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Baseline

Face masks related to COVID-19 in the beaches of the Moroccan Mediterranean: An emerging source of plastic pollution

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ABSTRACT

During the COVID-19 pandemic, face masks became a common type of litter invading many different environments, including tourist beaches. However, the presence of face masks on beaches threatens the marine environment with a new form of plastic pollution. In this study, we monitored the occurrence and density of face masks on five tourist beaches along the Moroccan Mediterranean during five months starting from February until June 2021. A total of 321 face masks were recorded on the five beaches, 96.27% of which were single use. The mean density of face masks was 0.0012 ± 0.0008 m⁻². Recreational beaches were the most polluted in the study area. This is related to the important influx of beachgoers on urban beaches compared to resort beaches. With the large number of masks introduced on the beach, we hypothesize that microplastic pollution could increase drastically in the Moroccan Mediterranean in the coming years. Significant efforts are required to reduce this type of waste.

Plastic pollution in the world’s oceans is now widely recognised as a major global challenge (Everaert et al., 2020). The dangers that plastic pollution presents to marine environments have been studied for a long time and are well documented (Derraik, 2002; Everaert et al., 2020; Bhagat et al., 2021; De-la-Torre et al., 2021a). These marine wastes are found on beaches and in oceans around the world, and have serious impact on marine wildlife, fishing, health, shipping, and tourism industries (Gall and Thompson, 2015; Krelling et al., 2017; Beaumont et al., 2019).

Since the appearance of the COVID-19 pandemic, the daily request for face masks has reached high levels. Millions of face masks are used globally every day, and these masks can enter the environment through landfills or discarded litter (Patricio Silva et al., 2020; Selvaranjan et al., 2021). According to a recent report of OceansAsia (2020), about 1.56 billion face masks entered the oceans in 2020. Recent studies confirm that face masks are potential sources of microplastic pollution in the water systems (Fadare and Okofo, 2020; Shruti et al., 2020; Ma et al., 2021; Saliu et al., 2021; Shen et al., 2021; Wang et al., 2021). They are produced from a variety of polymers such as polypropylene, polylactide, polyurethane, polycarbonate, polyethylene, or polyester (Aragaw, 2020; Fadare and Okofo, 2020). With the increase in both production and consumption of face masks, microplastics released from face masks will continue to increase in the coming years, potentially exacerbating the existing plastic pollution. If no mitigation strategies are adopted, it is expected to increase their amount in natural environments, with negative consequences for the marine biota (Patricio Silva et al., 2021).

The presence of face masks has been documented in several public places and natural environments, including tourist beaches (Okuku et al., 2020; Ammendolia et al., 2021; Ardusso et al., 2021; Cordova et al., 2021). The density of disposable face masks on beaches seems to be considerably greater than in any other location (Patricio Silva et al., 2021). Mismanaged face masks deposited on land or in landfills can find their way into marine environments through many routes (Okuku et al., 2020; De-la-Torre et al., 2021b; Rakib et al., 2021). They are easily transported to the beaches by rivers, wind, tides, drainage systems, shipping routes, or human activities (Patricio Silva et al., 2021). For instance, face masks were observed in Lima beach, Peru (De-la-Torre et al., 2021b), the Kenyan coast (Okuku et al., 2020), the Chilenan coast (Thiel et al., 2021), the Bushehr coast, in the Persian Gulf (Akbarzadeh et al., 2021), Cox’s Bazar coast, Bangladesh (Rakib et al., 2021), Colombian beaches (Ardusso et al., 2021), and the northern coast of São Paulo State, Brazil (Neto et al., 2021). Recent studies show that face masks have a negative impact on wildlife through entanglement and ingestion (Hiemstra et al., 2021; Neto et al., 2021).

As in all other countries across the world, Morocco lives a special

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situation after the spread of COVID-19 in March 2020. The Moroccan government has adopted a series of measures to avoid the transmission of the virus, including health, social, and economic measures. Moroccan authorities have mandated the use of face masks in closed environments. As a result, millions of face masks are being manufactured and used daily for protection against the SARS-CoV-2. A large number of these masks are being dumped on streets, beaches, rivers and sewers. In Morocco, several studies have been published indicating that disposable masks are not adequately treated with insufficient waste management (Ben Haddad et al., 2021; Mejjad et al., 2021). After the opening of the Moroccan public beaches following the lockdowns, Ben Haddad et al. (2021) reported an increase in the density of litter related to COVID-19 in Moroccan Atlantic beaches. Therefore, a small amount of mismanaged waste will lead to more plastic debris on Moroccan beaches. Due to the lack of litter data collected during the pandemic, there is an increasing need to identify key litter related to COVID-19 (Canning-Clode et al., 2020).

The main objective of this research was to report the occurrence and density of face masks on five beaches along the Moroccan Mediterranean. We also examined the probable role of face masks in the creation of secondary microplastics.

Tetouan coastline, located in the Western Moroccan coast of the Mediterranean Sea, adjacent to the Gibraltar strait. The coast of this region is one of the most traditional tourist destinations of the Moroccan Mediterranean. The study was conducted on five beaches (Fig. 1). The urban beaches of Fnideq, M’diq and Martil are fundamentally used for swimming and sunbathing by beach users and national tourists starting from June till September, but have an important recreational use throughout the year because they are a place for walk exercises, to enjoy the scenery, play sports as well as attending other activities. In contrast, Azla beach and Kaa Asrasse are located in an area of a low human occupation. Indeed, incorrect disposal of marine debris at these beaches has been reported by previous studies (Nachite et al., 2019; Mghili et al., 2020).

Face mask monitoring followed the previous studies conducted on tourist beaches by De-la-Torre et al. (2021b) and Rakib et al. (2021). For sampling in each beach, several transects were established. The number and length of transects varied with beach size and morphology. The surveyed transect was identified by GPS to guarantee that the same sample units were monitored for all surveys. Table 1 shows the geographic coordinates, beach typology, activities and areas covered in the five beaches. A total of 16 sampling campaigns were performed between February and June 2021. Each beach was surveyed three times per month with interval times ten days after the first sampling.

Face masks were identified visually by walking along each site (De-la-Torre et al., 2021b). In addition, each face mask item was examined

![Fig. 1. Study sites along the Moroccan Mediterranean and sampling locations.](image-url)
carefully with the naked eye to find any sign of alteration and/or degradation (Akhbarizadeh et al., 2021). Each face mask item with a sign of degradation was identified as a damaged mask.

At each station, the density of face masks was calculated using the following equation (Okuku et al., 2020):

\[ C = \frac{n}{A} \]

where \( C \) is the density of face masks items per m\(^2\), \( n \) is the number of face masks, and \( A \) is the area of the surveyed beach.

All five beaches monitored were contaminated with face masks (Fig. 2). The presence of face masks associated with COVID-19 was reported in 15 out of the 16 surveys. During the study period, 321 face masks were recorded in the five beaches surveyed (Table 2). No gloves were found on the five beaches. Face masks were principally composed of single-use surgical masks (96.27%; \( n = 309 \)), and the rest were reusable cloth masks (3.73%; \( n = 12 \)). Reusable masks are less likely to be discarded than single-use masks (Ammendolia et al., 2021). In many countries around the world, face masks are the most abundant type of personal protective equipment (PPE) on beaches and the Moroccan Mediterranean beaches are no exception to this (Akhbarizadeh et al., 2021; Ben Haddad et al., 2021; De-la-Torre et al., 2021b; Rakib et al., 2021; Neto et al., 2021; Thiel et al., 2021). In the urban environment, gloves are the most abundant type of PPE (Ammendolia et al., 2021).

In the five beaches, the mean density of face masks was 1.2 $\pm$ 8 $\times$ 10\(^{-3}\) m\(^{-2}\) and ranged from 0 to 3.67 $\times$ 10\(^{-3}\) m\(^{-2}\) (Table 2). Recent studies have documented the occurrence and density of PPE items on beaches (Table 3). The mean density of face masks in the study area were comparable to the values reported on the Kenyan coast (Okuku et al., 2020), the Bushehr coast, in the Persian Gulf (Akhbarizadeh et al., 2021) and in urban areas of Toronto (Ammendolia et al., 2021). On the other hand, the density was much higher than the values reported from Agadir beach, Morocco (Ben Haddad et al., 2021) and Lima, Peru (De-la-Torre et al., 2021b). At the same time, the mean density was lower than that found on the beaches of the Chilean coast (Thiel et al., 2021) and the Cox’s Bazar coast (Rakib et al., 2021). As shown in Table 3, PPE density varies among regions of the world, which may be influenced by sampling methods, area sampled, weather conditions (wind and precipitation), population density, type of region (tourist or non-tourist), and COVID-19 restrictions (Ben Haddad et al., 2021; De-la-Torre et al., 2021b; Patrício Silva et al., 2021).

As summarized in Table 2, the highest total number of items was found in Martil beach (32.72%; \( n = 105 \)), followed by Fnideq beach (30.85%; \( n = 99 \)), M’diq beach (16.82%; \( n = 54 \)), Azla beach (12.14%; \( n = 39 \)) and Kaa Arasse beach (7.47%; \( n = 24 \)). Based on the results, recreational beaches were the most polluted beaches by face masks along the study area (Table 2). Conversely, resort beaches were less polluted by face masks (Table 2). This is related to the important influx of beachgoers on urban beaches compared to resort beaches.

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![Fig. 2. Examples of surgical masks found on the five beaches along the Moroccan Mediterranean.](image-url)
human activity is limited (fishing). As urban beaches have attracted more visitors, the disposal of masks on beaches has also increased. In fact, 23.05% of the total number of masks were recorded during the period of April–May, which corresponds to the Ramadan month (Fig. 3). During this period, human activities are decreased during the day and restricted during the night. The maximum density of disposed masks reached during the month of June (41.43%), which is probably due to the higher number of visitors that came to the studied beaches (Fig. 3). It is noteworthy that these beaches are cleaned by the municipality every day during the summer season. The notable differences in face mask densities between the five months can be attributed to the number of persons visiting the studied beaches. Thiel et al. (2021) reported a high accumulation rate of face masks on Chilean beaches during the summer. A similar trend was observed in coastal São Paulo, Brazil (Neto et al., 2021). The number of face masks found in the supralittoral zone was higher than the number of masks sampled in the intertidal zone. This suggests that the majority of these wastes were left by beachgoers. This behavior and lack of environmental awareness of beach users in the Moroccan Mediterranean has been reported previously (Nachite et al., 2019; Mghili et al., 2020).

The Moroccan Mediterranean coasts already suffer from large amounts of plastic (Nachite et al., 2019; Mghili et al., 2020). The increase in the manufacture and consumption of face masks in the Kingdom of Morocco has created a new environmental challenge, adding a large amount of plastic discarded into the environment. These face masks will be altered when exposed to natural factors such as sunlight (including UV radiation), sea waves and sand abrasion (De-la-Torre and Aragaw, 2021; Salii et al., 2021). The potential threats presented by face masks as a source of microplastics fibers have already been demonstrated by several studies (Aragaw, 2020; Fadare and Okoffo, 2020; Patrício Silva et al., 2020; Shruti et al., 2020; Ma et al., 2021; Salii et al., 2021; Shen et al., 2021; Wang et al., 2021). Microplastics can be released from the degradation of the inner layer (polyethylene) and outer layer (polypropylene) fabrics of face masks (Fadare and Okoffo, 2020). Akhbarizadeh et al. (2021) illustrated the role of face masks in creating secondary microplastics on beaches. Physical abrasion induced by sand exaggerated the liberation of microplastic fibers from the masks, with more than 16 million fibers released from a single mask altered in the presence of sand (Wang et al., 2021). In static water, the released quantity of microplastics by one mask is 360 items, and with increasing vibration rate, this quantity tends to increase (Shen et al., 2021). Recently, Salii et al. (2021) indicated that a single surgical mask subjected to 180 h of UV-light irradiation and vigorous agitation in artificial seawater could release up to 173,000 fibers/day. In our case, signs of damage were observed on the face masks found on the beaches, confirming that these masks are altered under prolonged sunlight exposition (Fig. 4a). Based on the present study, about millions of disposable masks enter the sea with thousands of microfibers that can be released every day. The presence of microplastics in the study area was previously demonstrated by Alshawafi et al. (2017). With the high quantity of face masks introduced on the beach and the sea, we hypothesize that microplastic pollution could increase in the Moroccan Mediterranean, particularly in zones with a high quantity of face masks. The microplastics released by face masks as a result of a degradation process would be harmful to several organisms upon accidental ingestion (Patrício Silva et al., 2021).

Like other types of marine debris, face masks can interact with marine biota (Patrício Silva et al., 2021). During the sampling campaigns,
we have registered the observation of several seabird species, including Larus michaellis, Larus audouinii, Himantopus himantopus and Calidris alba. The presence of face masks on the beaches, constitutes a threat of entanglement for these species. We have already observed a bird wearing a face mask in the coastal city of Martil (Fig. 4b). Also, Hiemstra et al. (2021) reported photographic evidence of birds entrapped in a face mask and fish entrapped in gloves. Birds have also begun to include PPE litter in their nests (Hiemstra et al., 2021). Unfortunately, this issue is not limited to Moroccan beaches; divers from the association champions litter in their nests (Hiemstra et al., 2021). During the clean-up near the coast of Tetouan (Fig. 4c). The presence of this waste on the seabed poses a threat to ocean life. The NGO Argonauta Institute for Coastal and Marine Conservation previously reported the death of a Magellanic penguin (Spheniscus Magellanicus) by ingestion of an N95 mask on the northern coast of São Paulo state, Brazil (Neto et al., 2021).

During the COVID-19 pandemic, face masks have become a common type of waste on the beaches of the Moroccan Mediterranean due to the intensive use of these masks. Morocco was already suffering from inadequate waste management practices on beaches before the COVID-19 outbreak. The presence of debris related to COVID-19 in the environment has put additional pressure on the waste management systems. The majority of face masks arises from recreational sources, suggesting that some control measures are needed that would help minimize the amount of these wastes discarded by beachgoers. The most important ways to minimize single-use face masks are by replacing them with non-plastic reusable masks. In addition, the government must take immediate measures to promote public awareness and behavioral changes linked to the standardized use and disposal of face masks in order to reduce the threat of the COVID-19 pandemic. These include installations of more dustbins and signs on Moroccan beaches. The current situation also needs an extension of the spatio-temporal cleaning activities for a better management of these types of waste on the tourist beaches of the Moroccan Mediterranean. We also require an immediate and coordinated commitment to circular economy approaches, particularly strict policies and recycling practices against mask pollution.

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Mghili Bilal: Conceptualization, Investigation, Methodology, Writing- Original draft preparation.

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Aksissou Mustapha: Writing- Reviewing and Editing, Supervision.

**Declaration of competing interest**

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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