Nursing Education and Practice

AIJNEP VOL 2 NO 1 (2021) E-ISSN 2694-3697

Available online at www.acseusa.org
Journal homepage: https://www.acseusa.org/journal/index.php/aijnep
Published by American Center of Science and Education, USA

DISSEMINATING THE BIOMEDICAL WASTE GENERATION SCENARIO DURING COVID-19: AN OVERVIEW FROM THE LOWER MIDDLE INCOME COUNTRY BANGLADESH

Md. Iftakharul Muhib [(a)1] *Rifat Akter* [(b)] *Md. Humaun Kabir* [(c)] *Md. Shamim Rayhan* [(d)] *Md. Shawkut Ali Khan* [(e)]

[(a)] *Assistant Professor, General Education Department, Faculty of Science and Engineering, City University, Dhaka-1216, Bangladesh, E-mail: muhibiftakhar@gmail.com*
[(b)] *M.Sc., Department of Microbiology, Jagannath University, Dhaka-1100, Bangladesh, E-mail: rifatakter5@gmail.com*
[(c)] *Professor & Engineer, Department of Textile Engineering, City University, Dhaka-1216, Bangladesh, E-mail: mdhumaunkabir628@gmail.com*
[(d)] *Lecturer, Department of Mechanical Engineering, City University, Dhaka-1216, Bangladesh, E-mail: mechanicalenvironment10@gmail.com*
[(e)] *Professor, Department of Mechanical Engineering, City University, Dhaka-1216, Bangladesh, E-mail: shawkutali8@gmail.com*

ARTICLE INFO

Article History:

Received: 25 October 2021
Accepted: 16 December 2021
Online Publication: 31 December 2021

Keywords:

Biomedical Waste, COVID-19
Facemask, PPE, Bangladesh

JEL Classification Codes :

L65, Q53

ABSTRACT

This study investigates the present COVID-19-related medical waste generation scenario and suggests a way forward from the perspective of lower-middle-income countries like Bangladesh. Bangladesh is a densely populated vulnerable country in the perspective of the COVID-19 induced biomedical waste management field. The pandemic COVID-19 has already created enormous instability in healthcare waste handling and subsequent recycling around the world. The medical waste management sector in Bangladesh is struggling and COVID-19 makes the situation even more complicated. A rigorous time-series calculation was done to determine the facemask and medical waste load during COVID-19 in Bangladesh from March 8, 2020, to September 13, 2021 period. Results showed that about 1,58,10,400 pieces of facemask are disposed of alone in different urban areas which is equivalent to 517 tons of solid waste while extra 5,203 tons of biomedical waste is added every day to regular waste streams during this pandemic. The findings of this study suggest that these extra tons of hazardous waste threaten the aquaculture of the country and promote the risk of contagious diseases to the waste workers especially women and as well as at the community level. The findings also reveal that this pandemic has already created a hindrance to achieving the country's SDGs by 2020.

INTRODUCTION

COVID-19 pandemic emerges as one of the most pronounced challenges after the year of 2020 since World War II. This outbreak is now also considered to be syndemic due to its long lasting vulnerabilities. One of that vulnerabilities is the generation of huge amount of biomedical waste and its subsequent challenges to manage (Gravlee, 2020). Improper handling of these wastes pose serious risk of disease transmission to waste collectors, health workers and even though in the community level as well as the possibility of environmental deterioration. The subsequent recycling process also become challenging because of the high volume of biomedical waste generated and its contagious nature (Das et al., 2021). The current pandemic imparted a gross use of single-used plastic induced materials like personal protective equipment (PPE) e.g. mask, face shield, goggles, gloves, aprons etc. Again the COVID-19 outbreaks increase the production and random use of plastic based equipment, polythene, PET bottles, caps, one time plates etc. that have resulted a rapid accumulation in the biomedical waste streams (Yeasmin & Tasnime, 2020).

One recent study revealed that global market for PPE jumped from $40 billion to $58 billion during 2016-2020 that is 6.5% growth per year. Again WHO predicted that PPE production must increase by at least 40% per month to deal with COVID-19 pandemic more effectively. So it can be noted that PPE usage and their induced wastes are not expected to decline substantially during the post pandemic periods either (Market Reports, 2020).

[1]*Corresponding author: ORCID ID: 0000-0002-5143-2482*

https://doi.org/10.46545/aijnep.v2i1.247

To cite this article: Muhib , M. I. ., Akter, R. ., Kabir , M. H. ., Rayhan , M. S. ., & Khan , M. S. A. . (2021). DISSEMINATING THE BIOMEDICAL WASTE GENERATION SCENARIO DURING COVID-19: AN OVERVIEW FROM THE LOWER MIDDLE INCOME COUNTRY BANGLADESH. *American International Journal of Nursing Education and Practice*, *2*(1), 7–14. https://doi.org/10.46545/aijnep.v2i1.247

Bangladesh is one of the most densely populated lower middle income countries in the world. Despite that, this country improved its position gradually from 179th to 162nd out of 180 countries in terms of controlling the environmental pollution. At present millions of contaminated facemasks, gloves, materials for diagnosis, detecting and tracing COVID-19 and other pathogens posing the irreversible process of becoming infectious waste. This in turn, will cause both environmental and health hazard if they remain untreated (Nzediegwu & Chang 2020). Moreover, unsafe disposal of medical waste could spill over into environmental pollution is palpable and immediate (Singh et al., 2020a). A recent study also noticed that human coronavirus can remain active on solid surfaces (e.g. plastic, metal, glass) for up to nine days (Kampf et al., 2020). As a result, one of the many problems that will inevitably occur is biomedical waste if not managed wisely, may the root reason of severe disease and environmental problems. Therefore, the objective of this study is set to notify the present COVID-19 induced biomedical waste generation scenario of Bangladesh and thereby calling on the scientific communities to express their concern and take the responsible actions for the formulation of appropriate biomedical waste management policies and strategies to government at all levels.

BIOMEDICALWASTE GENERATION IN BANGLADESH FROM LITERATURE

Waste Generated from Facemask Disposal in Bangladesh

Calculation of daily facemask disposal depends on the total population in an area, urban population rate living in that area, face mask acceptance rate and mean daily facemask disposal per capita (Haque et al., 2020). Prata et al. (2020) estimated that about 2.65 billion pieces of facemask are needed to cover up the 160 million habitants of Bangladesh whereas Environment and Social Development Organization showed a more marginal calculation of 455 million pieces' facemask per month (Eco-Social Development Organization [ESDO] 2020). ESDO, 2020 also estimated that 472.3 MT of everyday COVID-19 waste production from PPE will give rise to 172402 MT waste in Bangladesh of which 36987 MT (21.45%) derived just from facemask disposal.

A comprehensive study was done in different division to calculate the surgical mask usage in Bangladesh from March 8, 2020 to November 18, 2020. Results showed that total 13099 million piece facemasks were disposed in the environment which is equivalent to 392970 tons of waste with generation 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 Chottogram (24086 tons), Khulna (8247 tons), Rajshahi (4302 tons), Rangpur (2108 tons), Sylhet (1456 tons), Mymensingh (1383 tons) and Barisal (1243 tons) (Patwary & Hossain 2021).

Biomedical Waste Generation Rate due to COVID-19 in Bangladesh

Since the large population, huge amount of infectious medical waste is generated every day in Bangladesh due to patients' treatment. Study revealed that average 206 tons of medical waste was generated per day alone in Dhaka while this amount was only likely to be 48 tons/day before the COVID-19 pandemic (Rahman et al. 2020). This waste load disputably accelerates with the increasing trend of COVID-19 positive cases. In pre-COVID era, medical waste generation rate in Bangladesh was estimated as 0.8 to 1.67 kg/bed/day. Another previous study in 2016 showed that average medical waste generation rate was 2.6 kg/bed/day in Dhaka city. The medical college hospital in the country produced an average of 1.54 kg/bed/day waste, specialized hospital produced a total of 1.62kg/bed/day and district hospitals merely generated 1.645 kg/bed/day medical waste. But in this COVID-19 pandemic situation, the medical waste load has risen to 3.40 kg/bed/day which is almost similar to the other countries suffering from high COVID-19 positive cases (Abu-Qdais et al., 2020; Haque et al., 2020).

Further study conducted by ESDO, 2020 revealed that about 14500 tons of medical related plastic waste was generated from all around Bangladesh in the first month of lockdown and consequently produce equivalent to more than 43000 tons of waste during the next three months of lockdown period. According to the same study, it was also found that about 50% of total population of Bangladesh using single used synthetic surgical mask. Besides them, about 30% of urban people use hand gloves and hand sanitizers. This empty hand sanitizer bottles add extra 900 tons/month of waste load to the COVID-19 generated waste stream (ESDO, 2020). It was revealed that Dhaka city alone produced about 3076 tons of plastic waste during the first three months of lockdown period (Patwary & Hossain, 2021).

Table 1 represents the increasing trend of medical plastic waste generation during the first three months of lockdown in the country (ESDO 2020); Haque et al. 2020). In span of single month, 455 million pieces' surgical masks were disposed of which is equivalent to 1,592 tons of plastic waste. This table also revealed that usage of polythene and disposable shopping bags at the community level had risen at an alarming pace. 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).

Table 1. Biomedical waste generation during COVID-19 lockdown in Bangladesh

Serial	Waste Item	Amount used in one-month lockdown period (piece)	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	5,796	193.20	17,388.0
3.	PE made hand gloves	1,216 million	3,039	101.30	9,117.0
4.	Hand sanitizer bottles	49 million	900	30.00	2,700.0
5.	Non-infectious waste	-	251.10	8.37	753.30

During the lockdown periods, there was an increase in medical waste production along with the increasing rate of infection throughout the country exponentially. Maps were generated on the basis of total medical waste generation during February, 2020- November, 2020 (Figure 1). The division wise active case data was taken from World Health Organization [WHO] (2020). The map suggesting that both highest infected case and highest amount of waste generated was found in Dhaka division followed by Chottogram, Khulna, Rajshahi, Sylhet and other major cities in Bangladesh (Patwary & Hossain 2021).

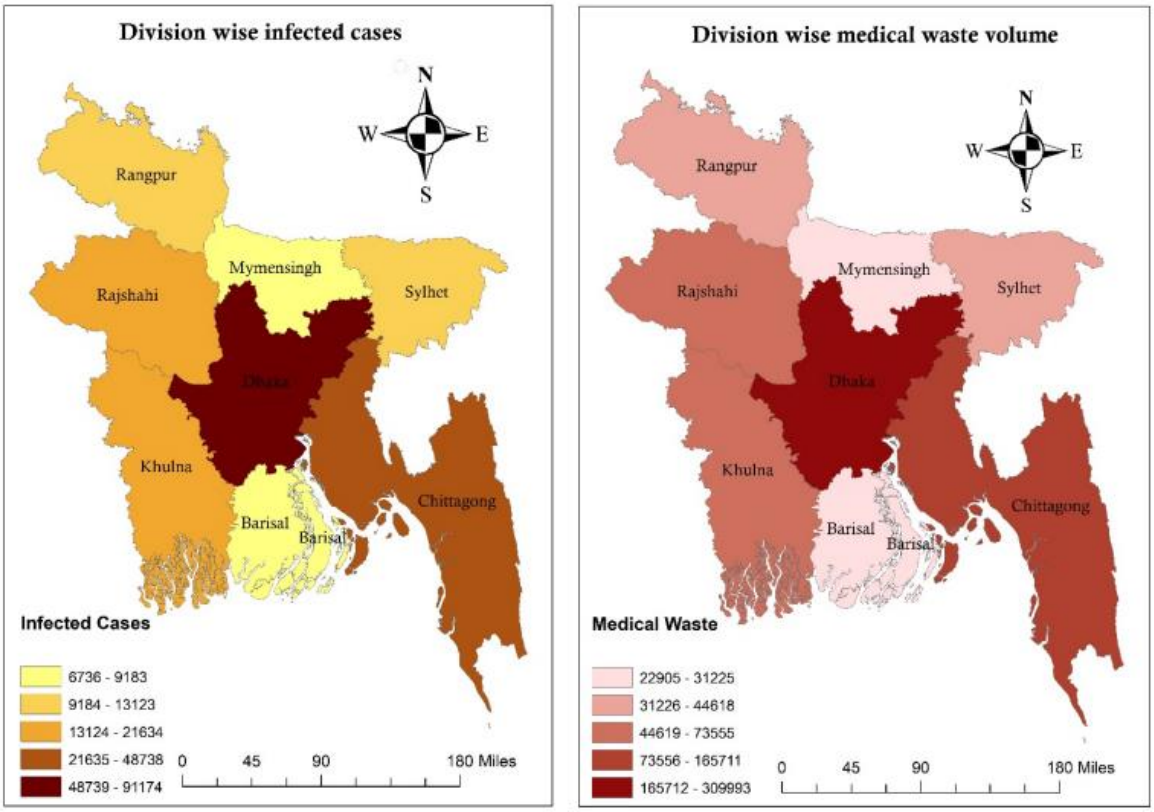

Figure 1. Map representing the simultaneous increase in medical waste volume (right map) along with infected cases (left map) in different divisions of Bangladesh from March 8-November 23, 2020 (Map Source: Patwary and Hossain (2021); Data Source: DGSH (2021)

ESTIMATION OF COVID-19 INDUCED DISPOSABLE FACEMASK WASTE BY PRESENT STUDY

The amount of waste generated from disposable masks is determined by the following equation (Boroujeni et al., 2021)-

$$F_{TW} = D_{FM} \times F_W$$

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

The amount of waste generated from daily disposal of facemask is estimated using the following equation adopted from Nzediegwu and Chang (2020) as follows:

$$D_{FM} = P \times U_P \times F_{MAR} \times F_{MGP}/10000$$

Here, D_{FM}= Total facemask disposed of (pieces), P= number of population (persons), U_P= Percentage of urban population (%), F_{MAR}= mask acceptance rate (80%), F_{MGP}= assume one facemask used by one person per capita/day (Sangkham, 2020).

(Urban population retrieved from City Population, 2021. Urban population, facemask acceptance rate, mask usage and facemask weight retrieved from Boroujeni et al. (2021) and Patwary and Hossain (2021)

Table 2 represents the current facemask disposal rate along with their consequent waste load in different major cities of Bangladesh. The total facemask disposal rate is 15820400 which is equivalent to waste load of 517 tons/day. The calculated results indicate that highest facemask disposal rate per day and their generated waste load is found to be highest in the capital Dhaka. The facemask induced waste load show the descending order by Dhaka>Chottogram>Gazipur>Narayanganj>Khulna>Rajshahi>Sylhet>Bogra>Comilla.

Table 2. Estimated Facemask Disposal and Their Induced Waste Generation Rate in Major Cities of Bangladesh

City	Population, P	Urban Population, U_P (%)	Facemask Acceptance rate, F_{MAR} (%)	Mask Usage, F_{MGP}	Facemask disposal/day, D_{FM}	Weight of facemask, F_W (g)	Waste load due to facemask, F_{TW} (ton/day)
Dhaka	1,10,86,309	100	80	1	88,69,048	30	266

Chottogram	36,69,170	100	80	1	29,35,336	30	88
Gazipur	18,20,374	100	80	1	14,56,300	30	44
Narayanganj	16,36,441	100	80	1	13,09,153	30	40
Khulna	10,46,341	100	80	1	8,37,073	30	26
Rajshahi	7,63,952	100	80	1	6,35,162	30	19
Sylhet	5,26,412	100	80	1	4,21,130	30	13
Bogra	4,12,537	100	80	1	3,30,030	30	11
Comilla	4,07,901	100	80	1	3,26,321	30	10
Total	2,13,69,437				1,58,10,400		517

ESTIMATION OF COVID-19 INDUCED MEDICAL WASTE GENERATION RATE IN BANGLADESH BY PRESENT STUDY

The amount of medical waste generated at different hospitals is proportional to the number of infected persons and the average waste generation per bed. In general, medical waste due to COVID-19 related diagnosis and patients' treatment is expected to be higher than the general average of disease affected patients. The estimation of division wise per day total medical waste generation during COVID-19 is done by the following equation (Sangkham, 2020)-

$$\mathbf{M_W = N_{CC} \times M_{WGR}/1000}$$

Here, M_w= Total Medical Waste generated (tons/day), N_{CC}= Total number of COVID-19 cases (infected persons), M_{WGR}= Medical waste generation rate, 3.40 kg/bed/day during COVID-19, (Sangkham, 2020; Patwary and Hossain 2021).

Table 3. Division wise COVID-19 Induced Medical Waste Generation Rate

Divisions	Number of COVID-19 Cases, N_{CC}	Total Medical Waste generated (tons/day), M_w
Dhaka	8,99,474	3,059
Mymensingh	36,189	123
Chottogram	2,36,653	805
Rajshahi	96,946	330
Rangpur	54,237	175
Khulna	1,10,702	377
Barisal	44,662	152
Sylhet	53,503	182
Total	15,32,366	5,203

Table 3 is formulated on the basis of division wise COVID-19 data cases which was retrieved from DGHS press release, 13 September, 2021. Director General of Health Services (DGHS, 2021). Total number of confirmed cases represent the infected persons who were treated in hospitals without recovering or those who were declared dead after being infected with COVID-19. Consequently, the total confirmed COVID-19 cases comprise the ones wherein patients were treated in hospitals during the emergency state (Sangkham, 2020). Up to 13 September, 2021, total 15,32,366 confirmed cases were found in Bangladesh which is equivalent to the production of 5,203 tons of medical waste per day. It should be noted that this 5,203 tons'/day load is only coming from COVID-19 related health care. Other health care induced biomedical waste loads are not considered here. So it can easily be assumed that adding other health care related biomedical waste load to this COVID-19 induced biomedical waste load is worsening the current scenario. Results from the Table 3 also shows that highest amount of medical waste is generated in the capital Dhaka (3,059 tons/day) which is similar to the facemask induced waste load result (Table 2). Considering the resultant division wise total medical waste load (tons/day) generation, the descending order will be Dhaka>Chottogram>Khulna>Rajshahi>Sylhet>Rangpur>Barisal>Mymensingh.

COVID-19 WASTE INDUCED CHALLANGES

Creating Burden in Waste Sector

The increasing trend of waste volume is pressuring the current fragile waste management infrastructures of Bangladesh which have proven insufficient to accommodate this unexpected increase (Haque et al., 2020). Figure 2 illustrates the potential impacts on COVID-19 on the waste sector. Medical waste volume has increased by 40% over the last years which is a threat for both environment and human health. Municipal solid waste also increased at significant amount; however, there is a drastic fall out in the industrial and commercial waste volume (Patwary & Hossain, 2021).

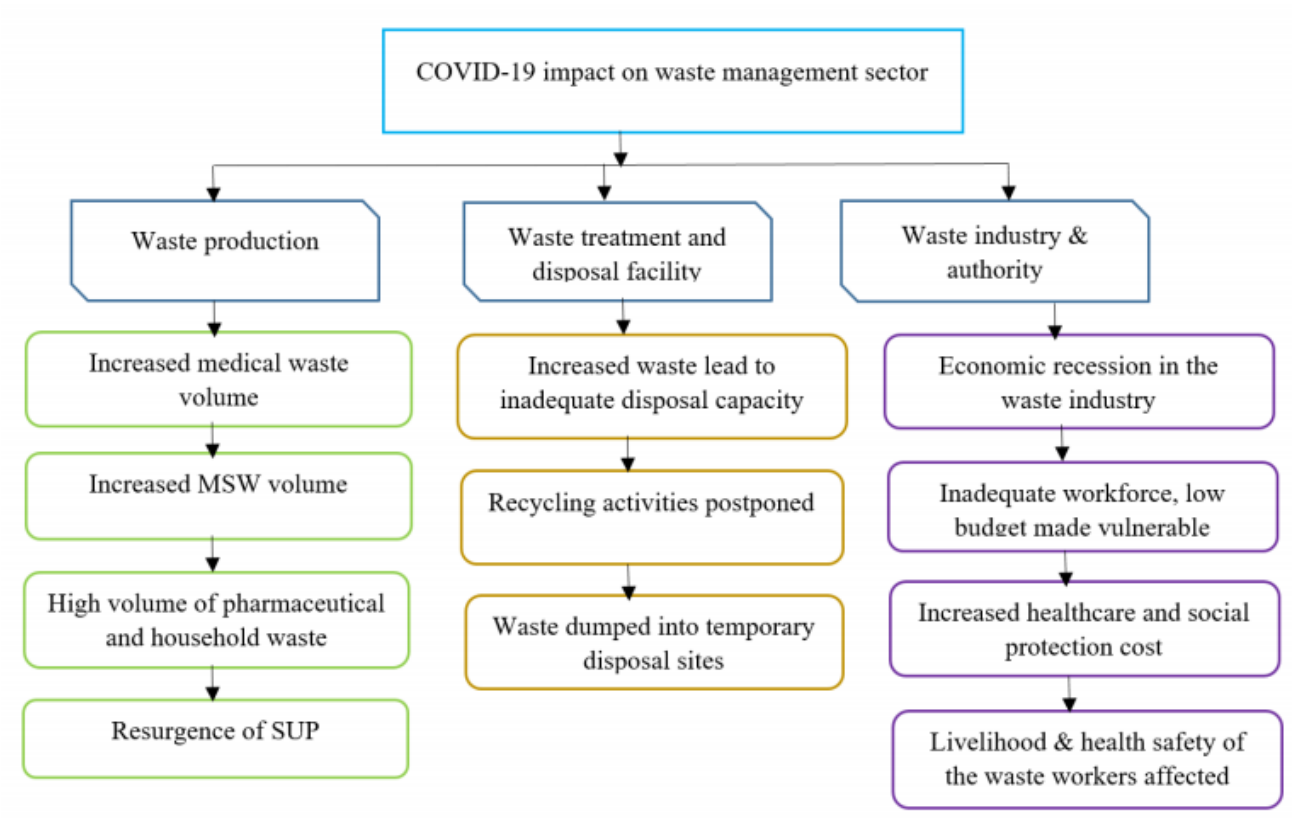

Figure 2. COVID-19 Creating Impact on Waste Sector (Haque et al., 2020)

Threatens the Aquatic Environment

Thrown single used plastic waste deposited on open space or landfill can find its way to aquatic ecosystems ultimately by many routes including weathering, aging and microbial degradation. Eventually the plastic reaches the Bay of Bengal via rivers and other water courses. During this journey the facemask or other plastic wastes will face fragmentation and degradation process changing in size from macro (≥5 mm) micro (<5 mm) and finally to nano (1-100 nm) size debris (Xu et al., 2020). Due to their existence in a wide range of particle debris they are therefore, accessible to a wide range of organisms as well as the ecosystems with the potential to create damaging effects. The fisheries and aquaculture sector which is one of the most promising sectors of Bangladesh will not be escaped from the afore mentioned problems originating from plastic debris like micro plastics and this may pose threat to the crustaceans (notably shrimp, crab), migratory fishes including hilsa and other freshwater fish cultured in ponds. This will put the shrimp industry, the second most flourishing sector of Bangladesh under pressure as breeders and extensive farmers depend on open water or brood stock and post larvae respectively (Hasan & Haque, 2020). Thus, it could also impact the emerging finfish aquaculture sector which supplies a significant amount of protein for national nutrition

Unmanaged Waste Promoting COVID-19 Spread

Transmission of COVID-19 virus can occur through sneezing, coughing, contact with touched objects as well as physical contacts. Survival period of COVID-19 virus on multiple substrates is very crucial for formulating appropriate management practices and taking measures for dealing with biomedical waste. The survival period of corona virus varies from a few hours to a few days, based on the substrate type and the environmental conditions. For example, the survival period of corona virus following aerosolization on copper, cardboard, plastic and stainless steel are 3 hours, 4 hours, 24 hours and 2-3 days respectively (Van Doremalen et al., 2020). It can also persist in dechlorinated tap water along with hospital waste water at 20 degrees for 2 days. The longer survival period of this corona virus associated with the improper handling of these biomedical waste poses an elevated risk of community transmission (Nzediegwu & Chang, 2020)

Bangladesh was already grappling with inadequate medical waste management let alone hygiene practices before the COVID-19 outbreak (Al-Zaman, 2020). Now the growing prevalence of misuse and improper disposal of facemask and other PPE related plastic waste has become the matter of concern for Bangladesh Government. There are also issues relating to false sense regarding the protection by compulsory usage of facemasks that could cause people to disregard other prevention measures. At present facemask may become an emerging means for the transmission of COVID-19 pandemic in Bangladesh, considering the potential risk of self-infection and environmental hazards when the masks are incorrectly disposed or used.

Current Treatment and Disposal Practice of Biomedical Waste in Bangladesh

As an emerging economy in relation with the increasing population growth and urbanization process, solid and medical waste volume are constantly growing in Bangladesh. Based on the available literatures, Bangladesh generates nearly 16380

tons of waste on a daily basis which is projected to reach at 47000 tons per day by 2025 that is generation rate would be 0.60 kg per capita per day (Bhuiyan, 2010). The present COVID-19 waste load worsen the scenario. However, ineffective and poor waste management service when merged with the responsible authorities' maladministration and negligence, about 50% of the daily produced waste remains uncollected and seen visible near roadside, adjacent space, drainage network and water bodies of major cities in Bangladesh (Ahsan et al., 2014).

At this moment, the waste generated in hospitals is first gathered in in-house storage; from there the PPE along with other medical wastes are kept in open drums and transported to landfill areas for final disposal. This open air collection and transportation of medical wastes over such a long distance are undoubtedly dangerous for public health (Shammi & Tareq, 2020). Unfortunately, in many rural, urban and semi-urban hospitals, even these minimum disposal facilities are absent. These hospitals and clinics burn medical wastes outside or mix them with garbage in the regular city corporation bins. In residential areas, the used PPE, masks, gloves and other COVID-19 wastes were discarded among the household bins, putting the waste collectors' health and lives at risk as this infectious waste is often not labelled.

Currently biomedical waste is largely handled by city corporations, third party organizations and non-governmental organizations (NGOs) namely PRISM Bangladesh Foundation, Nobo Waste Management, Chattogram Seba Sangstha and Prodipan. However, these organizations make contracts with the hopitals mostly located in urban areas like Dhaka, Chattagram and Narayanganj. PRISM Bangladesh Foundation actively treating the medical wastes since 2006 at Matuail landfilling plant Dhaka containing incinerator following an agreement signed with Dhaka North and South City Corporation. PRISM Bangladesh Foundation also runs well equipped medical waste management plants in Rangpur, Sylhet, Rajshahi using incinerator and in Jessore using an autoclave (Yeasmin & Tasnime, 2020).

At present there are around 654 government hospitals, 5,055 private hospitals and clinics with 1,41,903 beds in total along with an additional 9,061 diagnostic center beds all of which lead to the generation of huge amount of biomedical waste. So, only PRISM's capacity is not comparable to the demand for medical waste management throughout Bangladesh. About 6 tons of waste used to be collected for high temperature incineration treatment each day from more than 950 health centers in Dhaka by PRISM everyday which turned into 10-11 tons per day at the time of pre-COVID period (Amid COVID-19, 2020). The alarming issue is that a large amount of COVID related wastes like PPE, facemask, gloves, face shield, sanitizer containers are being also generated outside healthcare establishment which are not treated by any NGOs and are usually discarded for sanitary landfills. These household wastes during collection by unprotected, inefficient and unconscious cleaners and disposed of randomly in unauthorized places without proper treatment. Thus these single used contaminated plastic medical waste may pose prolonged re-emerging health hazard by being mixed with water bodies or scattered randomly during or after landfilling in Bangladesh along with the intensifying environmental hazards by disrupting the riverine ecosystem and burdening the sanitary landfill (Yeasmin & Tasnime, 2020).

COVID-19 and Waste Workers

Globally Healthcare workers like doctors, nurses, medical technologists have been appreciated much for their frontline role by the government and people of all sectors. However, other frontline warriors such as sanitation workers and waste pickers have also played undoubtedly significant roles during the pandemic by keeping the yards clean and healthy but not appreciated much in Bangladesh. These sanitation workers face a severe risk of infection, injury and even death than average workers and general people and they rarely have insurance or access to incentive health services (Water Aid, 2020). Several studies reported that 97% of general waste staff want to utilize protective gear when at work but about 48% of them don't feel good with those products; 37% employees do not have any safety gear; so on average poor workers had to spend USD 4 on safety gear within the first 60 days of the pandemic. It was also reported that almost half of the waste staff and their family members encountered COVID-19 symptoms. 37% of them deprived from getting information about whether or how to treat once they tested positive (Practical Action, 2020; Water Aid, 2020).

COVID-19 and Gender Issue in Medical Waste Management

Limited evidence exists on gender discrimination 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 Bangladesh are general may be at greater risk of health and economic problem. Gender disparities, obligations and task 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 (UN Environment Program ([UNEP], 2020) in Bangladesh.

COVID-19 vs Sustainable Development Goals (SDGs)

Since the COVID-19 outbreak, PPE is being widely used by medical settings and mass people which rapidly accumulates potential infectious waste in the solid waste streams throughout the world Singh et al. (2020b). Proper disposal of these wastes is vital for controlling the reemergence of viral infection and environmental protection; as well as to meet SDGs especially the SDG3, SDG6, SDG8, SDG12 and SDG13 (Health Care Without Harm [HCWH], 2020). Bangladesh government has taken measures to achieve SDGs since it launched the seventh 5 years plan 2016-2020 in 2015 which passed on July 2020 already. The effectiveness of this five years' plan is in question because the executions remains rather slow and the COVID-19 makes the scenario worst. The responsibility for it should fall not only on the Bangladesh Government but also on intervening international bodies such as donors, development agencies, NGOs, banks and private companies. The report suggested that "if at least some SDGs had been partly attained, the situation would not be as dire as it now and the people would feel less fear and worry about pandemic, unemployment and hunger" (Sakamoto et al., 2020).

CONCLUSION AND RECOMMENDATIONS

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 (Patwary & Hossain, 2021):

- Proper implementation of the 2008 Medical Waste Management and Processing Rules.
- Promotion of reusable PPE with adequate safety measures to reduce the problem of managing single-use plastics (SUP).
- 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 behavior 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).
-

LIMITATIONS OF THE STUDY

This study presents some limitations that should be considered when reading and findings. This is a cross-sectional study that aims to provide the present scenario of biomedical waste generation and management system associated with COVID-19 pandemic in Bangladesh. This examination depends on the available information in this regard.

Author Contributions: Conceptualization, M.I.M.; Data Curation, M.I.M.; Methodology, M.I.M.; Validation, M.I.M.; Visualization, R.A. M. H. K.; Formal Analysis, M.I.M.; Investigation, M.I.M.; Resources, M.I.M.; Writing – Original Draft, M.I.M.; Writing – Review & Editing, R.A.; M. H. K. and M.S.R, and M. S. A. K.; Supervision, M.H.K.; Software, M.I.M.; Project Administration, M.I.M.; Funding Acquisition, M.I.M. Authors have read and agreed to the published version of the manuscript.

Institutional Review Board Statement: Ethical review and approval were waived for this study, due to that the research does not deal with vulnerable groups or sensitive issues.

Funding: The authors received no direct funding for this research.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to restrictions.

Conflicts of Interest: The authors declare no conflict of interest.

REFERENCES

Abu-Qdais, H. A., Al-Ghazo, M. A., & Al-Ghazo, E. M. (2020). Statistical analysis and characteristics of hospital medical waste under novel Coronavirus outbreak. *Global Journal of Environmental Science and Management*, *6*(4), 1-10.

Ahsan, A., Alamgir, M., El-Sergany, M. M., Shams, S., Rowshon, M. K., & Daud, N. N. (2014). Assessment of municipal solid waste management system in a developing country. *Chinese Journal of Engineering*, *2014*(1-11), 561935.

Amid COVID 19. (2020). Amid COVID 19 Biomedical Waste Turning Hazardous, The Financial Express, April 10, 2020.

Al-Zaman, M. S. (2020). Healthcare crisis in Bangladesh during the COVID-19 pandemic. *The American journal of tropical medicine and hygiene*, *103*(4), 1357.

Bhuiyan, S. H. (2010). A crisis in governance: Urban solid waste management in Bangladesh. *Habitat international*, *34*(1), 125-133.

Boroujeni, M., Saberian, M., & Li, J. (2021). Environmental impacts of COVID-19 on Victoria, Australia, witnessed two waves of Coronavirus. *Environmental Science and Pollution Research*, *28(*11), 14182-14191.

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

Director General of Health Services [DGHS]. (2021). Press Release. Retrieved from https://dghs.gov.bd/index.php/bd/component/content/article?layout=edit&id=5612

Eco-Social Development Organization [ESDO]. (2020). Online Press Briefing on COVID-19 Pandemic Outbreak 14,500 Tons of Hazardous Plastic Waste in a Month.

Gravlee, C. C. (2020). Systemic racism, chronic health inequities, and COVID-19: A syndemic in the making?. *American Journal of Human Biology*, *32*(5), e23482.

Haque, M. S., Uddin, S., Sayem, S. M., & Mohib, K. M. (2021). Coronavirus disease 2019 (COVID-19) induced waste scenario: A short overview. *Journal of Environmental Chemical Engineering*, *9*(1), 104660.

Hasan, N. A., & Haque, M. M. (2020). Dataset of white spot disease affected shrimp farmers disaggregated by the variables of farm site, environment, disease history, operational practices, and saline zones. Data B, 31.

Health Care Without Harm [HCWH] (2020). Health Care Waste Management and the Sustainable Development Goals (SDGs).

Kampf, G., Todt, D., & Pfaender, S. (2020). Steinmann E. Persistence of coronaviruses on inanimate surfaces and their inactivation with biocidal agents. *Journal of Hospital Infection*, *104*(3), 246–251.

Market Reports. (2020). Personal Protective Equipment Market by Type (Hands & Arm Protection, Protective Clothing, Foot & Leg Protection, Respiratory Protection, Head Protection), End-Use Industry (Manufacturing, Construction, Oil & Gas, Healthcare) - Global Forecast to 2022.

Nzediegwu, C., & Chang, S. X. (2020). Improper solid waste management increases potential for COVID-19 spread in

developing countries. *Resource, Conservation and Recycling, 161*(104947).
Patwary, M. M., & Hossain, A. T. M. Z. (2021). COVID-19 Impacts on Waste in Bangladesh. Jagrata Juba Shangha with International Pollutants Elimination Network's (IPEN's) Toxics-Free SDGs Campaign. 5/8, TB Cross Road, Khulna-9100, Bangladesh.
Prata, J. C., Silva, A. L., Walker, T. R., Duarte, A. C., & Rocha-Santos, T. (2020). COVID-19 pandemic repercussions on the use and management of plastics. *Environmental science & technology, 54*(13), 7760-7765.
Practical Action. (2020). Hardship of Waste workers in Bangladesh during Coronavirus Pandemic revealed.
Rahman, M. M., Bodrud-Doza, M., Griffiths, M. D., & Mamun, M. A. (2020). Biomedical waste amid COVID-19: perspectives from Bangladesh. The Lancet. Glob Health.
Sakamoto, M., Begum, S., & Ahmed, T. (2020). Vulnerabilities to COVID-19 in Bangladesh and a Reconsideration of Sustainable Development Goals. *Sustainability, 12*(5296).
Sangkham, S. (2020). Face mask and medical waste disposal during the novel COVID-19 pandemic in Asia. *Case Studies in Chemical and Environmental Engineering, 2*(10005).
Shammi, M., & Tareq, S. M. (2021). Environmental catastrophe of COVID-19: disposal and management of PPE in Bangladesh. *Global Social Welfare*, *8*(2), 133-136.
Singh, N., Tang, Y., Zhang, Z., & Zheng, C. (2020a). COVID-19 waste management: Effective and successful measures in Wuhan, China. *Resource Conservation and Recycling*, *163*, 105071.
Singh, N., Tang, Y. Y., & Ogunseitan, O. A. (2020b). Environmentally sustainable Management of Used Personal Protective Equipment. *Environmental Science and Technology*, *54*, 8500–8502.
UN Environment Program [UNEP]. (2020). Waste Management during the COVID-19 Pandemic from Response to Recovery Title: Waste Management during the COVID-19 Pandemic from Response to Recovery.
Van Doremalen, N., Bushmaker, T., Morris, D. H., Holbrook, M. G., Gamble, A., Williamson, B. N., ... & Munster, V. J. (2020). Aerosol and surface stability of SARS-CoV-2 as compared with SARS-CoV-1. *New England journal of medicine*, *382*(16), 1564-1567.
Water Aid. (2020). Rapid Assessment of Measures on Safety of Sanitation and Waste Workers during Covid-19 in Pakistan A QUALITATIVE STUDY REPORT.
World Health Organization [WHO]. (2020). World Health Organization. Morbidity and Mortality Weekly Update (MMWU) No 39.
Xu, S., Ma, J., Ji, R., Pan, K., & Miao, A. J. (2020). Microplastics in aquatic environments: occurrence, accumulation, and biological effects. *Science of the Total Environment, Science of the Total Environment, 703, 134699.*
Yeasmin, F., & Tasnime, Z. (2020). Impact of Healthcare Related Plastic Waste Towards Sustainable Environment During Covid 19 Outbreak: Prospect of Bangladesh. *SSRG International Journal of Agriculture and Environmental Science, 7*(6), 33-37.