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Challenges in handling COVID-19 waste and its management mechanism: A Review

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ABSTRACT

COVID-19, the novel corona virus has become a household name. The global COVID-19 outbreak, become a pandemic in early 2020, and spurred millions of life across the world. The pandemic is spreading extremely and its impacts upon human health and environment intensifying day-by-day. Biomedical waste generated daily due to COVID-19 are about the major environmental health concern and its critical management becomes a global challenge. Tones of COVID-19 contaminated wastes are generated every day worldwide and its sound management is very essential to break the disease transmission. The safe and sustainable management of COVID-19 contaminated biomedical waste (BMW) is a social and legal responsibility of all people during this critical period of disease transmission. Unsound management of this waste could cause unforeseen “knock-on” effects on human health and the environment. Health workers, municipal workers, rag-pickers and other persons who are involved directly or indirectly in the COVID -19 war are at high risk and needs to be careful while discharging their responsibility with an efficient and effective waste disposal mechanism.

1. Introduction

Viral pathogens can be transmitted to healthcare and recycling workers due to the improper disposal or handling of contaminated waste. It has been found that due to improper disposal of medical waste up to 30 % of hepatitis B, 1–3 % of hepatitis C, and 0.3 % of HIV rates have been communicated from patients to healthcare workers (Singh et al., 2020). Therefore in a bid to maintain community sanitation amid corona virus spread, disposal of biomedical waste is of utter importance. The disease not only killing millions valuable life but also brought challenges for the management of the waste generated from hospital, municipal, and house contaminated with COVID-19. Most of the people round the globe are suffering and many institutions and industries are locked, people lost their jobs as well. Due to this outbreak, tones of medical wastes such as masks, gloves, gowns are generated daily. According to the South China Morning Post reports, during the pandemic at Wuhan the quantity of medical waste produced daily was increased from 40-ton to 240 tons. During this COVID-19 pandemic, production of medical waste has greatly increased in different country (Table 1). After pandemic, production of the quantity of medical waste produced per month is 2.5 million tons. Irresponsible management of such types of waste materials could gear the disease transmission. Generally COVID-19 virus remains active from 2 to 9 days on the material surface

(Kampf et al., 2020). But the survival of the virus varies on different surfaces, known as fomites (objects or materials that are likely to carry infection, such as clothes, utensils, and furniture etc.). Its survival may also vary with several factors like the temperature, relative humidity and the type of strain present on the surface. On smooth surfaces it survives for longer periods. In one of the investigation it has been found that the SARS-CoV-2 RNA can remain live 11–21 days on serum sample, 17–31 days on stool sample and 13–29 days on respiratory samples (Zheng et al., 2020) (Fig. 1). It has been observed that most of the persons recruited in waste handling process are labourer and not properly trained to handle such waste. They are also not provided any health preventives and PPEs to handle these wastes which may put them at high risk and cause serious disease. Moreover, the people at home quarantines are usually putting their house hold waste in the same dustbin as their contaminated face mask, tissue paper and other contaminated waste which can transmit the disease to the municipal workers and rag pickers those are collecting home quarantine garbage. Sound handling and disposal of such wastes in hospital, house, municipal and quarantine centres are very essential to stop the public spread of the disease. As per the waste management policy each such contaminated waste should need proper identification, collection, separation, storage, transportation, treatment and disposal (Fig. 2). The contaminated material should be properly disinfected if required before the disposal and the

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Table 1
Status of COVID-19 biomedical wastes produced in different country.

Name of the country	Biomedical wastes produced during COVID-19 pandemic (tonnes/day)	Reference
Brazil	2774.35	Haque et al. (2020)
South Africa	469.12	Haque et al. (2020)
India	2160.34	Haque et al. (2020)
Bangladesh	359.83	Haque et al. (2020)
Colombia	550.63	Haque et al. (2020)
Italy	45.09	Haque et al. (2020)
Manila	280	UNEP (2020)
Jakarta	212	UNEP (2020)
Kuala Lumpur	210	UNEP (2020)
United States of America	8055.03	Haque et al. (2020)
Mexico	385.75	Haque et al. (2020)
Iran	81.31	Haque et al. (2020)
Argentina	454.41	Haque et al. (2020)
Bangkok	160	UNEP (2020)
Ha Noi	154	UNEP (2020)
Egypt	128.54	Haque et al. (2020)



Fig. 1. Survival of SARS CoV-2 on the surface of different material.

people employed in this process should be properly trained to handle such waste. Waste materials generated from household such as tissues, masks, faeces may contain the virus and can spread and contaminate others easily. Management of such material are very difficult as the people are not well trained like other hospital and municipal personnel and some time the disease is asymptomatic too. There are maximum chances of mixing of such contaminated wastes with other house hold waste, hence should be handled and treated separately before its final disposal. These wastes should be separately stored from other household waste streams and collected by specialist municipality or waste management operators. Each and every individual of the community should take keen interest for the proper handling of such wastes so that we can be able to break the transmission chain. Effort should be made from every level to create community awareness to adopt good waste management practice. After identification and collection, the waste should be stored in respective bags and immediately hand over for final disposal

and treatment. The person handling such waste in medical centre, municipal and govt quarantine should be given appropriate training and personal protective equipments (PPEs) such as triple layer N95 mask, full hand gloves, gumboots, aprons and safety goggles etc. (Klemes et al., 2020; WHO, 2020a)

Hence, the present review aimed to address the different source of COVID-19 contamination, their management and safe disposal which will definitely help the readers.

2. Management of COVID-19 contaminated waste

2.1. Collection

All health-care waste produced during patient care, including those with confirmed COVID-19 infection, is considered to be infectious and should be collected safely in clearly marked lined containers and sharp safe boxes (WHO, 2020a). The infectious COVID-19 contaminated medical waste generated should be first disinfected properly then separated and packed in their respective standard waste disposal bags (Ministry of Ecology and Environment of the People's Republic of China, 2020). For timely waste collection, separate and dedicated sanitization worker should be employed so that waste can be collected and transferred in right time to waste storage area. To ensure adequate strength, double layered leak proof bags should be used for the collection of waste where COVID-19 patients are kept (CPCB guideline, 18th March 2020). COVID-19 waste containers should not be placed in any public areas as the chances of contamination will be more when public will use the same containers. The amount of waste generated from the COVID-19 isolation ward should be maintained daily in a record. After collection from isolation ward and before handing over the generated waste to the Common Bio-medical Waste Treatment Facility (CBWTF), all the wastes are transported to a separate storage area with a trolley levelled with COVID-19 waste (CPCB guideline, 18th March 2020). It has been well described in the Bio Medical Waste (BMW) rule (2016) (Table 2) for the category of waste, the types of bags for its collection and procedure adopted to dispose these waste which should be followed in case of COVID-19 bio waste management also (BMW rule, 2016; CPCB guideline, 18th March 2020). When waste collectors are collecting COVID-19 waste from hospitals, laboratories, infected patients under quarantine, they should be provided with appropriate PPEs (CPCB guideline, 18th March 2020).

As per the biomedical waste management policy red bags are specific for collection of PPEs such as goggles, face-shield, splash-proof apron, plastic coverall, hazmat suit, nitrile gloves etc. Non-chlorinated yellow plastic bags are used for collection of bedding or meters contaminated with body fluids or bloods. In case of any pathogenic microbial waste such as microbial culture, live attenuated vaccine, waste from biological cell culture, cultured agar petri dishes etc. have to be autoclaved first on site then should be sent for final disposal in yellow colour bags (BMW Rule, 2016). Non-chlorinated red plastic bags should be used for the collection of tubing, drains, oxygen mask, bottles, intravenous tubes, catheters, urine bags etc. Puncture proof and leak proof (Translucent) containers should be used during collection of sharp objects like scissor, blades, burner, scalpel, needles, syringes with fixed needles, etc. (BMW Rule, 2016). Similarly puncture proof blue coloured containers should be used for the collection of contaminated and broken glass, slides etc., (Table 2). But before packing and final disposal these waste materials should be disinfected with 1 % sodium hypochlorite at least for 30 min. Because chlorine present in sodium hypochlorite (NaOCl) is highly electronegative and can break the cell layers of the pathogens by denaturing the proteins due to oxidation of the peptide bond thus easily deactivate SARS-CoV-2 (Duarte and Santana, 2020).

COVID-19 bio medical waste not only generated from hospitals only but also by the general population in their residences and public spaces. COVID-19 contaminated waste produced from quarantine centres should be collected separately in yellow coloured bag and the same

should be handed over to the authorised waste collector engaged by local bodies. The waste collector engaged by the local bodies then inform the same to the bio-medical waste treatment centre for collection of such waste from a specific identified point or directly from quarantine houses (CPCB guideline, 18th March 2020).

According to the South China Morning Post report (2020) around 440 pounds used masks were collected from over 200 public bins stationed across the Wuhan city, China. Waste generated during home quarantine, should be packed in strong black bags and closed completely before disposal and eventual collection by municipal waste services. Tissues or other materials used when sneezing or coughing should immediately be thrown in a waste bin. After such disposal, correct hand hygiene should be performed (WHO, 2020a).

The used diaper from confirmed COVID-19 patients in treatment centre should be collected and sealed properly in yellow colour bag. On the other hand, if the patient is provided with bad pan then after use the bad pan should be washed in the toilet by closing the lid of the toilet. After washing, the bad pan should be cleaned with detergent and disinfected with 0.5–1 % sodium hypochlorite solution for at least 30 min and again rinsed with water. The water during rinsing such material should be carefully disposed into drain (BMW Rule, 2016; WHO, 2020a).

2.2. Proper separation and storage

Segregation of COVID-19 wastes are very important from ordinary solid waste with a special treatment before its final disposal. During collection, different categories of waste materials are generated and are collected in separate bags as discussed above. After collection and during separation, all the infectious COVID-19 medical waste should be separated from non-infectious waste such as paper, cardboard, and food scraps. The collected biomedical waste should be labelled as waste type, site of generation, date of generation before transportation from the generation site. Bio-medical waste should be segregated into different containers or coloured bags (Table 2) at point of generation (BMW Rule, 2016; WHO, 2020a). After separation each categories of waste should be packed in respective bags and the neck of the bag should be properly shield so that no liquid waste will flow out and contaminate the storage surface. After proper packaging all the bags are sprayed with disinfectant (0.5 % chlorine solution) and stored (Chartier et al., 2014) or can be transferred into CBWT collection van. (CPCB guideline, 18th March

2020).

A separate waste storage bin labelled with COVID-19 should be used to store and keep COVID-19 in a special storage room so that it can't mix with other types of wastes. This will help the waste treatment worker to easily identify the waste and treat it upon receipt. The COVID-19 waste material should not be stored in the COVID-19 store room more than 24 h and should be disinfected (0.5–1 % chlorine solution) immediately after the waste delivery (BMW Rule, 2016; Ministry of Ecology and Environment of the People's Republic of China, 2020). Any types of liquid leakages from the storage area should be disinfected and discharged into the medical wastewater treatment system for treatment (BMW Rule, 2016).

2.3. Transportation

All COVID-19 contaminated waste materials should be sealed, the number of bags should be bar-coded and documented properly before transportation. The waste materials from the collection site are first transported to the storage area with a separate trolley labelled with COVID-19. The trolley used for transportation of COVID-19 waste should be disinfected with 1 % sodium hypochlorite after use. From storage area the waste materials are transported to CBWTF. For safe transportation a suitable transfer route, dedicated, trained driver and separate vehicle should be arranged (BMW Rule, 2016). Transportation should not be done through crowded area and during rush hour. Proper training should be given to the waste collector collecting COVID-19 waste. The collected waste material should be transported in a separate dedicated COVID-19 waste transporter vehicle. The vehicle container should not be open type. It should be a closed container so that during transportation no material can come out in any accident or other extreme cases such as rain or wind. All the workers involved in transportation should be supplied with adequate personal protective equipment (PPEs) (CPCB guideline, 18th March 2020). The transport vehicle should be sterilised with sodium hypochlorite (1 %) after each trip (Ministry of Ecology and Environment of the People's Republic of China, 2020).

2.4. Treatment and disposal

The principal ways to treat the COVID-19 waste are chemical

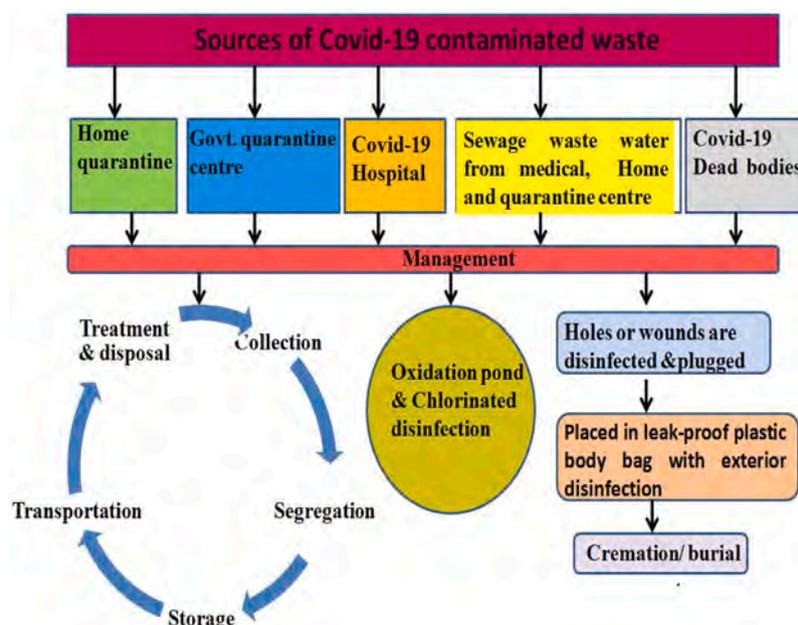


Fig. 2. Schematic flow diagram for safe management of COVID-19 waste.

Table 2
Biomedical wastes categories, their segregation, treatment and disposal options for COVID-19 patients (BMW rule, 2016; CPCB guideline, 18th March 2020).

Category of waste	Colour code (Non-chlorinated bags)	Pre-treatment required or not	Final disposal option
Soiled waste like items contaminated with blood (except blood bags), body fluids like dressings, plaster casts, cotton swabs etc.	Yellow	Not required	Incineration or deep burial ^a
Liquid waste generated due to discarded disinfectants, infected secretions, aspirated body fluids, liquid from laboratories and floor washings, cleaning, house-keeping etc.	Yellow	Separate collection system leading to effluent treatment system	The chemical liquid waste shall be pre-treated before mixing with other wastewater. The combined discharge shall conform to the BMW discharge norms
Personal protective material like face mask, gown, cap, etc (made of fibre material or others except those made of disposable plastics	Yellow	Not required	Incineration
Discarded linen, mattresses, beddings contaminated with blood or body fluid	Yellow	Not required	Non-chlorinated chemical disinfection followed by incineration
Microbiological laboratory waste like cultures, stocks, specimen, vaccine, dishes and devices used for cultures, blood bag etc.	Yellow	Pre-treatment to sterilize with non-chlorinated chemicals or autoclave, microwave, hydro-clave in safe plastic bag and container on-site	Pre-treatment followed by incineration
Wastes generated from disposable items such as tubing, bottles, intravenous tubes and sets, catheters, urine bags, syringes (without needles) and gloves	Red	Not required	Autoclave, shredding followed by recycling
Waste contaminated sharp object that may cause puncture and cuts like needles, syringes with fixed needles, needles from needle tip cutter or burner, scalpels, blades etc.	White (Translucent) puncture proof, leak proof, tamper proof containers	Not required	Autoclaving or Dry Heat Sterilization followed by shredding or mutilation or encapsulation in metal container or cement concrete or sent for final disposal to iron foundries or sanitary landfill or designated concrete waste sharp pit.

Table 2 (continued)

Category of waste	Colour code (Non-chlorinated bags)	Pre-treatment required or not	Final disposal option
Broken or discarded and contaminated glass including medicine vials and ampoules except those contaminated with cytotoxic wastes.	Cardboard boxes with blue colored marking	Not required	Disinfection followed by recycling

^a Disposal by deep burial is recommended only in rural or remote areas where there is no access to common bio-medical waste treatment facility with prior approval from the prescribed authority and as per the Standards of BMW rule, 2016.

treatment, autoclaving and incineration. As soon as the COVID-19 wastes are transported to the disposal site, should be disposed immediately. If the waste load is high then the transported waste material can be temporarily stored but not more than 12 h in a separate area designated for COVID-19 waste (Ministry of Ecology and Environment of the People's Republic of China, 2020). The COVID-19 disposal sites should be designed carefully to avoid contamination to any types of drinking water source, residential place, school, park and other public places. As the COVID-19 wastes can't be land filled, reused or recycled, it should be disposed at high-temperature (900–1200 °C) incinerator. At this high temperature all the viral contaminated waste materials are destroyed and viral pathogens are killed (Mattielo et al., 2013). The incinerators (Fig. 3) to be used for COVID-19 biomedical waste treatment should operate as per the BMW standard of operation and emission rule (BMW Rule, 2016). (99.00 % Combustion efficiency (CE), temperature in between 800 – 1050 °C, two second gas residence time, Dioxins and Furans of 0.1ngTEQ/Nm³. In most of the countries in Europe and North America preferred chemical treatment and autoclaving are the most sustainable method to dispose COVID-19 waste than incineration to avoid the harmful gases like furans and dioxins. These gases have very harmful and can cause cancer, diabetes, neurotoxicity, immunotoxicity and chloracne (Zubair and Adrees, 2019).

In addition to incineration two other types of alternative thermal technology such as high temperature pyrolysis technique, and medium-temperature microwave technique are now available for the disposal of COVID-19 waste that can destroy the dioxins completely with release of clean exhaust steam. The temperature range of high-temperature pyrolysis technique is between 540–830 °C which includes pyrolysis-

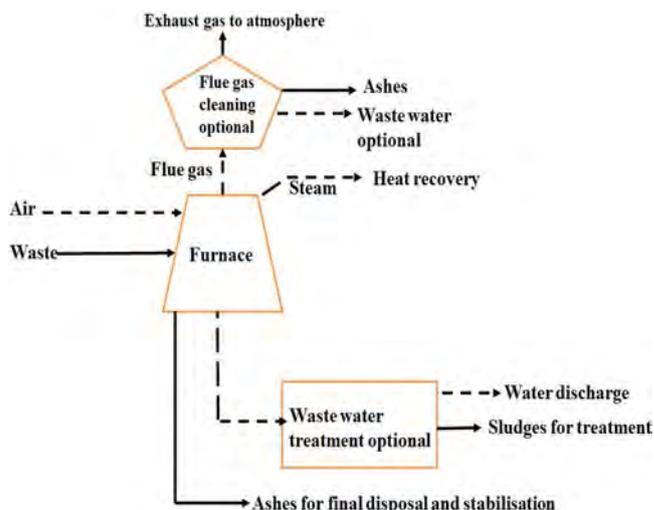


Fig. 3. Simplified flow scheme of Incinerator.

oxidation, plasma pyrolysis, induction-based pyrolysis, and laser-based pyrolysis (Datta et al., 2018). Plasma pyrolysis, with low emission rate, inert residual, volume reduction up to 95 %, and mass reduction up to 90 % is one of the most preferred techniques for quick decomposition of COVID-19 waste than usual laser/gaseous combustion (Wang et al., 2020a,b). Whereas, lower energy and action temperature, limited heat loss, and less environmental burden with no toxic residue after the disinfection process are the main advantages of medium temperature microwave technique which operates under the temperature range from 177 °C to 540 °C and can effectively inactivate SARS-CoV-2 (Wang et al., 2020a,b). Medium temperature microwave technique is proved very helpful for on-site disinfection of COVID-19 waste.

Tones of COVID-19 biomedical waste are generated daily in developing countries, and the numbers of available incinerators are not sufficient to treat such huge amount of waste. Engineered sanitary landfills (Fig. 4) act as alternative for safe disposals of these wastes (Texas commission of environ mental quality, 2019; ISWA, 2020). In the absence of incinerators, COVID-19 waste can also be disposed in small land fill pit prepared as per the BMW standard (Fig. 5) (BMW Rule, 2016). The pit should be two meters deep; half filled with waste then covered with lime and soil. The site of engineered sanitary landfills and pits should be away from the residential and general public places and minimum six meters above the ground water level (BMW Rule, 2016)

3. Treatment and disposal of COVID-19 dead bodies

Virus can be remained live in the lungs and other organs even if a person died due to COVID-19 (WHO, 2020b). Hence proper hand hygiene and use of PPE should be adopted during handling of such dead bodies (MoHFW, 2020). Before discharging the dead bodies to mortuary, the attached catheters and tubes should be removed. The holes generated due to removal should be disinfected with 1 % hypochlorite and closed or dressed properly (CDC, 2020a). To prevent leakage from oral and nasal orifices the dead body, it should be plugged properly. For transportation, leak-proof plastic bag can be used to pack the dead body with exterior disinfection of the bag by 1 % hypochlorite solution (Osborn et al., 2020). COVID-19 dead bodies can be cremated or buried. Hence, the dead body should be transported by a separate vehicle and handed over to the cremation/ burial staff (WHO, 2020b).

The authorities or local govt. should manage each case carefully. The rights and emotion of the family should be respected, proper cause of the death should be investigated and report should be provided to the family member. The family member (excluding small children and very older person above the age of 60), may be considered to view the dead body from distance without touching or kissing it (WHO, 2020b). Gathering of

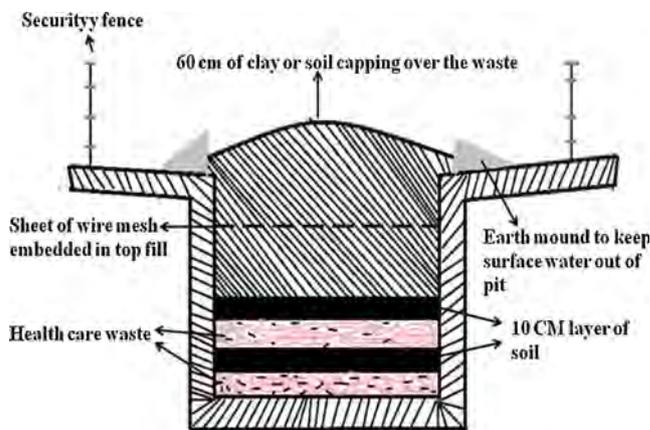


Fig. 5. A typical schematic design of a small land fill pit for health care waste (slight modification to UNEP, 2002).

larger number of people or relatives at the crematorium/ burial ground should be restricted. Mortuary or cremation worker handling the dead body should wear the PPEs and they should remove or dispose the same immediately after its use. They should perform necessary hand hygiene whenever required.

4. Water contamination and management during COVID-19 pandemic

Survival of corona virus on water depends up on several factors such as temperature, organic matter, and aerobic microorganisms (Gundy et al., 2009). Due to denaturation of viral enzyme and protein, the viral load decrease in water with increase in temperature (John and Rose, 2005). It has been observed that 99.9 % of corona virus reduced in water within 10 days at room temperature and within 100 days at 4 °C (Gundy et al., 2009). Organic matter and solids present in waste water system supports the survival of corona virus. Because virus are less soluble due to the hydrophobic property of viral envelope and can be easily adhered to the solids present in waste water. On the other hand, if solvents and detergents are present in wastewater that can deactivate the viral envelope and ultimately the viral load at ambient temperature (Gundy et al., 2009).

Several reports have been published on the survival ability of corona virus but no such research report till date on SARS-COV-2 (Gundy et al., 2009; Casanova et al., 2009). Though corona virus is not detected in treated drinking water and surface or groundwater sources yet but its

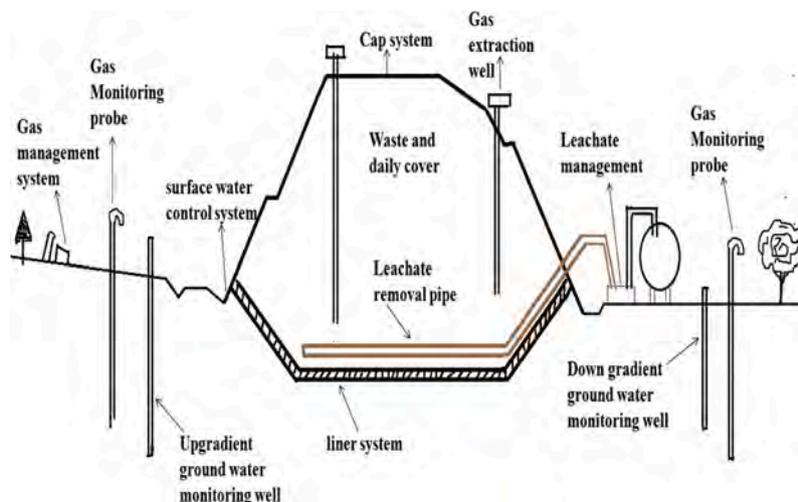


Fig. 4. A typical schematic design of an engineered landfill with a full leachate and gas (Source: UNEP, 2002).

presence in untreated drinking water can't be avoided (WHO, 2020a). Risk of corona viruses in regular water supplies is low (WHO Guidelines for drinking-quality, 2017). However, RNA of SARS-CoV-2 in the excreta of COVID-19 patients has been reported (Holshue et al., 2020; Wang et al., 2020a,b). In 2003, transmission of SARS through sewage pipes has been reported in the Amoy Gardens apartment, Hong Kong (Hung, 2003). A recent report also suggested about the transmission of COVID-19 through sewage in Hong Kong, but not confirmed yet (Gormley et al., 2020). Hence, the possible transmission of COVID-19 from excreta through sewage waste water can't be avoided and should be disinfected properly before its final disposal. In this scenario, application of technology such as oxidation pond with elevated pH, long retention times and proper sunlight is very good option to treat the waste water and to destroy the pathogen (WHO, 2020a). On the other hand, chlorine being a cheap and effective disinfectant, can be used as an alternative to the oxidation pond for treatment of waste water contaminated with corona virus. Chlorine converted to chloramines compounds when reacts with ammonia present in wastewater and become more effective than the earlier one (Rutala and Weber, 1997). Chlorine dose between 0.2-0.5 mg/L for 30 min and pH less than 8.0 has been recommended to disinfect SARS virus in water (Bibby et al., 2015; WHO, 2017). In addition to chlorine, treatment of corona virus contaminated water with filtration and ultraviolet (UV) light has been reported also (Darnell et al., 2004; Lai et al., 2005).

Villages and other rural area where drinking water supply facilities are not available, people can follow proper chlorination and boiling techniques to disinfect the COVID-19, viral pathogen (WHO, 2020a).

5. Scarcity of PPE and its rational use, reuse and recycling

During 2016–2020, the global PPE market increased 6.5 %, from approximately \$40 Billion to \$58 Billion. The World Health Organization projected 40 % increase in PPE demand due to rapid increasing rate of SARS-CoV-2 infection (Singh et al., 2020). Subsequent treatment process made the scarcity of such PPE in COVID-19 hospital and treatment centres. The health workers involved to face this uncertain war are the most sufferers. In view of this global PPE shortage, proper management strategies has been recommended that can facilitate optimal PPE availability (WHO, 2020c). These strategies include minimizing the need for PPE in health care settings, ensuring rational and appropriate use of PPE and coordinating PPE supply chain management mechanisms (WHO, 2020c). Though reuse of PPE in case of COVID-19 treatment is not recommendable as it can degrade the performance of the respirator but due to the scarcity of PPE, the Centers for Disease Control and Prevention (CDC) recommend for reusing the PPEs as a last option when it is not available (CDC, 2020b). Several disinfectant such as ultraviolet germicidal irradiation (UVGI), thermal disinfection (heat) and hydrogen peroxide vapour (HPV) are recommended to disinfect the SARS-CoV-2 contaminated material for reuse purpose depending upon the composition and condition of the material (MDDI, 2020; Tsai, 2020; Lowe et al., 2020). Highly soiled and damaged PPEs should not be recommended for disinfection and reuse. The major composition of PPE is plastic (20–25 % by weight) and should be properly recycled, as their disposal contributes substantially to hazardous environmental pollutants such as dioxins and toxic metals. Fluid resistant surgical masks and disposable respirators such as FFP3, FFP2, and N95 mask are recommended to reuse, if they are neither damaged nor soiled and are folded properly after use. Washable laboratory coats or patient gowns can be reuse after following proper disinfection protocol (BMJ, 2020).

According to the AIIMS guidelines, N95 masks can be decontaminated with 11 % hydrogen peroxide vapours (HPV) whereas 70 % ethanol and 0.5 % sodium hypochlorite solution can be used to decontaminate face shields and goggles. Fischer et al. (2020) during their analysis found that HPV treatment exhibits the best combination of rapid inactivation of SARS-CoV-2 and preservation of N95 respirator integrity than UV radiation which kills the virus more slowly and

preserves comparable respirator function. They also found that dry heating at 70 °C can kill the virus. Decontamination with alcohol can able to degrade the integrity of N95 mask, hence not recommended. They suggested that the respirators can be decontaminated maximum three times by UV and HPV treatment and two times by dry heat (Fischer et al., 2020)

6. Conclusion

COVID-waste may cause to the community spread if not handled properly. In the present study, various sources of COVID-19 waste generation, its possible disinfection and disposal strategy have been discussed in details which can assist the engineers, environmentalist, healthcare personnel and local municipal authorities to plan and manage the present pandemic hazardous waste. Besides training programs and social awareness, strict execution of identification, segregation, disinfection, transportation and safe disposal practice are the key factors for effective and safe management of COVID-19 waste. As community waste becomes logistical and practical challenge hence public participation along with proper micro-management policies for collection of community waste should be adopted.

Declaration of Competing Interest

The authors report no declarations of interest.

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