**Inadequate Wastewater Management in Dhaka's Major Hospitals: A Socio-Technical Systems Analysis of Leadership, Policy, and Technological Challenges**

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S2 Table: Summary of KII based on the STS components

| **STS components** | **KII results** |
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| Policies and regulations | Document review: The recent MoHFW guidelines did not provide clear instructions on how different types of liquid waste should be managed or the standards they should meet before being discharged into the environment or community drainage systems (MoHFW, 2019b; MoHFW, 2022)  Hospital directors: *“Our top priorities are patient treatment and recovery from diseases. Instances of patient death due to medical negligence gain national-level media attention. However, wastewater treatment doesn't receive the same level of priority from both media coverage and the hospital authority.” (Director, H1)*  PWD engineers: One engineer from government hospital stated *"The manpower shortage is caused because of a recent policy change by the ministry. We cannot keep permanent workers anymore (for repair and maintenance of the hospital), we have to outsource the workers from other organizations. We have some gaps outsourcing people currently and this requiring time*" (Engineer, H7).  Hospital staff: Many ward masters (7 out of 10) pointed out that delays in tank emptying or the repair of major structures were attributed to the delayed response from the PWD office. One of the ward-masters from hospital H5 stated, “*Whenever there was any breakage or overflow of the septic tank, we immediately informed the PWD office. We hardly get an immediate response from the PWD office, and it took a long time to resolve the issue. Sometimes it took several months.*" |
| People | Document review: A total of 30 interviews were conducted, encompassing individual interviews held in thirteen hospitals in Dhaka city. These participants comprised seven engineers, 10 cleaners, and 13 ward masters. Among the 30 respondents, nine recruited from private hospitals, while 21 were selected from the government hospitals.  Hospital directors: When asked about their priorities concerning hospital fecal sludge and liquid waste management, most (9 out of 12) directors noted that their primary focus is on patient care, maintaining essential equipment, and ensuring the safety of both staff and patients. One director emphasized, *“Hospitals are faced with numerous administrative challenges daily, often constrained by limited resources. Recently, we acquired expensive (medical) equipment, but due to inadequate space, installation has become an issue. If not resolved promptly, these machines may malfunction.”*  PWD engineers: Four PWD engineers agreed that they have a shortage of manpower and due to the lack of manpower, the services were delayed. One engineer from government hospital stated *"The manpower shortage is caused because of a recent policy change by the ministry. We cannot keep permanent workers anymore (for repair and maintenance of the hospital), we have to outsource the workers from other organizations. We have some gaps outsourcing people currently and this require time*" (Engineer, H7).  Hospital staff: Hospital staff, particularly cleaners and ward masters, had a very limited or no understanding of the types of hospital liquid waste generated, how it is discharged from the hospital to the community, and how it is treated. Among the 23 staff members (ward masters and cleaners) interviewed, none could describe how biomedical liquid waste is managed in the hospital. Similarly, among the seven PWD engineers, nearly all stated that managing biomedical waste is not their responsibility; they are primarily tasked with treating HWW and fecal sludge. |
| Leadership and management procedure | Document review: The MoHFW is responsible for managing the overall WASH in HCFs (WHO, 2019a). Many hospitals in Bangladesh have dedicated WASH committees comprising healthcare professionals, administrators, and support staff. These committees are responsible for planning, implementing, and monitoring WASH activities in HCFs.  Hospital directors: The management of HWW differs significantly between government and private hospitals. In private hospitals, decision-making is streamlined, allowing hospital directors, in consultation with on-site engineers, to quickly allocate funds and approve procurement. Simpler procurement policies and the presence of engineers on-site enable faster responses to emergencies and more effective maintenance of wastewater systems. However, government hospitals operate within a more bureaucratic framework overseen by the MoHFW and the PWD. While each government hospital has an assigned PWD engineer, these engineers may not always be on-site, instead working from local or regional offices, which leads to slower communication and response times. Additionally, the procurement of materials and the hiring of workers must follow strict public procurement procedures, causing further delays. To improve wastewater management in government hospitals, reforms are needed to streamline decision-making processes, decentralize certain powers, and revise procurement policies to allow quicker responses to maintenance and repair needs [1, 2].  PWD engineers: Most of the engineers (five out of seven) were not aware of the microbial efficacy of the treatment system used in the hospitals. When asked about the performance of the septic tank, the engineer at a specialized hospital (H5) mentioned that the septic tank is operating well, and he is satisfied with its efficacy. When questioned about how he tested the efficacy of the wastewater treatment system and whether there is any periodic testing done to assess the effluent quality before discharging, the engineer responded that there was no facility to test the samples in the laboratory. The engineer also acknowledged that, to assess the efficacy of the treatment plant, they need to test the effluent in the laboratory for pathogen removal. "*The septic tank here is operating well. However, if the water is tested, it is possible to know its results like the amount of water it can purify or the amount it cannot”* (Engineer, H5).  Hospital staff: Six key areas of responsibility likely to define the role of ward managers: general performance/quality issues, people management/HRM, planning and scheduling of work, managing operational costs, dealing with clinical work and communication outside the immediate team [3]. Typically, cleaners operate under the supervision of a ward master or nurse [4]. Discharging wastewater/liquid waste without proper treatment is common in hospitals in Dhaka city. This practice is also acceptable among hospital managers (ward masters) and cleaners because lack of knowledge on health and environmental impacts of HWW. Most ward masters (11 out of 13) lacked awareness about the discharge details, such as the type, volume, and pathways of liquid waste from their own hospital. One ward master stated, *"I am not sure how the liquid waste flows from the hospital to the environment, but we have a good treatment system (i.e., septic tank) with the capacity to treat all liquid waste." (Ward master, H5)* The same ward master also mentioned that the septic tanks have not been emptied for the last five years. |
| Cultural norms | Document review: The National Strategy for WASH in Healthcare Facilities 2019-2023 emphasizes solid waste management but lacks guidance on liquid waste discharge and management. According to the report, solid waste management falls under the responsibility of City Corporations in Bangladesh, while PRISM, a prominent NGO in Dhaka city, manages hospital solid waste for a nominal fee [5]. The Health Services Division (HSD) of MoHFW published an environmental management plan for emergency response (i.e., COVID-19 pandemic) in 2022. However, this plan primarily focuses on guidelines for handling and disposing of hospital clinical wastes (e.g., body fluids, antibiotics, and chemicals) and does not address overall liquid waste discharge, including effluent from sanitation systems [6]. The recent MoHFW guidelines did not provide clear instructions on how different types of liquid waste should be managed or the standards they should meet before being discharged into the environment or community drainage systems [5, 6].  Hospital directors: When asked about their priorities concerning hospital fecal sludge and liquid waste management, most (9 out of 12) directors noted that their primary focus is on patient care, maintaining essential equipment, and ensuring the safety of both staff and patients. One director highlighted, *“Our top priorities are patient treatment and recovery from diseases. Instances of patient death due to medical negligence gain national-level media attention. However, wastewater treatment doesn't receive the same level of priority from both media coverage and the hospital authority.” (Director, H1)*  PWD engineers: Seven PWD engineers, nearly all stated that managing biomedical waste is not their responsibility; they are primarily tasked with treating HWW and fecal sludge. One engineer from a government hospital (H8) underscored this concern, stating, "*Our hospital had a number of septic tanks to treat the sludge but there are no advanced wastewater treatment options like (full-scale) STP in these (government) hospitals* " (Engineer, H6 and H8). Specifically, one engineer from a private hospital (P1) highlighted this, mentioning that "*We do not have any full-scale STP or any septic tank in this hospital. So, we are directly connecting and disposing of it (sludge and liquid waste) to the WASA’s (municipal) sewage line without any treatment" (Engineer, P1).*  Hospital staff: Hospital staff, particularly cleaners and ward masters, had a very limited or no understanding of the types of hospital liquid waste generated, how it is discharged from the hospital to the community, and how it is treated. Among the 23 staff members (ward masters and cleaners) interviewed, none could describe how biomedical liquid waste is managed in the hospital. |
| Technology | Document review: The Department of Environment (DoE) Dhaka's 2015 report on Bangladesh standards and guidelines for sludge management classifies liquid wastes from medical care facilities as highly hazardous [7]. Despite this classification of liquid waste, the recent MoHFW guidelines did not provide clear instructions on how different types of liquid waste should be managed or the standards they should meet before being discharged into the environment or community drainage systems [5, 6].  Hospital directors: One director emphasized, *“Hospitals are faced with numerous administrative challenges daily, often constrained by limited resources. Recently, we acquired expensive (medical) equipment, but due to inadequate space, installation has become an issue. If not resolved promptly, these machines may malfunction.”* Another director highlighted, *“Our top priorities are patient treatment and recovery from diseases. Instances of patient death due to medical negligence gain national-level media attention. However, wastewater treatment doesn't receive the same level of priority from both media coverage and the hospital authority.” (Director, H1)***.**  PWD engineers: All engineers (N=5) working in government hospitals highlighted the absence of advanced on-site wastewater treatment options, such as full-scale STP, within these facilities. Specifically, one engineer from a government hospital (H8) underscored this concern, stating, "*Our hospital had a number of septic tanks to treat the sludge but there are no advanced wastewater treatment options like (full-scale) STP in these (government) hospitals* " (Engineer, H6 and H8). Two out of three engineers from private hospitals also indicated the absence of advanced wastewater treatment options within their hospital premises.  Hospital staff: One ward master from a government hospital (H10) stated, *“Septic tank is cleaned jointly by the city corporation staff and our (PWD) staff when the tanks need to be cleaned. Usually, if there is any issue with the septic tank in the hospital, our hospital (cleaning) staff tried to fix it (tank). If we fail to fix the problem, we call PWD staff.”* |
| Infrastructure | Document review: Although the MoHFW developed a National Strategy for WASH in HCFs from 2019 to 2023 to enhance the comprehensive Quality of Care (QoC), the implementation of this policy by healthcare authorities is infrequent [5]. WASH FIT is a risk management tool for HCFs at various levels, and it offers a framework to devise, track, and implement continuous infrastructure improvements and prioritize WASH actions [2]. While many governments in LMIC have adopted the WASH FIT tool for assessing WASH in HCFs [8, 9], there is limited evidence of its utilization in Bangladeshi HCFs, except for those in Rohingya camps in Cox’s Bazar [10].  Hospital directors: Private hospitals tend to maintain their infrastructure better, largely because they can make quick decisions and implement solutions without the delays that typically accompany government procurement processes. In private hospitals, decision-making is streamlined, allowing hospital directors, in consultation with on-site engineers, to quickly allocate funds and approve procurement. Simpler procurement policies and the presence of engineers on-site enable faster responses to emergencies and more effective maintenance of wastewater systems. However, government hospitals operate within a more bureaucratic framework overseen by the MoHFW and the PWD.  PWD engineers: The building structure and component infrastructure were identified as one of the critical factors for effectively treating HWW, as stated by the PWD engineers. Three out of seven engineers mentioned that buildings with old structures faced serious challenges in managing wastewater because the pipes and drainage networks were prone to breaking. Due to the narrow pipes in the old buildings, the pipe networks (including both internal and external pipes) often become clogged, leading to liquid waste overflow into the environment. Additionally, the number of patients has increased significantly over the last two decades, but the old hospital buildings were not modified to accommodate the increased patient load and associated wastewater flows.  Hospital staff: Ward master from a government hospital also stated, “*If there is any need for minor repair and maintenance of the sanitation system, we manage them with our own staff. For example, cleaning drains is our regular task to maintain the flow of the water. If any sewage pipes are clogged, we call the sweeper (local sanitation worker/pit emptier), and he fixes the problem. But for septic tank emptying or major repair and maintenance, we have to call the PWD engineers. This is not our responsibility.” (Ward master, H2)* |

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