Original Article

Impact of the COVID-19 face mask disposal on environment and perception of people of the Sultanate of Oman

Mahaad Issa Shammas[1*], Catia Algieri[2], Gerardo Coppola[3], Sudip Chakraborty[3*]

Abstract

Background: Environmental concerns are increasing in and around us due to improper discharge of personal protective gear or equipment (PPEs) during the current pandemic with SARS-CoV-2. The residents of Salalah, under the Dhofar governorate of Oman, were hastening to take every possible measure to safeguard their health against the COVID-19 pandemic. In this scenario, improper discard of facemasks in the environment entails a significant problem for public health and aquatic environments.

Objective: This study aims to assess how the SARS-CoV-2 virus disrupted the household waste management chain in the Sultanate of Oman. In addition, descriptive survey has also identified people's perception about the existing household waste management system.

Methods: Total 200 respondents were personally selected under the purposive sampling category. Data were analyzed using SPSS version 26. The mean, standard deviation, and distribution shape were calculated based on the retrieved data. The variables and frequencies were tabulated for categorical variables. Results show negative impacts on the environment, wildlife, and public health. It was also observed that there was a significant difference when grouped according to residence location since the obtainedalso observed a significant difference when grouped according to residence location since the p-value of 0.007 was less than 0.05 alpha level. This means that the responses differ significantly. It shows from the test conducted that participants from the village experienced and observed a negative impact on the discarded face masks compared to those in the city.

Conclusion and recommendation: This study illustrates the real impact of the COVID-19 face masks on the environment, wildlife, and public health. In addition, the new management of the user's face masks for eliminating or reducing the risks to human health and the environment has been suggested. [*Ethiop. J. Health Dev*. 2022; 36(2):000-000]

Keywords: Environmental Health, Face mask, Microplastic, SARS-CoV-2, Survey, Statistical Analysis.

Introduction

The SARS-CoV-2 pandemic invited a massive use of surgical and face masks considering that the transmission occurs through airborne droplets (5–10 μm) and aerosols (≤5 μm) from asymptomatic as well as symptomatic individuals (1). Due to COVID-19, about 89 million masks are used worldwide (2). This aspect has determined a large employment of polymeric materials as polyethylene (PE), polypropylene (PP), polyvinylchloride (PVC), polyurethane (PU), polyacrylonitrile (PAN), polystyrene (PS) and polycarbonate (PC) (2). A consistent fraction of used masks are discarded on the streets and in public areas, thus generating an environmental problem; in fact, those materials degrade by forming nanofibers, micro and nano-plastics caused by the changes in temperature and pH, physical stress, and under the effect of UV light (5,6).

Microplastics (polymeric particles smaller than 5 mm) are dangerous pollutants for their detrimental effect on marine animals and human health. In particular, these polymeric particles accumulate a vast amount of chemical contaminants (as persistent organic pollutants and heavy metals) by hydrophobic and/or electrostatic interactions. They can be transported over long distances and available to other organisms (9-29). Microplastic in soil pollution usually results from farming practices (36), sewage sludges dispersal (34), and land irrigation (37). Poorly discarded plastics are responsible for including microplastics in food chains (ours and those of the animal world) and soils and water sources (30). Some investigations have remarked how the interaction of microplastics with pollutants they may absorb can affect soil healthiness while constituting a risk for a possible migration into the food chains (31).

The primary role of PPEs is to reduce employee exposure to hazards when engineering and administrative controls are not feasible or practical to reduce these risks to acceptable levels, most likely in the hospitals and other health care providers everywhere (38). PPEs that had been improperly disposed of and collected by sanitation workers put them at an increased risk of contracting COVID-19 by handling potentially contaminated PPE. Fig. 1 shows the types of PPEs that could damage human and environmental health when improperly disposed of.

[1] Civil and Environmental Engineering Department, College of Engineering, Dhofar University, Sultanate of Oman
[2] Institute on Membrane Technology, (ITM–CNR), Rende, 87036, Italy
[3] Department of DIMES, University of Calabria, 87036 Rende, Italy.
* Joint Corresponding Author : mahad@du.edu.om / sudip.chakraborty@unical.it
† All three authors has equal contribution

Figure 1. **Different types of PPEs worn for protection.**

On Table 1, shows the summary of the most used polymers for manufacturing PPEs. It is quite easy to understand that gloves are the most used and discarded equipment since they are strictly suitable for single use only.

Table 1. **Materials used in different PPE components (38).**

PPE	Raw material used
N95 respirators	Polypropylene
Powered Air Purifying Respirators	Rubber or silicone
Face shields	Polycarbonate, Propionate, Acetate, Polyvinyl chloride, Polyethylene terephthalate glycol
Normal surgical masks	Polypropylene
Goggles	High quality polycarbonates
Single use protective gowns	Normally polypropylene
Coveralls	High density polyethylene

Something worth mentioning when dealing with microplastics is additives that can migrate into soil, primarily through the water. Most plastics are manufactured by enriching the original polymer with a palette of additives, which will most likely increase the manufacturing performance during molding or extrusion. The most widely used additives are coloring agents, plasticizers, lubricants, reinforcing fibers, antioxidants, stabilizers, flame retardants (38).

Recently, different studies have focused on the COVID-19 origin, the impact of the PPEs on the environment, and the management strategy and approaches to address the disposal of the facemasks (39,40,41). In this study, a survey was carried out among 200 respondents of the Salalah city, the capital and largest town of the southern Omani governorate of Dhofar. The statistical analysis has been performed by using the statistical software package SPSS. Finally, the new management of the used facemasks for eliminating and reducing the risks to human health and the environment has been suggested.

Materials and method

Experimental setting and statistical analysis

A survey (questionnaire and personal/oral interview) on the discharge of the face mask used during the COVID-19 outbreak has been carried out the Sultanate of Oman population. The following questions have been formulated to elicit the problem supported by survey questionnaires and personal/oral interviews.

- *What are the types of face masks worn by the residents of Salalah?*
- *Where do the residents of Salalah throw their discarded face masks?*
- *What are the damaging impacts of throwing the discarded face masks to public health, environment, marines and agriculture?*
- *What damages may the discarded surgical face masks bring to human health, marine life, and the environment?*
- *How are the surgical face masks worn by health front liners and patients compared to the face masks worn by the general public?*
- *What interventions could be done to inform Salalah residents on the damages that the discarded face masks may bring to public health, environment, and marine life?*

The responses have been scored using the five-point Likert Scale shown in Table 2.

Table 2. The Likert scale range for scoring.

Option	Scale Range	Verbal Interpretation
5	93-98	Strongly Agree
4	86-92	Agree
3	80-85	Neutral
2	70-79	Disagree
1	69 below	Strongly Disagree

The respondents were two hundred (200 key informants from all walks of life (except the children) in the entire city of Salalah, which were personally selected under the purposive sampling category. This sampling was the best option to determine the respondent's ability to answer the items in the questionnaire. Table 3 displays the distribution of respondents.

Table 3. **Distribution of respondents.**

Respondents	Number
Academicians	20
Farmers	20
Fishermen	20
Health Service Providers	20
Non-working residents	20
Private sector employees	20
Police, Army, Navy	20
Public sector Employees	20
Students (19 years old and above)	20
Vendors	20
TOTAL	**200**

Data collected from the survey were analyzed using the statistical software package SPSS (Version 26.0. SPSS Inc., Chicago, IL, USA). The mean, standard deviation, and distribution shape have been calculated on the retrieved (or retrieval) data. The variables and frequencies were tabulated for categorical variables. The participants' perceptions were measured using a five-point Likert scale and continuously computed the obtained weighted means. The gathered data was tested using the Shapiro Wilk test to determine the normality utiliznormality. This is an effective measure for parametric test considering the Independent Sample t-test and analysis of variance (ANOVA). Bonferroni was used for the pairwise comparison to determine the significant variables (76).

Results and discussion

The survey questionnaire has been focused on analyzing the behavior of a part of the Sultanate of Oman community living in Salalah. The perception of the damaging impact of the discarded face masks on the environment, wildlife, and public health has been reported in Table 4. The composite mean of 4.09 indicates that the respondents agreed on the above indicators. These results evidenced the negative impacts on the environment, wildlife, and public health.

Table 4. **Perceptions on the damaging impact of the discarded facemasks to the environment, wildlife and public health.**

Indicators	M	SD	VI	R
The mask will be stuck in the digestive system of the sea animals once ingested, thus killing them.	4.31	0.922	Agree	6
The mask contains plastic that does not disappear; rather, it breaks down slowly into micro –plastics and enters food chains.	3.93	1.021	Agree	13
The burnt masks release toxins that harm human and non-human health.	3.94	0.904	Agree	12
Their colors can be mistaken for food by sea birds, turtles and other marine mammals, putting them at risk of severe injuries and deaths.	4.11	0.906	Agree	10
Dropped used masks during pandemics contain non-biodegradable materials.	3.82	0.910	Agree	14
There is a human health risk from the discarded surgical masks since people consume sea foods as their primary source of	4.30	0.872	Agree	7

protein.				
If the discarded masks are thrown on the streets and it rains, the masks will eventually end up at seas, resulting in negative consequences to wildlife.	4.38	0.768	Agree	2
Masks in the trash could ultimately end up in nature and eventually harm them.	3.74	1.063	Agree	16.5
When left long enough, Masks thrown on the forests and farms will invite the algae and bacteria to grow. They might be mistaken as foods by land animals and insects.	4.15	0.843	Agree	9
Improper disposal of masks everyday cause pollution to the environment and ecology.	4.37	0.788	Agree	3
Proper incineration of discarded masks will ensure compliance with the emission standards to protect the environment.	4.16	0.807	Agree	8
The masks, made of polypropylene, will not break down easily.	3.80	0.812	Agree	15
Littering the used mask makes more work and worries the people responsible for picking the trash.	4.36	0.706	Agree	4
The thrown masks could end up killing the plants and trees.	3.53	0.950	Agree	18
Touching the used masks is dangerous to human health.	4.59	0.610	Strongly Agree	1
Once discarded into the environment, masks will go into water bodies and sewer system.	4.04	0.885	Agree	11
Used surgical masks should not be recycled. They should be placed in a securely tight garbage bag, and place outside for regular trash for collection.	4.34	0.946	Agree	5
Microplastics that result from the breaking down the discarded masks in the environment also attack pesticides and other harmful chemicals.	3.74	0.848	Agree	17.5
Composite Mean	**4.09**	**0.514**	**Agree**	**-**

Legend: 4.50 – 5.00 = Strongly Agree; 3.50 – 4.49 = Agree; 2.50 – 3.49 = Neutral; 1.50 – 2.49 = Disagree; 1.00 – 1.49 = Strongly Disagree; M= Mean, SD= Standard Deviation, VI= verbal Interpretation, R-Rank

In addition, mask touching has been perceived as dangerous to human health as supported by the obtained mean score of 4.59. Almost all of the participants observed this effect as it brings risk to the community. Other aspects have also been considered harmful, such as the discharge of the masks on the streets and in the sea (M- 4.38). In addition, the daily improper disposal of masks causes pollution to the environment and ecology (M-4.37). In addition, the littered used mask could be very harmful to the people responsible for picking the trash (M-4.36). The discarded surgical masks should not be recycled but placed in a securely tight garbage bag, placed outside as regular trash for collection (M-4.34). However, the masks put in the trash could ultimately end up in nature and have a detrimental effect on the environment even if this indicator was lower than the others (M-3.74). Microplastics that resulted from the breaking down of the discarded masks in the environment also attacks pesticides and other harmful chemicals (M-3.74) and thrown masks could end up killing the plants and trees (M-3.53).

In the participant's profile shown in Table 5, it was revealed that 198 males and only 36 were females. Most of them worked in the public sector. Others were academicians, non-working residents, working in private sectors, police officers, army and navy, and even students. They mostly live in the city proper as revealed by 75.60% and 24.40% from the villages. 93.20% said they were not wearing facemasks inside the house to protect themselves from coronavirus disease, and 6.80% agreed that they were always wearing masks inside the house for protection. Among them, 226 or 96.60% wear masks whenever they go out but there were 3.40% who honestly affirmed that they don't.

Regarding the type of masks being worn, 145 preferred surgical masks, 43 for non-surgical masks, and 46 for cotton masks. The 62 % amenable to wearing surgical masks justified their preference because it is affordable, always available, and provides assurance for protection, safety, convenience, and good quality. Regarding disposals of worn masks, 69.70% used waste bins, 5.10% in plastic bags, others in zip lock bags, and others just threw wherever they wanted.

Table 5. Percentage distribution of the participants profile.

Demographic Profile	F	(%)
Gender		
Male	198	84.60
Female	36	15.40
In Salalah you are		
Academician	30	12.80
Non-working resident	29	12.40

Private Sector Employee	36	15.40
Police, Army, Navy	10	4.30
Public Sector Employee	89	38.00
Student	13	5.60
Vendor	10	4.30
Others	17	7.30
Residence location		
City	177	75.60
Village	57	24.40
Do you wear face mask inside the house to protect yourself from corona virus disease?		
Yes	16	6.80
No	218	93.20
Do you wear face mask outside the house to protect yourself from corona virus disease?		
Yes	226	96.60
No	8	3.40
Which type of face mask do you always wear?		
Surgical Mask	145	62.00
Non-Surgical Mask	43	18.40
Cotton Mask	46	19.60
Why do you prefer to wear this type of mask?		
Affordable	6	
Availability	7	
Protection / Safety	10	
Convenient	3	
Quality	4	
Where do you throw your discarded mask?		
Waste Bin	210	89.70
Medical Waste Container	2	0.90
Plastic Bags	12	5.10
Zip Lock Bags	5	2.10
Roads and Bridges	1	0.40
Others	4	1.70

F= frequency

The residents knew that touching the discarded masks is dangerous to human health. According to infectious disease experts, masks are an imperfect defense against the coronavirus disease. However, evidence has mounted that, when touched the discarded masks, there are tendencies to be contacted with the virus-laden droplets directly.

Table 6. Different responses on the impact of discarded face masks on environment, wildlife and public health When Grouped According to Profile.

Profile Variables	F-value	p-value	Decision	Interpretation
Gender	0.511	0.610	Fail to Reject	Not Significant
Group	2.047	0.050	Fail to Reject	Not Significant
Residence location	3.871	0.000	Rejected	Highly Significant
Wearing Face masks Inside the House	0.160	0.873	Fail to Reject	Not Significant
Wearing Face masks Outside the House	1.476	0.141	Fail to Reject	Not Significant
Type of masks	1.469	0.232	Fail to Reject	Not Significant
Place to throw Face masks	0.720	0.609	Fail to Reject	Not Significant

Legend: Sgnificant at p-value < 0.05

Table 6 compares responses on the impact of discarded face masks on the environment, wildlife, and public health. It was observed that there was a significant difference when the respondents were grouped according to residence location since the p-value of 0.000 was less than the 0.05 alpha level. This means that the responses differ significantly. It shows from the test conducted that participants from the village experienced or observed a negative impact on the discarded face masks compared to those in the city. A follow-up study is essential to determine the existence of significant differences. Table 7 shows the suggested possible interventions to be done by the public (citizens) to avoid the risks of dumping the discarded facemasks anywhere, thus, protecting themselves and the environment of Salalah.

"To place in a secured tight garbage bag."	"Raise community awareness on the dangers of discarded masks."	"Be handled by professionals"	"Assign places for disposals."
"Educate the residents."	"To collect from the dumpsters."	"Bury or incinerate them."	"Allocate waste baskets only for face masks in public places"
"Enforce legal charges."	"Alert social media for awareness."	"Impose penalties for mask littering."	"Allocate containers for medical stuff in the neighborhood."
"Assign people who are trained in handling medical waste for proper" collection	"Ministry of Municipalities and the Municipality should take the lead."	"Special baskets for discarded masks should be placed all over the public places."	"Orient residents on the harmful damage of the discarded masks"
"To bury in the MOH landfills."	"Educate people to save the environment and its inhabitants."	"Shops should motivate their buyers to surrender the used masks and get discount in buying a new one."	"Everyday house-to-house collection of the used masks by the assigned collectors of the municipality"
"Proper compensation for face masks collectors"	"Classify wastes to segregate the discarded masks."	"Conduct additional hygienic courses in school and outside"	"Impose no recycling for the discarded surgical masks."

Table 7. **The Direct and Possible Interventions to be done by the Public**

Conclusions

The COVID-19 pandemic brought a new form of pollution due to protective equipment (mainly facemasks). Most of the masks are discarded on the streets, in public areas, and in seawaters, generating dangerous effects on the environment, mainly because they degrade in micro and nano-plastics due to the changes in temperature and pH, physical stress, and for the UV light effect.

This paper highlighted a sustainable approach by integrating the use of biopolymers in the face mask technology with the possibility to re-use them to reduce plastic waste.

In this paper a section has been devoted to a survey towards the population of the Sultanate of Oman on the discharge of the facemask used during the covid-19 outbreak. The results of the survey and their analysis indicated how the user behavior toward the use and management of facemasks intensely affects their impact on the environment.

The perception of the Oman residents towards the e current system of household waste management is not satisfying for the discharge of the COVID-19 facemasks. Therefore, the government should implement an effective policy formulation for sustainable management of the PPEs discharge utilized during the pandemic.

Conflict of Interest

The authors declare that no conflicts of interest are associated with this manuscript, and there has been no financial support for this work that could have influenced its outcome.

References

1. Sommerstein, R.; Fux, C. A.; Vuichard-Gysin, D.; Abbas, M.; Marschall, J.; Balmelli, C.; Troillet, N.; Harbarth, S.; Schlegel, M.; Widmer, A. Risk of SARS-CoV-2 Transmission by Aerosols, the Rational Use of Masks, and Protection of Healthcare Workers from COVID-19. *Antimicrob. Resist. Infect. Control 2020 91* 2020, *9* (1), 1–8. https://doi.org/10.1186/S13756-020-00763-0.
2. Fadare, O. O.; Okoffo, E. D. Covid-19 Face Masks: A Potential Source of Microplastic Fibers in the Environment. *Sci. Total Environ.* 2020, *737*, 140279. https://doi.org/10.1016/J.SCITOTENV.2020.140279.
3. Donato, L.; Algieri, C.; Miriello, V.; Mazzei, R.; Clarizia, G.; Giorno, L. Biocatalytic Zeolite Membrane for the Production of L-DOPA. *J. Memb. Sci.* 2012, *407–408*. https://doi.org/10.1016/j.memsci.2012.03.034.
4. Torkashvand, J.; Jafari, A. J.; Godini, K.; Kazemi, Z.; Kazemi, Z.; Farzadkia, M. Municipal Solid Waste Management during COVID-19 Pandemic: A Comparison between the Current Activities and Guidelines. *J. Environ. Heal. Sci. Eng. 2021 191* 2021, *19* (1), 173–179. https://doi.org/10.1007/S40201-020-00591-9.
5. Silva, A. L. P.; Prata, J. C.; Duarte, A. C.; Soares, A. M. V. M.; Barceló, D.; Rocha-Santos, T. Microplastics in Landfill Leachates: The Need for Reconnaissance Studies and Remediation Technologies. *Case Stud. Chem. Environ. Eng.* 2021, *3*, 100072. https://doi.org/10.1016/J.CSCEE.2020.100072.
6. Saliu, F.; Veronelli, M.; Raguso, C.; Barana,

D.; Galli, P.; Lasagni, M. The Release Process of Microfibers: From Surgical Face Masks into the Marine Environment. *Environ. Adv.* 2021, *4*, 100042. https://doi.org/10.1016/J.ENVADV.2021.100042.

7. Sharma, S.; Chatterjee, S. Microplastic Pollution, a Threat to Marine Ecosystem and Human Health: A Short Review. *Environ. Sci. Pollut. Res. 2017 2427* 2017, *24* (27), 21530–21547. https://doi.org/10.1007/S11356-017-9910-8.
8. Petrosino, F.; Mukherjee, D.; Coppola, G.; Gaudio, M. T.; Curcio, S.; Calabro, V.; Marra, F.; Bhattacharya, P.; Pal, U.; Khélifi, N.; Chakraborty, S. Transmission of SARS-Cov-2 and Other Enveloped Viruses to the Environment through Protective Gear: A Brief Review. *Euro-Mediterranean J. Environ. Integr.* 2021, *6* (2), 48. https://doi.org/10.1007/S41207-021-00251-W.
9. Browne, M. A.; Underwood, A. J.; Chapman, M. G.; Williams, R.; Thompson, R. C.; Franeker, J. A. van. Linking Effects of Anthropogenic Debris to Ecological Impacts. *Proc. R. Soc. B Biol. Sci.* 2015, *282* (1807). https://doi.org/10.1098/RSPB.2014.2929.
10. Cole, M.; Lindeque, P.; Halsband, C.; Galloway, T. S. Microplastics as Contaminants in the Marine Environment: A Review. *Mar. Pollut. Bull.* 2011, *62* (12), 2588–2597. https://doi.org/10.1016/J.MARPOLBUL.2011.09.025.
11. Liao, Y. liang; Yang, J. yan. Microplastic Serves as a Potential Vector for Cr in an In-Vitro Human Digestive Model. *Sci. Total Environ.* 2020, *703*, 134805. https://doi.org/10.1016/J.SCITOTENV.2019.134805.
12. Zhu, J.; Zhang, Q.; Li, Y.; Tan, S.; Kang, Z.; Yu, X.; Lan, W.; Cai, L.; Wang, J.; Shi, H. Microplastic Pollution in the Maowei Sea, a Typical Mariculture Bay of China. *Sci. Total Environ.* 2019, *658*, 62–68. https://doi.org/10.1016/J.SCITOTENV.2018.12.192.
13. Brennecke, D.; Duarte, B.; Paiva, F.; Caçador, I.; Canning-Clode, J. Microplastics as Vector for Heavy Metal Contamination from the Marine Environment. *Estuar. Coast. Shelf Sci.* 2016, *178*, 189–195. https://doi.org/10.1016/J.ECSS.2015.12.003.
14. Davarpanah, E.; Guilhermino, L. Single and Combined Effects of Microplastics and Copper on the Population Growth of the Marine Microalgae Tetraselmis Chuii. *Estuar. Coast. Shelf Sci.* 2015, *167*, 269–275. https://doi.org/10.1016/J.ECSS.2015.07.023.
15. Khan, F. R.; Syberg, K.; Shashoua, Y.; Bury, N. R. Influence of Polyethylene Microplastic Beads on the Uptake and Localization of Silver in Zebrafish (Danio Rerio). *Environ. Pollut.* 2015, *206*, 73–79. https://doi.org/10.1016/J.ENVPOL.2015.06.009.
16. Abidli, S.; Lahbib, Y.; Trigui El Menif, N. Microplastics in Commercial Molluscs from the Lagoon of Bizerte (Northern Tunisia). *Mar. Pollut. Bull.* 2019, *142*, 243–252. https://doi.org/10.1016/J.MARPOLBUL.2019.03.048.
17. Zhang, F.; Wang, X.; Xu, J.; Zhu, L.; Peng, G.; Xu, P.; Li, D. Food-Web Transfer of Microplastics between Wild Caught Fish and Crustaceans in East China Sea. *Mar. Pollut. Bull.* 2019, *146*, 173–182. https://doi.org/10.1016/J.MARPOLBUL.2019.05.061.
18. Zhang, Z.; Wang, J.; Gao, M.; Li, X.; Cheng, Y.; Zhang, X.; Tian, H.; Wang, W.; Ru, S. New Methods for Purification of Paralichthys Olivaceus Lipovitellin and Immunoassay-Based Detection of Vitellogenin. *Ecotoxicol. Environ. Saf.* 2019, *180*, 624–631. https://doi.org/10.1016/J.ECOENV.2019.04.087.
19. Giani, D.; Baini, M.; Galli, M.; Casini, S.; Fossi, M. C. Microplastics Occurrence in Edible Fish Species (Mullus Barbatus and Merluccius Merluccius) Collected in Three Different Geographical Sub-Areas of the Mediterranean Sea. *Mar. Pollut. Bull.* 2019, *140*, 129–137. https://doi.org/10.1016/J.MARPOLBUL.2019.01.005.
20. Patrício Silva, A. L.; Prata, J. C.; Walker, T. R.; Campos, D.; Duarte, A. C.; Soares, A. M. V. M.; Barcelò, D.; Rocha-Santos, T. 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.* 2020, *742*, 140565. https://doi.org/10.1016/J.SCITOTENV.2020.140565.
21. MR, C.; IS, N.; E, R.; None, N.; MY, I. Unprecedented Plastic-Made Personal Protective Equipment (PPE) Debris in River Outlets into Jakarta Bay during COVID-19 Pandemic. *Chemosphere* 2021, *268*. https://doi.org/10.1016/J.CHEMOSPHERE.2020.129360.
22. Aragaw, T. A. Surgical Face Masks as a Potential Source for Microplastic Pollution in the COVID-19 Scenario. *Mar. Pollut. Bull.* 2020, *159*, 111517. https://doi.org/10.1016/J.MARPOLBUL.2020.111517.
23. Shen, M.; Zeng, Z.; Song, B.; Yi, H.; Hu, T.; Zhang, Y.; Zeng, G.; Xiao, R. Neglected Microplastics Pollution in Global COVID-19: Disposable Surgical Masks. *Sci. Total Environ.* 2021, *790*, 148130. https://doi.org/10.1016/J.SCITOTENV.2021.148130.
24. Iben Nasser, I.; Algieri, C.; Garofalo, A.; Drioli, E.; Ahmed, C.; Donato, L. Hybrid Imprinted Membranes for Selective Recognition of Quercetin. *Sep. Purif. Technol.*

2016, *163*. https://doi.org/10.1016/j.seppur.2016.03.015.
25. Wang, Z.; An, C.; Chen, X.; Lee, K.; Zhang, B.; Feng, Q. Disposable Masks Release Microplastics to the Aqueous Environment with Exacerbation by Natural Weathering. *J. Hazard. Mater.* 2021, *417*, 126036. https://doi.org/10.1016/J.JHAZMAT.2021.126036.
26. Anastopoulos, I.; Pashalidis, I. Single-Use Surgical Face Masks, as a Potential Source of Microplastics: Do They Act as Pollutant Carriers? *J. Mol. Liq.* 2021, *326*, 115247. https://doi.org/10.1016/J.MOLLIQ.2020.115247.
27. Kallus S. ; Condre J.M. ; Hahn A. ; Golemme G. ; Algieri C. ; Dieudonné P. ; Timmins P. ; Ramsay J.D.F.; Colloidal zeolites and zeolite membranes ; *J. Mater. Chem*. 2002, *12*, 33340-3350. https://doi.org/ 10.1039/b204171p
28. Ma, J.; Chen, F.; Xu, H.; Jiang, H.; Liu, J.; Li, P.; Chen, C. C.; Pan, K. Face Masks as a Source of Nanoplastics and Microplastics in the Environment: Quantification, Characterization, and Potential for Bioaccumulation. *Environ. Pollut.* 2021, *288*, 117748. https://doi.org/10.1016/J.ENVPOL.2021.117748.
29. Gallo Neto, H.; Gomes Bantel, C.; Browning, J.; Della Fina, N.; Albuquerque Ballabio, T.; Teles de Santana, F.; de Karam e Britto, M.; Beatriz Barbosa, C. 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.* 2021, *166*, 112232. https://doi.org/10.1016/J.MARPOLBUL.2021.112232.
30. Coppola, G.; Gaudio, M. T.; Catia, ·; Lopresto, G.; Calabro, V.; Curcio, S.; Chakraborty, S. Bioplastic from Renewable Biomass: A Facile Solution for a Greener Environment. 2021, *5*, 231–251. https://doi.org/10.1007/s41748-021-00208-7.
31. Yang, L.; Zhang, Y.; Kang, S.; Wang, Z.; Wu, C. Microplastics in Soil: A Review on Methods, Occurrence, Sources, and Potential Risk. *Sci. Total Environ.* 2021, *780*, 146546. https://doi.org/10.1016/J.SCITOTENV.2021.146546.
32. Bas Boots, Connor William Russell, D. S. G. Effects of Microplastics in Soil Ecosystems: Above and Below Ground. *Environ. Sci. Technol.* 2019, *53* (19), 11496–11506. https://doi.org/10.1021/acs.est.9b03304.
33. Ng, E.-L.; Huerta Lwanga, E.; Eldridge, S. M.; Johnston, P. . H.; H.-W.; Geissen, V.; Chen, D. An Overview of Microplastic and Nanoplastic Pollution in Agroecosystems. *Sci. Total Environ.* 2018, No. 627, 1377−1388.
34. Nizzetto, L.; Futter, M.; Langaas, S. Are Agricultural Soils Dumps for Microplastics of Urban Origin? *Environ. Sci. Technol.* 2016, *50*, 10777−10779.
35. Briassoulis, D.; Hiskakis, M.; Scarascia, G.; Picuno, P. . D.; C.; Dejean, C. L. Labeling Scheme for Agricultural Plastic Wastes in Europe. *Qual. Assur. Saf. Crop. Foods* 2010.
36. Steinmetz, Z.; Wollmann, C.; Schaefer, M.; Buchmann, C. .; David, J.; Tröger, J.; Muñoz, K.; Frör, O.; Schaumann, G. E. Plastic Mulching in Agriculture. Trading Short-Term Agronomic Benefits for Long-Term Soil Degradation? *Sci. Total Environ.* 2016.
37. Peng, J.; Wang, J.; Cai, L. Current Understanding of Microplastics in the Environment: Occurrence, Fate, Risks, and What We Should Do. *Integr. Environ. Assess. Manag.* 2017.
38. Petrosino, F., Mukherjee, D., Coppola, G. et al. Transmission of SARS-Cov-2 and other enveloped viruses to the environment through protective gear: a brief review. Euro-Mediterr J Environ Integr 6, 48 (2021). https://doi.org/10.1007/s41207-021-00251-w.
39. Cherif, E.K.; Vodopivec, M.; Mejjad, N.; Da Silva, J.C.G.E.; Simonovi˘c, S.; Boulaassal, H. COVID-19 Pandemic Consequences on Coastal Water Quality Using WST Sentinel-3 Data: Case of Tangier, Morocco. *Water* 2020, 12, 2638.
40. Vanapalli, K.R.; Sharma, H.B.; Ranjan, V.P.; Samal, B.; Bhattacharya, J.; Dubey, B.K.; Goel, S. Challenges and strategies for effective plastic waste management during and post COVID-19 pandemic. *Sci. Total Environ*. 2021, *750*, 141514.
41. Behera, B.C. Challenges in handling COVID-19 waste and its management mechanism: A Review. Environ. Nanotechnol. Monit. *Manag*. 2021, 15, 100432
42. WA, R.; DJ, W. Selection of the Ideal Disinfectant. *Infect. Control Hosp. Epidemiol.* 2014, *35* (7), 855–865. https://doi.org/10.1086/676877.
43. Mahmood, S. U.; Crimbly, F.; Khan, S.; Choudry, E.; Mehwish, S. Strategies for Rational Use of Personal Protective Equipment (PPE) Among Healthcare Providers During the COVID-19 Crisis. *Cureus* 2020, *12* (5). https://doi.org/10.7759/CUREUS.8248.
44. Toomey, E. C.; Conway, Y.; Burton, C.; Smith, S.; Smalle, M.; Chan, X.-H. S.; Adisesh, A.; Tanveer, S.; Ross, L.; Thomson, I.; Devane, D.; Greenhalgh, T. Extended Use or Reuse of Single-Use Surgical Masks and Filtering Face-Piece Respirators during the Coronavirus Disease 2019 (COVID-19) Pandemic: A Rapid Systematic Review. *Infect. Control Hosp. Epidemiol.* 2021, *42* (1), 1. https://doi.org/10.1017/ICE.2020.1243.
45. Lv, D.; Zhu, M.; Jiang, Z.; Jiang, S.; Zhang, Q.; Xiong, R.; Huang, C. Green Electrospun Nanofibers and Their Application in Air Filtration. *Macromol. Mater. Eng.* 2018, *303* (12). https://doi.org/10.1002/MAME.201800336.
46. Zhu, M.; Han, J.; Wang, F.; Shao, W.; Xiong, R.; Zhang, Q.; Pan, H.; Yang, Y.; Samal, S. K.;

Zhang, F.; Huang, C. Electrospun Nanofibers Membranes for Effective Air Filtration. *Macromol. Mater. Eng.* 2017, *302* (1). https://doi.org/10.1002/MAME.201600353.

47. Cui, J.; Lu, T.; Li, F.; Wang, Y.; Lei, J.; Ma, W.; Zou, Y.; Huang, C. Flexible and Transparent Composite Nanofibre Membrane That Was Fabricated via a "Green" Electrospinning Method for Efficient Particulate Matter 2.5 Capture. *J. Colloid Interface Sci.* 2021, *582*, 506–514. https://doi.org/10.1016/J.JCIS.2020.08.075.
48. Strain, I. N.; Wu, Q.; Pourrahimi, A. M.; Hedenqvist, M. S.; Olsson, R. T.; Andersson, R. L. Electrospinning of Recycled PET to Generate Tough Mesomorphic Fibre Membranes for Smoke Filtration. *J. Mater. Chem. A* 2014, *3* (4), 1632–1640. https://doi.org/10.1039/C4TA06191H.
49. Das, O.; Neisiany, R. E.; Capezza, A. J.; Hedenqvist, M. S.; Försth, M.; Xu, Q.; Jiang, L.; Ji, D.; Ramakrishna, S. The Need for Fully Bio-Based Facemasks to Counter Coronavirus Outbreaks: A Perspective. *Sci. Total Environ.* 2020, *736*, 139611. https://doi.org/10.1016/J.SCITOTENV.2020.139611.
50. S, S. A.; Chem, K. C.-J. P. B. P.; 2014, undefined. Fabrication of Poly (Caprolactone) Nanofibers by Electrospinning. *researchgate.net* 2014, *2* (4), 62–66. https://doi.org/10.12691/jpbpc-2-4-1.
51. Halim, N. A.; Wirzal, M.; … S. H.-J. of; 2020, undefined. Recent Development on Electrospun Nanofiber Membrane for Produced Water Treatment: A Review. *Elsevier*.
52. Lee, J.; Chen, N.; Peng, S.; Li, L.; Tian, L.; … N. T.-P. in P.; 2018, undefined. Polymer-Based Composites by Electrospinning: Preparation & Functionalization with Nanocarbons. *Elsevier*.
53. Russo, F.; Ursino, C.; Avruscio, E.; Desiderio, G.; Membranes, A. P.-; 2020, undefined. Innovative Poly (Vinylidene Fluoride)(PVDF) Electrospun Nanofiber Membrane Preparation Using DMSO as a Low Toxicity Solvent. *mdpi.com*. https://doi.org/10.3390/membranes10030036.
54. Robb, B.; Lennox, B. The Electrospinning Process, Conditions and Control. *Electrospinning Tissue Regen.* 2011, 51–66. https://doi.org/10.1533/9780857092915.1.51.
55. Kadam, V. V; Wang, L.; Padhye, R. Electrospun Nanofibre Materials to Filter Air Pollutants – A Review: *https://biblioproxy.cnr.it:2481/10.1177/1528083716676812* 2016, *47* (8), 2253–2280. https://doi.org/10.1177/1528083716676812.
56. Kikionis, S.; Ioannou, E.; Toskas, G.; Roussis, V. Electrospun Biocomposite Nanofibers of Ulvan/PCL and Ulvan/PEO. *J. Appl. Polym. Sci.* 2015, *132* (26), 42153. https://doi.org/10.1002/APP.42153.
57. Torres, F. G.; De-la-Torre, G. E. Polysaccharide-Based Triboelectric Nanogenerators: A Review. *Carbohydr. Polym.* 2021, *251*, 117055. https://doi.org/10.1016/J.CARBPOL.2020.117055.
58. Tsuguyuki Saito, †; Satoshi Kimura, †; Yoshiharu Nishiyama, ‡ and; Akira Isogai*, †. Cellulose Nanofibers Prepared by TEMPO-Mediated Oxidation of Native Cellulose. *Biomacromolecules* 2007, *8* (8), 2485–2491. https://doi.org/10.1021/BM0703970.
59. Liu, H.; Hsieh, Y. Lo. Ultrafine Fibrous Cellulose Membranes from Electrospinning of Cellulose Acetate. *J. Polym. Sci. Part B Polym. Phys.* 2002, *40* (18), 2119–2129. https://doi.org/10.1002/POLB.10261.
60. Elieh-Ali-Komi, D.; Hamblin, M. R. Chitin and Chitosan: Production and Application of Versatile Biomedical Nanomaterials. *Int. J. Adv. Res.* 2016, *4* (3), 411.
61. Shanmugam, V.; Babu, K.; … T. G.-J. of A.; 2021, undefined. Potential Natural Polymer-based Nanofibres for the Development of Facemasks in Countering Viral Outbreaks. *Wiley Online Libr.* 2021, *138* (27). https://doi.org/10.1002/app.50658.
62. Ji, Y.; Wolfe, P. S.; Rodriguez, I. A.; Bowlin, G. L. Preparation of Chitin Nanofibril/Polycaprolactone Nanocomposite from a Nonaqueous Medium Suspension. *Carbohydr. Polym.* 2012, *3* (87), 2313–2319. https://doi.org/10.1016/J.CARBPOL.2011.10.066.
63. Choy, S.; Moon, H.; Park, Y.; Jung, Y. M.; Koo, J. M.; Oh, D. X.; Hwang, D. S. Mechanical Properties and Thermal Stability of Intermolecular-Fitted Poly(Vinyl Alcohol)/α-Chitin Nanofibrous Mat. *Carbohydr. Polym.* 2020, *244*. https://doi.org/10.1016/J.CARBPOL.2020.116476.
64. Park, B. K.; Kim, M.-M. Applications of Chitin and Its Derivatives in Biological Medicine. *Int. J. Mol. Sci.* 2010, *11* (12), 5152. https://doi.org/10.3390/IJMS11125152.
65. Wang, L.; Zhang, C.; Gao, F.; Pan, G. Needleless Electrospinning for Scaled-up Production of Ultrafine Chitosan Hybrid Nanofibers Used for Air Filtration. *RSC Adv.* 2016, *6* (107), 105988–105995. https://doi.org/10.1039/C6RA24557A.
66. Algieri, C.; Drioli, E.; Donato, L. Development of Mixed Matrix Membranes for Controlled Release of Ibuprofen. *J. Appl. Polym. Sci.* 2013, *128* (1). https://doi.org/10.1002/app.38102.
67. Li, H.; Wang, Z.; Zhang, H.; Pan, Z. Nanoporous PLA/(Chitosan Nanoparticle) Composite Fibrous Membranes with Excellent Air Filtration and Antibacterial Performance. *Polym. 2018, Vol. 10, Page 1085* 2018, *10* (10), 1085. https://doi.org/10.3390/POLYM10101085.
68. da Silva, D.; Kaduri, M.; Poley, M.; Adir, O.; Krinsky, N.; Shainsky-Roitman, J.; Schroeder, A. Biocompatibility, Biodegradation and

Excretion of Polylactic Acid (PLA) in Medical Implants and Theranostic Systems. *Chem. Eng. J.* 2018, *340*, 9–14. https://doi.org/10.1016/J.CEJ.2018.01.010.

69. A, N.; A, H.; S, S.; RS, M.; PK, D.; WJ, W. Silver Nanoparticles Embedded in Zeolite Membranes: Release of Silver Ions and Mechanism of Antibacterial Action. *Int. J. Nanomedicine* 2011, *6*, 1833–1852. https://doi.org/10.2147/IJN.S24019.
70. Qin, Y. Alginate Fibres: An Overview of the Production Processes and Applications in Wound Management. *Polym. Int.* 2008, *57* (2), 171–180. https://doi.org/10.1002/PI.2296.
71. Bhattarai, N.; Li, Z.; Edmondson, D.; Zhang, M. Alginate-Based Nanofibrous Scaffolds: Structural, Mechanical, and Biological Properties. *Adv. Mater.* 2006, *18* (11), 1463–1467. https://doi.org/10.1002/ADMA.200502537.
72. Tonin, C.; Aluigi, A.; Varesano, A.; Vineis, C. Keratin-Based Nanofibres. *Nanofibers* 2010. https://doi.org/10.5772/8151.
73. Cipitria, A.; Skelton, A.; Dargaville, T. R.; Dalton, P. D.; Hutmacher, D. W. Design, Fabrication and Characterization of PCL Electrospun Scaffolds—a Review. *J. Mater. Chem.* 2011, *21* (26), 9419–9453. https://doi.org/10.1039/C0JM04502K.
74. He, M.; Zhang, B.; Dou, Y.; Yin, G.; Cui, Y.; Chen, X. Fabrication and Characterization of Electrospun Feather Keratin/Poly(Vinyl Alcohol) Composite Nanofibers. *RSC Adv.* 2017, *7* (16), 9854–9861. https://doi.org/10.1039/C6RA25009B.
75. Shen, B.; Zhang, D.; Wei, Y.; Zhao, Z.; Ma, X.; Zhao, X.; Wang, S.; Yang, W. Preparation of Ag Doped Keratin/PA6 Nanofiber Membrane with Enhanced Air Filtration and Antimicrobial Properties. *Polymers (Basel).* 2019, *11* (9). https://doi.org/10.3390/POLYM11091511.
76. Argyrous, G. Statistics for Research with a Guide to SPSS. *Stat. Res. with SPSS Guid.* 2011, 535–536.
77. Prince William C. Dangers of Improperly Discarded PPE. UVA Health. November 2, 2020. [a] https://www.who.int/news/item/03-03-2020-shortage-of-personal-protective-equipment-endangering-health-workers-worldwide