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Face masks, waste in tourist sites in Nayarit, Mexico

Cubrebocas, residuos en sitios turísticos de Nayarit, México

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ABSTRACT

The COVID-19 pandemic brought with it the use of personal protective equipment; mainly face masks. The large number of face masks are used daily, and their inadequate final disposal has turned them into an environmental problem. The goal of this research is to determine the amount of face mask waste as an environmental contaminant. By collecting such waste in five tourist sites (urban, beach, and lake) in Nayarit, Mexico, during five months of the years 2021 and 2022. A greater presence of this type of waste was found during the year 2022. More adult mouth covers prevailed than infant mouth covers. Finally, urban areas showed a higher density of face masks than the rest of the analyzed areas. It is concluded that it is necessary for adequate measures to be implemented for the correct disposal of the waste generated with the pandemic.

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RESUMEN

La pandemia de COVID-19 trajo consigo el uso de equipo de protección personal, principalmente cubrebocas. La gran cantidad de ellos que se utilizaron diariamente y su inadecuada disposición final, los han convertido un problema ambiental. El objetivo de esta investigación fue determinar la presencia de residuos de cubrebocas como contaminantes ambientales. Mediante la recolección de dichos residuos, en cinco sitios turísticos (urbanos, de playa y un lago) de Nayarit, México, durante cinco meses de los años 2021 y 2022. Se obtuvo mayor presencia de este tipo de residuos durante el año 2022. Prevalecieron más los cubrebocas utilizados por adultos que por infantes. Finalmente, las zonas urbanas mostraron una mayor densidad de cubrebocas que el resto de las zonas analizadas. Se concluye que es necesario que se implementen medidas adecuadas para la correcta disposición de los residuos generados con la pandemia.

PALABRAS CLAVE: Equipos de protección personal (PPE), COVID-19, pandemia.

Introduction

The World Health Organization (WHO), at the beginning of the pandemic caused by the SARS-CoV-2 virus, recommended the use of face masks for healthcare workers (López-León *et al.,* 2020). However, some countries implemented their use for the general population. As of January 2023, the WHO continued to promote the use of face masks, along with the following recommendations: maintaining physical distancing, ventilating rooms, avoiding crowds, handwashing, and proper cough etiquette (WHO, 2023). Regarding the environment, during the first six months of confinement, it benefited from the decrease in anthropogenic activities, leading to an improvement in the quality of water and air on the planet, and the presence of wild animals was observed in urban spaces (Abdullah *et al.,* 2020; Lanchipa *et al.,* 2020; Tarazona & Ceballos, 2021). However, solid waste resulting from the use of personal protective equipment (PPE) in COVID-19 prevention, such as face masks, shields, gloves, gowns, disinfectant containers, medical supplies, and various types of plastics, increased (Sanchez, 2021).

During the first year of the pandemic, approximately 89 million face masks were used worldwide each month (WHO, 2020). On the other hand, until May 2020, 88 % of the world's population used them in public spaces (Akarsu *et al*., 2021). According to Liang *et al*. (2021), the use of personal protective equipment (PPE) during the pandemic increased from 18 % to 425 % worldwide. Additionally, the World Wildlife Foundation (2020) reported that improper management of 1 % of face masks contributed to generate between 30,000 to 40,000 kg of solid waste per day.

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As of January 2023, surgical face masks were the most commonly used type. These masks are composed of an inner layer of cotton, which serves as an absorbent, a middle layer made of a non-absorbent material like polypropylene, and a third layer of polyester or a combination of them (Abedin *et al*., 2022). Polymers such as polystyrene, polycarbonate, or polyethylene are also employed in their manufacturing process (Dharmaraj *et al.,* 2021). Face masks and other personal protective equipment (PPE) containing plastic degrade due to factors such as mechanical stress, heat intensity, chemical composition, ultraviolet (UV) radiation, and biodegradation, among others. These processes lead to the generation of microplastics, exacerbating the environmental problem as they fragment and bioaccumulate in organisms, disrupting the food chain (Ray *et al.,* 2022). The composition of these plastics, improper disposal, and lack of management, coupled with misinformation among the population, at least in Mexico, has led to a growing prevalence of these types of waste in urban areas, recreational sites, and water bodies as the pandemic progressed. Without proper management, these waste materials end up in aquatic and terrestrial ecosystems since they are easily transported by rivers, carried by the wind, through drainage systems, navigation routes, or human activities (Akarsu *et al*., 2021). Inadequate disposal in aquatic ecosystems has been studied more extensively than in terrestrial and urban areas.

The objective of this study was to analyze, in five tourist destinations in the state of Nayarit, Mexico (Santa María del Oro Lake, Las Islitas Beach, Matanchén Bay, de la Cruz hill esplanade, and de la Cruz Hill), the number of face masks used by the population and discarded in the open environment, superficially, in common pedestrian areas (walkways, sidewalks, streets, and sandy beach zones) during the months of March to July of 2021 and 2022. It is important to mention that these periods were chosen for comparison between sites and years, as after July 2021, the second period of confinement was implemented, and access to the sampling sites was prohibited.

Study Area

Nayarit is a state in Mexico, that borders the Pacific Ocean to the west. It consists of twenty municipalities and accounts for 1.4 % of the country's total area (INEGI, 2022). Nayarit is home to 1,235,456 people, with 50.4 % being women and 49.6 % men (INEGI, 2023). The capital of the state is Tepic, and it shares boundaries with seven municipalities. Among these municipalities, two of them, Santa María del Oro (SAMAO) and San Blas (Figure 1), are well-known tourist attractions at the national level. One of these attractions is the volcanic-origin lake called "Laguna de Santa María del Oro", Las Islitas Beach and the Matanchén Bay pier are both located in the municipality of San Blas. In contrast, the capital city offers various attractions, including de la Cruz Hill and its esplanade, which are situated within the city and are considered places for physical activity and recreation. The proximity of these sites to the capital city attracts both locals from Tepic and tourists to visit these destinations. During 2021, due to restrictions, people had access to beaches, lakes, hills, and some outdoor locations during the months of March to July. However, access was not permitted again until February 2022.

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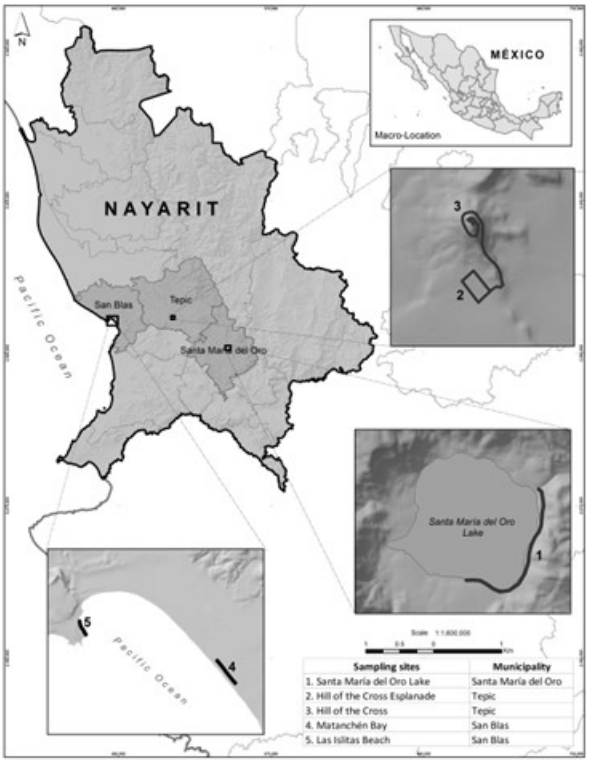

Figure 1. Map of the State of Nayarit, Mexico. Geographical location of sampling sites.

Source: Own elaboration from ArcMap 10.4

Methodology

Sampling was conducted on the first Sunday of each month from March to July 2021 and 2022, between 6:00 am and 8:00 am, before the municipal cleaning service passed through the areas. Face masks observed on the surface of the ground were manually collected one by one in the study zones (Table 1) within the delineated polygon (Figure 1), which corresponded to pedestrian transit areas. In the Santa María del Oro Lake, collection took place along the surrounding road (Figure 2. A), including the pier (Figure 2. B). For Las Islitas Beach, the sampling area included the section of dry sand from the sea to the restaurants (Figure 2. C). In Matanchén, the sampling area covered the following sites: Matanchén Bay (Figure 2.D), the dry sandy beach (Figure 2. E), and the pedestrian area adjacent to the road (Figure 2. F). At the esplanade de la Cruz Hill (Figure 2. G), walkways and green areas were sampled, and finally, the stone-paved

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path with sidewalks (Figure 2. H) and the viewpoint (Figure 2. I) de la Cruz Hill were considered for sampling.

As the face masks were collected, they were disinfected *in situ* before being placed in bags. Once in the laboratory, they were dried, excess soil and dust were removed, and they were sorted and weighed.

The classification of face masks was divided into six groups: medical-grade or surgical face masks, neoprene masks, single-layer medical masks, masks containing respirators such as KN95 and KN94; double-layer masks with non-original valves, and homemade masks. They were also classified by user: child or adult, and by color: black, blue, white, patterned, green, purple, pink, red, grey, beige, and yellow, as those were the colors of the face masks found.

Table 1. Sampling sites.

Sampling sites	**Area (m^2) ***	**Geographic location***
Santa María del Oro Lake	28,527.57	21°22′22″N, 104°33′37″ W
de la Cruz hill esplanade	43,151.12	21°31′42″N, 104°53′02″ W
de la Cruz hill	21,233.92	21°32′06″N, 104°53′02″ W
Matanchen Bay	108,136.49	21°30′17″N, 105°12′27″ W
Las Islitas beach	7,874.25	21°31′03″N, 105°14′54″ W

*Geographic location and area estimated in Google Earth, 2022

Obtained data was analyzed using Microsoft® Excel® version 2021, and the density at the sampling sites was calculated based on the methodology proposed by Okuku *et al*., 2021. The equation used to calculate density is as follows (Equation 1). Where C represents the density (pieces m^{-2}), *n* is the number of pieces, and *a* corresponds to the sampling area.

$$C = n/a \quad \text{(Equation 1)}$$

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Figure 2. Sampling Sites. A) Surrounding path of SAMAO Lake, B) SAMAO pier, C) Sampling area in Las Islitas beach, D) Matanchén Bay pier, E) Sampling area of Matanchén Bay beach, F) Sidewalk and pedestrian area near Matanchén Bay pier, G) Esplanade de la Cruz, H) Hill de la Cruz path, and I) Hill de la Cruz viewpoint.

Results and Discussion

A total of 746 pieces of various face masks (Figure 3) were collected from all the sampling sites during the two established periods, 272 pieces (weighing 1,117.2 g) in the year 2021, and 474 pieces (weighing 1,671.3 g) in 2022. de la Cruz hill and its esplanade, which are recreational sites within the urban area of Tepic, Nayarit, accounted for a total of 509 face masks over the two years of this study, equivalent to 1,858.63 g (Figure 4). This amount represents more than two-thirds of the total collected from all the sampling sites. The SAMAO lake was the second site with 134 pieces (weighing 579.12 g), followed by Matanchén Bay with 67 pieces (weighing 240.33 g), and finally, Las Islitas Beach with 33 pieces (weighing 165.58 g).

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Figure 3. Diversity of mask identified in the sampling sites.

By user, face masks used by adults were the most abundant (Figure 4). Information about the infection rate in infants at the beginning of the pandemic indicated that it was lower in that age group compared to adults, and the infant population was considered the least vulnerable (Lessler *et al*., 2021; WHO, 2021). This would explain the difference in quantities, in terms of the number of pieces and mass, between the two years of sampling, as it was not deemed necessary for infants to use this protective equipment. According to cases by age reported to the WHO between December 30, 2019, and September 13, 2021, “infants under the age of 5 accounted for 1.8 % (1,695,265) of cases and 0.1 % (1,721) of global deaths. Infants and younger adolescents (aged 5 to 14 years) represented 6.3 % (6,020,084) of cases, and 0.1 % (1,245) of deaths globally, while older adolescents and young adults (15 to 24 years) the 14.5 % (13,647,211) of cases and the 0.4 % (6,436) of deaths in the world” (WHO, 2021). This data supported the lower presence of face masks used by infants compared to adults in the study. It is probable that adults used face masks more frequently than infants, as infants and adolescents tended to stay at home more often, while adults were more likely to go to work or engage in other activities, some of which might have taken place in open spaces to remain active.

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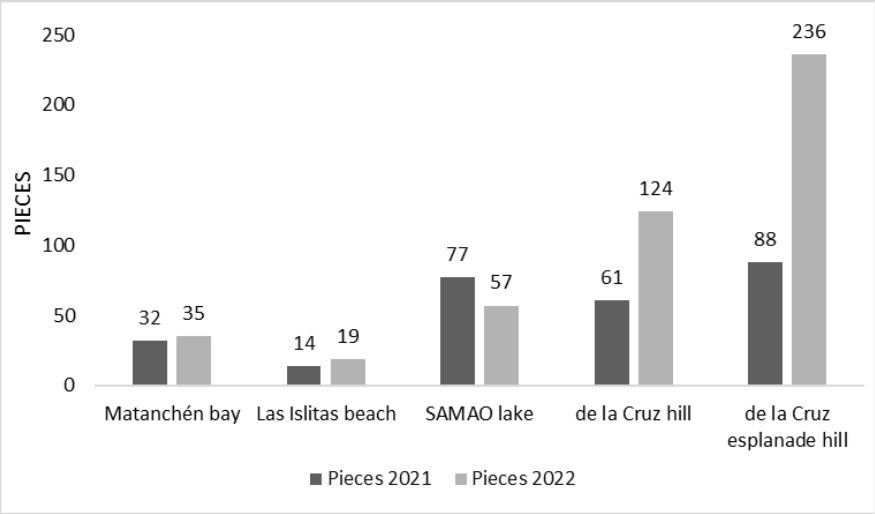

Figure 4. Number of masks identified in each of the sampling sites, in the two study periods.

On the other hand, the results of density (C) were higher in sites within the urban area (Table 2) as the combined results de la Cruz hill and its esplanade presented a higher average density (4.0 x 10^{-3} pieces m^{-2}) than the sampled lake and beaches. Patricio *et al*. (2021), reported that the density of these waste items could vary based on sampling areas, climatic conditions (wind, precipitation), and population density, and the number of face masks discarded in rivers and beaches seems considerably higher than in any other location. However, the results from this research for the urban area yielded an average density of 4.0 x 10^{-3} pieces m^{-2}, 2.3 x 10^{-3} pieces m^{-2} for the lake, and 0.4 x 10^{-3} pieces m^{-2} for the beaches, which aligns with previous investigations where urban areas in Canada, Peru, and Kenya showed higher waste density than beaches (Ammendolia *et al*., 2021; De-la-Torre *et al*., 2021; Okuku *et al*., 2021). The identification of face masks in urban areas highlights the lack of proper management and final disposal of this type of waste by the population and municipal authorities. In the United States of America, it was recommended that face masks, gloves, tissues, and other contaminated waste be disposed of in double bags due to the risk of pathogen contamination (ACR, 2020). However, the situation in Latin America and the Caribbean is different (Gómez & Cilia, 2021), which could pose a risk factor for the general population and formal and informal workers involved in public sanitation services.

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Table 2. Density of masks identified by sampling site and year.

	Density (C) (pieces/m^2) 10^{-3}	
Sampling sites	the year 2021	the year 2022
Santa María del Oro lake	2.70	2.00
del Cerro de la Cruz esplanade	2.04	5.47
de la Cruz hill	2.87	5.84
Matanchén Bay beach	0.30	0.32
Las Islitas beach	1.78	2.41

The identification by type and color of face masks showed that the double-layer surgical face masks had the highest presence, with a total of 658 pieces collected for both years of sampling (Figure 5). The color blue followed by black predominated for this type of face mask during 2021. However, for 2022, the presence of black face masks was more than triple that of the previous year (Figure 6 and 7). The color and type of face masks are important for the environment since they can be related to the environmental repercussions they may generate. For example, in the gastrointestinal system of the green sea turtle (*Chelonia mydas*), in a feeding area in the Mexican Caribbean, dark-colored fibers were identified in 50 % of the cases, followed by transparent pieces (42 %), and blue ones (8 %) (Maldonado *et al*., 2022). The coasts of the Pacific Ocean that border Nayarit are inhabited by turtle species such as *Lepidochelys olivacea* (olive ridley turtle), *Dermochelys coriacea* (leatherback turtle), *Eretmochelys imbricata* (hawksbill turtle), and *Chelonia agassizzii* (black turtle) (PROFEPA, 2019), all of which are classified as endangered (EN) according to the Mexican Official Standard NOM-059-SEMARNAT-2010. Due to the drastic decline in the populations of Pacific leatherback and Caribbean hawksbill turtles, the International Union for Conservation of Nature (IUCN) classifies them as critically endangered (CR) (PROFEPA, 2019). The presence of face masks in the marine ecosystem could further complicate the situation for turtles and other animals that may ingest these waste items directly or indirectly through other species as part of the food chain. Consuming these waste items and other plastics can cause suffocation, malnutrition (as animals feel satiated with this material), and entanglement, among other complications (Rojo-Nieto & Montoto, 2017). Moreover, the most abundant face masks were surgical ones, which are made of materials such as polypropylene, polyester blends, polyester (Abedin *et al*., 2022), polystyrene, polycarbonate, or polyethylene (Dharmaraj *et al*., 2021), contributing to the generation of microplastics. Bowley *et al*. (2021) mentioned that human pathogenic microorganisms have been found on microplastics present in ocean waters, and while their pathogenicity and virulence are not fully understood, there is a possibility of transmission to other organisms. These potentially pathogenic microorganisms can be present in plastic waste eliminated on beaches (Keswani *et al*., 2016) but also in waste like face masks, which have been reported in various ecosystems. These potentially pathogenic microorganisms could endanger public safety.

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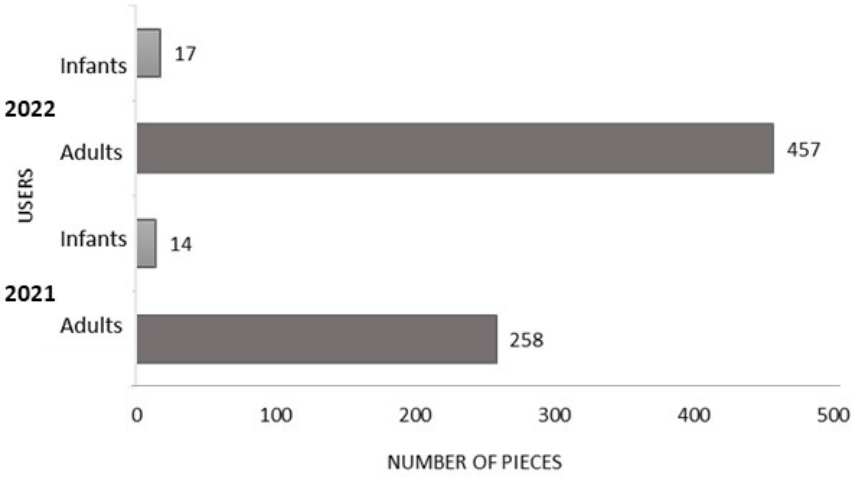

Figure 5. Classification of face masks by users. Total pieces were collected at all sampling sites within the established periods.

The management of solid waste, in general, continues to be a complex problem in the state of Nayarit. Currently, part of the population still uses face masks, and their disposal in inappropriate places is observed. It is recommended to implement waste management for COVID-19-related waste and measures for the proper disposal of these residues, along with providing clear recommendations to society. Additionally, it is suggested that industries get involved in the circular economy, contributing to waste collection campaigns and developing personal protective equipment using environmentally friendly materials. These actions could contribute to minimizing the environmental issues related to this type of contaminant.

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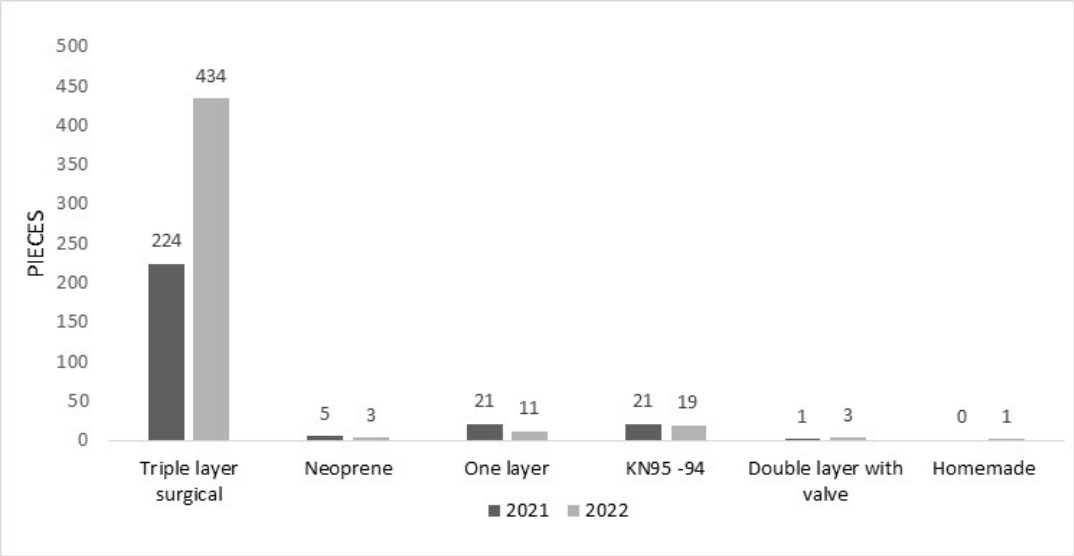

Figure 6. Abundance of face masks by type.

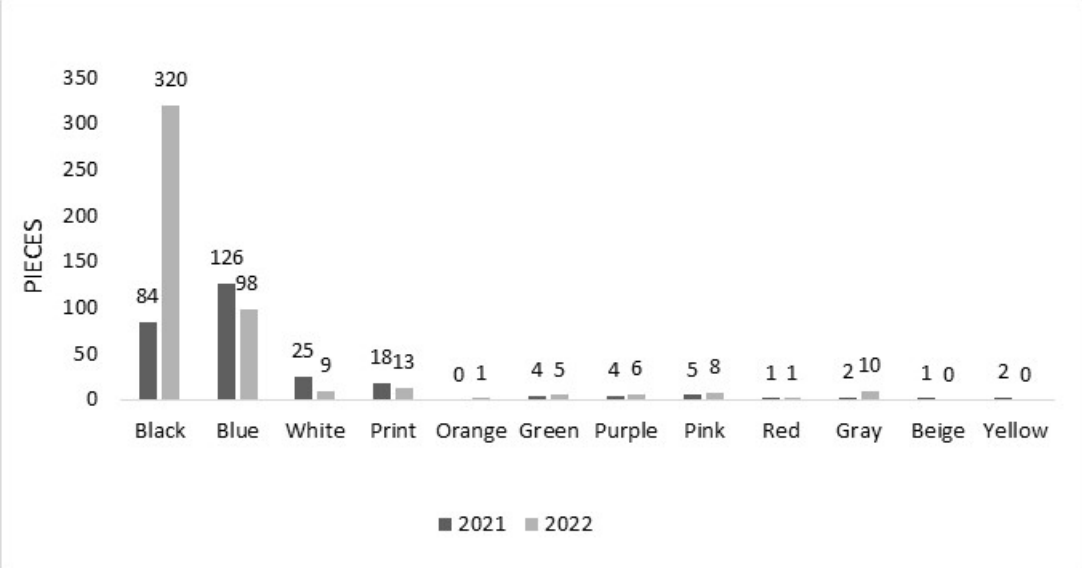

Figure 7. The abundance of face masks by colors.

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Conclusions

It is recommended to implement waste management for COVID-19-related waste and measures for the proper disposal of these residues, along with providing clear recommendations to society. Additionally, it is suggested that industries get involved in the circular economy, contributing to waste collection campaigns and developing personal protective equipment using environmentally friendly materials. These actions could contribute to minimizing the environmental issues related to this type of contaminant.

Contribution of the authors

Conceptualization of the work, L.C.R.R.; development of the methodology, L.C.R. R.; experimental validation, L.C.R.R., R.E.M.C.; analysis of results, L.C.R.R., R.E.M.C., J.R.T.V., A.F.F.; Data Management, L.C.R.R., R.E.M.C., J.R.T.V.; writing and preparation of the manuscript, L.C.R.R., R.E.M.C., J.R.T.V., A.F.F.; writing, reviewing and editing, L.C.R.R., R.E.M.C., J.R.T.V., A.F.F. All authors of this manuscript have read and accepted the published version of the manuscript.

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Interest conflict

The authors declare no conflict of interest.

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