Science of the Total Environment 810 (2022) 152046

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Contamination of the marine environment in Egypt and Saudi Arabia with personal protective equipment during COVID-19 pandemic: A short focus

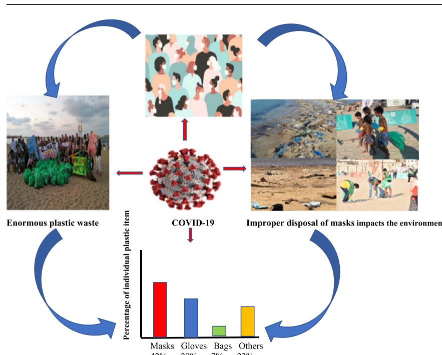
Ibrahim A. Hassan [a,b,*], Alaa Younis [b,c], Mansour A. Al Ghamdi [d], Mansour Almazroui [e,f], Jalal M. Basahi [d], Mostafa M. El-Sheekh [g], Emad K. Abouelkhair [h], Nesreen S. Haiba [i], Mohammed S. Alhussaini [j], Dina Hajjar [k], Magdy M. Abdel Wahab [b,l], Dahlia M. El Maghraby [a]

[a] Faculty of Science, Alexandria University, 21511 Moharem Bay, Alexandria. Egypt
[b] National Scientific Committee of Problems in Environment (SCOPE), Academy of Scientific Research & Technology (ASRT), 101 Kasr Al-Ini Street, Cairo, Egypt
[c] Aquatic Environment Department, Faculty of Fish Resources, Suez University, Egypt
[d] Faculty of Meteorology, Environment and Arid Land Agriculture, King Abdulaziz University, Jeddah, Saudi Arabia
[e] Centre of Excellence for Climate Change Research/Department of Meteorology, King Abdulaziz University, PO Box 80208, Jeddah 21589, Saudi Arabia
[f] Climatic Research Unit, School of Environmental Sciences, University of East Anglia, Norwich, UK
[g] Department of Botany & Microbiology, Faculty of Science, Tanta University, Tanta, Egypt
[h] Biology Departments, Al-Azhar University, Gaza, Egypt
[i] Department of Physics & Chemistry, Faculty of Education, Alexandria University, El Shatby, Alexandria. Egypt
[j] Department of Clinical Laboratory Sciences, College of Applied Medical Sciences, Shaqra University, Saudi Arabia
[k] Department of Biochemistry, Faculty of Science, University of Jeddah, Jeddah, Saudi Arabia
[l] Department of Space science, Faculty of Science, Cairo University, Giza, Egypt

HIGHLIGHTS

- COVID-19 pandemic drastically increased the use of PPE.
- Improper disposal of single use plastics has led to an increase in plastic pollution.
- It is a must to counter environmental impact of COVID-19 and plastic pollution.
- There is an urgent need for sustainable technologies such as biodegradable PPE.
- Public awareness and social responsibility are a challenging goal.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 28 August 2021
Received in revised form 20 November 2021
Accepted 24 November 2021
Available online 29 November 2021

Editor: Damia Barcelo

Keywords:
Plastic pollution
Personal protective equipment (PPE)

ABSTRACT

Plastic pollution and its impact on marine ecosystems are major concerns globally, and the situation was exacerbated after the outbreak of COVID-19.
Clean-up campaigns took place during the summer season (June–August 2020) in two coastal cities in Egypt (Alexandria and Hurghada) and Jeddah, Saudi Arabia to document the abundance of beach debris through public involvement, and then remove it. A total of 3673, 255, and 848 items were collected from Alexandria, Hurghada, and Jeddah daily, respectively. Gloves and face masks (personal protective equipment “PPE”) represent represented 40–60% of the total plastic items collected from each of the three cities, while plastic bags represented 7–20% of the total plastics litter collected from the same cities. The results indicated the presence of 2.79, 0.29, and 0.86 PPE item m^{-2} in Alexandria, Hurghada and Jeddah, respectively.

* Corresponding author at: Faculty of Science, Alexandria University, 21511 Moharem Bay, Alexandria. Egypt.
E-mail addresses: ibrahim.abdelmaged@alexu.edu.eg (I.A. Hassan), mansour@kau.edu.sa (M. Almazroui).

http://dx.doi.org/10.1016/j.scitotenv.2021.152046

COVID-19
Marine ecosystems
Volunteers

This short focus provides an assessment of the environmental impacts of single-use gloves and masks used for COVID-19 protection from June to August 2020. To the best of our knowledge, this study presents the first such information from the Middle East, specifically Egypt and Saudi Arabia. It highlights the need for further knowledge and action, such as safe, sustainable, and transparent waste management processes related to COVID-19 to reduce the negative impacts now, as well as in future events. Furthermore, this study helps in achieving key components of the United Nation's Sustainable Development Goals (SDGs). This short focus can serve as a multipurpose document, not only for scientists of different disciplines but for social media and citizens in general.

1. Introduction

Millions of plastic items of different sizes are discharged into water bodies around the world daily, causing plastic pollution (De-la-Torre and Aragaw, 2021). This situation was exacerbated, worldwide, during the COVID-19 pandemic, as millions of people used single-use plastic face masks, gloves, and face shields as personal protective equipment (PPE). The continuous and massive increase of gloves, masks, and various sorts of wrapping made from single-use plastics, ended up littering the land and marine environments globally, a visible side-effect of the increased use of PPE, causing hazardous problems (Adyel, 2020; European Environmental Agency, 2021). Moreover, such pollution could also lead to emissions of greenhouse gases, potentially further harming the environment (Prata et al., 2020; Vanapalli et al., 2021; Farahat et al., 2021). Connexion (2020), stated that more than 20 million French citizens (about 16% of the population) admitted throwing away their masks on public roads, on beaches, and along coasts. Environmentalists fear that gloves and masks thrown out of car windows will pollute the environment for decades to come.

The rate of accumulation of plastics in marine environments depends on anthropogenic activities, direction and speed of the wind, and coastal water uses (James et al., 2021). Macro-and microplastic pollution has caused problems in many parts of the world, through ingestion by and entanglement of marine animals (Cauwenberghe et al., 2013; Thompson et al., 2014; James et al., 2021).

The sustainable management of PPE is a key challenge (Mallick et al., 2021). The lack of a coordinated national and international strategy to manage the PPE disposal threatens to impact progress towards achieving key components of the United Nation's Sustainable Development Goals (SDGs), including SDG 3 good health and wellbeing, SDG 6 clean water and sanitation, SDG 12 responsible consumption and production and SDG 13 climate action (Singh et al., 2020).

Although studies related to plastic pollution and its consequences on the ecosystem have been carried out worldwide, nothing is known about this type of pollution in the Middle East. The present study was particularly aimed at understanding the distribution of the macro-and microplastics in the surface waters, and the impact of the COVID-19 pandemic on this type of pollution.

Plastics, in general, are non-biodegradable materials (Ryan, 2015; Ali et al., 2021). However, photooxidation by UV radiation and mechanical friction can help in the fragmentation of the plastics into small fragments (Tamara et al., 2017). Microplastics (having size <5 ml) have an enormous impact on the marine ecosystem and they are considered a potential threat (Gewert et al., 2015; James et al., 2021; Patrício et al., 2021). These plastics can travel thousands of miles, carried by water currents and wind action (Barnes et al., 2009; Al-Salem et al., 2021; Onoja et al., 2022).

Immense quantities of PPE plastic wastes have been generated globally due to the COVID-19 pandemic, which added extra pressure to conventional solid waste management practices (Singh et al., 2020). Countless face masks, face shields, different types of gloves, garments, and plastic materials were consumed during the COVID-19 pandemic as a preventive measure against the spread of coronavirus (OSPAR, 2020; Vanapalli et al., 2021, El-Sheekh and Hassan, 2020). Unfortunately, they are found stranded along the beaches, coastlines, and rivers, and littering cities instead of being disposed of properly in suitable garbage bins, for subsequent removal for recycling or to landfills. Inappropriate disposal ends up polluting the marine environment and the situation is exacerbating. The PPE are potentially infectious litter, and special handling is required. Nevertheless, in the absence of clear instructions for disposal, people are improperly disposing PPE items, throwing them away near the location where they end their usefulness, where they may be carried off by a gust of wind. Accumulation of these plastics will continue to aggravate over time, polluting the marine environment (Moore, 2020; Rhee, 2020). Therefore, it is worthwhile to measure the plastic-associated environmental load of the pandemic as a starting point in efforts to prevent the continued worsening of the marine plastic pollution situation. Singh et al. (2020) stated that the increase in PPE manufacture and distribution is generating an equivalent increase in the waste stream, compounded by health and environmental risks along the waste management chain, especially in countries with underdeveloped infrastructure. Proper, safe, and sustainable recovery and treatment of PPEs, urgent and essential public service, should be intensified to minimize possible secondary impacts upon health and the environment. Unfortunately, medical waste has not been adequately regulated in developing countries especially among informal recyclers.

The present study was undertaken to provide a narrow focus and baseline information on the distribution of the PPE in coastal waters, in order to better understanding the impacts plastic pollution on the marine environment in the Middle East during the COVID-19 pandemic.

2. Methodology

2.1. The study area

The study was conducted simultaneously in three cities in the Middle East; two in Egypt (Alexandria 31.2001° N, 29.9187° E and Hurghada, 27.2579° N, 33.8116° E) and one in Saudi Arabia (Jeddah, 21.4858° N, 39.1925° E) (Fig. 1).

These cities were selected due to the presence of intensive human activities (Fishing, sightseeing, swimming, and tourism). Moreover, the

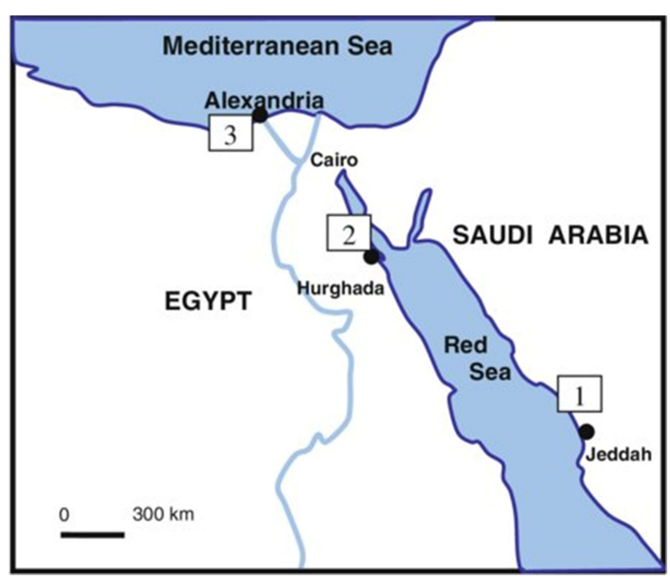


Fig. 1. Location map showing the studied areas in Egypt (Alexandria and Hurghada) and Saudi Arabia (Jeddah).

Table 1
Size of sampling sites.

Size (m^2)	Location
20 × 25 = 500	Alexandria (Egypt)
17 × 30 = 510	Hurghada (Egypt)
12 × 40 = 480	Jeddah (Saudi Arabia)

sampling sites were selected because they were approximately the same size (Table 1).

2.2. Sampling

Plastics were collected manually by volunteers, at all locations in all regions, daily during summer, (beginning of June – end of August 2020). The collection of plastic debris started after the departure of visitors (at 18:00 local time).

A youth campaign was launched called "summer without plastics" (Fig. 2), where tens of teenagers and even younger children collected plastic debris from the coasts of Alexandria and Jeddah cities, simultaneously. They were very enthusiastic, and they built a fish-like perforated rubbish bin to collect all plastic debris and remove excess sands (Fig. 3).

There is a lack of standardized procedures in plastic sampling, leading to the reporting of data in a variety of units. The best unit is plastic pieces per m^2 (Wessel et al., 2016 cited in Onoja et al., 2022).

Once marine plastics are collected, the next objective is to separate the different items of plastics from non-plastic particles based on physical properties that are unique to plastics. A standard method for doing this is yet to be established (Onoja et al., 2022).

Fig. 2. Youth campaigns "summer without plastics" in Egypt (The upper six photographs) and Jeddah (the last two photographs).

Fig. 3. Collecting the plastic litter in a fish-like perforated box.

The final step is the identification and quantification of macro-and microplastics by visual sorting.

2.3. Statistical analysis

Two-way analysis of variance (ANOVA) was used to evaluate the variability in the number of different plastic items and the local effect of sampling site, using the STATGRAPH Statistical package (Statgraph 5, UK).

3. Results & discussion

Immense quantities of personal protective equipment (PPE) plastic wastes were found in coastal areas of Egypt (Fig. 4) and Jeddah (Fig. 5).

Table 2 shows the average collection values for the distribution of different plastic litter collected from the different sites. Gloves and face masks (PPE) accounted for 38.1%, 57.3%, and 48.8%, while plastic bags represent 18.3%, 7.0%, and 8% of the total litter collected from Alexandria, Hurghada, and Jeddah, respectively. The high percentage of PPE items (about 57%) in Hurghada could be due to the proximity of the harbor, while the lower percentage recorded in Alexandria could be due to regular cleaning of the beach. The ban on plastic bags and encouragement to use paper bags instead could be another reason for the lower percentage of plastic bags in Hurghada and Jeddah.

Table 3 shows the relative abundance of PPE and total litter. There were 2.93, 0.29, and 0.86 PPE item m^{-2} laid down in Alexandria, Hurghada, and Jeddah, respectively. Moreover, the total amount of litter collected from

Fig. 4. Photographs of COVID-19 personal protective equipment (PPEs) found in coastal areas of the Mediterranean (upper panel) and the Red (lower panel) Seas in Egypt.

Fig. 5. Photographs of COVID-19 personal protective equipment (PPEs) and plastic debris found in coastal areas of Jeddah.

the same cities followed the same pattern; they were 7.2, 0.51, and 1.77 item m^{-2}, respectively (Table 3).

There was a significant difference in the number of PPE items collected from Alexandria and Jeddah during weekdays and weekends (Table 4). The amount of PPE increased by 76.3 and 48% during weekends in Alexandria and Jeddah, respectively. It is worth mentioning that the weekend in Egypt is Friday only, while in Saudi Arabia it is Friday and Saturday. Table 4 shows that people litter more on weekends than weekdays. Therefore, it is also to be expected that amount of PPE during summer would be higher than that collected during other seasons. However, it was worth studying the daily distribution of the PPEs to give a better picture of their distribution. Fig. 5 shows the daily collection of PPEs from the three sites. It was clear that the items of the PPEs collected from Alexandria (ranged between 798 and 988) were higher than those collected from Jeddah city (ranged between 234 and 401). Moreover, the highest number of the PPEs collected from both sites was during weekends (1000–1689 in Alexandria, and 628–743 in Jeddah). The peaks in Fig. 5 correspond to the number of PPEs collected during the weekends in both cities (Friday in Egypt, and Friday and Saturday in Jeddah). However, the number of PPES collected from Hurghada (122–177, with the maximum number occurring in weekends 178) was lower than in other cities, and there was no significant variation between weekdays and weekends (Fig. 6).

The weight of macro-and microplastics collected from the different sites is presented in Table 5. For comparability purposes and simplicity, weight is calculated on a m^2 basis. The average weight of macroplastics collected from Alexandria, Hurghada, and Jeddah was 25.66 g m^{-2}, 3.78 g m^{-2}, and 11.92 g m^{-2}, respectively, while the weight of microplastics was 0.81 g m^{-2}, 0.03 g m^{-2}, and 1.67 g m^{-2} for the same sites, respectively (Table 4).

The dominance of macroplastics in Alexandria could be attributed to a high population and the increased number of visitors from outside the city during the summer season, especially from the neighboring villages. Most of visitors tend to throw out their plastics on the beach instead of using litter bins.

Fig. 7 shows the microplastic debris collected from the coastal areas of the Mediterranean Sea (Alexandria) and the Red Sea (Jeddah). It is clear that microplastics collected from Jeddah are smaller than those collected from Alexandria. The dominance of microplastics at Jeddah's shore may be attributed to the high temperature; and high ultraviolet radiation as well as the weather prevailing in Jeddah during the summer (50 °C ± 4) (Basahi et al., 2017; Hassan et al., 2017; Qari and Hassan, 2017; Ismail et al., 2021). Microplastic pollution could be the direct sequence of breaking down discarded gloves and masks into smaller pieces due to the effects of high temperature, ultraviolet radiation, abrasion, and weathering (Aragaw, 2020; Fadare and Okoffo, 2020; Ali et al., 2021).

Plastic litter may have different fates after reaching the marine environment; the low-density plastics can float and stay in the marine environment for long periods, probably subject to surface water currents, while high-density plastics sink and reach the bottom marine sediments, and some may become buried in the sediments, in which case they eventually become part of the geological record (Fadare and Okoffo, 2020; De-la-Torre and Aragaw, 2021). This is an alert as they do not degrade naturally, and they will pollute the environment for many years to come (Adelodun, 2021). Moreover, Mallick et al. (2021) reported that the sustainable development

Table 2
Daily distribution of different plastic items collected from different sites day^{-1} (n = 90 + SE). Means not followed by the same letter are significantly different from each other at $p \leq 0.01$. Figures between parentheses represent the relative ratio of each item.

Total	Others	Bottles	Bags	Masks	Gloves	Location
3673 ± 427.17	501^c ± 33.47 −13.60%	1103^c ± 225.33 −30.00%	671^c ± 43.91 −18.30%	918c ± 66.28 −25.00%	480^c ± 75.14 −13.10%	Alexandria (Egypt)
255 ± 46.92	70^a ± 9.21 −27.50%	21^a ± 2.11 −8.20%	18^b ± 1.41 −7.00%	81^a ± 15.22 −31.80%	65^a ± 13.23 −25.50%	Hurghada (Egypt)
848 ± 52.63	277^b ± 23.17 −32.70%	89b ± 11.26 −10.50%	6^a ± 0.31 −7.90%	217b ± 19.11 −25.60%	198^b ± 22.32 −23.30%	Jeddah (Saudi Arabia)

Table 3
Relative abundance of PPE (gloves and masks) and total plastic litter (m^{-2} $site^{-1}$). (n = 90 ± SE).

Total litter	PPE	Location
7.20^c ± 1.03	2.79^c ± 0.311	Alexandria (Egypt)
0.51^a ± 0.021	0.29^a ± 0.018	Hurghada (Egypt)
1.77^b ± 0.039	0.86^b ± 0.032	Jeddah (Saudi Arabia)

Table 4
The number of PPE items (gloves and masks) collected during weekdays and weekends. (n for weekdays = 77 ± SE and 64 ± SE for Egypt and Saudi Arabia, respectively; while n for weekends = 13 ± SE and 26 ± SE for both countries, respectively; means not followed by the same letter are significantly different at $P < 0.001$ "***"; n.s. = not significant).

% increase during the weekend	Weekends	Weekdays	Location
76.3%***	1532^{b} ± 21.88	869^{a} ± 77.3	Alexandria (Egypt)
7% (n.s.)	157^{a} ± 19.6	146^{a} ± 13.5	Hurghada (Egypt)
48%***	549^{b} ± 99.8	371^{a} ± 23.7	Jeddah (Saudi Arabia)

Table 5
Average weight of macro-and microplastics collected from different sites (g m^{-2}) (n = 90 ± SE).

Weight of microplastics (g m^{-2})	Weight of macroplastics (g m^{-2})	Location
0.86^{b} ± 0.023	25.66^{c} ± 4.01	Alexandria (Egypt)
0.05^{a} ± 0.001	6.28^{a} ± 1.18	Hurghada (Egypt)
1.71^{c} ± 0.106	13.45^{b} ± 2.17	Jeddah (Saudi Arabia)

goals are hampered by upsurges medical plastic waste and this needs people awareness.

Egypt and Saudi Arabia are witnessing intense tourism, fishery, and other anthropogenic activities that have made their coastal zones and biota vulnerable to macro-and microplastic contamination. This form of plastic pollution is alarming yet poorly understood. Research is needed to fill the current knowledge gaps regarding COVID-19-associated PPE pollution and to lay the groundwork for better waste management and legislation. Reducing the accumulation of plastics through their degradation (biological, chemical, or physical), is yet to be resolved. It is necessary to identify sources and drivers of plastics, including PPE, and to track them after entering the marine ecosystem and so understand their potential fate (Al-Salem et al., 2021).

The magnitude of PPE pollution remains unknown, especially in the Middle East, despite there being some published reports worldwide (Fadare and Okoffo, 2020; Prata et al., 2020; De-la-Torre and Aragaw, 2021; Galgani et al., 2021). Public education campaigns to promote appropriate PPE stewardship should be integrated into policy implementation, monitoring, and enforcement. Development of infrastructure to ensure safety in informal waste collection. There is a debate that PPE and PPE-derived microplastics are a potential source and vector of chemical pollutants in marine ecosystem (Fred-Ahmadu et al., 2020). Thus, it is necessary to consider these two drivers of marine pollution with associated pollutants.

This briefing highlighted the need for further research to accurately evaluate and lessen the potential environmental impact of litter in public spaces. There is an urgent need for improved products and policies to encourage desirable consumer behavior related to the use, sanitation, collection, and safe disposal of litter to prevent it from polluting the environment. Finally, national and international campaigns for monitoring single-use plastic are needed to facilitate research and guide future policy options (including the collection of reliable up-to-date data on littering). Raising awareness to change behavior and better municipal waste management (including efficient collection, safety, hygiene, and recycling schemes) are also needed. Public education campaigns to promote appropriate PPE stewardship should be integrated into policy implementation, monitoring, and enforcement. The development of infrastructure to ensure safety in informal waste collection and recycling in low-income countries is essential (Barceló, 2020). PPE management policies need to be integrated into economic models that promote the adoption of green technology and alternative assessments to identify and adopt safer processes based on comprehensive materials life cycle assessments and consumer preferences to be sustainable.

It is worth to measure the presence and impact of plastic debris on freshwater shorelines as the information is scarce for freshwater environments and is not yet been available for the Middle East.

4. Conclusions & recommendations

To the best of our knowledge, this is the first attempt to document the abundance of plastic debris on the beaches of Egypt and Saudi Arabia through public involvement. This short study revealed a relatively low level of knowledge about the proper disposal of PPE among laymen in Middle Eastern countries. Policymakers should develop national and local educational campaigns to promote applicable PPE stewardship.

More collection bins for PPE should be installed in the cities. Used masks, used gloves, used personal clothes and all PPE must be separately collected and discharged in closed garbage bags to safely transport them

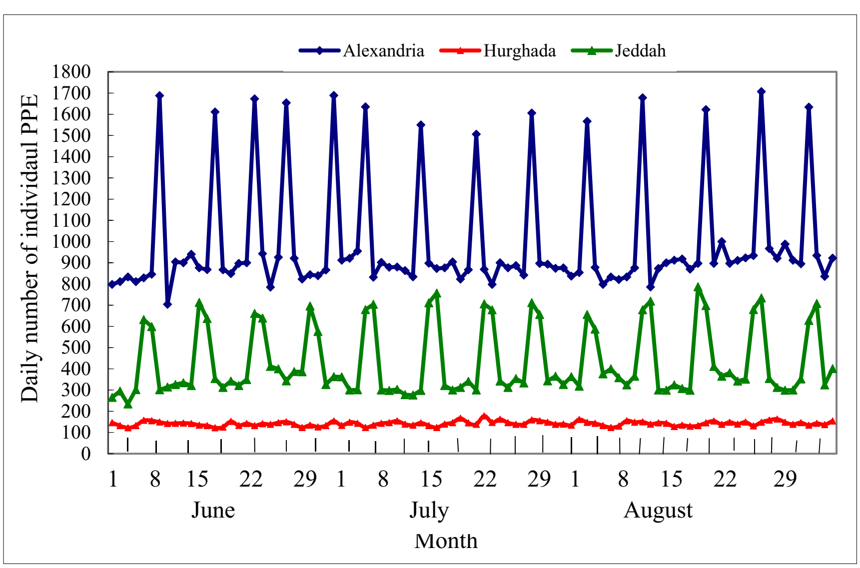


Fig. 6. The daily collection figures of PPE (masks and gloves) collected from the different sites.

Fig. 7. Photographs of COVID-19 microplastic debris found in coastal areas of the Mediterranean Sea in Egypt (a) and the Red Sea (b).

to final treatments (e.g. landfilling or incineration). Recyclable plastics should be used, rather than unrecyclable ones. Simply, good knowledge, optimistic attitudes, and responsible practices towards COVID-19 will help us to cope with the pandemic.

The most important lesson learned from the COVID-19 pandemic is that we should prepare now for further potentially disruptive events in an uncertain future. PPE will continue to be in high demand, and this is the time to invest in research and development for new PPE materials that reduce waste generation, and for improved strategies for safe and sustainable management of used PPE with policy guidance at the global level. Therefore, the new products should contain minimum recycling content. Moreover, public education campaigns to promote appropriate PPE stewardship should be integrated into policy implementation, monitoring, and enforcement.

Single-use PPE is not a sustainable practice, therefore, it is essential to tackle the PPE pollution problem. PPE disinfection and reuse are potential through irradiation, gasification, and spray-on disinfectants. The circular economy principle focusing on reducing, reusing, and recycling resources should guide policy development for PPE management during and after the current pandemic.

Funding

There is no external funding for the research, authorship, and/or publication of this article.

CRediT authorship contribution statement

All authors are equally contributed, and we declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Declaration of competing interest

We believe this subject is interesting and no data were published from Egypt or Saudi Arabia.

We have the pleasure to submit this paper as a short communication. Having said that, I could not find a short communication option regarding the submission, so I have selected the nearest option.

The authors declare no potential conflicts of interest concerning the research, authorship, and/or publication of this article.

Acknowledgments

The authors thank the volunteers who carried out the beach clean-ups for their hard work and dedication. We would like to thank from the bottom of our hearts anonymous reviewers for their invaluable comments.

References

Adelodun, A.A., 2021. Plastic recovery and utilization: from ocean pollution to green economy. Front. Environ. Sci. 09. https://doi.org/10.3389/fenvs.2021.683403.

Adyel, T.M., 2020. Accumulation of plastic waste during COVID-19. Science 369 (6509), 1314–1315. https://doi.org/10.1126/science.abd9925.

Ali, S.S., Elsamahy, T., Koutra, E., Kornaros, M., El-Sheekh, M.M., Abdelkarim, E.A., Zhu, D., Sun, J.Z., 2021. Degradation of conventional plastic wastes in the environment: a review on current status of knowledge and future perspectives of disposal. Sci. Total Environ. 771, 144719. https://doi.org/10.1016/j.scitotenv.2020.144719.

Al-Salem, S.M., El-Eskandarani, M.S., Constantinoun, A., 2021. Can plastic waste management be a novel solution in combating the novel coronavirus (COVID-19)? A short research note. Waste Manag. Res. 39 (7), 910–913. https://doi.org/10.1177/0734242X20978444.

Aragaw, T.A., 2020. Surgical face masks as a potential source for microplastic pollution in the COVID-19 scenario. Mar. Pollut. Bull. 159, 111517. https://doi.org/10.1016/j.marpolbul.2020.111517.

Barceló, D., 2020. An environmental and health perspective for COVID-19 outbreak: meteorology and air quality influence, sewage epidemiology indicator, hospitals disinfection, drug therapies and recommendations. J. Environ. Chem. Eng. 8, 102006. https://doi.org/10.1016/j.jece.2020.104006.

Barnes, D.K., Galgani, F., Thompson, R.C., Barlaz, M., 2009. Accumulation and fragmentation of plastic debris in global environments. Philos. Trans. R. Soc. B 364 (1526), 1985–1998. https://doi.org/10.1098/rstb.2008.0205.

Basahi, J.M., Ismail, I.M., Hammam, E., Hassan, I.A., 2017. Total suspended particulate matter (TSP) and its associated heavy metals in atmosphere on the Western coast of Saudi Arabia. Polish J. Environ Studies 26 (5), 2419–2424. https://doi.org/10.15244/pjoes/69102/a.

Cauwenberghe, V., Vanreusel, A., Mees, J., Janssen, C.R., 2013. Microplastic pollution in deep–sea sediments. Environ. Pollut. 182, 495–499.

Connexion, J., 2020. French firm finds way to recycle single-use masks. . https://www.connexionfrance.com/French-news/Coronavirus-How-to-recycle-single-use-masks. (Accessed 22 July 2021).

De-la-Torre, G.E., Aragaw, T.A., 2021. What we need to know about PPE associated with the COVID-19 pandemic in the marine environment. Mar. Pollut. Bull. 163. https://doi.org/10.1016/j.marpolbul.2020.111879.

El-Sheekh, M.M., Hassan, I.A., 2020. Lockdowns and reduction of economic activities during the COVID- 9 pandemic improved air quality in Alexandria cityEgypt. Environmental Monitoring & Assessment 193, 11. https://doi.org/10.1007/s10661-020-08780-7.

European Environmental Agency, 2021. Impacts of COVID-19 on Single-use Plastic in Europe's Environment. . https://www.eea.europa.eu/publications/impacts-of-covid-19-on.

Fadare, O.O., Okoffo, E.D., 2020. Covid-19 face masks: a potential source of microplastic fibers in the environment. Sci. Total Environ. 737, 140279. https://doi.org/10.1016/j.scitotenv.2020.140279.

Farahat, A., Chauhan, A., Al Otaibi, M., Singh, R.P., 2021. Air quality over major cities of Saudi Arabia during hajj periods of 2019 and 2020. Earth Syst. Environ. 5, 101–114. https://doi.org/10.1007/s41748-021-00202-z.

Fred-Ahmadu, O.H., Bhagwat, G., Oluyoye, I., Benson, N.U., Palanisami, Ayejuyo O.O., T, 2020. Interaction of chemical contaminants with microplastics: principles and perspectives. Sci. Total Environ. 706, 135978. https://doi.org/10.1016/j.scitotenv.2019.135978.

Galgani, F., Brien, A., Weise, J., Ioakeimidis, C., Schuyler, Q., Makarenko, I., 2021. Are litter, plastic and microplastic quantities increasing in the ocean? Microplastics Nanoplastics 1, 2. https://doi.org/10.1186/s43591-020-00002-8.

Gewert, B., Plassmann, M.M., MacLeod, M., 2015. Pathways for degradation of plastic polymers floating in the marine environment. Environ. Sci. Process. Impacts 17, 1513. https://doi.org/10.1039/00207a.

Hassan, I.A., Basahi, J., Ismail, I., Almeelbi, T., Hammam, E., Cotrozzi, L., Haiba, N.S., 2017. Trace elements in the fruits of date palm (Phoenix dactylifera L.) in Jeddah City, Saudi Arabia. Agrochimica 61 (1), 75–93. https://doi.org/10.12871/0021857201716.

Ismail, I.M., Summan, A.S., Basahi, J.M., Yassin, M.F., Hassan, I.A., 2021. First measurements of carbonaceous aerosol across urban, rural and residential areas in Jeddah City, Saudi Arabia. Asian J. Atmos. Environ. 15 (2), 1–14. https://doi.org/10.5572/ajae.2021.021.

James, K., Vasant, K., Batcha, S.M., Padua, S., Jeyabaskaran, R., Thirumalaiselvan, S., Vineetha, G., Benjamin, L.V., 2021. Seasonal variability in the distribution of microplastics in the coastal ecosystems and in some commercially important fishes of the Gulf of Mannar and Palk Bay, southeast coast of India. Reg. Stud. Mar. Sci. 41, 101558. https://doi.org/10.1016/j.rsma.2020.101558.

Mallick, S.K., Pramanik, M., Maity, B., Das, P., Sahana, M., 2021. Plastic waste footprint in the context of COVID-19: reduction challenges and policy recommendations towards sustainable development goals. Sci. Total Environ. 796. https://doi.org/10.1016/j.scitotenv.2021.148951.

Moore, C., 2020. Plastic pollution. Encyclopedia Britannica. 15 Oct. 2020 .. https://www.britannica.com/science/plastic-pollution. (Accessed 16 June 2021).

Onoja, H.A., Abdallah, M.A., Harrad, S., 2022. Microplastics in freshwater sediments: analytical methods, temporal trends, and risk of associated organophosphate esters as exemplar plastics additives. Environ. Res. 203, 111830. https://doi.org/10.1016/j.envres.2021.111830.

OSPAR, 2020. CEMP Guidelines for Marine Monitoring and Assessment of Beach Litter. . https://www.ospar.org/documents?v=44122. (Accessed 19 July 2021).

Patrício, S.A.L., Prata, J.C., Walker, T.R., Duarte, A.C., Barcelò, D., Rocha-Santos, T., 2021. Increased plastic pollution due to COVID-19 pandemic: challenges and recommendations. Chemical Engeneering J. 405, 126683. https://doi.org/10.1016/j.cej.2020.126683.

Prata, J.C., da Costa, J.P., Lopes, I., Duartea, A.C., Rocha-Santosa, T., 2020. Environmental exposure to microplastics: an overview on possible human health effects. Sci. Total Environ. 702, 134455. https://doi.org/10.1016/j.scitotenv.2019.134455.

Qari, H., Hassan, I.A., 2017. Bioaccumulation of PAHs in algae collected from a contaminated site at the red sea, Saudi Arabia. Pol. J. Environ. Stud. 27 (1), 435–439. https://doi.org/10.15244/pjoes/63937.

Rhee, S.-W., 2020. Management of used personal protective equipment and wastes related to COVID-19 in South Korea. Waste Manag. Res. 38 (8), 820–824. https://doi.org/10.1177/0734242X20933343.

Ryan, P.G., 2015. A brief history of marine litter research. In: Bergmann, M., Gutow, L., Klages, M. (Eds.), Marine Anthropogenic Litter. Springer, Cham https://doi.org/10.1007/978-3-319-16510-3_1 Publisher.

Singh, N., Tang, Y., Ogunseitan, O.A., 2020. Environmentally sustainable management of used personal protective equipment. Environ. Sci. Technol. 54, 8500–8502. https://doi.org/10.1021/acs.est.0c03022.

Tamara, S., Galloway, C.M., Lewis, C., 2017. Interactions of microplastic debris throughout the marine ecosystem. Nature Ecol. Evol. https://doi.org/10.1038/s41559-017-0116.

Thompson, R.C., Olsen, Y., Mitchell, R.P., Davis, A., Rowland, S.J., John, A.W., McGonigle, D., Russell, A.E., 2014. Lost at sea: where is all the plastic? Science 304, 838. https://doi.org/10.1126/science.1094559.

Vanapalli, K.R., Sharma, H.B., Ranjan, V.P., Samal, B., Bhattacharya, J., Dubey, B., Goel, S., 2021. Challenges and strategies for effective plastic waste management during and post COVID-19 pandemic. Sci. Total Environ. 750, 141514. https://doi.org/10.1016/j.scitotenv.2020.141514.