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PRACTICE NOTE

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Consequences of COVID-19 pandemic on solid waste management: Scenarios pertaining to developing countries

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[Correction added on 27th July 2021 after first online publication: We have updated Affiliation of first Author and bios. Remove question mark in abstract after aprons, instead put full stop]

Abstract

Undoubtedly the most searched and spoken word of last year is coronavirus disease 2019 (COVID-19), which initially originated in Wuhan, China near the end of 2019. COVID-19 is a disease caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). Albeit almost all countries shut down their borders to prevent rapid spread of the virus. However, the number of cases continues to increase in developing countries at a faster rate due to community and cluster transmission. The severity of this epidemic made it a pandemic as it progressed to over 200 countries. The World Health Organization (WHO), governments, and national disease control and prevention units worked together to break the chain and are working to contain the catastrophic impact of COVID-19. They formulated and recommended various guidelines like social distancing, frequent hand washing, and social distancing to inhibit the spread of the virus. WHO also advised that the general population and medical personnel wear face masks, face shields, gloves, and aprons. As a result, this waste category has substantially increased and, if not disposed of properly, may cause the infection or help to catalyze COVID-19. In developing countries, poor solid waste management may aggravate chances of spreading COVID-19. Sustainable solid waste management is a critical parameter for the health, wellbeing, and development of society. The measures adopted to contain and restrict the spread of the COVID-19 pandemic and minimize the degrees of freedom in commercial events affected solid waste management considerably. During this crucial time, the services provided by waste management agencies and personnel are invaluable and these services help to prevent the improper disposal of waste, which may lead to health risks due to the spread of COVID. COVID-19 is a new and novel virus and experts are learning more about it overtime and with evolving science. This review paper provides insight into different types of solid wastes generated during the pandemic, their consequences, and the implication of various policies.

KEYWORDS

disposal, face masks, medical waste, policies, solid waste management

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1 | INTRODUCTION

The global catastrophe of the coronavirus severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and the disease it causes (COVID-19) that struck the world in late 2019, originating in Wuhan, China and speedily proliferated and took the entire globe in its claws. To date, May 18, 2021 (11:20 a.m.), there have been 163,368,005 confirmed cases, 3,385,518 deaths (2.07% rate) and 143,004,248 recovered cases (https://www.statista.com/statistics/1087466/covid19-cases-recoveries-deaths-worldwide/). The vaccination drive started in December 2020 and there are 1,480,958,362 doses administered to date (https://coronavirus.jhu.edu/map.html). In March 2020, the World Health Organization (WHO) declared COVID-19 as a pandemic disease, which spread suddenly and rapidly to almost all the countries in the world (222 countries). The impact of COVID-19 was devastating in terms of socioeconomic aspects as many countries imposed partial or full movement control orders (lockdowns) as a measure to mitigate the outbreak. This made the situation more traumatic because all the activities, like tourism, sports, social, and religious gatherings either stopped or reduced to a minimum level. The outbreak posed tremendous pressure on health care facilities and workers and even the developed nations succumbed to the pressure. There was an acute shortage of hospital beds, life support equipment, and the worthiest oxygen in the countries which are too vulnerable in terms of population and development like India. Hence, the medical care agencies and professionals are facing the daunting task of providing sufficient, appropriate, and timely treatment and medical services to a flood of patients.

Since the demand is increasing at a much higher rate than the supply and availability, to cope with it efficiently, safely, and safeguarding themselves from the infection will lead to breaking the chain (WHO, 2020). There were negative consequences of lockdowns but, in terms of the environment, the condition seems to be improved as the concentration of greenhouse gas emissions decreased because of reduced vehicular emissions and industrial air pollution. On the other hand, there was a considerable increase in the generation of solid waste due to excessive use of masks, personal protective equipment (PPE), restaurant take-away plastic boxes, empty sanitizer bottles, disinfectant bottles, and throat and nasopharyngeal swab kits to conduct corona polymerase chain reaction (PCR) test (Abu-Qdais et al., 2020). None of these items are biodegradable and ultimately become solid wastes. PPE waste generated at medical facilities must be properly collected, transported, and readily disposed of as medical waste (hazardous) to avoid the risk of infection (Hua & Shaw, 2020). Taking the case of face masks, which became a necessity during the outbreak, their excessive use and properties are creating an impact on the environment. Stacked piles of face masks were found near the coasts of Taiwan, Hongkong, mainland China, the United States, and France (https://www.reuters.com/article/us-health-coronavirus-hongkong-environme-idUSKBN20Z0PP; https://www.greenpeace.org/aotearoa/story/where-did-5500-tonnes-of-discarded-face-masks-end-up/).

Some of the disadvantages of used face masks are:

(i) They are unrecyclable because putting them in recycling may lead to the transmission of the virus and possible infection;
(ii) Medical face masks are made up of polypropylene (PP), which takes a long time to degrade and releases toxic substances during the process;
(iii) Their improper disposal may pose risk to wildlife and ocean animals, because of their contaminated nature; and
(iv) Overwhelming pressure on landfills (Ahmad et al., 2019)

and incineration facilities, may lead to contaminated landfill leachate and acute air pollution.

Furthermore, issues associated with COVIDd-19-related air pollution may cause risks problems to the human population as the health effects from COVID-19 are mostly related to breathing (Qarani, 2020). To understand the severity and overwhelming nature of the problem, Green Peace International conducted a survey in Taiwan to assess the solid waste impacts of used face masks. The case study estimated that in just three months 1.3 billion masks accounting for 5500 metric tonnes (1100 trucks each of 5 tonnes capacity) of face masks were disposed of (Jenny, 2020). The nonbiodegradable masks were made of polypropene, weighing between 4680–6240 metric tonnes, and could take a minimum of 450 years to degrade. Microplastics released from the degrading masks disposed of in water bodies could enter marine creatures, impacting their life-cycle (Alok, 2020). Various problems and pollution caused due to face masks are shown in Figure 1.

Literature on COVID-19 shows that there are many papers on the symptoms, preventive measures, and its effect on the population and economy. But fewer studies are focussing on the scenario of solid waste generation, especially in developing countries that are more susceptible and vulnerable to the pandemic. The research presented herein provides an insight on the impact of COVID-19 on the generation of solid waste including medical and other types of waste. The review focuses on the potential problems arising from the improper disposal of waste generated as a result of COVID-19 and also summarizes policies and remedial measures that should be considered to overcome the situation.

2 | ISSUES ASSOCIATED WITH COVID-19 SOLID WASTE

The generation of waste can vary depending on the consumption dynamics of the population or the modification of social habits. From the recent situation imposed by the COVID-19 pandemic, people have had to make changes in the dynamics of life. Being at home more often was transformed from being a measure of self-care to an order derived from preventive isolation. Undoubtedly, these lifestyle changes resulted in environmental repercussions related to the generation and management of solid waste. In the first aspect, this is due to variations in consumption habits and the associated changes in waste generation (Van Doremalen et al., 2020).

FIGURE 1 Illustrations showing different cases of pollution caused by face masks [Color figure can be viewed at wileyonlinelibrary.com]

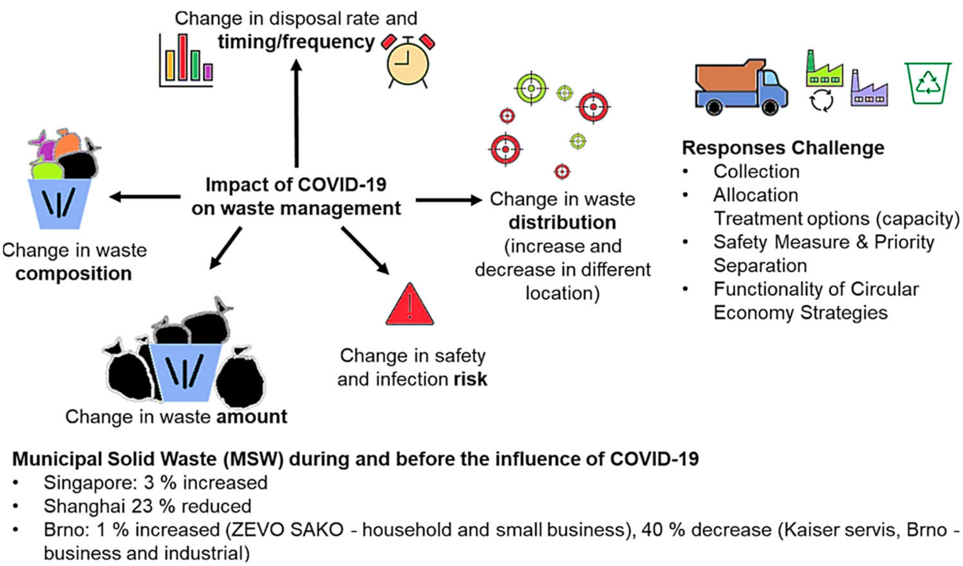

FIGURE 2 An appraisal of COVID-19 influence on waste management (Van Fan et al., 2021). COVID-19, coronavirus disease 2019 [Color figure can be viewed at wileyonlinelibrary.com]

First, the permanence of people at home, the suspension of classes in public and private schools, and the interruption of recreational and commercial activities influence the generation of waste. Based on this, public waste management services must make proper adjustments in collection routes and schedules (Klemeš et al., 2020; Nzeadibe, 2020). Second, wastes from the homes of people infected with COVID-19 may have traces of the virus. Although the intra-hospital management of patients infected with COVID-19 places controls on COVID-19-containing solid waste streams, the same does not happen in homes. Used masks, tissues, gloves, containers, and other wastes generated by infected people can be contaminated with the virus and should be managed separately from other wastes generated in the homes of COVID-19-infected people (Feng et al., 2020).

Undoubtedly, the use of disposable gloves and protective clothing (usually plastic) had lead to an increase in waste generation and precautions should be taken to prevent the spread of contagions from these discarded wastes. During the COVID-19 pandemic, the commitment of the public is necessary to deal with new waste management challenges (Global Network of Civil Society Organizations for Disasters Reduction, 2020). Awareness must be made of the importance of correctly separating the waste at the source, and disposing of non-contaminated wastes in separate containers for subsequent transportation to recycling or solid waste management facilities. Potentially infected wastes must be separated from other wastes and containerized in tightly closed bags before being transferred to waste management service providers. The effect on solid waste generation and management during the COVID-19 outbreak is shown in Figure 2.

Those who are at home infected with the COVID-19 virus should adopt preventive measures around the management of their wastes to avoid the spread of the disease; in particular, to waste management personnel who collect waste without using PPE (McKibbin & Fernando, 2020; Pan et al., 2020). Although as a society there is a lack of training for the appropriate management of solid waste, there is an opportunity at a global level for the public to act in a responsible and supportive manner concerning waste management during the pandemic.

Humans are part of the complex fabric of life, on which people impose their mark on the desire to guarantee sustenance and opportunities with patterns shaped by desires or ambitions. Human activities have been altering ecosystems and causing unprecedented environmental impacts for decades. Today, an impaired planet continues to support life, but the resources are finite, the carrying capacity limited, and in this struggle between the resilience of nature and the transforming power of man, the former does not always win (International Solid Waste Association, 2020). A few years ago, scientists warned about the impact of climate change on the increase in intensity, extension, and impact of epidemics, as well as the need to be prepared to face a major pandemic (Walsh et al., 2005). In recent decades, the emergence of viral epidemics, such as haemorrhagic fevers (Lassa, Ebola), new coronaviruses (CoV) associated with respiratory syndromes (SARS-CoV, Middle East Respiratory Syndrome-CoV), influenza, and dengue, among other diseases, have caused a great impact on human health and society due to their high mortality rates.

3 | GENERATION AND DISPOSAL OF MEDICAL WASTE

Worldwide deaths due to diseases related to unmanaged medical waste are estimated to be approximately 5.2 million annually, including 4 million children (The Daily Star, 2020). Due to the surge of COVID-19, excessive biomedical waste has been generated which is posing a threat to public health and the environment. Further, the improper handling of the generated medical waste led to the spread of SAR-COV-2 (Sarawut, 2020).

Since the infections are being transmitted by different routes, such as droplets/aerosols, there has been a wide mandate for PPE. PPE is comprised of gloves, masks, face shields, gowns, and goggles used to prevent individual-to-individual transmission (Iyer et al., 2021). The WHO estimated that 76 million gloves, 1.6 million goggles, and 89 million medical masks will be required due to COVID-19 (WHO, 2020). There is an urgency to manufacture a sufficient quantity of PPE which also demands segregating PPE and other Covid-19-related medical wastes and implementing proper waste management practices to minimize the spread of infection (Saar et al., 2004; EU, 2020).

3.1 | Biomedical waste

The waste generated in managing pathogens or infections in a community is referred to as biomedical waste (BMW). BMW includes human tissues, body fluids, cotton swabs, bandages, contaminated beddings, dressings, blood bags, needles, and syringes along with disposable items, such as PPE, including masks, gloves, gowns, caps, goggles, face shield, and shoe covers (Bengali, 2020). Sectors of solid waste management are facing challenges due to the increase in the quantity of BMW (Minghua et al., 2009). It is estimated that approximately 200,000 metric tonnes of BMW are generated annually worldwide which is treated by 198 BMW treatment facilities and 225 BMW incinerators (Minoglou et al., 2017). Thus, the daily generation of BMW is approximately 5500 metric tonnes (Ranjan et al., 2020). During the current pandemic, it was reported that approximately 214 metric tonnes of additional medical waste were generated per day in Wuhan, China alone (https://news.cgtn.com/news/; 2020-03-17/How-Wuhan-copes-with-its-mountains-of-medical-waste--OUxhr4jW1i/index.html). As another example, an Asian Development Bank survey of BMW generated due to the pandemic revealed the following BMW generation rates: Bangkok, Thailand—210 tonnes/day, Manila, Philippines—280 tonnes/day, and Jakarta, Indonesia—212 tonnes/day (ADB, 2020). Thus, it is important to understand the categories of biomedical wastes, various methods of safe disposal of the various types of BMW generated as a result of COVID-19 as shown in Table 1.

The increase of BMW generation during the pandemic without proper waste management practices may contribute to plastic contamination generated from manufacturing PPE (Schnurr et al., 2018). Further, releases of virus contamination to soil or water ecosystems can lead to the advancement of antibiotic-resistant bacteria and antibiotic-resistance genes (Chi et al., 2020; He et al., 2020). It is reported that 10% to 25% of BMW is dangerous and, thus, BMW should be properly managed or it can pose a risk to public health (Rao & Ghosh, 2020).

3.2 | Assessment of biomedical waste management

Segregation is a fundamental step to managing BMW. An example of BMW segregation and management is India's 2016 Bare Acts rules that require the separation of different wastes and management of these waste types based on color codes. (Sharma, 1998). Schedule III (https://megspcb.gov.in/documents/SCHEDULE%20III%20BMW.pdf) of the Bares Act rules require waste bags to be properly labelled with a biohazard or cytotoxic symbol. Container labelling must include the name of the department/laboratory for tracing purposes. The collected BMW is required to be stored in collection rooms or a dedicated storage area where the bags are stored until being transported for treatment and/or disposal. The BMW is transported by a truck with identification tags of radiofrequency. The waste transportation vehicle must be segregated into separate cabins for different types of BMW (https://umibiomedical.com/5-types-biohazardous-waste/). The truck must also have a leak-proof cover and an interior of made of aluminium or stainless steel for

TABLE 1 Categories of biomedical waste and treatment/disposal methods

Category	Components in waste	Content in waste	Methods to treat and dispose
Category 1	Human tissues, organs and other body	Anatomical	Incineration
Category 2	Animal tissues, organs, and other body parts	Anatomical	Landfill disposal and incineration
Category 3	Laboratory cultures and microorganisms used in research	Microorganisms	Microwaving, autoclaving, and incineration
Category 4	Needles, scalpels, syringes, blades, glass, etc.	Waste sharps	Chemical treatment and disinfection
Category 5	Outdated medicines that are discarded	Discarded medicines; cytotoxic drugs	Incineration
Category 6	Blood-contaminated cotton, dressings, soiled plaster casts, and delivery tubing	Blood	Microwaving, autoclaving, and incineration
Category 7	Catheters, tubing, and intravenous sets	Bodily fluids	Disinfection and incineration
Category 8	Waste from laboratory cleaning, washing, housekeeping, and disinfecting	Liquid waste	Chemical and biological treatment
Category 9	BMW incineration ash	Solid waste	Chemical treatment (stabilization) and landfill disposal
Category 10	Waste laboratory chemicals	Liquid and solid waste	Chemical treatment and incineration

TABLE 2 SARS-CoV-2 virus longevity on surfaces of several materials

Items/materials	Longevity (h)
Printing and tissue paper	3
Copper	4
Cardboard	24
Wood and cloth	48
Plastics	72
Stainless steel	72
Glass and Banknote	96

Abbreviation: SARS-CoV-2, severe acute respiratory syndrome coronavirus 2.

proper washing and disinfection. The SARS-CoV-2 related BMW and its longevity on surfaces of various materials can be categorized as shown in Table 2.

3.3 | Personal protective equipment (PPE)

According to WHO, COVID-19 transmission among humans can be mitigated by practising various rules, such as social distancing, wearing face masks, face shields, regular washing of hands, and using sanitizer (WHO, 2020; Manikandan, 2020). The fundamental PPE for medical personnel caring for patients with COVID-19 includes face masks, aprons, rubber boots, shoe covers, gloves, face shields, medical test kits, and plastic containers (Kampf et al., 2020). The single-use plastic items and PPE along with other BMW are inducing "PPE pollution" in the environment.

An example of PPE pollution is the presence of used face masks dispersed within stretches at Soko Island Beach, Hong Kong (Saadat, Rawtani, Hussain 2020). Also, reports of wastes floating in the waters along the French Coast wherein 80%–90% of the wastes was comprised of PPE, which poses an immediate concern due to the mismanagement of potentially infected wastes (Kitchener, 2020). The average generation rate of plastic waste in the Southeast Asian countries before COVID-19 was 5500 metric tonnes per day. However, during the pandemic, this quantity increased to 6300 tons per day. Thailand can expect a 30% increase in annual plastic waste volume (TEI Asia Food, 2020; TEI Plastics, 2020). Indian scientists have suggested using pyrolysis to convert the plastic used in PPE into a renewable liquid fuel to lessen the impact of increased plastic waste generated during COVID-19 (Jambeck et al., 2015). Prata et al. (2020) reports an estimated 129 billion disposable face masks and 65 billion plastic gloves generated annually as a visible manifestation of the new normal.

A literature survey reported that approximately 22 kg of plastic waste is generated during PCR techniques for every 1000 coronavirus tests (CPCB, 2020). There is evidence that reverse transcription-PCR (RT-PCR) generates 37.27 g of plastic residues per sample (Celis et al., 2021). Therefore, based on approximately 1 billion COVID-19 tests to date, the worldwide plastic residues from COVID-19 testing with RT-PCR have generated approximately 18,600 tons through June 2021.

3.4 | Face masks

As previously discussed, the COVID-19 pandemic has increased the usage of face masks, subsequently increasing BMW (Sangkham, 2020). In response to regular alerts from WHO and government mandates to wear face masks to control the spread of SARS-CoV-2, people are now more inclined to wear different types of face coverings (Feitzelberg, 2020), including bandanas, hand-sewn masks, commercial, and disposable medical masks.

A mask is a disposable unit that provides a barrier between the mouth and nose of the wearer and airborne contaminants. As face masks become a requirement for people around the world and not just medical professionals; the purposes they serve are as varied as the individuals who wear them. Different types of masks that are specifically designed to prevent the spread of COVID-19 include the following:

1. Basic cloth face mask
2. Surgical face mask
3. N95 respirator
4. KN95 respirator
5. Self-contained breathing apparatus
6. Filtering face-piece respirator
7. P100 respirator/gas mask
8. Full face respirator
9. Full-length face shield

The daily face mask quantity can be assessed using the following equation adapted from Nzediegwu and Chang (Nzediegwu & Chang, 2020):

$$D_{FM} = P \times U_p \times F_{MAR} \times (F_{MGP}/10{,}000)$$

Where, D_{FM} = Daily face mask use (pieces);
P = Population (persons);
U_P = Urban population (%);
F_{MAR} = Face masks acceptance rate (80%);
F_{MGP} = Number of face mask used (per person/day) (assumed to be 1).

Face masks became part of most people's daily lives during the pandemic. Many face masks are made from plastics and designed to be used just once leading to thousands of tonnes of additional waste going to landfill. A study by (Nsikak et al., 2021) reports that 3.4 billion face masks or face shields are discarded every day. Asia is projected to throw away 1.8 billion face masks daily, the highest quantity of any continent globally. China, with the world's largest population (1.4 billion) discards nearly 702 million face masks daily (https://www.nationalgeographic.com/environment/article/how-to-stop-discarded-face-masks-from-polluting-the-planet). In another estimate. If the United Kingdom population used a single-use mask each day for a year, it would create 66,000 tonnes of waste and 57,000 tonnes of plastic packaging (https://theconversation.com/millions-of-face-masks-are-being-thrown-away-during-covid-19-heres-how-to-choose-the-best-one-for-the-planet-147787).

4 | HOUSEHOLD WASTE

Household waste (HW) is one of the constituents of municipal solid waste (MSW). The surge of MSW in urban areas needs to be monitored as it is generated daily and thus there is a requirement to manage this waste. Municipal solid waste management practices are typically implemented by local authorities to maintain hygienic conditions in residential areas (Hornweg et al., 2012). In a case study in Dehradun City, India, it was reported the major HW constituents are: food/kitchen (≥80% of total weight) which is tailed by polythene and plastic (≈7%), paper (≈6%), cardboard (≈2%), glass/ceramic scraps (≈1%), and other miscellaneous items (e. g., cloth, silt, dirt, rubber; ≈ 4%). The HW generation rate is dependent on the socioeconomic groups within a community and increases with an increase in family income. Suthar and Singh (2015) observed a positive correlation between the rate of HW waste generation and higher income groups and family size.

5 | COVID-19'S INCREASE IN PLASTIC WASTE DUE TO TAKEAWAY RESTAURANTS

As a result of the COVID-19 pandemic, the restaurant industry has shown an increase in the amount of takeaway business as customers are relying on delivery, instead of in-person, services. In addition, online shopping has also increased. During the COVID-19 crisis and abrupt lockdown in several countries for several months, restaurants and consumers have become dependent on single-use plastic bags and containers for takeaway (Chaudhary et al., 2021; Gagan et al., 2020). The reusability concept of plastics has taken a back seat during this crisis due to concerns regarding potential contamination. For example, before the pandemic. Just Salad, a popular food chain in (USA), was producing reusable bowls saving 75,000 pounds of plastic a year. But during the pandemic, the restaurant halted the program and focused on pickup and delivery which meant only using disposable plastics for packaging. Further, Starbucks and Dunkin Donuts prohibited customers from using reusable mugs.

6 | PROBLEMS ASSOCIATED WITH THE COLLECTION, TRANSPORT, AND DISPOSAL FOR PRIVATE AND PUBLIC WASTE MANAGEMENT

6.1 | Collection and transport

Biosecurity precautions for BMW, such as gloves, eye protection, masks, plastic aprons, and boots or shoe covers, are recommended to maintain hygienic conditions. These precautions include the following:

- Sealing trash bags containing BMW by knotting bags containing BMW and
- avoiding emptying waste from one container to another
- Consider all waste BMW containers as contaminated
- Ensure all sharps and biohazard wastes have been disinfected.

- Maintain the containers, transport carts, storage areas, and final waste disposal areas in optimal hygiene conditions.

6.2 | Disposal

The disposal of solid wastes in many countries is carried out mostly in an uncontrolled or semi-controlled way, with only 30% of the garbage being deposited in sanitary landfills (Abed Al Ahad et al., 2020). Solid waste is typically classified in various ways according to its materials, biodegradability, toxicity, etc. Solid waste is also classified according to the domestic, commercial, or service activity that generates it. They can be domiciliary, coming directly from domestic activity such as kitchen waste, paper, and consumer goods in general. On the other hand, increasing urbanization favors a greater generation of waste or waste. These aspects must be evaluated for the COVID-19 pandemic, which implies a crucial and evident challenge today. These wastes are made up of materials discarded by families, industrial and commercial waste that, in general, represent a problem that has consequences on health, the environment, and the local economy if they are not managed properly. Given the multidimensional nature of the phenomenon studied, it is necessary to combine comprehensive care towards a root solution, which requires an institutional commitment to the awareness and participation of all sectors of the population, including private initiative and civil society. The new post-COVID-19 scenario represents an opportunity to redefine the social purpose of companies, develop action plans aimed at guaranteeing integration.

The pandemic could become an opportunity to unite in solidarity and turn the crisis into a catalyst for the integration of the economic, social, and environmental dimensions. The different polymers used in the manufacture of plastic can be additive with biocidal and viricidal substances capable of eliminating any undesirable viral or bacterial system from their surface. This can be achieved both by polymeric coatings and by providing viricidal or antibacterial properties to the plastic in bulk. However, the post-COVID-19 era represents a paradigm shift and a real qualitative leap. From now on, it will be necessary to increase safety and the prevention of possible contagions derived from contact with surfaces through technology (Walker, 2020). Public spaces will move towards greater automation, accelerating the development of technologies. World & Indian and Romanian waste circumstances are shown in Figures 3 and 4, respectively.

The COVID-19 pandemic has resulted in an increase in the amount of sanitary waste, with PPE such as masks and gloves representing the highest proportion, along with other medical waste. In addition, the quarantine policies established in most countries have encouraged consumers to become more dependent on online purchases of food, which have led to a plausible increase in the generation of plastic and plastic packaging waste; single-use only. Although this new paradigm has underlined the public value of plastic, it has also highlighted changes in consumption patterns and waste disposal.

Furthermore, deficiencies and discrepancies in existing waste management systems before the COVID-19 pandemic (Di Marco et al., 2020), such as staff shortages, limited capacity of treatment and disposal facilities, lack of technical knowledge and resources. Economic conditions can further exacerbate health and environmental problems, especially in developing countries or emerging economies, both for public and private companies. Therefore, designing strategies for sustainable management, which guarantees the safe handling and proper disposal of these wastes, is an urgent and essential challenge to minimize the possible impacts. While the rapid disposal of single-use products is often seen as beneficial to the health of staff and consumers, the imminent increase in the volume of this waste from the COVID-19 pandemic challenges with overwhelming systems of existing waste management, which have not been able to deal with existing plastic waste satisfactorily. However, before the COVID-19 pandemic, the world was already facing challenges in the waste management sector, where approximately two billion people worldwide lacked access to waste collection and approximately three billion, lacked controlled waste disposal facilities (https://www.unep.org/news-and-stories/press-release/mounting-problem-worlds-cities-produce-10-billion-tonnes-waste-each). Whereas, workers involved in waste management, especially in developing countries, did not have PPE and the increased reliance on plastics during the COVID-19 pandemic (Wu & McGoogan, 2020) may be temporary or it may change our long-term goals of accelerating the transition to a circular economy. The adoption of the circular economy as a model that guarantees innovations in existing products and integrates new sustainable technologies (Hui

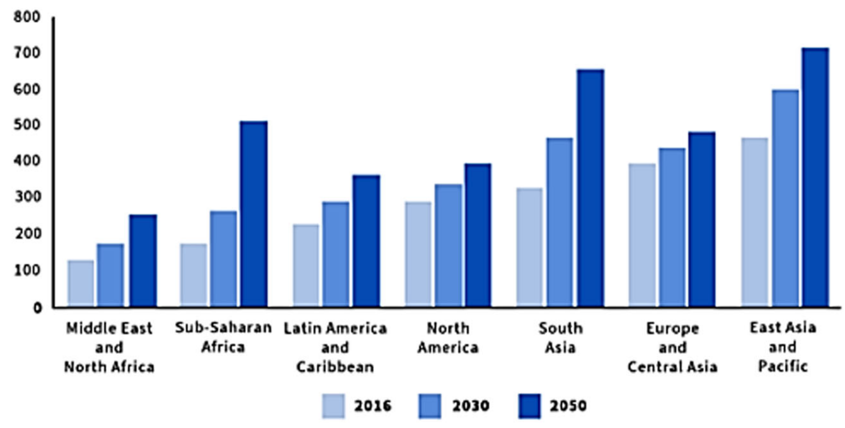

FIGURE 3 A wasteful enterprise: COVID-19 and World & India's Waste Management Story-degrees of change (Banerjee, 2020). COVID-19, coronavirus disease 2019 [Color figure can be viewed at wileyonlinelibrary.com]

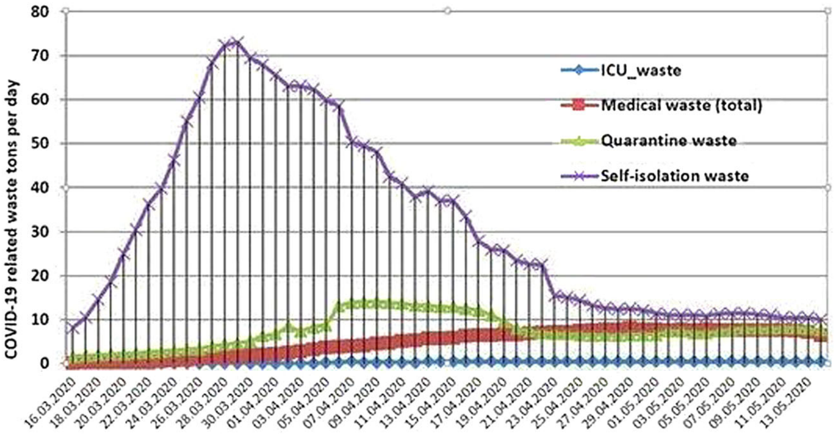

FIGURE 4 Assessment of COVID-19 waste flows during the emergency state in Romania and related public health and environmental concerns (Mihai, 2020). COVID-19, coronavirus disease 2019; ICU, intensive care unit [Color figure can be viewed at wileyonlinelibrary.com]

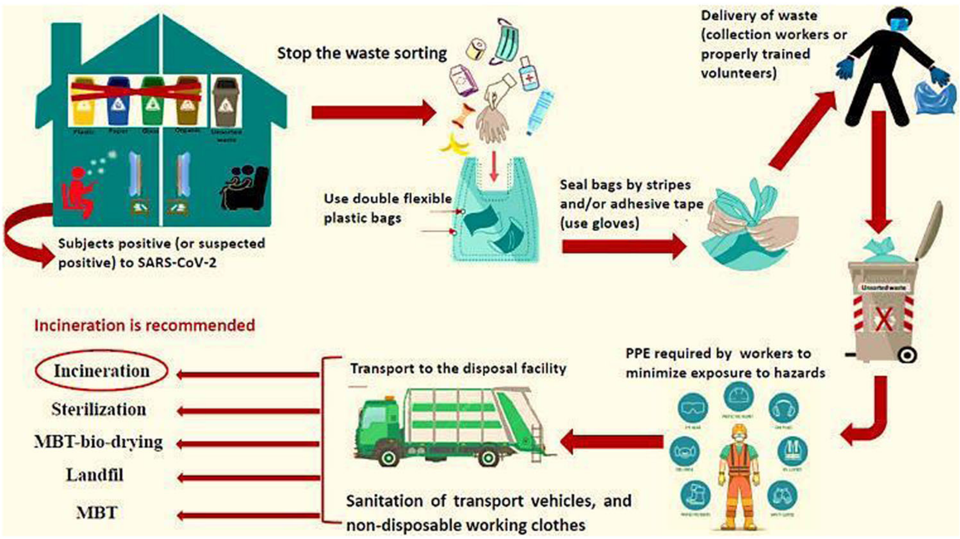

FIGURE 5 Minimization of the spread of SARS-CoV-2 via household waste produced by subjects affected by COVID-19 or in quarantine (Di Maria et al., 2020). COVID-19, coronavirus disease 2019; MBT, mechanical-biological treatment; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2 [Color figure can be viewed at wileyonlinelibrary.com]

et al., 2006), will allow retaining more and more resources in the production and consumption circle, thus reducing the generation of waste, such as plastic waste. In developing countries, informal waste collectors/waste recyclers are the most vulnerable despite their enormous contribution to the informal recycling of waste (Ellen et al., 2001; Prüss-Ustün & Corvalan, 2006).

7 | POLICIES IMPLICATION

The authors have developed the following policy recommendations for governmental agencies to consider.

Recycling: One of the habits to maintain is recycling, but to take into consideration controls during pandemic conditions to prevent potential exposure to contagions. A serious issue as a result of the Covid-19 pandemic will be a decrease in recyclable materials. Recycling represents an important source of energy and income in many countries (i.e., Mexico, France, Germany, Brazil, and Colombia).

Home management of waste in positive or quarantined homes for COVID-19: For people with a positive COVID-19 test, the patient's waste, including disposable materials used by the sick person (gloves, handkerchiefs, masks), should be disposed of in a plastic bag in a dedicated garbage can, preferably with a lid and an opening pedal, without separating recyclable wastes. The plastic bag should be tightly closed and placed in a second garbage bag, next to the room exit, while wearing gloves and a mask. Immediately after removing the bag, the caregiver or patient should complete hand hygiene, with soap and water, for at least 40–60 s.

Sanitation worker protection: Prioritize permanent training for sanitation workers on the handling of waste collected at homes and equip them with PPE verifying their use and implementing

COVID-19 biosafety protocols for solid waste management.

Municipalities should also consider developing indicators that measure the efficiency of the measures taken and the application of said measures by the municipalities (Danso et al., 2019; Fuso et al., 2019).

Figure 5 illustrates the measures to contain the spread of the COVID-19 virus by proper waste management.

There are four types of landfill infrastructures for the final disposal of waste: (1) sanitary landfill (municipal waste), (2) security landfills (hazardous waste), (3) mixed landfills (can include municipal and non-municipal waste), and (4) construction and demolition debris landfills. The lack of information and monitoring systems restrict the ability to plan and develop elements for decision-making, management, the formalization of plans and programs, the prioritization of activities, the allocation of resources, and the performance of monitoring and surveillance tasks and controls.

8 | CONCLUSION

With the rapid spread and waves (1–4) of COVID-19 currently with over 20.1 million global confirmed cases and approximately 742,000 deaths across the globe (Sarkodie & Owusu, 2021), waste management is becoming critical to socioeconomic development and health outcomes during the COVID-19 pandemic. There is an urgent global call for waste management from households and medical facilities to be treated as an essential public service which may mitigate the potential threats of the COVID-19 pandemic on environmental sustainability and health outcomes. It is important to establish guidelines for solid waste management and sanitation services to manage risks posed by SARS-CoV-2. Medical facilities should ensure that BMW is managed with specific biosafety precautions. The general population should be informed of proper waste management provisions when dealing with wastes generated by those with COVID-19, such as segregating masks, gloves, and other wastes and following the waste management techniques described herein.

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CONFLICT OF INTERESTS

The authors declare that there are no conflict of interests.

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