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Application of short and rapid strategic environmental assessment (SEA) for biomedical waste management in Bangladesh

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ABSTRACT

In this study a rapid and short Strategic environmental assessment (SEA) conducted to find the existing policy and legal gaps of biomedical waste management regulations during the COVID-19.15 Key Informant Interviews (KIIs) were taken from the regulatory bodies, public and private medical college hospitals, corporations, civil societies, and the third-party organization involved in medical waste management. A DPSIR framework and SWOT analysis shows that the existing biomedical waste management suffers from institutional conflicts, lack of monitoring, and environmental regulations. The revised rules must be implementable with "3-R policy", and "polluter pays principle," and environmental impact assessment guided by SEA.

1. Introduction

It is nearly two years COVID-19 pandemic-borne biomedical wastes are causing a global threat to humans and the environment. In developing countries like Bangladesh, managing organizations struggle with limited resources for biomedical waste treatment (Shammi et al., 2020; [1]. Biomedical waste management in Bangladesh is struggling with limited resources such as land, energy, and limited finances. In addition, biomedical waste treatment facilities include functional transfer stations, transfer vehicles, and incinerators in the hospitals and clinics, which are also notable. Furthermore, a trained workforce and operators of biomedical waste management in Bangladesh can also be considered a limitation. A recently published article informed that COVID-19 medical wastes from patients were 658.08 tons in March 2020, which had increased to 16,164.74 tons in April 2021 [1]. The biomedical waste generation rate before the Covid-19 pandemic from the hospitals in Bangladesh ranged from 1.63 kg/day/bed to 1.99kg/day/bed for the rural and urban areas, which escalated during the COVID-19 significantly [2]. The rising uses of personal protective equipment (PPE), testing kits, surgical facemasks, and nitrile gloves contribute significantly to the new biomedical waste volume trend [3–5].

Bangladesh is a small country with a massive population of 166.68 million people [6]. The poor biomedical waste management in Bangladesh is one of the significant sources of environmental pollution. Since early 2020, the quick spreading of COVID-19 across Bangladesh has increased PPEs in the healthcare sector and everyday life of concern Bangladeshis for their protection. However, unprecedented uses of PPEs have increased biomedical wastes from healthcare centers and home users, leading to a secondary environmental catastrophe (Shammi & Tareq 2020). Biomedical waste management is essential for accomplishing clean water, sanitation, and sustainable cities and communities. Yet biomedical waste management is one of the neglected sectors in Bangladesh that requires special attention. In addition, the COVID-19 pandemic has put an urgency on the unique needs of biomedical waste management in the country. Yet, the environmental disposal of biomedical waste increased by several factors, which had no studies to date.

Biomedical waste management requires special attention and a

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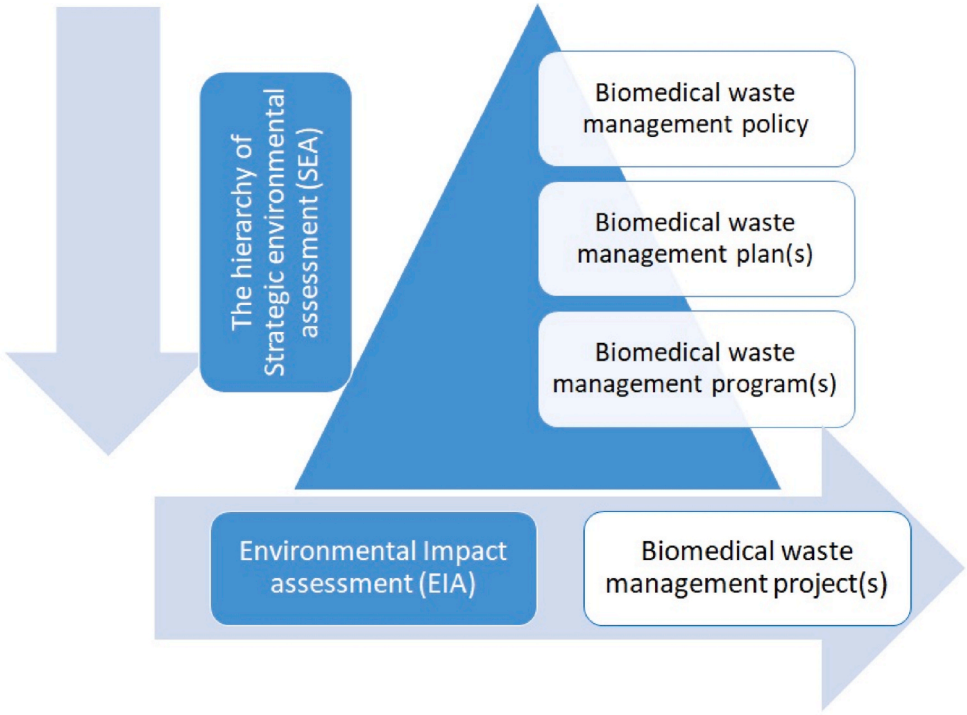

Fig. 1. The application of Strategic Environmental Assessment (SEA) in the decision-making hierarchy of policy, plans, programs (PPPs), and the application of Environmental Impact assessment at the project level of biomedical waste management.

paradigm shift at the policy level to reform the existing decision-making policies strategically, significantly, and practically [2]. For the biomedical waste management PPE, masks, gloves, and shields, and other infectious waste requires modernized management in a country like Bangladesh, which includes a modification and transformation of the general policies, plans, and programs (PPPs) as well as guidelines [7]. National institutions and legislations involved in biomedical waste management and other stakeholders essentially deliver the basic structure for implementing biomedical waste management policies, plans, and programs. It means strategic actions are required for biomedical waste management guided by proper decision-making approaches at the policy, plans, and program level.

The hierarchy of decision-making usually comprises PPPs, rules, and guidelines followed by individual projects [8]. PPPs are more 'strategic' than projects as they decide the overall course or strategy with specific objectives. In recent decades, growing importance has been placed on the SEA rather than its original roots of environmental impact assessment (EIA) [9]. SEA is extensively employed as a policymaking tool to help decision-makers make effective decisions to curtail negative environmental impacts on a broader scale [10]. SEA facilitates tactical ideas that enable problem-solving ability and shifts for sustainable development [9]. Since the introduction of SEA in the 1980s, its application has

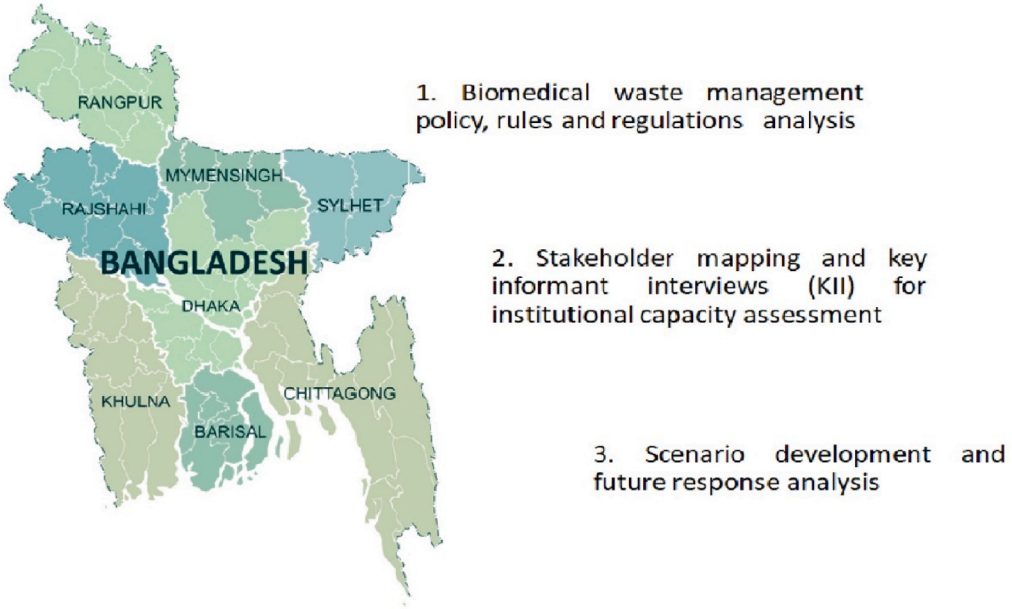

Fig. 2. Methodology of applying SEA in Biomedical waste management in Bangladesh.

grown worldwide to support PPP implementation [11]. SEA is a practical tool for the PPPs model to develop an integrated method for a sustainable society and a way forward to achieve the sustainable development goals (SDGs) [12]. SEA provides environmental and socio-economic knowledge generation and stakeholder forums to debate in a well-structured democratic discussion on these topics comprising governmental representatives, NGOs, and civil societies. A broad range of alternatives is considered considering scenarios, growth, and different trajectories, and a framework to examine the effects of evaluation and assessment to the government and the administration. SEA extends to decision-making changes as the hierarchy from policy to projects changes for biomedical waste management. So does the quality of environmental and socio-economic assessment need (Fig. 1) using a range of appraisal methods.

Moreover, a lack of suitable PPPs has been observed in Bangladesh's municipal and biomedical healthcare waste management. There have been limited SEA experiences in Bangladesh. Following a growing number of countries in the Asian region, Bangladesh adopted SEA legislation in the Environmental Policy (GoB, 2018) and 7th 5-year plan [13]. Some SEA-related initiatives that have been undertaken are "Policies for Mainstreaming SEA in the Urban Development of Greater Dhaka (2008)" [14], SEA study of Dhaka City Urban Resilience Project 2019 [15], the Bangladesh Water Development Board (BWDB) conducted a Strategic Environmental and Social Assessment (SESA) of the River Stabilization Plan under the Flood and Riverbank Erosion Risk Management Investment Program [16], ongoing SEA of South West Region and the Sundarbans [17] etc. In addition, a lack of literature regarding policy formulation of biomedical waste management has also been observed. Therefore, a SEA application for biomedical waste management is crucial for Bangladesh. So, this research article is playing a pilot role in raising awareness of the SEA process and its methodology in biomedical waste management to stimulate its broader uptake in Bangladesh for the first time. The specific objective of the present article focuses on facilitating informed decision-making regarding transitioning towards a sustainable, resilient, and resource-efficient economy to develop alternative response strategies to minimize direct/indirect environmental effects of biomedical waste management in Bangladesh.

2. Methodology and framework development

This article focused on applying a short and rapid Strategic Environmental Assessment (SEA) for biomedical waste management in Bangladesh. Since there are no institutional guidelines on SEA conducting in Bangladesh except the mentioned terms in the Bangladesh National Environmental Policy, the following methodological framework for the SEA study of biomedical waste management was applied (Fig. 2). In the study framework includes i) review of existing biomedical waste management legislation and policies, ii) Stakeholder analysis and Key informant interviews (KII) for institutional capacity and gap analysis, and iii) Scenario development for biomedical waste management and analysis followed by future suggestions on biomedical waste management.

2.1. Legislations and existing policy review

Existing biomedical waste management and associated PPPs and projects of Bangladesh were reviewed. Significant environmental or socio-economic impacts of the PPPs and projects for both the public and private sectors were analyzed in terms of implementation. In addition, relevant scientific literature on biomedical waste management published specifically from Bangladesh perspective from 2019 to 2021 were also reviewed.

2.2. Stakeholder mapping and key informant interviews (KII)

Stakeholder identification and institutional capacity analysis are effective methods of SEA study [18]. Significant stakeholders in biomedical waste management in Bangladesh were mapped in this phase. Three important stakeholders are DGHS (Directorate General of Health Services under the Ministry of Health and Family Welfare), DoE (Department of Environment under the Ministry of Environment, Forest, and Climate change), the city corporations. The fourth major stakeholder is the third-party organizations (usually NGOs) responsible for managing biomedical waste. Under the 2008 rules, the organization must be licensed by the Department of Environment (DoE), the government body responsible for environmental PPPs and environmental management. PRISM Bangladesh is an NGO responsible for biomedical waste management in Dhaka and other major city corporations as a third-party organization. The institutional capacities and lackings in biomedical waste management following KIIs were analyzed by a set of KII questionnaires (Table 1). The interviewees were contacted from the government ministries, city corporations, medical colleges, universities to INGOs, and third parties responsible for biomedical waste management in Bangladesh. Due to the pandemic, the respondents were interviewed by phone calls and emails.

Table 1
Key informant interview (KII) questionnaire.

1	Do you think that COVID-19 has created more pressure on the existing biomedical waste management system in Bangladesh?
2	Do you think the waste generation and treatment/management facility is in a balanced condition?
3	Do you think that COVID-19 related biomedical waste will increase the amount of hazardous waste both in households and healthcare facilities?
4	Do you think there is a public health risk if these biomedical wastes are not managed properly? How?
5	What are the gaps you see in healthcare waste management in the time of COVID-19?
6	What can be done to manage the escalating amount of biomedical wastes in a pandemic situation?
7	What are the challenges you think in terms of biomedical wastes management in Bangladesh?
8	How has COVID-19 created more pressure on the existing biomedical waste management capacity?
9	What's needs to be updated in biomedical waste management considering the COVID-19 situation?
10	What technologies can be introduced for managing the escalating biomedical waste considering environmental safety?
11	What can be done to increase the capacity for managing biomedical waste in Bangladesh?
12	How can we ensure the occupational safety of the waste handlers?
13	What are the scopes you see in the medical waste management sector?
14	Any other suggestions related to biomedical waste management in Bangladesh.

Based on the responses of KIIs, a SWOT analysis (Strengths- Weakness- Opportunities- Threats) was prepared (Fig. 3), which is a frequently applied device for strategic planning and is conventionally outcomes in the shape of brainstorming [19]. Strengths and opportunities are seen as helpful for organization/legislation, while weaknesses and threats are harmful. Moreover, strengths and weaknesses are of internal origin, while opportunities and threats are of external origin.

2.3. Scenario development and analysis

Scenario analysis is a flexible group process that encourages knowledge exchange and develops a mutual understanding of central issues relevant to sustainable development. The purpose of scenario planning is to look at each plausible future scenario and examine how prepared the government, the private sector, and civil society are for biomedical waste management. It would further check how robust PPPs on biomedical waste management can potentially change and bring environmental sustainability. The scenario is led by a "driving forces–pressures – state – impact – response" (DPSIR) framework developed by the OECD [20] (Fig. 4). DPSIR framework is an easy method for assessing PPPs' developmental impacts and projects [21]. In addition, it also helps us identify the linkages and interconnectedness for the

Biomedical waste management	Helpful	Harmful
Internal Origin	Strengths in institutional capacities for Biomedical waste management	Weakness in institutional capacities for Biomedical waste management
External Origin	Opportunities for the institutions in Biomedical waste management from external collaboration	Threats for the institutions in Biomedical waste management from external sources

Fig. 3. SWOT analysis framework of institutional capacity assessment of the organizations involved in biomedical waste management in Bangladesh.

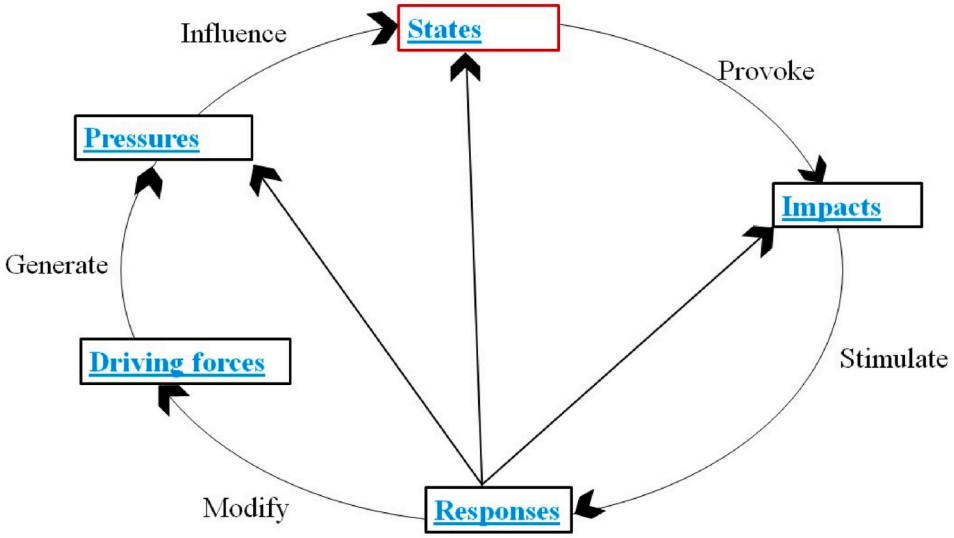

Fig. 4. DPSIR framework (modified and redrawn after [20].

strategic environmental assessments.

3. Results and discussion

3.1. Legislation and policy review regarding biomedical waste management

Safe and accurate biomedical waste management is a legal necessity for any country. Practical biomedical waste management requires formulating policies, plans, and programs (PPPs) that Bangladesh lacks. The first legislation regarding biomedical waste management of Bangladesh was promulgated in 2008. The rule is "Bangladesh Medical Waste (Management and Processing) Rules 2008" [22] in compliance with the Bangladesh Environmental Conservation Act (1995) (Amended in 2010) provides the legal basis for Environment Conservation Rules, 1997 (ECR′97) [23]. The rules suffered from a lack of implementation due to inter-ministerial conflicts and the competing nature of the authorities. Due to the competing nature of the authorities, the national advisory committee was never formed even after 13 years. The roles and responsibilities of the government bodies such as DoE (Department of Environment under the Ministry of Environment, Forest, and Climate change), DGHS (Directorate General of Health Services under the Ministry of Health and Family Welfare), and Dhaka north and south City corporations (DNCC/DSCC) who are responsible for municipal solid waste management as well as oversee medical wastes were not defined in the rules of 2008.

A disordered divisional committee was proposed in the rules of 2008. Moreover, the roles of local government authorities such as the Ministry of Local Government, Rural Development, and Cooperatives (LGRD) and the Local Government Engineering Department (LGED) at the divisional level were missed entirely. The division level Authorities with the authorization of granting licenses have never been established. Therefore, the third parties operating at the divisional levels are without license and usually without monitoring and accountability.

Table 2
The legislative scenario of Biomedical waste management in Bangladesh.

Legislation	Formulated year	Main focus	References	Status of implementation
Rules and responses relevant to biomedical waste management in Bangladesh by the Ministry of Health and Family Welfare (MHFW)				
Bangladesh Medical Waste Management and Processing Rules 2008	2008	✓ Implementation of the rules just remained as paperwork. ✓ The rules focused on source segregation based on color-coding and only discussed hospital waste disposal. ✓ The regulations' major highlights included establishing divisional authorities and a divisional dumping ground for Bangladesh's eight divisions. ✓ The divisional authorities have not yet been established even after 13 years. ✓ There are no guidelines on the treatment and management of biomedical waste management mentioned. ✓ Complex incomprehensible pictograms for understanding ✓ Unregulated, third-party dominated waste management without a license at the divisional level. ✓ Biomedical waste management workers usually do not receive any occupational health and safety training. ✓ EIA ignored for dumping, incineration and landfill burial of biomedical wastes	[22]	Not implemented due to competing authorities
National Preparedness and Response Plan for COVID-19	March 2020	✓ This plan only focused on waste generated from the laboratory activities such as sample collection, transportation, sample preparation, and test procedures according to the WHO biosafety level 2 guideline. ✓ There is no mention of the household level generation of biomedical wastes and how to collect and treat it. ✓ There is no update on vaccine related waste management	[24]	Partly implemented
Rules and responses relevant to biomedical waste management in Bangladesh by the Department of Environment (DoE/MoEFCC)				
Bangladesh Environmental conservation Rules	1997	✓ Implemented for industrial waste management but not for hospital and clinical biomedical waste management ✓ "Polluter Pays Principle" is not implemented in the case of public and private hospitals. ✓ EIA and SIA were not conducted, and subsequently, EMP ignored	[25]	Rules require an update regarding biomedical waste management and air emissions
Bangladesh National Environmental Policy	2018	✓ Section 3.6 (page 9) Public Health and Health Services ✓ Section 3.6.9–3.6.11 gives direction on the color-coding of waste generated and the amount of waste generation for each code. The hospital and clinic authority should keep a register for each color-code generated wastes ✓ The hospital and clinic authority should carry all the expenses of safe waste transportation and treatment ✓ The concept of 3-R (reduce, reuse and recycle) and least waste generation to be implemented where possible ✓ All the hospitals and clinics must ensure management and treatment of all kinds of waste generated, including biomedical waste management ✓ "Polluter Pays Principle" is not implemented in the public and private hospitals.	[23]	Not implemented by the Ministry of Health and Family welfare

Besides, a complex color-coding of biomedical wastes is another factor that caused the non-application of the rules. The hazard symbols and pictograms used are a mix-up of globally harmonized systems (GHS), non-GHS symbols, and UN transportation systems. The management system was primarily landfill-dominated [22], which needs to be updated in the latest 3-R policy of waste reduction and national environmental policy of 2018.

In March 2020, during the beginning of the COVID-19 pandemic, MHFW prepared a "National Preparedness and Response Plan for COVID-19" [24]. This plan also suffers from proper implementation as it did not mention household-level management of biomedical wastes, which the agency would collect and manage. However, an extensive revision is required for "Bangladesh Medical Waste Management and Processing Rules 2008″ and "National Preparedness and Response Plan for COVID-19." Specific consideration should be given for incinerator emission is required for particulate matters, ash disposal, and heavy metal such as mercury management. Establishing environmental treatment plants (ETP) is needed for extensive healthcare facilities, both public and private, which must be addressed. Water quality should be treated and monitored before discharging in the public sewer system. Radioactive substances such as discarded equipment and waste from diagnostics centers and health care facilities should have special consideration and should not be sent into the designated landfill. A routine environmental impact assessment (EIA) or social impact assessment (SIA) should be done before deep-burial and geological and environmental settings should be considered. Accordingly, a better environmental management plan (EMP) should be prepared for biomedical waste management. However, the provision of EIA was ignored entirely in 2008 rules which is an essential section of the Bangladesh environmental conservation rules 1997 (Table 2).

Furthermore, establishing standard biomedical waste management facilities requires training and awareness-raising in the Upazilas and remote villages, a big challenge that was never overcome in the past 13 years. The rules of 2008 are mainly third-party-dominated biomedical waste management systems that suffer integration in the governmental ministries in monitoring and supervision. Because of these lackings, during the COVID-19 pandemic in Bangladesh, 7684.60 tons of hazardous biomedical wastes were generated from March 2020 to November 2020 (IPEN 2021). In addition, biomedical waste operators and staffs at the healthcare facilities are usually temporary recruitments, and they do not receive any training on occupational health and safety-related to the handling of biomedical wastes.

Table 3
Identification of institutional gaps of biomedical waste management.

Criteria for assessment	Current biomedical waste management scenario	Problems	Statement	Recommended future Management strategies
✓ Management Capacity development	✓ Twenty-five tons of biomedical waste per day can be managed in Dhaka, developed by PRISM Bangladesh.	✓ Poor coordination among the ministries and the government departments	✓ Waste management disposal projects are being developed by the Ministry of Environment Forest and Climate Change and the Ministry of Health and Family welfare.	✓ DoE has a critical role in controlling the open dumping of medical wastes. ✓ Law enforcement has to be more cooperative.
✓ Implementation of Bangladesh Medical Waste Management and Processing Rules 2008	✓ Not implemented		✓ City corporations do not have lands for disposal and filling.	✓ It should be updated to incorporate proper treatment methods and technological advancements.
✓ Bangladesh National Environmental Policy 2018 section 3.6 on Public Health and Health Services	✓ Not implemented			✓ Inter-ministerial coordination is required to manage biomedical wastes.
✓ Budget	✓ Limited budget	✓ The government only discharges the budget twice yearly for medical waste management purposes for public hospitals.	✓ Private hospitals are more willing to pay PRISM than government hospitals.	✓ Budget allocation is a must to improve the waste management and incineration system.
	✓ Management costs and incineration costs	✓ Costs of biomedical waste management remained the same, but the incineration costs increased due to the less capability to treat PPE.	✓ Public hospitals have institutional and bureaucratic lengthiness in budget release	✓ Install a decent capacity incinerator is mandatory to manage PPE wastes and filter the smoke.
✓ Corruption	✓ Poor documentation	✓ Documentation of waste generation in government hospitals is abysmal	✓ The government hospital cleaners sell used saline bottles, tubes, syringes, etc., in the market.	✓ Proper documentation and inspection of waste generation are required.
	✓ Distinguishing COVID-19 biomedical waste management	✓ The trash bags are not distinguishable, which means the color coding is not used	✓ All kinds of wastes, including PPE, are put into incinerators. ✓ 3-R policy hardly implemented	✓ Implementation of biomedical waste management rules of 2008 on the color-coding scheme is a must. ✓ Update and optimization of the rules are a must.
✓ Household medical waste	✓ Household medical waste gloves, masks, and PPE are usually mixed up with the solid wastes	✓ Distinguish biomedical waste from solid waste. ✓ Unaware citizens. ✓ Absence of data.	✓ The masks/gloves that are being thrown away from the households are not treated separately from the city corporation waste and usually go to landfill	✓ City Corporation should act proactively and thoroughly at the domestic level PPE disposal. ✓ DNCC and DSCC should handover the waste to PRISM
✓ Technological assessments	✓ Limited incineration capacity ✓ Landfilling ✓ Open burning	✓ Often dysfunctional ✓ Particulate matters in the air emission ✓ Ash management ✓ Heavy metal in the ash	✓ Technology choice of incineration ✓ lacking environmental standards	✓ Upgrade to efficient incinerator technology such as Moving Grate, Static Hearth, Furnace and Multiple Hearth, Rotary Kiln, and Fluidized Bed type incinerators with scrubbers.
✓ Untapped areas	✓ Open dumping zones in rural areas	✓ No biomedical waste management strategy applies. ✓ Absence of data.	✓ City corporations are being established across the country, but there are rural unions that are untapped.	✓ Open dumping zone in front of Upazila health complex must be controlled and taken under strict waste management. ✓ Integration with the Ministry of Local Government, Rural Development and Cooperatives (LGRD) and the Local government and engineering department (LGED) might be helpful for biomedical waste management in rural areas.

3.2. Environmental legislation and policy regarding biomedical waste management

In compliance with the Bangladesh Environmental Conservation Act (1995), Bangladesh devised Environmental Conservation Rules (ECR) [25] regarding environmental management of industrial and other wastes. However, the rules of 1997 also suffer from applicable sections regarding biomedical waste management, standard air emission criterion for incinerators, and standard criterion for landfilling. The rules require the addition of the requirements of biomedical waste management. The latest Environmental policy of 2018 clearly instructs the color-coding of waste generated and the amount of waste generation for each hospital code. It further urged the hospitals and clinic authorities to register each color-code-generated waste and carry all the safe waste transportation, treatment, and biomedical waste management expenses. Likewise, the concept of 3-R (reduce, reuse, and recycle) and least waste generation was suggested to implement where possible [23].

Moreover, both BECR 1997 and National environmental policy (2018) emphasized on “polluter pays principle,” which means that the polluting entity would bear the cost of pollution. In Table 2, the existing and updated biomedical waste management policies, rules, and regulations in Bangladesh are shown. It explains the current environmental policies, regulations, and guidelines indirectly relevant to biomedical waste management. Unfortunately, the “polluter pays principle” policy and rules were never implemented due to institutional conflicts and policy ownership.

3.3. Stakeholder analysis and institutional capacity assessment

Although the hospital authorities are aware of biomedical waste generation, most of them are unaware of the management of waste generation before COVID-19 and during the ongoing COVID-19 pandemic. For the criteria of institutional capacity assessment, five key points of biomedical waste management were picked: capacity development, implementation of Bangladesh Medical Waste Management and Processing Rules 2008, implementation of Bangladesh National Environmental Policy 2018 section 3.6 on Public Health and Health Services, budget allocation. In addition, other minor but important issues such as institutional corruption, household medical waste management, technological assessment and untapped rural areas must be addressed for proper biomedical waste management practices (Table 3).

This KII survey found that despite the ongoing COVID-19 pandemic, dumping biomedical waste into the community dustbin, open burning, and handing over the waste to the municipal authority. However, there is often a biomedical waste management system such as incinerators in large public medical hospitals. Yet, frequently the incinerators are not functional, and the waste is dumped into the community dustbins. If there is no third-party contact for handing over biomedical wastes, it is dumped into the community bins together with household wastes. The biomedical wastes are then disposed of in the city landfills. The method of biomedical waste management in rural districts is nonexistent. [26]; revealed that the disposal practices of the hospital solid waste were environmentally unsustainable.

City corporation authorities (DNCC and DSCC) collect household solid wastes. Unfortunately, citizens mix up biomedical waste with solid waste due to unawareness. The masks/gloves thrown away from the households are not treated separately from the city corporation waste and usually go to landfill. For many rural districts, despite the presence of city corporations, data on waste generation and management are not available.

The three major ministerial stakeholders further reveal that proper training, awareness, and motivation are necessary for biomedical waste management at public, private, and rural medical centers. Besides, budget, trained personnel, transportation, and reducing corruption are significant factors in implementing proper biomedical waste management in Bangladesh. According to all three stakeholders, institutional capacity building, a sufficiently trained workforce, awareness building among patients and health care providers, and financial incentives are essential to improving institutional capacity. A recent study [26] informed that at public hospitals, 20.4% of the doctors and 6% of the nurses had occupational illnesses despite wearing PPEs. On the contrary, 36% of the doctors and 26.5% of the nurses had occupational diseases in the private hospitals. At the public hospital, 67.8% of the nurses wore PPE during waste collection, compared to 17.7% in the private hospital. Furthermore, public and private medical hospitals in the major city areas did not adequately deal with biomedical wastes and occupational safety.

PRISM Bangladesh is a third-party organization that provides waste management services to all the public and private available medical and health care centers in Dhaka with 100% coverage. PRISM is the only organization that provides certification of having a medical waste management system in the hospitals. The organization has 11 waste-collecting covered vans that can cover up to 20 tons with its current setup and the surroundings of Dhaka city. Compared to the per day generation 15 tons/day in 2014, it is 18–19 tons/day in 2020 before COVID-19 infection started. According to the audio interview, medical waste has increased over the years. From a developed city Victoria, Australia, it was estimated that the daily generations of face masks used during the first and second pandemic waves were approximately 104 and 160 tons [27]. During the COVID-19 infection period, all the COVID19 testing centers produced nearly 7 tons/day of COVID19 related medical waste only in Dhaka, including isolation centers and public and private hospitals. In Table 2, we have shown the criteria for biomedical waste management practice along with the problems and status and recommended future management strategies identified from the KII.

Table 4
SWOT analysis of current biomedical waste management practice in Bangladesh.

	Helpful	Harmful
Internal Origin	**Strengths in institutional capacities** 1. Presence of biomedical waste management policies and rules [22] 2. Presence of environmental policy addressing biomedical waste management [23] 3. Presence of governmental and non-governmental institutions responsible for biomedical waste management such as DNCC/DSCC and PRISM	**Weakness in institutional capacities** 1. An integrated sound policy of biomedical waste management is absent, along with the strict implications of the law 2. Outdated biomedical waste management rules that require modernization 3. Clauses, pictograms are incomprehensible 4. National monitoring and inter-ministerial coordination are absent for biomedical waste management. 5. Absence of a proper biomedical waste management treatment system, along with a lack of funds to procure a modern waste management system and budget constraints 6. Institutional conflicts and carelessness 7. Lack of supervision and monitoring for third-parties 8. Non-inclusion of local government authorities 9. Transparency
External Origin	**Opportunities** 1. Private investment would be more helpful with govt compensation. 2. Integration of the stakeholder ministries regarding PPPs implementation 3. Extension of biomedical waste management in rural areas by integrating LGED and LGRD. 4. Privatised supply chain on biomedical waste management in the country. 5. Entry of more biomedical waste management players (private companies) with standardization (such as ISO 9001, 14001, and 45001) development 6. Private biomedical waste management companies can be turned into service-oriented companies.	**Threats** 1. Government-backed medical waste management may not be helpful in the long run. 2. Implementation and enforcement of the existing policies are required and may remain red-tapped unless taken proper action 3. Biomedical waste management throughout the country may be limited only to megacities 4. A monopoly market of biomedical waste management

3.4. SWOT analysis for strategic biomedical waste management

SWOT analysis is a robust method for assessing the strengths and weaknesses of an organization with an inside viewpoint [28]. The approach also considers the opportunities and the threats from an outside perspective from the biomedical waste management managing organizations. These characteristics of SWOT is a frequently employed methodology in strategic management [28]. Significant gaps and management strategies at the institutional level have been identified for biomedical waste management in Bangladesh.

There are legislations regarding biomedical waste management in

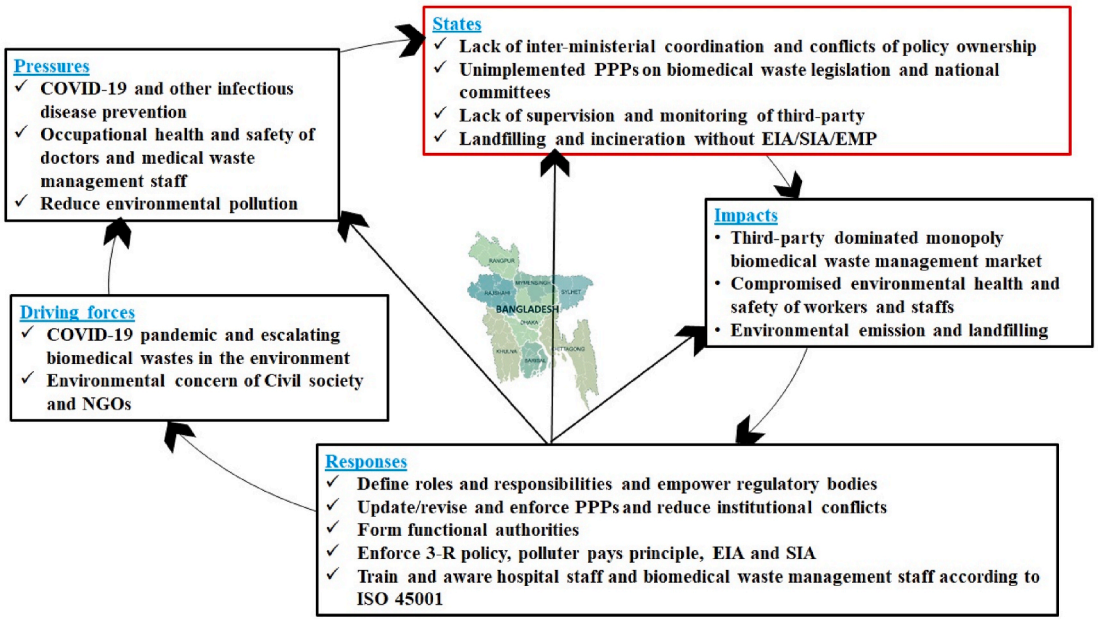

Fig. 5. DPSIR framework of biomedical waste management in Bangladesh.

Bangladesh, which is a tremendous strength and helpful for institutional capacity building for DGHS and DoE. In addition, there are city corporation authorities and private NGOs responsible for biomedical waste management. However, the weaknesses in the institutional capacities are tremendous, which included a revision of the legislation, particularly of the rules, reducing institutional conflicts by defining roles and responsibilities. The technological constraints and institutional corruption should be reduced by lessening bureaucratic processes.

Regarding opportunities for biomedical waste management, more private investment and supply chain development is possible for biomedical waste management. Integration of other stakeholder ministries is also possible, particularly the engagement of The Ministry of Local Government, Rural Development and Cooperatives (LGRD), Local Government Engineering Department (LGED) in the rural areas for biomedical waste management. By following standardization such as ISO 9001, 14001, and 4500, private companies can be turned into service-oriented companies. The following possibilities are considered regarding threat minimization: implementation and enforcement of the existing and revised policies are required, and if the institutional conflicts are not reduced, they would remain red-tapped. If the rural areas are not considered, biomedical waste management may be limited only to megacities. More private investments are required to reduce a monopoly market of biomedical waste management. In Table 4, we have analyzed SWOT from the current biomedical waste management practices in institutional capacity.

3.5. *Strategic responses of biomedical waste management*

The driving forces – pressures – state – impact - response (DPSIR) model has been effectively applied in many sustainable waste management strategies and circular economies around the world as well as in the strategic environmental assessment of PPPs. DPSIR model is the most conventional technique for informing the link between ecological causes and the effects of any problems [29]. DPSIR framework comes with some boundaries, including its failure to suggest non-linear linkages, incapacity to take into account natural drivers of environmental changes, and inability to clarify new signs of progress or trends unless studied with frequent intervals [21]. The KII summary of the responses is shown using a DPSIR framework. DPSIR framework developed by the OECD is used to understand some of the critical environmental issues facing unmanaged biomedical wastes from the COVID-19 (Fig. 5).

The COVID-19 pandemic, infectious disease prevention, and environmental concern of civil societies and NGOs have been driving for managing biomedical waste in Bangladesh. Several international NGOs such as [30,31] have identified the increasing biomedical waste and plastic waste generation increased manifold during the pandemic, which remained unmanaged. The environmental catastrophe of biomedical wastes, such as microplastic pollution in the environment, was predicted [7]. However, many countries and global organizations have revised and updated their legislation according to the waves of the COVID-19 pandemic [32,33]. India's Central Pollution Control Board revised its medical waste management policy and guidelines several times [7,34]. Yet the status of existing biomedical waste management rules 2008 was not implemented, while the department of environment (MoEFCC) and DGHS (MHFW) did not update or revise legislation.

The inactive status of biomedical waste management legislation in Bangladesh was identified as a lack of inter-ministerial coordination, conflicts of policy ownership, lack of awareness, supervision, and monitoring by the ministerial agencies. These conflicts lead to the impact of third-party-dominated monopoly biomedical waste management market, compromised environmental health and safety of workers and staff, and environmental emission and landfilling of biomedical wastes [7,35]. The strategic responses that we found were defining roles and responsibilities, empowering regulatory bodies, updating/-revising/enforcing PPPs, reducing institutional conflicts, and enforcing 3-R policy; the polluter pays principle. Introducing state-of-the-art incineration technology is essential to reduce the emission problem and sustainably manage biomedical waste in the present and future waste generation scenario. Moreover, to standardize government and private organizations involved in biomedical waste management, staff and employees should be trained on occupational health and safety according to ISO 45001. The respective authority must maintain a safe waste disposal system to save the environment and protect public health from impending health threats. Implications of sound policy and strict monitoring are required and the formation of a national committee for better coordination. In addition, appropriate training of hospitals, doctors, nurses, technicians, hospital cleaners, and waste management staff should be given emphasis. Moreover, a proper medical waste treatment plant, including incinerators which is a limitation of biomedical waste management across the country, should be ensured for all divisional

hospitals. Moreover, proper environmental impact assessment for all medical waste treatment facilities, including incinerators and sanitary landfills, is also recommended.

4. Concluding remarks

Bangladesh is a developing country where the application of SEA in policy plans and programs is still minimal. Moreover, environmental rules, regulations, and guidelines often have been prepared with limited research and consequence analysis. The practical applicability of the rules and regulations often remains paperwork. In Bangladesh, biomedical waste management rules is an example that has been formulated without proper policy, plans, and program. Due to the inter-ministerial conflicts, ownership, and complex nature, the country's biomedical waste management rules were never implemented. The responses obtained and identified for biomedical waste management of Bangladesh would be helpful for the ongoing COVID-19 pandemic-related biomedical waste management and even after the normalization period. The responses from the DPSIR framework and SWOT analysis are beneficial for ministerial agencies, policymakers, and local authorities to take practical actions related to the revisions of the existing biomedical waste management rules and implement them. It is evident that revising existing rules is time demanding, along with a separate biomedical waste management policy, plans, and programs in Bangladesh's 2nd perspective plans of 2041. The notable responses are reducing institutional conflicts, forming functional authorities, ensuring transparency, and enforcing 3-R policy and Polluter Pays Principle policy. In addition, biomedical waste management research and developments require data to ensure sustainable technological management in biomedical waste. Biomedical waste management projects involving incinerators, land-filling require EIA of projects guided by SEA of PPPs.

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Declaration of competing interest

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