CHAPTER 8

Handling and treatment strategies of biomedical wastes and biosolids contaminated with SARS-CoV-2 in waste environment

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8.1 Introduction

Biomedical wastes (BW) are the potential source of major hazardous environmen tal pollutants. It includes not only solid wastes such as needles, plastics, and syringes from the hospitals but also comprised of the drugs which are highly proactive, few are radioactive, and some pathogens are present in the excreta of various patients. If not managed or handled properly, all the aforementioned wastes may be carriers of a high amount of pathogenic activity and can cause serious health issues such as respiratory illness, viral, bacterial, fungal, parasitic infections, gastronomical problems, and so on.[1] Studies from Tehran show that there is a direct link between the number of coronavirus infected patients and the biomedical waste produced.[2] In simpler words, the hospital waste increases at increments with coronavirus-infected patients. Reports say that approximately 5.2 million people die every year owing to the mismanagement and improper disposal of biomedical wastes.[3]

In India, 600 tons of BW are generated each day, and the treatment of these wastes is indeed a major obstacle.[4] Having the second-highest number of cases during this global pandemic, India has already crossed the saturation stage of the disposal facilities available.[5] Similarly, in Wuhan, China, the numbers have been estimated to increase from 40 tons per day to 240 tons per day of BW. The figures in the United States has increased drastically from 5 million tons per year to 2.5 million tons per month.[1]

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Considering the previous incidences of pandemics, it has been reported that the coronavirus family, which comprises not only SARS-CoV-2 but also SARS-CoV and MERS-CoV that were spread as epidemics in 2002–03 and 2012–13 respectively, continued to remain mostly on surfaces for nine days.[6] It has been reported that SARS-CoV-2 spreads more rapidly than the previous outbreaks from the same coronavirus family.[7,8] The SARS and MERS outbreak unfolded many flaws present in the healthcare system. These flaws were majorly related to the preparedness for a global health emergency that took a toll on healthcare professionals. Digging deeper into the facts, healthcare workers were the among the majorly infected populations at higher rates due to these superspreader situations. About 18.6% and 21% of healthcare workers were infected by MERS and SARS, respectively.[8] Based on these earlier experiences, during the Nipah virus outbreak in 2018 at Kerala, India, the state and central government took immediate actions that were acknowledged as a story of success.[9] When Zika virus cases were found in Brazil in the year 2015, the World Health Organization (WHO) gave immediate guidelines to suppress the virus by spreading information and also strengthened healthcare facilities and research laboratories. Since the transmission of disease is through the vector Aedes mosquito, which cannot travel for more than 400 m, the viral outbreak in a particular region was controlled.[10] The high rate of human-to-human transmissibility of SARS-CoV-2, and with the place of origin in China, being the hub of global trade, has led to the more rapid and uncontrollable spread of the coronavirus compared to SARS-CoV and MERS-CoV.[8]

The COVID-19 wave has been estimated to disrupt the waste recycling industry.[11] It has been reported that 19% of mismanagement of the recycling industry took place pre-pandemic. This overlook of management could aggravate the high risk of this virus to enter the environment.[12] The use of disposable materials such as masks, personal protective equipment (PPE) kits, used towels, and tissues in every sector of society has increased the amount of solid wastes generated, and this has caused a façade in the environment.[13] In addition, personnel and workers involved in municipal waste management are at risk of exposure to the coronavirus. Are we inviting another problem to protect ourselves from one? The question still lingers. According to recent studies, it has become an emergency to ensure handling of solid waste with the utmost care.[14] This chapter is focused on the characteristics and classification of wastes generated from health care sectors and ways to dispose of such highly contagious, virus-infected biosolids.

8.2 Solid wastes from health care units

The wastes that are generated from health care sectors, which includes various establishments, laboratories, and research facilities, is termed as healthcare wastes. It also includes wastes that come from "scattered or minor" sources. These sources may include healthcare courses in home, which may include syringe, dialysis, insulin shots, and so forth.[15]

8.2.1 Classification

Waste can be divided into two general categories. They are:

- **Non-hazardous waste**: General waste that comes from housekeeping and domestic activities, which take place in the health care sector. It comprises 75%–90% of the total waste according to the World Health Organization.[15]
- **Hazardous waste**: As the name suggests, it poses a risk to the health and environment and can be of various types, which have been discussed in detail in the subsequent sections.[15]

8.2.1.1 Infectious waste[15]

These wastes contain a specific amount of disease-causing microorganisms that may be bacteria, parasites, viruses, or fungi that can cause the spread of disease. For example, waste from the isolation wards, bandages, blood-coated tissues, disposable syringes, excreta of patients, and so on.

8.2.1.2 Pathological wastes[15]

These wastes are also called anatomical waste. These consist of blood, organs, tissues, and animal carcasses.

8.2.1.3 Sharps[15]

These wastes can cause wounds and cuts. For example, sharp blades, scalpel, scissors, and hypodermic needles.

8.2.1.4 Pharmaceutical waste[15]

Pharmaceutical waste that has expired, unused, and infected substances from industry, medicines, and vaccines that are not required and need to be disposed of properly. Items to be discarded in the pharmaceutical include drug vials, bottles, and gloves.

8.2.1.5 Chemical wastes[15]

These wastes contain harmful chemicals which may be toxic, flammable, and corrosive in nature. These are discarded from laboratories as chemical forms, and disinfectants from housekeeping work. These can further be organic or inorganic due to their nature of compound. For example, formaldehyde, solvents, and alkalis and acids.

8.2.1.6 Radioactive wastes[15]

The purpose can be to make medicine compositions containing radioactive elements, called nuclear medicine, in pharmaceutical departments for the treatment of hypothyroidism, carcinoma, and so on. It is also used for the clinical research for radioimmunoassay.[16] The discards may contain significant radioactive material that may pose hazards to human health.

8.2.2 Modes of transmission of SARS-CoV-2

COVID-19 shows resemblance to the pandemic outbreak caused by SARS-CoV in 2002 and MERS-CoV in 2012 because they belong to the same family of viruses, coronavirus.[17] These viruses are highly contagious and mainly target the respiratory tract in humans and cause severe infections.[18] The coronavirus can spread directly from one individual to another and indirectly from contaminated surfaces,[19] as shown in Fig. 8.1.

Transmission through droplets is the most common mode. If an infected person sneezes, coughs, or moist talks, the viruses from the mouth escape in the form of droplets and transmit to the other person.[20] The size of respiratory droplets when released by coughing, sneezing, etc. is larger than 5 μm in diameter, while in aerosols, the droplet size is smaller than 5 μm in diameter.[21] The dilution of the virus in aerosols leads to inactivation if left in the environment for a time period of six days.[22] Patients in quarantine homes produce waste in the form of feces or urine discharge. A study shows that the virus was present in fecal specimens collected from infected patients contradicting the WHO reports that suggested no evidence of the presence

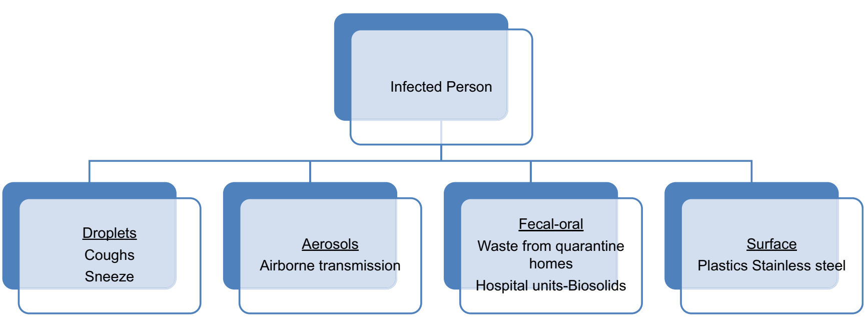

Figure 8.1 Modes of transmission of COVID-19.

and transmission of coronavirus through fecal-oral pathway.[23,24] The coronaviruses have also shown an extended survival rate of up to 17 days in fecal matter and 16.6 days in blood samples.[25] The virus can be transmitted indirectly from the contaminated surface to the healthy person, also known as fomite transmission.[19] It occurs either by the deposition of droplets released by the patient during coughing or sneezing on the surface or by the items such as clothes and bottles used by an infected person that comes in contact with the surface.[21] As stated in a report, there is only 1.3% virus transmission by fomites and 1.3% by aerosols whereas 89.5% transmission through droplets.[26] Hence, the chances of transmission of COVID-19 infection is less through contaminated surfaces as compared to direct contact.

The transmission of SARS-CoV-2 is influenced majorly by three factors: the survival rate of virus on waste surface and biosolids, population density, and socio-economic conditions.[27] The factors of population density and socio-economic conditions are interrelated. Healthcare workers and waste-handlers are in direct contact with SARS-CoV-2. These workers often belong to the lower sections of society, live in close proximity with each other, and also tend to have inferior levels of hygiene practices, which puts them at greater risk of outbreak.

8.3 Occurrence of virus in biomedical waste

The large amount of waste generated from health care centers, laboratories, and isolation homes during the treatment of patients contributes to an increase in transmission. The BW produced from these sources, if not properly marked and segregated, could cause danger to people involved in waste handling and disposal.[1] The BW produced during COVID-19 includes used PPE kits, masks, and sewage from quarantine shelters, gloves, blood collection bags, and laboratory waste. As per the reports from Central Pollution Control Board (CPCB), India there is an increase in BW production in the country by 550 tons per day amid the pandemic.[28]

The tracing of the disposal of BW can help us to keep a check on the spread of infection and reemergence of the virus at different sites. Early detection will thus help to control the outbreak by following preventive measures. As these viruses tend to remain viable on waste surfaces, they may come in contact with workers or other people and lead to infection.[29]

8.4 A comparative study on viruses potentially similar to COVID-19

The zoonotic diseases are dynamic mostly as a result of human activities. The adaptation of species to the environment is due to a genetic mutation. This mutation is constantly leading to the emergence of characters like a crossing of species barrier and transmission of infectious disease from one species to another.[30] The period between the encounter with the virus and onset of symptoms is known as the incubation period. This period varies depending upon the virus encountered. For example, SARS-CoV-1 has an incubation period of 2—8 days,[31] MERS-CoV for 2—15 days,[30] SARS-CoV-2 approximately for 1—19 days,[31] and Ebola virus for 4—10 days.[32] SARS-CoV-1 showed crossed species transmission from bats to palm civets in the live animal trading market in China,[33] whereas MERS-CoV is believed to be transferred cross-species 30 years ago in camels.[34] The similarities included no specific vaccine for controlling the transmission of the diseases; only preventive measures were introduced for both SARS and MERS.[35] The nosocomial transmission of the disease was observed in both the diseases greatly affecting hospital workers and patients.[36] However, the difference in the death rates were comparatively higher than the MERS epidemic of about 30%—40% than that caused by the SARS pandemic, which was less than 10% of deaths.[35] The mortality rate differed greatly since MERS originated as a point source and then followed an explosive epidemiological curve.[37]

Recent studies show that the survival rate and transmission route of SARS-CoV-2 is equivalent to SARS-CoV-1 and differs from MERS-CoV since it was observed that transmission of MERS-CoV was difficult from one person to another and was also confined to Middle Eastern countries.[35,37] The people suffering from chronic respiratory infections, diabetes, high blood pressure, or have low immunity have reported higher mortality risk of 9.6% and 36% when infected with SARS-CoV-1 or MERS-CoV, respectively.[30]

According to the WHO report,[24] no cases were reported for transmission of SARS-CoV-2 through food but they can be present in raw food products, especially in frozen items.[38] The SARS-CoV-2 was observed to survive on imported frozen food products, which include packaged meat, fish, and dairy items at 4°C for about 14—21 days.[39] The studies also suggest that there is a possibility of food contamination by fecal transmission or unclean practices adopted by infected people, which includes improper hand and mouth hygiene;[41] it is advisable to follow personal and food hygiene along with safety precautions. Although there are many incidents of indirect foodborne transmission of SARS-CoV-2, thorough research is required to draw out the direct connection between COVID-19 infection and transmission by food products.[39]

According to a study, about 51% patient's stool tested positive for both SARS-CoV-1 and SARS-CoV-2. In urine samples, 42% and 4% tested SARS-CoV-1 and SARS-CoV-2 tested positive, respectively.[40] The infectious time period of SARS-CoV-1 in human stools is for 2–4 and 17 days in urine.[41] MERS-CoV can survive in organic waste for 2 days at a temperature of 20°C.[25] The human intestinal epithelial layer can stimulate the replication of the virus and act as an optional infective route, which supports the survival of the virus. According to reports,[32] the Ebola virus showed survival on human discharge for a maximum of 8 days at normal temperature. This report also suggested that the waste produced by patients infected from Ebola was directly discharged into sewage after disinfection and the components of organic waste and halogenated groups react to decrease the efficiency of the disinfectants. This increased survival rate of Ebola virus in waste rendering the disinfection process void. As stated earlier, SARS-CoV-1 shown similarity to SARS-CoV-2 hence the survival rate of SARS-CoV in hospital waste can be employed for better understanding of persistence of SARS-CoV-2. SARS-CoV was present in hospital sewage for up to 2 days at 20°C in reactive form and inert isolated form for 8 days. The temperature above 20°C reduces the viability of the virus isolates to a great extent.[38]

The inactivation of human coronavirus (HCoV) was reported by various biocidal products, which includes 71% concentrated ethanol, 0.05% concentrated sodium hypochlorite, and 2% concentrated glutardaldehyde.[6] These chemicals very highly effective with reduction of viral isolates to >3 $\log_{10}$ hence can also be employed for disinfecting SARS-CoV-2. It was reported in the study that the SARS-CoV-2 was weakened at temperature >40°C and could survive only for 24 h.[42]

8.5 Survival of SARS-CoV-2 on different surfaces

SARS-CoV-2 can survive up to 72 h on plastic and steel and is less stable on copper surfaces.[43] The viability of the virus on different surfaces depends on the type of surface, suspending medium, temperature, relative humidity, mode of deposition, and drying time.[44] Studies have demonstrated the

Table 8.1 Survival of SARS-CoV and MERS-CoV on dry surfaces.

Substrate	Test virus	Temperature	Duration
Plastic	SARS-CoV	22–25°C	<5 days
	MERS-CoV	20°C	48 h
Steel	MERS-CoV	20°C	48 h
Metal	SARS-CoV	RT	5 days
Wood	SARS-CoV	RT	4 days
Paper	SARS-CoV	RT	4–5 days
Disposable gowns	SARS-CoV	RT	2 days
Glass	SARS-CoV	RT	4 days

CoV, coronavirus; *MERS*, Middle East respiratory syndrome; *RT*, Room temperature; *SARS*, severe acute respiratory syndrome.

capacity of coronaviruses to survive on different matrices like plastic, copper, and stainless steel as shown in Table 8.1. The survival rate analysis helps to disinfect the surface contaminated by SARS-CoV-2.[6]

The results demonstrated that SARS-CoV, HCoV, and MERS-CoV can effectively and efficiently survive on dry surfaces.[6] However, HCoV has more viability in the cell culture medium as compared to SARS-CoV and MERS-CoV.[38] MERS-CoV can survive at low temperatures (4°C for 72 h); it is also thermolabile making it susceptible to high temperatures.[38]

The research on various viruses comprehended some of the important findings related to SARS-CoV-2. The virus can survive on plastics (2–3 days), hard surface and stainless steel (2–3 days), copper (<4 h), cardboard (<24 h), and air (<3 h). The SARS-CoV-2 is less viable on fabrics and food.[24] However, it is advisable to use PPE kits and coveralls by frontline workers who are in close to infected patients.

The reduced survival of the SARS-CoV-2 in water is due to the flora present in water, which hinders the metabolism of the virus, causing its inactivation.[40] The SARS-CoV have shown an extended survival rate of 96 h when in contact with biosolids.[45] A similar study was carried out for SARS-CoV-2,[48] which suggested the presence of this virus in the primary sludge and thickened sludge (>20%). The sewage sludge is considered as the pool of SARS-CoV-2 as it contains 30%–50% of the total pollutants discharged in sewage system.[46] Therefore, it is important to conduct further studies and analyze the risk for secondary transmission of the virus from contaminated sludge of wastewater treatment plants.

8.6 Safe handling and management of health care waste generated through the care of COVID-19 patients

The safe handling and management of waste produced by the treatment of COVID-19 patients is based on three essential principles. The following principles was used for managing Ebola virus—associated healthcare wastes:[8]

- Safe handling and processing of the waste should be carried out as close to the point of generation as possible. After primary containment personnel should avoid opening containers to control the waste.
- Limit the number of personnel entering the area of care for COVID-19 patients and those handling waste generated before and after primary containment.
- Must use suitable PPE and waste management techniques for off-site inactivation before inactivation or transportation away from hospital.

8.6.1 Preparing a waste management plan as part of COVID-19 patient care

The following waste management plan has to be implemented while handling a COVID-19 patient care unit:[48]

- Comply with the state and local regulations like SPCB (State Pollution Control Board), CBWTF (Common Biomedical Waste Treatment and disposal Facility), and ULB (urban local bodies) on coronavirus-associated waste handling, storage, treatment, and disposal.
- Determine if coronavirus-associated waste should be processed at the hospital for inactivation or moved off-site.
- Identify a waste management team with thorough training on uniform waste handling techniques, including wearing acceptable PPE and secured bag and packaging waste policies, processing waste, and transporting processed waste.
- Make sure the staff in healthcare and environmental services are qualified to wear approved PPE (same for patient care) and follow appropriate procedures.
- The handling and primary waste packaging should take place in the patient room and the area where PPE is removed and performed by primary healthcare workers (i.e., doctors and nurses) wearing PPE as specified in the hospital guidance.

8.7 Collection, transport, and storage of waste

8.7.1 Collection

COVID-19 associated waste should be collected regularly and can be transported in leak/puncture proof containers, labeled with a biohazard sign. The patient's room should be placed with an individual waste bag. The patient's used tissue paper and face masks should be immediately discarded in the waste bag. Gloves and face masks used by the caretaker and the cleaner should be disposed off in the second waste bag immediately next to the patient's room door when the caretaker or cleaner leaves the room.[47] Once the waste bag is three-fourths full the nursing staff and other working personnel must ensure that the waste bags are properly closed and sealed. Fresh bags and containers at all sites where waste is generated should be readily accessible for collecting them regularly. Wastes should not be permitted to accumulate at any point.[47] A regular waste management system must be developed in order to collect the health care wastes as shown in Fig. 8.2.

8.7.2 Storage

Within the healthcare facility, a place of storage for the BW should be allocated. Health care waste that is collected in bags and containers should be stored separately in an area, space, or building in an appropriate size for the quantity of waste generated and depending upon how often the wastes are collected. Storage areas should be clean, safe, and secured against the

Figure 8.2 Health care facility waste management in relation to COVID-19.[15]

weather, pests, and disease-causing vectors. The area where the healthcare wastes are collected and stored should provide easier access to the waste management personnel. It is important that waste disposal vehicles have convenient access to the storage area. The storage should be locked to prevent unauthorized persons from reaching it. Storage bins must have a biohazard sign.[15] Regular inspection and cleaning of the storage area is necessary.

- Storage areas should be clean, secure, and protected from direct contact with other vectors like pests and public.[48]
- The waste that are collected and stored should be handed over to CBWTF personnel.[48]

8.8 Treatment and disposal

8.8.1 Treatment

Best management strategies recommend that the waste should be disinfected by non-incineration processes in particular, by steam-based treatment such as autoclave or microwave.[49] All systems should be checked and reviewed periodically. Organisations like WHO and UNEP (United Nations Environment Program) prefer steam-based or other forms of nonincineration methods for disinfection due to the persistent organic pollutants (POP) produced by incineration. However, incineration is much costlier than steam-based systems and has a higher carbon footprint.[49]

8.8.1.1 Preferred technologies for treating virus infected solid waste

8.8.1.1.1 Autoclave

Autoclave is the most common and efficient wet thermal technology used for treating medical waste, which is based upon pressure and vacuum using high temperature steam. This method is often preferred as it is simple, cheap and has reduced air pollution.[15] The merits and demerits of adoption of this technique have been tabulated in Table 8.2. It is suitable for treating solid healthcare wastes, used PPE, medical instruments that can be reused, glassware, and sharp wastes.[50]

8.8.1.1.2 Sterilization

This method is based upon using a microwave and high temperature steam process with integrated shredding.[51]

Table 8.2 Merits and demerits of autoclave.

Merits	Demerits
Overall handling and operation is very simple It is one of the cost-effective technology It has reduced air pollution	Heat sensitive materials cannot be used No waste volume reduction Remaining waste need to be transported and land-filled

8.8.1.1.2.1 Microwave disinfection In recent days microwave disinfection is considered as an effective supplementary technology for incineration as it has several advantages as mentioned in Table 8.3.[51] In this method the wastes are loaded into a shredder and reduced into small bits, after which the waste is humidified and sent to a chamber containing a series of microwave generators for irradiation process.[15] Merits and demerits of microwave-based disinfection technology have been shown in Table 8.3.

8.8.1.1.2.2 High temperature steam-based technology It is a disinfection technology where pathogenic microorganisms are killed in a high temperature steam (temperature greater than 100°C). For a certain period of time the health care wastes are exposed in a high temperature steam, which contains lot of water vapor. The water vapor emits a latent heat, which results in coagulation and protein denaturation of the microorganisms causing death of the pathogenic microorganisms.[52] This method also has its own merits and demerits which is shown in Table 8.4.

8.8.1.1.3 Shredding

Before carrying out disinfection and the other treatment process it is necessary that the solid BW be taken through a process known as shredding. Shredding increases the contact between the waste and disinfectant by raising the surface area and possibly removing all the enclosed gaps in order to decrease the waste volume. Shredding is a much effective method as it reduces the initial waste volume to a maximum extent (60%–90%).[15]

Table 8.3 Merits and demerits of microwave disinfection technology.

Merits	Demerits
Slow heat loss and rapid action in a reduced space Energy saving technology Low environmental pollution and no residues or toxic wastes after disinfection	Takes longer time when compared to autoclave No waste volume reduction Can sterilize only limited number of materials at a time

Table 8.4 Merits and demerits of high temperature steam-based technology.[50]

Merits	Demerits
Low cost and safe technology	Cannot be used for heat sensitive materials due to melting
Nontoxic and negligible air pollution	May leave instruments wet, causing corrosion
Cycle easy to control and monitor	Requires proper maintenance for controlling high temperature
Rapid cycle action and more efficient	No waste volume reduction

8.8.1.1.4 Incineration

Incineration is one of the widely used technologies for safe management of various wastes that results from healthcare activities.[53] Healthcare waste consists of organic and combustible waste and is reduced to inorganic, incombustible substance in a dry oxidation process using high-temperature range. Initial volume and weight of the waste is significantly reduced by this process. Incineration is a selective process used for treating those types of healthcare waste that cannot be recycled or reused and disposed of directly.[53]

An incinerator usually operates at the temperature range of 900−1200°C at which combustion of organic compounds takes place. The combustion of organic compounds results in the emission of gaseous substances like carbon dioxide, steam, and various other toxic materials in the form of ashes. During combustion, various conditions should be properly controlled or else it may result in the production of harmful carbon monoxide gas. The ash and wastewater generated at the end of the process contains some toxic compounds that are necessary to be treated to avoid harmful effects.[15] The two most widely used incinerators for treating the health care wastes are:

(1) Pyrolytic incinerator and
(2) Rotary kiln incinerator.

8.8.1.1.4.1 Pyrolytic incinerator The pyrolytic incinerator consists of two important chambers: one is a pyrolytic chamber and the other is a post-combustion chamber. Inside the pyrolytic chamber the healthcare waste undergoes a combustion process in the low supply or near absence of oxygen, and they are thermally decomposed through incomplete oxidation, which results in production of gaseous compounds and ash (solid residue) at the end of the process.[15] The operation is carried out using a fuel burner that is present in the pyrolytic chamber. Mixture of gas generated during the process are burned at a high temperature range by the post-combustion chamber fuel burner, which reduces excess smoke and odor. Larger-sized pyrolytic incinerators are equipped in a way that it runs continuously. These may also be able to work entirely automatically, including waste storage and ash removal. In hospitals, limited size pyrolytic incinerators are most widely used since they do not need any special equipment for cleaning. It is also used for disposing various healthcare wastes because they are known for their controlled air incineration.[53]

8.8.1.1.4.2 Rotary kiln incinerator This incinerator works on the rotatory motion basis which consists of a rotating oven and a post-combustion chamber. Rotation helps in mixing the waste, thereby increasing the efficiency of incineration.[55] Waste is fed inside the chamber from the top and the ashes and other solid residues are collected at the bottom end. The gas produced during the process are heated in the post-combustion chamber where the temperature range is very high, resulting in deduction of the harmful volatile organic gaseous compounds.[15] This type of incinerator can operate continuously even with heavy loads. Almost all hazardous substances are destroyed as this incinerator operates at a temperature of 1200°C.[53]

8.8.1.1.4.3 Plasma incineration Plasma incineration is a new waste disposal technology. The aim of this technology is to transfer energy through plasma to rapidly decompose waste into smaller particles or even atoms.[54] Compared with conventional incineration techniques, plasma incineration demonstrates a higher energy efficiency, which demonstrates promising application prospects.[55] The merits and demerits of incineration technology have been tabulated in Table 8.5.

Table 8.5 Merits and demerits of incineration-based technology.

Merits	Demerits
High waste volume reduction	It is an expensive technology in terms installation and maintenance
More efficient as it burns almost 90% of the initial waste generated	Releases harmful gases like nitrogen oxide and acid gases during combustion which causes environmental pollution
Handles different types of wastes by its uniform action	Ash waste can potentially harm both public health and the environment
Prevents transportation of wastes and less dependence on landfills	Releases POP and has a high carbon footprint

8.8.2 Disposal

After various treatments for disinfection the harmful health-care wastes become non-risky and are safe to be disposed at landfills. A landfill site should be properly designed and engineered for disposal of the reduced hazardous waste. Regular monitoring of such sites is mandatory inorder to avoid leaching and other environmental problems like groundwater contamination. General wastes which are not contaminated can be disposed normally as solid waste. Used masks and gloves are to be kept in a paper bag for atleast 72 h before disposing it. Before disposing of the used masks it is better to cut or mutilate it to prevent its reuse.[49] Access to the disposal sites should strictly be allowed only for the authorized persons. Encapsulation is one of the cheap, safe, and easier methods for disposal of health care wastes, where the waste containing metallic drums or containers are added with an immobilizing material, which acts as a medium for immobilizing the waste. The medium is allowed to get dried completely and then, the immobilized containers can be tightly sealed and disposed of into landfills.[15]

8.9 Measures to protection of personnel and waste disposal workers from contracting COVID-19

Poor healthcare waste management easily exposes to waste handlers, patients, and the wider population to illness, harmful effects, and environmental pollution risks. Patients who were treated at home are generating infected waste, possibly discarded as domestic waste, which may pose risks to sanitary staff and the environment, depending on the conditions of transport and disposal.[56] Therefore, these wastes should be regularly tracked and properly handled. Sanitation workers are the most insecure as they come into close contact with various forms of waste, including liquid waste, solid waste, organic waste, and hazardous waste.[48] During this pandemic, waste disposal workers should be careful, and close interaction with the waste during this pandemic makes them more vulnerable to the coronavirus, and it may even infect their family members and spread rapidly. Thus, such waste disposal personnel should be adequately trained, and protective equipment to be regularly provided.

The most affected groups from these health care wastes are as follows:

- nurses and other frontline employees in the hospital,
- waste disposal workers,
- workers bringing waste to a disposal or recycling plant, and

- workers in waste treatment plant (incinerator plant or landfills).

Even common people are also at risk when they get in close contact with those healthcare wastes. The most significant problem that leads to this risk is mainly due to the unavailability of protective equipment, and the government or the respective organization should regularly supply these protective essentials. Globally, most workers employed in waste disposal and treatment plants are poor, so the public also should come forward to supply these protective kits free of cost, which may prevent them from infection (Fig. 8.3).[56]

8.9.1 Actions to reduce the risk of exposure

To reduce the risk of exposure to these sanitary wastes, waste disposal workers should follow the following protective measures.[57]

8.9.1.1 Personal protective equipment (PPE) kit

PPE plays an important role in guaranteeing overall safety and health to the waste disposal workers in treatment or in disposal sites. Ensure that all sanitation workers are equipped with protective kits suited to the nature of their work, along with soaps and hand sanitizers. PPE acts as a barrier between the suspected infectious substance and the healthcare worker; PPE eliminates contact with an infectious agent. Disposal workers must wear PPE. Ineffectiveness of PPE may lead to nosocomial transmission of SARS-CoV.[57]

Components of PPE kits include masks, gloves, goggles, glasses, and gowns. Health institutions and waste disposal services should have practices

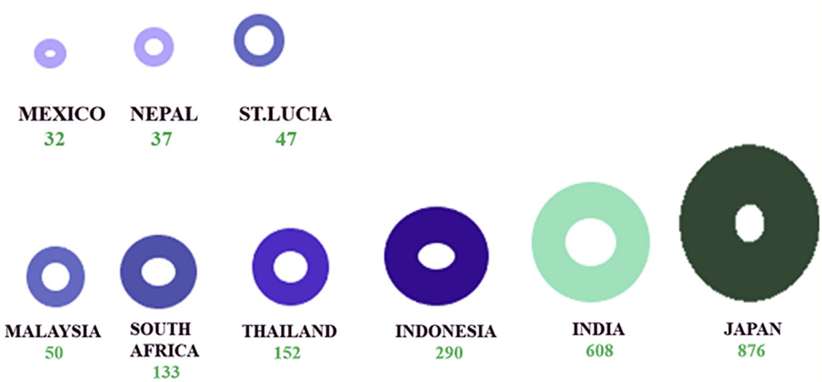

Figure 8.3 Amount of health care waste generation (tons per day) in selected countries.[56]

and regulations that describe the correct order of donning and safely doffing these PPEs. The order for donning the PPE after performing hand hygiene is gown, then mask, goggles, face shield, and gloves; the order for removing the PPE is gloves, face shield, goggles, gown, and then the mask should be removed.[58] PPE kits are not reusable; once they are used they must be disposed, except for goggles (can be reused). Though PPE kits are costlier, service-providing companies should offer workers with high-quality PPE.[58]

Single-use PPE kits should be properly disposed in a plastic bag and should be labeled as hazardous or biomedical waste and segregated from general waste securely. The reusable PPE equipment such as googles, should be washed with detergent and water after use and allowed to dry. Strict adherence to improved hygiene practices, including regular alteration and cleaning of PPE and professional clothing, replacement of professional gloves in case of breakage or other possible incident contamination, routine sanitizing of buildings, cabins and clothes for vehicles. Make sure of strict guidelines on how to put and take off PPE. Avoid incidental contact and contamination.[59]

8.9.1.2 Face masks

Since the COVID-19 pandemic, the wearing of face masks has received numerous guidelines from different public health authorities and government. The WHO and other public health organizations believe that the spread of respiratory viral diseases like COVID-19 can be restricted by the masks.[58] Along with hand washing and social distancing, the face mask has emerged as the most powerful tool in our society against COVID-19. Yet, with billions of people around world using masks every day since COVID-19 began, it is mandatory that governments of different countries and waste disposal organizations provide workers with a continuous supply of face masks and protective apparel to defend themselves against the pandemic. Different kinds of face masks that are feasible to utilize during a pandemic have been represented in Fig. 8.4.[58]

8.9.1.3 Reusable cloth mask

Cloth masks are widely used, and their demand is increasing day by day due to their low costs and reusability nature. Depending on the frequency of use, the WHO recommends that sanitary workers should routinely wash these face cloth masks. After every wear, a reusable cloth mask should be washed.[58] When you take it off, fold it in half to contain the inner secretions and place it in a laundry bin, ideally one with a lid that you can

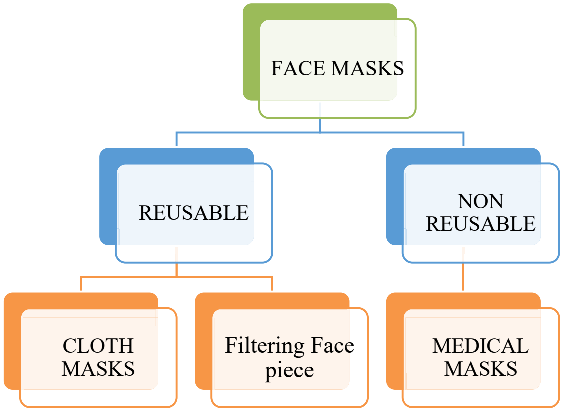

Figure 8.4 Types of masks employed for health care workers.

close if you cannot wash it right away. These cloth masks cannot be used by disposal workers while working, but they can be used when they are away from the disposal site or treatment plant. The collected mass should be safely disposed; recently there has been an increase in mass waste in developing countries (Table 8.6) and governments must devise appropriate strategies to handle it.[62]

8.9.1.4 Gloves

Gloves are the second skin for sanitary workers. The collection of waste from garbage or waste storage yards may contain harmful wastes such as blood-stained injections, cottons, needles, glass bottles, etc. Thus, gloves are essential to protect the sanitary workers from injuries and infections. If the gloves are damaged or contaminated, hand hygiene should be checked and gloves should be changed with new ones. Once it is used it should be disposed in a safe manner.[58] Gloves need not be dried and reused. Strict adherence to improved hygiene practices, including regular alteration and cleaning of gloves and replacement of professional gloves in case of breakage or other possible incidental contamination.[58]

8.9.1.5 Head covers and goggles

Head covers and goggles are also very important because they protect from the entry of infectious droplets and dust by forming a barrier for the medium of the disease, which is necessary for sanitary workers. Eye protection should not be ignored and should be considered part of PPE.[60]

Table 8.6 Estimated daily usage of face mask and medical waste in Asia with confirmed COVID-19 cases.[62]

Country	Population	Total COVID-19 cases	Urban population (%)	Face masks acceptance rate (%)	Number of face mask need of each general population each day	Total daily face mask use (pieces)
India	1,381,085,714	1,643,416	35	80	1	381,179,657
Iran	84,077,062	301,530	75	80	1	50,648,022
Pakistan	221,213,683	278,305	35	80	1	61,762,860
Saudi Arabia	34,855,542	274,219	84	80	1	23,367,155
Bangladesh	164,820,045	234,889	75	80	1	99,155,739
Turkey	84,410,984	229,891	39	80	1	26,066,112
Iraq	40,288,721	121,263	96	80	1	30,973,969
Qatar	2,807,805	110,460	60	80	1	1,341,008

8.9.1.6 Adequate hand washing facilities at the place of work

Appropriate hand washing facilities should be provided at the treatment site, with daily water, soap, and sanitary supplies. Temporary devices such as foot-operated hand-washing systems can be built in the worksite. Bathing facilities close to the place of work may also be required, depending on the nature of the work. Sanitizers must be often used by workers before and after their work. Since sanitizers are alcohol-based they should be continuously used by workers to defend them against germs.[15]

Steps should be followed by both patients and sanitary workers for the disposal of waste:

- Paper tissues, gloves, and face masks among patients must be disposed by putting in the waste bag that was kept in the patient's room.[47]
- Segregate waste at the source, Storage facilities should be clean, secure, and designed to protect from the elements, pathogens, and vectors of disease.[61]
- Gloves and face masks used by the sanitary workers should be immediately put in a second waste bag and should be disposed separately.[47]
- The waste bags should be closed before they are disposed from the patient's room and replaced often; they should never be emptied in another bag.[61]
- Collect the waste at least daily and carry it in air-tight containers, puncture-proof, marked with the biohazard symbol.[61]
- These waste bags can be accumulated and placed in a clean waste yard; the closed waste-containing bags can be directly disposed of in the common garbage yard. No specific collection of waste activity or other disposal method is mandatory.[61]

After disposing of waste bags, strict hand hygiene should be followed by the workers and insist on using water and soap or alcohol-based hand disinfectants.[61]

8.9.1.7 Awareness and training

For waste disposal workers, training and awareness-building are needed in an effort to minimize the transmission of COVID-19. The preparation of workers leads to a more educated workforce, which is the basis for achieving this superior infection prevention performance. Expert staff can also assist patients and other visitors in understanding their role in maintaining good hygiene and becoming more responsible for the waste they generate. Most waste disposal and sanitary workers are from poor economic backgrounds in regions such as the Indian subcontinent and Africa, where they are mostly unaware about these harmful and hazardous wastes.[15] Therefore, they need to educate regarding the handling and transporting of waste securely during this pandemic. The awareness camps for these workers should be conducted on a regular basis by hospitals and treatment service centers. Such camps will help them to gain some knowledge and also prevent them from risk of infection. Education and training are essential parts of the waste management programs for healthcare. When healthcare workers are adequately sensitized to the importance of waste management, they follow professional best practices and help improve and maintain a proper waste management system.[15] Training should be essentially defined and incorporated into the regular functions of the healthcare facility. The trainer who delivers the training and awareness to the workers must be an expert. The trainer should address how to handle these biowastes, cautious of the pandemic, and train them by explaining the facts in their own language so that they can easily understand.[15]

The goals of training and awareness are:

- Increase awareness of health, protection, and environmental concerns related to sanitary waste.[59]
- Ensure that healthcare workers are familiar with best practices and waste care technologies managing them and being able to adapt them to their everyday work.
- Promote responsibility to the control of health care waste among all health care staff.

8.9.2 Offer support for sanitary workers by government

Funds may be obtained at a local level, if necessary, to ensure that workers have proper safety equipment. Government should also support health workers' organizations to ensure that health insurance and regular health check-ups are provided to all health workers. The government should provide food and accommodation to the sanitary workers, if necessary, and they also need to allocate a set member to monitor disposal of waste and to check the health condition of the workers regularly.[15] Governments should also provide a separate disposing yard so that the transmission of the disease can be controlled.[59]

8.10 Conclusion

Recent pandemic situation has altered the ways of waste management and the material recycle process. The sudden hike in BW production during

COVID-19 infection calls for an urgent need for disposal of contaminated waste to ensure sustainable development. SARS-CoV-2 is highly contagious and has the potential to spread through frozen raw food products and fecal-oral routes, and as a result, there is concern among the healthcare employers and waste recyclers. Chemical treatment has proved to be a prominent preventive measure in handling waste surfaces, whereas physical treatment by incineration, microwave disinfection, and autoclave have been utilized for disposal of residual waste products. Incineration is the preferred method by the ignition of waste at high temperatures where SARS-CoV-2 cannot thrive. Further, there is a requirement for public—private partnership and cooperation to safeguard sanitation employers and frontline workers. International organizations like the UNEP, in collaboration with policy makers, have postulated recommendations and guidelines for waste recycling mechanisms to mitigate non-targeted segments of society (sanitary workers) and maintain environment sustainability during pandemic situations.

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