast Index, these two beaches were classified as extremely dirty whereas Kuriat Island was considered as very clean. Plastic items corresponded to the highest concentration of litter in all studied sites and for all seasons varying between 69 % and 89 % of total items. Cigarette butts are the most frequent type of debris.

Introduction

Human activity and behavior, whether deliberate or unintentional, contribute to marine litter (debris). It is also the result of poor waste disposal and a lack of public awareness of the potential consequences of mismanagement [1]. Litter can be transported from land to the marine habitat via rivers, storm water, wind, and sewage, or it can be discarded directly on beaches and at sea [2]. There are numerous types of marine litter, including plastics, metals, glass, and textiles, which can be found on beaches, floating on the surface of the sea, or sunk to the seafloor. It is a global issue and a direct threat to the marine environment; whether social, economic, or ecological in nature [3]. Plastic litter accounts for the majority of marine litter in most of the world's oceans [4].

The Mediterranean Sea is a semi-closed basin with high densities of marine litter due to marine traffic, populated coastlines, complex currents, river inlets, and tidal flow, as well as limited water exchange via the Suez Canal and the Strait of Gibraltar [5]. The Mediterranean Sea has the world's fourth highest concentration of floating marine litter, with 22 000 t, accounting for 9 % of the total [6].

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Monastir Governorate (Tunisia, eastern Mediterranean) has a land area of approximately 1024 km^2 and a population of 548 000 people. Tourism and fishing are important economic activities in the area. Monastir is Tunisia's first seafood producer and the fishing sector is one of the main pillars of the local economy [7]. Furthermore, Monastir is one of Tunisia's most important tourism areas. What's more, the future marine protected area (MPA), Kuriat Islands, located in the north-east corner of Monastir Bay (Tunisia), has a high touristic appeal. For many years, the Kuriat Islands, particularly the small one, have served as a place of relaxation for visitors [7].

Anthropogenic pressures, the intensity of tourism and commercial ship traffic in Monastir Bay, and the large number of domestic and foreign tourists' activities, particularly during the summer, all contribute to marine pollution. Furthermore, the COVID-19 pandemic revealed some of the vulnerability of the Monastir Bay's social-ecological system. Monitoring beach litter in Monastir Governorate may be necessary for developing management strategies aimed at preserving the integrity and functioning of these vital ecosystems. The primary goal of this study is to assess and quantify the abundance, composition, and occurrence of marine litter in three beaches and Kuriat Islands in Monastir. This is, to the best of our knowledge, the first study on marine litter in this area. The current work contains the first recorded data.

Materials and Methods

Study area

Monastir city is considered as one of the most important commercial capital in Tunisia. During the last decades, it has reported an increase in urban density and industrial activities (textile, agri-business industry, fishing activity offshore fish farm, etc.).
The presence of marine debris along the coastaline of Monastir bay, was investigated in three beaches (Palmier, Marina, Karaia) and on Kuriat Island during four seasons (Spring 21, Summer 21, Autumn 21 and Winter 21) (Fig. 1).

Figure 1 – Location map of the beaches investigated.

The beaches were selected in order to fulfil the following requirements: composed of sand or gravel and exposed to the open sea; accessible to surveyors throughout the year; characterised by a minimum length of 100 m; lack of tourism facilities during the survey period; preferentially, not being subject to any litter removal actions.

At each beach, 100 meters survey section was chosen and cover the entire beach width, from the shoreline to the end of the beach identified with: beginning of vegetation, dunes, base of the cliff, road or other anthropic structures. The monitoring was performed with the help of NGB organisation. In each beach, the boundaries of each transect were geo-referenced using a GPS in order to ensure that the same sampling units were monitored in all surveys.

Beach monitoring

The beach litter surveys were performed in line according the same protocol as the one proposed by the European Environment Agency in the MarineLitter Watch program and it is used by other NGOs and research institutes. The operational toolkit used in this stydy was developped within the Interreg MED Plastic Busters MPAs Project and capitalized in the ENI CBC Med Common Project.

Walking through the sampling area, all macroscopic litter items larger than 2.5 cm in the longest dimension were collected, categorized and counted, ensuring the inclusion of caps, lids and cigarette butts. The surveys were conducted without disturbing the upper layer of the sampling unit (i.e. without digging to release litter buried in the sand), as envisaged by the protocol. Monitoring operations were usually carried out early in the morning. All collected litter items were identified by assigning them to different categories according to their composition: Artificial polymer materials, Rubber, Cloth/textile, Paper/Cardboard, Processed/Worked wood, Metal, Glass, Ceramics, Sanitary waste, Medical waste, COVID-19, Paraffine/Wax pieces and Food waste composed by 169 items, according to the classification list of marine litter items.

Data Analysis

To allow comparability with other publications on coastal litter surveys, litter abundance was expressed as total number of items per 100 meter of shoreline [items/100m], number of items per square meter [items/m^2] and weight per square meter [g/m^2]. For assessing the cleanliness level of the coast, the Clean Coastal Index (CCI)) was calculated using the formula below:

$$CCI = (\text{Total number of plastic parts} / \text{Sampled area}) \times K \qquad [8]$$

Consistent with the CCI index calculation [10], a coefficient K = 20 was inserted into equation (1) for statistical and convenience reasons. This index only takes plastic items with a size greater than 2 cm into account. The result corresponds to the beach CCI rank as: 0-2: very clean (no litter is seen); 2-5: clean (no litter is seen over a large area); 5-10: moderate (a few pieces of litter can be detected) 10-20: dirty (a lot of debris on the shore) and 20 or more: extremely dirty (most of the beach is covered with debris) [8]. The General

Index (GI) employed in this study is the same as proposed for the Clean Coastal Index but considering all types of debris instead of just plastic items.

Results and Discussion

Beach monitoring was carried out in 2021 on three beaches (Marina, Palmier, and Karaia) and on Kuriat Island. Except for Kuriat Island, where monitoring was only done in the summer and spring, all beaches were monitored throughout the year. Access to Kuriat Island was difficult for several reasons, including the difficulty of obtaining authorization for access, the bad weather, and the pandemic covid conditions.

Beach Litter Spatial and Temporal Distribution

Beach litter items varied greatly in composition and number across all beaches surveyed during this study. During all seasons studied, the total number of items accumulated ranged from 1125 to 21700 items. In the spring season, the density of collected items ranged from 0.004 to 8.49 items m^{-2} at Kuriat Island and Marina beach, respectively. (Table 1). Such values are somewhat higher than those recorded in many studies carried out along the Mediterranean sea. The average of litter density found on the Mediterranean coasts varied between 0.062 and 2.71 items m^{-2} [9].

Table 1 – Litter abundance at investigated beaches (items per 100 m beach sectors and items m^{-2}).

Beach	Spring		Summer		Autumn		Winter		Total Items
	N° Items	Density	N° Items	Density	N° Items	Density	N° Items	Density	
Marina	13540	8.49	3403	5.35	1916	2.80	2841	2.37	**21700**
Palmier	3230	1.16	1621	0.53	6205	2.00	5514	3.55	**16570**
Karaia	6842	6.11	2832	1.67	2933	1.72	3025	1.32	**15632**
Kuriat	103	0.04	1022	0.34	*	*	*	*	**1125**
Total Items	**23715**		**8877**		**11054**		**11380**		**55027**

In Moroccan Mediterranean coasts it ranged between 0.02 and 0.153 items m^{-2} [10]. At Ionian sea the litter density extended from 0.08 to 0.91 items m^{-2} [11]. In the Eastern Mediterranean region of Turkey, the litter density varied from 1.422 to 3.53 items m^{-2} [9]. However, in the Southeastern Black Sea beaches, the debris litter ranged between 1.22 to 4.2 items m^{-2} [12].

The average abundance for each beach and for all sampling seasons showed that Kuriat Island beach was the cleanest coastal site (average value: 563 items/100 m, or 0.19 items m^{-2}) and the Marina beach was the most litter-polluted (average value:

5425 items/100 m, or 4.75 items m^{-2}). The most significant differences were found between Marina beach vs. Kuriat Island. The highest content of litter at most polluted site can discourage beachgoers, and this can affect the economic value of a beach and also its adjacent economy (e.g., shops, bars, restaurants, etc.).

When all beaches were considered, litter abundance varied by season; for example, 23715 items (43 percent of all items) were collected in Spring, a decrease was recorded in Autumn and Winter with respectively 11054 and 11380 items or 20 percent of all items, and the greatest decrease was observed in Summer (8877 items or 16 percent of all items (Table1).These findings contrast with other findings that indicated that the most abundant litter was found in the summer. Indeed, the highest values of litter density were reported in the Mediterranean Sea during the summer [9]. The difference between our results and the other findings might be related to the period of beach monitoring. Indeed, our summer sampling was carried out at the first week of June, considered as the beginning of the summer season, whereas, in the other studies, summer sampling was done in August when the beach became actively used for swimming-sun bathing and picnic activities opened for summer [9]. Otherwise, local municipalities' cleaning efforts on the studied beaches are increased during the summer season. These investments are significantly greater, as is the number of beachgoers. During this time, beaches are frequently cleaned because there is an increase in litter due to increased tourist pressure.

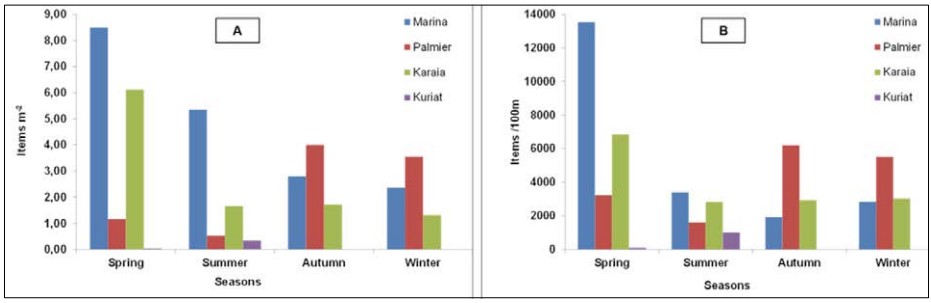

Figure 2 – Density (A) and Abundance litter (B) by beach in each season.

The highest values of abundance and litter density were recorded in spring at both beaches of Marina and Karaia whereas at Palmier beach, the most litter content was observed in autumn and winter. These findings might be related firstly to the reduction of beach cleaning operations realized by local municipality and secondly to the accumulation of debris transported by winds and storms. On the other hand, the increase of litter density recorded in spring at Marina and Karaia beaches is due to that beaches are located in the city center and therefore more frequented by citizens and used as a picnic area in spring season.

Composition of Beach Macro-Litter

Litter items were composed of different materials (Fig. 3): Artificial polymer materials is being the most represented (70 %–83 %), followed by Processed /Worked Wood (3-11 %), metal (2–9 %), cloth (1-6 %), paper and cardboard (1–5 %), glass (1–4 %),

ceramics (1–2 %), rubber, sanitary waste and covid (1 %). Similar percentages, especially for plastics, were found in other studies carried out on different coastal zones: from 75 % to 83 % at the Adriatic Sea [13, 14], 82.6 and 83.5 % on Mediterranean coastal sites of Alicante Province (SE Spain) [15], 70.64 % on the Moroccan Mediterranean coast [10], 81 % on Mediterranean beaches [16] and 83 % on the coast of South Africa [17]. Furthermore, Chitaka and von Blottnitz, [18] indicated that plastics exceeded 90 % of the total debris composition at Cape Town in Africa.

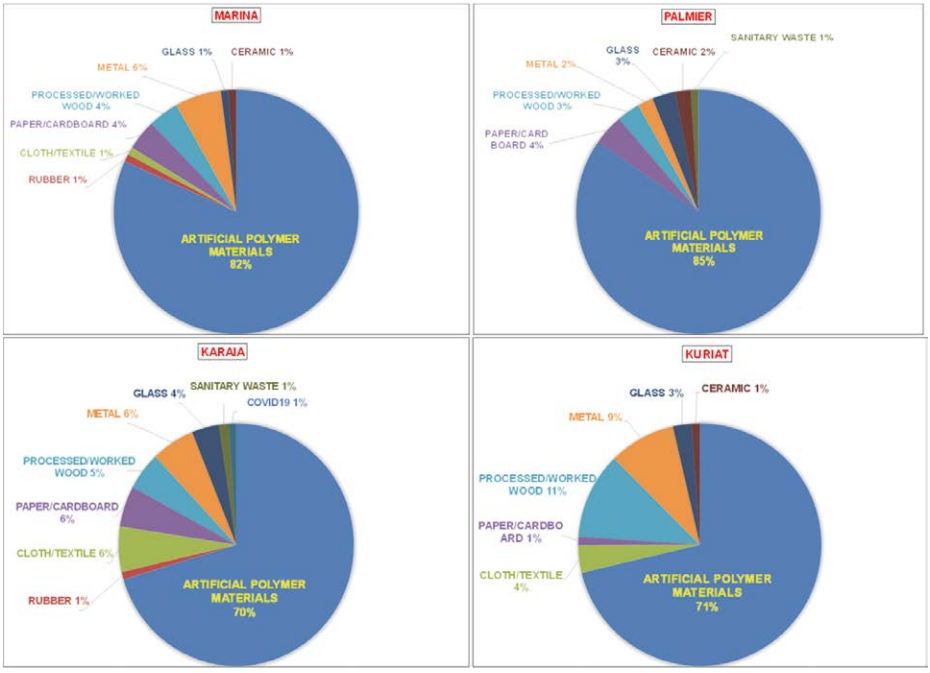

Figure 3 – Composition of litter items according to material categories in terms of number during all surveyed seasons.

Plastic items, which are made of land, had the highest concentration of litter in all the sites we studied. These findings are consistent with other related studies in developed and developing countries which have linked beach litter to land-based sources [19, 20]. Topçu and Öztürk [21] mentioned that plastic abundance is driven by input, great persistence, and high floatability. Of all the litter items observed in the four surveyed beaches, the most plastic abundance was recorded on Palmier and Marina beaches with respectively 82 and 85 % of total collected litter items during all sampling periods.

Figure (4) depicts the abundance of various artificial polymer materials at each investigated beach. Cigarette butts were the most abundant items in Karaia and Marina beaches with respectively 34 % and 21 % of the total plastic amount.

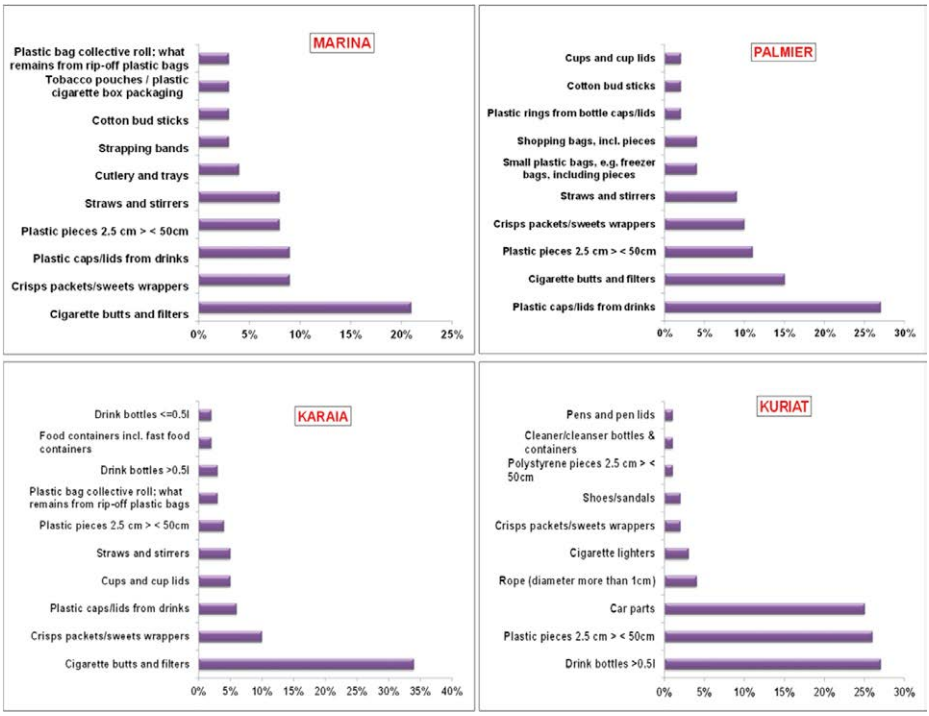

Figure 4 – Artificial Polymer Materials Top ten Items (%).

In Palmier beach the most abundant litter was plastic caps/lids from drinks (27 %) whereas in Kuriat Island the most abundant litters are drink bottles >0.5 l, plastic pieces 2.5 cm><50 cm and rope with respectively 27 %, 26 % and 25 %. These findings are in accordance with those observed on the Moroccan Mediterranean coast [10], where cigarette butts accounted for 31.5 percent of the total collected items. These results confirming observations in Spanish beaches where cigarette butts are the most abundant litter items [15]. Simeonova et al. [22] reported that the cigarette butts and filters were the highest in the artificial polymer material categories quantitative distribution in the Bulgarian coast and the significant amounts of in the summer period were related to the recreational activities. Cigarette butts were one of the most frequent litter items found on beaches in several areas in Europe [23].

The abundance of these type of items was attributed to their persistent in the environment [24]. In addition, mechanical cleaning is less effective for removing cigarettes butts than for general litter. The rest of the surveyed groups represented less than 11% and is also be attributed to beachgoers, such as drinking and food items, etc. [25].

In Kuriat Island no cigarette butts were observed which was aligned with findings observed on remote and rural beaches in Moroccan Mediterranean coasts. Plastic fragments, plastic bags (shopping bags), and plastic bottles were the most common plastic items found across all sites. These findings also support previous findings in other parts of

the world that fragments are the most commonly occurring items in many of the world's coastal areas. Examples can be found in the United Kingdom and Spain [26, 27]

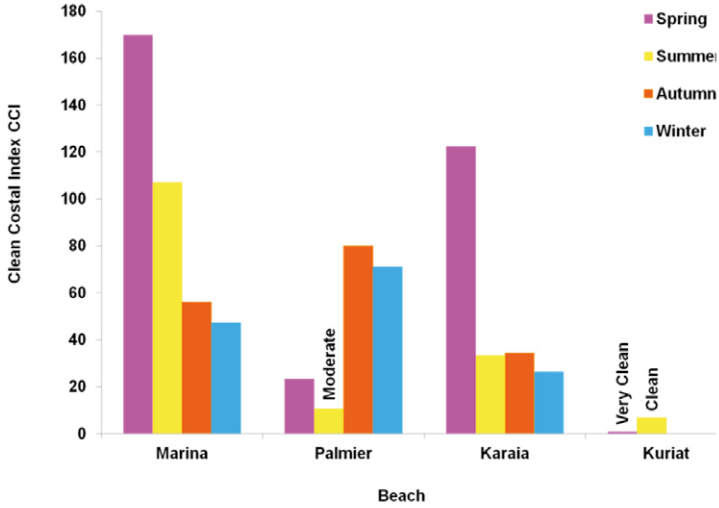

Figure 5 – Clean Coast Index (CCI) in all surveyed beaches during all seasons.

Clean Coast Index (CCI) is one approach to assess cleanliness levels of beaches [9]. The calculation result of CCI found that all beaches during all surveyed seasons were considered as extremely dirty except Kuriat Island which was indicated as clean in summer and very clean in spring and Palmier beach which was classed as moderate in summer (Fig. 5). Akyatan beach was also classified to extremely dirty [9] as it was found in Southeastern Mediterranean Sea. Similarly, Aytan et al. [12] using the same index in Black Sea beaches, found the beaches classified as extremely dirty. However, the same index was used in the Sinop coasts and the beach was found very clean. The marine litter amount of our surveyed beaches was found to be higher than the studies conducted in Black Sea and Mediterranean beaches.

Conclusion

Anthropogenic impact, lack of public awareness, poor waste management, and weather conditions all have a significant impact on the spatial and temporal distribution of marine litter. Our findings highlight the problem by collecting enough data and analyzing the distribution and composition of marine litter to fill a knowledge gap in the Monastir Governorate (Tunisia, eastern Mediterranean). In addition, for future decisions more data on marine litter is needed with a proper database, including records from ports' waste disposals (ship inputs and fisheries), input from rivers, and facilities near shores, in order to increase the coverage of monitoring rather than beaches. Finally, marine litter is a major

issue that should be strictly avoided by limiting land-based pollutants, encouraging recycling, and improving waste management before it reaches the marine environment.

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