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Strengthening citizen science partnerships with frontline sanitation personnel to study and tackle plastic pollution

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ABSTRACT

The COVID-19 outbreak has boosted demand for and use of personal protective equipment (PPE) and other single-use plastics, adding to the environment’s already high levels of plastic pollution and endangering biota. Estimating the relative abundance of PPE wastes that end up in the environment is crucial and has remained a challenge for COVID-19 researchers. Citizen science has been utilized in recent studies to monitor and collect data using volunteers, and it has proven to be a valuable approach even in difficult situations. The expansion of citizen scientific participation groups is important in light of the growing anthropogenic impacts of plastic pollution. To date, frontline sanitary personnel are often overlooked and underutilized in a citizen science perspective, yet they serve critical roles in maintaining cleanliness in key environmental settings (e.g., beaches and streets) both during and beyond the pandemic. This paper explores and emphasizes the advantages and need of including frontline sanitary personnel into citizen science for the benefit of both researchers and communities, as well as to encourage long-term goals in global plastic litter monitoring, thereby exemplifying citizen science opportunities. Recommendations are made to design in order to improve the future status of citizen science development.

1. Citizen science research during the COVID-19 outbreak

Plastics are generally composed of a variety of polymers and additives that have been produced and used for decades in a wide range of applications, including food packaging, industry, agriculture, medical treatment, and many more. Global plastic output reached 288 million tons in 2012, a 620 % increase from 1975, and it rapidly increased to 368 million tons in 2019 (PlasticsEurope, 2020). They have accumulated in the environment as a result of the lack of effective management in the life cycle of plastic products and the durability of plastic itself (Geyer et al., 2017). With the marine environment serving as the primary sink of larger plastics, they can disintegrate into microplastics and nanoplastics under the impact of physical, chemical, and biological forces (Anderson et al., 2015; Koelmans et al., 2019). As the COVID-19 pandemic stretches towards the end of its third year, the demand for and usage of personal protection equipment (PPE) and other single-use plastics has grown rapidly. Since then, the amount of PPE and other plastics that end up in the environment has increased at least many times due to human activities, contributing to the previously existing problems of macro, meso, micro, and nano plastic pollution (Thiel et al., 2021; De-la-Torre et al., 2021; Kutralam-Muniasamy et al., 2022; Kutralam-Muniasamy and Shruti, 2022). The expected plastic waste volume during the first seven months of the COVID-19 outbreak (December 2019–June 2020) surpassed 530 Mt (Benson et al., 2020). They can endanger the ecosystem and biota in a variety of ways, including entanglement or ingestion, breakdown into micro-and nano-plastics, and serving as a vehicle for a range of chemical additives (Neto et al., 2021; Kutralam-Muniasamy et al., 2022). On the one hand, research and policy have focused on ways to limit and minimize plastic waste (e.g., PPE) emissions into ecosystems (Da Costa, 2021), therefore reducing their environmental and health consequences. On the other hand, estimating the relative abundance of PPE waste that ends up in the environment is deemed crucial to understanding the impact of the COVID-19 pandemic on marine litter contamination.

There are at least 22 peer-reviewed publications on the abundance of littered PPE in marine, freshwater, and street environments for the period between April 2020 and July 2022 (Supplementary Material Table S1). Thanks to all the researchers who have made important
contributions to the understanding of the COVID-19 pandemic’s impact on plastic pollution. Surveying COVID-19-related PPE waste has taken two approaches, with some engaging researchers and teams directly, and others relying on citizen science. The citizen science approach of environmental information collection and protective action, for example, employs more locals, establishes collaboration between communities, institutions and the private sector and encourages public participation in the scientific process, as well as includes data and information on the topic of attention (Bonney et al., 2009), such as plastic or PPE pollution. Citizen science projects have been integrated into Open Science, Open Innovation, Open Government, and/or Open Data initiatives in the United States and Europe (Shanley et al., 2019). As an emerging field, citizen science initiatives have been helping researchers to monitor and estimate the amount of plastic entering major ecosystems all over the world, ranging from macro to microplastics (e.g., France, 2021; Thiel et al., 2021; Ammendolia et al., 2021; Zettler et al., 2017; Forrest et al., 2019; Rambonnet et al., 2019). A recent study on citizen science also emphasizes its importance as one of the most effective strategies in the field of plastic litter monitoring, as well as policymakers’ plastic pollution decision-making (Ammendolia and Walker, 2022). It can be said that public involvement in COVID-19 PPE surveys via citizen science is useful in terms of informing and increasing awareness about plastic pollution issues and, as a result, reducing contamination.

Citizen science programs for data collection are notoriously difficult, yet they remain essential, particularly in pandemic situations. There were several shortcomings in having a prepared citizen science research infrastructure in such a short time during the pandemic scenario. First, it has remained a great challenge for COVID-19 researchers due to the lockdown restrictions, social distancing measures, and the temporary closure of field campaigns in many countries. As a result, the majority of peer-reviewed articles available now have taken advantage of the lockdown relaxations and undertaken analyses on PPE contamination in a variety of environments (Kutralam-Muniasamy et al., 2022). Second, probably most importantly, concerns about health and virus transmission are a major bottleneck for citizen scientific initiatives. The general public was instructed to stay at home in order to stop transmission, avoid infection, and save lives. The uncertainties surrounding scientific proof of possible SARS-CoV-2 airborne transmission would have prevented the public from engaging throughout the pandemic. Furthermore, inter-personal distance has been demonstrated to be insufficient for preventing environmental infections (Morawska and Cao, 2020; Setti et al., 2020), prompting scientists to reconsider the organization and implementation of citizen science initiatives during the COVID-19 pandemic. Third, there are significant health risks associated with the COVID-19 survey of discarded PPE in the environment, such as the possibility of SARS-CoV-2 transmission via handling or contact with PPE litter (Kutralam-Muniasamy et al., 2022). It necessitates the implementation of strict safety standards as well as extensive formal training for those who participate in citizen research. A lack of sufficient training in a timely manner may risk the public health or contribute to relatively incorrect rates of PPE distribution in the environment. Fourth, it is unfortunate that when the number of COVID-19 cases rises, there is a risk that some survey participants may opt out in the middle or at the end of the survey, or that the citizen science project will come to a halt, resulting in survey incompletion. Fifth, citizen science programs require resources and financial support to be effective; a lack of financial support for citizen science projects from state and municipal governments would have impacted support for the project’s implementation, particularly in developing and underdeveloped countries. Sixth, another challenge is the possibility of legal and administrative barriers under pandemic conditions to carry out citizen science projects. Many of these factors, when combined, would have complicated face-to-face consultations with the public and limited researchers’ ability to engage in citizen science during the COVID-19 pandemic. In addition, health-care concerns among the general public would have made it challenging for researchers to involve as many people as feasible in citizen science. In response to the health crisis, the proportion of citizen scientific activities as well as publications related to them will have decreased dramatically, leading to a gap in environmental information in previous years. This also would have contributed to a dearth of citizen scientific contributions to COVID-19 PPE investigations, and the magnitude and source of the problem are elusive in many countries.

With the environmental effect of plastics, especially PPE, on the line, the necessity to develop alternatives and novel strategies has become apparent to enhance the functionality of citizen science for the benefit of researchers and communities. While widespread public engagement is not possible, citizen science projects will require a shift in order to use available resources and build collaborations with existing communities, both of which must be safe and effective in order to address current and future environmental challenges efficiently. This prompted us to explore alternatives, assessing who would support and collaborate in the efforts to embrace citizen science. Frontline sanitation (FSA) personnel draw our attention and stand out as one of the communities to be considered and engaged to identify, support, and address plastic pollution concerns by collaborating with citizen science programs during and beyond the pandemic.

2. Strengths, features, and prospects for citizen science with FSA personnel

Here, the intention is to bring researchers’ attention to the nature and scope of the benefits of working with FSA personnel on citizen science initiatives. Especially, in the citizen science project, how do FSA personnel contribute to citizen science and plastic pollution? What are the implications of taking advantage of the potential of FSA personnel towards citizen science projects?

FSA personnel can be formal or informal, which means that formal workers, like street sweepers, can be financially supported by the federal government, whilst informal workers, mainly scavengers and foragers, must rely on garbage collected and contributions from the public. Regardless of the scenario, they can go out and continue to collect, process, and dispose of solid waste and recyclables on a regular basis in designated sites within a geographical region, encompassing environmental compartments ranging from metropolitan to marine areas (e.g., beaches). Everyone who read the article would have recognized the laborious work of sanitation personnel since the pandemic, as sanitation, waste collection, and waste management operations were allowed to continue in practically all nations during the COVID-19 pandemic. Furthermore, they are informed about the precautionary measures for collecting the PPE from the government and are provided with the necessary tools to handle them (e.g., CDC, 2020; WHO, 2020). The key advantage of involving FSA personnel is that they do not have to devote more time, as the general public does, to participate in citizen science activities. They are already familiar with solid waste and its handling in real-world situations, so training them is not difficult. It is also straightforward for researchers/scientists to teach, adopt, and train them in the methods required for citizen science projects. Because of their daily availability and involvement in keeping the environment clean, they are an excellent candidate for citizen science programs that require continuous monitoring of community issues, like plastic pollution.

Writing from the perspective of plastic pollution issues, they can use the instructions of the researchers/scientists to do monitoring of plastics, in this case, e.g., PPE, while still performing their normal activities. Since FSA personnel have a comprehensive coverage of waste collection, the obtaining of data regarding plastic litter and their sources is conceivable. For example, informal sanitation personnel have the slogan “tu basura, mi fortuna (your garbage, my fortune),” wherein they separate plastics from waste collected (through door-to-door collection or garbage bins) in order to make money for the day-to-day basis of their life. And with that regular activity, the types of frequent plastics and
estimate the plastics density collected for each day can be determined, leading to a better knowledge of plastics usage and disposal in the specific region of interest. Another key example is in marine environments, where the FSA personnel involved in the beach cleanup may also be employed in PPE surveys and plastic litter monitoring (for e.g., fish nets, cigarette buds, plastic bottles, single-use plastics), particularly during tourist seasons. If this is the case, a litter monitoring citizen science program could be launched on a wide variety of plastics or a small set of plastic materials via FSA personnel. Nonetheless, exploring the spatial and temporal scope of the research is a vital goal that will be difficult at times with the same group of people utilized for citizen science. The FSA personnel participation in citizen science may ensure the collection of data for a certain geographical region over time, covering a wide range of habitats (streets, sea, and beach areas) within the defined boundaries. For example, in the context of citizen initiatives in urban areas, given that these people are required to operate near households and apartments for door-to-door waste collection, they can be well-suited for the purpose of spatial and temporal monitoring, especially for the improperly discarded COVID-19 wastes near streets, hospitals, and shopping centers, etc.

Moreover, the availability of FSA personnel would help to speed up and enhance environmental detection, allowing for more effective data collection. While data alone would not contribute to the cause, their assistance and knowledge of the given area may be expanded to include complicated situations and wider domains, allowing to monitor and identify source attribution for plastic pollution. Plastic litter data for a housing system within a 1000-foot range or a 1 km stretch of beach coastline, for example, is crucial because it may be utilized for upstream prevention at the source, thus supporting environmental protection. It is also possible to collect larger data sets with more measured factors (e.g., types of plastic materials) and assess the potential extent of the environmental problem in more detail. Furthermore, the data sets may be utilized to identify areas on a local or regional scale that are the most and least contaminated by plastics, providing alternative or find solutions to limit the usage and disposal of plastics. At the same time, it can help to highlight and explain the implications and long-term consequences of current trends and choices that may lie ahead. When data collected through the collaboration of FSA personnel in citizen science is shared and informed to local government, it has the potential to provide guidance, ideas, management practices, and decision making through alternative perspectives and goals. Aside from being useful for investigation, their knowledge of the local environment lets communities better comprehend current environmental challenges. It also attracts media attention in order to inform the general public or specialized target groups about relevant environmental developments. Considering the situation beyond the pandemic, citizen science initiatives may benefit from sanitation personnel contributions to environmental information and address issues related to plastic pollution. It also implies that including the FSA team in citizen science is advantageous for environmental monitoring and protection, as well as accelerate the fulfillment of environmental goals.

3. A call for action

As discussed in the previous section, the FSA community’s significant roles in citizen science programs to address environmental problems are critical. With the importance of environmental monitoring and data collection increasing, FSA personnel capabilities should be utilized through citizen science. Given the already difficult task of organizing citizen science programs, which is exacerbated by the pandemic’s numerous impediments, coupling FSA personnel with citizen science would be a valuable tool for answering this pertinent situation and advancing the global COVID-19 PPE surveys. To put it another way, the greater the number of communities who participate in citizen science, the more likely it is that high-quality data will be collected, and environmental changes will be detected early. Assuming that their involvement in the supposedly organized citizen science projects since pandemic circumstances, there would have been much more progress and made a better evaluation of plastic and PPE-related issues, particularly in times of crisis. However, the core issue is that they are often omitted in participating communities of citizen science, and frontline personnel are not included in any of the recent publications. To the author’s knowledge, a few studies have raised the possibility of having sanitation personnel for citizen science projects. For example, the possibility of street sweepers as personal sensing devices to aid in environmental community action has been investigated (Aoki et al., 2009). It raises the question of whether the potential of FSA personnel in citizen science on diverse environmental challenges was underutilized. Nonetheless, the treaty to unite frontline sanitation personnel and citizen science is becoming relevant and has the potential to heavily influence the environmental outcomes. In this sense, apart from the public, FSA personnel are potentially critical to citizen scientific programs, and the time is right to engage in partnerships and cooperation with them to bring citizen science from data and information to action. Thus, researchers are encouraged to promote and shed light on the future inclusion and design of citizen science activities in collaboration with FSA personnel.

3.1. Collaboration of FSA personnel in citizen science: tool development for basic and applied research

With previous citizen science experiences, devising strategies are possible for dealing with FSA personnel that are more analogous to those with the public. Researchers who wish to collaborate with FSA staff on citizen science initiatives can do so in two ways: either individually or collectively. The first approach solely targets the FSA staff community, in which one might tackle a specific persistent environmental risk such as PPE. The second approach, on the other hand, has the potential to mix different sorts of communities (both the general public and FSA personnel), making citizen science projects more adaptable and with a larger scope. Bringing multiple communities from various backgrounds together would promote public awareness, leading to an improvement in usage and disposal behavior among participants. In either of the approaches, there is a need to build capacity for efficient and effective infrastructure to organize and manage such citizen science projects. Although a formal strategy could not be developed at this time, Table 1 highlights crucial areas that would assist researchers in accomplishing their goal. The initial step is to seek cooperation from FSA personnel (both formal and informal), as well as investments for citizen scientific initiatives. Of course, organizing and integrating them into a citizen science program is a challenging and time-consuming procedure that needs the aid of government regulatory agencies and environmental action organizations. In the case of formal FSA personnel, a deal with the local government is required to enlist their assistance in citizen science. They could provide a connection to the citizen science community’s needs and concerns while also guiding knowledge sharing and training for FSA participants. As an important part of this effort, the recruiting process can also be leveraged through a combination of sources, i.e., private companies, associations, nongovernmental organizations, app developers and other stakeholders. Alternatively, FSA informal personnel might be recruited individually or in groups through their organizations for citizen science assistance.

However, critical issues remain, such as how practical it is to engage with FSA personnel. For instance, it is vital to ascertain their readiness prior to involvement since they may perceive it as an added burden to their normal activities and may not be interested in data collection activities. Indeed, local government, in collaboration with researchers, should hold official meetings to disseminate the importance, encourage FSA staff engagement, and provide finances and authorizations to carry out the projects. In terms of meetings, researchers and scientific experts must present solid discussions with examples, utilizing graphics and presentations, to fully understand the foundations of environmental
participation in citizen science initiatives.

Since FSA personnel are regularly collecting solid waste, they could be potential citizen science volunteers. For this reason, a short-term beneficial. In this regard, the one-day science method might serve as a benchmark, providing insight about how FSA citizen science initiatives can be improved, as well as where it is weak and how additional studies can be developed. Regular meetings should be held with them to build trust and collaboration, discuss their experiences, identify any problems with filling out the forms, find solutions, and enhance the process as a whole. Further coordination from governmental agencies is required to guarantee that FSA participants are open to disclosing all of the results they uncover, so that there is no hesitation among them, and data may be used for meaningful analysis and effective measures. While the relative contribution of FSA personnel in citizen science projects is a matter of scientific interest, there is still much exploitation to be done here, since using FSA volunteers is a novel tool in the field of citizen science. If the current interest proposal becomes realistic, its importance can be expanded to other fields of environmental science, including e-waste and microplastic pollution. Therefore, future research needs to align with a global view of taking citizen science with FSA personnel to identifying research questions; conducting scientific investigations; collecting, processing, and analyzing data; developing mobile tools; and solving complex problems. It also urges research funders, regulators, and scientific societies to focus their efforts on developing a thorough framework for overseeing the potential use of FSA participants in future citizen science programs.

4. Concluding remarks

To summarize, although research continues to improve the understanding of the COVID-19 period’s impact on plastic pollution, citizen science programs relying on general public volunteers were burdened by the pandemic limitations and suffered a significant setback. During uncertain times, the path ahead for citizen research necessitates the quick adoption of innovative collaborations and change of approach that can ensure the participation, time, effort commitment, and environmental information for the benefit of research and communities. In line with this, the current study articulates an example of engaging FSA personnel in citizen science initiatives and urges researchers to take advantage of and create opportunities with them in improving environmental problems through citizen science. The collaboration between FSA personnel and citizen science would provide a crucial and significant step forward in the development of future citizen scientific activities. Using the FSA personnel background in citizen science would be immensely helpful to address and enhance several types of scientific study during and beyond the pandemic conditions in diverse environmental and complex settings, including COVID-19 PPE-related studies and marine litter pollution. Thinking from the perspective of citizen science research, it needs to evolve in order to fully reap the advantages of FSA personnel, and the major challenge is the need for a well-designed approach for data gathering and beyond. There is also clearly an urgent need for more funding to support research in this area and for commitments from both governmental and non-governmental entities along with FSA personnel on carrying out this kind of

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Table 1

| Step | Role | Actions |
|------|------|---------|
| 1    | Recruit | Collaborate, Individually or collectively, Consult & seek cooperation, Local government assistance, Involvement of other sources like private companies, nongovernmental organizations, app developers and other stakeholders |
| 2    | Involve | Official meetings of FSA with researchers and scientific experts, Encourage involvement, Highlighting their role in environmental protection, Provide finances and authorizations, Safety support |
| 3    | Guide  | Organize short- & long-term research, Step-by-step instructions with images for data collection & monitoring, Worksheet or e-data uploads via mobile apps, Mock presentation of entire monitoring and data collection in field |
| 4    | Data use | Community engagement (e.g., public outreach), Condition indicator (e.g., media campaign), Research (e.g., baseline datasets), Management (e.g., remediation), Regulatory decisions & standard setting (e.g., new mandatory standards), Enforcement (e.g., investigations) |

FSA: Frontline Sanitation Personnel.

Concerns. And it is crucial to show them how significant their role is in improving and laying the groundwork for monitoring and environmental protection, particularly in plastic pollution. Declaring unequivocally that their regular exercising is all that is necessary for plastic litter monitoring would provide FSA participants with a more accurate depiction of their collaboration in citizen science projects. In addition, proper financial (e.g., a sort of incentive through prize, discount or grocery voucher) and safety support is required, particularly during a health crisis. Despite their important contributions, there has been a lack of direct support for healthcare PPE kits and financial support (Salve and Jungari, 2020). It strongly indicated a clear need for FSA personnel to receive immediate support to enable them to cope with the heightened risks as the pandemic continues, and beyond. A questionnaire can be used then to solicit their feedback in order to find what they agree and disagree with. This would help them to present their own ideas and views, understand the potential benefits and significance of their position, and identifying as one of the cornerstones of ecologically significant initiatives. Interaction with the locals boosts morale and helps FSA participants feel valued and respected, while also providing them with necessary security and financial aid. Performing all of these things together will reduce their skepticism and increase FSA personnel participation in citizen science initiatives.

If so, how should plastic litter monitoring be measured via FSA citizen science programs?

Initially, information from FSA participants in citizen science activities should be acquired, such as how many streets, residences, and distances they collect solid waste from each day, as well as the types of solid waste they collect. Based on the information supplied, short-and long-term research can be organized, providing easy-to-follow step-by-step instructions with images for data collection and monitoring. For example, if the purpose of the FSA citizen science program is to monitor PPE pollution, FSA participants must seek for, count, and collect data on improperly disposed PPE wastes such as face masks, wipes, and disinfectant containers every day while on service. In contrast to pandemic circumstances, if the citizen science project’s goal is to monitor plastic litter in general, participants may be requested to sort the collected materials and report on them in a worksheet like the one shown in Supplementary Material Table S2. When data sheets and/or electronic data uploads are offered, they will be able to fill out or submit data via an online platform or a mobile app. Meanwhile, a mock presentation on the entire process in the field, from monitoring to data to action, should be held in the meeting halls with FSA participants and other citizen science volunteers with the help of scientific community, non-profit governmental organizations, and local government. This allows them to become familiar with and customize the procedures they are working with. At the same time, new technologies, such as data collection and monitoring advances, as well as tools to map the landscape surrounding one’s own group need to be harnessed. This enables for a better understanding of the data by mapping the regions covered at a local or regional scale.

The comparison and integration of various trials is required for the FSA citizen science endeavor to be effective, well-established, and long-term beneficial. In this regard, the one-day science method might serve as a benchmark, providing insight about how FSA citizen science initiatives can be improved, as well as where it is weak and how additional studies can be developed. Regular meetings should be held with them to build trust and collaboration, discuss their experiences, identify any problems with filling out the forms, find solutions, and enhance the process as a whole. Further coordination from governmental agencies is required to guarantee that FSA participants are open to disclosing all of the results they uncover, so that there is no hesitation among them, and data may be used for meaningful analysis and effective measures. While the relative contribution of FSA personnel in citizen science projects is a matter of scientific interest, there is still much exploitation to be done here, since using FSA volunteers is a novel tool in the field of citizen science. If the current interest proposal becomes realistic, its importance can be expanded to other fields of environmental science, including e-waste and microplastic pollution. Therefore, future research needs to align with a global view of taking citizen science with FSA personnel to identifying research questions; conducting scientific investigations; collecting, processing, and analyzing data; developing mobile tools; and solving complex problems. It also urges research funders, regulators, and scientific societies to focus their efforts on developing a thorough framework for overseeing the potential use of FSA participants in future citizen science programs.
research. Overall, this work will pique the interest of researchers and stakeholders by highlighting the benefits and prospects for the alliance to take shape and materialize in the advancement of both research and environmental challenges. Furthermore, more study is needed to validate the implications of the integration of FSA personnel in citizen science, which may lead to new opportunities and improvements in the future.

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.

Data availability

No data was used for the research described in the article.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.envsci.2022.08.011.

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