University of Tehran Press

Pollution

Print ISSN: 2383-451X
Online ISSN: 2383-4501

https://jpoll.ut.ac.ir/

COVID-19 Waste as Source of Microplastics in the Environment: Implication for Aquatic Species, Human, and Remediation Measures- A Review

Stanley Iheanacho[1]✉ | Miracle Ogbu[2] | Joshua Ekpenyong[1] | Elizabeth Tabi[1] | Angus Iheanacho[3] | Md. Simul Bhuyan[4] | Johnny Ogunji[1]

1. Department of Fisheries and Aquaculture, Alex Ekwueme Federal University Ndufu-Alike, P.M.B 1010, Abakaliki, Nigeria
2. Department of Biology, Alex Ekwueme Federal University Ndufu-Alike, P.M.B 1010, Abakaliki, Nigeria.
3. Department of Chemistry and Industrial Chemistry, University of Nigeria Nsukka, P.M.B 410001, Enugu, Nigeria
4. Bangladesh Oceanographic Research Institute, Cox's Bazar, Bangladesh

Article Info

Article type:
Review Paper

Article history:
Received: 28 Aug 2022
Revised: 10 Dec 2022
Accepted: 17 Jan 2023

Keywords:
COVID-19
Microplastics
Risk
Aquatic systems
Organisms
Human

ABSTRACT

Coronavirus (COVID-19) pandemic ushered in a new era that led to the adjustments of diverse ecosystems. The pandemic restructured the global socio-economic events which prompted several adaptation measures as a response mechanism to cushion the negative impact of the disease pandemic. Critical health safety actions were imperative to curtail the spread of the disease such as wearing personal protective equipment (PPEs), masks, goggles, and using sanitizers for disinfection purposes. The daily demands for the products by individuals and medical personnel heightened their production and consumption, leading to a corresponding increase of COVID-19 wastes in the environment following indiscriminate waste disposal and poor waste management. The persistent occurrence of COVID-19 wastes aggravated microplastics (MPs) contamination in the aquatic ecosystem following the breakdown of PPEs-based plastics via oxidation, fragmentation, and photo-degradation actions. These MPs are transported in the aquatic environment via surface runoff and wind action, apart from discrete sources. MPs' presence in the aquatic systems is not without repercussions. Ingestion of MPs by aquatic organisms can cause several diseases (e.g., poor growth, oxidative distress, neurotoxicity, developmental toxicity, reproductive toxicity, immunotoxicity, and organ toxicity). Humans are at high risk of MPs uptake. Apart from aerial and soil contamination sources, consumption of aquatic food products is a critical pathway of MPs into the human body. MP toxicities in humans include liver disorder, respiratory failure, infertility, hormonal imbalance, diarrhea, developmental disorder, and mortality. Measures to alleviate the effect of COVID-19 waste litters include effective waste management plans and the adoption of technologies to extract cum degrade MPs from the aquatic and terrestrial environment.

Cite this article: Iheanacho, S., Ogbu, M., Ekpenyong, J., Tabi, E., Iheanacho, A., Bhuyan, MD.S., & Ogunji, J. (2023). COVID-19 Waste as Source of Microplastics in the Environment: Implication for Aquatic Species, Human, and Remediation Measures- A Review. *Pollution* , 9 (2), 591-614.
http://doi.org/10.22059/POLL.2022.347858.1601

 Publisher: University of Tehran Press.
DOI: http://doi.org/10.22059/POLL.2022.347858.1601

INTRODUCTION

The COVID-19 is a contagious ailment instigated by acute respiratory syndrome corona virus 2 (Fig. 1). The virus was originally detected in December 2019; from the Hunan seafood market in Wuhan, China, from whence it gained worldwide spread via human movements across cities and countries, affecting almost every country of the world and was pronounced a

*Corresponding Author Email: *stanley.iheanacho@funai.edu.ng*

pandemic (Hui et al., 2020; WHO, 2020; Dai, 2020; Elsaida et al, .2021; Cascella, 2022). During the peak of the disease pandemic, several preventive measures were rolled out by public health experts and organizations to curb the rapid spread/transmission of the disease from person to person. The measures involved limited social gathering, clothing with PPEs, use of hand sanitizers, and wearing of masks, gloves, goggles by both citizens and medical personnel (Jribi et al., 2020; Ogunji et al., 2021). Furthermore, therapeutic measures included treatment with important pharmaceutical drugs, orthodox and unorthodox medicines, as available options to desperately curtail and treat the disease. Most of the COVID-19 materials are made of plastic or packaged with various types of plastic materials (polystyrene, polycarbonate, polypropylene, polyvinyl chloride, polyethylene) (Prata et al., 2021; Ray et al., 2022), hence serve as potential source of microplastics.

The COVID-19 pandemic intensified the use of plastic products in protecting human populace from transmittable disease (Prata et al., 2020; Ma et al., 2021; Patricio Silva et al., 2021; Shukla et al., 2022). Demand for masks and other PPEs has increased exponentially following the outburst of the pandemic. Face masks amounting to billions are consumed worldwide on daily basis (Ma et al., 2021) and these materials enter into the aquatic environment as waste following the reckless and indiscriminate disposal, without recourse to their impact on the environmental health (Hartmann et al., 2019; Henderson and Green, 2020; Aragwa, 2020; Olaiya, 2022). On the other hand, these waste materials can leach out from medical, industrial, and public waste facilities into the environment as a result of poor handling and managing of waste (Doremalen et al., 2020; De-la-Torre and Aragaw, 2021). Consequently, some of the waste materials find their way into the aquatic ecosystem via discrete or indiscrete pathways (Alimi et al., 2021; Issac and Kandasubramanian, 2021; De-la-Torre and Aragaw, 2021; Iheanacho et al., 2021; 2022), and consequently pollute the aquatic systems with more plastics, while complementing other sources (shipment, photo-degradation, industrial effluent, fishing gears, etc.) of microplastics into the aquatic ecosystems (Plastic Europe, 2018; Pico and Barcelo, 2019; Iheanacho and Odo, 2020a,b; Yahaya et al., 2022). There have been numerous reports of occurrence of COVID-19 wastes (PPEs) in the aquatic habitat (Stokes, 2020; Rhee, 2020; De-la-Torre and Aragaw, 2021). Depending on the type and characteristics of plastics, some can be neutral, positive, or negatively resilient in column and sediment of the aquatic system (De-la-Torre and Aragaw, 2021). For example, less dense polymers (polypropylene, polyethylene, and polystyrene), can stay afloat in marine water, whereas high-dense polymers (polyvinyl chloride, polyester, polyvinyl alcohol), can sink deep-down the benthic (sediment) region of the sea (Fadare and Okoffo, 2020; De-la-Torre and Aragaw, 2021; Alimi et al., 2021). Interestingly, plastics are potential vectors of several toxicants/pollutants like heavy metals, chemicals, organic compounds, and pathogens in the aquatic environment (Wingender and Flemming, 2011; Okoro et al., 2019; Wu et al., 2019; Mei et al., 2020; Bhuyan, 2022).

The presence of MPs from PPEs in the aquatic ecosystem cannot be perceived without consequences. Uptake and bioaccumulation of MPs released from masks have been reported in some aquatic organisms like shrimp, copepods, rotifers, scallops, and grouper on sub-chronic exposure (Ma et al., 2021). Parton et al. (2020) noted the incidence of MPs and fibers in demersal shark species of the United Kingdom. Gut accumulation and bio-translocation of MPs to other tissues have been reported in mammalians (Bisht et al., 2020; Wang et al., 2020; Wang et al., 2019). MP uptake by aquatic species produces detrimental effects on their biological performance and perhaps extended through bio-magnification along the critical nutrient chain supplies (food chain and food web) (Ma et al., 2021; Kavya et al., 2020), which causes harms to higher vertebrates including humans (Shukla et al., 2022). Polystyrene PS-MP ingestion resulted in oxidative distress and intestinal injury in Zebra fish (*Dano rerio*) (Lei et al., 2018), and decreased growth in Mollusca (*Crepidula onyx*) (Lo and Chan, 2018). MP ingestion by zooplankton-like copepods affected fertility, feed habit, and general performance (Cole et al., 2015). The possible impacts on human health include headache, infertility, respiratory failure, developmental disorders, hormonal imbalance reduced appetite, etc. (Issac and Kandasubramanian, 2021). This study (review) explored COVID-19 materials as a potential vector of MPs in the aquatic systems and their potential effects on aquatic organisms and humans largely.

COVID-19 AND THE ENVIRONMENT

The earthly environment is playing a prominent role of sustaining and harboring great diversity of both living and non-living creatures. The environment is a promoter of many biotic and abiotic activities that support the function and survival of its various components. OECD (2005), explicitly interpreted the phenomenon 'environment' to mean the whole of land, air, water, and the interrelations among the trio in connection with humans and other living organisms. The environment is also a fertile ground for many single-celled organisms to thrive. The environment and components (including humans and animals) play host to non-cellular organisms like viruses and viroids. The outburst of COVID-19 permeated the nook and cranny of the earth with devastating consequence (Ogunji et al., 2021). The COVID-19 pandemic created many constraints to the human well-being and the environment. The pandemic also threatened global food security, health and socio-economy (Kumar et al., 2022). The compulsory lockdown imposed across the world to curtail the distribution of the virus prompted the marked modifications in ecological paradigm of the different environments (UNSCN, 2020; Jribi et al., 2020; Ogunji et al., 2021). The implications of COVID-19 include changes in the lifestyle, mode of human events (adoption of virtual/online activities), commerce, etc. (Dente and Hashimoto, 2020; Yusoff et al., 2021).

COVID-19 and the Atmosphere

The COVID-19 lockdown restricted many activities that contribute to air pollution, thus reducing aerial contaminants (drastic restrictions of traffic, reduced emissions of dangerous gases from automobiles, factories, and burning of fossil fuel) and allowed for air quality improvement although on a temporal basis (NASA, 2020; Chakraborty, 2020; Kanniah et al., 2020; Nigam et al., 2021). Drastic reductions of nitrogen dioxide (NO_2) and carbon dioxide (CO_2) (Hashim et al., 2021) and other tracers of air pollution were witnessed in many cities of the world including China (Dutheil et al., 2020; Carbon Brief, 2020), India (Mishra et al., 2021; Mor et al., 2021), Italy (Malpede and Percoco, 2021), Brazil (Beringui et al., 2022), Spain (Querol et al.,, 2021), Nigeria (Olusola et al. 2021). Nevertheless, the gases in the atmosphere play a significant role in the transmission of COVID-19. From a fluid dynamic standpoint, the transmission course of the virus is facilitated by multifaceted flow kinetics emanating from the air-mucous exchange,

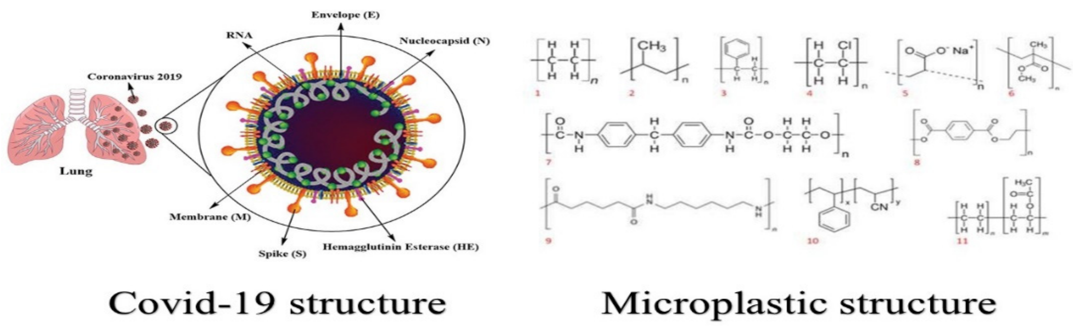

Fig. 1. Structures of COVID-19 and Microplastics

droplet diffusion, fluid disintegration and droplet deposition surfaces, following possible gulping by individuals (El-Ramady et al., 2020; Mittal et al., 2020; Ghahvemanloo et al., 2021). The transmission of COVID-19 in the air is through particle droplets that are deposited and dispersed via aerial tides (Coccia, 2020; Bilal et al., 2020). According to Coccia (2020) and Asadi et al. (2020), there is an established connection between air pollution, wind current, and circulation of COVID-19, suggesting that high concentrations of air contaminants correlate with squat wind currents, and could result in lengthy dwelling time for viral droplets in the air. Interestingly, the transmission of COVID-19 has a prominent correlation with the aerial temperature and pollutants (Ahmadi et al., 2020; Bilal et al., 2020; El-Ramady et al., 2020; Ju et al., 2021).

Covid-19 and Soil

The soil is an integral part of the environment that harbors large diversities of lower animals and microorganisms. Furthermore, the soil, depending on its state and characteristics provides food, fuel, mineral elements and shelters humanity and animals (George et al., 2019; El-Ramady et al., 2020). The COVID-19 plague aggravated soil contamination following the littering of the environment with medical bio-wastes and PPEs (surgical gloves, facemasks, hand and surface sanitizers, aprons) (Lal, 2020; Iqbal et al., 2020; Alimi et al., 2021; De-la-Torre and Aragaw, 2021). The transmission of COVID-19 can be extended to other environments such as aquatic and air following oxidative processes and the leaching of waste materials (Fadare and Okoffo, 2020; De-la-Torre and Aragaw, 2021). In addition, the leachates can percolate into the soil and by extension, reaching the ground waters, hence causing serious harm to soil health, microorganisms/pathogens (Qian et al., 2020) and polluting the ground waters (Aragwa, 2020; Ma et al., 2021).

COVID-19 also serves as a vector of MPs, heavy metals, and chemical compounds (polyaromatic hydrocarbons (PAHs), polybrominated biphenyls (PBBs), and polychlorinated biphenyls (PCBs)) (Ng et al., 2018; Iqbal et al., 2020; Neckel et al., 2021; Yang et al., 2021; Xu et al., 2020; Kicinska et al., 2022). Weathering, fragmentation, and photo-degradation of plastic-based PPEs can lead to breakdown into microfibers, MPs, and NPs in the soil (Wang et al., 2020; Yang et al., 2021; Issac and Kandasubramanian, 2021) and percolate into the soil via natural (leaching, wind and surface runoff) processes (Lu et al., 2020; Xu et al., 2020). The porosity of soil enables the downward migration of MPs via the soil pores (Yang et al., 2021). High-level contaminants of copper and iron in the cemeteries' soil were confirmed to be connected to COVID-19 deaths.

Covid-19 and water

The water habitat is made up of diverse ecologies (from their sources to their mouths) and the shore environment, interrupted by brooks and water courses (Qadri and Bhaf, 2020; Hart and Heldon, 2020; Yusoff et al., 2021).The water ecosystems (lakes, wetlands in flood plains rivers which form the lotic-lentic water body complex) and coastal waters swiftly returned to normalcy (general upgrade in water quality) following the reduced anthropogenic influence prompted by the COVID-19 lockdown (Liu et al., 2022; Yunus, 2020) which was reversed after the lockdown period (Liu et al., 2022). The general trend showed an upgrade in water quality parameters during the lockdown (Tokatlı and Varol, 2021; Yusoff, 2021). Heavy metal (Chromium, Nickel, Zinc, Copper, Arsenic, lead, and Cadmium) levels in waters declined substantially following the COVID-19 lockdown, leading to a reduced heavy metal pollution index (low ecological risk) (Chakraborty et al., 2021). Further evidence for the respite of the environment during the lockdown was seen in the upgrade of ground water where the levels of Na^+, K^+, Cl^-, NO_3^- reduced, and there was increased HCO_3^- ion concentration (Karunanidhi et al., 2020). The limited operational status of most industries during the lockdown decreased the volume of industrial wastes drastically, resulting to substantial upgrade of surface water quality for metal(loid)s (Tokatlı and Varol, 2021; Chakraborty et al., 2021). The rejuvenation of rivers and streams to proper and semi-rich health conditions from densely polluted state was linked to the COVID-19 lockdown (Chakraborty et al. 2021). Wagh et al. (2021) reported a decline in algal bloom and dissolved organic matters following the reduced effluence releases from industries during the COVID-19 lockdown. Additionally, COVID-19 lockdown encouraged the improvement of groundwater health from early contamination (Karunanidhi et al., 2021).

COVID-19 necessitated massive environmental disinfection exercises all over the globe, which led to the transportation of disinfection byproducts (DBP) and PPEs waste into the aquatic environment via surface off and wind action (Cortti et al., 2019; Ardusso et al., 2021; Saliu et al., 2021). On the other hand, acute concentrations of pharmaceuticals (those used for the treatment of COVID-19) increased in wastewater effluents and surface water (Zhang et al., 2020; De-la-Torre et al., 2021). Zhang et al. (2020) reported substantial levels of pharmaceutical drugs (used for COVID-19 treatment) in the aquatic environment. In recent times, lethal concentrations of azithromycin (AZT) and hydroxychloroquine (HCQ) (popular drugs for treating COVID-19) have been detected in rivers, and streams due to direct disposal of hospital wastes or through leaching from waste containers and landfills (Ansari et al., 2019; Urban and Nakada, 2021).

The aquaculture and fisheries sectors could be at risk due to the presence of COVID-19 biowaste from human excreta, wastewaters, and sludge, transported to the water ecosystems, hence threatens food safety and security (El-Ramady et al., 2020; Ghahvemanloo et al., 2021). Yusoff et al. (2021) stated that COVID-19 pandemic-associated aquatic contamination might cause a high risk to aquatic food security and human health. The transportation of COVID-19 (SARS-CoV-2) to natural waters from wastes waters can occur in countries with inefficient waste water management systems or those with zero sewage treatment (developing world), where raw sewage is directly discharged into natural water bodies (De-la-Torre and Aragaw, 2021; Yusoff, 2021).

COVID-19 WASTE AS A BASIS OF MPS IN THE WATER ENVIRONMENT.

The surge of COVID-19 disease pandemic prompted several safety actions. This was in a bid to mitigate the spread of this dreaded virus. These actions included compulsory use of Personal Protective Equipment (PPE) and nose masks in public places, partial/total lockdown and a ban on public gatherings (such as religious places, markets, banks, etc.) (Rakib et al., 2021; Siam et al., 2020). The COVID-19 pandemic prevention and/or control measures amid poor disposal and management mechanisms could have accentuated the occurrence of MPs in the environment. This is because the majority of the PPEs, hand sanitizers, face masks, vaccine bottles, coatings, and syringes are mostly made of MP materials (Fig. 2). Due to the high-speed of fragmentation, environmental pollution from MPs has tremendously become a source of concern; aiding the transfer of chemical toxicants contained in the MPs when subsequently ingested by aquatic organisms (Hermabessere et al., 2017; Gumeiro et al., 2018; Li et al., 2020; Weis, 2020; Yossuf et al., 2021). This, therefore, is a potential risk for humans and their health given that the exposure to MPs by the consumption of contaminated seafood is highly probable; as well as posing a great challenge to food security (Cole et al., 2011; Conkle et al., 2017; De-la-Torre, 2020). Saliu et al. (2021) estimated the quantity of microfibers released into the marine environment from surgical facemasks alone. According to their study, after one hundred and eighty (180 H) hours of UV light exposure and vigorous stirring in artificial seawater, up to 173,000 fibers per day from one facemask could be released.

Across the globe, MPs have been reported to increase in worrisome quantities in the environment, most of which end up in the aquatic environment through different sources, mostly terrestrial (Ng et al. 2018; Liu et al., 2021). About 400,000 particles of MP pollutants have been recorded per square kilometer of the Great Lakes of the USA alone (Eerkes-Medrano et al., 2015). This is fast becoming a major issue of global concern that could have multiple effects; not just on the aquatic biota but also all life forms that depend on the aquatic environment and on humans by extension via contaminated aquatic food sources (Van-Cauwenberghe and Janssen, 2014; Rochman et al., 2015). The aquatic environment is important in various ways for different categories of individuals. These include being a source of water (drinking, washing, etc) for different households, and recreational purposes, and also a source of food materials (fish, crustaceans, mollusks, edible salt, aquatic weeds). Very worrying is that MPs have been detected in some of these food materials (Van and Janssen, 2014; Bellas et al., 2016; Guzzetti et al., 2018; Chaukura et al., 2021). Aside from these negative effects recorded, MP contamination also could lead to economic drawbacks emanating from reduced tourist attraction for tourist centers and maritime industries (GESAMP, 2015; Raynaud, 2014; Thevenon et al., 2014). Highlighted below are critical sources of COVID-19-related MPs in the aquatic systems.

Personal Protective Equipment (PPEs)

Generally, PPEs (Nose/face masks, aprons, gloves) used during the COVID-19 pandemic to curb the distribution of the virus are made of plastic polymers (Parashar and Hait, 2021; Babaahmadi et al., 2021; de Sousa, 2021). An estimated monthly requirement for hand gloves and masks worldwide is 65 billion and 129 billion, respectively (Prata et al., 2020). The vast production of these PPEs, particularly hand gloves and face masks contributed to the upsurge of MPs in the environment (Benson et al., 2021). PPEs have been instrumental alongside the vaccines and other preventive measures applied by different countries to achieve success crosswise the world in curbing the effects of the disease. However, it sounds disturbing due to the challenge it poses in the management of solid wastes and the tendency of these single-use plastics to readily release the several classes of plastic (macro-, meso-, micro-nano-plastics microfibers) into the environment (Dissanayake et al., 2021; Rhee, 2020; Kutralam-Muniasamy et al., 2022). Many of the PPEs are trapped in the streams, lakes, bays, brooks, canals, and littering municipal areas (Canning-Clode et al., 2020; Dissanayake et al., 2021). Rhee (2020) stated that indirect infection with COVID-19 (an infection that occurs as a result of exposure to improperly disposed of PPEs rather than contact with an infected person) is possible. MP fibers can also penetrate the soil column and may get to the ground water level when left for a long period as a consequence of indiscriminate disposal and improper waste management (De-la-Torre, 2020; Dissanayake, 2021).

Fabrics and textiles

Based on multiple environmental sampling carried out to identify MP particles, fibre was the commonest and the most abundant MPs in the environment (De-la-Torre, 2020; Benson et al., 2021; EEA,2022). Fibers are predominantly reported to be released from textiles (Carney Almroth et al., 2018). Most PPEs are made from fabrics and loosely bound plastic fibers. In particular, the one-use face masks are made of non-woven materials (e.g., spun-bond and melt-blown spun-bond), with polypropylene and polyethylene (Silva et al., 2021; Fadare and Okoffo, 2020), and the gloves are mostly made of different plastic materials (Low-Density Polyethylene, nitrile, latex, vinyl) (Briassoulis et al., 2004; Lambert et al., 2013; Sen and Raut, 2015). The waste from PPEs can potentially release fibers up to seven (7) times more than newly disposed of ones (Chen et al., 2021). These fibers can be discharged into the environment after disposal (Chen et al., 2021), like the discharge of microfiber from fabric and textile materials during laundry (Hernandez et al., 2017; Kelly et al., 2019). MP fibers are released through abrasion when synthetic textiles are washed via industrial laundries and households. However, it's important to note that the aging of garments affects the number of MP fibers that are eventually released during washing i.e., more fibers are released as particular textile age from use and reuse (Carney Almroth et al., 2018). This is in line with the discovery of Bruce et al. (2016). The authors observed that old garments give off a higher quantity of fibers compared to newer ones.

MP fibers discharged during laundry find their way to the ocean from sewage water (Browne et al. 2011; Magnuson et al., 2016). About 100-300 fibers per liter could be potentially released from laundry wastewater (Brown et al. 2011). In a similar study, Napper and Thompson (2016) reported that no fewer than 700,000 fibers are released from washing 6 kg of laundry, leaving so much to ponder on, given that even higher numbers are expected as consumption increases over the years. From the foregoing, it's obvious that textile fibers of both natural origin (wool, linen, and cotton) and synthetic origin (polyester, polyamide) are present in the marine environment (Bhuyan et al., 2022). This has been reported by many researchers in many in situ sampling studies both in open water and marine sediments (Mathalon and Hill, 2014; Remy et al., 2015; Browne et al., 2011). These synthetic fibers have been shown to have negative effects on organisms. For instance, there was an increase in the mortality rate in *Daphnia magna* found to have ingested polyester fibers (Jemec et al., 2016).

Facemasks

Wearing of face mask is one of the important safety measures adopted during and after the COVID-19 pandemic, hence prompting the surge in the production and use of face masks globally (Saadat et al., 2020; Dissanayake et al., 2021; Selvaranjan et al., 2021a, b). A survey study between 2020-2021 revealed that a minimum of 1381 million face masks were released daily in South Korea, indicating that seventy percent of the country's municipal populace uses one (1) face mask daily (Dissanayake et al., 2021). The number significantly rose to a whopping 5707 million microfiber-based face masks on an average of four (4) face masks per individual daily. In similar research conducted by Benson et al. (2021), it was discovered that not less than twelve (12) billion medical and fabric face masks including surgical-grade (SG), Filtering face Piece 2 (FFP2), and Homemade (HM) facemasks made from fabrics are discarded monthly in Africa. This leaves the status in the neighborhood of about 105,000 tons of face masks per month which could find their way into the environment and ultimately into the aquatic environment. Invariably, this estimate was directly proportional to the population of the country which was obtained by estimating the number of compliant population (those who used face masks as standard procedure for use in public gatherings). According to Benson et al. (2021), this evidenced that about fifteen (15) countries out of the 57 African countries produced more, compared to other countries with fewer populations. The top six countries include Nigeria (15%), Ethiopia (8.6%), Egypt (7.6%), DR Congo (6.7%), Tanzania (4.5%), and South Africa (4.4%) (Benson et al., 2021). On the global scale, it was discovered that daily consumption of facemask was highest in China (702,390.002), followed by India (386,401,228), the United States (219,785,760), Brazil (140,289,215), with Poland having the lowest daily consumption of facemask (18,166,373) (Benson et al., 2020). After MP characterization which was done using FTIR spectra, it was revealed that there were both natural and artificial fibers including polyester fibers (PE), polypropylene (PP), natural latex resin (NL), polyethylene terephthalate, styrene isoprene, and styrene butadiene rubber (Fadare and Okoffo, 2020).

Hand sanitizers

Hand and surface sanitizers are products or substances used to get rid of or minimize pathogenic agents like bacteria on the skin and objects. Hand sanitizers are important disinfectants used on surfaces as preventative measures to lower the risk of disease transmission (Mvovo and Magagula, 2022; Selvaranjan et al., 2021a; WHO, 2022). During the COVID-19 outbreak, the production of sanitizers drastically increased across the globe (Das et al., 2021). Sanitizers have reportedly been found to include microbeads, a type of MP utilized as raw material in the manufacture of numerous household and personal items (Abuwatfa et al., 2021). Because of the high consumer demand and ubiquitous use of the product (Saadat et al., 2020), they have been

Fig. 2. COVID-19 materials as sources of microplastics in the aquatic environment

found to leave a negative impact on the environment. A study on the environmental impacts of PPE used in households of Dhaka City Corporation (DCC), Bangladesh has shown hand sanitizers to boost carbon footprint and heighten plastic pollution surge (Monolina et al., 2022).

RISK OF COVID-19-ASSOCIATED MICROPLASTICS ON THE AQUATIC ENVIRONMENT

The massive production of personal protective equipment (PPE) like plastic gloves, face masks, safety glasses, protective aprons, and sanitizer containers, was a response to COVID-19 and the need to prevent its spread (Patricio Silva et al., 2020; Fadare and Okoffo, 2020; Ray et al., 2020, 2022). PPEs are plastic materials made up of synthetic polymers such as polyethylene, polypropylene, polyester, and polystyrene (Fadare and Okoffo, 2020; Aragaw, 2020). Over time, at a very slow rate, PPEs undergo fragmentation and break into smaller molecular products (<5 mm) to form MPs through various processes subject to their chemical characteristics (Ardusso et al., 2021). During the COVID-19 lockdown period, these materials increased tremendously in the aquatic environment as waste due to a lack of efficient treatment facilities, poor management, and inappropriate disposal, particularly in underdeveloped and developing countries (Praveena and Aris, 2021; Yadav et al., 2020; Haque et al., 2021). According to Ray et al. (2020), the marine system gets between 4.8 and 12.7 $\times 10^6$ tonnes of plastic waste annually as a result of poor waste management. These waste materials are transported to the environment by wind, storm, surface runoff, and floods through industrial discharges, wastewaters, fisheries activities, etc. and represent a significant percentage of the marine litter (Severini et al., 2020; Yadav et al., 2020). Marine litter, one of the acute forms of environmental pollution poses a threat to the health of marine biodiversity (Miranda-Urbina et al., 2015; de Sa et al., 2018; Alimi et al., 2021). Their extensive production, consumption, and improper disposal have turned plastics into one of the most problematic environmental challenges of present times (Fadare and Okoffo 2020; De-la-Torre et al., 2021). The global environment is distressed by the harmful effects of plastic trash originating from single-use face masks, syringe, gloves, and other equipment. Plastic bottles of hand sanitizer, waterlogged masks, gloves, and other rubbish are being traced to the ocean bottom, which intensify the number of debris found in the environment daily (Ray et al., 2022; Mirand-Urbina et al., 2015). During the process of disintegration, toxic substances and chemicals produced by plastic waste may be discharged into the aquatic environment, hence worsening the situation (Aragaw, 2020; Iheanacho and Odo, 2020a; Selvaranjan et al., 2021b; Alimi et al., 2021). Inappropriate disposal of these wastes might have a long-lasting effect on the aquatic environment (Wang et al., 2020; Ammendolia et al., 2021; Ma et al., 2021; Shukla et al., 2022).

The PPEs worn by healthcare professionals, patients, and the general public are composed of synthetic polymers like nitrile, latex, or polyethylene, which need the addition of stabilizers and softeners to improve their physical properties. These compounds, which are widely dispersed in PPE kits and undergo leaching processes in waterbodies, can be extremely hazardous to many aquatic fauna (Sullivan et al., 2021; Ray et al., 2022). According to Chen et al. (2019), additives used in plastic production processes contain compounds that have the potential to interfere with aquatic species' endocrine systems, having a severe effect on their health (Fig. 3). MPs have an affinity for chemicals (PAHs, PCB, PBBs), and can absorb them (Rochman et al., 2015; Lu et al., 2016; Gomeiro et al., 2018). After the ingestion processes, MPs can release the adsorbed chemicals, hence enhancing their bioavailability and bioaccumulation in several tissues/organs (Syberg et al., 2015; Gomeiro et al., 2018; Pellini et al., 2018), causing harmful effects on the biota (de Sa et al., 2018; Wu et al., 2019; Mei et al., 2020; De-la-Torre et al., 2021). MPs have also been emphasized to inhibit photosynthetic process of microalgae (Zhang et al., 2017), and produced a negative impact on mammals (Plastic Europe, 2016; de Sa et al., 2018; Yong et al., 2020; Meaza et al., 2021). By ingesting plastic-based particles, aquatic species may become poisoned in the process (Hernandez et al., 2019; Asim et al., 2021). Ma et al. (2021) studied different layers of facemasks and found that they contained a large quantity of MPs. The authors noted that mask MPs were absorbed onto diatom surfaces and subsequently gulped by aquatic (marine) organisms of various trophic levels, posing a health risk to aquatic life. Similarly, Aragaw (2020) discovered that large aquatic species including fish, turtles, and water birds can easily consume face masks, having a significant negative impact on their populations and survival. Issac and Kandasubramanian (2020) opined that MPs deposited in the aquatic systems globally affect the growth, feeding, spawning, and survival of aquatic organisms.

Also, Walker (2021) reported the problem of entanglement associated with threads from plastic waste resulting in the death of aquatic animals like sea birds and turtles. Improper disposal and mismanagement of PPE kits serve as a medium for the COVID-19 outbreaks and biomagnification of harmful compounds that ultimately infiltrate the aquatic food chain (Klemes et al., 2020). Over 20% of marine shellfishes have been reported to uptake masks and other PPEs-related MPs (Ray et al., 2022). MPs can absorb polycyclic aromatic hydrocarbons, heavy metals, and persistent organic pollutants, making them vectors of chemical contaminants (Gomeiro et al., 2018; Torres et al., 2021; Yusoff et al., 2021). They function as a vector for xenobiotics which may exacerbate harmful effects on aquatic life (Zettler et al., 2013; Auta et

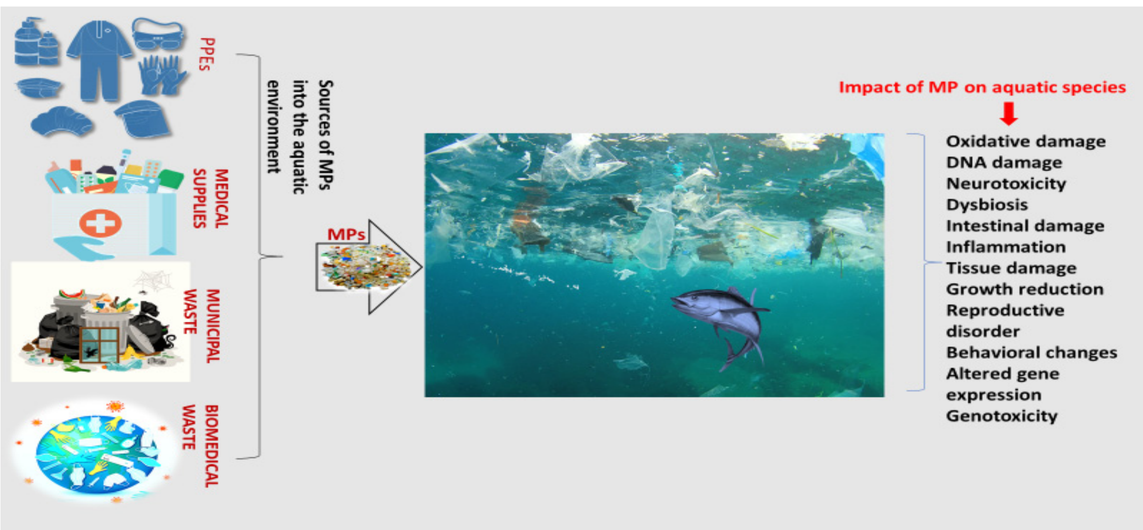

Fig. 3. Impact of microplastics on aquatic organisms

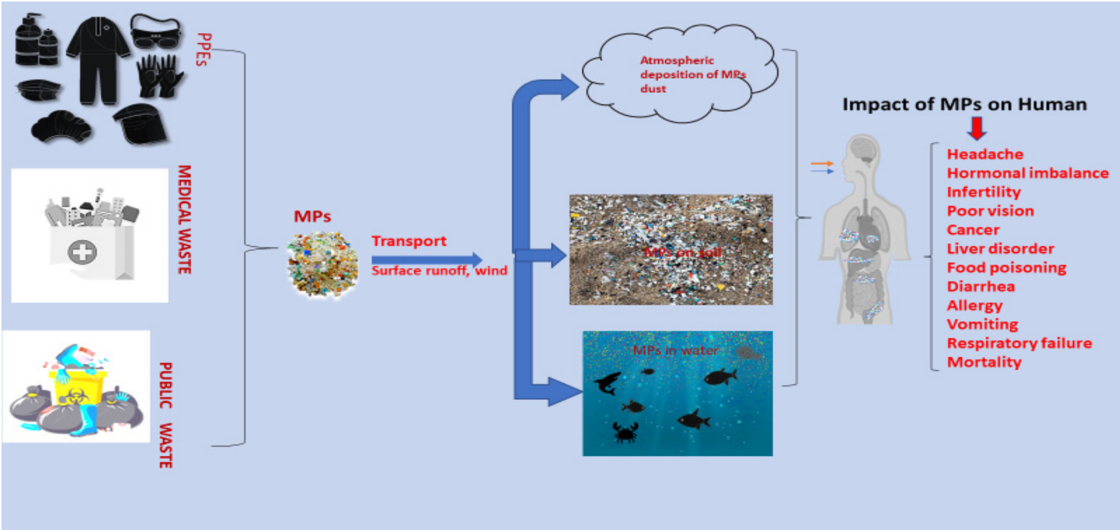

Fig. 4. Impact of microplastics on Human

al., 2017; Bhagat et al., 2021; Rakib et al., 2021). MPs ingestion can slow down the growth rate of aquatic organisms following complications in their reproduction (de Souza Machado et al., 2018). Constituents of plastics are chemical additives such as plasticizers, colorants, plastic resins and stabilizers (Rochman et al., 2015; Nordic council report, 2017; Iheanacho et al., 2020c). Chronic exposure to these chemical additives can promote adverse effects on growth, reproduction, immune and endocrine systems, development, and behavior in aquatic organisms (de Sa et al., 2018; Gomeiro et al., 2018; Issac and Kandasubramanian, 2020; Iheanacho et al., 2020c; Ma et al., 2021; Iheanacho et al., 2021; Shukla et al., 2022). In a shocking discovery, Neto et al. (2021) reported the death of a Magellanic penguin (*Spheniscus magellanicus*) in Juquehy Beach municipality of São Sebastião, Brazil. The authors described the cause of death, as the presence of an adult-size PFF-2 protective mask found within the stomach of the penguin.

IMPACTS OF COVID-19 ASSOCIATED MPS ON HUMANS

The vulnerability of humans to COVID-19 has been emphasized based on their existence and contact with the various types of environments namely; air, water, and soil (Fig. 4) (Silva et al., 2021; Yang et al., 2021; Yusoff et al., 2021). The PPEs undergo physicochemical cum geological processes (photo-degradation, oxidation, weathering, aerosolization, etc.), leading to the breakdown and release of MPs into the different ecosystems (Fadare and Okoffo, 2020; Alimi et al., 2021; De-la-Torre and Aragaw, 2021; Ardusso et al., 2021; Issac and Kandasubramanian, 2021; Ray et al., 2022). Sea food products are highly contaminated with MPs (Saha et al., 2021), and humans, being the ultimate consumers of aquatic foods are predisposed to a high risk of MP uptake (Smith et al., 2018). The existence of MPs in sea salt (Selvam et al., 2020), ground and tap water (Tong et al., 2020), and bottled water (Mason et al., 2018) are evidence of possible pathways of MPs reaching the human body. Detection of MPs in the human placenta (Ragusa et al., 2021; Bhuyan, 2022) and feces (Zhang et al., 2021), are evidence of their existence in the human body. MPs also can bio-accumulate in phytoplankton eventually bio magnify up the aquatic food chain to higher trophic levels and even to humans leading to public health risk (Galloway et al., 2017; Wu et al., 2020). Investigations have shown that human health is also endangered at any point of the plastic lifecycle, beginning from the mining of fossil fuels to consummation to discarding of plastic waste (Gore et al., 2016; Gharde and Kandasubramanian, 2019; Issac and Kandasubramanian, 2020).Congenital illnesses and cancers (malignant) in humans have been associated with the consumption of MP-contaminated foods, as well as the occurrence of paltry levels of phthalates in dolls (Smith et al., 2018; Saha et al., 2021).Plastic polymers contain dioxin chemicals known as persistent organic toxicants, of which can cause tumor and neurological damage in humans upon exposure (Rajmohan et al. 2019; Bhuyan, 2022).

The direct effects of PPEs on humans have also been reported in some studies (Gore et al., 2016; Matusiak et al., 2020; Issac and Kandasubramanian, 2020). Health workers, care givers, professionals, and other individuals who have to put on face masks for long durations of up to six hours encounter certain inconveniences such as increased skin temperature, redness, hydration, and sebum secretion (Park et al., 2021). Similarly, Matusiak et al. (2020) took a survey of inconveniences incurred by individuals resulting from the use of face masks. The authors found that 3.1% of individuals involved in the study did not complain of any problems. However, some of the inconveniences reported in their survey include breathing difficulty (35.9%), warming/ sweating (21.3%), misting up of the glasses (21.3%), and slurred speech (12.3%). However, the authors conclude that wearing surgical masks preferably to other mask types could lessen the perils of developing most of these common inconveniences. This is in line with the suggestion of Kim (2020) who opined that surgical masks are the best types of face masks recommended to prevent transmission via exposure to droplets. These face masks also leave individuals at the risk of exposure to micro- and nano-fibers which can be deposited in the respiratory tract via hand-to-mouth contact, or inhalation (Han and He, 2021; Li et al., 2021).

MITIGATION STRATEGIES AND POSSIBILITIES

Microplastics have had a serious negative impact on ecosystems and human lives, thus becoming an emerging conundrum of global concern. They have been abundantly reported in different water resources; freshwater, wastewater, groundwater, and oceans (Auta et al., 2017; Xu et al., 2020b; Alimi et al., 2019; Ray et al., 2022). This has drawn the attention of the scientific community, environmental experts and managers as to the way forward such as finding solutions to what looks like a major global catastrophe in the making (Rume and Islam, 2020; Hale et al., 2020; Henderson and Green, 2020). Several mitigation strategies that have been suggested to be effective in curbing the menace of MPs through recycling include the physical, chemical and biological treatments (Fig. 5) (Singh and Pant, 2016; Jaiswal et al., 2020; Amobonye et al., 2022).

Al-Salem et al. (2009) stated that pulverization and grinding of MPs to minimal waste size is an effective physical method that degrades polymers and prepare them for more treatment. Other important physical treatment methods include thermal degradation and photooxidation

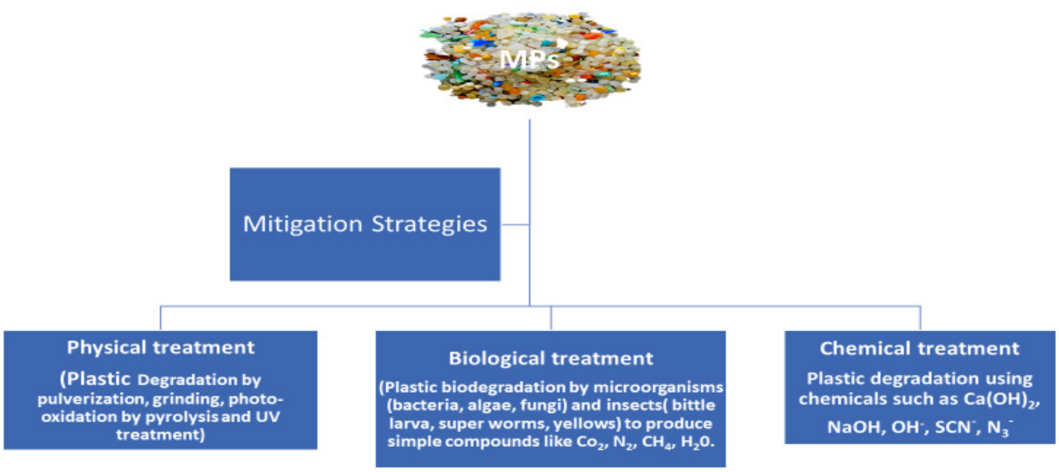

Fig. 5. Plastic degradation via different treatment techniques

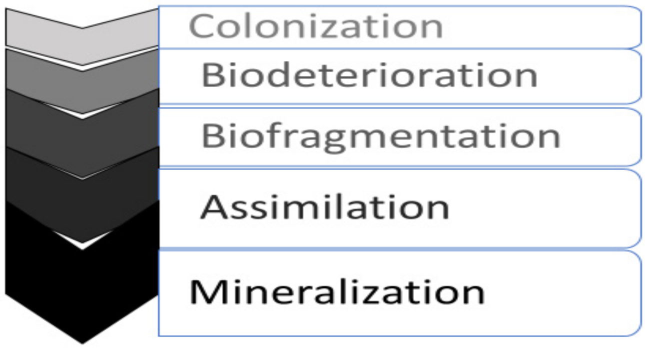

Fig. 6. Biodegradation progressions of plastics by microorganism

via ultraviolet (UV) treatment technique (Moharir and Kumar, 2019; Amobonye et al., 2022). Plastics such as PVC polymers are speedily degraded via photooxidation (exposure to sunlight and UV radiation), which can break up the strong bond characteristically exhibited by PVC polymers (Amobonye et al., 2022). Thermal treatment (burning, combustion, pyrolysis) is also a conventional method of plastic degradation, but may be hazardous due to the emission of toxic gases and other harmful by-products like furans, dioxins, sulfides and heavy metals, which poses threat to environment and diverse forms of life including humans (Moharir and Kumar, 2019; Vollmer et al., 2020; Thind et al., 2021). The use of dynamic membranes (Li et al., 2018b) and advanced filtration techniques (Rume and Islam 2020; Padervand et al., 2020; Iyare et al., 2021) have also been efficient in MPs treatment. Yuan et al. (2020), in their study modeled the adsorption of polystyrene MPs by three-dimensional reduced graphene oxide (3-D RGO) sheets. However, with this particular technique, the maximum adsorption capability of the 3-D RGO is a function of the solution pH, temperature, initial concentration of micropollutants and ions in the solution, and adsorption time (Abuwatfa et al., 2021). Ragossnig and Agamuthu (2021) envisioned the Near Infra-Red (NIR) sorting and recycling.

Degradation of MPs via biological means (using microorganisms) is the most efficient and cost-effective technique for MPs waste recycling with no obnoxious environmental consequence or threat to ecosystems (Kumar et al., 2019; Peng et al., 2020; Amobonye et al., 2022). MPs materials are biodegraded using different microorganisms (Insect, larva, algae, enzymes, bacteria, fungi) capable of converting plastic polymers into simple non-toxic compounds such as carbon dioxide, nitrogen, methane and water (Jaiswal et al., 2020; Peng et al., 2020; Ali et al., 2021). The depolymerization of plastic polymer is made possible by the gut microbiome which degrade and subsequently mineralize polymers to produce monomeric compounds (Amobonye et al., 2022). Digestibility of plastics by insects particularly at the larva stage is related to their ability to degrade and metabolize lignin-based molecules (Wertz and Bechade, 2020).

The biological method is one of recent achievement in MPs waste management, believed to stimulate more research and biotechnological applications regarding safer protocols on plastic waste management and recycling. Several plastic-eating insects have been reported to include wax moth (*Galleria mellonella*) (Cassone et al., 2020), waxworms (*Achroia grisella*) (Brandon, 2018) (superworms (*Zophobas morio*) (Yang et al., 2021), yellow mealworms (*Tenebrio molitor*) (Yang and Wu, 2020), giant mealworms (*Zophobas atratus*) (Xu et al., 2020). Bozek et al. (2017) in their study confirmed that yellow mealworms degraded PS, PVC and polylactide (PLA) polymers within twenty-one days of feeding trial. Biodegradation of MPs by microorganisms follow several biochemical progressions such as colonization, biodeterioration, biofragmentation, assimilation and mineralization (Fig 6) (Ganesh Kumar et al. 2020; Amobonye et al., 2020;

Ali et al., 2021; Taghavi et al., 2021). In the very first biodegradation process (colonization), microorganisms are deployed on the surface of plastics. The microorganisms adhere to plastic surface and agglomerate to create biofilm, causing damage to the plastic surface (Taghavi et al., 2021; Ali et al., 2021). Biodeterioration of plastics can occur through the chemical and biological actions of microorganisms (Amobonye et al., 2020). This is achieved by altering the physico-chemical characteristics of plastic polymers (Ganesh Kumar et al., 2020; Amobonye et al., 2022), thus aided by environmental situations such as temperature, light and chemo-oxidation, hence expanding the pores and allowing aging (Ali et al., 2021). In a progressive manner (biofragmentation), the microorganisms (bacteria) further dissolve the polymers into monomers and dimers, by synthesizing specific enzymes known as hydrolases and oxidoreductases (Peng et al., 2020). Other plastic-degrading enzymes have been reported to include lipases, peroxidase, hydroxylases, monooxygenase, laccases, esterase (Kawai et al., 2019; Othman et al., 2021). The chief functions of these enzymes are to significantly decrease the molecular weight of the polymers and further engage in the peroxidation of reduced molecules (Restrepo-Florez et al., 2014). Following the enzymatic depolymerization of polymer plastics into monomers, the microorganisms assimilate and mineralize them to produce non-hazardous metabolites like carbon dioxide, methane, nitrogen, water (Ho et al., 2018; Amobonye et al., 2022) which are reabsorbed into several biochemical cycles. Several bacterial strains have been reported to efficiently degrade plastic polymers. These bacteria include *Acanthopleuribacter pedis, Bacilus cereus, Pseudomonas otitidis* (Sah et al., 2011), *P. citronellolis, B. flexus* (Giacomucci et al., 2019), *Clostrdium sp*. and *Acetobacterium sp*. (Giacomucci et al., 2020). Interestingly, fungi have been found to play a prominent role biodegradation of plastics, of which can serve as their energy (carbon) sources (Ali et al., 2021; Amobonye et al., 2022). According to Amobonye et al. (2022), fungi are able to degrade plastic polymers attributing to their capacity to form mycelial network that assist in the anchorage and permeation of fungi to polymer surface and further commence depolymerization process. Several fungal sp. has been reported to efficiently degrade plastic polymers like the *Mucor rouxii,* (Singh and Pant, 2016) *Aspergillus niger, A. sydowii,* and *Lentinus tigrinus* (Ali et al., 2014).

Degradation of plastic polymers via chemical treatment has been reported to be effective method of plastic recycling (Rajmohan et al., 2019; Moharri and Kumar, 2019; Thind et al., 2021). This involves the use of chemicals such as sodium hydroxide, calcium hydroxide, oxides and nitrite to disrupt the polymeric chains and alter polymers to non-hazards (Amobonye et al., 2022). According to Moharir and Kumar (2019), these chemicals modify the form and structure of plastic polymers, leading to reduced molecular weight and surface breakdown, which is culpable for their aging.

CONCLUSION

COVID-19 reshaped world activity and its post-effect is continuing due to variations in the managerial ability of different countries. The major challenge associated with COVID-19 is the management of both solid (PPEs) and biomedical (effluent) wastes which are potential pathways of MPs in the environment, following indiscriminate waste disposal. The mismanagement of these wastes could further raise concerns regarding their impact on the environment particularly the aquatic ecosystem perceived to be a potential destination of waste materials from different ecological systems. Large diversities of aquatic biota are affected consequent to the ingestion, bioavailability, and bioaccumulation of COVID-related MPs. This study showed that humans are the culprit and also victims of the ecotoxicological impact of MPs as it relates to the consumption of aquatic food products contaminated with MPs. It is advocated that more awareness on COVID-19 as it relates to mitigation and coping strategies is needed to protect the environment and humans from further harm.

RECOMMENDATION

Despite the success recorded so far, there is still much to be done to reduce the plastic load exacerbated by COVID-19-related waste materials, even as the pandemic's effects and the number of cases worldwide continue to decline. As a matter of fact, plastic or MP pollution mitigation should be viewed from a multidisciplinary approach requiring global participation in other to make headway (Mallik et al., 2021). Undoubtedly heightened by the unprecedented increase in the production of COVID-19-related materials globally and improper disposal across different land and water sites; it may appear difficult to completely eradicate plastics from the aquatic environment (Sharma et al., 2021). However, as it has been observed that most MPs in the aquatic ecosystem come from land sources. Consequently, more attention needs to be given to MP pollution in the terrestrial environment and inland aquatic bodies (Horton et al., 2017a, b). No doubt that reduced waste litter of plastic origin and proper waste management practices can potentially restore the ocean environment to its normal functional range (Hartmann et al., 2019). Ragossnig and Agamuthu (2021) suggested an integrated plastic management approach including reducing, recycling, reusing, and recovering the plastic debris and hindering the plastic from entering the ocean. Dissanayake et al. (2021) opined that proper solid waste management policies should be implemented at a global scale to prevent PPEs, and other single-use plastics from reaching and consequently polluting the aquatic or soil ecosystems.

In furtherance of the highlighted recommendations, more studies are required to identify and isolate more microorganisms (strains of cyanobacteria, insects, algae) that can degrade plastic polymers in order to encourage organic means (green energy) and nonhazardous procedures for plastic degradation, order than the toxic popular methods (thermal treatment) of plastic waste recycling that pollutes the environment. Notwithstanding the progress made so far on the biodegradation techniques and mechanisms of microbial action, there is scare scientific information regarding specific microbes and enzymes responsible for plastic polymer degradation like PVC (Amobonye et al. 2022), to exploit more microbial species and advance knowledge on biodegradation of plastics. Sophisticated biotechnological application such as genetic engineering procedures can be very helpful to advance the efficacy of existing microbes to degrade plastics.

GRANT SUPPORT DETAILS

The present research has been financially supported by African-German Network of Excellence in Science (AGNES) foundation, in partnership with the Alexander von Humboldt (AvH) Foundation and the German Federal Ministry of Education and Research (BMBF).

CONFLICT OF INTEREST

The authors declare that there is not any conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy has been completely observed by the authors.

LIFE SCIENCE REPORTING

No life science threat was practiced in this research.

ACKNOWLEDGMENT

Authors are also thankful to SS&T Consultancy LTD, their **Research Masterclass C1 that prepared our team to put this review together** and for providing academic/editorial services.

REFERENCES

Abuwatfa, W. H., Al-Muqbel, D., Al-Othman, A., Halalsheh, N. and Tawalbeh, M. (2021). Insights into the removal of microplastics from water using biochar in the era of COVID-19: A mini review. Case Stud. Chem. Environ. Eng., 4: 100151.

Ahmadi, M., Sharifi, A., Shadi, D., Jafarzadeh, G.S. and Negar, G. (2020). Investigation of effective climatology parameters on COVID19 outbreak in Iran. Sci. Tot. Environ.,729, 138705.

Ali, M. I., Ahmed, S., Robson, G., Javed, I., Ali, N., Atiq, N. and Hameed, A. (2014). Isolation and molecular characterization of polyvinyl chloride (PVC) plastic degrading fungal isolates. J. Basic Microbiol., 54(1), 18e27. https://doi.org/10.1002/jobm.201200496

Ali, S. S., Elsamahy, T., Koutra, E., Kornaros, M., El-Sheekh, M., Abdelkarim, E. A., Zhu, D. and Sun, J. (2021). Degradation of conventional plastic wastes in the environment: A review on current status of knowledge and future perspectives of disposal. Sci. Tot. Environ. https://doi.org/10.1016/j.scitotenv.2020.144719

Alimi, O.S., Fadare, O.O. and Okoffo, E.D. (2021). Microplastics in African ecosystems: current knowledge, abundance, associated contaminants, techniques, and research needs. Sci. Tot. Environ., 755:142422. https://doi.org/10.1016/j.scitotenv.2020.142422

Al-Salem, S. M., Lettieri, P. and Baeyens, J. (2009). Recycling and recovery routes of plastic solid waste (PSW): A review. Waste Mgt., 29(10), 2625e2643. https://doi.org/10.1016/j.wasman.2009.06.004

Ammendolia, J., Saturno, J., Brooks, A.L., Jacobs, S. and Jambeck, J.R. (2021). An emerging source of plastic pollution: environmental presence of plastic personal protective equipment (PPE) debris related to COVID-19 in a metropolitan city. Environ. Poll., 269:116160.

Amobonye, A., Bhagwat, P., Singh, S. and Pillai, S. (2020). Plastic biodegradation: Frontline microbes and their enzymes (p. 759). Sci. Tot. Environ., 759, 143536.

Amobonye, A.E., Bhagwat, P., Singh, S. and Pillai, S., (2022). Biodegradability of polyvinyl chloride in Biodegradability of conventional plastics.pp.201-214), Elsevier https://doi.org/10.1016/B978-0-323-89858-4.00017-8.

Ansari, M., Ehrampoush, M. H., Farzadkia, M., Ahmadi, E. (2019). Dynamic assessment of economic and environmental performance index and generation, composition, environmental and human health risks of hospital solid waste in developing countries; A state of the art of review. Environ Inter., 132, 105073.

Aragaw, T.A. (2020). Surgical face masks as a potential source for microplastic pollution in the COVID-19 scenario. Mar. Pollut. Bull. 159, 111517. https://doi.org/10.1016/ j.marpolbul.2020.111517.

Ardusso, M.,, Forero-López A.D., Buzzi, N.S., Spetter, C.V. and Fernández- Severini, M.D. (2021). COVID-19 pandemic repercussions on plastic and antiviral polymeric textile causing pollution on beaches and coasts of South America. Sci. Tot. Environ., 763:144365.

Asadi-Bouvier, N., Wexler, A.S. and Ristenpart, W.D. (2020). The coronavirus pandemic and aerosols: Does COVID-19 transmit via expiratory particles? Aerosol Sci. Tech., 54, 6: 635-638.

Asim, Badiei, M. and Sopian, K. (2021). Review of the valorisation options for the proper disposal of face masks during the COVID-19 pandemic. Environ. Technol. Innov., 23, 101797.

Auta, H. S., Emenike, C. U., and Fauziah, S. H. (2017). Distribution and importance of microplastics in the marine environment: a review of the sources, fate, effects, and potential solutions. Environ. Inter.,102, 165-176.

Babaahmadi, V., Hooman Amid, H., Naeimirad, M. and Ramakrishna, S. (2021). Biodegradable and multifunctional surgical face masks: A brief review on demands during COVID-19 pandemic, recent developments, and future perspectives. Sci. Tot. Environ., 798 (2021) 149233 https://doi.org/10.1016/j.scitotenv.2021.149233

Bellas, J., Martínez-Armental, J., Martínez-Cámara, A., Besada, V. and Martínez-Gómez, C. (2016). Ingestion of microplastics by demersal fish from the Spanish Atlantic and Mediterranean coasts. Mar. Poll. Bull., 109(1), 55-60.

Benson, N. U., Fred-Ahmadu, O. H., Bassey, D. E. and Atayero, A. A. (2021). COVID-19 pandemic and emerging plastic-based personal protective equipment waste pollution and management in Africa. J. Environ. Chem. Eng., 9(3), 105222.

Beringui, K., Justo, E.P.S., Falco, A.D., Santa-Helena E., Rocha, W.F.C., Deroubaix, A. and Gioda A. (2022). Assessment of air quality changes during COVID-19 partial lockdown in a Brazilian metropolis: from lockdown to economic opening of Rio de Janeoro, Brazil. Air Quality, Atm. Health, 15, 1205-

1220.

Bhuyan, M. (2022). Effects of Microplastics on Fish and in Human Health. Front. Environ., Sci., 250. https://doi.org/10.3389/fenvs.2022.827289.

Bilal Bashir, M.F., Benghoul, M., Numan, U., Shakoor, A., Komal, B., Bashir, M.A., Bashir, M. and Tan, D. (2020). Environmental pollution and COVID-19 outbreak: insights from Germany. Air Quality, Atmo Health, 13, 1385–1394.

Bisht, V.S. and Negi, D. (2020). Microplastics in aquatic ecosystem: Sources, trophic transfer and implications. Int. J. Fish. Aquat. Stud. 8, 227–234.

Brandon, A.M., Gao, S-H., Ning, D., Yang, S.S., Zhou, J., Wu, W.M. and Criddle, C.S. (2018). Biodegradation of polyethylene and plastic mixtures in mealworms (larvae of Tenebrio molitor) and effects on the gut microbiome. Environ. Sci. Technol., 52, 6526-6533.

Briassoulis, D., Aristopoulou, A., Bonora, M. and Verlodt, I. (2004). Degradation characterization of agricultural low-density polyethylene films. Biosyst. Eng, 88(2), 131-143.

Browne, M. A., Crump, P., Niven, S. J., Teuten, E., Tonkin, A., Galloway, T. and Thompson, R. (2011). Accumulation of microplastic on shorelines worldwide: sources and sinks. Environ. Sci. Technol., 45(21), 9175-9179.

Bruce, N., Hartline, N., Karba, S., Ruff, B., Sonar, S. and Holden, P. (2016). Microfiber pollution and the apparel industry. University of California Santa Barbara, Bren School of Environmental Science & Management (accessed 19 Aug 2016) http://brenmicroplastics. weebly. com/ uploads/5/1/7/0/51702815/bren-patagonia_final_report. pdf.

Campanale, C., Massarelli, C., Savino, I., Locaputo, V. and Uricchio, V.F. (2020). *"A Detailed Review Study on Potential Effects of Microplastics and Additives of Concern on Human Health"*. pdf. Int. J. Environ. Res. Public Health (2020); 17(4), 1212.

Canning-Clode, J., Sepulveda, P., Almeida, S. and Monteriro, J., (2020). Will COVID-19 containment and treatment measures drive shifts in marine litter pollution? Front. Mar. Sci. ,7:691.

CarbonBrief (2020). As China Battles One of the Most Serious Virus Epidemics of the Century, the Impacts on the Country's Energy Demand and Emissions Are Only Beginning to Be Felt.

Carney Almroth, B. M., Åström, L., Roslund, S., Petersson, H., Johansson, M., and Persson, N. K. (2018). Quantifying shedding of synthetic fibers from textiles; a source of microplastics released into the environment. Environ. Sci. Poll. Res., 25(2), 1191-1199.

Cascella, M., Rajnik, M. Aleem, A. Dulebohn, S.C. and Napoli, R. (2022). Features, Evaluation and Treatment of Coronavirus (COVID-19). In: StatPearls [Internet]. StatPearls Publishing: Treasure Island (FL)

Cassone, B.J., Grove, H.C., Elebute, O., Villanueva, S.M.P. and LeMoine, C.M.R. (2020). Role of the intestinal microbiome in low-density polyethylene degradation by caterpillar larvae of the greater wax moth, *Galleria mellonella*. Proc. R. Soc. B., 287:20200112.

Chakraborty, I. and Maity, P. (2020). COVID-19 outbreak: Migration, effects on society, global environment and prevention. Sci Tot. Environ., 234, 138882.

Chaukura, N., Kefeni, K. K., Chikurunhe, I., Nyambiya, I., Gwenzi, W., Moyo, W., Nkambule, T. I., Mamba, B. B. and Abulude, F. O. (2021). Microplastics in the aquatic environment—the occurrence, sources, ecological impacts, fate, and remediation challenges. Pollut.,1(2), 95-118.

Chen, X., Chen, X., Liu, Q., Zhao, Q., Xiong, X. and Wu, C. (2021). Used disposable face masks are significant sources of microplastics to environment. Environ. Poll., 285, 117485.

Ciotti, M., Angeletti, S., Minieri, M., Giovannetti, M., Benvenuto, D., Pascarella, S., Sagnelli, C., Bianchi, M., Bernardini, S. and Ciccozzi, M., (2019). COVID-19 outbreak: an overview. Chemotherapy, 215-223.

Coccia, M. (2020). Factors determining the diffusion of COVID-19 and suggested strategy to prevent future accelerated viral infectivity similar to COVID. Sci. Tot. Environ., 729: 138474

Cole, M., Lindeque, P., Halsband, C. and Galloway, T.S. (2011). *"Microplastics as Contaminants in Marine Environment: A Review"*. Mar. Poll. Bull. 62(2011): 2588-2597.

Cole, M., Lindeque, P., Fileman E et al (2015). The impact of polystyrene microplastics on feeding, function and fecundity in the marine copepod Calanus helgolandicus. Environ. Sci. Technol., 49:1130–1137. https://doi.org/10.1021/es504525u

Conkle J. L., Báez Del Valle, C. D. and Turner, J. W. (2017). *"Are We Underestimating Microplastic Contamination in Aquatic Environments?"*. pdf. Journal of Env. Mgt.

Dai, C. (2020). *"The Disruptive Effects of COVID-19 on the Aviation Industry, Food Industry, and*

E-commerce Industry". Advances in Economics, Business and Management Research, vol. 155., 45P.

Das, K. P., Sharma, D., Saha, S. and Satapathy, B. K. (2021). From outbreak of COVID-19 to launching of vaccination drive: invigorating single-use plastics, mitigation strategies, and way forward. Environ. Sci. Poll. Res., 28: 55811-55845.

del Hombre Bueno, B. R., de los Ángeles, M., Boluda-Botella, N. and Prats Rico, D. (2019). Removal of emerging pollutants in water treatment plants: adsorption of methyl and propylparaben onto powdered activated carbon. Adsorption, 25(5), 983-999.

de Sousa, F.D.B. (2021). Plastic and its consequences during the COVID-19 pandemic. Environ Sci Poll. Res., 28, 46067–46078. https://doi.org/10.1007/s11356-021-15425-w

de Souza Machado, A.A., Kloas, W., Zarfl, C., Hempel, S. and Rillig, M.C. (2018). Microplastics as an emerging threat to terrestrial ecosystems. Glob. Chang. Biol. 24, 1405–1416. https://doi.org/10.1111/gcb.14020.

De-la-Torre, G.E., Rakib, M.D., Jahan, R., Pizarro-Ortega, C.I. and Dioses-Salinas, D.C. (2021). Occurrence of personal protective equipment (PPE) associated with the COVID-19 pandemic along the coast of Lima, Peru. Sci. Tot. Environ., 774: 145774.

De-la-Torre, G. E. (2020). Microplastics: an emerging threat to food security and human health. J. food Sci. Technol., 57(5), 1601-1608.

De-la-Torre, G.E. and Aragaw, T.A. (2021). What we need to know about PPE associated with the COVID-19 pandemic in the marine environment. Mar. Poll. Bull., 163, 111879

Dissanayake, J., Torres-Quiroz, C., Mahato, J., and Park, J. (2021). Facemasks: a looming microplastic crisis. Inter. J. Environ. Res. Pub. Health, 18(13), 7068.

Doremalen, N., Bushmaker, T., Morris, D. H., Holbrook, M.G., Gamble, A., Williamson, B.N., Tamin, A., Harcourt, J.L., Thornburg, N.J., Gerber, S.I., Lioyd-Smith, J.O., Wit, E. and Munster, V.J. (2020). Aerosol and Stability of HCoV-19 (SARS-CoV-2) Compared to SARS-CoV-1. N Eng. J. Med., 382:1564-1567.

Dutheil F., Baker, J.S. and Navel, V. (2020). COVID-19 as a factor influencing air pollution? Environ. Poll., 263, 114466.

El-Ramady, H., Brevik, E.C., Amer, M., Elsakhawy, T., Omara, A.E, Elbasiouny, H., Mosa A.A., El-Ghamry A., Bayoumi Y. and Shalaby T.A. (2020). Soil and air pollution in the era of COVID-19: A global Issue. Egypt J. Soil Sci., 60 (4): 437-448.

Elsaida, K., Olabib, V., Sayed, E. T., Wilberforce, T. and Abdelkareem, M. A. (2021). *"Effects of COVID-19 on the Environment: An Overview on Air, Water, Wastewater, and Solid Waste"*. J. Environ. Mgt., 292, 112694.

Eerkes-Medrano, D., Thompson, R. C., and Aldridge, D. C. (2015). Microplastics in freshwater systems: a review of the emerging threats, identification of knowledge gaps and prioritization of research needs. Water Res., 75, 63-82.

European Environment Agency (EEA) (2022). COVID-19: lessons for sustainability? PDF. Retrieved from https://www.eea.europa.eu/publications/COVID-19-lessons-for-sustainability

Fadare, O. O. and Okoffo, E. D. (2020). Covid-19 face masks: A potential source of microplastic fibers in the environment. Sci. Tot. Environ., 737, 140279.

Galloway, T.S., Cole, M. and Lewis, C. (2017) Interactions ofmicroplastic debris throughout the marine ecosystem. Nat Ecol. Evol., 1:0116. https://doi.org/10.1038/s41559-017-0116

Ganesh Kumar, A., Anjana, K., Hinduja, M., Sujitha, K. and Dharani, G. (2020). Review on plastic wastes in marine environment, Biodegradation and biotechnological solutions. Mar. Poll. Bull., 150, 110733.

GESAMP (2015). Sources, fate and effects of microplastics in the marine environnement : a global assessment (GESAMP).

Gharde, S. and Kandasubramanian, B. (2019) Mechanothermal and chemical recycling methodologies for the Fibre Reinforced Plastic (FRP). Environ. Technol. Innov., 14:100311. https://doi.org/10.1016/j.eti.2019.01.005

Ghahremanloo, M., Lops, Y., Choi, Y. and Mousavinezhad, S. (2021). Impact of the COVID-19 outbreak on air pollution levels in East Asia. Sci. Tot. Environ., 754, 142226.

Gomiero A, Strafella P, Pellini G, Salvalaggio V and Fabi G (2018) Comparative Effects of Ingested PVC Micro Particles with and Without Adsorbed Benzo(a)pyrene vs. Spiked Sediments on the Cellular and Sub Cellular Processes of the Benthic Organism *Hediste diversicolor*. Front. Mar. Sci. 5:99. doi:

10.3389/fmars.2018.00099

Giacomucci, L., Raddadi, N., Soccio, M., Lotti, N. and Fava, F. (2019). Polyvinyl chloride biodegradation by *Pseudomonas citronellolis* and *Bacillus flexus.* New Biotechnol., 52, 35e41. https://doi.org/10.1016/j.nbt.2019.04.005

Giacomucci, L., Raddadi, N., Soccio, M., Lotti, N. and Fava, F. (2020). Biodegradation of polyvinyl chloride plastic films by enriched anaerobic marine consortia. Mar. Environ. Res., 158. https://doi.org/ 10.1016/j.marenvres.2020.104949

Gore, P.M. and Dhanshetty, M. K. B. (2016). Bionic creation of nano-engineered Janus fabric for selective oil/organic solvent absorption. RSC Adv., 6: 111250–111260. https://doi.org/10.1039/C6RA24106A

Guzzetti E., Sureda A., Tejeda S., andFaggio C. (2018). "Microplastic in Marine Organism: Environment and Toxicological Effects." Environ. Toxicol. Pharmacol. 64:164-171. Doi: 10.1016/j.etap.2018.10.009

Hale, R. C., Seeley, M. E., La Guardia, M. J., Mai, L. and Zeng, E. Y. (2020). A global perspective on microplastics. J. Geophys. Res. Oceans,125(1), e2018JC014719.

Han, J. and He, S. (2021). Need for assessing the inhalation of micro(nano)plastic debris shed from masks, respirators, and home-made face coverings during the COVID-19 pandemic. Environ. Poll., 268, 115728.

Haque, S., Sharif, S., Masnoon, A. and Rashid, E. (2021). SARS-CoV-2 pandemic-induced PPE and single-use plastic waste generation scenario. The J. Sustain. Cir. Econs., https://doi.org/10.1177/0734242X20980828.

Hart, O. E. and Halden, R.U. (2020). "Computational Analysis of SARS-CoV-2/COVID-19 Surveillance by wastewater-based epidemiology locally and globally; feasibility, economy, opportunities and Challenges. Sci. Tot. Environ., 730, 138875.

Hartmann, N.B., Hüffer, T., Thompson, R.C., Hassellöv, M., Verschoor, A., Daugaard, A.E., Rist, S., Karlsson, T., Brennholt, N. and Cole, M. (2019). Are We Speaking the Same Language? Recommendations for a Definition and Categorization Framework for Plastic Debris. ACS Publications.

Hashim, B.M., Al-Naseri, S.K., Al-Maliki, A. and Al-Ansari, N., (2021). Impact of COVID-19 lockdown on NO_2, O_3, $PM_{2.5}$ and PM_{10} concentrations and assessing air quality changes in Baghdad, Iraq. Sci. Tot Environ. 754, 141978.

Henderson, L. and Green, C. (2020). Making sense of microplastics? Public understandings of plastic pollution. Mar. Poll. Bull., *152*, 110908.

Hermabessiere, L., Dehaut A., Paul-Pont I., Lacroix c., Jezequel R., Soudant P. and Duflos G., (2017). *"Occurrence and Effects of Plastic Additives on Marine Environments and Organisms: A Review"*. Chemos., 182:781-793.

Hernandez, L.M., Yousefi, N. and Tufenkji, N. (2017). Are there nanoplastics in your personal care products? Environ. Sci. Technol. Lett., 4 (7),280–285. https://doi.org/10.1021/acs.estlett.7b00187.

Hernandez, L.M., Xu, E.G., Larsson, H.C.E., Tahara, R., Maisuria, V.B. and Tufenkji, N. (2019). Plastic teabags release billions of microparticles and nanoparticles into tea. Environ. Sci. Technol., 53, 12300–12310. https://doi.org/10.1021/acs.est.9b02540

Horton, A.A., Svendsen, C., Williams, R.J., Spurgeon, D.J. and Lahive, E. (2017a). Large microplastic particles in sediments of tributaries of the River Thames, UK–abundance, sources and methods for effective quantification. Mar. Poll. Bull., 114(1), 218–226.

Horton, A.A., Walton, A., Spurgeon, D.J., Lahive, E. and Svendsen, C., (2017b.) Microplastics in freshwater and terrestrial environments: evaluating the current understanding to identify the knowledge gaps and future research priorities. Sci. Tot Environ., 586, 127-141.

Hui, D.S., Azhar, E., Madani, T.A., Ntoumi, F., Kock R. and Dar O. (2020). *"The Continuing 2019-nCoVepidermic Threat of Novel Coronaviruses to global Health-The Latest 2019 Novel coronavirus `outbreaking Wuhan, China"*. Int. J. Infect. Dis., 91:264-266.

Iheanacho, S. C. and Odo, G. E. (2020a). Neurotoxicity, oxidative stress biomarkers and haematological responses in African catfish (*Clarias* gariepinus) exposed to polyvinyl chloride microparticles. Comp. Biochem. Physiol. Part C: Toxicol &Pharmacol, 232, 108741.

Iheanacho, S. C. and Odo, G. E. (2020b). Dietary exposure to polyvinyl chloride microparticles induced oxidative stress and hepatic damage in *Clarias gariepinus* (Burchell, 1822). Environ. Sci. Poll. Res., 27(17), 21159-21173.

Iheanacho, S. C., Igberi, C., Amadi-Eke, A., Chinonyerem, D., Iheanacho, A. and Avwemoya, F. (2020c).

Biomarkers of neurotoxicity, oxidative stress, hepatotoxicity and lipid peroxidation in *Clarias gariepinus* exposed to melamine and polyvinyl chloride. Biomark., 25(7), 603-610.

Iheanacho, S.C., Odo, G.E. and Ezewudo, B.I. (2021). Adulteration of Aquafeed with melamine and melamine-formaldehyde chemicals; Ex situ study of impact on hematology and antioxidant systems in *Clarias gariepinus*. Aquacult. Res., 52:2078–2084. https://doi.org/10.1111/are.15059

Iheanacho, S.C., Adeolu, A.I., Nwose, R., Ekpenyong, J., Offu, P., Amadi-Eke, A, ... Ogunji, J. (2021). Genotoxicity, oxidative stress and lysozyme induction in *Clarias gariepinus* chronically exposed to water-soluble fraction of burnt tire ash. Ecotoxicol., 30(10), 1983-1996.

Iheanacho, SC, Ekpenyong, J, Nwose, R, Adeolu, AI, Offu, P, Amadi-Eke, A, ... Ogunji, J. (2022). Effects of burnt tire-ash on Na+/K+, Ca2+-ATPase, serum immunoglobulin and brain acetylcholinesterase activities in *Clarias gariepinus* (Burchell, 1822). Drug Chem. Toxicol., https://doi.org.10.1080/01480545.2022.2061987

Iqbal, S., Xu J., Allen, S.D., Khan, S., Nadir, S., Arif, M.S. and Yasmeen, T. (2020). Unraveling consequences of soil micro- and nano-plastic pollution on soil-plant system: Implications for nitrogen (N) cycling and soil microbial activity. Chemos., 260, 127578.

Issac, M.N. and Kandasubramanian, B. (2021). Effect of microplastics on water and aquatic systems. Environ. Sci. Poll. Res., 28:19544–19562.

Iyare, P. U., Ouki, S. K. and Bond, T. (2020). Microplastics removal in wastewater treatment plants: a critical review. *Environmental Science:* Water Res. Technol., 6(10), 2664-2675.

Jaiswal, S., Sharma, B. and Shukla, P. (2020). Integrated approaches in microbial degradation of plastics. Environ. Technol. Innov., 17. https://doi.org/10.1016/j.eti.2019.10056

Jemec, A., Horvat, P., Kunej, U., Bele, M. and Kržan, A. (2016). Uptake and effects of microplastic textile fibers on freshwater crustacean Daphnia magna. Environ. Poll., 219, 201-209.

Jribi, S.; Ismail, H.B.; Doggui, D.; Debbabi, H. (2020). COVID-19 virus outbreak lockdown: What impacts on household food wastage?Environ. Dev. Sustain., 22, 3939–3955.

Ju, MJ., Oh, J. and Choi, Y-H. (2021). Changes in air pollution levels after COVID-19 outbreak in Korea. Sci. Tot. Environ., 750, 141521.

Kanniah, K.D., Zaman, N.A.F. K., Kaskaoutis, D.G. and Latif, M.T. (2020). COVID-19's impact on the atomospheric environment in the Southern Asia region. Sci Tot. Environ., 736, 139658.

Kawai, F., Kawabata, T. and Oda, M. (2019). Current knowledge on enzymatic PET degradation and its possible application to waste stream management and other fields. Appl. Microbiol. Biotechnol., 103(11), 4253e4268. https://doi.org/10.1007/s00253-019-09717-y

Kavya, N.V.L.A., Sundarrajan, S. and Ramakrishna, S. (2020). Identification and characterization of micro-plastics in the marine environment: a mini review. Mar. Poll. Bull. 160, 111704 https://doi.org/10.1016/j.marpolbul.2020.111704.

Kelly, M.R., Lant, N.J., Kurr, M. and Burgess, J.G. (2019). Importance of water-volume on the release of microplastic fibers from laundry. Environ. Sci. Tech., 53, 20, 11735-11744.

Kicinska, A., Pomykala, R. and Izquierdo-Diaz, M. (2022). "Changes in Soil pH and Mobility of Heavy Metals in Contaminated Soils". Wiley. Euro. J. Soil Sci., 73(1): e13203.

Kim, S., Jeong, Y.D., Byun, H., Cho, G., Park, A., Jung J.H. et al. (2020). Evaluation of COVID-19 epidemic outbreak caused by temporal contact-increase in South Korea. Int J Infect. Dis., 96, 454-457.

Klemes, J.J., Van Fan, Y., Tan, R.R. and Jiang, P. (220). Minimizing the present and future plastic waste, energy and environmental footprints related to COVID-19. Renew., Sustain. Energy Rev., 127, 109883.

Kumar, S. (2019). Recent developments of bio-based plasticizers and their effect on mechanical and thermal properties of poly(vinyl chloride): A review. Indust. Eng. Chem. Res., 58(27), 11659e11672. https://doi.org/10.1021/acs.iecr.9b02080

Kumar, S., Getirana, A., Libonati, R., Hain, C., Mahanama, S. and Andela, N., (2022). Changes in land use enhance the sensitivity of tropical ecosystems to fire-climate extremes. Sci rep., 12, 964.

Kutralam-Muniasamy, G., Pérez-Guevara, F. and Shruti, V. C. (2022). A critical synthesis of current peer-reviewed literature on the environmental and human health impacts of COVID-19 PPE litter: new findings and next steps. J. Haz. Mater., 422, 126945.

Lai, M. M. and Cavanagh, D. (1997). The molecular biology of coronaviruses. Adv.Virus Res., 1-100.

Lal, R. (2020). Home gardening and urban agriculture for advancing food and nutritional security in response to the COVID-19 pandemic. Food Security, 12, 871- 876.

Lambert, S., Sinclair, C. J., Bradley, E. L. and Boxall, A. B. (2013). Environmental fate of processed natural rubber latex. Environ. Sci.: Processes and Impacts, 15(7), 1359-1368.

Li, L., Xu, G., Yu, H. and Xing, J. (2018b) Dynamic membrane for micro-particle removal in wastewater treatment: performance and influencing factors. Sci. Tot. Environ., 627:332–340.

Li, D., Shi, Y., Yang, L., Xiao, L., Kehoe, D. K., Gun'ko, Y. K., land, J.J. and Wang, J. J. (2020). Microplastic release from the degradation of polypropylene feeding bottles during infant formula preparation. Natr. food, 1(11), 746-754.

Liu, Y., Jia, X., Zhu, H., Zhang, Q., He, Y., Shen, Y., Xu, X. and Li, J. (2022). The effects of exposure to microplastics on grass carp (*Ctenopharyngodon idella*) at the physiological, biochemical, and transcriptomic levels. Chemos, 286, 131831.

Liu, Y., Zhang, J., Tang, Y., He, Y., Li, Y., You, J., Breider, F., Tao, S. and Liu, W. (2021). Effects of anthropogenic discharge and hydraulic deposition on the distribution and accumulation of microplastics in surface sediments of a typical seagoing river: the Haihe River. J. Haz. Mater., 404, 124180.

Lo, H.K.A. and Chan, K.Y.K. (2018). Negative effects of microplastic exposure on growth and development of *Crepidula onyx*. Environ. Poll., 233: 588–595. https://doi.org/10.1016/j.envpol.2017.10.095

Lu, L., Wan, Z., Luo, T., Fu, Z. and Jin, Y. (2020). Polystyrene microplastics induce gut microbiota dysbiosis and hepatic lipid metabolism disorder in mice. Sci. Tot. Environ, 631, 449-458.

Lu, Y., Zhang, Y., Deng, Y., Jiang, W., Zhao, Y., Geng, J., Ding, L. and Ren, H. (2016). Uptake and accumulation of polystyrene microplastics in zebrafish (*Danio rerio*) and toxic effects in liver. Environ. Sci.Technol., 50(7), 4054-4060.

Ma, J., Chen, F., Xu, H., Jiang, H., Liu, J., Li, P., Chen, C.C. and Pan K. (2021). Face masks as a source of nanoplastics and microplastics in the environment: Quantification, characterization, and potential for bioaccumulation. Environ. Poll., 288, 117748.

Magnusson, K., Eliaeson, K., Fråne, A., Haikonen, K., Olshammar, M., Stadmark, J. and Hultén, J. (2016). Swedish sources and pathways for microplastics to the marine environment: microplastic particles in sediments of tributaries of the River Thames, UK–abundance, sources and methods for effective quantification. Mar. Poll. Bull., 114(1), 218–226.

Mallik, A., Xavier, K.A.M.,Naidu, B.C. and Nayak, B.B. (2021). Ecotoxicological and physiological risks of microplastics on fish and their possible mitigation measures. Sci. Total Environ., 779, 146433.

Malpede, M. and Percoco M. (2021). Lockdown measures and air quality: evidence from Italian provinces. Lett. Spatial Res. Sci., 14, 101-110.

Masindi, V., Mkhonza, P. and Tekere, M. (2021). "Sources of Heavy Metals Pollution". https://www.researchgate.net/publication/339974686.

Mason, S.A., Welch, V.G. and Neratko, J. (2018). Synthetic polymer contamination in bottled water. Front. Chem.,6. 3452. https://doi.org/10.3389/fchem.2018.00407

Mathalon, A. and Hill, P. (2014). Microplastic fibers in the intertidal ecosystem surrounding Halifax Harbor, Nova Scotia. Mar. Poll. Bull., *81*(1), 69-79.

Matusiak, Ł., Szepietowska, M., Krajewski, P., Białynicki-Birula, R., and Szepietowski, J. C. (2020). Inconveniences due to the use of face masks during the COVID-19 pandemic: a survey study of 876 young people. *Dermatologic therapy*.

Meaza I., Toyoda JH., Wise JP, (2021). Microplastics in Sea Turtles, marine mammals and humans: A one environmental health perspective. Front. Environ. Sci., 8: 575614.

Mei, X., Lee H., Diao, K., Huang, M., Lin, B.,M Lin C. et al. (2020). Artificial intelligence-enabled rapid diagnosis of patients with COVID-19. Natur. Med., 26, 1224-1228.

Miranda-Urbina, D., Thiel, M. and Luna-Jorquera, G. (2015). Litter and seabirds found across a longitudinal gradient in the South Pacific Ocean. Mar. Poll. Bull., 96, 2, 235-244.

Mishra AK., Rajput P., Singh A., Singh CK. and Mall, R.K. (2021). Effect of Lockdown amid COVID-19 on ambient air quality in 16 Indian cities. Frontier on Sustain., 3:705051.

Moharir, R. V. and Kumar, S. (2019). Challenges associated with plastic waste disposal and allied microbial routes for its effective degradation: A comprehensive review. J. Clean Prod., 208, 65e76. https:// doi.org/10.1016/j.jclepro.2018.10.059

Monolina, P., Chowdhury, M. H. and Haque, M. (2022). The use of personal protective equipment (PPE) and associated environmental challenges: A study on Dhaka, Bangladesh. Heliyon. 8: e09847.

Mor, S., Kumar, S., Singh, T., Dogra, S., Pandey, V. and Ravindra, K.(2021). *"Impact of COVID- 19 lockdown on air quality in Chandigarh, India: understanding the emission sources during controlled anthropogenic activities"*. Chemos., 263, 127978.

Mvovo, I. and Magagula, H. (2022). Prevalence of Covid-19 personal protective equipment in aquatic systems and impact on associated fauna. Environ. Syst. Decisions. 42, 328-337.

Napper, I. E. and Thompson, R. C. (2016). Release of synthetic microplastic plastic fibres from domestic washing machines: Effects of fabric type and washing conditions. Mar. Poll. Bull., 112(1-2), 39-45.

NASA, (2020). Airborne Nitrogen Dioxide Plummets over China.

Neckel, A., Korcelski C. and Silva, L.F.O, (2021).Mtals in the soil of urban cemeteries in Carazinho (South Brazil) in view of the increase in deaths from COVID-19: Projects for cemeteries to mitigate environmental impacts.Environ. Dev. Sustain. 10, 1-24.

Neto, H. G., Bantel, C. G., Browning, J., Della Fina, N., Ballabio, T. A., de Santana, F. T., e Britto M. D.b, Barbosa CB. and Barbosa, C. B. (2021). Mortality of a juvenile Magellanic penguin (*Spheniscus magellanicus,* Spheniscidae) associated with the ingestion of a PFF-2 protective mask during the Covid-19 pandemic. Mar. Poll. Bull., 166, 112232

Nigam, R., Pandya, K., Luis, A.J., Sengupta, R. and Kotha, M., (2021). Positive effects of COVID-19 lockdown on airquality of in dustrial cities (Ankleshwar andVapi) of Western India, Sci. Rep., 11, 4285.

Ng, E.L., Lwanga E.H., Eldridge S.M., Johnson P., Hu H.W., Geissen V. and Chen D. (2018). An overview of microplastics and nanoplatic pollution in agroecosystems. Sci. Tot. Environ., 627, 1377-1388.

Nordic Council (2017). Aims to stimulate circular economy, combat microplastic pollution. Nordic, 2017

Ogunji, J., Iheanacho, S., Ogunji, C.V., Olaolu, M., Oleforuh-Okoleh, V., Amaechi, N.,David, E., Ndukauba, O.,Ikegwu, T.M. and Biamba, C. (20201). Counting the Cost: The Effect of COVID-19 Lockdown on Households in South East Nigeria. Sustain., 13, 12417. https://doi.org/10.3390/su132212417

Okoro, N, Iheanacho SC, Nwakpa JN, Eze, C (2019). Effects of *Chromolaena odorata* leaf extract on behavior and haematology of *Clarias gariepinus* (Burchell, 1822). Afr. J. Aquat. Sci., 44, 421–427. https://doi.org/10.2989/16085914.2019. 1661823.

Olaiya, T.T. (2022). "End COVID-19 vaccine inequalities, AHF tells EU-AU summit". The Guardian Newspapers. Retrieved from https://guardian.ng/news/end-COVID-19-vaccine-inequalities-ahf-tells-eu-au-summit/

Olusola, J.A., Shote, A.A., Ouigmane, A. and Isaifan, R.J. (2021). The impact of COVID-19 pandemic on nitrogen dioxide levels in Nigeria. PeerJ, 9: e11387

Othman, A. R., Hasan, H. A., Muhamad, M. H., Ismail, N. I. and Sheikh Abdullah, S. R. (2021). Microbial degradation of microplastics by enzymatic processes: A review. Environ. Chem. Lett. https:// doi.org/10.1007/s10311-021-01197-9

Parashar N. and Hait S. (2021). Plastics in the time of COVID-19 pandemic: protector or polluter? Sci. Total Environ.;759:144274. doi: 10.1016/j.scitotenv.2020.144274.

Padervand, M., Lichtfouse, E., Robert, D., and Wang, C. (2020). Removal of microplastics from the environment. A review. Environ Chem Lett. 18(3), 807-828.

Park, H. and Park, B., (2021). Review of microplastic distribution, toxicity, analysis methods, and removal technologies. Water, 13, 2736.

Peng, B. Y., Chen, Z., Chen, J., Yu, H., Zhou, X., Criddle, C. S., Wu, W.-M. and Zhang, Y. (2020). Biodegradation of polyvinylchloride (PVC) in Tenebrio molitor (Coleoptera: Tenebrionidae) larvae. Environ. Intern., 145, 106106.

Pellini G., Gomiero A., Fortibuoni T., Ferrà C., Grati F., Tassetti N., et al. (2018). Characterization of microplastic litter in the gastrointestinal tract of Soleasolea from the Adriatic Sea. Environ. Pollut., 234, 943–952.doi: 10.1016/j.envpol.2017.12.038

Pico, Y. and Barcelo, D. (2019). Analysis and prevention of microplastics pollution in water: Current perspectives and future directions. Acs Omega, 4: 6709-6719.

Plastics Europe (2018). Plastics—the Facts 2018. An Analysis of European Plastics Production, Demand and Waste Data. Brussels: Plastics Europe.

Prata, J.C., Silva, A.L.P., Da Costa, J.P., Mouneyrac, C., Walker, T.R., Duarte, A.C. and Rocha-Santos, T. (2019. Solutions and integrated strategies for the control and mitigation of plastic and microplastic pollution. Inter. J. Environ. Res. Public Health, 16, 2411.

Prata, J. C., Silva, A. L., Walker, T. R., Duarte, A. C. and Rocha-Santos, T. (2020). COVID-19 pandemic repercussions on the use and management of plastics. Environ. Sci. Technol., 54(13), 7760-7765.

Prata, J.C., Silva, A.L.P., Duarte, A.C. and Rocha-Santos, T. (2021). Disposable over reusable face masks: Public safety or environmental disaster? Environ, 8, 31.

Praveena, S. and Aris, A.Z. (2021). The impacts of COVID-19 on the environmental sustainability: a perspective from the Southeast Asian region. Environ Sci. Poll. Res., 28, 63829-63836.

Qadri, H., and Bhaf, R.A. (2020). The Concerns for Global Sustainability of Freshwater Ecosystems (eds.), *Fresh Water Pollution Dynamics and Remediation*.

Qian, H., Zhang, Q., Lu, T., Peijnenburg, W.J.G.M., Penuelas, J. and Zhu Y. (2020). Learns learned from COVID-19 on potentially pathogenic soil microorganisms. Soil Ecol. Lett., 3:55,681.

Querol, X., Massague, J., Alastuey, A.,, Moreno, T., Gangoiti G. et al. (2021). Lessons from the COVID-19 air pollution decrease in Spain: Now what?. Sci. Tot. Environ., 779, 146380.

Ragossnig, A. M. and Agamuthu, P. (2021). Plastic waste: Challenges and opportunities. Waste Mgt. Res., 39(5), 629-630.

Ragusa, A., Svelato, A., Santacroce, C. et al (2021). Plasticenta: first evidence of microplastics in human placenta. Environ. Int., 146:106274. https://doi.org/10.1016/j.envint.2020.106274

Rajhans, A., Gore, P.M., Siddique, S.K. and Kandasubramanian, B. (2019). Ion imprinted nanofibers of PVDF/1-butyl-3-methylimidazolium tetrafluoroborate for dynamic recovery of europium (III) ions from mimicked effluent. J. Environ. Chem. Eng., 7:103068. https://doi.org/10.1016/j.jece.2019.103068

Rajmohan, K. V. S., Ramya, C., Raja Viswanathan, M., and Varjani, S. (2019). Plastic pollutants: Effective waste management for pollution control and abatement. Curr. Opin in Environ. Sci. Health, 12, 72e84. https://doi.org/10.1016/j.coesh.2019.08.006

Rakib, M. R. J., De-la-Torre, G. E., Pizarro-Ortega, C. I., Dioses-Salinas, D. C and Al-Nahian, S. (2021). Personal protective equipment (PPE) pollution driven by the COVID-19 pandemic in Cox's Bazar, the longest natural beach in the world. Mar. Poll. Bull., 169, 112497.

Ray, S.S., Lee H.K., Huyen D.T.T., Chenb S.S and Kwon, Y.N. (2022). *"Microplastics waste in environment: A perspective on recycling issues from PPE kits and face masks during the COVID-19 pandemic."* Environ. Technol. Innov., 26, 102290.

Raynaud, J. (2014). Valuing plastics: The business case for measuring, managing and disclosing plastic use in the consumer goods industry. UNEP.

Remy, F., Collard, F., Gilbert, B., Compère, P., Eppe, G. and Lepoint, G. (2015). When microplastic is not plastic: the ingestion of artificial cellulose fibers by macrofauna living in seagrass macrophyto-detritus. Environ. Sci. Technol., 49(18), 11158-11166.

Restrepo-Flo´rez, J. M., Bassi, A. and Thompson, M. R. (2014). Microbial degradation and deterioration of polyethylene - a review. Inter. Biodeter. Biodegrad., 88, 83e90. https://doi.org/ 10.1016/j.ibiod.2013.12.014

Rhee, S. W. (2020). Management of used personal protective equipment and wastes related to COVID-19 in South Korea. Waste Mgt. Res., 38(8), 820-824.

Rochman, C. M., Tahir, A., Williams, S. L., Baxa, D. V., Lam, R., Miller, J. T., Teh, F.C., Werorilangi, S. and Teh, S. J. (2015). Anthropogenic debris in seafood: Plastic debris and fibers from textiles in fish and bivalves sold for human consumption. Sci. Rep., 5(1), 1-10.

Rume T. and Islam S.M.D. (2020). "*Environmental Effects of COVID-19 Pandemic and Potential Strategies of Sustainability*". Heliyon, 6(9): e04965.

de Sá, LC, Oliveira M, Ribeiro F et al. (2018). Studies of the effects of microplastics on aquatic organisms: What do we know and where should we focus our efforts in the future? Sci. Tot. Environ., 645: 1029–1039. https://doi.org/10.1016/j.scitotenv.2018.07.207

Saadat, S., Rawtani, D. and Hussain, C. M. (2020). Environmental perspective of COVID-19, Sci. Tot. Environ., 728: 138870.

Sah, A., Negi, H., Kapri, A., Anwar, S. and Goel, R. (2011). Comparative shelf life and efficacy of LDPE and PVC degrading bacterial consortia under bioformulation. Ekologija, 57(2), 55e61. https://doi.org/10.6001/ ekologija. v57i2.1885

Saha, M., Naik, A., Desai, A. et al (2021). Microplastics in seafood as an emerging threat to marine environment: a case study in Goa, west coast of India. Chemos., 270:129359. https://doi.org/10.1016/j.chemosphere.2020.129359

Saliu, F., Veronelli, M., Raguso, C., Barana, D, Galli, P. and Lasagni, M. (2021). The release process of microfibers: from surgical face masks into the marine environment. Environ. Adv., 4:100042.

Selvaranjan, K., Navaratnam, S., Rajeev P. and Ravintherakumaran N. (2021). Environmental challenges induced by extensive use of face masks during COVID-19: a review and potential solutions. Environ. Challenge. (3), 100039.

Selvam, S., Manisha, A., Venkatramanan, S. et al (2020). Microplastic presence in commercial marine sea salts: a baseline study alongTuticorin Coastal salt pan stations, Gulf of Mannar, South India. Mar. Poll. Bull., 150:110675. https://doi.org/10.1016/j.marpolbul. 2019.110675

Sharma, S., Basu, S., Shetti, N.P., Nadagouda, M.N. and Aminabhavi, T.M. (2021). Microplsatics in the environment: occurrence, perils and eradication. Chem Eng. J., 408, 127317.

Shukla, S., Khan, R., Saxena, A. and Sekar, S. (2022). Microplastics from face masks: A potential hazard post Covid-19 pandemic. Chemos., 302, 134805.

Siam, M., Banna, H., Nishat, N. H., Ahmed, A. and Hossain, M. S. (2020). Stopping the COVID-19 pandemic: a review on the advances of diagnosis, treatment, and control measures. J. Pathogens, 20, 145.

Singh, R. and Pant, D. (2016). Polyvinyl chloride degradation by hybrid (chemical and biological) modification. Polymer Degrad. Stability, 123, 80e87. https://doi.org/10.1016/j.polymdegradstab.2015.11.012

Silva, A. L. P., Prata, J. C., Walker, T. R., Duarte, A. C., Ouyang, W., Barcelò, D. and Rocha-Santos, T. (2021). Increased plastic pollution due to COVID-19 pandemic: Challenges and recommendations. Chem. Eng. J., 405, 126683

Smith, M., Love, D.C., Rochman, C.M. and Neff, R.A. (2018). Microplastics in seafood and the implications for human health. Curr Environ Heal Rep., 5:375–386. https://doi.org/10.1007/s40572-018-0206-z

Stokes, G. (2020). No Shortage of Masks at the Beach - OCEANS ASIA [WWW Document]. OceanAsia. URL https://oceansasia.org/beach-mask-coronavirus/ (accessed 10.27.20)

Syberg, K., Khan, F. R., Selck, H., Palmqvist, A., Banta, G. T., Daley, J., et al. (2015). Microplastics: addressing ecological risk through lessons learned. Environ. Toxicol. Chem. 34, 945–953.

Taghavi, N., Singhal, N., Zhuang, W. Q. and Baroutian, S. (2021). Degradation of plastic waste using stimulated and naturally occurring microbial strains. Chemos., 263. https://doi.org/10.1016/j.chemosphere.2020.127975

Thevenon, F., Carroll, C. and Sousa, J. (2014). Plastic debris in the ocean: the characterization of marine plastics and their environmental impacts, situation analysis report. *Gland, Switzerland: IUCN*, *52*.

Thind, P. S., Sareen, A., Singh, D. D., Singh, S. and John, S. (2021). Compromising situation of India's bio-medical waste incineration units during pandemic outbreak of COVID-19: Associated environmental-health impacts and mitigation measures. Environ. Poll., 276, 116621. https://doi.org/10.1016/ j.envpol.2021.116621

Tokatli, C. and Varol, M. (2021). Impact of the COVID-19 lockdown period on surface water quality in the Meric-Ergene River Basin, Northwest Turkey. Environ. Res., 197, 111051.

Tong, H., Jiang, Q., Hu, X. and Zhong, X. (2020). Occurrence and identification of microplastics in tap water from China. Chemos., 252:126493. https://doi.org/10.1016/j.chemosphere.2020.126493

Torres, F.G., Dioses-Salinas, D.C., Pizarro-Ortega, C.I. and De-la- Torre, G.E. (2021). Sorption of chemical contaminants on degradable and non-degradable microplastics: recent progress and research trends. Sci. Tot. Environ., 757:143875.

UNSCN-United Nations System Standing Committee on Nutrition. Food Environments in the COVID-19 Pandemic (2020). Available online: https://www.unscn.org/en/news-events/recent-news?idnews=2040/ (accessed on 16 April 2020).

Urban, R. C., Nakada, L. Y. K. (2021). COVID-19 pandemic: Solid waste and environmental impacts in Brazil. Sci. the Total Environ., 755, 142471.

Van Cauwenberghe, L. and Janssen, C. R. (2014). Microplastics in bivalves cultured for human consumption. Environ. Poll., 193, 65-70.

Van Doremalen, N., Bushmaker, T., Morris, D. H., Holbrook, M. G., Gamble, A., Williamson, B. N., Tamin, A., Harcourt, J.L., Thornburg, N.J., Gerber, S.I. and Lloyd-Smith, J.O. Munster, V. J. (2020). Aerosol and surface stability of SARS-CoV-2 as compared with SARS-CoV-1. New England J. Med., 382(16), 1564-1567.

Vollmer, I., Jenks, M. J. F., Roelands, M. C. P., White, R. J., van Harmelen, T., de Wild, P., van der Laan, G. P., Meirer, F., Keurentjes, J. T. F. and Weckhuysen, B. M. (2020). Beyond mechanical recycling: Giving new life to plastic waste. Angewandte Chemie - International Edition, 59(36), 15402e15423. https://doi.org/10.1002/ anie.201915651

Wagner, M. and Lambert, S. (Eds) (2018). *"Freshwater Microplastics; Emerging Environmental Contaminants?"; in The Handbook of Environmental Chemistry*.

Walker, T. (2021). Microplastics and the UN sustainable development goals. Current Opinion Green Sustain. Chem., 30, 100497.

Wang, W. and Wang, J. (2018). Investigation of microplastics in aquatic environments: an overview of the methods used, from field sampling to laboratory analysis. TrAC Trends in Analyt. Chem., 108, 195-202.

Wang, W., Ge, J., Yu, X. and Li, H. (2020). Environmental fate and impacts of microplastics in soil ecosystems: progress and perspective. Sci. Tot. Environ., 708, 134841.

Weis, J. S. (2020). Aquatic microplastic research-a critique and suggestions for the future. Water, 12(5), 1475.

Wertz, J. T. and Be´chade, B. (2020). Symbiont-mediated degradation of dietary carbon sources in social herbivorous insects. In Advances in insect Physiology. Academic Press Inc. https://doi.org/10.1016/bs.aiip.2020.04.001

Wingender, J. and Flemming, H.C. (2011). Biofilms in drinking water and their role as reservoir for pathogens. Int. J. Hyg. Environ. Health 214, 417–423. https://doi.org/ 10.1016/j.ijheh.2011.05.009.

WHO, (2020). Transmission of SARS-CoV-2: Implications for Infection Prevention Precautions: Scientific Brief. Retrieved from: https://www.who.int/news-room/commentaries/detail/transmission-of-sars-cov-2-implications-for-infection-prevention-precautions

WHO, (2022). "WHO Coronavirus (COVID-19) Dashboard". Retrieved from: https://covid19.who.int/

Wu, X., Pan, J., Li, M., Li, Y., Bartlam, M. and Wang, Y. (2019). Selective enrichment of bacterial pathogens by microplastic biofilm. Water Res., 165, 114979. https://doi. org/10.1016/j.watres.2019.114979.

Wu, H., Huang, J., Zhang, C.J.P. et al (2020). Facemask shortage and the novel coronavirus disease (COVID-19) outbreak: Reflections on public health measures. EClinicalMedicine 21:100329. https://doi.org/10.1016/j.eclinm.2020.100329

Xu B., Liu F., Cryder Z., Huang D., Lu Z., He Y., Wang H., Lu Z., Brookes P.C, Tang C., Gan J., and Xu. (2020). Microplastics in the soil environment: Occurrence, risks, interactions and fate, a review. Critical Rev. Environ. Sci. Technol., 50, 212175-2222.

Xu, S., Ma, J., Ji, M., Pan, K. and Miao, A. (2020b). Microplastics in aquatic environments: occurrence, accumulation and biological effects. Sci. Total Environ., 703, 134699.

Xu, Z., Xia, M., Huo, Y. X. and Yang, Y. (2020). Intestinirhabdus alba gen. Nov., sp. nov., a novel genus of the family enterobacteriaceae, isolated from the gut of plastic-eating larvae of the coleoptera insect *Zophobas atratus*. Inter J. Sys Evol. Microbiol., 70(9), 4951e4959. https:// doi.org/10.1099/ijsem.0.004364

Yadav, D., Mahestavari, H. and Chandra, U. (2020). Outbreak prediction of COVID-19 in most susceptible countries. Global J. Environ. Sci. Mgt., 6, 4-10.

Yahaya, T., Abdulazeez, A., Oladele, E., Funmilayo, W. E., Dikko, O.C., Ja'afar, U. and Salisu, N. (2022). Microplastics abundance, characteristics and risk in Badagry Lagoon in Lagos State, Nigeria. Poll., 8(4):1325-1337.

Yang, S. S. and Wu, W. M. (2020). Biodegradation of plastics in Tenebrio genus (mealworms). In Handbook of environmental Chemistry (Vol. 95, pp. 385e422). Springer Science and Business Media Deutschland GmbH. https://doi.org/10.1007/698_2020_457

Yang L., Zhang Y., Kang S., Wang Z. and Wu C. (2021). Microplastics in soil: A review on methods, occurrence, sources, and potential risk. Sci. Tot. Environ., 780, 146546.

Yang, S.S., Ding, M.Q., He, L., Zhang, C.H., Li, Q.X., Xing, D.F., Cao, G.L., Zhao, L., Ding, J., Ren, N.Q. and Wu, W.-M. (2021). Biodegradation of polypropylene by yellow mealworms (*Tenebrio molitor*) and superworms (*Zophobas atratus*) via gut-microbe-dependent depolymerization. Sci. Tot. Environ., 756, 144087. https://doi.org/10.1016/j.scitotenv.2020.14408

Yong, C.Q., Valiyaveetil S. and Tang, B.L. (2020). Toxicity of microplastics and nanoplastics in mammalian systems. Int. J. Environ. Res. Public Health, 17 (5), 1509.

Yuan, F., Yue, L., Zhao, H., and Wu, H. (2020). Study on the adsorption of polystyrene microplastics by three-dimensional reduced graphene oxide. Water Sci. Technol., 81(10), 2163-2175.

Yusoff, F., Abdullah, A.F., Aris A.Z. and Umi, W.A.D., (2021). Impacts of COVID-19 on the aquatic environment and implication on aquatic food production. Sustain., 13 20, 11281.

Zettler, E. R., Mincer, T. J. and Amaral-Zettler, L. A. (2013). Life in the "plastisphere": microbial communities on plastic marine debris. Environ. Sci. Technol., 47(13), 7137-7146.

Zhang, C., Chen, X., Wang, J. and Tan, L. (2017). Toxic effects of microplastic on marine microalgae *Skeletonema costatum*: interactions between microplastic and algae. Environ. Poll., 220, 1282-1288.

Zhang, D., Liu, X., Huang, W. et al (2020). Microplastic pollution in deepsea sediments and organisms of the Western Pacific Ocean. Environ Poll., 259:113948. https://doi.org/10.1016/j.envpol.2020.113948