American Journal of Environmental Sciences

Review

Challenges in Healthcare Waste Management of the UN 2030 Agenda in the COVID-19 Era

[1]Gabriella Marfe, [1]Stefania Perna and [2]Arturo Hermann

[1]Department of Scienze e Tecnologie Ambientali, Biologiche e Farmaceutiche, University of Campania "Luigi Vanvitelli," via Vivaldi 43, Caserta 81100, Italy
[2]Italian National Institute of Statistics (ISTAT), Viale Liegi 13 Rome Italy

Article history
Received: 24-09-2021
Revised: 07-02-2022
Accepted: 14-02-2022

Corresponding Author:
Gabriella Marfe
Department of Scienze e Tecnologie Ambientali, Biologiche e Farmaceutiche, University of Campania "Luigi Vanvitelli" Italy
Email: gabmarfe@alice.it

Abstract: Today, the COVID-19 pandemic has caused a remarkable and sudden increase in global demand for Personal Protective Equipment (PPE), such as masks, gloves, gowns. The growing biomedical and municipal streams of potentially infectious waste is a new challenge for every country since an inadequate waste management might have serious public health consequences and significant impact on the environment. In this scenario, this review study is aimed to point out that the current pandemic can impact on the achievement of the UN Sustainable Development Goals (SDGs). Specifically, within SDG12, the crisis of waste could offer countries a new production patterns towards a more sustainable future in its management. From review study, we believe that a new specific target for biomedical and municipal waste management could be added to SDG12: Target 12.9: "Ensure a safe and sustainable management of biomedical and municipal solid waste to attain an environmental sustainability during and especially after this widespread pandemic". In this regard, it will be important to distinguish the ordinary waste from COVID-19 waste both in biomedical and municipal solid waste management to reach this target. In addition, innovative and sustainable strategies in biomedical and municipal waste management should be adopted in association with a new regulation at the legislative level during and after this pandemic. Therefore, new investments in clean techniques and in new infrastructures in management practice can play a crucial role to promote a new environmental transition stage. Furthermore, The United Nation's Agenda 2030 for Sustainable Development has created an important framework to realize environmental sustainability. through the 17 Sustainable Development Goals (SDGs) with 169 targets. In the last five years, many efforts are made to achieve SDGs, but today this pandemic could be a threat for the realization of these goals by 2030. In this context, all countries can consider this pandemic as a new opportunity to launch a plan to stop pollution, climate change and possible new pandemics.

Keywords: Sustainable Development Goals (SDGs), Biomedical Waste Management, Face Masks, Gloves, COVID-19, Hazardous Waste

Introduction

In December 2019, a new coronavirus was identified in Wuhan (a province of Hubei), called COVID-19 (Coronavirus Disease 2019), which after passing into exotic animals, infected humans with marked virulence leading to the spread of a mysterious pneumonia (Ge *et al*., 2020; Mousavizadeh and Ghasem, 2020; Verity *et al*., 2020; WHO, 2020a). In this regard, the lockdown in Wuhan was declared with a delay of almost a month

compared to the first cases as well as the communication to the WHO (World Health Organization) happened after the first communication of Public Health Emergency of International Concern (PHEIC). Different guidelines (such as frequent hand washing, social distancing and quarantine) were announced by WHO and the US Centers for Disease Control and Prevention, the National Centers for Disease Control and local governments in order to diminish the spread of Severe acute respiratory syndrome coronavirus-2 (SARSCoV-2). In addition, the same institutions have also advised the use of Personal Protective Equipment (PPE) (surgical masks, gloves, goggles, gowns and aprons, disposable protecting cloths) for both medical personnel such as physicians, caregivers and other people dealing COVID-19 patients and the general population. According to the WHO, before COVID-19, the 58% of the studied facilities with adequate biomedical waste management was present in 24 countries. Furthermore, in low-income countries, there is not a proper separation between hazardous and nonhazardous waste above all in biomedical Municipal Solid Waste (MSW). Naturally, this problem has multiplied for enormous production of hazardous waste in COVID-19 pandemic. In the outbreak, around the globe, 129 billion face masks (about three million masks every single minute of the day) and 65 billion gloves are utilized every month during this pandemic (Xu and Ren, 2021). In Hubei, medical waste rate has recorded an increase of 600% from 40 to 240 tons, causing a significant overload of existing waste collection and disposal systems. For example, Wuhan has generated about 247 tons of medical waste for day, while the medical waste rate was about 50 tons for day before pandemic. In addition, the data of Ministry of Ecology and Environment of China reported an increased disposal of biomedical waste to 4903 tons/day to 6022 tons/day during the pandemic. In Malaysia, the biomedical waste was on pace to increase 30% during March 2020 (Agamuthu and Barasarathi, 2021). In Bangladesh, only in April 2020, 14,500 tons from biomedical waste was generated during the COVID-19 outbreak. In South Korea almost 2,600 tons biomedical waste was generated from 91 COVID-19 hospitals, 8 residential centers, 24 temporary facilities and households in quarantine until the mid of July 2020, that was burned into incinerator (Ilyas *et al*., 2020). In US, the biomedical waste production has been 5 million tons per month during the pandemic, while the generation rate was 2,5 million tons per year (Sarkodie and Owusu, 2021). Based on report 101 Metric Tons (MT) of COVID-19–related biomedical municipal solid waste (BMSW) per day was generated during April 2020, considering also the normal quantity of BMSW generation of ~609 MT per day (Ilyas *et al*., 2020; Capoor and Parida, 2021). It has been estimated, on average, a production of 2.5 kg/bed/day of COVID-19 biomedical waste in developing countries by considering the results of 2.85 kg/bed/day in Thailand, 2.23 kg/bed/day in Indonesia and 2.0-2.2 kg/bed/day in Mexico. Furthermore, a strong increased biomedical waste generation in West Java, Indonesia during the COVID-19 pandemic, was detected in the months of January, March and April 2020 (about 10,903, 11,646 and 14,606 tons of biomedical waste generation, respectively) with a peak of about 30% between January and April (Ilyas *et al*., 2020; Singh *et al*., 2020; Capoor and Parida, 2021). In according with the results provided by (ADB) 2020, in five Asian cities, it has been calculated an increased biomedical waste generation from healthcare facilities associated with COVID-19 as shown in Table 1 (Prasetiawan *et al*., 2020; UNEP, 2020). This trend has been observed also in Europe including France and the Netherlands where the medical waste was incremented with a rate from 40 to 50 and 45 to 50%, respectively (Wei and Manyu, 2020). The same trend has also been observed in Brazil (Martins *et al*., 2021) and in other countries such as Iran (Zand and Heir, 2020a, Zand and Heir, 2020b, Zand and Heir, 2021) Kingdom of Saudi Arabia. Jalal *et al*. (2021). Actually, it is necessary also to consider the impact of COVID-19 infection on municipal solid waste generation and management for the increased use in the number of PPE (such masks, gloves and other protective equipment) utilized by ordinary population, patient's relative visiting hospitals, care centers, public and private staff of offices, staffs of airport and railway stations, schools and universities. Many of these new consumers do not know the right rules to dispose of in proper manner this protective gear since they are not properly informed (Ikiz *et al.*, 2021). In this context, such pandemic has created several problems on MSW management because of an increased use of PPE. Specifically, both the production and volume of home waste are changing MSW and consequently the municipal waste programs should require adjustments for coping with this strong influx of used PPE, often made of single-use plastics, as well as single-use and recyclable plastics of foodstuffs and other consumer goods (Vanapalli *et al*., 2021). Furthermore, in most developing countries, such as Cambodia, Philippines, Thailand, India, Malaysia, Indonesia Bangladesh, Vietnam and Palestine the MSW is poorly managed and disposed of in open landfills (Ferronato and Torretta, 2019; WBSWM, 2020). In this regard, the increased use of masks and gloves are causing a new source of plastic pollution in the environment (Silva *et al*., 2021). Surgical masks are made by the Polypropylene (PP), a thermoplastic polymer, that does not undergo a complete degradation in the environment due to its strong resistance, (Aragaw, 2020; Li *et al*., 2020). Furthermore, these

masks (Polypropylene-Surgical Masks PP-SMs) can be reduced through photochemical and mechanical processes due to effects of heat, wind, ultraviolet radiation and ocean current, eventually forming Microplastics (MPs) with sizes of <5 mm, which could remain in the environment for hundreds of years (Majewsky *et al*, 2016; Liu *et al*., 2019). Like other plastic fragments and microplastics, these masks may accumulate and release harmful chemical substances, such as bisphenol A, dye and heavy metals (Sullivan *et al*., 2021). Furthermore, the new generation of nano masks (made with nano-sized plastic fibers) adds new sources of nanoplastic fiber pollution, which may worsen the effect (Xu and Ren, 2021). In 2019, a report (Plastic and Health, 2019) pointed out that plastic waste had a harmful impact on human health during its life cycle from the extraction (from crude oil or natural gas), production, consumption and until to disposal. Today, it is possible to find masks and gloves on beaches, ocean beds and cities environments. Different studies showed their negative impact on gastrointestinal and liver apparatus or immune system (Advisors *et al*., 2019; Li *et al*., 2016). Furthermore, in a recent study, the authors have revealed the presence of microplastics. in four out six human placentas, collected from consenting women with physiological pregnancies (Ragusa *et al*., 2021). An Italian study carried out by a consumer association (Adiconsum in Veneto Italy) analyzed several lots of face masks. Such analysis found that these masks contained titanium dioxide in high concentrations (from 100 to 200 ppm-corresponding to mg/kg) Adiconsum Veneto 2020). This finding was confirmed by a report of the Belgian public health authority ”Sciensano” that found titanium dioxide (TiO_2) (Mast *et al*., 2021). This compound is an additive that is used in both the cosmetic and food industries as a whitener. Titanium dioxide or E171 is a chemical compound that was defined by the International Agency for Research on Cancer (IARC) in 2006 as a "possible human carcinogen" when inhaled (IARC, 2010). Moreover, in 2017, one research carried out by the French National Institute for Agronomic Research (INRA) reported that chronic exposure to titanium dioxide, through ingestion, "causes early stages of carcinogenesis" (INRA, 2017). This study recommends to institutions for waste management to comply with the circular economy in the context of an efficient waste recycle, also through an improvement of environmental controls and of the fight against illegal dumping. In this scenario, the improper management of plastic and plastic particles of face masks and gloves could have a negative influence on human health and environment as reported by multiple articles (de Sousa, 2020; Sangkham, 2020; Parashar and Hait, 2021; Selvaranjan *et al*., 2021). Furthermore, the generation of the face masks are also responsible to the emissions of CO_2 that are involved in the global warming (Liebsch, 2020). Moreover, the production of N95 and surgical mask using propylene or polypropylene contributes to the increase of CO_2 emission to the environment.

Table 1: The amount of medical waste generation in five Asiatic cities (Metric ton = 1000 kilograms t/d = metric tons per day). Source: Data extracted from ABD 2020 and article Prasetiawan *et al*., 2020)

City	Population	Healthcare waste Production (tonnes/day before COVID-19 pandemic)	Healthcare waste Production (tonnes/day after COVID-19 pandemic)
Manila	14×10^6	47	280
Jakarta	$10{,}6 \times 10^6$	35	212
Kuala Lampur	$10{,}5 \times 10^6$	35	210
Bangkok	8×10^6	27	160
Ha Noi	$7{,}7 \times 10^6$	26	154

Table 2: COVID-19 waste types (Source: CPCB, 2020. Revision 4 Guidelines for Handling, Treatment and Disposal of Waste Generated during Treatment/Diagnosis/Quarantine of COVID-19 Patients Central Pollution Control Board).).

Infected or potentially infected waste	Used masks (such N95 mask, surgical mask, etc.,), head cap, shoe cover, coverall suit, splash proof apron, face-shield, hazmat suite, nitrile gloves, feces from COVID-19 confirmed patient, body fluids or blood soaked tissues/cotton, microbiology, biotechnology and other clinical laboratory waste, viral transport media, plastic vials, vacutainers, Eppendorf tubes, plastic cryovials, pipette tips, used syringes, urine bags, drain bags, medicine vials
Pathological waste and	Human tissues, organs or fluids of COVID-19 confirmed patients
sharp waste	Contaminated and used needles and syringes with fixed needles
Pharmaceutical waste	Drugs and vaccines used during diagnosis or treatment of COVID-19 patients
Non hazardous or general waste	Such waste may include wrappers of medical items, fruit peels, empty or used bottles, Waste paper, carton boxes of medicines, disinfectant bottles, left-over food, disposable cutlery, packaging material etc.

Table 3: The guidalines program for the waste management during the COVID-19 pandemic

Guidelines and policies	Institutions	Instructions
Waste Management in the COVID-19 Pandemic Biomedical and Minicipal Solid Waste Management	UNEP	Practical information and guidelines on
Factsheet on environmentally sound management of medical waste	Basel Convention	The implementation of the biomedical waste management produced during the pandemic
Waste Management during the COVID-19 pandemic	ISWA	1 Countries, States/Provinces and Cities should ensure that waste management, recycling services, treatment and disposal facilities will not be stopped a. Waste management workers, especially those in waste collection, should take additional precautions and Ensure health and safety procedures to be protected by any potential infection by the waste streams and/or the equipment. 2. Recycling activities should be re-adjusted to avoid cross-contamination and infections. 3. The increased quantities of healthcare and medical waste should be safely treated and disposed of, making sure that they pose no risk for further infections and pollution.
Infection control in the household management of people with suspected or confirmed coronavirus disease (COVID-19)	ECDC	Management of household waste
Waste management in the coronavirus outbreak	EC	Guidance to proper waste management services

Additionally, cloth masks are produced through fabric, sewing and weaving process that increase CO_2 emission to the environment (Liebsch, 2020). A study carried out in the UK observed that if every day one disposable surgical mask is used by each person for a year, this would lead a generation of 124,000 tons of unrecyclable plastic waste, 66,000 tons of contaminated waste and 57,000 tons of plastic packaging (Ayse *et al*., 2020). For example, in another study, the authors, through a telephone survey found that special measures for management and collection of waste PPE were applied by 80% of local governments in the Silesian region, but only 13% of waste collection companies have followed these rules (Nowakowski *et al*., 2020). Another interesting study monitored in situ data on riverine debris releases into Jakarta Bay, Indonesia and the authors reported d a high presence of PPE (De-la-Torre *et al*., 2021). Currently, there is no specific process in waste management of these products that are thrown in the streets or in the parks or collected as unsorted waste. In summary, this pandemic re can play a crucial role to improve both urban solid waste and hazardous medic waste management.

Materials and Methods of Data Collection

The approach method to collect the data was based to better understand the relationship between COVID-19 and waste management, in particular with SDG12. We considered scientific literature articles, reliable information from online sources, journals and media reports. The literature was collected from March 2020 (at the begging of the first wave of COVID-19 pandemic) until the end of this study (30th December 2021). The data collection was based on different categories of: (a) Precautionary measures used to stop this virus (such as face mask, gloves and other PPE); (b) the components of the PPE; (c) problems due to the management of the medical and municipal solid waste; (d) sustainable solutions to face the impact of wastes on SDG12, specifically on target SDG12.5. We are used different databases including Scopus (scopus.com), Web of Science (webofscience.com), Google scholar and PubMed Central (PMC). In this way, we obtained many similar papers to the subject to reduce the risk of missing any important document. To start this process, keywords such "COVID- 19" or SARS-CoV2 from the end of 2019 until December 2021" were used to develop the right search criteria. The search keywords were 'biomedical waste', 'COVID-19', 'pandemic', 'novel corona', 'SARS-CoV-2', 'types of biomedical waste', biomedical waste management', face mask, gloves and municipal solid waste management, plastic pollution, SDGs and in particular SDG12. We selected only articles in English language that were analysed considering the selected keywords. In conclusion, in this review, we pointed out the issues, challenges about waste management during COVID-19 pandemic within SDG12 and also the interplay among the different SDGs with waste management and COVID-19.

COVID-19 Pandemic: Correlation Between Biomedical and Municipal Waste Management and SDG12

The inception of the COVID-19 can be considered a challenge for SDG12 since the generation of infectious medical waste, specifically gloves and facemasks, as well as of the other biomedical hazards is increasing in enormous amount within a very short

period. Target 5 of the SDG 12 which is "By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse" will be very difficult to reach. In this context, we believe that this target is too generic and, for this reason, it could be important to add a new specific target in biomedical and municipal solid waste management:

Target 12.9
Ensure a safe and sustainable management of biomedical and municipal solid waste to attain an environmental sustainability during and especially after this widespread pandemic.

In pandemic era, it is very important to distinguish the ordinary waste from COVID-19 waste both in biomedical and municipal solid waste management to avoid spreading the COVID-19 infection (Gupta, 2022).

COVID-19 waste consists of (Fig. 1 A B):

1. Waste produced during home quarantine period
2. Waste derived from a healthy person who has been close to someone with a COVID-19 infection
3. Any PPE derived from healthy or asymptomatic persons (such as masks, gloves etc.,)
4. Waste produced in new COVID-19 isolation facilities, COVID Intensive Care Unit (ICU) and COVID care centers

In summary, biomedical and municipal solid waste from places where COVID-19 infected patients are under treatment or discarded PPE from households and by general public could be collectively treated under the category of COVID-19 waste as reported in Table 2 Furthermore, biomedical waste generated from any healthcare facility which is not linked to any COVID-19 related activity (diagnosis, research or treatment) does not fall under COVID-19 waste. The sources of COVID-19 waste in biomedical field are represented from COVID-19 Hospitals, COVID-19 facilities, Intensive Care Units (ICUs), Clinics, private testing centers (such pharmacies), private and public laboratories and sample collection facilities, ambulances, mobile diagnosis and testing units can produce COVID-19 waste and at the end, the personal protective equipment of health workers (Fig. 1A, B).

In the case of solid municipal waste, the COVID-19 waste is generated from (Fig. 1A, B):

1. Households with COVID-19 infected patients have been isolated and followed -up through the remote monitoring or visiting physicians
2. Mortuary, graveyards and crematoriums where all workers wear the personal protective equipment PPE also
3. Commercial facilities, public offices, school, university and public transportation where all people wear masks and PPEs after the lockdown restrictions

Different international organizations, such as the WHO, the Basel Convention, European Centre for Disease Prevention and Control (ECDC) and the United Nations Environment Programme (UNEP), have provided the guidelines for the proper management of biomedical and municipal solid waste produced in households during the pandemic as shown Table 3 (Basel Convention, 2020a, b; ECDC, 2020; European Commission, 2020; ISWA, 2020; UNEP, 2020a, b; UNICEF, 2020). The Basel Convention's guidance document-Factsheet on Environmentally Sound Management of Medical Waste provides the information both for managers to handle and dispose of biomedical waste at facilities in sustainable manner and for transporters and collectors. Furthermore, the WHO has provided information on how to manage biomedical and municipal waste produced by quarantined people (UNEP, 2020a; UNICEF, 2020; Liang *et al*., 2021). Furthermore, several COVID-19 Waste Management Factsheets were published by the UNEP to choose the better waste management technology during this pandemic (UNEP, 2020b) In this scenario, innovative strategies should be adopted both by biomedical and municipal solid waste management with a new regulation at the legislative level to face this new challenge through a new way forward.

Biomedical Waste

In this time, biomedical waste should be collected, separated, stored and tracked (such as the radio-frequency identification-RFID) in order to proper manage and dispose and to avoid the illegal dumping (Fig. 2). The first basis of this new framework should provide:

1) Identification of the waste categories (hazardous and not hazardous) generated by each hospital
2) Identification of the strategy to prevent and minimize the waste amount of each hospital
3) Knowledge of the collection and transport of biomedical waste of each hospital
4) Knowledge of segregation process of each hospital. This method allows to separate infectious waste from no infectious waste, hazardous waste from no hazardous waste.

After this process, the waste should be placed in special bags with specific-colored labels to identify the type of waste and then, in the suitable container (rigid, leak-proof, break-resistant and puncture-resistant) for disposal

5) Knowledge of final disposal of waste for each hospital towards sanitary landfills and incinerators after the strategies of reuse and recycle
6) Healthcare waste workers should wear PPE, (including boots, long-sleeved gowns, gloves, masks, goggles and face shields) and in addition, they should wash very often their hands with disinfectants in particular after disposing of the hazardous wastes (WHO, 2020b).

Therefore, both the recycle and the decrease of landfills of biomedical wastes could play a crucial role to allow a sustainable management of these wastes during and after the COVID-19 pandemic. To realize this program, significant changes should happen in control hospital system of waste management with a new department with specific expertise in environmental issues. The creation of this biomedical waste management control department requires highly qualified personnel able to build an environmental monitoring system. In particular, employees should be able to classify the types of waste (hazardous and not hazardous; infected and not infected). After such process they can decide the type of collection, transport, final destination and suitable treatments for the recycling and reuse in according with waste disposal companies (Fig. 2). This organization needs of a close interaction and collaboration among the various departments such as the compilation of technical documents of in-put materials (medicines, equipment, hazardous substances) and outputs materials (expired medicines, laboratory calibration equipment). Furthermore, precise protocols of waste disposal should be provided to all health professionals. For example, in Germany, hospitals give instructions on the disposal of non-hazardous waste to external companies. In addition, hospitals pay waste taxes based on the classification and amount of produced waste. A recent study in Italy, carried out in operating theatres of public tertiary Hospital of Piedmont, has reported that 57% of the waste was disposed of in improper way: In this case 71 and 1% of these wastes could be recycled and recovered, respectively.

Table 4: Different types of PPE (gloves and face masks)

PPE	Components	Disposal
Latex gloves	Latex is a natural product, obtained from the incision of the bark of rubber trees	They are not recyclable and they can be disposed of in an unsorted bin.
Nitrile gloves	Nitrile is a very elastic synthetic rubber, with mechanical and chemical resistance	They can be recycled only after specific treatments. There is project study entitled “Nitrile Glove Recycling Assessment” University of British Columbia[1]
Vinyl gloves	PVC (polyvinyl chloride), a synthetic resin obtained from the polymerization of vinyl chloride and they such are treated with plasticizers	These gloves must be discarded in proper manner for recycling. If, they are destined to incineration, they can release harmful substances (such as dioxin family composed by highly carcinogenic elements) since they are formed by organic chlorine molecules. For these reasons, vinyl gloves must be collected as plastic and treated in special recycling plants through the recovery of the various plastic materials to obtain new products or also heat and electricity.
A N95 respirator masks	Such masks consists of multiple layers of nonwoven fabric, often made from polypropylene. They filter out at least 95% of very small particles (0.3 micron) and they should be used in health care center	This masks are placed ina plastic bag or zip-lock bag and dispose of in biomedical waste disposal unit In the hospital setting, it is possible use different techiniques to decontaminate them such masks used in public setting, need to be discarded after one use they should be placed into two small plastic bags and throw them away with your general domestic waste
FFP 1, 2, 3 respirator masks	Such masks consists of multiple layers of nonwoven fabric, often made from polypropylene They filter at least 80, 94 and 99% of airbone particle, respectively.	This type of mask are placed ina plastic cosed and dispose of in biomedical waste disposal unit in the hospital setting, it is possible use different techiniques to decontaminate them Such masks used in public setting, need to be discarded after one use and they should be placed into two small plastic bags and throw them away with your general domestic waste
Surgical masks Type I II and III	Such masks consists of multiple layers of nonwoven fabric, often made from polypropylene	These masks should be placed into two small plastic bags and throw them away with your general domestic waste.

1https://sustain.ubc.ca/sites/default/files/seedslibrary/VOL_400_Nitrile%20Glove%20Recycling_%20Final%20Report.pdf

Table 5: The most common techonologies for decontamination of face masks

Decontamination technologies of face masks	Antimicrobial efficacy performance	Impact of maskface fit
Ultraviolet radiation (Viscusi *et al*., 2009; Viscusi *et al*., 2011; Lindsley *et al*., 2015; Bhattacharjee *et al*., 2020; Smith *et al*., 2020; Choi *et al*., 2021)	99,9%	Rate fit: 90-100% after 3 treatments
Hydrogen peroxide (H_20_2) vapour (Bhattacharjee *et al*., 2020; Smith *et al*., 2020; Choi *et al*., 2021)	≥99,999%	Rate fit is good after 20 treatnments
Hydrogen peroxide (H_20_2) liquid (Viscusi *et al*., 2007; Bergman *et al*., 2010; Fisher *et al*., 2011, Heimbuch *et al*., 2011)	Not determined	Not determined
Moist heat decontamination (Viscusi *et al*., 2011; Heimbuch *et al*., 2011)	99,9%	Good
Microwave steam bags (Fisher *et al*., 2011)	99,9%	Not determined
Microwave-generated steam (Heimbuch *et al*., 2011)	99,9%	Rate fit: 95%-100% after 3 and 20 treatments
Ethanol (Bhattacharjee *et al*., 2020))	Effective treatment for Sars-CoV2	Deformed mask integrity
Rice Cooker-Steamer (Viscusi *et al*., 2007; Li *et al*., 2011; Bhattacharjee *et al*., 2020)	Effective treatment for bacteria	Not determined

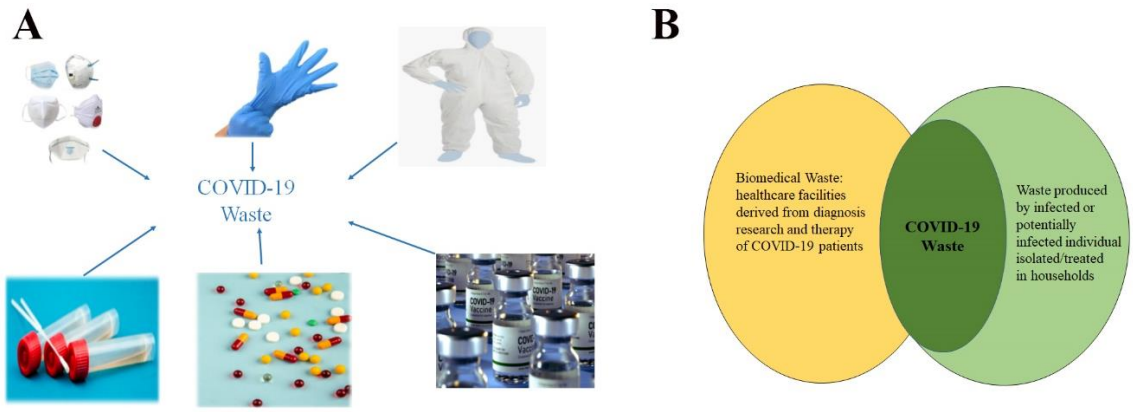

Fig. 1: Humans are exposed to micro plastics through inhalation, ingestion and direct skin contact

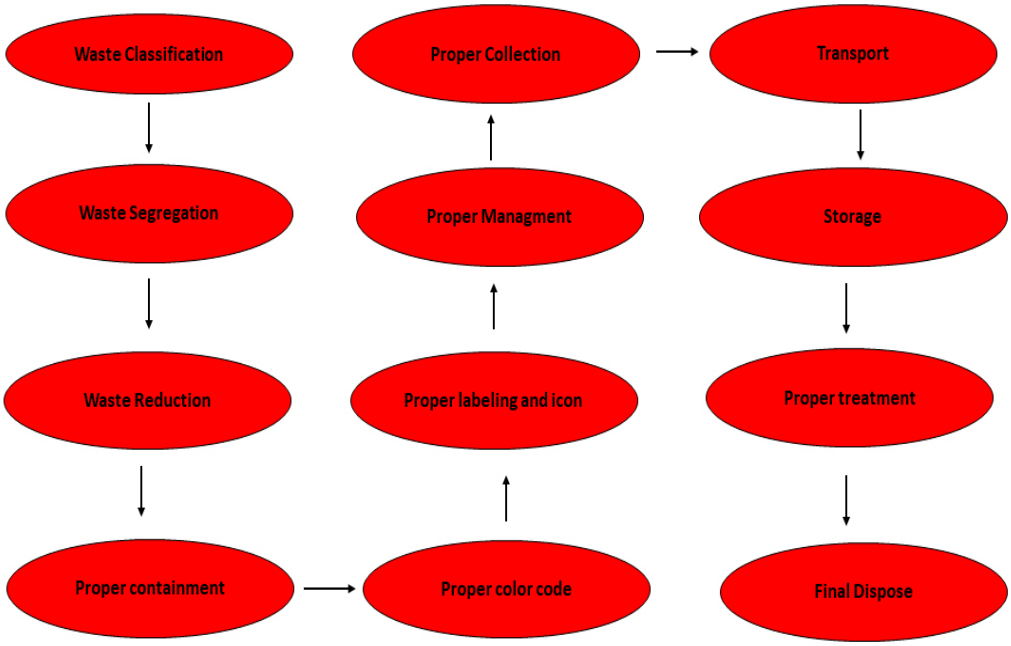

Fig. 2: Phases for the safe management of biomedical waste

Furthermore, the preoperative phases in hospital produced a high amount of biomedical waste (48%) that are generally disposed of in unsafe manner. The authors have observed that 66% of waste considered as "undifferentiated" could have been recycled, while 54% of waste managed as hazardous could have been recycled, reused or otherwise segregated stood. In addition, 5% of hazardous waste was disposed of in unsafe way. (Amariglio and Depaoli, 2021). For instance, in Hubei, China, infected biomedical waste was separated, disinfected by using 0.5% chlorine solution and packed in special bags and in temporary storage close to the hospitals. This kind of waste was collected by waste workers with special vehicles and sterilized in autoclave or irradiated and then, disposed of in safe landfills. In other hospitals, such waste was incinerated on-site or in a special isolated area (ADB, 2020). In the Philippines, a special registry for COVID-19 waste has been established for collection, transportation treatment and storage facilities for a proper handling and final disposing of it in the Luzon Island. Every pathological infectious biomedical waste was collected and then registered with a document with every detail for transportation and safe disposal. In addition, every vehicle used for transporting was recorded with name and ID of transportation by label in which was specified the waste class and the waste number (EMB, 2020). In Jordan, the waste workers had to wear PPE such as ultra-filtered masks (Nano) and protective clothing with cap, shoes, professional leather gloves with elbow length sleeve and elastic band, safety glasses or full-face shield to manage the infected waste in safe manner. Furthermore, COVID-19 waste derived by infected patients was disposed of in temporary storage areas, but every container and biomedical waste bag were sterilized to prevent the spread of the virus (ISWA-Jordan, 2020). In the United States of America (USA), biomedical COVID-19 waste is considered as waste produced by other patients and for this reason they are treated with normal methods (Commendatore, 2020; Das *et al*., 2021). On the other hand, the biomedical COVID-19 waste needs temporary storage areas, particular treatment and safe waste collection from COVID-19 hospitals and other COVID-19 health care centers (Yu *et al*., 2020). Furthermore, alternative technologies are necessary (Ilyas *et al*., 2020; WHO, 2020a) such as sterilization method with supercritical fluid carbon dioxide ($SF\text{-}CO_{(2)}$)$SF\text{-}CO_2$ sterilization technology (Hossain *et al*., 2011) or sterile wave (an ultra-compact technique) to reduce the infected waste and to kill the virus. Further studies are needed to assess wastes disposal in both public and private hospitals in order to improve their management. This is a new challenge around the globe, but it will be difficult to manage, since medical waste treatment, collection and transportation are too much different among countries.

Municipal Solid Waste Management

During the pandemic, the recycling facilities have not worked well with a negative impact on waste cycle in different countries. The use of virgin plastic as a substitute for recycled plastic is a less expensive process and, in addition, all kinds of waste are burned through incinerators with harmful effects on environment and human health (Plastics Recyclers Europe 2020). For example, in Oregon, Michigan and California states, different recycling cooperatives have received lower number of recyclable wastes in April 2020 in comparison to April in 2019 (Staub, 2020). Also in Vienna, there was a 10-15% reduction in the collection of recyclable materials. A strong increase in the amount of waste was produced from households during the outbreak of COVID-19. For instance, in US the domestic residential waste has recorded an increased trend between 20 and 30% greater than normal (SWANA, 2020). Furthermore, the municipal solid waste plans also had many problems with both strong increase of used PPE (such as face masks, face shields, gloves, head mobs, gowns and shoe covers) and with infected waste residues. In this context, new technological strategies are needed to handle the municipal solid waste. The WHO recommends onsite segregation and collection of non-infectious wastes for municipal solid waste in strong black plastic bags, while households with infected person are advised to put contaminated waste in double bags and well tied. However, different countries have modified their waste management systems. For example, Spain has used the co-incineration in cement plants, while in Norway have been introduced new rules for disposing of in landfills of COVID-19 waste (ACR 2020; Roberton *et al*., 2020). In China, contaminated waste was treated with mobile facilities (high-temperature incineration) (Klemes *et al*., 2020; Peng *et al*., 2020). Temporary storage facilities are created to manage increasing municipal solid waste during COVID-19 pandemic (Defra, 2021). Generally, most municipal solid waste was disposed of into landfills in both developed and developing countries before pandemic, except for three developed countries Japan, Denmark, Sweden (Kulkarni and Anantharama, 2020). In developed countries, incineration is the primary waste management method for MSW, followed by landfills and then resource recovery, while in developing countries, the landfills represent the principal method to manage MSW (Kulkarni and Anantharama, 2020). In this scenario, changes of MSW management are necessary all countries during and after the COVID-19 pandemic to prevent the transmission of the virus. We believe that every city should introduce new regulation on municipal solid waste management such as:

1) Segregation method for contaminated and uncontaminated waste at the source
2) Recycling and appropriate waste management strategies
3) to avoid putting the PPE directly the unsorted garbage
4) The implementation of an international strategy to manage this PPE waste by considering the different components and ways of disposal of kind of this waste as reported in Table 4
5) The introduction of specialized containers of the PPE after having placed them in sealed plastic bags
6) To introduce of novel alternatives to redesign masks based on degradable plastics such as in Hong Kong, where a local public research institute has created a reusable-masks that employ enhanced filtration technology that allows their washing and reusing up to 60 times
7) To recycle PPE by obtaining liquid fuels through pyrolysis
8) To use the decontaminating methods for reuse of face masks as reported in Table 5 (considering that these methods can remove all threat of virus, without sacrificing the filtration efficiency or fit and be safe (non-toxic) for the user) (Choi *et al*., 2021; Bhattacharje *et al*., 2020; Smith *et al*., 2020; Lindsley *et al*., 2015; Fisher *et al*., 2011; Heimbuch *et al*., 2011; Viscusi *et al*., 2011; Bergman *et al*., 2010; Li *et al*., 2010; Viscusi *et al*., 2009; Viscusi *et al*., 2007)
9) To provide safe equipment to waste management personnel above all in suspected municipal solid waste
10) To provide safe vehicle to collect and transport of this type of waste
11) A direct transport from generation and collection sites to the incineration plants or to treatment facilities to provide a proper treatment of these wastes
12) To provide disinfection of all vehicles and the containers in safe manner to stop the spread of the virus among waste management personnel.

This approach of waste collection companies would mean to increase operational costs, but most companies (both private and public) prefer not to invest in safety, endangering the health of their operators and citizens. In conclusion, there is a fundamental global need to implement several changes in waste management at biomedical and municipal level to achieve environmental sustainability and to avoid harmful outcomes for our health.

The Impact of COVID-19 Pandemic on the Different SDGS and their Implication with Waste Management

In 2015, the United Nations Member States adopted the 2030 Agenda for Sustainable Development that consists of 17 Sustainable Development Goals (SDGs) with 169 targets, to be achieved by 2030, for transforming our world. In the last five years, many efforts are made to achieve SDGs, but today it is very difficult to face this challenge in many countries in during this pandemic. (Sachs *et al*., 2019). There are many signs that the COVID-19 pandemic can be a threat for the realization of the SDGs by 2030. Nevertheless, this pandemic could be considered an opportunity to launch a plan to "defeat the virus and build a better world". Today, in different papers, the authors have considered the interaction among pandemic and few SDGs and for this reason, further studies are necessary to better understand the impact (both restricting and promotin9 of pandemic on all SDGs (Adhikari *et al*., 2021; Filho *et al*., 2020; Fleetwood, 2020; UN, 2020).

In this context, here we evaluated the interconnections among all SDGs with waste management in light of the COVID-19 pandemic (Fig. 3 A, B).

Goal 1-End poverty in all its forms everywhere.

In the global context, the increase of global poverty will involve as more than 71 million people worldwide that exert back into extreme poverty (Valensisi, 2020). Furthermore, decreased labour income and poor job quality is negatively affecting the women and young workers and creating strong disparities during the pandemic (UN, 2020). Therefore, this pandemic has negatively impacted the economies of the less developed countries and, for this reason, it has been estimated that about 4 billion people will have not any social protection scheme and they will be more vulnerable to the COVID-19 infection. In this context, it will be important to manage the biomedical and municipal solid waste in proper manner with new strategies and technologies in order create jobs. For example, in Europe, it has been estimated that a proper waste management could create 400.000 new jobs considering the current legislation and a further 180.000 new jobs could be created going towards green and circular economy by 2030 (https://ec.europa.eu/commission/presscorner/detail/en/MEMO_14_450).

Goal 2-End hunger, achieve food security and improved nutrition and promote sustainable agriculture.

In some countries, food security is becoming an important issue during COVID 19 pandemic. because lockdowns have negatively affected jobs, production and distribution of agricultural inputs. Furthermore, the disruption in transport networks, has also negatively influenced food security (Pothan *et al*., 2020). The Global Nutrition Report 2020 showed that 37.9% of children under five years are stunted and 20.8% have a high incidence of malnutrition. Considering the global impact, it is possible to calculate that 2 billion people around the world are crossing a moderate food insecurity, while around 700 million are crossing a strong food insecurity. In 2019, this report pointed out that 47 million children had stunting and wasting because to malnourishment. In this context, it is possible to suppose that further 6.5 million children could suffer of malnourishment. due

limited accessibility to food. Furthermore, the food prices are resulted higher during the COVID-19 pandemic due the disruption of the supply chains. In this regard, it can be important to reduce food waste around the globe since the people affected by hunger are increasing from 2014. Globally, around 14% of food produced is lost between harvest and retail, while an estimated 17% of total global food production is wasted (11% in households, 5% in the food service and 2% in retail). Food loss and waste undermine the sustainability of our food systems. When food is lost or wasted, all the resources that were used to produce this food-including water, land, energy, labour and capital-go to waste. In addition, the disposal of food loss and waste in landfills, leads to greenhouse gas emissions, contributing to climate change. Food loss and waste can also negatively impact food security, food availability and contribute to increasing the cost of food (https://www.fao.org/food-loss-and-food-waste/flw-data).

Goal 3-Ensure healthy lives and promote wellbeing for all at all ages.

During this pandemic, the hospitals are filled by COVID-19 patients and the routine care for other patients with different diseases are blocked in many cases. In this context, the absence of routine healthcare service will lead an increase of death. Furthermore, a recent study has hypothesized a strong increase in child and maternal deaths since standard care service care is blocked and access to food is reduced in many low- and middle-income countries. In this regard, it has been estimated an increased children death (1-5 years old) from 9.8% to 44.8% per month and a rise in maternal deaths from 8.3% to 38.6% per month, over six months (Roberton *et al*., 2020). This pandemic is devastating health systems around the world with a negative impact on this goal.

Several investigations showed that poor and illegal waste management caused the contamination of soil and groundwater. For example, in 2007, 1240 hazardous waste sites (157 federal facilities) were identified by the US Environmental Protection Agency's National Priority List (NPL). Furthermore, the Environmental Protection Agency (EPA) calculated that 41 million people were living close to NPL sites. In Europe, in 2014, many contaminated sites (342.000) were identified (5,7 per 10.000 inhabitants) (Fazzo *et al*., 2017). In middle-low-income countries, these data are really difficult to get. Furthermore, in seven Asian countries, only contaminated 679 areas were found. Of these, 169 sites contained lead and it is calculated that about 245.949 0-4 years old children were exposed to toxic heavy metals that can cause acute and chronic adverse effects (Fazzo *et al*., 2017). In a paper. the authors found 373 hazardous waste sites in three Asian countries (India, Indonesia, Philippines) and they estimated that almost 9 million people was at risk. Furthermore, they calculated that about 43 million people can be at high risk from never screened sites through DALYs method (disability-adjusted life years) associated with hazardous waste sites. In Africa, WHO has estimated that 1/3 of the burden of disease is correlated to environmental risk factors (Prüss-Üstin and Corvalá 2006; Nweke and Sanders 2009; McCormack and Schuz 2012). Indeed, the only 20% of municipal solid waste is disposed of in legal landfills, while the 80% of MSW is dumped in in illegal manner (Achankeng, 2003). Furthermore, Africa is also one of the main destinations of illegal transboundary trade of urban and hazardous waste from industrialized countries. In 2007, a WHO report on waste and health concluded: "Despite the methodological limitations, the scientific literature on the health effects of landfills provides some indication of the association between residing near a landfill site and adverse health effects (WHO, 2007). In recent years, many published studies reported the association between health risks (such as adverse pregnancy outcomes, low birth weight, total birth defects and cardiac, musculoskeletal and central nervous system defects) for populations living close to contaminated areas. Other studies reported an association between exposure to incinerator emissions and adverse reproductive outcomes (Dummer *et al*., 2003), respiratory problems (Miyake *et al*., 2005) and cancer (Knox, 2000; Comba *et al*., 2003; Viel *et al*., 2008; Marfe and Di Stefano, 2016). For these reasons, the increased amount of hazardous waste linked to the virus, if it is not disposed of in proper manner, can lead a new rise of different diseases.

Goal 4-Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.

In the global context, according to a UNESCO report, the closure of schools could have had a negative impact on more than 2,90 million students from 22 countries due to the COVID-19 pandemic. During this time, many schools and universities, had chosen to use e-learning. For example, Climate Change Induced Disaster Management in Africa (CIDMA) has created up-to-date courses on disaster management online. In this case, at least 500 million students around the globe are excluded from digital access to school, Therefore, this situation will lead to worse learning outcomes, particularly for students from economically poor families (UN, 2020).

The increasing amount of waste can lead to significant global ecological risks such as the shortage of natural resources, climate changes, mass pollution of water, air and soil. This issue can be solved through education that makes human beings knowledgeable to environmental problems. The environmental education can play a crucial role in successful waste management system. In particular, it is necessary to render consumers aware through education of the need for adequate waste management. In this context, it should

be important to instruct people how to reduce the amount of waste which they generate. To raise public awareness about this problem, the environmental education can be the key to acquire ecological knowledge and skills for real improvement of the waste management.

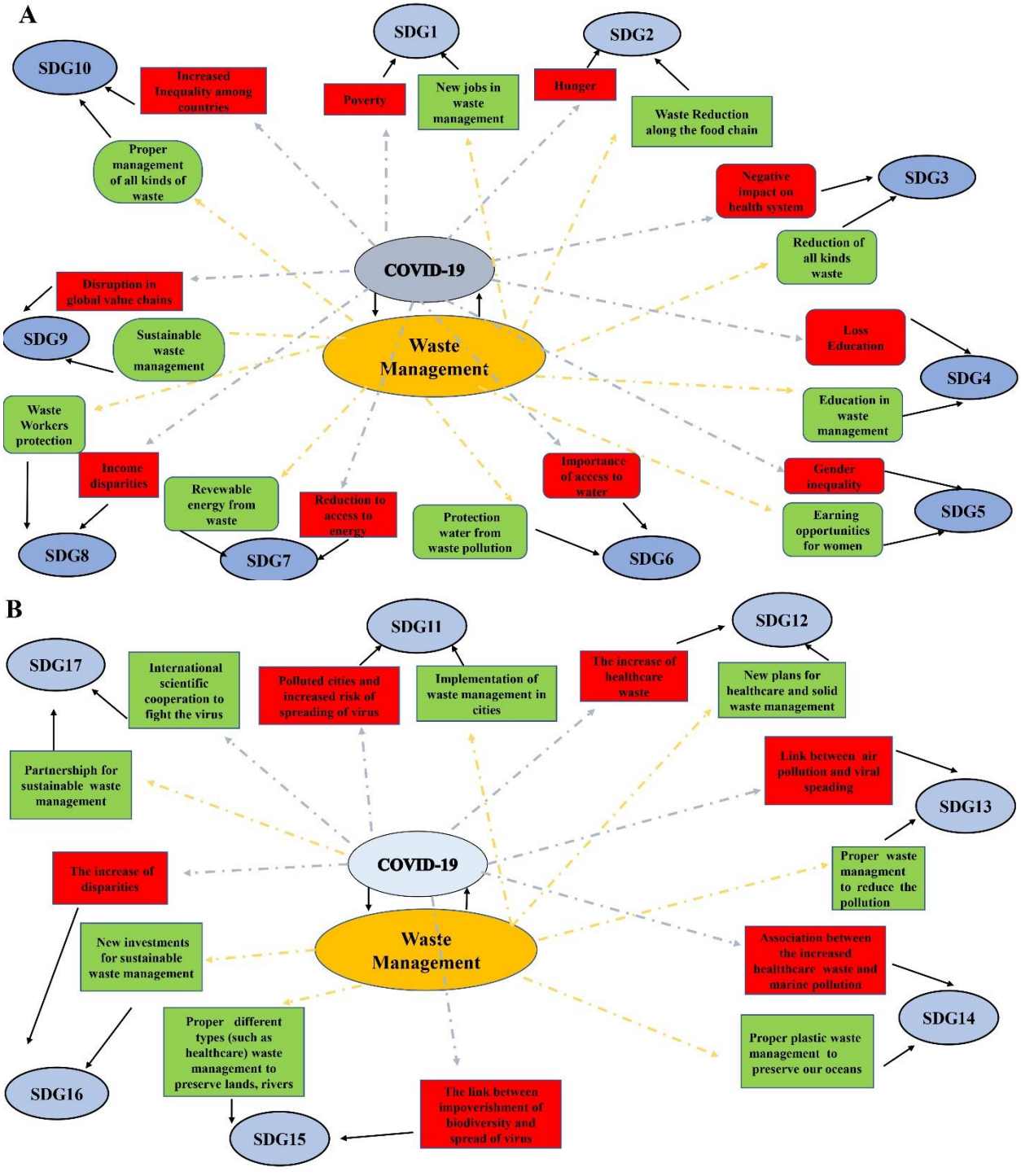

Fig. 3: Interconnections among SDGs with COVID-19 and waste management considering negative (red) and positive (green) impact: (a) Interconnections among SDGs 1-10 with COVID-19 and waste management; (b) Interconnections among SDGs 11-17 with COVID-19 and waste management

New values in the education and promotion strategies in kindergartens, primary and secondary schools, colleges and households and companies are very important for suitable knowledge. Establishment of educational centers, educational partnership with key environmental groups [teachers, Non-Governmental Organizations (NGOs), governments] and citizens can help implement sustainable waste and recycling initiatives. Schools and local communities with NGOs can be a network for information distribution and platform for changing negative habits. Promoting the awareness and understanding of waste educational centers should provide clear picture about waste characterization, waste methods like composting at home, waste collecting, health problems and other related issues.

In this historical period, in which the consequences of air pollution and climate change are starting to be felt, it is important to educate the new generations to a sustainable lifestyle that respects the resources of our planet. Starting from kindergartens and primary schools, environmental education must pass through the teaching of concepts such as sustainable development, green economy, resource conservation but also civic and cultural education.

Goal 5-Achieve gender equality and empower all women and girls.

This crisis, also in their socio-economic impact, has affected the issue of gender equality. Specifically, many women have lost and are losing their jobs (both legal and illegal). Furthermore, during the lockdown, an increase of household chores represents a threat to girls who could not go again to school. Furthermore, the domestic violence during the lockdown were increased around the globe. Many cases have reported in countries such as France, Argentina, Cyprus and Singapore where it has estimated an increase by 25-30%, while in many countries-like Germany, Canada, Italy, Spain, UK, US and others-the demand for shelter homes by women has gone up (UNW, 2020),

The key role of women and girls in primary level waste generation and management activities requires waste budgets, policies and strategies. In many cases, many families perceive waste only as a burden and consider it as useless. Consequently, there is no waste separation at any point along the waste management chain. On that account, in many countries the waste management should be considered as resourceful. This can be done by a policy that adds monetary value to household waste through incentives for waste separation. Such policy could create income avenues for women that meet their strategic gender needs. Therefore, women and girls can play a major role in the waste sorting stage. Generally, in many countries, the waste sorting happens inside residential spaces and streets and such process could affect women's health toward serious diseases (Elsheekh *et al*., 2021). Moreover, the involvement of young girls in this process increases the school dropout rate among girls. For example, in Egypt, the Association for the Protection of the Environment (APE) and the Youth Spirit Association (YSA) are spreading awareness of the importance of adopting proper practices for sorting solid waste, as well as providing proper job opportunities based on solid waste recycling directed at women and girls and providing medical assistance to women who got infected and in addition, the inclusion of young girls in recycling schools allows them to practice this service for a paid fee while ensuring their continuation in the educational system.

Goal 6-Ensure availability and sustainable management of water and sanitation for all.

The COVID-19 pandemic has demonstrated the critical importance of sanitation, hygiene and adequate access to clean water for preventing and containing diseases. Two billion people around the world are without safe drinking water and this crisis has highlighted the lack of access to sanitation even more. For this reason, millions of persons are at risk due to the infectious diseases above all for rural populations or urban slum dwellers due to the lack of clean water and sanitation. During the pandemic outbreak there has been a slowdown of investments in the water sector. In this regard, in the areas with low access, reliability and the quality of water and absence of sanitation, the virus is able to spread more quickly. New investments in adequate infrastructures of waste supply and sanitation facilities are necessary to allow universal access to safe hygiene and to clean water to prevent new diseases.

New infrastructures are needed to allow sustainable access to essential services such as drinking water supply, sanitation and waste management in developing countries. This approach to essential services is an important key to strengthen the association between public and private stakeholders to create these services (project ownership, management of services) through new techniques and methodologies in association with the local context. In this regard, different NGO's teams provide know-how from technical engineering to social intermediation, to rebalance business and sustainability. In this way, it is possible to support the stakeholders' missions to improve essential service such as supply of drinking water, sanitation and waste management.

Goal 7-Ensure access to affordable, reliable, sustainable and modern energy for all.

In 2018, the people without access to electricity decreased from 1.2 billion to 789 million, but it will be very difficult to achieve the targets of this SDG by 2030 after the pandemic. Furthermore, the rate of renewable energy is growing by 1.7% only and, in this regard, it will be difficult to provide electricity for 1 billion people who are relying on health facilities without electricity (UN-ESCAP-2020).

The pandemic has impaired global energy investments owing to supply chain disruptions, construction delays, reduction in energy demand and financial challenges. However, the COVID-19

pandemic may lead the governments to reducing their ability to implement energy access projects.

Today, Municipal Solid Waste (MSW) can be considered as a source of renewable energy because it contains a high proportion of biomass materials such as paper/cardboard, wood and food. For the no recyclable fractions, an energy recovery method becomes essential because it can reduce the use of fossil fuels. At the same time, it can also be important to use alternative methods for waste disposal to reduce the environmental and health impact. To obtain Energy From Waste (EfW) is possible to use the direct combustion (incineration), but there are several alternative technologies such as Refuse-Derived Fuel (RDF) production, gasification and anaerobic digestion. In this regard, the Combination of Heat and Power (CHP) is the best option for obtaining the energy from waste with a good energy efficiency. Furthermore, the potential of EfW and its impact on GHG emission reduction can be very important. For example, estimates in the United Kingdom have reported that the potential electricity yield derived household, commercial and industrial wastes could furnish about 17% of the total electricity consumption in 2020 in combination with the advanced thermal conversion method. Some studies have shown a decrease of GHG emissions derived from municipal solid waste in European Union countries about 47 MtCO2, eq/yr in 2000 to 8 MtCO2, eq/yr in 2020 in association with both an increase of recycling and EfW rates (4,3 and 23% in 2020, respectively) (Skovgaard *et al*., 2008; Changkook, 2010). For example, in the United States, electricity production from EfW (about 7.7% of MSW) was 13.5 TWh in 2002 (about 28% of the renewable power) (Psomopoulo *et al*., 2009).

Goal 8-Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all.

The global impact of COVID-19 could increase the number of children who are obliged to work and decrease decent jobs for women and men involved in informal sector. Furthermore, labour productivity will be reduced in 2022 in association with the decrease of working hours and economic crisis due to the pandemic. It is estimated that half of the employed population are in informal economic sector and approximately 1.6 billion workers could severely be affected by this pandemic. The challenge for governments, therefore, would be to restore economic activity without replicating, however, the old patterns of environmental degradation. In this perspective, waste management should become more sustainable with the green technologies to protect workers' health (above all in the biomedical waste management). Greening the waste sector can play a significant role to create new jobs, to reduce environmental and health impacts and to generate new economic development. Upcycling is the creative modification of discarded objects in such a way to create new product of higher quality or value towards the upper end of the innovation scale. Upcycling can create job opportunities more than landfill or incineration on a per ton basis. Greening the waste sector and following an appropriate MSW management approach can lead to employment generation where more employees will be required to successfully maintain a new management system. Furthermore, improving labour conditions in the informal waste sector is imperative. In developing countries, the activities of collection, processing and redistribution of solid waste are usually done by scavengers with poor facilities and little education on the risks correlated with their jobs, principally for serious health impacts (such as HIV and hepatitis). Thus, the job conditions in the waste sector should be improved through the provision of personal protection equipment (i.e., gloves, safety shoes, protective clothes) and the introduction of trainings and workshops to raise worker awareness on risks and potential solutions. In summary, new incentives are necessary to increase investments in sustainable waste technologies, by using new options on research incentives and development.

Goal 9-Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation.

The sustainable industrialization, together with innovation and infrastructure, can be very important to generate new employment and income. In this regard, new technologies play a key role to promote a development of clean and green industries. In less developed countries, their manufacturing sector should be more developed to reach the 2030 target by investing in scientific research and innovation. For example, global manufacturing growth has been decreased since the COVID-19 pandemic had disrupted global value chains and the supply of products. In this context, innovation and technological progress are fundamental to face both economic and environmental challenges, such as increased resource and energy-efficiency. Globally, investment in research and development (R&D) should be increased both in developed than developing countries. For example, the Asian Development Bank reports that infrastructures in many countries are inadequate, while Economic and Social Survey of Asia and the Pacific points out that are necessary investments of about 434$ billion per year to implement infrastructures resilient to disasters and climate change. In line with the achievement of the all SDGs for 2030, it is necessary to develop a proper biomedical and municipal solid waste management, starting with attention to the environment and prevent the spread of infectious diseases. In this context, illegal and informal waste management should be addressed to collect and include recyclables back into the value chain. Therefore, it is necessary the development of action plans in each country (principally in developing countries) so that the biomedical and municipal solid

waste management generated by COVID-19 can be handled in safe and sustainable manner. In according with SDG9, it should be important to assemble the know-how, experiences and relationships around the globe, to overcome the challenges related to the needs of developed, developing and less developed countries, such as the absence of technological infrastructures. Hence, it is necessary to engage in international cooperation projects to consolidate global partnerships and grow a network of companies around the world.

Goal 10-Reduce inequality within and among countries.

Today, the educated employees working in Information Technology (IT) sector or public service, or other similar sectors have not undergone negative impact on their work during the pandemic. Besides, the workers of poorer segments have to face a very hard time because many of them have lost their job and they depleted their few savings and in addition, there is a lack of access to credit for them. Therefore, different reports have observed that, also in relation to the lockdown, the in access to quality education is decreasing for low-income households, since they have not reliable access to the internet at home. Furthermore, this will have a negative consequence in the future in the employment opportunities for low-income people. Finally, the pandemic has negatively influenced the migrant job since many people lost their job and their livelihoods. Moreover, we noted that globally many workers are receiving a lower salary than in previous years due to decreased production. Disabled people should be faced many challenges regarding their education and their healthcare. Finally, during this pandemic, a reduction in the influx of money has been recorded from the developed nations to developing and least developed countries, by increasing the gap between the countries (Piraste *et al*., 2021). The increase of medical and municipal wastes is a new environmental challenge across the world. Many industrialized countries are developing new technologies to treat healthcare waste, while the less developed countries use the old methodologies to dump their healthcare waste, causing negative effects to human health and environment. It is known that waste management in developing countries does not happen following international standards and, during the pandemic, the increased amount of potentially infected waste has created new problems. International organizations and academic associations have issued guidelines for infectious waste management in response to the current condition of COVID-19 waste management. The state of waste management is different among developed, developing and less developed countries because developing and less developed countries lack capacity in terms of financial, technical, social and institutional aspects. The less developed countries risk being used for illegal dumping of toxic or hazardous waste by developed and developing countries with a negative impact on human health and enormous environmental degradation.

Goal 11-Make cities and human settlements inclusive, safe, resilient and sustainable.

Globally, during the pandemic, many people living in slums and informal settlements have a lot of problems. They have not access to essentials like water, sanitation, waste management. Furthermore, in these places it is impossible social distancing due to overcrowding and for this reason, the virus spreads very fast among people. Moreover, it is necessary to increase the public transport to keep social distancing on bus metro etc. to avoid the overcrowding Therefore, the pandemic is pushing towards a new planning of our cities. Many countries are revisiting their urban plans to make their cities more sustainable (Piraste *et al*., 2021). In this regards it is calculated that 5 billion people will live within cities by 2030. In this scenario, it is necessary to prioritize programs for a safe removal and management of municipal solid waste within cities to reduce pollution and to avoid new pandemics. By looking at the services of biomedical and municipal solid waste management, around the globe, almost two billion people have not access to waste collection services, while 3 billion people live in countries without controlled waste disposal facilities according to data collected between 2010 and 2018 (UN, 2019). Therefore, an adequate municipal solid waste management with the implementation of reduction, reuse, recycling wastes and production of energy from wastes could play a crucial role in sustainable city management.

Goal 13-Take urgent action to combat climate change and its impacts.

The phenomena of the onset and propagation of epidemic diseases due to human-induced environmental imbalances are increasing. Today, it is necessary a Green Deal around the globe to decrease the pollution and the inequities among population. The impacts of COVID-19 on climate action are studied. According with different studies, the lockdowns used as a precautionary measure against the spread of virus have improved air and water quality across the globe. Furthermore, global healthcare systems have shown their vulnerabilities under pressure of this pandemic, while governance and early warning systems can play a crucial role in the management of the disasters due to climate change. Furthermore, the visible positive effects of lockdown on the environment, could be a greater push towards a sustainable growth with alternative solutions or new and clean technologies.

Greenhouse gasses such as methane emitted from solid waste are a major factor in air pollution and climate change. For example, many medical and municipal solid waste disposal facilities in developing countries are open dumpsites that contribute to air, water and soil pollution, as well as greenhouse gas emissions. In 2016, 5% of global emissions were generated from solid waste (Products Eurostat, 2021). Today, it is necessary to dispose of the waste in safe manner in most parts of the world to reduce their open burning that contributes to

climate change. Sustainable management of solid waste will allow to decrease the spread of carbon dioxide and other greenhouse gasses in the atmosphere.

Goal 14-Conserve and sustainably use the oceans, seas and marine resources for sustainable development.

The pandemic has negatively impacted the livelihoods of small-scale fishermen since the demand for sea food is decreased around the globe for supply chain disruptions during the lockdowns However, piracy, poaching phenomena and illicit shing is increased in association with fewer resources to monitor the coastal areas. Furthermore, during the lockdowns, the use of chemical fertilizers and other human activities near the sea are decreased and are improving the quality of water. The increased use of PPE during the pandemic are raising concerns about how their disposal might eventually hurt the oceans. The World Economic Forum has reported that infection control protocols have increased utilization of single-use plastic products, especially related to protective equipment. In addition, disruptions in recycling may lead to more waste ending up in the oceans.

Goal 15-Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification and halt and reverse land degradation and halt biodiversity loss.

Different studies point out the direct link between pandemic and pollution above all the climate change are causing the impoverishment of biodiversity on the planet. In this context it is necessary to stop the loss of biodiversity and reverse the course since this can play an essential role in preventing future pandemics. Specifically, the target 15.1, includes conservation, restoration and sustainable use of terrestrial freshwater ecosystems for forests, wetlands, mountains and drylands. Unfortunately, today, many toxic chemicals derived from illegal hazardous waste management are spilled into groundwater streams and rivers. In accordance with these considerations, all kinds of waste should be safely managed to avoid negative impact on environment. One of the aspects of preserving the ecosystems on the earth's surface is the safe disposal of medical ad municipal solid waste. It is necessary to implement an integrated and sustainable waste management system, which takes care of reducing the amount of waste from the source according to a set of concepts related to such as the 5Rs (reduce, reuse, repurpose, recycle and responsibility). The importance of using these concepts is due to the reduction of waste production, which supports the reduction of the need for land utilized for the sanitary burying of waste and the use of a lower amount of land sustainably in order to reduce the pollution of soil, water and air.

Goal 16-Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels.

The COVID-19 spreads more easily in conditions of hardship, increasing the disparities between rich and poor in terms of access to basic services with repercussions on the whole society in terms of production and consumption. The pandemic has disrupted humanitarian aid flows and limited the peace operations. This might increase the unrest as conflicts arise within and among the countries. For example, there was a geopolitical friction between US and China because of COVID-19. In this regard, the US has blamed China for the COVID-19 pandemic. Moreover, China has offered international aid to many countries to face this pandemic and thus, to obtain favor. Indeed, in different countries where there are internal conflicts, the pandemic has caused many problems in their vulnerable health care systems. For example, in Libya, during the war, many foreign physicians had abandoned the country. Today, all governments should make new investments since all communities should live in healthy and resilient places, in this regard, poor people can choose to pay for waste management when they are aware of its benefits. Furthermore, Producer Responsibility schemes (principally fiscal transparency) allow to everyone to pay their "fair share" in taxes in order to keep the planet clean. Many developing countries are creating the institutional framework based on the principle of decentralization since, in this way, it will be possible to promote an integrated solid waste management system, by considering local interests, inducing citizen involvement and activating transparency and accountability of all population to monitor the costs of plans and projects.

Goal 17-Strengthen the means of implementation and revitalize the global partnership for sustainable development.

This SDG can allow a sustainable waste management in each country since it highlights the importance to share knowledge, promote the creation of new environmentally sound technologies. From that standpoint, we believe the sharing of research, knowledge and innovation among the countries will help to save the planet. The impacts of COVID-19 have changed the nature of the collaborations among countries. For example, global remittances have declined sharply by about 20% in 2020 due to the economic crisis induced by the COVID-19 pandemic and shutdown. Remittances to Low and Middle-Income Countries (LMICs) have decreased by 19,7% to $445 billion, representing a loss of a crucial financing lifeline for many vulnerable households. The Global foreign direct investments decreased by 40% in 2020. However, there are instances where new partnerships have been created to face the negative impact of this pandemic such as in the case of the African Union that has established an Africa Task force for Coronavirus (AFTCOR). Furthermore, the partnership between the African Union and the UN has also been strengthened to deal with the pandemic outbreak (https://www.un.org/africarenewal/web-features/coronavirus/osaa/covid-19-strong-international-partnerships-key-bolstering-africa's-response). The European Union and the Member States have created 'Team

Europe' to improve the healthcare, water and sanitation systems during the COVID-19 pandemic. In addition, they collaborated among them to allow fast access to effective and affordable tests, treatments and vaccines against coronavirus for the partner countries (https://ec.europa.eu/international-partnerships/topics/eu-global-response-covid-19_en). In addition, WHO has started a Research and Development (R&D) Blueprint program to increase the research of diagnostics, vaccines and therapeutics against COVID-19 (WHO, 2020). Today, both public and private companies of waste management have to face an increased production of biomedical waste. In this context, it is necessary to handle supply chains with a new strategy to improve the global waste infrastructures and to enforce sanitation practices. The participation of many parties in the sustainable waste management is one of the most important issues for the future. In this light, it is necessary to adopt multi-lateral partnerships among public and private sector, non-governmental organizations and the local community for the success of the sustainable waste management system. Furthermore, it will be necessary to establish partnerships with other sectors such as industry and trade. To realize this system, it will need to learn from the local and foreign experiences from the informal sector to support the improvement of the SWM systems. In addition, partnerships with donors will be useful to improve the system technically and financially at the end, the achievement of goal 17 will be possible through the experiences derived from partnerships principally on their resource mobilization strategies.

Conclusion

In this scenario, every country should be able to respond to a such large global influx of waste with an increase of management facility capacities through new technologies. Addressing this challenge will take a determined and sustained effort to manage supply chains and distribution channels and provide clear and transparent marketing and communications as well as a strategic approach to customers and geographic engagement to maximize the global impact of waste infrastructures and enforcing sanitation practices.

Our Reflection

We wish to know the infection rate of COVID-19 among people living close to hazardous dumpsites. In fact, chemicals derived from dumps can damage immune systems, especially in children and cause serious illnesses, including cancers. We think that people with weakened immune systems and other health issues are more at risk of contracting coronavirus.

Acknowledgment

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this study.

Author Contributions

Gabriella Marfe: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Data curation, Writing - original draft, Visualization.

Stefania Perna: Conceptualization, Writing - review and editing.

Arturo Hermann: Methodology, Software, Validation, Formal analysis, Data curation, Visualization.

Ethics

This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and no ethical issues involved

References

Achankeng, E. (2003, October). Globalization, urbanization and municipal solid waste management in Africa. In Proceedings of the African Studies Association of Australasia and the Pacific 26th annual conference (pp. 1-22).

Adhikari, J., Timsina, J., Khadka, S. R., Ghale, Y., & Ojha, H. (2021). COVID-19 impacts on agriculture and food systems in Nepal: Implications for SDGs. Agricultural Systems, 186, 102990. doi.org/10.1016/j.agsy.2020.102990

Adiconsum Veneto. (2020). https://www.youtube.com/watch?v=TNuQSqukbnU

Advisors, D., de Wit, W. & Bigaud, N. (2019). No plastic in nature: assessing plastic ingestion from nature to people 12 June 2019 PUBLISHER World Wildlife Fund.

Agamuthu, P., & Barasarathi, J. (2021). Clinical waste management under COVID-19 scenario in Malaysia. Waste Management & Research, 39(1_suppl), 18-26 oi.org/10.1177/0734242X20959701. Epub 2020 Sep 24.

Amariglio, A., & Depaoli, (2021). Waste management in an Italian Hospital's operating theatres: An observational study. Am J Infect Control 49(2), 184-187. doi.org/10.1016/j.ajic.2020.07.013. Epub 2020 Jul 11.

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

ADB. (2020). Managing Infectious Medical Waste during the COVID-19 Pandemic: https://www. adb.org/publications/managing-medical-waste-covid19.

ACR. (2020). Municipal waste management and COVID-19. http://www.basel.int/Implementation/PublicAwareness/PressReleases/-WastemanagementandCOVID19/tabid/8376/Default.aspx.

Ayse LA, Dempsther EA, Aparsi TD, Bawn M, Arreondo MG, Chau C, Chandeler K, Dragana D, Hailes H, Lettieri P, Liu C, Medda F, Michie F, Miodownik M, Purkiss D, Ward J. (2020). The Environmental Dangers of Employing Single-Use Face Masks as Part of a COVID-19 Exit Strategy UCL Open: Environment Preprint doi.org/10.14324/111.444/000031.v1

Basel Convention (2020a). Waste management an essential public service in the fight to beat COVID-19: Basel Convention. Available online at the website of www.basel.int/Implementation/PublicAwareness Press Releases/Waste management and COVID19/tabid/8376/ Default.aspx.

Basel Convention (2020b). Healthcare or Medical Waste. Available online at the website of www.brsmeas.org/Portals/4/download.aspx?d=UNEP-CHW-PUB-Factsheets-Healthcare-MedicalWaste-2020. English.pdf.

Bergman, M. S., Viscusi, D. J., Heimbuch, B. K., Wander, J. D., Sambol, A. R., & Shaffer, R. E. (2010). Evaluation of multiple (3-cycle) decontamination processing for filtering facepiece respirators. Journal of Engineered Fibers and Fabrics, 5(4), 155892501000500405. doi.org/10.1177/155892501000500405

Bhattacharjee, S., Bahl, P., Chughtai, A. A., & MacIntyre, C. R. (2020). Last-resort strategies during mask shortages: optimal design features of cloth masks and decontamination of disposable masks during the COVID-19 pandemic. BMJ open respiratory research, 7(1), e000698. doi.org/10.1136/bmjresp-2020-000698

Capoor, M. R., & Parida, A. (2021). Biomedical Waste and Solid Waste Management in the Time of COVID-19: A Comprehensive Review of the National and International Scenario and Guidelines. Journal of Laboratory Physicians. doi.org/10.1055/s-0041-1729132.

Changkook R. (2010) Potential of Municipal Solid Waste for Renewable Energy Production and Reduction of Greenhouse Gas Emissions in South Korea, Journal of the Air & Waste Management Association, 60:2, 176-183, doi.org/10.3155/1047-3289.60.2.176

Choi, Y. W., Richardson, A. W., Sunderman, M., Mladineo, M. J., Keyes, P. H., Hofacre, K. C., & Middleton, J. K. (2021). Decontamination of SARS-CoV-2 contaminated N95 filtering facepiece respirators (FFRs) with moist heat generated by a multicooker. Letters in Applied Microbiology, 72(4), 366-374. doi.org/10.1111/lam.13443

Comba, P., Ascoli, V., Belli, S., Benedetti, M., Gatti, L., Ricci, P., & Tieghi, A. (2003). Risk of soft tissue sarcomas and residence in the neighbourhood of an incinerator of industrial wastes. Occupational and Environmental Medicine, 60(9), 680-683. doi.org/10.1136/oem.60.9.680

Commendatore, C. (2020). Coronavirus Impacts Hit Solid Waste Managers, Generators.

Das, A. K., Islam, M. N., Billah, M. M., & Sarker, A. (2021). COVID-19 pandemic and healthcare solid waste management strategy–A mini-review. Science of the Total Environment, 778, 146220. doi.org/10.1016/j.scitotenv.2021.146220

De-la-Torre, G. E., Rakib, M. R. J., Pizarro-Ortega, C. I., & Dioses-Salinas, D. C. (2021). Occurrence of personal protective equipment (PPE) associated with the COVID-19 pandemic along the coast of Lima, Peru. Science of The Total Environment, 774, 145774. doi.org/10.1016/j.scitotenv.2021.145774

Department for Environment, Food and Rural Affairs (DEFRA 2020). Guidance on prioritising waste collection services during coronavirus (COVID-19) pandemic; Department for Environment Food & Rural Affairs, Government of UK, 2020.

de Sousa, F. D. B. (2020). Pros and cons of plastic during the COVID-19 pandemic. Recycling, 5(4), 27. doi.org/10.3390/recycling5040027

De Wit, W., & Bigaud, N. (2019). No plastic in nature: Assessing plastic ingestion from nature to people. https://apo.org.au/node/244456

Dummer, T. J., Dickinson, H.O, & Parker, L., (2003). Adverse pregnancy outcomes around incinerators and crematoriums in Cumbria, north west England, 1956-93. J Epidemiol Community Health. 57(6), 456-61. doi.org/10.1136/jech.57.6.456

Elsheekh, K.M., Kamel, R.R., Elsherif, D.M. Shalaby M. (2021). Achieving sustainable development goals from the perspective of solid waste management plans. J. Eng. Appl. Sci. 68, 9. doi.org/10.1186/s44147-021-00009-9

EMB. (2020). Enviromental Management Bureau. ManagementofInfectiousHealthcareWasteDuringCovid-19Pandemic, https:// emb.gov.ph/management-of-infectious-healthcare-waste-during-covid-19-pandemic/, 2020.

ECDC (2020). Infection prevention and control in the household management of people with suspected or confirmed coronavirus disease (COVID- 19). European Centre for Disease Prevention and Control. www.ecdc.europa.eu/en/ publications-data/infection-prevention-control-household-management- covid-19.

European Commission (2020). Waste management in the context of the coronavirus crisis. Available online at the website of: ec.europa.eu/ info/sites/info/files/waste_management_guidance _dg-env.pdf.

Fazzo, L., Minichilli, F., Santoro, M., Ceccarini, A., Della Seta, M., Bianchi, F., ... & Martuzzi, M. (2017). Hazardous waste and health impact: a systematic review of the scientific literature. Environmental health, 16(1), 1-11. doi.org/10.1186/s12940-017-0311-8

Ferronato, N., & Torretta, V. (2019). Waste mismanagement in developing countries: A review of global issues. International journal of environmental research and public health, 16(6), 1060. doi.org/10.3390/ijerph16061060

Filho, W. L., Brandli, L. L., Salvia, A. L., Rayman-Bacchus, L., & Platje, J. (2020). COVID-19 and the UN sustainable development goals: Threat to solidarity or an opportunity? Sustainability, 12(13), 1–14. doi.org/10.3390/su12135343.

Fisher, E. M., Williams, J. L., & Shaffer, R. E. (2011). Evaluation of microwave steam bags for the decontamination of filtering facepiece respirators. PLoS One, 6(4), e18585. doi.org/10.1371/journal.pone.0018585

Fleetwood, J. (2020). Social justice, food loss and the sustainable development goals in the era of COVID-19. Sustainability, 12(12), 5027. doi.org/10.3390/su12125027

Ge, H., Wang, X., Yuan, X., Xiao, G., Wang, C., Deng, T., ... & Xiao, X. (2020). The epidemiology and clinical information about COVID-19. European Journal of Clinical Microbiology & Infectious Diseases, 39(6), 1011-1019. doi.org/10.1001/jama.2020.1585

Global Nutrition Report. (2020). GLOBAL Nutrition Report in the context of Covid-19.

Gupta, G. (2022). Management of COVID-19 waste. In COVID-19 in the Environment (pp. 277-294). Elsevier. doi.org/10.1016/B978-0-323-90272-4.00003-8

Heimbuch, B. K., Wallace, W. H., Kinney, K., Lumley, A. E., Wu, C. Y., Woo, M. H., & Wander, J. D. (2011). A pandemic influenza preparedness study: use of energetic methods to decontaminate filtering facepiece respirators contaminated with H1N1 aerosols and droplets. American journal of infection control, 39(1), e1-e9. doi.org/10.1016/j.ajic.2010.07.004

Hossain, M. S., Santhanam, A., Norulaini, N. N., & Omar, A. M. (2011). Clinical solid waste management practices and its impact on human health and environment–A review. Waste management, 31(4), 754-766. doi.org/10.1016/j.wasman.2010.11.008

IARC. (2010). Working Group on the Evaluation of Carcinogenic Risks to Humans. (2010). Carbon black, titanium dioxide and talc. IARC monographs on the evaluation of carcinogenic risks to humans, 93, 1. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4781574/.

Ikiz, E., Maclaren, V. W., Alfred, E., & Sivanesan, S. (2021). Impact of COVID-19 on household waste flows, diversion and reuse: The case of multi-residential buildings in Toronto, Canada. Resources, Conservation and Recycling, 164, 105111. doi.org/10.1016/j.resconrec.2020.105111

Ilyas, S., Srivastava, R. R., & Kim, H. (2020). Disinfection technology and strategies for COVID-19 hospital and bio-medical waste management. Science of the Total Environment, 749, 141652. doi.org/10.1016/j.scitotenv.2020.141652

INRA. (2017). France Food additive E171: First findings of oral exposure to titanium dioxide nanoparticles.

ISWA. (2020). Waste Management During the COVID-19 Pandemic. International Solid Waste Association. www.iswa.org/iswa/COVID-19.

ISWA-Jordan. (2020). Country Specific Waste Management Responses, COVID-19 Response International knowledge sharing on Waste Management. International Solid Waste Association. https://www.iswa.org/fileadmin/galleries/0001_COVID/Jordan_Solid_Waste_Handling_Manual_Coronaviruscrisis ENG.pdf:https://www.iswa.org/iswa/covid-19/, 2020.

Jalal, S. M., Akhter, F., Abdelhafez, A. I., & Alrajeh, A. M. (2021). Assessment of knowledge, practice and attitude about biomedical waste management among healthcare professionals during COVID-19 crises in Al-Ahsa. In Healthcare (Vol. 9, No. 6, p. 747). Multidisciplinary Digital Publishing Institute. doi.org/10.3390/healthcare9060747

Klemeš, J. J., Van Fan, Y., Tan, R. R., & Jiang, P. (2020). Minimising the present and future plastic waste, energy and environmental footprints related to COVID-19. Renewable and Sustainable Energy Reviews, 127, 109883. doi.org/10.1016/j.rser.2020.109883

Knox, E. G. (2000). Childhood cancers, birthplaces, incinerators and landfill sites. International Journal of Epidemiology, 29(3), 391-397. doi.org/10.1093/ije/29.3.391

Kulkarni, B. N., & Anantharama, V. (2020). Repercussions of COVID-19 pandemic on municipal solid waste management: Challenges and opportunities. Science of the Total Environment, 743, 140693. doi.org/10.1016/j.scitotenv.2020.140693

Li, C., Busquets, R., & Campos, L. C. (2020a). Assessment of microplastics in freshwater systems: A review. Science of the Total Environment, 707, 135578. doi.org/10.1016/j.scitotenv.2019.135578

Li, D. F., Cadnum, J. L., Redmond, S. N., Jones, L. D., & Donskey, C. J. (2020b). It's not the heat, it's the humidity: effectiveness of a rice cooker-steamer for decontamination of cloth and surgical face masks and N95 respirators. American journal of infection control, 48(7), 854. doi.org/10.1016/j.ajic.2020.04.012

Li, W.C., Tse, H.F., & Fok L. (2016). Plastic waste in the marine environment: A review of sources, occurrence and effects Sci. Total Environ., 566–567; 333 349. doi.org/10.1016/J.SCITOTENV.2016.05.084

Liang, Y., Song, Q., Wu, N., Li, J., Zhong, Y., & Zeng, W. (2021). Repercussions of COVID-19 pandemic on solid waste generation and management strategies. Front. Environ. Sci. Eng. 15**,** 115. doi.org/10.1007/s11783-021-1407-5

Liebsch, T. (2020). The rise of the face mask: What's the environmental impact of 17 million N95 masks. Ecochain www. ecochain. com.

Lindsley, W. G., Martin Jr, S. B., Thewlis, R. E., Sarkisian, K., Nwoko, J. O., Mead, K. R., & Noti, J. D. (2015). Effects of ultraviolet germicidal irradiation (UVGI) on N95 respirator filtration performance and structural integrity. Journal of occupational and environmental hygiene, 12(8), 509-517. doi.org/10.1080/15459624.2015.1018518

Liu, C., Dai, Z., Zhou, R., Ke, Q., & Huang, C. (2019). Fabrication of polypropylene-g-(diallylamino triazine) bifunctional nonwovens with antibacterial and air filtration activities by reactive extrusion and melt-blown technology. Journal of Chemistry, 2019. doi.org/10.1155/2019/3435095.

Majewsky, M., Bitter, H., Eiche, E., & Horn, H. (2016). Determination of microplastic Polyethylene (PE) and Polypropylene (PP) in environmental samples using thermal analysis (TGA-DSC). Science of the Total Environment, 568, 507-511. doi.org/10.1016/j.scitotenv.2016.06.017

Marfe, G., & Di Stefano, C. (2016). The evidence of toxic wastes dumping in Campania, Italy. Critical Reviews in Oncology/Hematology, 105, 84-91. doi.org/10.1016/j.critrevonc.2016.05.007

Martins, M. A., Pataca, L. C. M., Santos, E. D. S., Faria, S. M. D. C., Cruz, L. A., Silva, G. A. S., & Mol, M. P. G. (2021). Generation of infectious waste during the COVID-19 pandemic: The case of a Brazilian hospital. Waste Management & Research, 39(10), 1245-1255. doi.org/10.1177/0734242X211049301

Mast J, Blaud MN, Siciliani L Cheyns K, Waegeneers N, Van Loco J, Vleminckx C, Verleysen E. (2021). Identification, physicochemical characterisation and preliminary risk analysis of titanium dioxide particles in face masks. Brussels, Belgium, Sciensano; 500 p. Report number: >Depot number. Available from https://www.sciensano.be/sites/default/files/intermediate_report_tio2-mask_project_-_for_publication_database.pd.

McCormack, V. A., & Schüz, J. (2012). Africa's growing cancer burden: Environmental and occupational contributions. Cancer epidemiology, 36(1), 1-7. doi.org/10.1016/j.canep.2011.09.005

Miyake, Y., Yura, A., Misaki, H., Ikeda, Y., Usui, T., Iki, M., & Shimizu, T. (2005). Relationship between distance of schools from the nearest municipal waste incineration plant and child health in Japan. European journal of epidemiology, 20(12), 1023-1029. doi.org/10.1007/s10654-005-4116-7

Mousavizadeh, L., & Ghasemi, S.J. (2020). Genotype and phenotype of COVID-19: Their roles in pathogenesis. Microbiol Immunol Infect. S1684-1182(20)30082-7. doi.org/10.1016/j.jmii.2020.03.022

Nowakowski, P., Kuśnierz, S., Sosna, P., Mauer, J., & Maj, D. (2020). Disposal of personal protective equipment during the COVID-19 pandemic is a challenge for waste collection companies and society: A case study in Poland. Resources, 9(10), 116. doi.org/10.3390/resources9100116

Nweke, O. C., & Sanders III, W. H. (2009). Modern environmental health hazards: A public health issue of increasing significance in Africa. Environmental health perspectives, 117(6), 863-870. doi.org/10.1289/ehp.0800126

Parashar, N., & Hait, S. (2021). Plastics in the time of COVID-19 pandemic: Protector or polluter? Science of the Total Environment, 759, 144274. doi.org/10.1016/j.scitotenv.2020.144274

Peng, J., Wu, X., Wang, R., Li, C., Zhang, Q., & Wei, D. (2020). Medical waste management practice during the 2019-2020 novel coronavirus pandemic: Experience in a general hospital. American journal of infection control, 48(8), 918-921. doi.org/10.1016/j.ajic.2020.05.035

Piraste, S., Husain, H., & Rajitha. T., (2021) Chapter 40-COVID-19 Pandemic Challenges and Impacts on the SDGs 2030: Indian Perspective Book COVID-19 Pandemic, Geospatial Information and Community Resilience Global Applications and Lessons By Abbas Rajabifard, Greg Foliente, Daniel Paez 10 Iune 2021 doi.org/10.1201/9781003181590

Plastic Recyclers Europe. (2020). Plastics recyclers cease production, Recyclates demand impacted by the COVID-19 pandemic 2020. (https://www.plasticsrecyclers.eu/post/plastics-recyclers-cease-production).

Pothan, P. E., Taguchi, M., Santini, G. (2020). Local food systems andCOVID-19: A glimpse on India's responses. FAO ((Food and Agriculture Organization).

Prasetiawan T. Problems over Medical Waste. 2020 (http://berkas.dpr.go.id/puslit/files/info_singkat/Info %20Singkat-XII-9-I-P3DI-Mei-2020-223-EN.pdf).

Products Eurostat. (2021). Greenhouse gas emissions from waste 2021. https://ec.europa.eu/eurostat/web/products-eurostat-news/-/DDN-20200123.

Prüss-Üstin, A., & Corvalán, C. (2006). Preventing disease through healthy environments. Towards an estimate of the environmental burden of disease. Geneva: World Health Organization; 2006.

Ragusa, A., Svelato, A., Santacroce, C., Catalano, P., Notarstefano, V., Carnevali, O., & Giorgini, E. (2021). Plasticenta: First evidence of microplastics in human placenta. Environment International, 146, 106274. doi.org/10.1016/j.envint.2020.106274

Roberton, T., Carter, E. D., Chou, V. B., Stegmuller, A. R., Jackson, B.D, Tam Y, Sawadogo-Lewis T, Walker N. Early estimates of the indirect effects of the COVID-19 pandemic on maternal and child mortality in low-income and middle-income countries: A modelling study. Lancet Glob Health. 8(7), e901-e908. doi.org/10.1016/S2214-109X(20)30229-1

Sachs, J. D., Schmidt-Traub, G., Mazzucato, M., Messner, D., Nakicenovic, N., & Rockström, J. (2019). Six Transformations to achieve the Sustainable Development Goals. Nature Sustainability, 2(9), 805–814. doi.org/10.1038/s41893-019-0352-9

Sangkham, S. (2020). Face mask and medical waste disposal during the novel COVID-19 pandemic in Asia. Case Studies in Chemical and Environmental Engineering, 2, 100052. doi.org/10.1016/j.cscee.2020.100052

Sarkodie, S. A., & Owusu, P. A. (2021). Impact of COVID-19 pandemic on waste management. Environment, development and sustainability, 23(5), 7951-7960. doi.org/10.1007/s10668-020-00956-y

Selvaranjan, K., Navaratnam, S., Rajeev, P., & Ravintherakumaran, N. (2021). Environmental challenges induced by extensive use of face masks during COVID-19: A review and potential solutions. Environmental Challenges, 3, 100039. doi.org/10.1016/j.envc.2021.100039

Silva, A. L. P., Prata, J. C., Walker, T. R., Duarte, A. C., Ouyang, W., Barcelò, D., & Rocha-Santos, T. (2021). Increased plastic pollution due to COVID-19 pandemic: Challenges and recommendations. Chemical Engineering Journal, 405, 126683. doi.org/10.1016/j.cej.2020.126683

Singh, N., Tang, Y., Zhang, Z., & Zheng, C. (2020). COVID-19 waste management: Effective and successful measures in Wuhan, China. Resources, conservation and recycling, 163, 105071. doi.org/10.1016/j.resconrec.2020.105071

Skovgaard, M., Hedal, N., Villanueva, A. andersen, F. M., & Larsen, H. (2008). Municipal waste management and greenhouse gases. European Topic Centre (ETC)/Resource Waste Management (RWM) Working Paper, 1.

Smith, J. S., Hanseler, H., Welle, J., Rattray, R., Campbell, M., Brotherton, T., Moudgil, T., Pack, T. F., Wegmann, K., Jensen, S., Jin, J., Bifulco, C. B., Prahl, S. A., Fox, B. A., & Stucky, N. L. (2020). Effect of various decontamination procedures on disposable N95 mask integrity and SARS-CoV-2 infectivity. Journal of Clinical and Translational Science, 5(1), e10. doi.org/10.1017/cts.2020.494

Staub, C. (2020). City data shows COVID-19 impacts on recycling tonnages. Resour. Recycl. https://resource-recycling.com/recycling/2020/04/28/city-data-showscovid-19-impacts-on-recycling-tonnages/

Sullivan, G. L., Delgado-Gallardo, J., Watson, T. M., & Sarp, S. (2021). An investigation into the leaching of micro and nano particles and chemical pollutants from disposable face masks-linked to the COVID-19 pandemic. Water Research, 196, 117033. doi.org/10.1016/j.watres.2021.117033

SWANA (Solid Waste Association of North America article) (2020). SWANA reminds all state and local governments that solid waste management is an essential public service. Solid Waste Association of North America. https://swana.org/news/swana-news/article/2020/03/19/swana-reminds-all-state-and-local-governments-that-solid-waste-management-is-an-essential-public-service

UN. (2019) The sustainable development goals report. Department of economic and social affairs, p 45 Available via: https://unstats.un.org/sdgs/report/2019/The-Sustainable-Development-Goals-Report-2019.pdf

UN. (2020). The Sustainable Development Goals Report 2020. In United Nations. https://doi.org/10.18356/2282dd98-en.

ESCAP. (2020). Accelerating SDG7 achievement in the time of Covid-19: policy briefs in support of the high-level political forum 2020. https://repository.unescap.org/handle/20.500.12870/922

UNEP. (2020a). United Nations Industrial Development Organization (UNIDO). (2020). Emergency Response Assistance to the Outbreak of Coronavirus Disease 2019 in China. United Nations Industrial Development Organization.

UNEP. (2020b) United Nations Environment Programme, International Environmental Technology Centre (IETC) IGES Center Collaborating with UNEP on Environmental Technologies (CCET). Report Title: Waste Management during the COVID-19 Pandemic from Response to Recovery ISBN No: 978-92-807-3794-3 Job No: DTI/2292/PA.

UNEP (2020a). COVID-19 Waste management Factsheets. Introduction to COVID19 waste Management https://wedocs.unep.org/bitstream/handle/20.500.11822/32282/COVIDWM.pdf?sequence=1&isAllowed=y

UNICEF. (2020). Water, sanitation, hygiene and waste management for COVID-19: technical brief. United Nations International Children's Emergency Fund. https://apps.who.int/iris/bitstream/handle/10665/331499/WHO-2019-nCoV-IPC_WASH-2020.2-eng.pdf?sequence=1&isAllowed=y

UNW. (2020). Policy Brief: The Impact of COVID-19 on Women. 2020. https://asiapacific.unwomen.org/sites/default/files/Headquarters/Attachments/Sections/Library/Publications/2020/Policy-brief-The-impact-of-COVID-19-on-women-en.pdf

Valensisi G. (2020). COVID-19 and Global Poverty: Are LDCs Being Left Behind? Eur J Dev Res. 1-23. doi.org/10.1057/s41287-020-00314-8

Vanapalli, K. R., Sharma, H. B., Ranjan, V. P., Samal, B., Bhattacharya, J., Dubey, B. K., & Goel, S. (2021). Challenges and strategies for effective plastic waste management during and post COVID-19 pandemic. Science of The Total Environment, 750, 141514. doi.org/10.1016/j.scitotenv.2020.141514

Verity, R., Okell, L.C., Dorigatti, I., Winskill, P., Whittaker, C., Imai, N., Cuomo-Dannenburg, G., Thompson, H., Walker, P.G.T., Fu, H., Dighe, A., Griffin, J.T., Baguelin, M., Bhatia, S., Boonyasiri, A., Cori, A., Cucunubá, Z., FitzJohn, R., Gaythorpe, K., Green, W., Hamlet, A., Hinsley, W., Laydon, D., Nedjati-Gilani, G., Riley, S., van Elsland, S., Volz, E., Wang, H., Wang, Y., Xi, X., Donnelly, C.A., Ghani, A.C, & Ferguson, N.M. (2020). Estimates of the severity of coronavirus disease 2019: A model-based analysis Lancet Infec 20(6), 669-677. doi.org/10.1016/S1473-3099 (20)30243-7.

Viel, J. F., Daniau, C., Goria, S., Fabre, P., de Crouy-Chanel, P., Sauleau, E. A., & Empereur-Bissonnet, P. (2008). Risk for non Hodgkin's lymphoma in the vicinity of French municipal solid waste incinerators. Environmental Health, 7(1), 1-9. doi.org/10.1186/1476-069X-7-51

Viscusi, D. J., Bergman, M. S., Eimer, B. C., & Shaffer, R. E. (2009). Evaluation of five decontamination methods for filtering facepiece respirators. Annals of occupational hygiene, 53(8), 815-827. doi.org/10.1093/annhyg/mep070

Viscusi, D. J., Bergman, M. S., Novak, D. A., Faulkner, K. A., Palmiero, A., Powell, J., & Shaffer, R. E. (2011). Impact of three biological decontamination methods on filtering facepiece respirator fit, odor, comfort and donning ease. Journal of occupational and environmental hygiene, 8(7), 426-436. doi.org/10.1080/15459624.2011.585927

Viscusi. D. J., King, W. P., & Shaffer, R. E. (2007). Effect of decontamination on the filtration efficiency of two filtering facepiece respirator models. J Int Soc Respir. 24:93–107. (https://www.isrp.com/the-isrp-journal/journal-public-abstracts/1138-vol-24-no-3-and-no-4-2007-pp-93-107-viscusi-open-access/file

Wei, G., Manyu, L. (2020) (The Hidden Risks of Medical Waste and the COVID-19 Pandemic, https://www.waste360.com/medical-waste/hidden-risks-medical-waste-and-covid-19-pandemic.

WBSWM. (2020) Kaza, Silpa; Yao, Lisa C.; Bhada-Tata, Perinaz; Van Woerden, Frank. 2018. What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050. Urban Development; Washington, DC: World Bank. © World Bank. World Bank Solid Waste Management. https://openknowledge.worldbank.org/handle/10986/30317 License: CC BY 3.0 IGO.

WHO. (2007). Population health and waste management: Scientific data and policy options. Report of a WHO workshop, Rome, Italy, 29-30 March, 2007. In Population health and waste management: Scientific data and policy options. Report of a WHO workshop, Rome, Italy, 29-30 March, 2007. World Health Organization. https://www.cabdirect.org/cabdirect/abstract/20093115499

WHO (2020a). Announces COVID-19 Outbreak a pandemic. Available online. http://www.euro.who.int/en/healthtopics/health-emergencies/coronavirus-covid.5]5.

WHO. (2020b). Water, sanitation, hygiene and waste management for SARS-CoV-2, the virus that causes COVID-19: Interim guidance, 29 July 2020 (No. WHO/2019-nCoV/IPC_WASH/2020.4). World Health Organization. https://apps.who.int/iris/bitstream/handle/10665/333560/WHO-2019-nCoV-IPC_WASH-2020.4-eng.pdf

WHO. (2020). R&D Blueprint and COVID-19. World Health Organization. https://www.who.int/teams/blueprint/covid-19

Xu, E. G., & Ren, Z. J. (2021). Preventing masks from becoming the next plastic problem. Frontiers of environmental science & engineering, 15(6). doi.org/10.1007/s11783-021-1413-7

Yu, H., Sun, X., Solvang, W. D., & Zhao, X. (2020). Reverse logistics network design for effective management of medical waste in epidemic outbreaks: Insights from the coronavirus disease 2019 (COVID-19) outbreak in Wuhan (China). International journal of environmental research and public health, 17(5), 1770. doi.org/10.3390/ijerph17051770

Zand, A. D., & Heir, A. V. (2020). Emerging challenges in urban waste management in Tehran, Iran during the COVID-19 pandemic. Resources, conservation and recycling, 162, 105051. doi.org/10.1016/j.resconrec.2020.105051

Zand, A. D., & Heir, A. V. (2021a). Emanating challenges in urban and healthcare waste management in Isfahan, Iran after the outbreak of COVID-19. Environmental technology, 42(2), 329-336. doi.org/10.1080/09593330.2020.1866082

Zand, A. D., & Heir, A. V. (2021b). Environmental impacts of new Coronavirus outbreak in Iran with an emphasis on waste management sector. Journal of Material Cycles and Waste Management, 23(1), 240-247. doi.org/10.34172/aim.2020.05