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Personal protective equipment (PPE) pollution in the Caspian Sea, the largest enclosed inland water body in the world

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HIGHLIGHTS
• First PPE waste survey in the Caspian Sea - the largest enclosed inland water body.
• Mean PPE density reached 1.02 × 10⁻⁴ PPE/m² and masks were the most abundant type.
• PPE density showed a downward trend due to behavioral and seasonality reasons.
• Recommendations for coastal waste management were provided.

GRAPHICAL ABSTRACT

ABSTRACT

The COVID-19 pandemic led to a still ongoing international health and sanity crisis. In the current scenario, the actions taken by the national authorities and the public prioritized measures to control the transmission of the virus, such as social distancing, and face mask-wearing. Unfortunately, due to the debilitated waste management systems and incorrect disposal of single-use face masks and other types of personal protective equipment (PPE), the occurrence of these types of items has led to the exacerbation of marine plastic pollution. Although various studies have focused on surveying marine coasts for PPE pollution, studies on inland water are largely lacking. In order to fill this knowledge gap, the present study assessed PPE pollution in the Iranian coast of the Caspian Sea, the largest enclosed inland water body in the world by following standard monitoring procedures. The results concerning the density (1.02 × 10⁻⁴ PPE/m²) composition (face masks represented 95.3% of all PPE) of PPE are comparable to previous studies in marine waters. However, a notable decrease in the occurrence of PPE was observed, probably due to behavioral and seasonality reasons. The possible consequences of PPE pollution were discussed, although much more research is needed regarding the ecotoxicological aspects of secondary PPE contaminants, such as microplastics and chemical additives. It is expected that face mask mandates will be eventually halted, and PPE will stop being emitted to the environment. However, based on the lessons learned from the COVID-19 scenario, several recommendations for coastal solid waste management are provided. These are proposed to serve during and after the pandemic.

Keywords: Face mask Polypropylene Glove COVID-19 Plastic Contamination

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1. Introduction

The global COVID-19 pandemic has changed the priority to public health with little attention to the impact of the actions taken on the environment. Early research highlighted the short-term and positive effects of COVID-19, such as improved air quality, lower greenhouse gas emissions, and reduced noise levels (Espejo et al., 2020; Zambrano-Monserrate et al., 2020). However, some of these effects seemed paradoxical due to the complexity of socio-ecological systems (Battisti, 2021). For instance, the presence of tourists “guarded” common murres (Uria aalge) from white-tailed eagles (Haliaeetus albicilla) in Sweden (Hentati-Sundberg et al., 2021). The COVID-19 lockdown and, thus, the absence of tourists in breeding areas led to a 7-fold increase in the presence of the white-tailed eagle and a significant decline in the productivity of murres due to the disturbance caused by the white-tailed eagles. On the other hand, as a result of the inappropriate disposal of numerous types of single-use plastics associated with the pandemic, these are likely to reach aquatic environments and potentially cause detrimental effects. The impacts of marine litter are multiple and very complex, such as entanglement, ingestion, dispersal of alien species, and release of secondary contaminants, such as plastic additives and microplastics (MPs) (Bergmann et al., 2015; De-la-Torre et al., 2021a). Among the impacted species, 258 species of birds, 101 species of mammals, 11 species of reptiles, and a wide range of macroinvertebrate species have been recognized (Battisti et al., 2019a, 2019b; Poeta et al., 2017b; Staffieri et al., 2019).

One of the most effective ways to slow down the spread of the COVID-19 pandemic is through the use of personal protective equipment (PPE) (Ji et al., 2021). According to the World Health Organization (WHO), PPE comprises face masks, gloves, face shields, goggles, and gowns (WHO, 2020). Fundamentally, any type of wearable material used to prevent the transmission of the virus is considered PPE. Most PPEs are made up of single-use synthetic plastic, including polypropylene (PP), polyurethane (PU), and polyacrylonitrile in masks, and latex, vinyl, polyethylene (PE), and nitrile rubber in gloves (Ammendolia et al., 2021; Okuku et al., 2020).

The number of face masks that arrived in the ocean in 2020 has been estimated as 1.56 billion (Ben-Haddad et al., 2021). PPE items could directly affect aquatic organisms (e.g., the entanglement and entrapment of aquatic organisms and biological attacks) (Hiemstra et al., 2021), release secondary contaminants, and disturb the ecosystemic stability of marine habitats through the spread of invasive species and microbes (De-la-Torre and Aragaw, 2021; Ghayebzadeh et al., 2020a; Zhou et al., 2021). Plastic-based PPEs are subject to chemical and physical degradation by physicochemical (e.g., UV radiation, wind, waves) and biochemical (enzymatic activity) processes, resulting in fragmentation of the polymer matrix (Alfonso et al., 2021; Dey et al., 2021; Patrício Silva et al., 2021). The resulting fragments, smaller than 5 mm, are regarded as MPs (Rakib et al., 2021a). MPs are bioavailable to a broad range of aquatic organisms and can cause toxic effects, the impacts of which can spread through the food chain (De-la-Torre et al., 2020; Ghayebzadeh et al., 2020a; Santillán et al., 2020). MPs are able to release toxic chemical additives (Hajilouini et al., 2022), as well as adsorb pollutants such as organic compounds, heavy metals, and pathogens, ultimately acting as a vector of contaminants (Agboola and Benson, 2021; Torres et al., 2021). Recently, it was demonstrated that MPs released from face masks could pose reproductive and toxicological effects on aquatic and soil biota (Onyena et al., 2021; Jedruchiewicz et al., 2021; Patrício Silva et al., 2021).

Recently, various studies focused on monitoring PPEs in coastal shorelines (Morocco, Peru, Bangladesh, Chile, Persian Gulf, and Kenya), river outlets (Ismenia), and cities (Canada and South Africa). Face masks accounted for 88–98% of all PPE types in the studies conducted in Bangladesh, Morocco, and Peru. The PPE density found along Moroccan, Peruvian, Brazilian, Chilean, and Kenyan coastal shorelines was 1.13 × 10^{-5} PPE m^{-2}, 7.44 × 10^{-4} PPE m^{-2}, 6.29 × 10^{-3} PPE m^{-2}, 6.00 × 10^{-3} PPE m^{-2}, and 3.8 × 10^{-2} PPE m^{-2}, respectively (Ammendolia et al., 2021; Cordova et al., 2021; De-la-Torre et al., 2021a, 2021b, 2021c; Ben-Haddad et al., 2021; Okuku et al., 2020; Rakib et al., 2021b; Ryan et al., 2020; Thiel et al., 2021). This suggests that poor disposal practices of medical care plastics during COVID-19 have polluted the environment with plastic debris (Ardusso et al., 2021).

While the vast majority of studies focused mainly on marine coasts and urban environments, information concerning PPE pollution in inland waters is largely lacking. The Caspian Sea, the world’s largest inland body of water, located between Europe and Asia, is home to unique biodiversity and endemic species (Lattuada et al., 2020). Aiming to contribute to the knowledge concerning environmental pollution with PPEs in inland waters, in the present study, 12 weekly consecutive PPE surveys were conducted for the first time in the southern coastal areas of the Caspian Sea, north of Iran. Thirteen sites along the beach with recreational, fishing, and tourism activities were selected. The abundance, density, characteristics, and distribution of PPE pollution were reported.

2. Materials and methods

2.1. Study area

The Caspian Sea is the largest enclosed inland water body in the world with an approximate area of 436,000 km². It is surrounded by five countries, Iran, Russia, Azerbaijan, Kazakhstan, and Turkmenistan (Ghayebzadeh et al., 2020a; Mataji et al., 2020). The southern coast of the Caspian Sea (Iran’s coast) is roughly 820 km in length and consists of Golستان, Mazandaran, and Guilan provinces (Nematollahi et al., 2020). Over 8 million people live in these provinces and during holidays, the population grows by over 40% (Manbohi et al., 2021). Human activities (e.g., industrialization, urbanization, improper waste management, fishing, tourism activity, and residential wastewater), and river discharge can transport a variety of wastes, especially plastics, to the sea (Ghayebzadeh et al., 2020a). Water fluctuations, seasonal storms, and floods can wash the plastics of farmlands, houses, and dumping areas into the sea (Taghizadeh Rahmat Abadi et al., 2021). As this water body is closed, it is less tolerant and more susceptible to environmental and anthropogenic pollutants than similar environments (Ghayebzadeh et al., 2020b).

The study area is located in Mazandaran province, which encompasses the longest Iranian coastline (487 km) and is an important center of eco-tourism in Iran (Fig. 1). The common activities on the southern shores of the Caspian Sea include swimming, walking, sunbathing, quad-bike riding, horse riding, beach camping, fishing, and other touristic activities.

2.2. PPE survey strategy

To better understand PPE pollution in coastal areas of the Caspian Sea, 13 stations were monitored for 12 consecutive weeks from August 2021 to November 2021 (Fig. 1). Surveys were conducted during the morning, usually before beach cleaning by municipal staff. The sites were well distributed and represented almost the entire coastline of the Caspian Sea. Based on field observations, the major activities of each site were identified and categorized as recreational, fishing, and tourism activities. The coordinates of the sampling stations, the type of coast (rock and sand), principal activities performed at each site, and the estimated area of each sampling site are shown in Table S1.

For the sake of standardization, sampling procedures followed previous studies (Ben-Haddad et al., 2021; De-la-Torre et al., 2022; Rakib et al., 2022). In brief, several transects parallel to the tideline (separated by ~10 m from each other) were established for each sampling site that enabled a complete survey of the beach (from the low tideline up to the beach limit [road or vegetation]). The number and length of the transects varied significantly per beach depending on its extension and distance between the tideline and the limit (width). For instance, S1 extended 400 m in length and about 50 m width; thus, a total of 5 transects extending ~400 m were determined to cover the entirety of the beach. PPEs were visually recognized while walking along each transect and classified as face masks, gloves, or others (e.g., alcohol or disinfectant container). The PPE density in each sampling site was calculated using Eq. (1) (Okuku et al., 2020):

\[
C = \frac{N}{A}
\]
where \( C \) is PPE density (item/m\(^2\)), \( N \) is the number of PPE, and \( A \) is the covered area (m\(^2\)).

### 2.3. Statistical analysis

To determine whether parametric or non-parametric tests were suitable, Shapiro-Wilk and Kolmogorov-Smirnov tests were performed on the data. After invalidating the assumption of normality, non-parametric tests (Kruskal-Wallis and Dunn’s multiple comparisons) were used to compare the PPE density among different activities (Dytham, 2011). The significance level was set at 0.05 in all the analyses. Statistical analyses and graphs were conducted with GraphPad Prism (version 8.4.3) and maps were performed using ArcGIS (version 10.3).

![Image of the study area and sampling sites.](image)

**Fig. 1.** Map of the study area and sampling sites.

![Examples of PPEs debris found during surveys along beaches of Caspian Sea.](image)

**Fig. 2.** Examples of PPEs debris found during surveys along beaches of Caspian Sea.
3. Results and discussion

Different types of PPE were found (Fig. 2), including face masks, gloves, and alcohol containers (classified as “others”). Face masks were largely more numerous (total of 343, representing 95.3%), followed by alcohol containers, and gloves (Fig. 3a). The dominance of face masks (>85%) has been observed in coastal areas of various countries, including Peru (De-la-Torre et al., 2021c, 2022), Morocco (Ben-Haddad et al., 2021; Mghili et al., 2021), and Bangladesh (Rakib et al., 2021b). In Argentina, however, face masks equaled the number of gloves (48% each) found in 15 sites distributed along its coast (De-la-Torre et al., 2022). Similarly, while a previous study in Iran (Bushehr shores, the Persian Gulf) face masks were the most abundant type of PPE, these reached only 66.2%, which is significantly lower than in other studies (Akhbarizadeh et al., 2021). No face shields were found, which was reported as a fairly common type of PPE in Peru (De-la-Torre et al., 2021c). This trend is due to the protocols imposed worldwide to prevent the transmission of the virus (use of face masks are mandatory in public places), which may have become more flexible as the pandemic progressed and vaccination rates took off.

As displayed in Fig. 3b, a decreasing trend concerning the cumulative number of PPE is seen starting with 63 and 70 items (weeks 1 and 2, respectively) and down to 3 and 1 items total (weeks 11 and 12, respectively). This may be due to several factors regarding face mask usage, season, and progression of the pandemic. In the early stages of the pandemic (mid-2020), behavioral and observational studies carried out in Iran indicated a good attitude and performance towards face mask use (Rahimi et al., 2020), behavioral and observational studies carried out in Iran indicated that face masks were mandatory in public places), which may have become more acceptable and usage in a population translates into PPE pollution. Another possible explanation of the PPE pollution downward trend is the season (coastal sites are generally preferred during the summer season), a signifi- cantly lower than in other studies (Akhbarizadeh et al., 2021). Face masks were largely

Fig. 4. Box plot of the PPE density in each sampling site. Box indicates the interquartile range and whiskers the minimum and maximum values in each dataset.

was obtained (Fig. 4). The highest mean density was observed in S13 (2.41 × 10⁻⁴ PPE/m²), and the lowest in S4 (5.94 × 10⁻⁵ PPE/m²). The Kruskal-Wallis test indicated no significant differences among sampling sites (Chi-square = 18.47, p = 0.1022). Thus, the multiple comparisons test was deemed unnecessary.

The mean densities found in the present study are comparable to previous reports, as summarized in Table 1. In Bushehr, Iran, Akhbarizadeh et al. (2021) indicated that PPE densities ranged from 7.71 × 10⁻⁵ to 2.70 × 10⁻⁴ PPE/m², several orders of magnitude higher than in the Iranian coasts of the Caspian Sea. Similar density inconsistencies were observed in the studies of Ben-Haddad et al. (2021) and Mghili et al. (2020), both carried out in Morocco (Table 1), as well as the broad range of PPE densities along the coast of Peru and Argentina in nationwide studies (De-la-Torre et al., 2022). These differences indicate that PPE pollution is not even across countries and cities. This is due to the various factors involved in this issue, such as seasonality (coastal sites are generally preferred during the summer season), legislation and law enforcement (maintaining or halting face mask use mandates), willingness to wear masks as the pandemic progresses, and solid waste management systems and infrastructure. These factors may vary consistently among cities and sampling dates, ultimately resulting in differentiated PPE accumulation. Regardless, this evidence suggests that litter PPE has become ubiquitous in the environment, possibly contributing significantly to plastic pollution. To understand the contribution of PPE to the already widespread plastic pollution and marine litter issue, studies must provide comprehensive data of marine litter characterization,
including PPE. However, the studies listed in Table 1, including the present, focused on PPE only, ultimately overlooking other types of marine litter. In order to evaluate the influence of the level of urbanization on PPE pollution along the coast of the Caspian Sea, the mean PPE densities in each site were grouped as “urban” (S1 – S11) or “remote” (S12 and S13) sites (Fig. 5) (the data obtained in each sampling week was grouped per activity). Since only two sites were regarded as “remote”, the data was insufficient to carry out statistical analyzes. Nevertheless, the site with the highest PPE density was classified as “remote”. This may be due to the lack of coastal cleaning procedures in areas located far from tourist attractions and recreational activities. However, a more extensive survey is needed to confirm the influence of urbanized areas on PPE pollution while taking into account factors that are specific to each sampling site. For instance, in previous research carried out in the overpopulated city of Lima, the capital of Peru, three sites were treated as controls due to their unpopularity among beachgoers and inaccessibility (De-la-Torre et al., 2021c). Despite their proximity to highly urbanized areas, the control sites were almost PPE-free under a similar methodological approach. Thus, accessibility and popularity, as well as the activities carried out are site-specific and should be taken into account. The case of comparing remote vs. urbanized areas puts into perspective two factors that influence the occurrence of PPE waste. While urbanized areas are expected to be greater sources of litter and a higher number of beachgoers (possible pollutants) (Poeta et al., 2016), remote areas are weakly influenced by the proximity of cities with high population densities. However, in light of the recognized influence of the population over marine litter, urbanized areas are cleaned more frequently and thoroughly, which is not the case for remote areas. These factors may serve as a sort of balance, resulting in mild differences between the two. Regardless, the direct association of these two factors and the abundance/generation of PPE litter requires further research.

Various aquatic organisms are affected directly by marine litter, particularly plastics. According to Kühn et al. (2015), the number of independent species affected by entanglement or ingestion of plastic litter has more than doubled since 1997. PPE is no exception. Gallo Neto et al. (2021) reported the mortality of a Magellanic penguin (Spheniscus magellanicus) to be associated with the ingestion of a whole face mask, which was found in the stomach of the animal following necropsy. Hiemstra et al. (2021) provided an overview, as well as new documented evidence, of all the cases of entrapment, entanglement, ingestion, or interaction of various types of aquatic and terrestrial animals with PPE. These reports encompassed a perch (Perca fluviatilis) entrapped in a glove (Hiemstra et al., 2021), entanglement of an American robin (Turdus migratorius) in a face mask (Denisuk, 2020), a long-tailed macaque (Macaca fascicularis) chewing a face mask (Images, 2020), a common coot (Fulica atra) that used a face mask and glove as nesting material (Hiemstra et al., 2021), and many other interactions.

The studies that first reported the occurrence of PPE litter under the COVID-19 scenario speculated that these materials could be a significant source of MPs (Aragav et al., 2020; Fadare and Okoffo, 2020). Later reports confirmed this by conducting in vitro MP release experiments and estimating the release rate through various analytical techniques. For instance, Wang et al., 2021 estimated a release of >16 million MPs (1–500 μm) per surgical mask under natural weathering conditions (UV light irradiation in the presence of sand for 24 h) using laser in-situ scattering and transmissometry analyzer. On the other hand, Saliu et al., 2021 counted 61 and 117,400 MPs ranging from 1 to 5 mm and from 25 to 500 μm, respectively, released from a single surgical mask under UV light irradiation using a stereomicroscope. (Ma et al., 2021) estimated through field-emission SEM that the nanoplastics (<1 μm) release per mask would reach numbers many orders of magnitude than previous reports. Others have carried out similar experimental setups and estimations (Chen et al., 2021; Rathinamoothy and Balasaraswathi, 2021), ultimately confirming that face masks are significant sources of MPs/NPs in the environment (Kutralam-Muniasamy et al., 2022).

The Caspian sea is home to hundreds of endemic species from various taxa, including over 100 mollusks and fishes and the Caspian seal (Phoca caspica), and provides important sites for migratory birds and nesting (Esmaelli and Abbasi, 2021; Kuiken et al., 2006; WWF, 2021). Apart from the aquatic ecosystem of the Caspian Sea, other terrestrial environments located in its vicinity may be endangered too. For instance, the Caspian forests located between the Caspian sea and the Alborz Mountains are home to more than 100 endemic species of plants (Ghorbanalizadeh et al., 2021). However, the rich biodiversity and endemism the Caspian Sea provides could be endangered by PPE pollution. In particular, beachcast phytodetritus (or “wrack”) could act as a trap for PPE waste. This has been reported for multiple types of anthropogenic litter in, for instance, wracks of the Giant reed (Arundo donax) in Italy; thus, serving as a possible sink for anthropogenic litter (Battisti et al., 2020a). Furthermore, other types of litter, such as expanded polystyrene, have been reported as a

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**Table 1**

Summary of the mean and range PPE densities across studies worldwide.

| Country   | Location/city | Mean PPE density (PPE/m²) | Range | Ref.  |
|-----------|---------------|---------------------------|-------|-------|
| Peru      | Lima          | 6.42 × 10⁻⁵              | 0.00–7.44 × 10⁻⁴ | (De-la-Torre et al., 2021c) |
| Peru      | Multiple      | 6.60 × 10⁻⁴              | 0.00–5.01 × 10⁻³ | (De-la-Torre et al., 2022) |
| Argentina | Multiple      | 7.21 × 10⁻⁴              | 0.00–5.60 × 10⁻³ | (De-la-Torre et al., 2022) |
| Chile     | Multiple      | 6.00 × 10⁻⁵              |       |       |
| Brazil    | Santos        | 7.46 × 10⁻⁵              |       | (Thiel et al., 2021) |
| Bangladesh| Cox’s Bazar   | 6.29 × 10⁻³              | 3.16 × 10⁻⁴–2.18 × 10⁻² | (Rakib et al., 2021b) |
| Morocco   | Agadir        | 1.13 × 10⁻⁵              | 0.00–1.21 × 10⁻⁴ | (Ben-Haddad et al., 2021) |
| Morocco   | Treouan       | 1.20 × 10⁻⁵              | 0.00–3.67 × 10⁻⁵ | (Mghi et al., 2020) |
| Ethiopia  | Bahir Dar     | 1.54 × 10⁻⁴              | 1.22 × 10⁻³–2.88 × 10⁻⁴ | (Aragav et al., 2022) |
| Iran      | Bushehr       | —                         | 7.71 × 10⁻¹–2.79 × 10⁻² | (Abakaranzadeh et al., 2021) |
| Iran      | Mazandaran    | 1.02 × 10⁻⁴              | 0.00 to 7.16 × 10⁻⁴ | This study |

**Fig. 5.** Bar graph displaying the average PPE density in the sampled sites grouped by proximity to urbanized centers (urban or remote). Error bars indicate standard error of the mean. Points indicate individual values.
substrate for dunal plants (e.g., *Anthemis maritima*, *Spartina versicolor*, and *Phragmites australis*) (Poeta et al., 2017a). Although this type of plant-litter interaction has not been observed in the surveys carried out in the present study, photographic evidence shows a surgical face mask rooted by a dunal plant at a beach in Peru (Fig. S1). Apart from direct effects, such as entanglement and ingestion, MPs/NPs released from face masks could serve as a secondary pathway to impact biodiversity (De-la-Torre et al., 2021b). Initially, Ma et al. (2021) documented the ingestion and bioaccumulation of MPs released by disposable face masks in various model organisms, including rotifer *Brachionus rotundiformis*, copepod *Parvocalanus crassirostris*, shrimp *Penaeus vannamei*, scallop *Chlamys nobilis*, and juvenile grouper *Epinephelus lanceolatus*. Later on, Sun et al. (2021) showed that MPs released from discarded face masks were ingested by the marine copepod *Tigriopus japonicus* under experimental conditions (10 MPFs/mL for 24 h) and induced a significant decline in their fecundity. Furthermore, the same type of MPs inhibited the reproduction and growth of springtails and spermatogenesis in earthworms (Kovak and An, 2021). While the studies investigating the ecotoxicological impacts of MPs derived from face masks are still scarce, these studies confirm the possible threat that PPE poses to aquatic and terrestrial organisms of multiple taxa.

As previously described, pollution levels have declined significantly since the first PPE survey probably due to multiple factors. As of now, many nations are still deciding whether to halt or maintain face mask use mandates. The progress of vaccination rates worldwide will probably be indicative that the population will soon go back to normality. However, coastal management lessons have been learned during the time of the pandemic. Specifically, concerning single-use plastics. From the lessons learned during the pandemic, several recommendations that can be applied even after everything comes back to normal are provided:

1) Despite having various alternatives, single-use products are always preferred. Hence, the entry to coastal areas of particular biodiversity and ecosystemic relevancy should be prohibited with single-use plastic products.

2) Basic waste management infrastructure, such as bins, should be sufficient and at the reach of all beachgoers.

3) During the pandemic, various signposts indicating to maintain social distancing and wear a mask were installed in beach areas, aiming to safeguard the wellbeing of the beachgoers. However, none of these clearly indicated how and where to dispose of their used PPE or COVID-related materials. Hence, signaling in the beach area should take into account these two elements.

4) Long-term environmental awareness campaigns should be implemented in order to educate the population regarding the impacts of marine pollution and how to correctly dispose of their litter.

5) In the most populous or touristic destinations, promoting beach cleaning activities involving the public, as well as providing incentives for participating and collecting marine litter more actively, is recommended. Furthermore, special attention and prevention should be taken when collecting potentially contaminated or toxic wastes. To this end, Battisti et al. (2020b) suggested the use of appropriate equipment and supervision, as well as an elaborated plan to stimulate collective research (citizen science).

6) Lastly, the beach administration must seek to establish strategic alliances with businesses or start-ups that focus on innovative ways to recycle marine litter.

4. Conclusion

It is evident that the behavior towards the pandemic evolves as time passes and the pandemic progresses. This may be reflected in the occurrence and abundance of PPE polluting beach sites, which is apparently declining despite being regarded as an emerging and important source of single-use plastics. However, the complexity of the social-ecological systems and how these are related to PPE emitted to the environment are poorly understood. As the actions are taken to fight the COVID-19 pandemic (e.g., vaccination, treatment, slowdown of mortality rates, etc.) progress, it is likely that face mask and PPE mandates will be halted eventually. Hence, significantly reducing the number of PPE being emitted to the oceans. Regardless, several recommendations based on the lessons learned during the coastal waste management crisis driven by the pandemic have been provided. These recommendations will be useful for coastal management plans even after the pandemic.

CRediT authorship contribution statement

Tara Hatami: Software, Data Curation, Investigation, Conceptualization, Methodology, Software, Writing Original – Draft. Md. Refat Jahan Rakib: Project administration, Visualization, Formal Analysis, Resources, Software, Data Curation, Investigation, Conceptualization, Methodology, Software, Supervision, Writing Original – Draft; Writing – Original Review & Editing. Reyhane Madadi: Visualization, Formal Analysis, Software, Data Curation, Investigation, Conceptualization, Methodology, Software, Writing Original – Draft. Gabriel E. De-la-Torre: Conceptualization, Methodology, Supervision, Writing Original – Draft; Writing – Original Review & Editing. Abubakr M. Idris: Writing– Original Review & Editing.

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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Appendix A. Supplementary data

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