DESIGN OF A NUISANCE-FREE WASTE COLLECTION SYSTEM FOR A PLANNED RESIDENTIAL AREA IN KHULNA CITY

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ABSTRACT

Sustainable solid waste management (SWM) is imperative for enhancing environmental quality and the welfare of urban inhabitants in both developed and developing countries. This study aims to improve the SWM system in Sonadanga residential area phase-1 (SRA-1), Khulna, Bangladesh, by evaluating the existing SWM scenario and developing a collection system that minimizes nuisances. Onsite data were collected through conducting key informant interviews (KII), focused group discussions (FGDs), field investigations, and consultations with local authorities. The findings highlight that the waste collection, transportation, sorting, and storage processes within the current SWM system are conducted in open-air conditions, resulting in the generation of odors that adversely affect residents and the environment of SRA-1. To address these issues, an effective waste collection system is proposed, involving the distribution of biodegradable bags to households. This approach ensures an odor-free, house-to-house waste collection and transfer process. Additionally, a modified rickshaw van equipped with a sorting system is designed to enhance efficiency by separating recyclables, hazardous waste, and biodegradables during the collection and transportation phases. Considering waterlogging conditions and analyzing rainfall data in the study area, recommendations are made to modify the secondary transfer site (STS). The integrated strategies proposed in this study could create a comprehensive framework to advance SWM practices.

Keywords: *Municipal solid waste, secondary transfer site, waste collection system, waterlogging*

1. INTRODUCTION

Sustainable solid waste management (SWM) is an approach to improving the environment in developed and developing countries. Long-term environmental quality is a prerequisite for the welfare of inhabitants. A significant area of research and development is needed to investigate emerging applications for sustainable and environmentally sound SWM, a global issue (Ayininuola, 2008). This problem is a primordial and current issue in developing countries like Bangladesh. The attempts to improve SWM services are hampered due to the high rate of population growth, increased economic activity in metropolitan areas of emerging countries, and a lack of training in SWM (Bhuiyan, 2010). Sustainable management of Municipal Solid Waste (MSW) is a crucial issue for the municipal authority in the majority of cities across the world due to the increasing generation of municipal waste with the presence of odor and additives in different waste sections (Bari, 1999; Jeswani & Azapagic, 2016). Odor is generally emits due to the degradation of easily biodegradable organic solid waste (Bari & Koenig, 2002; Bari et al., 2012; Atauzzaman & Bari, 2023). In developing countries, unskilled handling of MSW leads to soil, water, and atmosphere contamination and significantly impacts public health (Batool & Ch, 2009).

According to the basic statistics of Khulna City Corporation (KCC), in 2022, the total amount of daily generated waste is approximately 450 tons (Moniruzzaman et al., 2011). The wastes are comprised of plastic (Ahmed et al., 2023), paper (Raj et al., 2017), garments (Tabassum et al., 2017), bones (Siddique et al., 2015) etc. The authority of KCC is responsible for managing waste in this city. MSW is often dumped on the roadside, at secondary disposal site (STS), and hauled containers by the inhabitants, Community-Based Organizations (CBOs), or non-government organizations through their door-to-door collecting system (Ashrafuddoula et al., 2015; Islam et al., 2017). Then recycled or reusable waste is separated in STS, or it is separated from the source and sent to the nearby recycling shops for recycling or reuse. KCC workers collect the remaining MSW from STS and transfer it to Rajbandh, the final disposal facility, which is 10 km from the city headquarters (Khair & Rafizul, 2018). The waste collection infrastructure in Khulna city needs improvement, especially regarding segregating waste at the source. Establishing a better material flow path from higher clean to lower clean is essential for effective SWM (Bari et al., 2012). If the primary collection vans are not taken directly to the Ultimate Disposal Point (UDP) and deposited at a specific place, i.e., a STS, from there, the wastes are taken to UDP by big vehicles using a convenient schedule and traffic route (Ahsan et al., 2014). MSW should be collected and segregated more efficiently according to characteristics in the primary collection or STS. In addition, MSW-carrying vans should be arranged so that nothing falls on the road and does not spread odors while carrying them. A model area should be selected for applying such an operation.

An open space bounded by low brick walls is used as STS. Moreover, as this STS is exposed, the accumulated MSW emits a pungent stench, which makes it challenging to travel through the adjacent roads. Then, when the Dumping or Disposal truck comes to take the deposited MSW from here to UDP, the traffic route through which it is carried stinks because the MSW is carried openly. This matter has become a major public nuisance for the people of this region. Rahman et al. (2018) suggested conducting an awareness campaign about door-to-door collection, waste storage, source separation, reducing, reusing, recycling, and reusing to improve the present scenario. But this approuch is not enough to implement odor free SWM system. Waste collection procedure, water transportation, storage, and dumping are all aspects that need to modify to eliminate odor in the operation of the SWM system. Therefore, the objectives of the study is to design a nuisance free sustainable SWM system.

2. METHODOLOGY

2.1 Study Area

Khulna, located in Bangladesh, sits south of the Tropic of Cancer at the junction of approximately 22.49° N latitude and 89.34° E longitude. As the third-largest city in the country, the surrounding urban area is home to an estimated population of 1.5 million. Comprising 31 wards, Khulna spans an estimated land area of 47 km², resulting in a population density of 67,994 individuals per km² (Ahsan et al., 2014). Khulna experiences natural cyclones almost yearly. Moreover, heavy rains and waterlogging are noticeable in the Khulna district (Khan, 2017). In the water logging risk zones in KCC, 20%, 42%, and 38% of the area are in high, medium, and low water logging risk zones, respectively (Azad et al., 2022). Therefore, under the influence of natural disasters, especially water logging conditions, MSW from the open STS can be scattered in the city and create a considerable hazard, posing a threat to public life and the environment. For this reason, the waterlogging condition is a concern for developing a closed waste collection system. Sonadanga residential area phase-1 (SRA-1) was selected as the study area, which is in a moderately risky water logging zone. The location of SRA-1 is shown in Figure 1.

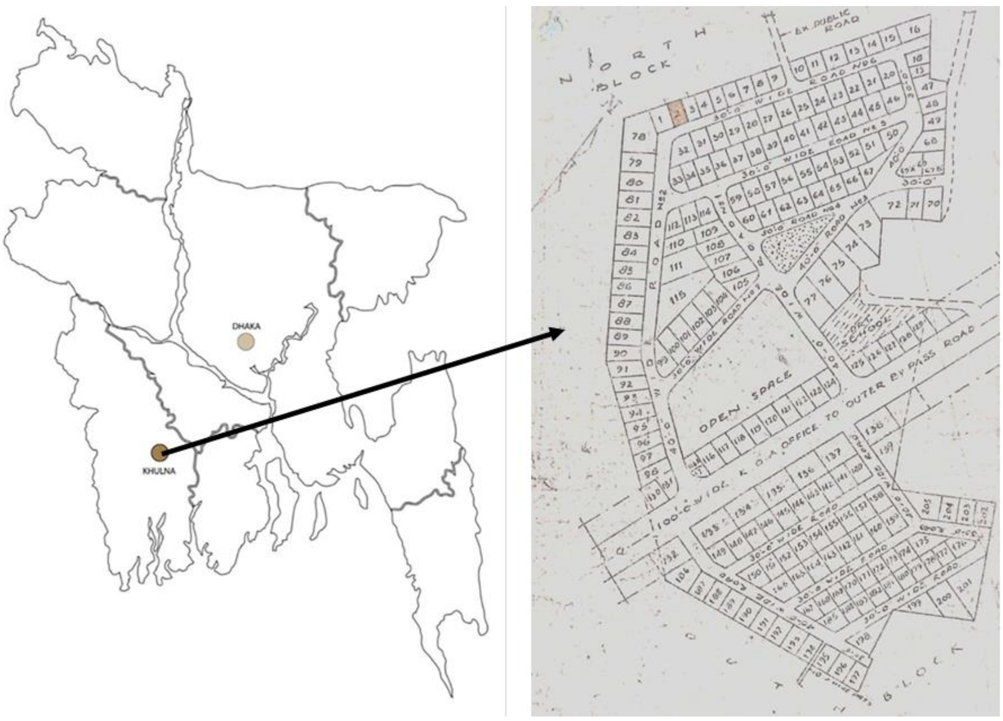

Figure 1: Location of SRA-1, Khulna, Bangladesh

2.2 Data Collection and Analysis

To achieve an odor-free collection and transfer system of MSW in the selected model area, SRA-1 at Khulna City, existing conditions and challenges were identified during the field investigation. Onsite data were collected through conducting key informant interviews (KIIs), focused group discussions (FGDs), field investigations, and consultations with local authorities. Additionally, insights gathered from discussions with various stakeholders and residents. In design phase, consulting with the relevant authorities ensure that the proposed models align with the community's needs and expectations.

The secondary data was collected from scholarly publications and non-government reports. Additionally, articles from reputable sources offer contemporary perspectives and case studies, presenting practical applications and success stories from similar projects globally. Moreover, insights and guidelines derived from local governing bodies such as the KDA and KCC are instrumental in aligning the SWM system with regional policies, regulations, and urban development strategies. These authoritative sources provide crucial data on existing waste management infrastructure, policies, and initiatives in the specific context of Khulna, thereby informing and guiding the design process. Combining academic research, real-world practices, and institutional knowledge makes the SWM system efficient, sustainable, and tailored to the community's needs.

Integrating primary and secondary data, including demographic composition alternative methods of MSW collection was implemented. The information gathered from precise measurements conducted on rickshaw vans and dumping trucks is essential for understanding waste transportation dynamics and determining the optimal layout for sorting options within the limited space of these vehicles. Through a comprehensive investigation into waste-carrying vehicles' collection and disposal processes, the proposed models include innovative sorting mechanisms within rickshaw vans. These mechanisms enable the segregation of different types of waste at the source, promoting a more streamlined and sustainable SWM process. The design objective of sorting options in rickshaw vans is to facilitate the separation of recyclable, hazardous, and biodegradable materials during the waste collection and transportation process. This initiative aims to enhance SWM efficiency by optimizing the logistics of the MSW transfer system.

The study considers the region's vulnerability to natural disasters, emphasizing the need for a system resilient to adverse weather conditions. The design includes infrastructure and operational considerations that mitigate the impact of water logging on waste collection and disposal processes. The objective is to create a system that not only meets the community's immediate needs but also aligns with long-term goals of sustainability and environmental preservation in the face of water logging challenges. The proposed models address this issue by introducing enclosed transfer stations with effective odor control mechanisms. The area's vulnerability to natural disasters, such as waterlogging, is considered in the design to ensure the safety and functionality of the proposed system under various conditions. The models incorporate advanced waste containment technologies and closed transfer station designs to prevent the release of unpleasant odors into the surrounding environment.

3. RESULTS AND DISCUSSION

By collecting and analysing relevant data, the study achieved its objectives. Alternative methods for collecting MSW were extensively developed. The waste-collecting paddle van was modified with an emphasis on sustainability and effectiveness. Furthermore, a suitable SWM environment was carefully considered when conceptualizing a modern STS. The study area is vulnerable to disaster, so the STS was designed to be effective under waterlogging conditions. Notably, the STS design process was the most important in creating an odor-free system. The resulting STS design was practical and sustainable for the dumping truck and garbage collection paddle van.

3.1 Solid Waste Collection System

It was found in SRA-1 that the MSW was not separated from the source where the waste was generated. MSW was collected in the Primary Disposal Point (PDP), such as community bins, household trash, dustbins, etc. The paddle van collects the MSW into the STS, which emits extreme odor to the environment. The residents in the study area endured unbearable odors that lingered in the air, severely affecting their quality of life. The pungent stench permeated the atmosphere, creating a sense of unease and discomfort among the community members. Furthermore, the environmental impact was extensive, as the foul smell attracted pests and insects, exacerbating the sanitation issues in the study area.

MSW collection has long been essential for urban cleanliness and sanitation. In the study area, a pressing issue arose as MSW was not being efficiently separated from its source, leading to various environmental challenges. MSW, such as community bins and household trash, is haphazardly collected in the PDP by paddle vans and transported to the STS (see Figure 2). This process emits an odor into the environment, negatively impacting the adjacent road users and residents. MSW is deposited randomly into the PDP without proper waste separation based on categories. As shown in Figure 3, from the PDPs, MSW is collected by a responsible worker into other bags or buckets carried with the paddle van by partially separating the recyclable or reusable waste.

Figure 2: The existing secondary transfer site (STS) in SRA-1

Figure 3: Waste collection in paddle van in SRA-1

3.1.1 Alternative methods of solid waste collection

The solid waste can be separated from the source and dumped into the PDP. If the waste is not separated in the source, the worker who collects the waste in the paddle van must collect the waste in separated according to waste categories into reusable or one-time biodegradable plastic bags. To eliminate odor while transporting waste from PDP to STS, it is mandatory to covey the waste into a closed system. In Figure 4, a framework shows how the MSW transferring system can be closed in different stages while transferring wastes. Waste sorting can also be executed in PDP, paddle van, STS, or UDP. The waste can be collected in a paddle van in separate bags, and the worker must seal it as the odor may not spread out while transferring it through the residential area.

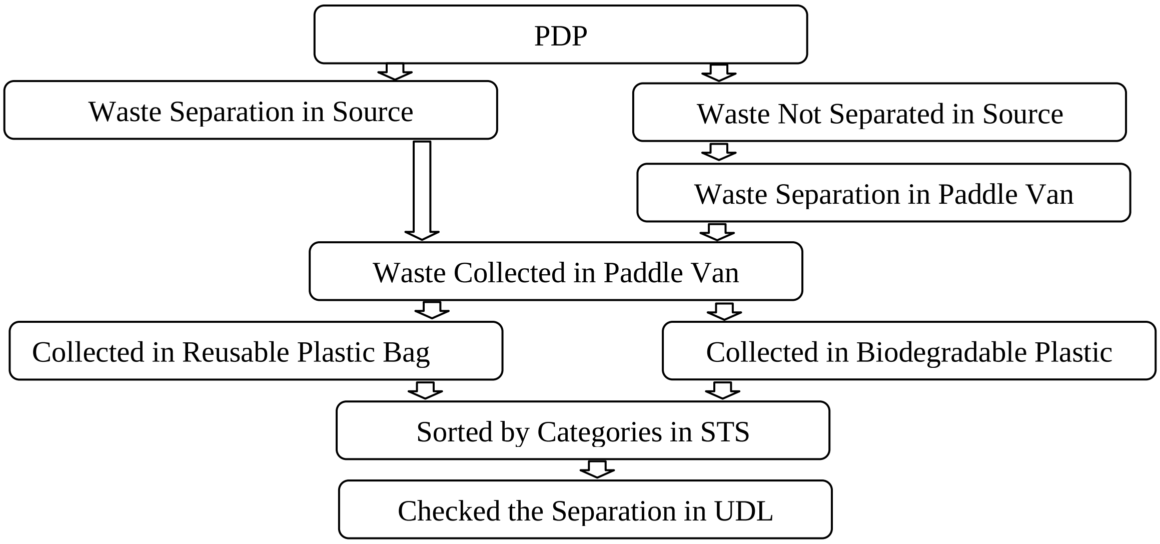

Figure 4: Designed alternative waste collection procedure in SRA-1

To address the arising challenges and create a more sustainable waste collection system, several alternative methods were developed:

Closed or covered containers at PDP: One effective solution was using closed or covered containers. This approach prevented direct exposure to waste and reduced environmental odor emission. Closed containers kept the waste concealed until it was ready for collection, thereby mitigating the nuisance caused by open dumping.

Reusable plastic bags: Another innovative approach involved reusable plastic bags for waste collection. Workers would carry these bags to the PDPs, collect MSW, and tie the opening. The waste remained sealed within the bag during transportation to the STS, effectively preventing odor emissions. The plastic bags could be retrieved at the UDP for reuse, promoting sustainability.

One-time biodegradable plastic bags: To further enhance waste collection efficiency and environmental friendliness, one-time biodegradable plastic bags were introduced. Workers collected waste from PDPs and sealed the biodegradable bags. Unlike reusable, these bags were not reopened until they reached the UDP. At this stage, the biodegradable bags and their contents were disposed of together, eliminating the need to retrieve the bags. This approach streamlined the waste collection process and reduced the environmental impact. These changes can reflect a growing awareness of the importance of responsible waste disposal and a commitment to a cleaner, healthier environment for all.

The utilization of biodegradable bags for the collection of MSW from the PDP to the STS presents a range of noteworthy advantages, underscoring the potential for enhanced SWM practices. These biodegradable bags afford the unique capability to encapsulate waste in a fully covered condition during the collection process. This feature becomes particularly advantageous when wastes are segregated within these bags, obviating the necessity to unseal them until they reach the UDP.

The primary objective of this study is to facilitate a nuisance-free SWM facility, and the implementation of biodegradable bags plays a pivotal role in achieving this goal. One salient benefit of employing biodegradable bags lies in the mitigation of noxious odors associated with waste transfer activities. The hermetic enclosure of waste within these bags serves as an effective barrier, preventing the escape of odorous substances during transportation from the PDP to the STS, and subsequently, to the UDP. The containment of odors is imperative for the well-being of SWM personnel and contributes to the overall improvement of environmental conditions surrounding waste handling facilities. Furthermore, implementing biodegradable bags extends its positive impact to the STS, where stored waste is prone to emitting unpleasant odors. By consistently utilizing biodegradable bags for waste segregation and collection, the STS is rendered a more odor-neutral environment. This is a significant advantage, as it aligns with the broader objective of establishing a SWM system that is not only efficient but also environmentally considerate.

The adoption of biodegradable bags for the collection and disposal of biodegradable waste addresses not only immediate concerns related to odor control and efficient SWM but also carries profound ecological benefits. One particularly noteworthy advantage is the facilitation of the decomposition process through a comprehensive approach to waste disposal. When biodegradable waste is meticulously segregated and deposited into dedicated biodegradable bags, the entire assemblage, encompassing both waste and bags, becomes conducive to natural decomposition. This holistic strategy aligns with the principles of sustainability, offering a closed-loop system wherein the entirety of the waste and its containment medium can undergo degradation over time. Unlike conventional waste disposal methods that may involve the accumulation of non-biodegradable materials, the use of biodegradable bags ensures that the entire waste stream, including the bags themselves, can ultimately return to the environment in a benign form. This cyclical nature of decomposition not only streamlines the waste disposal process but also contributes significantly to the reduction of non-biodegradable waste.

As the biodegradable bags break down in tandem with the waste they contain, the need for separate disposal or recycling of these bags is obviated. This, in turn, minimizes the burden on landfills and reduces the environmental footprint associated with SWM activities. The promotion of such a comprehensive decomposition process aligns seamlessly with contemporary sustainability goals. By embracing biodegradable bags in waste collection and dumping, we are fostering a system that not only addresses the immediate challenges of SWM but also adheres to the principles of circular economy and environmental stewardship. This approach resonates with the growing emphasis on sustainable practices, encouraging a paradigm shift in SWM strategies towards greater harmony with natural ecosystems. In essence, the use of biodegradable bags emerges as a pivotal step towards a more environmentally conscious and ecologically harmonious waste disposal framework.

Therefore, incorporation of biodegradable bags in the collection and segregation of MSW stands as a commendable practice with multifaceted advantages. From odor control during transportation to fostering a more ecologically sustainable waste disposal process, the adoption of biodegradable bags exemplifies a conscientious approach to contemporary SWM challenges.

3.2 Paddle van modification

MSW in SRA-1 is collected from the PDP by paddle van. There are 20 paddle vans for waste collection, of which nine were provided by Khulna City Corporation (KCC) and others provided by NGOs. MSW is collected in the paddle van in open conditions, which may cause nuisance and scatter the wastes on the roads when transported. The problem in the transportation of MSW from PDP was investigated, and a sustainable modification of the paddle van was designed. The paddle van collects MSW from the PDPs in the study area, such as resident bins, market trash, community dustbins, etc. The wastes are collected without separation and uncovered. The paddle van carries the wastes all the way to the STS openly, which caused odor and scattering. After coming to STS, the worker lifted the front side of the van as shown in Figure 5, so the waste could be dumped from behind the van. The workers used the shovels to dump the remaining waste from the van.

Figure 5: Waste collection and dumping procedure of Paddle van in SRA-1

To prevent odor and scattering of MSW while transporting MSW by paddle van from PDPs to STSs, the paddle van was modified sustainably and effectively to implement a modern SWM system. The paddle van's engineering data were collected from KCC. The van was designed to be covered entirely as odor, and scattering could be prevented. In order to mitigate odor emissions and prevent waste from scattering while being transported, the waste disposal van design was highly significant. Litter and offensive smells may escape because the top and back of traditional garbage collection vans are open.

An inventive waste collection system was suggested to solve these problems and enhance the waste disposal procedure. The top of the van was designed with a metal sheet shutter mechanism installed. When intended to load MSW, this shutter system can be opened; once the worker has loaded the waste, it can be securely closed by pulling the handle. Additionally, MSW was collected in recyclable or reusable airtight plastic bags to ensure an entirely odor-free and litter-free system. After that, the trash bags are placed inside the van to further prevent waste from spreading and emitting odors.

The integration of the top shutter mechanism brought an extra layer to the nuisance-free MSW collection system, improving the overall effectiveness and cleanliness of the waste disposal process. To make it easier to unload waste into STSs, the back panel of the van can still move. The back and top shutters of the van can be opened to access the waste upon arrival at the STS. The front of the van can be lifted to make it easier to discharge waste at the STS. The van's moveable back panel can act as a slope, creating a flat area that makes discharging the waste bags quickly from the paddle van easier.

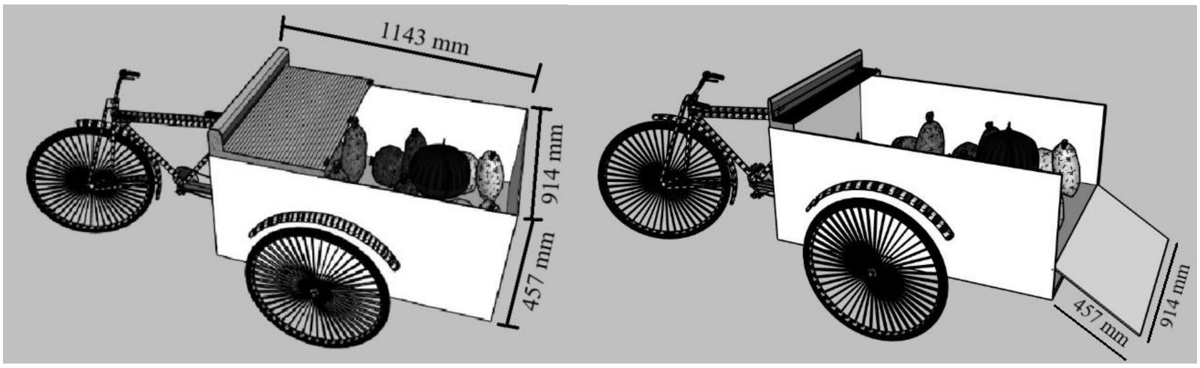

Figure 6: Modification of the waste collection paddle van

To collect waste, workers can open the top shutter using its handle. After collecting the waste, they can lock the shutter to prevent scattering and odor. At the STS, the van's top shutter and back panel can be opened to dispose of MSW. The van's front can be raised to facilitate disposal, and the back panel provides a slope for smooth discharge of the waste bags. A comparative measurement of the waste collection paddle van existing and modified is shown in Table 1.

Table 1: Comparison between the existing and modified paddle van

Components	**Existing Condition**		**Modified Condition**	
Side Panel	Length 1143 mm	Width 457 mm	Length 1143 mm	Width 457 mm
Front Panel	Length 914 mm	Width 457 mm	Length 914 mm	Width 457 mm
Rear Panel	Open		Length 914 mm	Width 457 mm
Top Panel	Open		Length 1143 mm	Width 457 mm
Resultant System	Open		Closed	

3.3 Secondary transfer site modification

Modifying the STS is essential in terms of a SWM system. Upgrading STS increases the efficiency of the SWM process. Well-designed STSs are essential for the seamless transfer of waste from collection vehicles to disposal facilities, reducing time and minimizing disruptions in the SWM chain. Suitably modified STS can facilitate waste sorting, recycling, and recovery. Effective separation of waste streams at the STS level can increase diversion rates and reduce waste sent to landfills, promoting sustainability and resource conservation. Enhanced STS infrastructure may also include odor control systems and control measures to prevent the release of unpleasant odors and pollutants into the surrounding area. Maintaining a high quality of life for the surrounding communities and ensuring public health is very important. In addition, an aesthetically pleasing and well-maintained STS can improve the quality of life for the neighbourhood’s residents.

The existing STS was visited and investigated in the study area. The arising problem of the STS was determined, and data was collected to integrate solutions to the problems. The existing STS was an open space bounded by a short brick wall for collecting waste, sorting waste by category, separating waste for recycling, and transferring waste to the UDP. Due to its open nature, the poorly designed STS caused waste and odor to be scattered to the adjacent road users and the community. It also caused a nuisance to the living people of the adjacent residents of SRA-1. After collecting MSW from the PDPs, the paddle van disposed of them to the STS. The randomly collected MSWs were stored at the STS and somehow separated immediately by the workers. In the STS, mostly papers and metals were separated by hand in this stage of the existing SWM system. The stored MSWs from the STS were carried by the dumping truck to the UDP. At the STS, the waste loader loaded the dumping trucks, and the shovel lifted the scattered waste. The dumping truck took the waste to the UDP, where it still had chances of lettering or emitting odor.

A nuisance-free modern STS must be designed to prevent the odor and scattering of MSW in the study area. The modified modern STS must be part of the closed SWM system. An in-house STS should be designed in this study area. Considering the waterlogging condition and analysing the rainfall data of the study area, the STS should be designed so that the stored MSW cannot be spread to the residents during waterlogging due to heavy rainfall.

4. CONCLUSIONS

The conclusions drawn from the present study are as follows:

- In Sonadanga residential area phase-1 (SRA-1), the processes of collecting, transporting, sorting, and storing waste are carried out in open-air conditions, resulting in the generation of odors that adversely affect residents and the environment.
- Reusable, or recyclable plastic bags and biodegradable plastic bags are suggested as waste collection alternatives to make the SWM system nuisance-free.
- In this study the waste collection paddle van is designed, which can collect waste separately in a closed system, as all the sides of the waste collection paddle van can be closed after collecting and disposing of waste.
- The study strongly recommends designing a modern in-house STS as Khulna city is vulnerable to natural disasters, with recurrent incidents of waterlogging during periods of heavy rainfall. An adequate plinth level should be meticulously devised to address this for the STS. This design feature, grounded in analysing rainfall data specific to the study area, may include calculating a rainfall return period to determine an appropriate plinth level.

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