COVID-19 Impacts on Waste in Bangladesh

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Title: COVID-19 Impacts on Waste in Bangladesh

Disclaimer

This report is developed on the basis of secondary information, journal reviews and analyses, comprehensive analysis of current reports and online findings to document the information regarding COVID-19 impact on chemicals and wastes in Bangladesh with support and collaboration from IPEN.

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This report was produced under the Research and Documentation Initiatives of Jagrata Juba Shangha (JJS) with financial support from the International Pollutants Elimination Network's (IPEN's) Toxics-Free SDGs Campaign. The overall objective was to document the information regarding COVID-19's impact on chemicals and wastes in Bangladesh.

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Abbreviations

COVID-19	Coronavirus Disease 2019
EPI	Environmental Performance Index
PPE	Personal Protective Equipment
SUP	Single-Use Plastic
IEDCR	Institute of Epidemiology Disease Control And Research
DGHS	Directorate General of Health Services
IPEN	International Pollutants Elimination Network
JJS	Jagrata Juba Shangha
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
FSM	Feacal Sludge Management
ESDO	Environment and Social Development Organization
MoHFW	Ministry of Health and Family Welfare
MoEFC	Ministry of Environment, Forestry and Climate Change
MoDMR	Ministry of Disaster Management and Relief
WHO	World Health Organization
HCW	Healthcare Worker
MSW	Municipal Solid Waste

Executive Summary

Bangladesh is one of the most densely populated countries in the world. Recently, the country ranked as one of the most polluted developing countries in the world. Despite its bad air quality, the country is substantially increasing its overall environmental condition. According to Environmental Performance Index (EPI 2020), Bangladesh has improved its rank from 179th to 162nd out of 180 countries in controlling environmental pollution. However, the ongoing COVID-19 (novel coronavirus disease 2019) pandemic has brought a public health crisis and socioeconomic catastrophe to all the nations. This strain is likely to be more severe in low-middle income countries where the healthcare system is vulnerable and population density is high. Bangladesh is no exception,, and the pandemic disrupted the country's fragile healthcare system and positioned it among the top 15 countries as of November 18, 2020, in terms of new infection with an increasing trend of COVID-19 infections and deaths. To cope with the COVID-19 pandemic, people adopted different non-pharmaceutical interventions such as personal protective equipment (PPE), including medical masks, goggles or face shields, gowns, and other respiratory protective equipment. This equipment has already generated increased amounts of hazardous waste during the pandemic that will certainly impact the country's poor waste management and overall environmental performances.

This report has been accomplished by Jagrata Juba Shangha (JJS). The research was drawn up based on current evidence, journal reviews, and secondary sources under the International Pollutants Elimination Network (IPEN) initiative on COVID-19 Chemicals and Wastes. JJS has documented information as the first attempt to report on the situation in the country. Further analysis is required, and detailed documentation of the biomedical waste scenario in Bangladesh is to be planned, which is critical for remedial action.

Key Findings of this study:

- As of November 18, 2020, the Bangladesh government has distributed 10.4 million Personal Protective Equipment (PPE) sets to hospitals. These sets, when used, could produce approximately 6971346 kilograms of hazardous medical waste.
- A total of 14,500 tons of plastic waste was produced from single-use plastic materials and personal protective equipment in the first month of the lockdown period (26 March-25 April 2020).
- Around 3076 tons of waste was produced by plastic products in Dhaka during the first three months of lockdown period. Of that, around 14.4% are plastic bags.
- Polythene shopping bags produced 5,796 tons of waste over the first three months of lockdown. Surgical masks or hand sanitizer packets added more than 900 tons of waste in the same period.
- Bangladesh disposed of a total of 13099 million face masks from March 8-November 18, 2020, which is the equivalent of 392970 tons of waste.

1. Introduction

1.1. Overview

An outbreak of a novel coronavirus disease with flu-like symptoms occurred in Wuhan, China, in December 2019. Originally, Wuhan was the epicenter of the disease (Velavan & Meyer, 2020). But over time, it spread quickly throughout China and further severely hit many other countries (Wang et al., 2020). The World Health Organization (WHO) announced the novel coronavirus outbreak to be a pandemic and a global public health emergency that causes an illness known as COVID-19 on 11 March, 2020 (Huang & Zhao, 2020). It is reported that there have been 56,660,391 confirmed cases of COVID-19 across 215 countries of the globe, including 1,356,706 confirmed deaths as of 17 November, 2020 (World Health Organization, 2020). In this unprecedented crisis, governments' main challenge was to protect people's lives and livelihoods. Globally, healthcare professionals have been working relentlessly to combat the pandemic within existing settings and limited resources. In the absence of a vaccine, maintaining medical norms, conducting massive testing, following public health interventions such as social distancing and practicing individual hygiene have been recommended so far to counter the pandemic (World Health Organization., 2020a).

Plastics products are non-degradable and remain for many years in the atmosphere. They have been considered as the biggest environmental problem of our time (Nielsen et al., 2020). In 1950, just 2 million tons of plastic was produced annually throughout the globe. In 2015, the production reached 381 million (Figure 1), which was 200 times greater than before (Geyer et al., 2017) and equivalent to the mass of two-thirds of the world population.

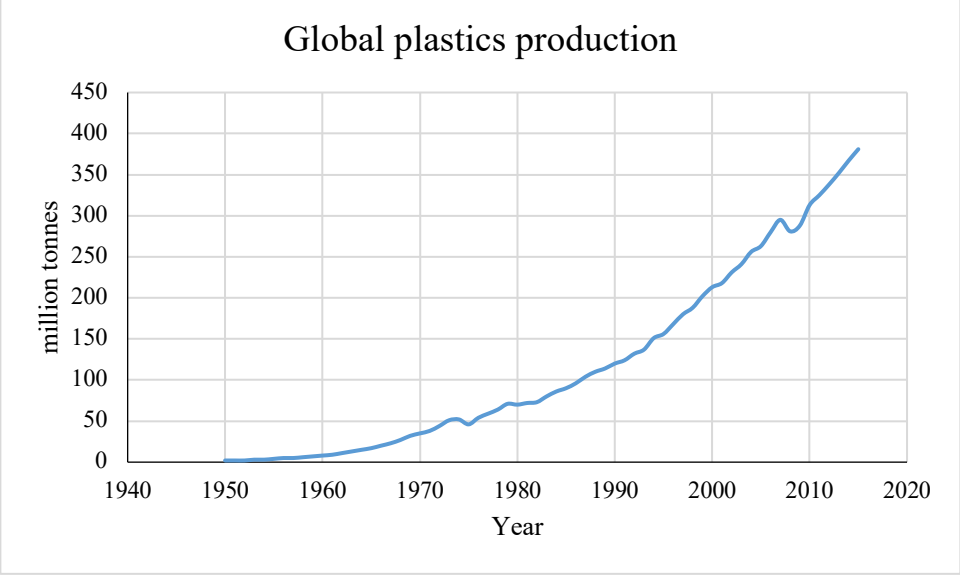

Figure 1. Global plastic waste generation during 1950-2015 (Geyer et al., 2017).

According to Geyer et al., (2017) estimation, 4600 million tons (55 percent) of plastics were disposed of, 700 million tons (8 percent) were incinerated, and 500 million tons (6 percent) were

recycled during 1950-2015. In 2015 , an estimated 55 percent of global plastic waste was discarded, 25 percent was incinerated, and 20 percent recycled (Geyer et al., 2017). The scenario has been further aggravated by the waste generated during the COVID-19 pandemic. The world has experienced some positive environmental implications during the COVID-19 lockdown, including reduction of greenhouse emissions, clean air, and clean rivers; however, the case is not the same about waste management (Rume & Islam, 2020; Saadat et al., 2020). The COVID-19 pandemic has suddenly intensified the need for the use of plastic products in terms of personal protective equipment (PPE) and other single-use medical equipment to protect the general population, health staff, patients, and other service workers (Patrício Silva et al., 2021).

Since the coronavirus is transmitted via human-to-human contact, there was an increasing surge in demand for PPE, including medical masks, gloves, hand sanitizer, gowns, and other necessary safety equipment (Parashar & Hait, 2021).

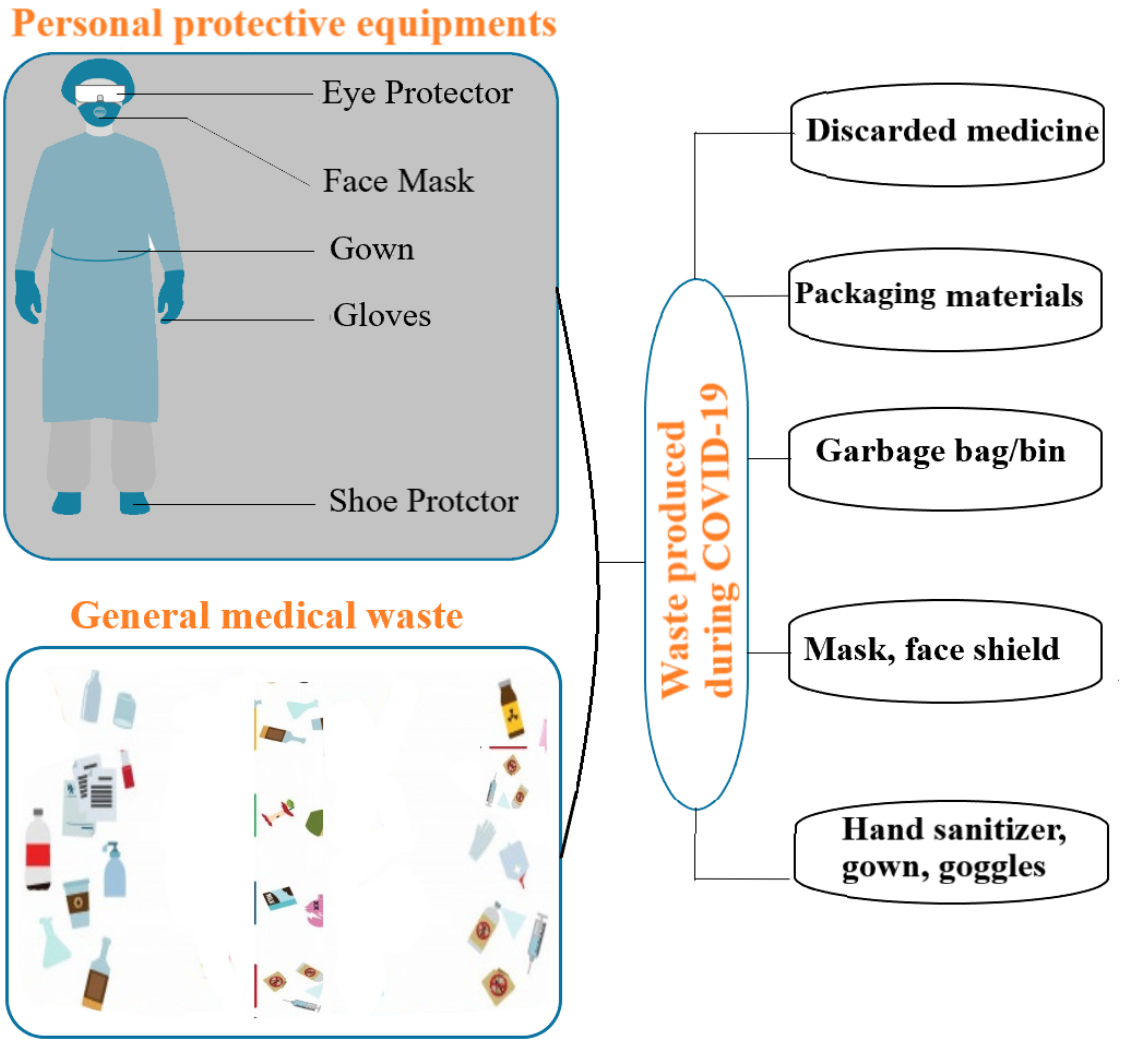

Figure 2. Healthcare waste produced during COVID-19 pandemic (Parashar & Hait, 2021).

In addition, there was also an increase in general medical waste including discarded medicine, saline packets, syringes, packaging materials and garbage bags, etc. during the COVID-19 pandemic (Figure 2). According to the WHO modeling report, as of March 4, 2020, a total of 89 million surgical masks, 1.6 million goggles, and 76 million gloves are required each month during COVID-19 globally (Aragaw & Mekonnen, 2021; Mahbubani, 2020; Sharma et al., 2020). Consequently, the world waste management system has been facing an unprecedented threat to deal with this large volume of COVID-19 wastes satisfactorily (Klemeš et al., 2020).

The increasing use of protective equipment during the COVID-19 has dramatically impacted waste generation, its collection and storage dynamics, worrying policymakers and workers that are closely related to waste management (Patrício Silva et al., 2021). The scenario could be even worse in developing countries, where there are a lack of standard waste management technologies and poor policies for waste emergencies during a pandemic (Sarkodie et al., 2020). Bangladesh is an overpopulated country in the global south that has already struggled with existing waste management, which is now compounded by the threat by sudden surges of large volumes of COVID-19 healthcare wastes (Islam et al., 2020; Mostafizur Rahman et al., 2020). In a country with more than 16 crore people (Worldometer, 2020b) and having the 15th-highest number of confirmed cases of COVID-19 in the world, overcrowded hospitals and a lack of emergency resources have been added challenges to the government of Bangladesh (Shammi & Tareq, 2020). Further, there have been several reports of haphazard dumping of COVID-19 wastes that have led to clogging of water channels, increases in environmental pollution, and higher risk of coronavirus infection to waste collectors in various cities of Bangladesh (Islam et al., 2020). Additionally, household waste mixed with COVID-19 healthcare waste puts further risk to the waste workers. It was reported in 2020 that about 40,000 informal waste and sanitation workers are at high-risk of getting infected with SARS-COV-2 as they work in conditions where there is a lack of proper protection and hygiene practices amid a pandemic (Mostafizur Rahman et al., 2020; Patwary et al., 2021). Considering the above situation, it is essential to explore effective waste management practices with special attention to risk-free handling, transportation and disposal process during the pandemic. Therefore, this study presents a review assessment of the impact of the COVID-19 pandemic on biomedical waste in Bangladesh based on data reported in published reports, journal articles, government platforms, development organizations, and news reports. This review study also provides recommendations for policymakers to design effective waste management processes in the pandemic and post-pandemic environment.

1.2. Objectives of the Study

Overall Objective: Document the biomedical waste consequences of the pandemic in Bangladesh.

Specific Objective: Report on COVID-19 and impacts on biomedical wastes with policy recommendations to deal with issues raised in the report.

Objective Results: Information about how the pandemic can impact biomedical wastes.

1.3. COVID-19 Pandemic situation in Bangladesh

On 8 March 2020, Bangladesh reported its first confirmed case of COVID-19. The country confirmed its first death from COVID-19 on 18th March (IEDCR, 2020). To prevent community transmission, the Bangladesh government declared a nationwide lockdown with the strict prohibition of inter-district movements, economic suspension except for essential services, and cessation of all social gatherings from 26 March 2020 (Anwar et al., 2020). As of 18 November 2020, Bangladesh reported 441,159 confirmed cases of COVID-19 across 64 districts, including 6,305 confirmed deaths.

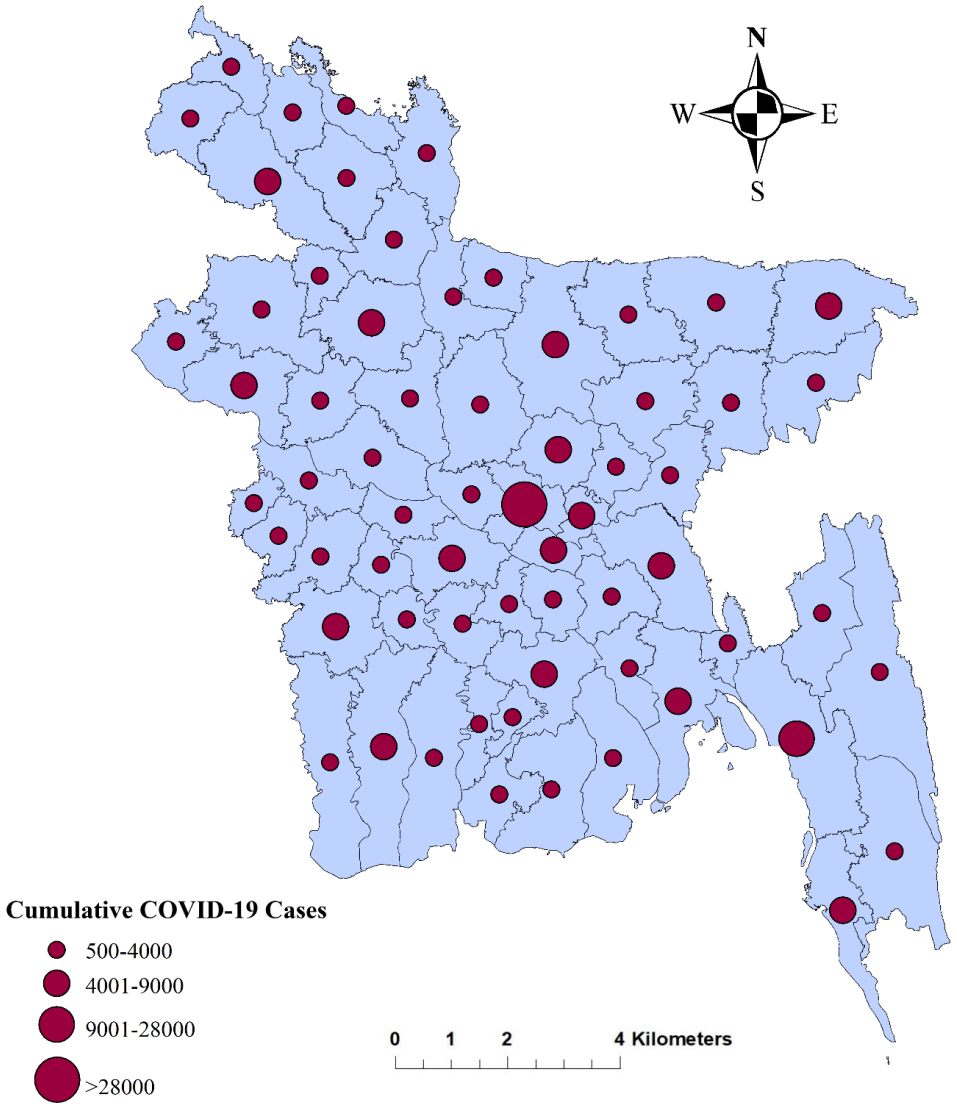

Figure 3. District-wise cumulative COVID-19 confirmed cases in Bangladesh (as of Nov, 18, 2020) (Source: Author: Patwary and Hossain, 2021).

2. Methodology

2.1. Details of review process

This study conducted an extensive review of existing information published in government and other reports, scientific journals, online news reports, and relevant national and international organization websites. The review was performed by following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2009 flow diagram (Figure 4) in a non-systematic manner.

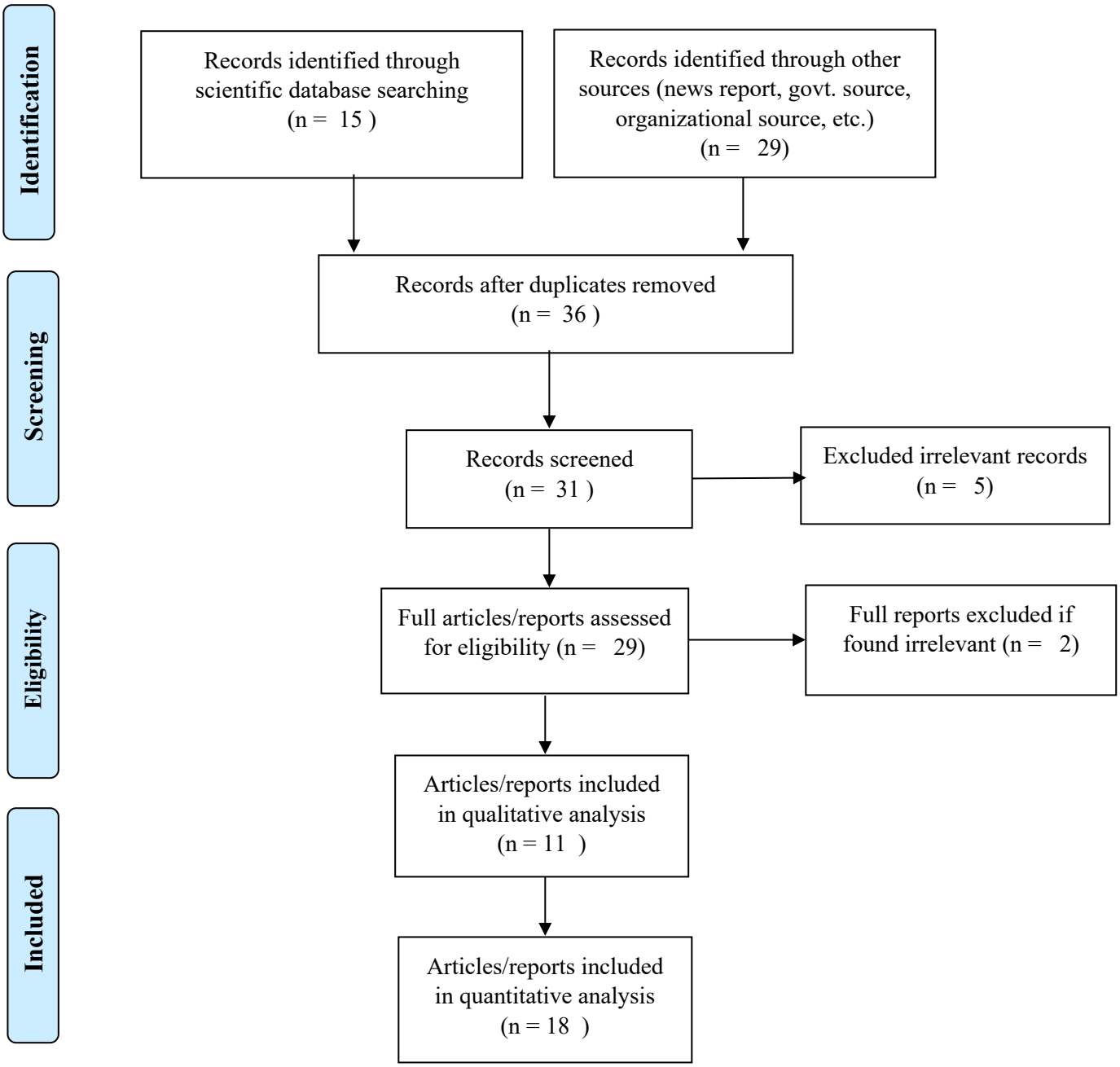

Figure 4. Flow chart of the detailed review process

The initial searches identified 12 scientific articles, 5 government reports, 14 organizational reports, and 15 online news reports. After checking the information, duplicate and non-relevant studies were excluded from the review. Finally, 8 scientific articles, 3 government reports, 12 organizational reports, and 6 online news reports were included and selected in the final assessment. The type of documents reviewed in this study are listed in Table 1.

Table 1. List of documents reviewed in the study.

	Guideline	Factsheets	Policy/ Strategy	Recommendations	Research Documents	Press release	Act
GOVERNMENT SOURCES							
MoHFW	2020						
MoEFC				2020			
MoDMR							2008
NATIONAL NGOs							
ESDO		2020				2020	
PRISM Bangladesh					2014	2020	
FSM Network					2020		
Waste Concern					2020		
INTERNATIONAL NGOs & UN AGENCIES							
SNV Netherlands						2020	
Water Aid					2020		
Practical Action						2020	
UNICEF						2020	
WHO	2014						
	2017						
	2020						
SCIENTIFIC DATABASES							
Web of Science					2020		
PubMed					2020		
Scopus					2020		
Google Scholar			2020		2020		
					2016		
					2010		
					2003		
ONLINE NEWS REPORT						2020	

For scientific articles, electronic databases were searched, including Scopus, PubMed, Web of Science, and Google Scholar. A manual search was also performed on Google Scholar to extract additional relevant studies. The Ministry of Health and Family Welfare of Bangladesh; Ministry of Environment, Forest and Climate Change; and Ministry of Disaster Management and Relief's websites were searched for government reports. Apart from that, the following national and international organizational websites were searched for extract information: World Health Organization (WHO), UNICEF Bangladesh, Practical Action, SNV Netherlands Development Organization, WaterAid Bangladesh, Feacal Sludge Management (FSM) Network Bangladesh, Environment and Social Development Organization (ESDO), PRISM Bangladesh and Waste Concern. Additionally, online newspapers and other published reports were searched for relevant information.

2.2. Quantification of waste generated during COVID-19

2.2.1. Estimation of disposable face mask waste by the general population

The amount of waste produced by disposable masks is determined (data on page 25, section 4.4) from the following equation (Boroujeni et al., 2021):

$$F_W = D_{FM} \times F_W \text{ ..... (1)}$$

Where, F_W = Total waste generated from face mask disposal (ton), D_{FM} = Total face mask disposed of (pieces), and F_W = average weight of a face mask.

The amount of waste generated from the daily disposal of face masks (data on page 25, section 4.4) is estimated using an equation adapted from (Nzediegwu & Chang, 2020) as follows:

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

Where D_{FM} = Total number of disposed face masks (pieces), P = Number of population (persons), U_P = Percentage of urban population (%), F_{MAR} = Face masks acceptance rate – 80%, F_{MGP} = Assume one face mask used by one person per capita/day.

2.2.2. Estimation of Medical waste

The quantity of medical waste is dependent on the number of people infected and the average waste produced per bed (Sangkham, 2020). The estimation of medical waste provided by a previous study (Haque et al., 2020) in Bangladesh (3.40 kg/bed/day) has been further considered in the medical waste analysis (data on page 21, section 4.3) as follows:

$$M_W = (N_{CC} \times M_{WGR} \times D_n) \text{ .....(3)}$$

Where M_W = Total medical waste (tons), N_{CC} = Total active COVID-19 cases, M_{WGR} = Medical waste generation rate, 3.40 kg/bed/day during COVID-19, D_n = Number of days taken into account.

The number of active cases is estimated by:

$$N_{CC} = Ic – Dc - Rc$$

Ic = Infected Cases

Dc = Death Cases

Rc = Recovered Cases

3. Current Practices of Healthcare Waste Management in Bangladesh

3.1. Characterization of healthcare waste

According to the Bangladesh Medical Waste Management Rules-2008, initiated by the Ministry of Environment, Forest and Climate Change in 2008, waste produced in health facilities or diagnostic test centers or labs is often considered as healthcare waste. It also contains domestic waste (e.g. home dialysis, self-administration of insulin, recuperative care). Healthcare waste is divided into eleven main categories, for both hazardous and non-hazardous elements, and is described in Table 2.

Table 2. Classification of healthcare waste in Bangladesh (MOEF, 2008).

Class	Waste Types	Example
Class-1	General Waste (Harmless/Germ free/uncontami-nated)	Used paper, plastic or metal container, medicine strip, empty box, packing box, polythene bag, mineral water bottle, empty glass bottle, empty injection vial, uncontaminated used saline bag, uncontaminated used syringe, uncontaminated cloth/wool, uncontaminated rubber/cork, empty pressurized container, etc.
Class-2	Anatomical waste	Body parts of humans, tissue, separated tumor, pregnancy-related waste
Class-3	Pathological waste	Laboratory culture, sample of vaccine, biological toxin, blood/cough/stool used for inspection, etc.
Class-4	Chemical waste	Different types of reagent, developer, chemicals used for dialysis, etc.
Class-5	Pharmaceutical waste	Expired, unused, contaminated medicinal drugs
Class-6	Contaminated waste	Gauze, bandage, wool, sponge, mob, plaster, catheter, drainage tube contaminated by blood/pus/body fluid, saline contaminated by blood, clotted blood/body fluid, clothes contaminated by the stool of diarrhea patient, contaminated syringe, etc.
Class-7	Radioactive waste	Radioactive isotope, all contaminated objects by radioactive elements, unused head of x-ray machine, etc.
Class-8	Sharp waste	All kinds of syringes used in medical treatment, blade, broken slide, used ampulla, broken bottle/glass/test tube, nail, steel wire, screw, steel plate, pin used for orthopedic work, etc.

Class-9	General reusable waste (harmless/germ free/uncontami-nated)	Used paper, plastic or metal container, medicine strip, empty box, packing box, polythene bag, mineral water bottle, empty glass bottle, empty injection vowel, uncontaminated used saline bag, uncontaminated used syringe, uncontaminated cloth/wool, uncontaminated rubber/cork, empty pressurized container, etc.
Class-10	Liquid waste	Used water, cough, vomitting, suction liquid, serum, body fluid, liquid blood, liquid chemicals, etc.
Class-11	Pressurized waste	Pressurized container

In Bangladesh, two types of healthcare waste are produced- hazardous and non-hazardous waste. Hazardous waste, including pathological, viral, sharps and chemical wastes, are usually produced in hospital wards, operating rooms, labs, etc. Non-hazardous medical waste is typically common waste that has no specific related handling or environmental issues.

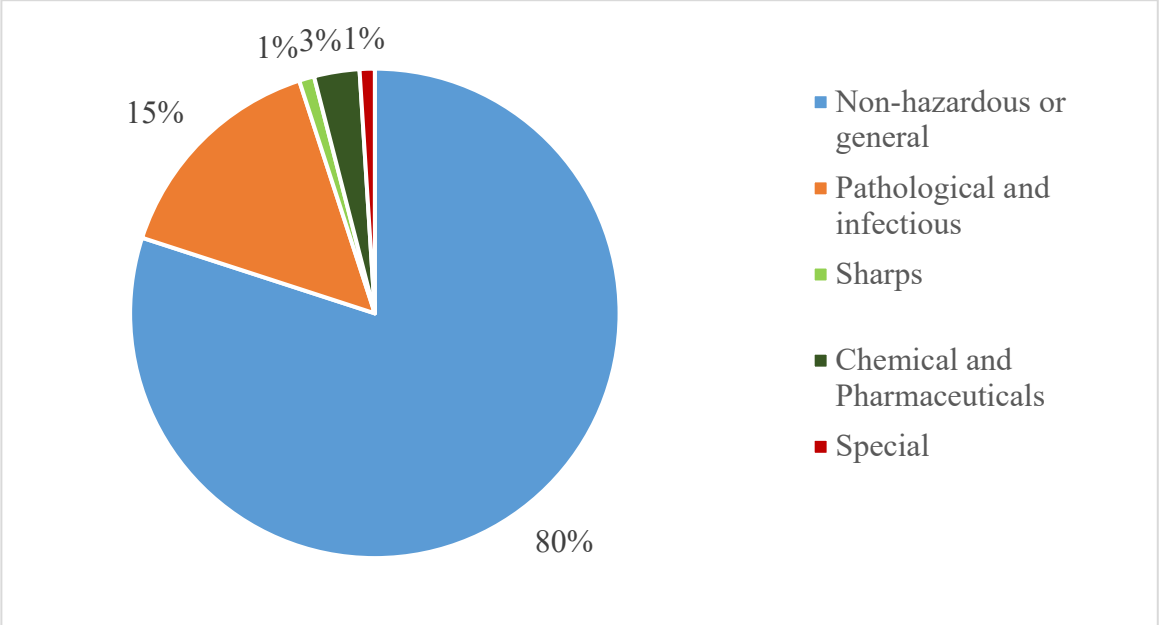

Figure 5. Composition of healthcare waste generation in Bangladesh (PRISM Bangladesh, 2014).

Most of these wastes were generated from ICU units, patients' ward areas, out-patient departments, caring homes, kitchens, etc. General medical waste generation in developing countries is lower than in developed countries; however, hazardous medical waste production does not vary much (UNEP, 2003). Only 15-20% of medical waste is contagious or dangerous in these countries (PRISM Bangladesh, 2014; World Bank, 2003). Around 80% of waste is classified as general or non-hazardous, 15% as pathological or infectious, 1% as sharp waste, 3% as chemical or pharmaceutical waste, and 1% as special waste (a collection of solid wastes that require special handling and disposal due to their quantity, concentration, physical or chemical characteristics, or

biological properties) in Bangladesh. Figure 5 illustrates the composition of medical waste in Bangladesh.

3.2. Current treatment and disposal practices of biomedical waste

Population development and urbanization in Bangladesh have been creating a growing amount of solid and healthcare waste. In 2018, the Ministry of Health and Family Welfare (MOHFW) estimated the trend of hazardous waste generation in major cities of Bangladesh from 2009-2015 (Figure 6). The estimation showed an increasing trend of hazardous waste in Bangladesh for given periods. According to the estimation, the highest amount of waste is produced in Dhaka City. Another estimation by Bhuiyan (2010) reported that a total of 16,380 tons of waste is produced per day, with a generation rate of 0.60 per person per day. This is projected to be 47,000 tons per day by 2025.

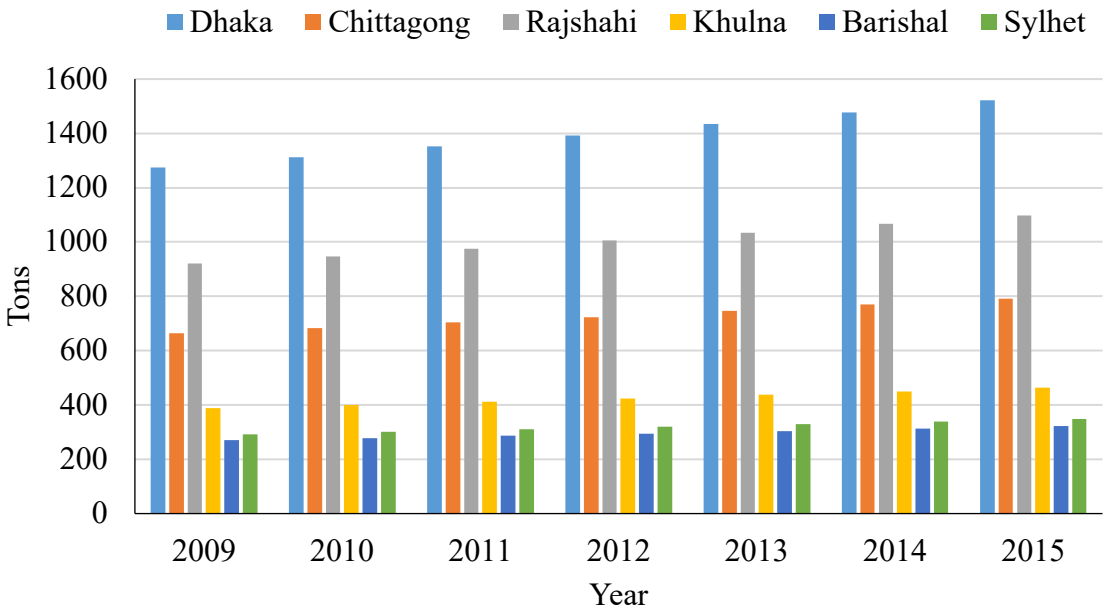

Figure 6. Hazardous waste generation (tons/year) in different cities of Bangladesh during 2009-2015 (MOHFW, 2018).

As reported in 2019, there are 645 public and 288 private hospitals, laboratories, and diagnostics centers (Haque et al., 2020) in Bangladesh. Like other developing countries, waste management is mainly managed by the municipal authority in the urban areas in Bangladesh. Most urban solid waste is gathered by private individuals who collect garbage from local homes on a bicycle or a van-based waste management system. The waste is shipped to a poorly managed collection location. Waste is collected from multiple outlets and delivered to a suburban landfill. Most of the waste is processed and marketed to illegal scrap merchants in the city's slums. These hazardous waste products are processed and stored at MSW collection points and are also discarded at landfill sites (Haque et al., 2020). However, several challenges have been identified to manage the medical waste, including lack of maintainance of any proper record of the different streams of medical waste generated; inadequate number of color-coded bins, often improperly placed; syringes that

were not destroyed before disposal; waste trolleys that have become defunct; only partial use of personal protective equipment (PPE); lack of uniformity in color-coding and segregation procedures; and lack of formal training for waste workers (MOHFW, 2018).

The improper disposals of healthcare waste pose a further risk to healthcare professionals in Bangladesh. In Dhaka City, about 5.7% of the total waste is hospital waste, which is disposed of openly in dustbins distributed by City Corporation Authority, buried in holes in the ground nearby the hospital, tossed in open landfills, and thrown into the roadside, drains and rivers. Around 59% of the city hospitals dispose of their wastes in the municipal bin without segregation (Behnam et al., 2020).

3.3. Bangladesh medical waste (management and treatment) rules, 2008

Initially, the existing Environment Conservation Act (ECA), 1995 and the Environment Conservation Rules (ECR), 1997 had no direct law related to medical waste management in the country. Any liquid, solid and/or radioactive substance that is discharged, disposed of or dumped and may cause adverse/ negative changes to the environment is classified as waste in the ECA. However, these are not specific to medical waste management. To address this issue, the Bangladesh government established medical waste (management and processing) rules in 2008 with active involvement of the Ministry of Health and Family Welfare, Ministry of Labor and Ministry of Forest, Environment and Climate Change. The main objective of the rule was to ensure proper management of healthcare waste and protect the environment. The regulations are only applicable to those involved in the waste management facility and include guidance on collections, storage, treatment and disposal of the medical waste. The institutions involved in this process would have to obtain authorization from Department of Environment to dispose of the medical waste as per the regulations (MOHFW, 2018).

According to the guidelines, medical waste must be categorised properly, such as infectious or general waste, and treated using environmentally acceptable technology as defined in schedule-1. As indicated in schedule-3, the rule makes suggestions for segregating medical waste at the source via the use of distinct color containers. Various symbols described in schedule-4 should be used to package and transport medical waste. The schedule 6 guideline establishes appropriate thresholds for incineration/autoclaving, deep burial and liquid waste treatment, as well as radioactive and hazardous wastes. The existing medical waste legislation requires that all medical waste management (MWM)-related activities be 'formed into jurisdiction' within three months after the proclamation (MOEF, 2008).

The regulation specified for different (6 nos.) color bins to be used for segregation of different MW, along with specification of container and standard for operation of equipment, effluent and emission standards (Table 3).

Table 3. Container and color code used for medical waste preservation and disposal and available treatment technology in Bangladesh (MOEF, 2008).

Color code	Waste Category	Waste Class	Waste type	Container	Treatment technology[a]
Black	General waste	Class-1,11	Harmless, Uncontaminated, Germ-free	Leak proof plastic bin	Microwave
Yellow	Harmful waste	Class-2,3,4,5,6	Anatomical, Pathological, Contaminated waste	Leak proof plastic bin	Incineration, Hydropulping
Red	Sharp waste	Class-8	Contaminated, Uncontaminated waste	Leak proof plastic bin, box	Autoclave, Hydropulping
Blue	Liquid waste	Class-10,4	Harmful, Harmless, Contaminated, Uncontaminated, Chemical waste	Leak proof plastic bin, bucket	Incineration, Composting
Silver	Radioactive waste	Class-6	Radiable waste	Leak proof lead box	Incineration
Green	General Recyclable waste	Class-9	Harmless, Uncontaminated, Germ-free waste	Leak proof plastic bin	Composting

[a]Source: (Hasan & Rahman, 2018)

In terms of the institutional framework of MWM, the MOHFW is responsible for in-house medical waste management and the City Corporation/Pouroshova is responsible for out-house medical waste management. City corporation/Pourosova can contract out-house management through NGOs. Government hospitals pay a service charge to the City Corporation /Pourashova for MWM. At the ministry level, a National Implementation Coordination Committee (NICC) and committee for different administrative level for out-house management for MWM was formed (MOHFW, 2018).

Until 2004, there was no waste treatment facility in Bangladesh. In 2004, the Project in Agriculture, Rural Industry, Science, and Medicine (PRISM) developed a medical waste treatment facility in Matuail, a suburb of Dhaka. The project began with 17 healthcare facilities (HCFs) and has grown to include 727 HCFs. In July 2013, another initiative began in Savar Pouroshova with 25 HCFs. PRISM was funded by the Canadian International Development Agency (CIDA) to create a low-cost medical waste management facility, and Dhaka City Corporation granted one acre of land for the MWM.

Prior to 2008, PRISM conducted capacity-building activities at about 185 health-care facilities. Since 2005, the Ministry of Health and Family Planning (MoHFP) has been undertaking capacity-

building activities for health care workers, which have benefited 328 HCFs. Until June 2015, fourteen MCHs, fifteen district hospitals (DHs), and eight specialty hospitals implemented standard in-house medical waste management. All public and private HCFs in Dhaka, Comilla, and Chittagong are currently covered by non-governmental organizations (NGOs) such as PRISM and INNOVATION under the MWM plan. SHOPNO, a non-governmental organization, has been hired to manage the MWM of all Bagura, Rangpur, and Dinajpur HCFs. No out-of-house medical waste management activities were discovered across the remainder of the nation.

According to the HPNSDP's action plan, medical waste management should be implemented in health-care facilities by 2015–2016. However, it was not executed effectively owing to a lack of funding, lack of human resources, lack of proper logistics, appropriate training, and so on.

However, since the beginning, the implementation of the MWM rules-2008 has not received significant improvement due to lack of man power, lack of coordination among implementers, low awareness and capacity in healthcare facilities, and lack of sufficient supervision and monitoring (MOHFW, 2018). As can be shown, the rules do not include any clear reference of waste created from COVID-19 patients. Since the humongous and increasing number of patients impacted by COVID-19 were unthinkable at the time the rules were finalized, the current scenario definitely calls for new guidelines, as, without them, further turmoil may occur in Bangladesh, one of the most heavily populated countries in the world. Following the COVID-19 outbreak and waste disruption, the Department of the Environment believes that current medical waste management regulations should be modified, but no action has been made so far (Amin, 2020).

4. Waste Generation Scenario During COVID-19 Pandemic in Bangladesh

4.1. Personal protective equipment (PPE) distribution

On average, 3.5 doctors and 1.7 nurses serve per 10,000 people in Bangladesh (Sayeed Al-Zaman, 2020). The healthcare workers use the PPE and dispose of it after use. The handling of COVID-19 contaminated patients produces a substantial quantity of managed medical waste from healthcare facilities. One of the causes of the HCW infection is COVID-19, which is created during healthcare activities. However, a serious issue could occur if the non-HCW is not picked up separately and handled according to the regulations (Shammi & Tareq, 2020).

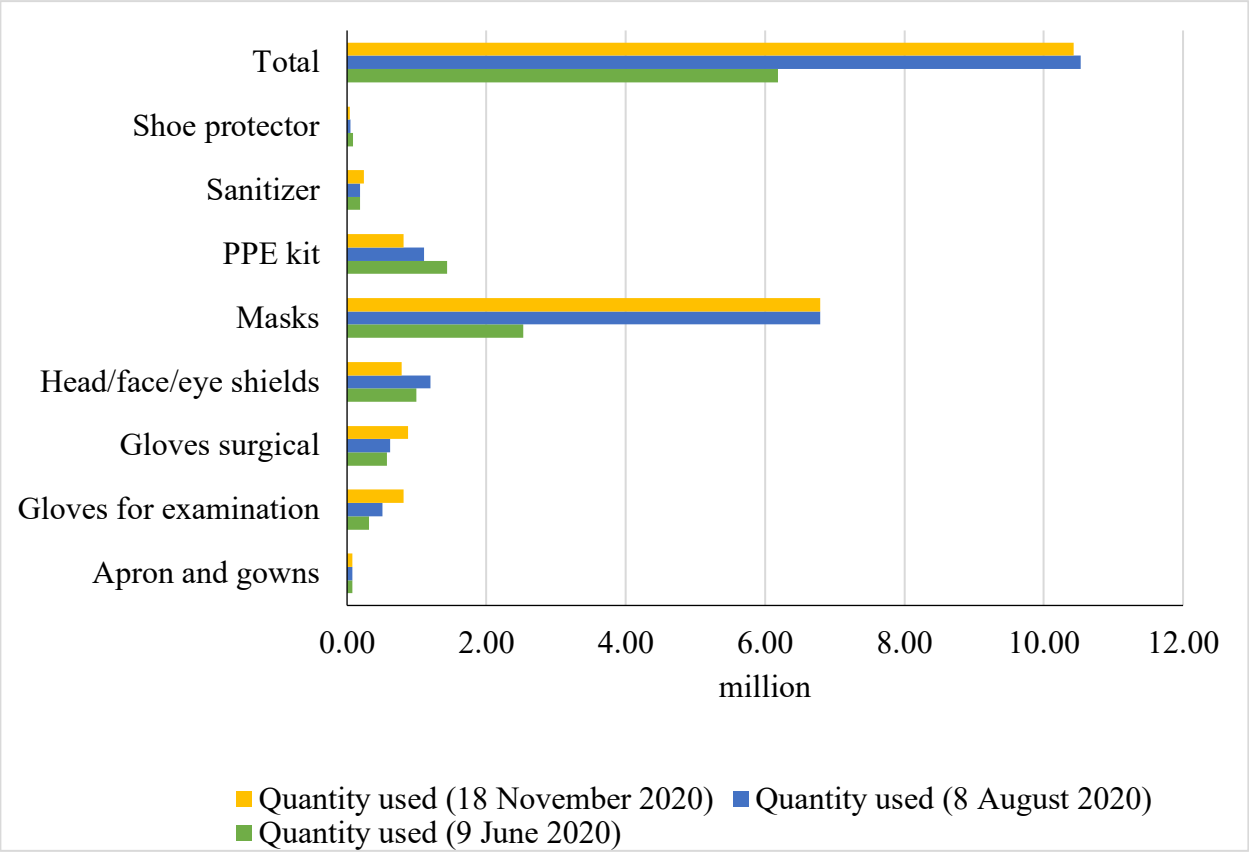

Figure 7. Personal protective equipment allocation in different hospitals during the COVID-19 treatments (DGSH, 2020).

The government has allocated more than 10 million PPE (Figure 7) sets to hospitals as of November 18, 2020. Using these sets would yield 6971346 kg of dangerous medical waste. PPE consists of cover-all, lengthy foot cover, face mask, a pair of hand gloves, mask, goggles, and face shield. The pieces are used one-time, except for the cloth mask and goggles, which can be re-used. Aside from these items, PPE has no reuse, and it has to be discarded by following standard protocol to guarantee the wellbeing of doctors, nurses, and technicians (DGSH, 2020).

4.2.Waste generation rate before and during the pandemic

Contagious medical waste increased by 600 percent in Hubei Province, China, during the COVID-19 pandemic (Das et al., 2021). Similarly, a large amount of infectious medical waste is generated in Bangladesh from patient treatment. As a result, there is rising concern about how to communicate effectively with healthcare workers who interact directly with COVID-19 patients, because COVID-19 has exacerbated the already-high level of medical waste creation in the country (The Independent, 2020). On average, 206 tons of medical waste are produced because of COVID-19 per day in Dhaka alone, while the amount was only 48 tons/day before the COVID-19 pandemic (Figure 8) (Mostafizur Rahman et al., 2020).

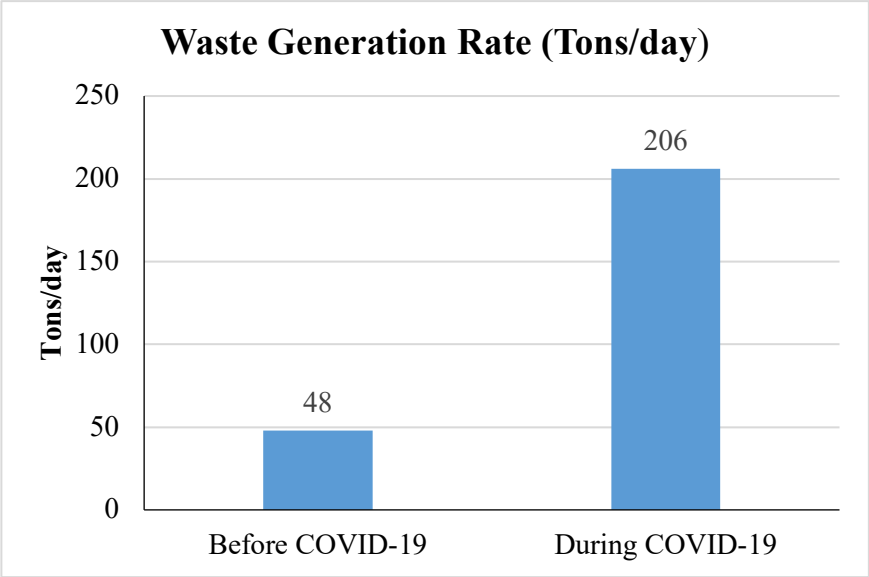

Figure 8. Medical waste generation rate per day in Bangladesh.

4.3.Medical waste generation

The Environment and Social Development Organization (ESDO, 2020) has conducted a study titled "*COVID-19 Pandemic Pushes Single-Use Plastic Waste Outbreak: No Management, No Protection: High Health and Environmental Risk Unveil*", which linked to single-use plastic safety gauges in neighborhoods and health care facilities. The study was conducted during the first month (March 26-April 25) of lockdown in Bangladesh. According to their estimation, Bangladesh produced almost 14500 tons of hazardous medical plastic waste within this period, which is equivalent to more than 43000 tons of waste during the first three months of lockdown period in Bangladesh.

The study also found that more than 50% of the total population in Bangladesh used single-use synthetic surgical masks. In addition, about 30% of the people in urban area used hand gloves and hand sanitizers. The empty containers of the hand sanitizers reportedly contributed around 900 tons/month in the COVID-19 generated single use (onetime) plastic waste stream. According to this study, Dhaka City alone produced 3076 tons of plastics waste during the first three months of the lockdown period.

Table 3. Biomedical waste generation during COVID-19 lockdown in Bangladesh.

Sl. No.	Waste Items	Amount used in one-month lockdown period (nos.)	Total waste generated (ton)	Estimated daily generation rate (ton/day)	Waste generated in 90 days (ton)
1.	Single-use surgical masks	455 million	1,592	53.07	4,776.30
2.	Polyethylene (PE) bags	1,449 million	5796	193.20	17,388.0
3.	PE made hand gloves	1,216 million	3,039	101.30	9,117.0

Sl. No.	Waste Items	Amount used in one-month lockdown period (nos.)	Total waste generated (ton)	Estimated daily generation rate (ton/day)	Waste generated in 90 days (ton)
4.	Hand sanitizer bottles	49 million	900	30.00	2,700.0
5.	Non-infectious waste	–	251.10	8.37	753.30

Source: (ESDO, 2020; Haque et al., 2020).

Table 3 shows the increase in plastic waste during the first three months of "lockdown" in the country. In a span of one month, 455 million disposable surgical masks made with plastic were used, which is equivalent to 1592 tons of plastic waste. An analysis of the results showed that usage of polythene and disposable shopping bags at the community level had risen at an alarming pace. Polythene bags are the most notable and largest source of plastic waste in Bangladesh during COVID-19. Emergency products and medicines were handily wrapped in polythene containers and produced 5796 tons of plastic waste in a single month. About 443 tons of plastic waste is produced in Bangladesh by shredding plastic bags and from the distribution of relief items in plastic packets to the poor (ESDO, 2020).

During the lockdown periods, there was an increase in hazardous medical waste production. However, there was also continuation of increased medical waste with the rise of infected cases throughout the country. We estimated the total amount of medical waste generated in given periods by using Eq. 2. The active cases of COVID-19 in different divisions of the country have been collected from the WHO's website (World Health Organization., 2020b). The map showed that the highest number of infected cases and the highest amount of waste generated was in the Dhaka division, followed by Chittagong, Khulna, Rajshahi, Sylhet, and other major cities of Bangladesh. The estimation of medical waste volume is presented in Figure 9.

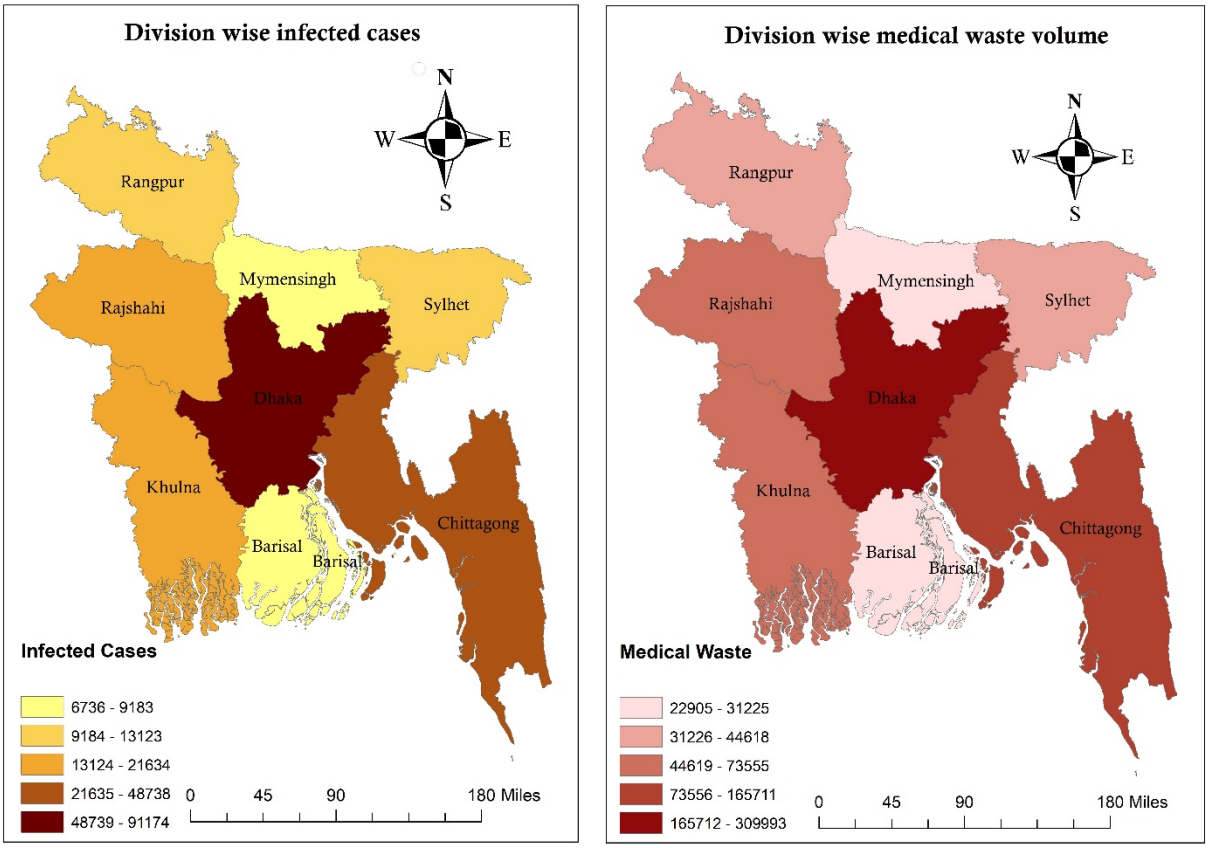

Figure 9. Map representing the simultaneous increase in medical waste volume (right map) (estimated by Eq. 2) along with infected cases (left map) in different divisions of Bangladesh from March 8-November 23, 2020 (Map Source: Authors created, Data Source: (DGSH, 2021).

4.4. Waste generated from face mask disposal

According to Nzediegwu & Chang (2020), there was an increasing trend of face mask disposal during the COVID-19 outbreak. Following its methodology, this study estimated the amount of face mask usage by the general population and calculated waste generated from the daily face mask disposal by using a mathematical calculation in major cities of Bangladesh. It was revealed that estimation of daily face mask disposal depends on the total population in a certain area, the percentage of urban population residing in that area, face mask acceptance rate, and mean daily disposal of face mask per capita. Thus, the waste generated from face mask disposal is calculated by multiplying the total number of face masks disposed of with the daily waste generation rate by face masks (Haque et al., 2020).

Bangladesh's government has made use of face masks mandatory in public places and initiated “No mask, No services” (The Prothom Alo, 2020). The number of masks disposed of in Bangladesh was estimated from the COVID-19 pandemic database from 08 March-18 November 2020. Due to lack of division-wise data, this study estimated the total waste generated from face mask disposal in major cities in Bangladesh within given a time-period. By taking the total

Dhaka

Chandpur

Khulna

Figure 10. Face mask disposal photos taken in different cities of Bangladesh

population of 16 million, urban population-39% (Worldometer, 2020a), Bangladesh disposed of a total of 13099 million face masks in the environment from March 8-November 18, 2020, which is the equivalent of 392970 tons of waste with a rate of 1535 tons/day. In particular, the selected major cities that disposed of and produced the most waste are Dhaka (63630 tons), followed by

Chittagong (24086 tons), Khulna (8247 tons), Rajshahi (4302 tons), Rangpur (2108 tons), Sylhet (1456 tons), Mymensingh (1383 tons) and Barishal (1243 tons) (see Table 5).

Table 5. Estimated waste generated from face mask disposal by per capita of general population in major cities of Bangladesh from March 8-November 18, 2020 (estimated by Eq 1).

City	Population	Urban population (%)	Facemask acceptance rate (%)	Daily disposal/10000	Total facemask disposal/day	Weight of a facemask (g)[a]	Waste generated (ton/day)	Total waste generated (ton)
Dhaka	10,356,500	100	80	1	8285200	30	249	63630
Chittagong	3,920,222	100	80	1	3136178	30	94	24086
Khulna	1,342,339	100	80	1	1073871	30	32	8247
Rangpur	343,122	100	80	1	274498	30	8	2108
Barishal	202,242	100	80	1	161794	30	5	1243
Rajshahi	700,133	100	80	1	560106	30	17	4302
Sylhet	237,000	100	80	1	189600	30	6	1456
Mymensingh	225,126	100	80	1	180101	30	5	1383
Total					13861348			105072

[a] (Boroujeni et al., 2021)

5. Impact of COVID-19 Outbreak in the Waste Sector

Due to its highly contagious nature, the COVID-19 outbreak led more people to wear face masks, helmets, safety suits and boots, and use water bottles, disposable bags, and single-use plastic items. This has led to an increased Municipal Solid Waste (MSW) volume, worldwide. During this pandemic, a clear preference for the protection and welfare of human health over environmental care has been seen across the globe (Haque et al., 2020).

5.1. COVID-19 waste induced challenges

The increasing rise in waste volume is pressuring the current waste management infrastructures, which have proven insufficient to accommodate this unexpected increase (Haque et al., 2020). The current pandemic has exposed vital vulnerabilities in our framework, such as the overwhelming amount and the ability to deal with plastic waste. To control this unparalleled amount of plastic waste generation, countries must set up formal waste management programs and track and implement legislation to function efficiently (The Daily Star, 2020a). Figure 11 illustrates the potential impact of COVID-19 on the waste sector. Medical waste volume has increased almost 40% over previous figures, which is a threat for both environment and human health. Municipal solid waste volume also increased at a significant amount; however, there is a drastic fallout in the industrial and commercial waste volume (Haque et al., 2020).

On the other hand, the resurgence of single use plastic and hazardous waste poses a serious threat for health and environment. In the suburban areas, PPEs, caps, and gloves were discarded into the household bins, putting waste collectors' health and life at risk. Toxic, viral, and unlabeled e-waste is stacked and discarded next to each other. The health and welfare of the waste collectors is ignored. Unplanned medical waste disposals will endanger the ecology of the riverine habitats of

Bangladesh and damage the marine environment of the Bay of Bengal (Shammi & Tareq, 2020; The Dhaka Tribune, 2020). No safe system has yet been created for handling health waste produced daily in hospitals, clinics, and families in Bangladesh, despite the introduction of the Medical Waste Management and Processing Rules in 2008 (Mostafizur Rahman et al., 2020).

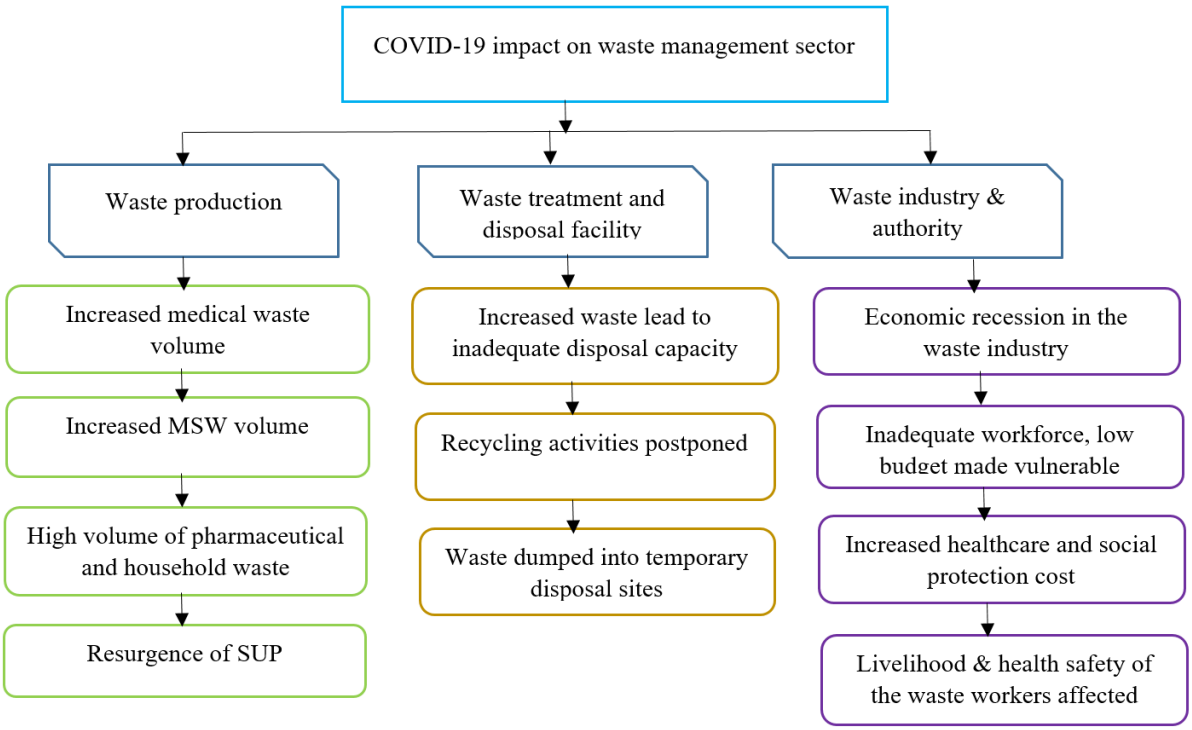

Figure 11. Potential COVID-19 impact on the waste sector (adopted from Haque et al., 2020).

The COVID-19 pandemic has also impacted the waste treatment and disposal facilities. Prior to the pandemic, many industries had begun recycling activities to show their commitment to protecting the earth. Following the economic catastrophe created by the pandemic, policymakers and industries have been reluctant to live up to their commitments to sustainable activities. Additionally, a rapid increase of toxic waste and plastic-based products disrupted the normal recycling capability as well as other waste management methods, and also there was fear of coronavirus infection, which initially forced them to stop recycling activities. Furthermore, a shortage of man power, high overhead and threat of COVID-19 infection have forced the industry to stop their recycling activities, which, in turn, increased the waste volume (The Daily Star, 2020a).

Lack of proper disposal facilities for healthcare waste could put the health of waste collectors at higher risk. Improper collection of COVID-19 wastes would likely threaten the health of the general population. In the past, there were approximately 40,000 informal waste collectors in all corners of the country. Fifty percent of the informal waste collectors have been eliminated, owing to the apprehension of exposure (ESDO, 2020). There have been several possible health threats for health care staff, informal waste collectors, and the citizens that live close to the waste collection areas due to the lack of proper disposal systems in the hospital.

5.2. COVID-19 and waste workers

Globally, healthcare workers have been appreciated much for their frontline role by the people, government, and others. However, other frontline warriors such as sanitation workers and waste pickers have also played significant roles during the pandemic by keeping cities clean and healthy, but are not appreciated much. Like other countries in the South Asia region, sanitation and waste workers in Bangladesh are generally marginalized socially and economically, living in congested colonies, slums or low-income informal settlements with limited access to sanitation facilities. Vulnerable groups, especially people living in poverty, those from a lower caste and religious minorities, are more likely to engage in this type of work and are discriminated against and stigmatized because of their profession. Sanitation workers face a greater risk of infection, injury and death than average workers and they rarely have insurance or access to health services. Given the nature of their work and their living conditions, they are at higher risk than the general population of becoming infected by COVID-19 (WaterAid, 2020).

Hygiene personnel are facing grueling conditions in workplace but have continued working during the pandemic in low-income countries. In Bangladesh, recent reports suggest that the authorities pressurized sanitation staff to work extra hours during the lock-up, with little pay, since the government wanted to clean up the waste quicker than ever to deal with the COVID-19 crisis (Patwary et al., 2021; Practical Action, 2020). They remain in low-income metropolitan neighborhoods. Their job is important to keep neighborhoods safe and free from trash and overflowing toilets, but it often places them at the frontline of risk. At the same time, they are at risk to lose their job anytime. A research was conducted on '*COVID-19 and waste and sanitation front-liners'* by Practical Action, SNV Netherlands Development Organization, and Water Aid. The research was carried out in ten urban centres, including city corporations and municipalities of Bangladesh. The study findings are summarized below:

- There was reducing demand (reduced up to 80%) of pit-emptying during the last two months of lockdown.
- About 48% of workers experienced reduced income, and 71% of them had to spend more than average time on their basic needs.
- With regard to household income, around 41% of income had been reduced per household, and it is estimated that one in every three members became unemployed. Thus, 70% of workers reduced their expenses, and 55% said they borrowed money from others to cope with this crisis.
- A third of employees said they've eaten just twice a day, and have reduced household food as a coping mechanism.
- 47% of individuals have a very low psychological stability (Practical Action, 2020; SNV, 2020; WaterAid, 2020).

On the other side, the worker is at the frontline of risk:

- Among employees, 39% do not have access to adequate handwashing facilities. The findings show that nearly half of medical personnel do not wash their hands after serving a patient.
- 97% of general waste staff utilize protective gear when at work, but about 48% don't feel good with those products. 37% of employees may not have the safety gear they need, so, on average, each worker spent $4 on safety gear within the first 60 days of the pandemic.
- Almost half of the waste staff and their family members encountered COVID-19 symptoms. 37% of staff lack information about whether or how to access care once they test positive (Practical Action, 2020; SNV, 2020; WaterAid, 2020).

5.3. COVID-19 and gender in waste management

Limited evidence exists on gender disparity in waste as it relates to COVID-19. Although there are many underlying factors which suggest that the COVID-19 pandemic put women at a higher health risk, women in general may be at greater risk of health and economic problems. Gender disparities, obligations and tasks remain profoundly rooted in certain facets of waste management. Therefore, recognizing that gender and waste are inter-linked is critical in context of COVID-19 (UNEP, 2020).

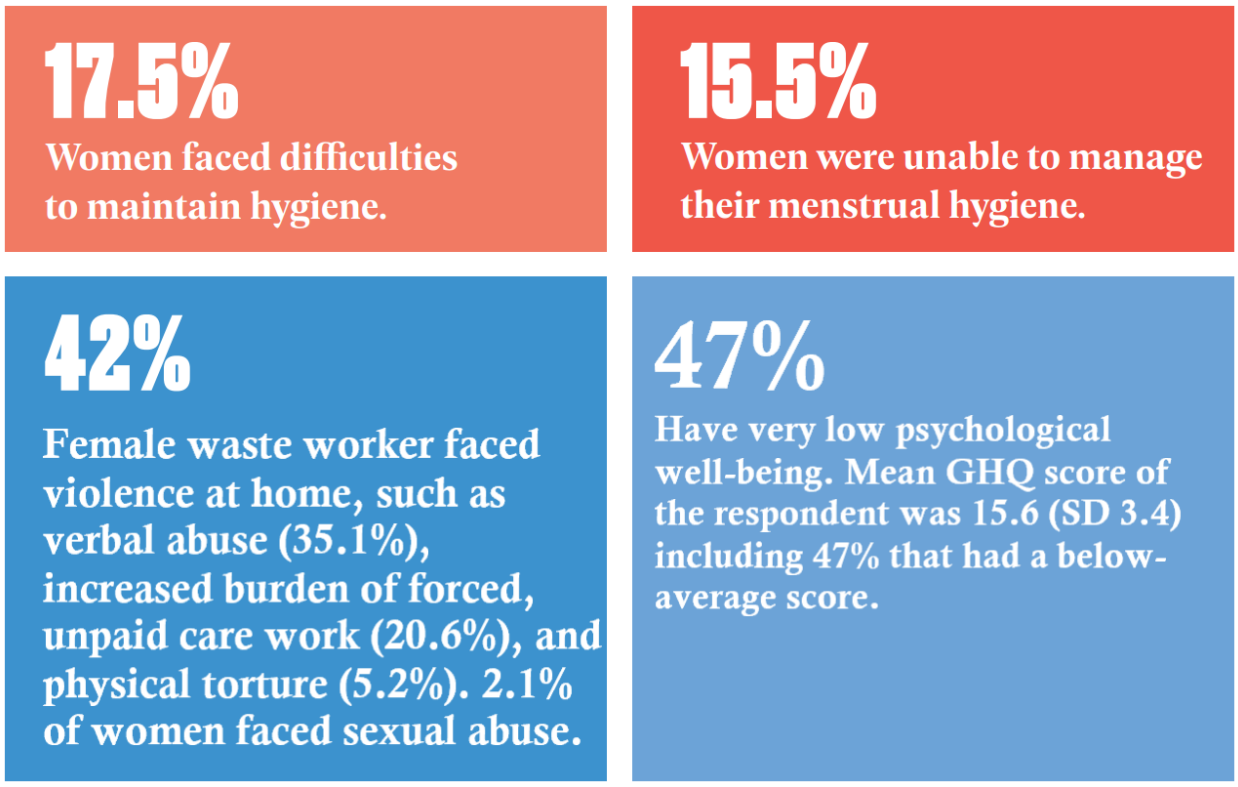

Figure 12. Impact of COVID-19 on female waste pickers (FSM Network Bangladesh, 2020).

6. Government Initiative and Policy Response

Waste minimization and recycling strategies and recommendations should be used together with the COVID-19 health protection guidance to enhance waste collection services and secure human health. The following initiatives and policy responses have been adopted by the Bangladesh government:

- A National Preparedness and Response Plan for COVID-19 in compliance with the WHO recommendation (MOHFW, 2020).
- Color-coded separate bins to separate non-hazardous waste (black), sharp waste (red), and infectious waste (yellow) (UNEP, 2020).
- Received from UNDP 5000 personal protective equipment (PPE), with assistance from the Australian government, for urban waste workers in Dhaka, Chattogram and Narayangaj city (The Daily Star, 2020b).
- Distributed around 50,000 polybags among the residents in the Dhaka North City Corporation (DNCC) areas and conducted awareness-raising campaigns across communities using four vans from the corporation.
- Initiated Medical Waste Management and Processing Rules in 2008. Due to the lack of implementation of the rules, no safe system has yet been developed to manage the health-care waste. However, there is section 269 of the Penal Code 1860 closely relatable. Under this statute, anybody that negligently or unlawfully induces the spread of an infectious epidemic and threatens public health shall be disciplined by imprisonment of 6 months or a fine or both (Mostafizur Rahman et al., 2020; Sejan, 2020)

7. Discussion and Policy Recommendation

Since policymakers and governments worldwide have concentrated on shielding public health from virus contamination, it is generally agreed that other core aspects of society and the climate are being ignored. The following recommendations could facilitate better waste management during pandemic periods:

- Proper implementation of the 2008 Medical Waste Management and Processing Rules.
- Re-initiation of the recycling facilities that were postponed due to economic recession and fear of COVID-19 infection. A proper adjustment is needed in recycling facilities to account for the continued postponed waste management services.
- Promotion of reusable PPE with adequate safety measures to reduce the problem of managing single-use plastics (SUP).
- Promotion of reusable face masks, hand sanitizer in glass bottles, cardboard containers for food take out, etc.
- Increasing the number of hazardous waste disposal sites or facilities. The on-site waste burial pits should be cost-effective (Haque et al., 2020).

- Emphasizing waste abatement campaigns- in particular, engage the community and local authority to reduce plastic waste by altering human behaviour towards plastic waste.
- Cooperation between city authorities, relevant actors, local NGOs and local waste staff, along with plastic manufacturers, to reduce the problem of plastic waste (Haque et al., 2020).

A possible policy action that concerns employees' health and safety might need authority approval and encouragement for employees' health and safety. It is necessary to ensure good practices in the waste management field. Therefore, the following recommendations need to be integrated with the waste management sector for health and safety of waste workers during pandemic time:

- Ensure the supply and proper use of PPEs and disinfectant items among the waste workers.
- Provide adequate training on the right use of masks and other PPEs, with strict adherence to standard safety protocols.
- Ensure that the staff wearing the PPEs and clothes that come into contact with the waste are cleaned regularly and that the cars they ride in and places they operate in are properly washed and sanitized.
- Ensure proper physical distancing in the workplace. Limit the number of workers in the same offices, undertake additional safety measures for the elderly staff and others with pre-existing health conditions, and improve ventilation.

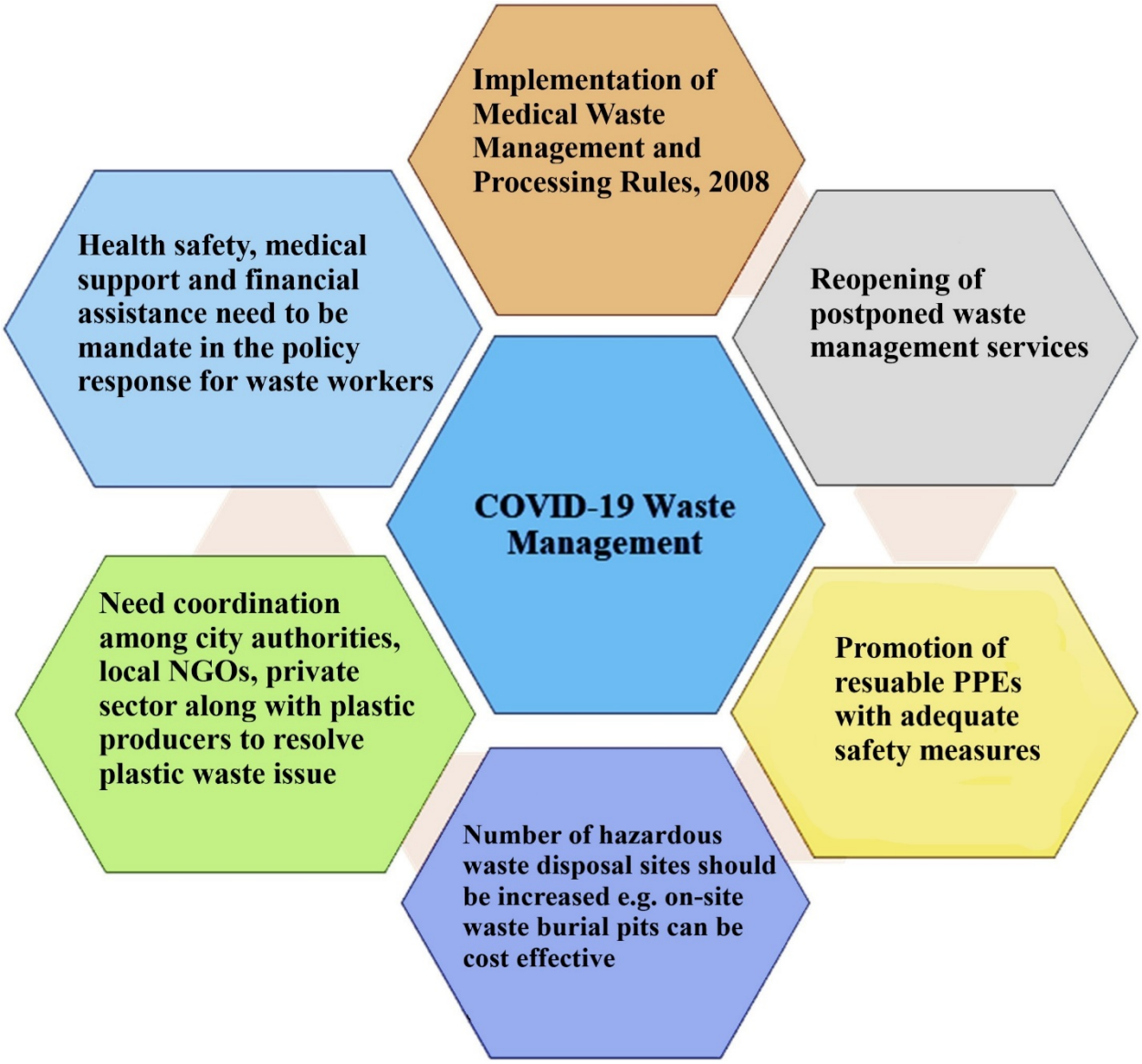

Figure 13. Recommended features that need to be integrated for safe management of COVID-19 waste

Most notably, as a consequence of this situation, we must benefit from this lesson and make a strong commitment to build a state of the art hazardous medical waste management program. City authorities and communities should establish and lead a medical waste collection scheme in the nation, with professional guidance from the Directorate General of Health. Both city authorities and municipalities should have the capacity to adequately and efficiently administer waste management systems.

8. Webinar

Jagrata Juba Shangha (JJS) organized a Webinar on "*COVID-19 Impacts on Waste in Bangladesh"* on 16 January, 2020 from 3.30 PM-5.00 PM. The IPEN hosted the webinar to share the knowledge and research conducted on this topic. The event was chaired by ATM Zakir Hossain, Executive

Director, JJS. He also delivered the opening and closing remarks. A total of 55 participants participated in the program. Among the participants, 29 (52.72%) were female. The webinar was attended by senior officials from Khulna City Corporation, medical officers, researchers, faculties of public universities, representatives from different national NGOs, and media representatives.

While chairing the session, **ATM Zakir Hossain**, *Executive Director of JJS*, highlighted the unprecedented challenge brought by COVID-19 in the waste sector in Bangladesh. He stressed the importance of emergency response in waste management to better prepare the country in the face of such a pandemic. He also emphasized the collaborative effort among financial institutions, city authorities, local NGOs, and community residents to get a better management of waste amidst the pandemic period.

Muhmmad Mainuddin Patwary, *research officer, JJS*, presented a review study on "*Impact of COVID-19 on waste in Bangladesh".* He discussed the current scenario of waste management services in Bangladesh. He also discussed the current and before COVID-19 scenario of waste generation in Bangladesh. In the study, he mentioned that Bangladesh produced a total of 69.51 million tons of waste only from face mask disposal. He pointed out the challenges faced by waste workers in particular and the entire sector in general due to the pandemic, and highlighted what sort of assistance they need from the government.

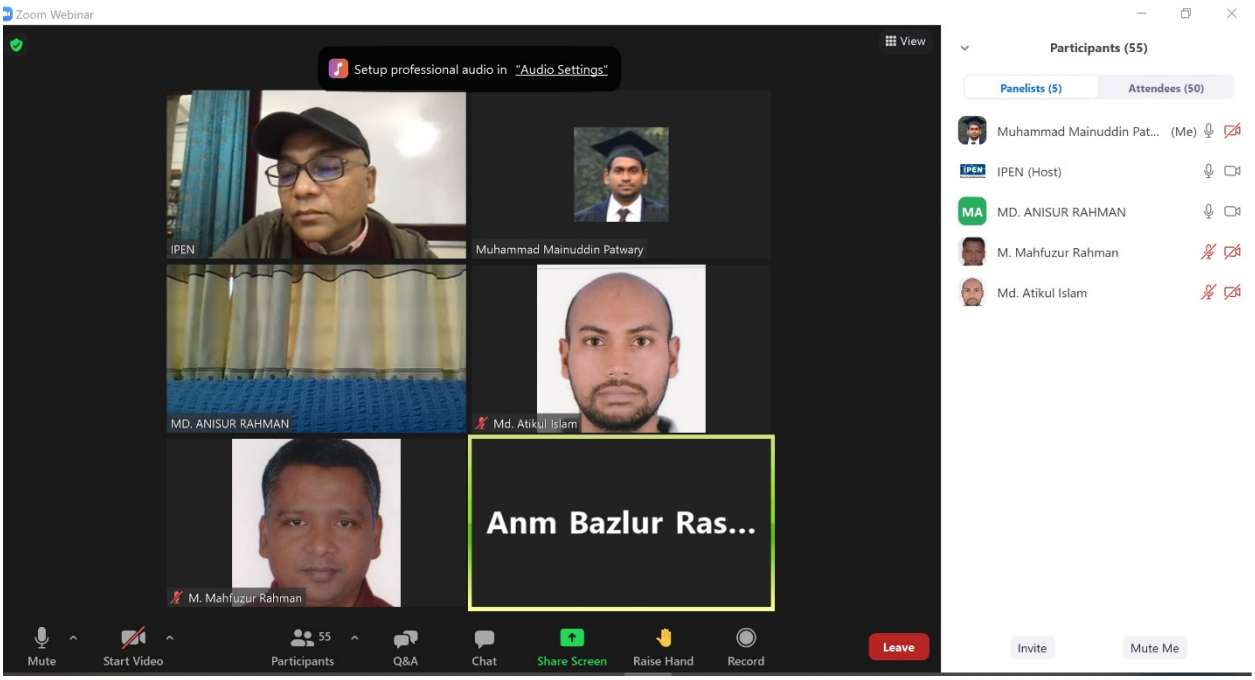

Figure 14. Live Webinar on COVID-19 Waste in Bangladesh

Dr. ANM Bazlur Rashid, *medical officer, Jashore Medical College Hospital (JMCH),* was one of the panelists in the webinar and spoke about hospital waste management during the pandemic. He mentioned some initiatives regarding medical waste management in JMCH. He also explained that PRISM Bangladesh, a national NGO working in the waste management sector, is responsible for waste collection in JMCH. He mentioned that special care was taken for waste management

during COVID-19. The hospital authority used separate bins and separate transportation systems for waste collection. However, the collected waste was burned in hospital backyards without proper treatment.

The panelist **Dr. Mohammad Mahfuzur Rahman,** *Associate Professor, Department of Environmental Science and Technology, Jashore University of Science of Technology (JSTU),* spoke about the current management of COVID-19-induced waste in Bangladesh. He recommended that a detailed study on this particular topic should be conducted in the near future. He mentioned that JSTU is one of the universities in Bangladesh that first initiated the COVID-19 testing facility. Till date, the university conducted 29737 tests precisely. The hospital administration used separate and sterilized container for sample collection. He also mentioned that they followed WHO guidelines to tackle the COVID-19 situation.

The panelist, **Anisur Rahman**, *Conservancy Officer, Khulna City Corporation (KCC)*, spoke about the initiative taken by the KCC in waste management during COVID-19. There were approximately 1.5 million households in the city that produced 550-800 tons of waste and 7.5-8 tons are medical waste. Two national NGOs, namely *Prodipon* and *Shodiccha,* are responsible for waste collection and transportion to dumping sites. The KCC was accompanied by the Ministry of Health's guidance for incorporating waste management systems in the city mentioned by Mr. Rahman. The city authority used 8 trucks to gather waste from their clinics for medical waste disposal. All the employers maintained proper safety measures and ensured personal protective equipment (PPE), and maintain safe hygiene practices at their work place. Mr. Rahman mentioned that about 250 waste collectors received PPE for waste collection.

Dr. Atikul Islam, *Professor, Environmental Science Discipline, Khulna University,* another of the panelists, discussed the environmental concerns of COVID-19 waste disposal in the country. He was so concerned about the sudden surge of COVID-19-related waste from the quarantine and isolated patients in Bangladesh. He expressed that an awareness mechanism should be developed to manage infectious wastes during the pandemic time. He also shed light on the implementation of Medical Waste Management and Processing Rules 2008 in the entirety of Bangladesh. Finally, he emphasized on the multilateral collaboration among the city authority, Department of Environment, university, research institutes and local organizations to improve the facility of waste management.

9. Conclusion

This study reviewed COVID-19 waste issues from a global viewpoint. This review highlighted the waste generation scenario in Bangladesh, which has been further exacerbated by the increase in COVID-19 waste. The report offers answers to the problems that threaten this sector and the need for an appropriate solution.

In every country, strengthening HCW practices begins with national laws. Thus, a national management strategy will be necessary to enable national optimization of HCWM alternatives on a national scale. The existing medical waste management rules-2008 must be revised and implemented in the field level accordingly. A policy document and technical recommendations for implementation should be established in conjunction with the legislation. This legal document

should include laws governing the treatment of various waste types, as well as their segregation, collection, storage, management, disposal, and transportation. Respective duties and training needs should also be included. It is necessary to educate healthcare professionals and the general public about cleanliness and HCWM in order to raise awareness and instill a sense of responsibility which will prevent exposure to related health hazards.

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