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Short Communication

Citizen science: A way forward in tackling the plastic pollution crisis during and beyond the COVID-19 pandemic



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HIGHLIGHTS

- The COVID-19 pandemic has driven increased consumption of single-use plastic (SUP).
- The pandemic led to the cancellation of global plastic pollution research programs.
- SUP and PPE mismanagement requires widespread scientific monitoring.
- Citizen science SUP and PPE pollution monitoring can fill research program gaps.
- Global citizen science initiatives can help inform pollution mitigation strategies.

GRAPHICAL ABSTRACT

The importance of citizen science plastic pollution monitoring during and post COVID-19 pandemic



Defining emerging litter categories (i.e. PPE)



Engaging with citizen scientists on an international scale



Identifying sources of pollution



Expanding geographic representation in open-access data bases

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ABSTRACT

The COVID-19 pandemic has resulted in an unprecedented surge of production, consumption, and disposal of single-use plastics (SUPs) and personal protective equipment (PPE) by the public. This widespread use of mostly plastic items like face masks and disposable gloves has led to global reports of improper disposal of potentially infectious PPE both in our urban and natural environments. Due to international travel restrictions during the pandemic, many research programs targeted at measuring plastic pollution were halted. These disruptions to research programs have stunted the ability to assess the true quantities of SUPs and PPE being mismanaged from the waste stream into the environment. This article calls for increased citizen science participation in collecting plastic pollution data both during and post pandemic. By initiating this dialogue and raising attention to the importance and potential of citizen science data collection, data can be used to develop globally informed plastic pollution mitigation strategies.

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1. Introduction

Following the declaration of the COVID-19 pandemic from the World Health Organization (WHO) in March 2020, countries took

immediate action to prevent widespread transmission (World Health Organization, 2020). Governments introduced travel bans and lockdown measures as well as physical distancing in public spaces (Patrício Silva et al., 2020; Prata et al., 2020). Due to these measures, many research programs were disrupted and even research fieldwork activities were cancelled due to these travel restrictions. As a result, many individuals were unable to access neighbouring communities or

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fieldwork sites both within and outside of national borders (Mallory, 2020). Ultimately, the COVID-19 pandemic has highlighted the importance of traditional laboratory or logistically complex fieldwork-based research to establish and promote the participation of the general public in critically important scientific data collection. This is particularly important for tackling the issue of widespread and indiscriminate environmental plastic pollution because capturing a wide breadth of geospatial and temporal data is critical to developing plastic pollution mitigation strategies.

During the COVID-19 pandemic, there was an increased global demand for disposable single-use plastic (SUP). Increased use and consumption of SUPs occurred in the form of items like take-away packaging from restaurants and the reversal or postponement of policies targeted to reduce SUPs within countries like the UK and US (Patrício Silva et al., 2020). There was also widespread use of personal protective equipment (PPE) (Prata et al., 2020). As PPE are designed to protect the user against infection, items like disposable face masks and gloves were widely consumed by the general public to prevent infection by SARS-CoV2 virus. It was conservatively estimated that during the COVID-19 pandemic 129 billion face masks and 65 billion gloves were being consumed per month, globally (Prata et al., 2020). Given the mass consumption of these items around the world, leakage from proper and improper waste management streams was inevitable from both accidental leakage and intentional indiscriminate littering.

2. Interruptions to plastic pollution research during the COVID-19 pandemic

Despite leakage occurring on a global scale, data collection on PPE mismanagement was particularly scarce. Studies published in early 2020 identified PPE pollution as a growing global problem (Prata et al., 2020; Patrício Silva et al., 2020; Canning-Clode et al., 2020; Patrício Silva et al., 2021). However most of these desktop studies were theoretical in nature and lacked empirical data from field-based assessments. Following these desktop reports a number of systematic field surveys that reported the growing presence and abundance of PPE were published from various countries, including: Canada (Ammendolia et al., 2021), Bangladesh (Rakib et al., 2021), Brazil (Neto et al., 2021), Chile (Thiel et al., 2021), Indonesia (Cordova et al., 2021), Iran (Akhbarizadeh et al., 2021), Kenya (Okuku et al., 2021), Morocco (Haddad et al., 2021), Peru (De-la-Torre et al., 2021), as well as South Africa (Ryan et al., 2020).

Although many of these systematic field-based surveys occurred in terrestrial, freshwater and marine environments, the geospatial representation was limited to a selected number of regions and did not represent the breadth of regions that were impacted by the COVID-19 pandemic. In some cases, structured surveys like those conducted in Morocco, assessed the impact of lockdown status on PPE litter, by replicating surveys both during and after regional lockdowns (Haddad et al., 2021). Despite the importance of quantifying PPE at different periods of the pandemic, under strict government lockdowns that occurred in certain countries the surveying protocols of such studies could not be replicated under such lockdown conditions. Similarly, many municipalities and NGOs cancelled annual group cleanup events which in some cases acted as long-term monitoring programs (Great Canadian Shoreline Cleanup, 2020). Overall, not being able to collect debris data during the COVID-19 pandemic hinders our ability to not only identify sources of leakage, but also understand how that might change during periods where relationships with disposability and plastics might shift.

3. Citizen science and the pandemic

The unique travel restrictions characterizing the pandemic demonstrate the importance of involving a broader citizen science community in data collection of not only PPE debris but all forms of debris. Citizen science (CS) is the practice of non-specialist individuals or members of

the general public participating in scientific research which can be in collaboration with scientists (Bonney et al., 2009). Individual involvement can vary from designing the research scope to collecting data to processing the results. There are hundreds of CS tools and programs that cover many areas like reporting biodiversity (iNaturalist; <https://www.inaturalist.org>) to mapping debris (Marine Debris Tracker; <https://debristracker.org>).

In order for CS projects to ensure the quality of collected data, projects need to provide training and instructional resources for citizen scientists. Projects typically recruit citizen scientists for specific criteria and train individuals on methodologies and technologies. Bonney et al. (2009) identified that CS projects that produce reliable data are defined by: straightforward sampling methods, clear ways to record data and the availability of additional resources on the activity. Through the practice of these principles, CS projects focused on coastal debris have resulted in scientifically reproducible methods and large datasets by citizen scientists of all ages, ranging from high school students in The Bahamas (Ambrose et al., 2019) to elementary schoolchildren in Chile (Hidalgo-Ruz and Thiel, 2013). Once involved in such initiatives, citizen scientists can foster their environmental awareness and values, which can also lead to positive social impact in their communities through mobilizing knowledge (i.e. teaching others about the problem) or taking action (i.e. advocating for policy or institutional changes) (Ambrose et al., 2019).

In the context of the pandemic, such initiatives can produce strong scientific datasets because citizen scientists can collect large quantities of data within their own regions making long-term monitoring projects possible (Kishimoto and Kobori, 2021). During this time, citizen scientists have been spending more time in their communities and in some cases CS environmental initiatives have reported higher rates of activity and data collection relative to non-pandemic periods (Basile et al., 2021). Such peaks in data submissions are advantageous to provide a bigger picture about debris landscapes because citizen scientists are able to use knowledge of their own communities and neighbourhoods to access different spaces like private lands which most scientists would be unable to sample (Spear et al., 2017).

CS initiatives are broadly accessible to audiences, especially during the pandemic. Many CS debris-specific initiatives are available via mobile applications or have an online component like Marine Debris Tracker (University of Georgia), Clean Swell (Ocean Conservancy; <https://oceanconservancy.org/trash-free-seas/international-coastal-cleanup/cleanswell/>) and Great Canadian Shoreline Cleanup (WWF and Ocean Wise; <https://shorelinecleanup.ca>). Many CS initiatives adapted to pandemic-related conditions and instead of hosting events in large gatherings transitioned to promoting small household groups or solo activities (Kishimoto and Kobori, 2021; Great Canadian Shoreline Cleanup, 2020). By promoting smaller groups sampling capacity can increase, thus, providing a more thorough picture of what debris composition looks like across regions. CS has reported invaluable data about real-time changes in the debris landscape during the pandemic. Only three months following policy requirements to wear face masks in the UK, citizen scientists participating in the Great British Beach Clean found that PPE debris was found at 69% of inland areas and 30% of beaches that were monitored (Marine Conservation Society, 2020). Similarly, throughout 2020 citizen scientists using the Ocean Conservancy's Clean Swell mobile app report reported and removed 107,219 individual pieces of PPE (Ocean Conservancy, 2021).

4. The future role of citizen science during and post pandemic

The significance of CS datasets can not be understated given the cancellation of many government, academic and NGO programs during this period. The frequency of uploads and vast geospatial distribution of CS data can reveal nuances of our changing debris landscapes. These trends can inform municipal policymakers and waste management facilities to prevent debris leakage from the waste stream, thus saving millions of

dollars in cleanup efforts (Borrelle et al., 2020). Indeed, many policy efforts to reduce sources of SUP pollution require frequent reassessment to test the efficacy of current policy interventions. CS may prove to be a valuable tool for decision-makers when they have to reassess their policies (Ambrose et al., 2019). Moving forward, NGOs that run CS programs should receive financial support so that data collection can continue and technologies can be developed to become increasingly more accessible (Patrício Silva et al., 2020).

There is a definite need to promote and make space for CS post-pandemic. As stated by Provenzi and Barello (2020) society should develop “a new form of participatory and collaborative engagement approach to research”. This call to action is incredibly timely because as we enter the United Nations, Decade of Ocean Science for Sustainable Development, internationally we need to address the issue of marine pollution to implement the United Nations Sustainable Development Goals (Walker, 2021). Addressing plastic debris and pollution from all sources and sinks involves intervention in all environmental compartments and this can only be achieved through a collective effort that embraces participation and contributions by CS around the world.

CRedit authorship contribution statement

Justine Ammendolia: Conceptualization, Investigation, Methodology, Project administration, Resources, Validation, Visualization, Writing – original draft, Writing – review & editing. **Tony R. Walker:** Conceptualization, Investigation, Methodology, Project administration, Resources, Validation, Visualization, Writing – 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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References

- Akhbarizadeh, R., Dobaradaran, S., Nabipour, I., Tangestani, M., Abedi, D., Javanfekr, F., Jeedi, F., Zendehtboodi, A., 2021. Abandoned Covid-19 personal protective equipment along the Bushehr shores, the Persian Gulf: an emerging source of secondary microplastics in coastlines. *Mar. Pollut. Bull.* 168, 112386. <https://doi.org/10.1016/j.marpolbul.2021.112386>.
- Ambrose, K.K., Box, C., Boxall, J., Brooks, A., Eriksen, M., Fabres, J., Flylakis, G., Walker, T.R., 2019. Spatial trends and drivers of marine debris accumulation on shorelines in South Eleuthera, the Bahamas using citizen science. *Mar. Pollut. Bull.* 142, 145–154. <https://doi.org/10.1016/j.marpolbul.2019.03.036>.
- Ammendolia, J., Saturno, J., Brooks, A.L., Jacobs, S., Jambeck, J.R., 2021. An emerging source of plastic pollution: environmental presence of plastic personal protective equipment (PPE) debris related to COVID-19 in a metropolitan city. *Environ. Pollut.* 269, 116160. <https://doi.org/10.1016/j.envpol.2020.116160>.
- Basile, M., Russo, L.F., Russo, V.G., Senese, A., Bernardo, N., 2021. Birds seen and not seen during the COVID-19 pandemic: the impact of lockdown measures on citizen science bird observations. *Biol. Conserv.* 256, 109079.
- Bonney, R., Ballard, H., Jordan, R., McCallie, E., Phillips, T., Shirk, J., Wilderman, C.C., 2009. Public participation in scientific research: defining the field and assessing its potential for informal science education. A CAISE Inquiry Group Report. Center for Advancement of Informal Science Education (CAISE), Washington, D.C.
- Borrelle, S.B., Ringma, J., Law, K.L., Monnahan, C.C., Lebreton, L., McGivern, A., Murphy, E., Jambeck, J., Leonard, G.H., Hilleary, M.A., Eriksen, M., 2020. Predicted growth in plastic waste exceeds efforts to mitigate plastic pollution. *Science* 369 (6510), 1515–1518. <https://doi.org/10.1126/science.aba3656>.
- Canning-Clode, J., Sepúlveda, P., Almeida, S., Monteiro, J., 2020. Will COVID-19 containment and treatment measures drive shifts in marine litter pollution? *Front. Mar. Sci.* 7, 691. <https://doi.org/10.3389/fmars.2020.00691>.

- Cordova, M.R., Nurhati, I.S., Riani, E., Iswari, M.Y., 2021. Unprecedented plastic-made personal protective equipment (PPE) debris in river outlets into Jakarta Bay during COVID-19 pandemic. *Chemosphere* 268, 129360. <https://doi.org/10.1016/j.chemosphere.2020.129360>.
- De-la-Torre, G.E., Rakib, M.R.J., Pizarro-Ortega, C.I., Dioses-Salinas, D.C., 2021. Occurrence of personal protective equipment (PPE) associated with the COVID-19 pandemic along the coast of Lima, Peru. *Sci. Total Environ.* 774, 145774. <https://doi.org/10.1016/j.scitotenv.2021.145774>.
- Great Canadian Shoreline Cleanup, 2020. [WWW Document]. Great Canadian shoreline cleanup. Organizing a solo, household or small team cleanup. <https://www.shorelinecleanup.ca/storage/resources/solo-and-small-team-cleanup-checklist-covid-19-2021.pdf> Accessed July 12 2021.
- Haddad, M.B., De-la-Torre, G.E., Abelouah, M.R., Hajji, S., Alla, A.A., 2021. Personal protective equipment (PPE) pollution associated with the COVID-19 pandemic along the coastline of Agadir, Morocco. *Sci. Total Environ.* 149282. <https://doi.org/10.1016/j.scitotenv.2021.149282>.
- Hidalgo-Ruz, V., Thiel, M., 2013. Distribution and abundance of small plastic debris on beaches in the SE Pacific (Chile): a study supported by a citizen science project. *Mar. Environ. Res.* 87, 12–18. <https://doi.org/10.1016/j.marenvres.2013.02.015>.
- Kishimoto, K., Kobori, H., 2021. COVID-19 pandemic drives changes in participation in citizen science project “City nature challenge” in Tokyo. *Biol. Conserv.* 255, 109001. <https://doi.org/10.1016/j.biocon.2021.109001>.
- Mallory, M., 2020. [WWW Document]. The Hills Times. Does a global pandemic signal the need for adjusted approaches to Arctic research? <https://www.hillstimes.com/2020/06/10/does-a-global-pandemic-signal-the-need-for-adjusted-approaches-to-arctic-research/251408> Accessed July 12 2021.
- Neto, H.G., Bantel, C.G., Browning, J., Della Fina, N., Ballabio, T.A., de Santana, F.T., Britto, M.D.K., Barbosa, C.B., 2021. Mortality of a juvenile magellanic penguin (*Spheniscus magellanicus*, Spheniscidae) associated with the ingestion of a PFF-2 protective mask during the Covid-19 pandemic. *Mar. Pollut. Bull.* 166, 112232. <https://doi.org/10.1016/j.marpolbul.2021.112232>.
- Ocean Conservancy, 2021. [WWW Document]. Ocean conservancy. Pandemic pollution: the rising tide of plastic PPE. <https://oceanconservancy.org/wp-content/uploads/2021/03/FINAL-Ocean-Conservancy-PPE-Report-March-2021.pdf> Accessed July 12 2021.
- Okuku, E., Kiteresi, L., Owato, G., Otieno, K., Mwalugha, C., Mbuche, M., Gwada, B., Nelson, A., Chepkemboi, P., Achieng, Q., Wanjeri, V., 2021. The impacts of COVID-19 pandemic on marine litter pollution along the kenyan coast: a synthesis after 100 days following the first reported case in Kenya. *Mar. Pollut. Bull.* 162, 111840. <https://doi.org/10.1016/j.marpolbul.2020.111840>.
- Patrício Silva, A.L., Prata, J.C., Walker, T.R., Campos, D., Duarte, A.C., Soares, A.M.V., Rocha-Santos, T., 2020. Rethinking and optimising plastic waste management under COVID-19 pandemic: policy solutions based on redesign and reduction of single-use plastics and personal protective equipment. *Sci. Total Environ.* 742, 140565. <https://doi.org/10.1016/j.scitotenv.2020.140565>.
- Patrício Silva, A.L., Prata, J.C., Walker, T.R., Duarte, A.C., Ouyang, W., Barcelo, D., Rocha-Santos, T., 2021. Increased plastic pollution due to COVID-19 pandemic: challenges and recommendations. *Chem. Eng. J.* 405, 126683. <https://doi.org/10.1016/j.cej.2020.126683>.
- Prata, J.C., Patrício Silva, A.L., Walker, T.R., Duarte, A.C., Rocha-Santos, T., 2020. COVID-19 pandemic repercussions on the use and management of plastics. *Environ. Sci. Technol.* 54 (13), 7760e7765. <https://doi.org/10.1021/acs.est.0c02178>.
- Provenzi, L., Barello, S., 2020. The science of the future: establishing a citizen-scientist collaborative agenda after COVID-19. *Front. Public Health* 8, 282. <https://doi.org/10.3389/fpubh.2020.00282>.
- Marine Conservation Society, 2020. [WWW Document]. Marine Conservation Society. The Great British Beach Clean results show concerning volume of PPE litter. <https://www.mcsuk.org/news/great-british-beach-clean-results-2020/>. Accessed July 12 2021.
- Rakib, M.R.J., De-la-Torre, G.E., Pizarro-Ortega, C.I., Dioses-Salinas, D.C., Al-Nahian, S., 2021. Personal protective equipment (PPE) pollution driven by the COVID-19 pandemic in Cox's Bazar, the longest natural beach in the world. *Mar. Pollut. Bull.* 169, 112497. <https://doi.org/10.1016/j.marpolbul.2021.112497>.
- Ryan, P.G., Maclean, K., Weideman, E.A., 2020. The impact of the COVID-19 lockdown on urban street litter in South Africa. *Environ. Process.* 7 (4), 1303–1312. <https://doi.org/10.1007/s40710-020-00472-1>.
- Spear, D.M., Pauly, G.B., Kaiser, K., 2017. Citizen science as a tool for augmenting museum collection data from urban areas. *Front. Ecol. Evol.* 5, 86. <https://doi.org/10.3389/fevo.2017.00086>.
- Thiel, M., de Veer, D., Espinoza-Fuenzalida, N.L., Espinoza, C., Gallardo, C., Hinojosa, I.A., Kiessling, T., Rojas, J., Sanchez, A., Sotomayor, F., Vasquez, N., 2021. COVID lessons from the global south—face masks invading tourist beaches and recommendations for the outdoor seasons. *Sci. Total Environ.* 786, 147486. <https://doi.org/10.1016/j.scitotenv.2021.147486>.
- Walker, T.R., 2021. Why are we still polluting the marine environment with personal protective equipment? *Mar. Pollut. Bull.* 169, 112528. <https://doi.org/10.1016/j.marpolbul.2021.112528>.
- World Health Organization, 2020. [WWW Document]. World Health Organization. Strengthening preparedness for COVID-19 in cities and Urban settings: interim guidance for local authorities. <https://apps.who.int/iris/handle/10665/331896> Accessed July 12 2021.