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Focus

What we need to know about PPE associated with the COVID-19 pandemic in the marine environment

Gabriel E. De-la-Torre [a,*], Tadele Assefa Aragaw [b]

[a] Universidad San Ignacio de Loyola, Av. La Fontana 501, Lima 12, Lima, Peru
[b] Faculty of Chemical and Food Engineering, Bahir Dar Institute of Technology-Bahir Dar University, Bahir Dar, Ethiopia

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ABSTRACT

Since the COVID-19 outbreak was declared as a global health emergency, the use of multiple types of plastic-based PPEs as a measure to reduce the infection increased tremendously. Recent evidence suggests that the overuse of PPEs during the COVID-19 pandemic is worsening plastic pollution in the marine environment. In this short focus, we discussed the potential sources, fate, and effects of PPE plastic to the marine environment and proposed five key research needs, involving (1) the occurrence and abundance of PPEs, (2) the sources, fate, and drivers of PPEs, (3) PPEs as a source of microplastics, (4) PPEs as a vector of invasive species and pathogens, and (5) PPEs as a source and vector of chemical pollutants in the marine environment. We suggest that addressing these knowledge gaps will lay the groundwork for improved COVID-19-associated waste management and legislation to prevent marine plastic pollution to continue exacerbating.

1. Introduction

Plastic pollution is one of the most challenging issues of trans-boundary scale with millions of plastic items of multiple sizes, from nano to macro, being discharged into the oceans daily (Everaert et al., 2020). The threats that plastic pollution poses to marine environments have been investigated for a long time and are well understood (Browne et al., 2011; Cole et al., 2011; Derraik, 2002; Kiessling et al., 2015). However, the ongoing COVID-19 pandemic has aggravated the use of single-use plastics worldwide, being most of them in the form of personal protective equipment (PPE) (Patrício Silva et al., 2021; Prata et al., 2020). This event issued new challenges to conventional waste management in order to face the massive production, use, and disposal of PPEs (Rhee, 2020; Saadat et al., 2020; Vanapalli et al., 2021). Recent reports have evidenced the occurrence of PPEs in the marine environment (Stokes, 2020), which will continue to exacerbate over time. This is an alarming, yet poorly understood, form of plastic pollution that have raised major concerns. In this short focus, we described the potential sources and fate of PPEs along with the suspected effects on the marine environment. Considering this, we suggested five research needs that will fill the current knowledge gaps regarding COVID-19-associated PPE pollution and lay groundwork for better waste management and legislation.

2. Sources and fate of PPE in the marine environment

During the COVID-19 pandemic, countless single-use plastics materials and disposable PPE are needed as an essential measure to prevent the spread of the infection. Because of the magnitude of the emergency, medical care workers, as well as the general public, have been demanding PPEs, especially face masks, face shields, and gloves with no clear instructions and disposing mechanisms, and the production of face masks has increased more than 10 times in the last months (Adyel, 2020). As a result, many PPEs, such as face masks, surgical gloves, Splashproof garments, and other PPE items are found stranded in the beaches, coastlines, rivers, and littering cities (Canning-Clode et al., 2020). This suggests that the extensive usage of medical care plastics in the COVID-19 era, together with poor disposal practices, is shifting marine pollution to this type of plastic debris as the main source. This type of marine pollution will potentially promote a spike in plastic pollution in the future. The evidence suggests that stakeholders, policymakers, and governments must advance green solution mechanisms including the three Rs (3R): Recycling, reusing, and reducing as sustainable solid waste management options (Patrício Silva et al., 2020). The need for disposable and single-use plastic items during the global COVID-19 pandemic should be considered to minimize the non-envisioned consequences soon.

* Corresponding author.
E-mail address: gabriel.delatorre@usil.pe (G.E. De-la-Torre).

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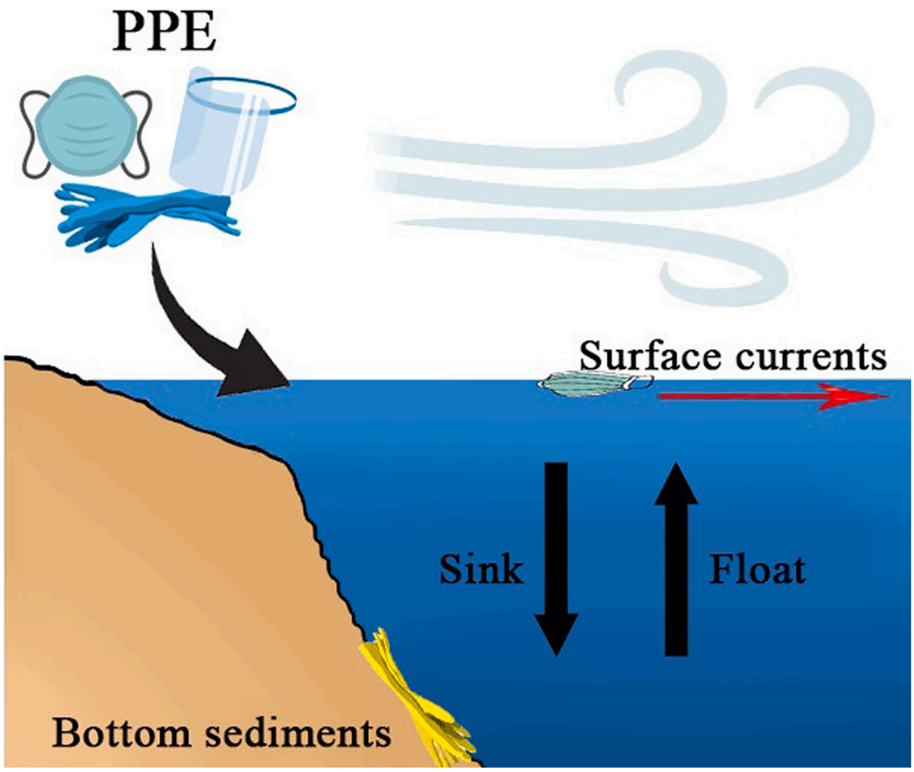

Fig. 1. Schematic representation of the potential fate of PPE in the marine environment.

After reaching the marine environment, PPE items may have different fates and sinks depending on their characteristics. Like most plastic litter, PPEs are mostly composite materials made of different synthetic non-degradable polymers (Fadare and Okoffo, 2020). Plastic polymers can be positively, neutrally, or negatively buoyant in the water system. High-density polymers, such as polyester (PEST), polyvinyl chloride (PVC), and polyvinyl alcohol (PVA), are likely to sink and reach bottom marine sediments. On the other hand, less dense polymers, like polyethylene (PE), expanded polystyrene (EPS), and polypropylene (PP), float in seawater (with a density of ~1.03 g cm^{-3}). However, the materials used for the manufacture of specific PPEs are subject to different companies or brands. Most 3-ply surgical masks are made of PP (0.90–0.91 g cm^{-3}), while others may include different materials like PS (1.04–1.1 g cm^{-3}), polycarbonate (PC; 1.20–1.22 g cm^{-3}), PE (0.92–0.97 g cm^{-3}), and PEST (1.24–2.3 g cm^{-3}) (Chua et al., 2020; Hidalgo-Ruz et al., 2012; Shim et al., 2018). Regarding gloves, the most commercially available materials are PVC (1.16–1.58), latex, and nitrile. Lastly, face shields are also manufactured by applying a wide range of materials, including polyethylene terephthalate glycol (PETG), PC, acetate, and PVC (Roberge, 2016). Owing to the multiple materials that constitute common PPE, along with their non-degradability and persistence in the environment, it is deductible that their fate will vary depending on these characteristics (Fig. 1). As observed of other types of plastic pollutants, some PPE items are expected to remain in the environment for long periods of time, probably subject to surface oceanic currents, while others may become buried in the sediments, ultimately becoming part of the geological record (De-la-Torre et al., 2021).

3. Potential effects and research needs

Like any other marine plastic litter, PPEs are expected to interact with the environment. It is safe to say that PPEs are likely to become a source of secondary microplastics in the marine environment (Aragaw, 2020; Fadare and Okoffo, 2020). Since many surgical masks are produced by nanofiber electrospinning (Zafar et al., 2016), micro- and nanofibers are most likely to be released under degradation conditions. Aragaw (2020) and Fadare and Okoffo (2020) analyzed face masks collected from Lake Tana in Ethiopia and a highway in Nigeria, respectively, by Fourier transformer infrared (FTIR) spectroscopy. Polymer identification by either library comparison or peak analysis revealed that the outer layer of the masks was composed of PP, while the inner layer by HDPE. Thus, the analyzed face masks are prone to release microplastic of these polymer types to the environment. Microplastics are widely known for their ubiquitous presence in the environment, bioavailability to organisms of all taxa, and detrimental effects (De-la-Torre, 2020; Garcés-Ordóñez et al., 2020; Santillán et al., 2020), like complications in the reproduction of aquatic organisms, consequently reducing their growth rate (de Souza Machado et al., 2018). However, PPE items may also be ingested entirely by marine megafauna and apex predators, such as whales, sharks, turtles, mammals, or seabirds (Fernández and Anastasopoulou, 2019; Kühn and van Franeker, 2020). Marine fauna could also become entangled with the elastic cords of face masks and some face shields.

Previous studies have determined the suitability of plastic litter as a habitat and vector of invasive species and microbial pathogens (Mantelatto et al., 2020; Rech et al., 2018; Wu et al., 2019). Under this context, PPE based on low-density polymers could serve as artificial substrates for rafting non-native or invasive species. It is unknown, however, whether PPEs are regarded as a litter of high rafting risk and the potential sinks. During their voyage, PPEs may be colonized by microbial consortia developing natural biofilms on the surfaces, which could become a reservoir for pathogenic microbes (Wingender and Flemming, 2011). Additionally, biofilms can cause plastic items to lose buoyancy and sink, thus altering their fate in the environment (Chen et al., 2019b).

PPEs could also serve as a vector and source of chemical contaminants. Organic compounds and heavy metals interact with plastic surfaces and become sorbed by means of one or multiple sorption mechanisms, such as hydrophobic interactions, electrostatic interactions, among others (Fred-Ahmadu et al., 2020; Mei et al., 2020).

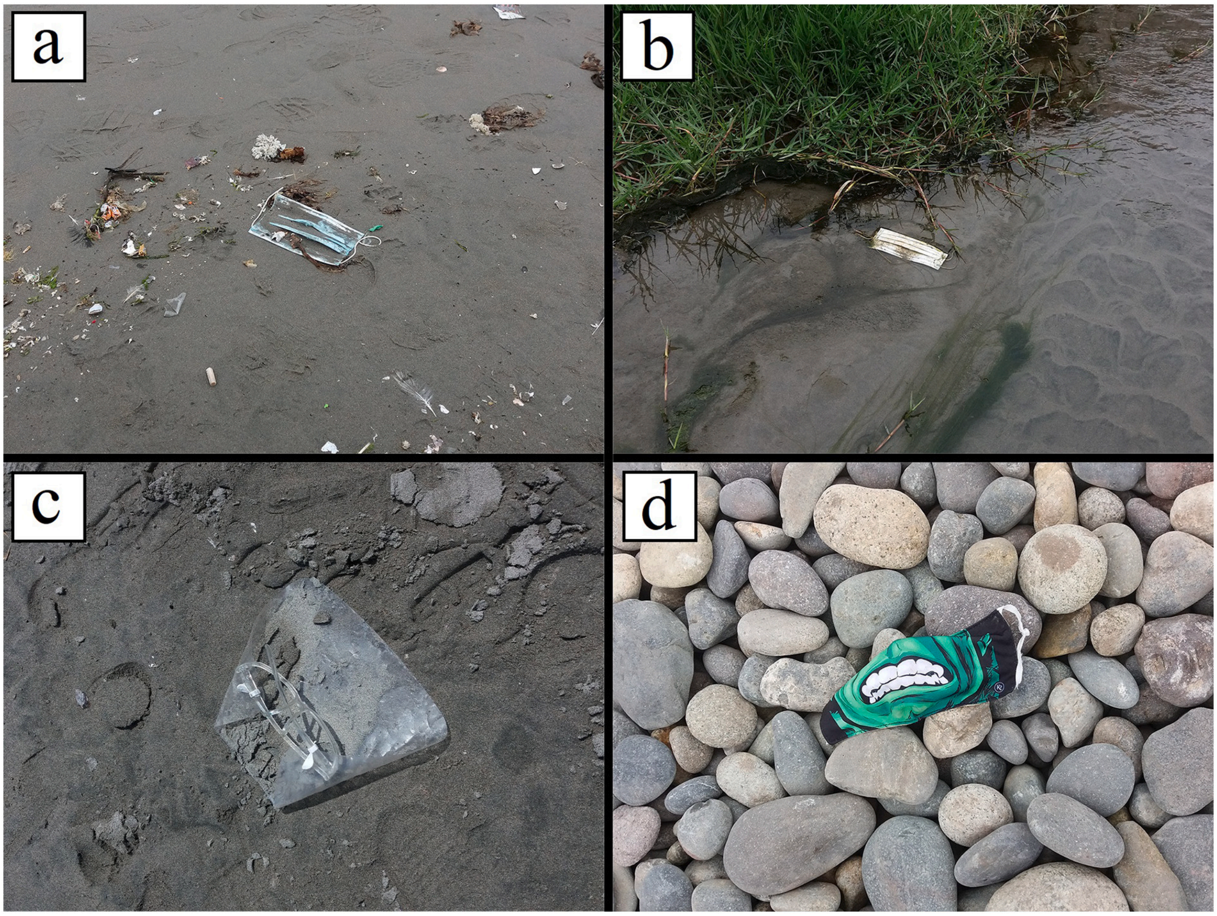

Fig. 2. Photographs of COVID-19 PPEs found in coastal areas of Lima, Peru. a) A face mask on the strandline in a sandy beach, b) a facemask in a water stream, c) a face shield discarded in a sandy beach, and d) a face mask discarded in a rocky beach.

Moreover, weathering conditions promote plastic items to leach toxic additives, like flame retardants and polychlorinated biphenyls (PCBs) (Bejgarn et al., 2015; De-la-Torre et al., 2020; Teuten et al., 2009). The effectiveness of the chemical sorption or release will vary depending on environmental factors and the physical-chemical characteristics of the plastic items.

With the increasing production, use, and disposal of PPEs associated with the COVID-19 pandemic, it is evident that a great environmental challenge lays ahead. The occurrence of PPEs has already been evidenced in coastal areas in surveys carried out by the authors (Fig. 2, unpublished data). Despite this, there is still very little understanding of their true impact and the potential effects previously described. Although previous works with typical marine litter and microplastics may give some knowledge to the potential effects, fate, and interactions of COVID-19 PPE in the marine environment, it is unsure whether these new contaminants may follow the same behavior as typical marine litter (e.g., plastic bags, bottles, PS materials, textiles, among others). Herein, we propose several research questions for further studies to prioritize:

Question 1. What is the abundance, characteristics, and types of PPEs found in marine environments around the world? How is it evolving over time? How are these related to legislation and legal framework?

Previous works have reported the occurrence of COVID-19 PPE in urban areas (Fadare and Okoffo, 2020; Prata et al., 2020; Ryan et al., 2020), and some photos of PPE in the marine environment have been circulating on social media. Despite this, the magnitude of PPE pollution remains unknown. It is necessary to include this category of marine litter in monitoring plans, understand if the occurrence of PPE is increasing or decreasing over time, and how is the recent legislation that prevents the COVID-19 spread influences the abundance.

Question 2. What are the main sources and drivers of PPEs to the marine environment? What is the fate of PPEs in the marine environment?

It is clear that with the COVID-19 pandemic, the production, use, and disposal of PPE have increased tremendously. In order to take action against PPE entering the marine environment, research must first understand what the main sources and drivers are (e.g., beachgoers, fishing activity, poor waste management, river flow, oceanic currents, among others). Additionally, researchers must track PPE after entering the marine environment and understand their potential fate.

Question 3. What is the abundance and types of microplastics, in terms of polymer, morphology, and size, generated by the degradation of PPE?

It has been widely investigated that plastic material of any kind will degrade into smaller pieces, namely microplastics. Plastic materials will degrade at different rates depending on their physical and chemical properties (Min et al., 2020). The most common PPEs, face masks, are mostly prepared by nanofiber electrospinning, which suggests that this PPE could be a source of microfibers. It is necessary to investigate if PPEs are an important source of microplastics and their main characteristics.

Question 4. Are PPEs suitable for the transportation of alien invasive species (AIS) in the marine environment?

Floating marine debris is a well-known driver of AIS. Various PPEs are composed of low-density polymers that may allow them to drift and become subject to oceanic currents. However, the likeliness of several species to colonize an artificial substrate depends on its specific characteristics (Chase et al., 2016; Pinochet et al., 2020). Most PPEs are unique compared to the typical marine litter in terms of surface morphology. Thus, their suitability as AIS drivers must be investigated.

Question 5. Are PPEs a potential source of chemical pollutants in the marine environment? Are PPEs and the microplastics generated by them a potential vector of chemical pollutants in the marine environment?

Plastic marine litter and microplastics are regarded as a source and vector of chemical contaminants (Chen et al., 2019a; Fred-Ahmadu et al., 2020). The sorption behavior of chemicals on PPEs or PPE-derived microplastics will vary depending on several factors. Likewise, the leaching of harmful chemicals from PPE depends on the additives that are included in their production. It is necessary to investigate these two drivers of marine pollution with associated contaminants.

4. Conclusions

The COVID-19 pandemic brought extra pressure to conventional solid waste management practices. Massive quantities of PPE plastic wastes have been generated worldwide with inappropriate disposal, landfilling, and/or incineration techniques that end up polluting the aquatic ecosystems. As a result, the amount of PPE wastes that reach the marine environment is exacerbating and will continue to do so. Here, we have discussed several issues that revolve around the pollution of the marine environment with COVID-19-related PPEs, including their source and fate in the environment, and the potential threats to the ecosystems. In light of the current lack of scientific knowledge regarding the impact of PPEs, we have proposed several research questions that need to be urgently addressed in order to elucidate the plastic-associated environmental burden of the pandemic. We believe that answering these questions may not pose a methodological barrier, as previous studies focusing on typical marine litter (other than PPE) are widespread in these lines of research. However, PPEs are potentially infectious objects and may require special handling and use of PPE by researchers themselves. Additionally, logistical constraints may surge during sampling campaigns or analytical procedures driven by unexpected lockdowns enforced by governments. Hence, contributing to filling these knowledge gaps will require significant efforts on behalf of researchers.

CRediT authorship contribution statement

Gabriel E. De-la-Torre: Project administration, Conceptualization, Formal analysis, Writing – original draft, Validation. **Tadele Assefa Aragaw:** Investigation, Formal analysis, Writing – original draft.

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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