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

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## 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

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.

Keywords: Plastic Pollution, Personal Protective Equipment (PPE), COVID-19, Marine Ecosystems; volunteers.

## INTRODUCTION

Millions of plastic items of different sizes are discharged into water bodies around the world daily, causing plastic pollution (De-la-Torre & 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 (Aydel, 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 toward 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 & Hassan 2021). 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.

## **METHODOLOGY**

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

## 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<sup>2</sup> (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).

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

## 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).

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

There was a significant difference in the number of PPE items collected from Alexandria and Jeddah during weekdays and weekends (Tab. 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. Figure 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 – 988) were higher than those collected from Jeddah city (ranged between 234 – 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  $25.66 \text{ g m}^{-2}$ ,  $3.78 \text{ g m}^{-2}$ , and  $11.92 \text{ g m}^{-2}$ , respectively, while the weight of microplastics was  $0.81 \text{ g m}^{-2}$ ,  $0.03 \text{ g m}^{-2}$ , and  $1.67 \text{ g m}^{-2}$  for the same sites, respectively (Tab.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.

Figure 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 ( $50^{\circ}\text{C} \pm 4$ ) (Basahi et al., 2017; Hassan et al., 2017; Qari & 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 & 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 et al., 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 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 et al., 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.

## **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 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 sprayer 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.

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Credit Author 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.

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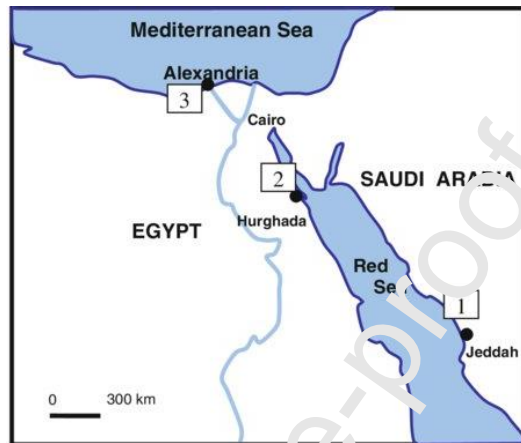
Declaration of Interest Statement

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

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



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



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

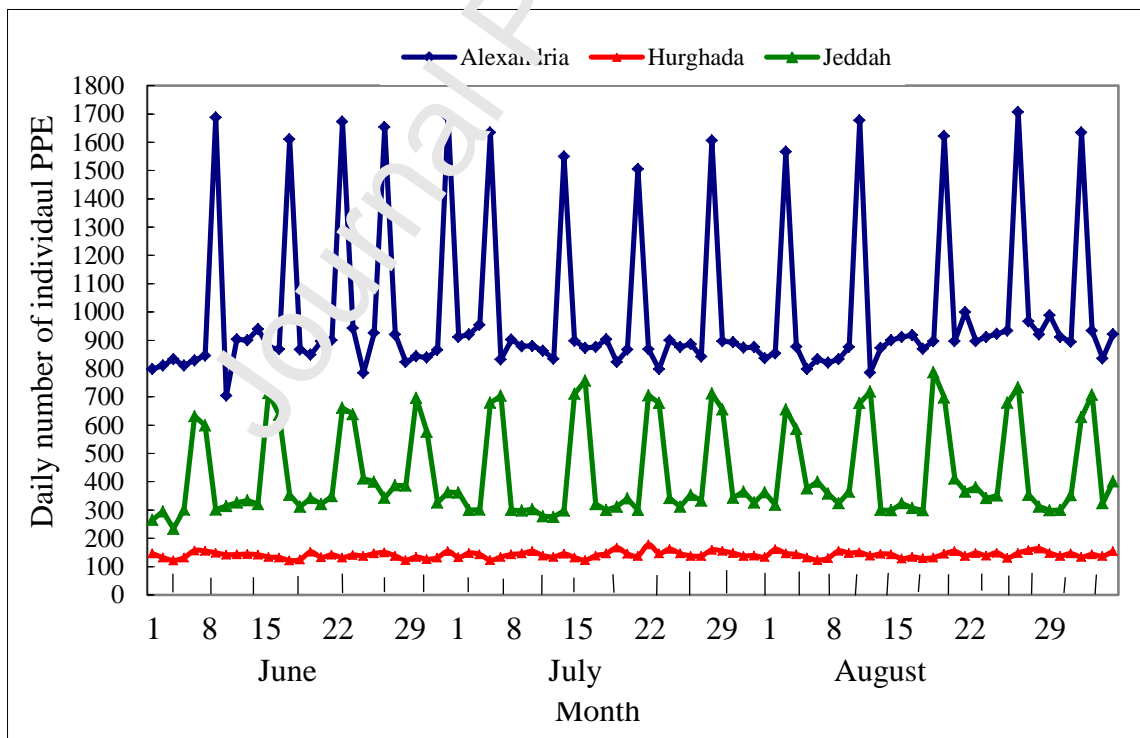


Fig. 6. The daily collection figures of PPE (masks and gloves) collected from the different sites.



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

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Table 1. Size of sampling sites.

Location	Size (m <sup>2</sup> )
Alexandria (Egypt)	20 x 25 = 500
Hurghada (Egypt)	17 x 30 = 510
Jeddah (Saudi Arabia)	12 x 40 = 480

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Table 2. Daily distribution of different plastic items collected from different sites day<sup>-1</sup> (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.

Location	Gloves	Masks	Bags	Bottles	Others	Total
Alexandria (Egypt)	480 <sup>c</sup> ±75.1 4 (13.1%)	918 <sup>c</sup> ±66.2 8 (25.0%)	671 <sup>c</sup> ±43.9 1 (18.3%)	1103 <sup>c</sup> ±225.3 3 (30.0%)	501 <sup>c</sup> ±33.4 7 (13.6%)	3673±427.1 7
Hurghada (Egypt)	65 <sup>a</sup> ± 13.23 (25.5%)	81 <sup>a</sup> ±15.22 (31.8%)	18 <sup>b</sup> ± 1.41 (7.0%)	21 <sup>a</sup> ± 2.11 (8.2%)	70 <sup>a</sup> ± 9.21 (27.5%)	255 ± 46.92
Jeddah (Saudi Arabia)	198 <sup>b</sup> ±22.3 2 (23.3%)	217 <sup>b</sup> ±19.1 1 (25.6%)	6 <sup>a</sup> ± 0.31 (7.9%)	89 <sup>b</sup> ±11.26 (10.5%)	277 <sup>b</sup> ±23.1 7 (32.7%)	848 ±52.63

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

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



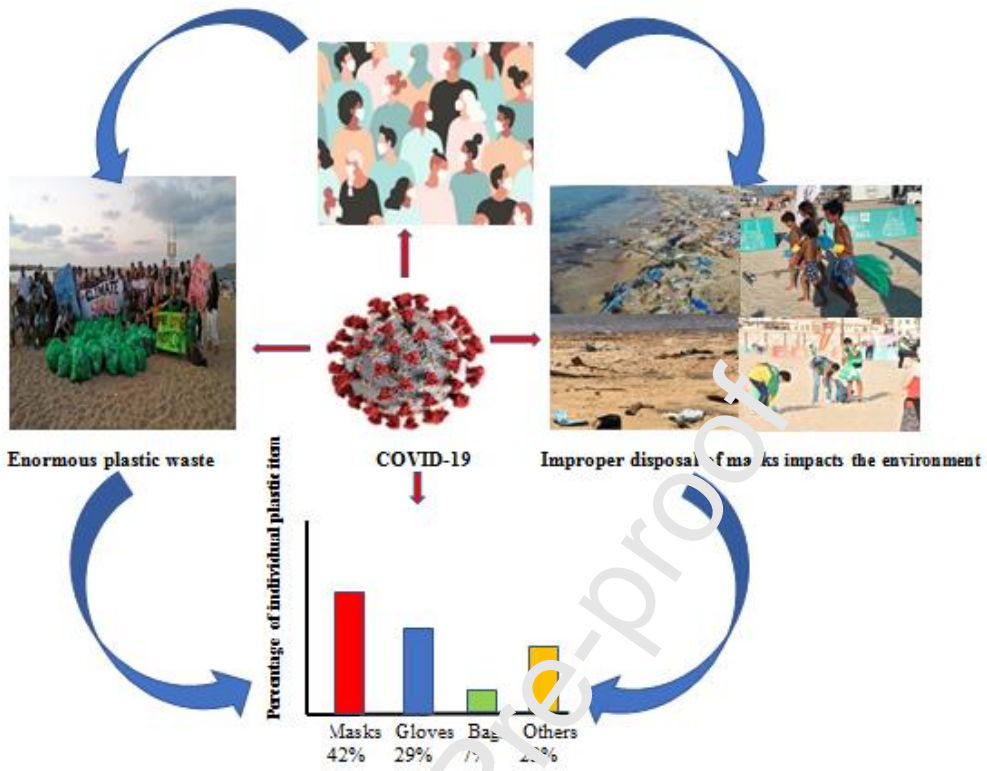
Tab 4. The number of PPE items (gloves and masks) collected during weekdays and weekends. (n for weekdays =  $77 \pm \text{SE}$  and  $64 \pm \text{SE}$  for Egypt and Saudi Arabia, respectively; while n for weekends =  $13 \pm \text{SE}$  and  $26 \pm \text{SE}$  for both countries, respectively; means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

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

Tab. 5. Average weight of macro-and microplastics collected from different sites ( $\text{g m}^{-2}$ ) ( $n=90 \pm \text{SE}$ ).

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

Graphical abstract



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