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OPEN SECONDARY DISPOSAL POINTS IN KHULNA CITY: PRESENT SCENARIO AND ITS FURTHER MODIFICATION

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ABSTRACT

Municipal Solid Waste (MSW) management is gradually becoming one of the major concerning issues because of the adverse effects of mismanagement on the environment and human body in developing countries like Bangladesh. Khulna is one of the largest metropolitan and industrial cities in Bangladesh and its population is around 1.50 million. This huge population is producing significant amounts of waste daily, including the environmentally relevant plastic fraction. The mismanagement of MSW is causing a negative impact on the environment and human health. This study aims to find out the present scenario of the open system of Secondary Disposal Points (SDPs), available waste management systems, and social conditions of waste workers in order to develop a master plan. To investigate the existing situation of SDPs, structured interviews with questionnaires, and field surveys were conducted and analysed. Geospatial datasets were fed into a GGIS based on QGIS. The biodegradable fraction (organic matter) makes up the largest weight-share with 83.02 %.in the solid waste composition at three selected SDPs due to the use of fresh vegetables and foods and the resulting high moisture content. Also, glass, leather, and rubber make up the smallest percentages, especially the plastic fraction found at 4.11%. This heterogeneous mass of materials with highly varying physical characteristics needs to be temporarily contained in SDPs. The survey of the physical conditions of all the open system SDPs found a number of critical technical aspects with the potential to cause environmental or health risks. Such aspects are "the existence of boundary walls exist only (33.3%), concrete floor (81%), waste leakage to drain (23.8%), waste spreading around (66.7%), and creating congestion on roads (48%). The social aspects of waste workers are at a marginal level although waste management sectors created an opportunity for their livelihood. Regarding the result of this study, a sustainable masterplan will be proposed for the modification of existing open system SDPs for proper waste management as well as to reduce the bad impact on the environment and human health in the future.
***Keywords**: SDP, plastic, waste management, waste worker, environment, waste flow, QGIS, modification.*

INTRODUCTION

Municipal solid waste (MSW) is becoming one of the most striking environmental issues facing city authorities in the Least Developed Asian Countries (LDACs), like Bangladesh (Ahsan et al., 2015a), With the rapidly growing urban population and the associated growth in solid waste creation, effective solid waste management remains a significant concern in developing countries (Abas et al. 2014). The urban economy has also grown, as have social advancements, and a number of other factors are also contributing to this enormous rise in the amount of MSW in emerging cities in Asia and Africa (Jodder et al., 2022). One of the obvious consequences of it is the increase in garbage generation and adverse effects on the environment.

The best planning, design, and execution of the functional elements involved in management are based on the estimation of MSW generation and composition. One of the major issues facing society in the twenty-first century is how to effectively and affordably manage solid waste. Any collection and disposal system for MSW must be in line with the amount of garbage generated. The volume and compositions of the MSW are produced each day in Khulna City by many sources, including residential, commercial, and institutional. The anticipated daily production of MSW is 520 Mg, with the majority (85.87%) coming from residential areas, with the remainder coming from commercial, institutional, street sweeper, and other areas (Ahsan et al., 2015b). According to a recent study (Ahsan et al. 2012), in Khulna 420 to 520 tons of MSW are generated per day, with a waste generation rate of 0.3 to 0.4 kilogram per person each day. However, the KCC vehicles' collection capability is 240 to 260 tons/day, or 50 to 55 percent of the entire generation (Ahsan et al. 2012). The waste compositions of MSW were food & vegetables 78.9%, paper & paper products 9.5%, polythene & plastics 3.1%, textiles and woods 1.3%, rubber and leathers 0.5%, metals and tins 1.1% glass and ceramics 0.5%, dust, ash and mud products 3.7% of Khulna city in 2015 (Ahmed & Moniruzzaman. 2017). Among these compositions, plastic has become an indispensable element of our daily lives due to its strength, lightweight, and affordable price(Ahmed & Moniruzzaman.2018).

In many parts of the world, the reuse and recycling of waste materials are now truly regarded as essential components of solid waste management. In the Khulna city region, there were 310 stores for reusable materials (SRMs), and 859 people were employed there for various tasks related to the established reuse network (Bari et al., 2012). Additionally, due to their widespread use, tenacity, and omnipresence in the environment, plastics are of great concern to science and society. In particular, small particles (Microplastic-MP and nano plastic-NP) pose a threat because of their potential toxicity and small size. Studies show that tiny particles can interact with various species at several biological levels, including humans. Estimating the risks these types of plastic provide to the environment and to human health is currently of great importance (Yadav et al., 2016a).

Normally, municipal authorities are responsible for managing MSW, but since 2012, some non-government organizations (NGOs), Community -Based Organizations (CBO), and private organizations have started to work on the door-to-door collection (M. R. Islam et al., 2012). Recently, door-to-door collection systems have been effective to collect MSW, mainly from homes, and disposing of the majority of it at the nearby transfer station (TS), as referred to Secondary Disposal Sites (SDPs) or Secondary Disposal Points (SDPs). NGOs and CBOs collect MSW from households and others generation points and deposit it to the SDS. However, they are not responsible for collecting and transporting the MSW that they deposited in the nearby SDS (Ahmed & Hossain, 2017). Due to the lack of adequate infrastructure and the significant rate of urbanization, managing municipal solid waste is a challenging issue for municipalities (Yadav et al., 2016b). Municipal solid waste (MSW) collection, transfer, and transport are some of the most challenging jobs faced by municipal governments, and they contribute to a substantial portion of their budget. Transfer stations (TSs) with the right planning can improve system performance and drive down costs (Höke & Yalcinkaya, 2021).

In addition, according to Islam et al (2015) MSW management system of Khulna city is still in the developing stage due to a lack of motivation, awareness, commitment, and expertise, as well as money. The KCC needs an easy and economically feasible waste management system that can effectively address and manage solid waste. However, the waste workers of the organizations are working both formally and informally but the scavengers are working independently as they not belonging to any company or organization involved in MSW management. Despite the occupational unhygienic environment of their workplace, there is no regulation, monitoring, or even enforcement to control their work. Waste pickers are typically prone to a range of occupational health risks and diseases since they are members of poor and socially marginalized socioeconomic groups. Although they are not part of the community's formal solid waste management system, they are key actors on the grassroots level who are rarely taken into account by management strategies (Islam et al. 2008). Direct contact with garbage, infected wounds, contaminated dust, wild animal attacks, and enteric diseases spread by insects feeding on waste are all potential sources of infection (Al-Khatib et al., 2020a). The present solid waste dumping system is neither environmentally friendly nor sustainable. Unplanned dumping of solid waste poses severe health hazards as they often contain pathogenic microorganisms. The runoff of MSW from dumping sites pollutes aquatic ecosystems (M. S. Islam et al., 2015)

Recycling and composting organic waste to reduce or eliminate CO_2 emissions caused by replacing virgin materials in the manufacturing of new products. It has been highlighted that recycling and other treatment methods like composting can help achieve the most effective environmental performance (Deus et al., 2020). The entire system is becoming a threat to city residents, planners, and other stakeholders due to severe financial constraints, a lack of appropriate technology, a lack of public awareness, motivation, and participation, ineffective legislation and law enforcement to protect the environment and to handle the waste, and other factors. The city government is looking for a safe and sustainable solution for the right management of solid wastes in order to provide a clean, hygienic, and environmentally friendly city (Alamgir et al., 2007). Reducing the bad effects of MSW needs long-term master planning and implementation. The master plan's fundamental goals are to increase the capacity of landfills, increase the efficiency of waste collection, increase public awareness of the requirement for community-based waste management, and strengthen stakeholder capacity.

Moreover, the primary function of a waste management plan is to specify the mix of waste management techniques and strategies required to gather and manage the garbage in a way that ensures the achievement of a particular set of goals. Sustainable and realistic goals must also be in line with environmental laws and regulations, and they must be tracked to ensure that they are being attained over time (Zaccariello et al., 2015). The Bangladesh Delta Plan 2100 must be the main emphasis of Khulna City's long-term municipal solid waste (MSW) management plan. Due to the complicated nature of MSW, the conventional system of MSW management approach has been shown to be unsustainable in the majority of developing countries (Rafew & Rafizul, 2021).

So, solid waste management is a multidimensional issue that incorporates economic, institutional, social, and environmental factors. Enhancing SWM in developing countries requires initiatives to promote public awareness, improve funds, build expertise, invest in infrastructure, and invest in knowledge. Communities must take action in order to adopt new SWM systems (Mcallister, 2015).

The aim of this study is to analyze the waste compositions especially plastic fraction, existing waste management system, waste worker's health, economic and social aspects, environmental challenges, population and waste generation prediction, and material flow to create a baseline scenario for a waste master plan, which specifically addresses possible modifications of the existing open system SDPs.

METHODOLOGY

In this study, for the assessment of the present scenario of open system SDPs and the socio-economical condition of the waste workers, a predesigned questionnaire survey was conducted. Environmental challenges were observed by direct field surveys and collecting qualitative and quantitative data. The quantitative part of this study included close-ended questionnaires, field measurements, and experiments. Geographical Information system (GIS) was used in geographical data capturing of the existing location of open system SDPs and the design and drawing of the modification model were done by AutoCAD software based on the waste generation amount in Khulna city.

Study Area

The study has been performed in Khulna city under KCC administrative area wards number 1 to 31 (Figure 1). Khulna city is known as the third-largest city of Bangladesh, situated in the south-western part at 22°49′0″N and 89°33′0″E. The area of KCC is 45.65 sq. km and has about 1.50 million populations (KCC, 2022). The population density of Khulna city is steadily rising because of the opening of the Padma Multipurpose Bridge and more industrial activities, resulting in the rapid growth of solid

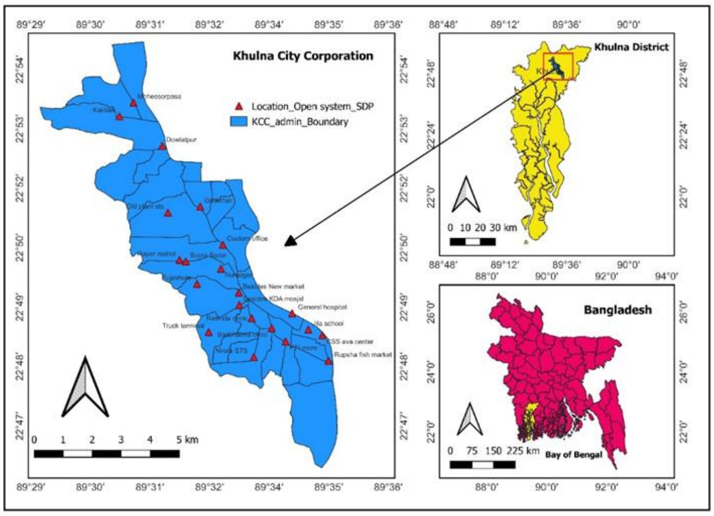


Figure 1 Map of the study area (Tariqul, 2022)

waste production. Also, rapid economic transition and the increasing urban population will reflect the escalation of solid waste generation. MSW management is strongly correlated with an increased amount of solid waste. Increased population refers to an increase in the waste quantity which impacts on the waste management system. The infrastructural improvement of capacity building in the waste management sector has been under construction since 2020 to proper management and ensure clean city. Khulna city is becoming more contaminated day by day due to a lack of an ineffective solid waste management system (Mayor, KCC). Figure 1 also shows the location of the open system of SDPs of KCC.

The study aims at evaluating open secondary disposal points, especially with regard to a better management of plastic waste within the city’s overall waste management system. For this, the study assesses waste composition, focusing on the plastic fraction, waste flow to and from SDPs and the impact of waste workers on SDP management. The final objective is to provide a baseline scenario to modify SDPs to potentially improve their performance within their health-, environmental, social, technical, and organizational dimensions (Figure 2).

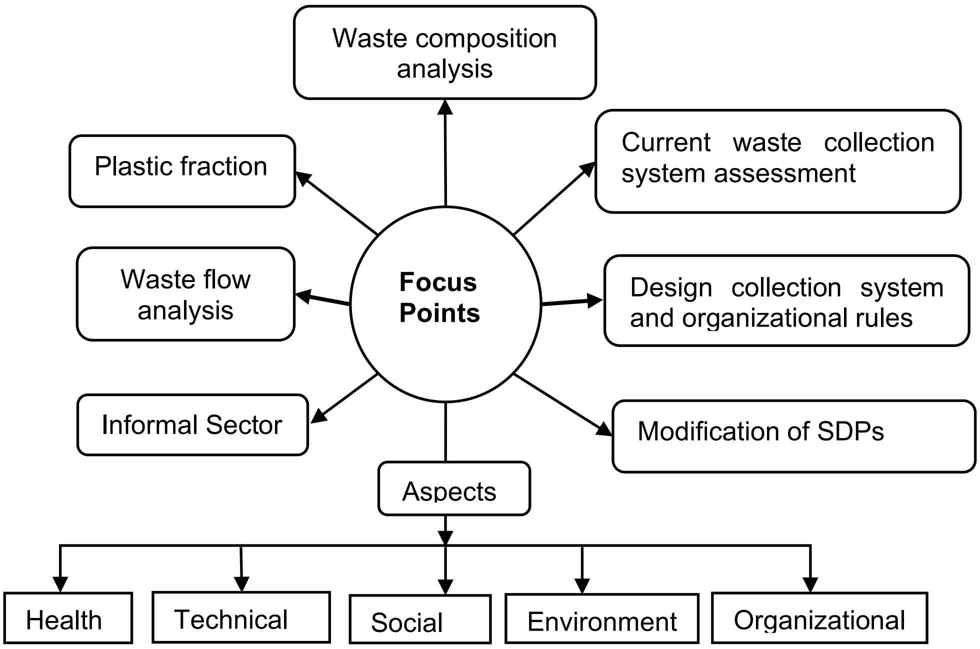


Figure 2 Study component of open system SDPs (Tariqul, 2022)

Data Collection and Field Survey

In this study, field surveys were carried out to collect the primary data of the existing open system SDPs in Khulna city. Firstly, an interview survey has been done at Khulna City Corporation (KCC) with the conservancy department about the existing waste management system. According to the KCC authority, 21 open-system SDPs are located in the Khulna City Corporation area. They provided the listed open system SDPs data (Table 1) to the survey team and started the survey according to this information. Open system SDPs related information was collected through direct interviews and field visits.

Table 1 Existing SDPs in Khulna

SL. No	SDP types	Number of SDP
1	Open system	21
2	Container system	56
3	In house system	4
4	**Total**	**81**

Sources: KCC

Three types of SDPs are shown below (Figure 3) and the locations of those SDPs are Khalishpur (In-house), Zilla school (Container), and Nirala (Open). The conditions of in-house SDP are improved compared to others because the side wall exists, improved concrete floor conditions, no leakage of waste to drain, and waste not spreading outside. Disadvantages for an in-house system SDPs large areas and fixed locations are required more than other systems of SDPs. Container system SDP is flexible to move to other places and waste does not spread frequently. This study focuses on open-system SDPs as shown in Figure 3 (a).

Figure 3 Existing SDPs in KCC (a) Open system (b) Container system (c) In-house system (Tariqul, 2022)

Secondly, the study's basic population who is working in waste management systems at the 21 open system SDPs in Khulna city was collected. Based on information collected during the field survey and interviews with supervisors at SDPs, there are 16 scavengers and 200 waste collectors working in open system. A random sample of the study population was selected in accordance with the Herbert Larkin equation (Al-Khatib et al., 2020b), as shown in the following equation.

$$n = \frac{p(1-p)}{\left(\frac{SE}{t}\right) + [p(1-p)/N]} \quad (1)$$

where N=study population 200 (waste collectors) & 16 scavengers; n= sample size; t= confidence coefficient and equal to 1.96 for 95% confidence interval; p is the value of the main estimate, which is a relative index assumed to be 50% in order to give the largest sample size possible for this type of indicator; SE: the standard error ratio is equal to 0.05. A minimum sample size of 132 waste workers and 13 scavengers is needed (Equation 1). A sample of 135 waste workers & 15 scavengers needs to be interviewed.

The predesigned questionnaire was set up according to the study goals and through a reconnaissance survey at each open system of SDP. The considerations for this questionnaire were the health, social, and economic condition of waste workers, present technical conditions, environmental conditions, and waste management systems. Then the interviews were conducted with people who are associated with SDPs such as waste collectors, scavengers, and supervisors according to the predesigned questionnaire. The information that they shared was collected in the datasheet. We also investigated the existing technical conditions and environmental conditions through field visits at each open system SDP.

In addition, the Global Positioning System (GPS) coordinates (Latitude & Longitude) of open system SDP were collected during the field visit and entered as shape file into a geographical information system (GIS) using QGIS software. These GPS coordinates were collected through physical field visits with help of Google Maps & image details. The spatial boundary lines up with KCC's geographical region and includes thirty-one wards' zones.

The existing scenario of waste generation, collection, transportation, and dumping system was supervised by a field visit. To analyze the MSW physical composition, this study followed the quarter method (Rojas-Valencia & Nájera-Aguilar, 2012) and hand sorting at three different locations of the open system of SDP. We took the total wet weight of a 200kg waste sample and then sorted a quarter portion 50kg sample by hand (Figure 4). After the sorting, each composition was weighed by an electronic scale. The amount of garbage collected from each open system SDP and their categories were measured and recorded separately. The composition categories for this study are given below:

1. Bio-degradable waste
2. Plastic (film & dense) waste
3. Paper and cardboard waste
4. Glass waste
5. Wood & Textile waste
6. Medical waste
7. Metals waste
8. Dust, ashes

Figure 4 Quarter method for solid waste sample (Tariqul, 2022)

In addition, for determining the bulk density the tare volume was noted at first. After sorting and weighing each composition wet weight was collected and the bulk density was measured in this collected data. Then we took the separated waste composition to the waste laboratory at KUET. After oven drying at 100 to 105 degrees Celsius, the sample dry weight was measured & noted separately. The moisture content was determined by this data. Bulk density is equal to the mass of waste divided by the total volume (equation 2). Moisture content is equal to the wet mass of waste minus the dry mass of waste and divided by the dry mass of waste multiplied by 100 (equation 3) (Alabdraba et al. 2013).

$$\text{Bulk Density (D)} = \frac{\text{Mass of waste (kg)}}{\text{Total volume } (m^3)} \quad (2)$$

$$\text{Moisture content(w)} = \frac{\text{(Wet mass} - \text{Dry mass of waste)(kg)}}{\text{Dry mass of waste (kg)}} x100 \quad (3)$$

The material flow was also assessed by field survey and direct interviews in a different location in Khulna city.

This study finds out the existing scenarios of open system SDPs, health and socio-economic conditions of waste workers, management systems of MSW, waste compositions as well as environmental conditions. Finally, based on all the data analysis, investigation, and interviews, a master plan will be proposed for effective waste management to KCC.

RESULT AND DISCUSSION

Waste Composition at Open System SDPs

In this study, the physical waste composition has been analyzed by hand sorting in three open-system SDPs in Khulna city. The SDPs are selected randomly for waste composition analysis as these three SDPs are sources of all kinds of waste composition. The waste composition of open system SDPs found to average biodegradable 83.02%, Plastic and polytene 4.11%, paper & cardboard 5.20%, glass 1.28%, wood & textiles 2.43%, metals 0.53%, medical 0.29%, dust & ashes 3.14% (Table 2). The plastic fraction of waste compositions at SDPs is found 4.11%. The largest portion among all compositions is biodegradable and the plastic fraction is lower because the waste collectors sorted the maximum portion of recyclable waste in SDPs when they collected the waste from door to door. The scavengers also collected the recyclable compositions at SDPs. The percentage of waste composition of Goalkhali SDPs, the percentage of waste composition of PTI mor SDPs, and the Percentage of the waste composition of Nirala SDPs are shown in Table 2, and these three SDP's locations in a different area in Khulna city. The wastes show a high portion of biodegradable waste mainly generated by households.

Table 2 Average wet weight fraction of Municipal Solid Waste (MSW) compositions

Types of Waste composition	(%) Waste compositions of Goalkhali SDP	(%) Waste compositions of PTI more SDP	(%) Waste compositions of Nirala SDP	(%) Average waste compositions
Biodegradable Waste	84.18	81.64	83.24	83.02
Plastics & polythene	4.10	4.2	4.04	4.11
Paper & cardboard	4.90	5.22	5.48	5.20
Glass	1.56	1.3	0.98	1.28
Textiles & wood	2.10	2.72	2.47	2.43
Metals	0.56	0.56	0.48	0.53
Medical waste	0.20	0.42	0.24	0.29
Dust & ashes	2.40	3.94	3.07	3.14

The average waste composition fraction of three open-system SDPs is shown in (Figure 5). The biodegradable fraction (Organic matter) is 83.02% weight which is greater than other components essentially due to the high-water content. Glass, leather and rubber were the smallest composition for all open system SDPs.

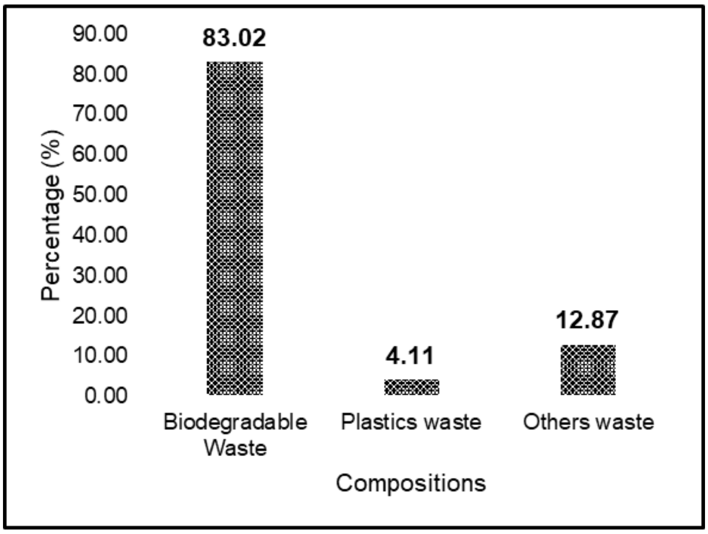


Figure 5 Biodegradable and plastic waste fraction

Moisture Content and Density

Table 3 displays the average bulk density and moisture content of the waste components in the selected location. The moisture content of municipal solid wastes is commonly expressed as the weight of water per unit weight of wet material. The results show that the water content of biodegradable garbage from mixed waste was the greatest, at 77.24%. The moisture contents of the various other components, such as plastics & polythene, paper & cardboard, glass, textiles & wood, metals, and medical waste, dust & ashes, were 18.76%, 31.56%, 3.98%, 33.10%, 6.09%, 9.10%, and 35.73%, respectively. Also, this study found that the bulk density of biodegradable waste is 542.6 kg/m^3 and plastic & polythene 18.76% respectively. All the required test has been done in KUET waste laboratory (Figure 6).

Table 3 Results of moisture content and bulk density of waste components

Composition	Moisture content (%)	Density (kg/m^3)
Biodegradable Waste	77.24	561.73
Plastics & polythene	18.76	44.20
Paper & cardboard	31.56	111.32
Glass	3.98	291.67
Textiles & woods	33.10	127.55
Metals	6.09	133.04
Medical waste	9.10	437.90
Dust & Ashes	35.73	415.69

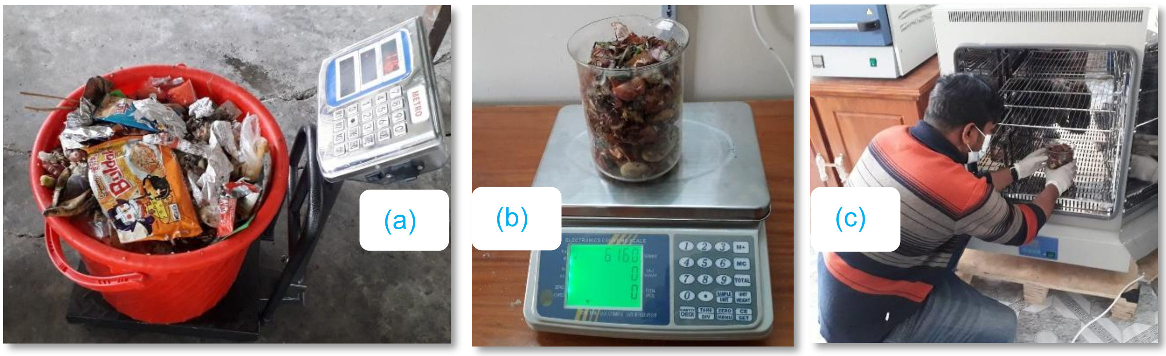


Figure 6 Taking the wet weight of MSW and oven dry at waste laboratory KUET (Noman, 2022)

MSW Collection and Transportation System

Normally, KCC is in charge of managing MSW, along with, a number of NGOs, CBOs, and small entrepreneurs who have started working on the door-to-door collection. Basically, some studies found that door-to-door collection systems have been effectively way & implemented for the collecting of MSW in Khulna city (Islam et al. 2008). This study found that primarily the waste is collected by the waste collectors from generation points, and dispose of the majority of it is at the closest SDPs. Generally, the primary collection is done the NGOs, CBOs, and small entrepreneurs. Three types of listed SDPs exist such as container, open dump, and inhouse system in Khulna city. This MSW is gathered by KCC and transferred to the open dump sites (Rajbandh) (Figure 7). The MSW is becoming a problem for city citizens, planners, and other concerned stakeholders due to severe financial restrictions, a lack of desire, the absence of appropriate environmental protection legislation, and the lack of a route plan.

Figure 7 MSW Management (a) Collection from household (b) Collection from SDP
(c) Transportation and dumping at landfill (Tariqul, 2022)

Material Flow at Open System SDPs

The municipal solid waste generation sources are households, institutions, commercial places, medical, industry, roads, and drains. This MSW is collected by NGOs and CBOs who are playing the key role in primarily waste collection systems. During the collection the waste from sources, some of the valuable materials are speared by waste collectors. This study found some key information through field surveys and direct interviews with related persons in waste management. It is found that the maximum number of interviewers stored their waste in a bin or polythene bag only a few of them were habitual to source separation. Some of the households collected their waste in community bins also. But all the waste is not stored in bins because of a lack of awareness/ mismanagement, this waste goes to drains/water bodies/ dumping scattered open spaces. The waste collectors collected the waste from door to door and transferred it to SDPs. They also sorted the valuable materials during the collection of the waste from sources and the scavengers also pick up the valuable materials at SDPs. MSW also goes to drains/water bodies from SDPs because of weak infrastructure/mismanagement. The waste from SDPs is transported by KCC to the landfill which is the key role of the organization. The sorted materials are sold to small-scale plastic recycling shops and resorted. After completing the resort, they sold again to a recycling shop. An unused portion of plastic from recycling shops also goes to drains/ water bodies and SDPs express by the red line of the flow diagram. But the maximum portion of the medical waste directly dumps at a landfill. The complete scenarios are shown in Figure 8 of the waste flow diagram. However, the red marks expressed the adverse impact that occurred on the management system as well as human health and the environment.

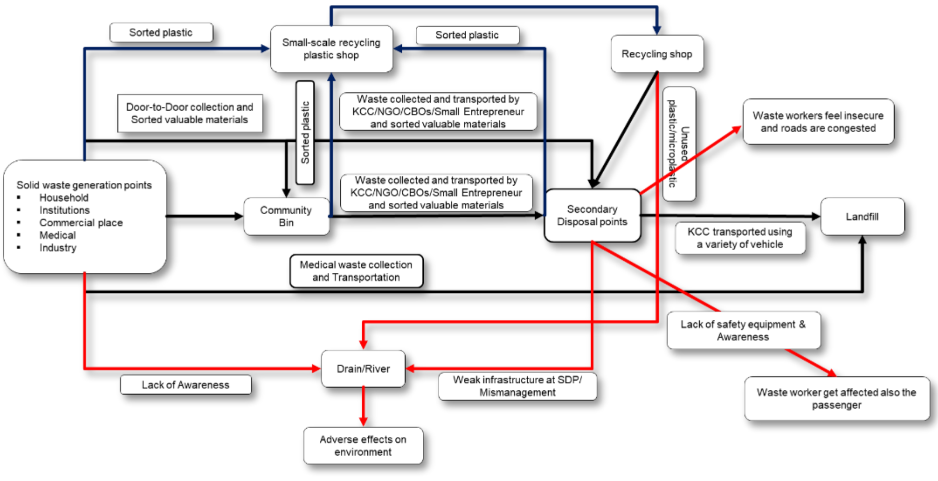


Figure 8 Materials flow of MSW in Khulna city (Tariqul, 2022)

Present Scenarios of Existing Conditions

The field visit at open system SDPs was conducted to investigate the existing technical conditions at KCC. The visit and interviews with related persons at 21 listed how open-system SDPs were operated. The survey results on technical aspects were surrounding boundary wall of open system SDPs (33.3%), concrete floor (81%), drain connection (23.8%), Waste spreading around (66.7%), and creating congestion on roads (48%) among the 21 open system SDPs (Figure 9). Absence of a boundary wall the waste has been spreading easily around the spaces that are affected by the movement of the vehicle and create congestion (Figure 10). Also, this study found that this mismanagement affected drainage water flow and finally human health that occurred by open system SDPs.

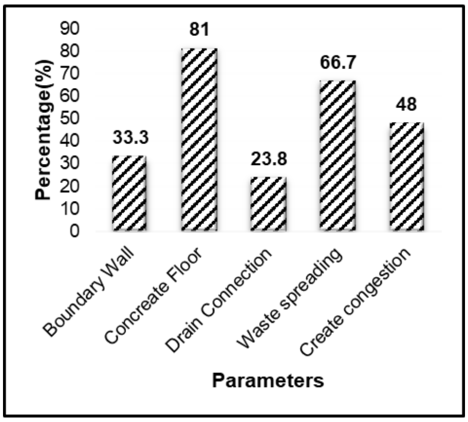
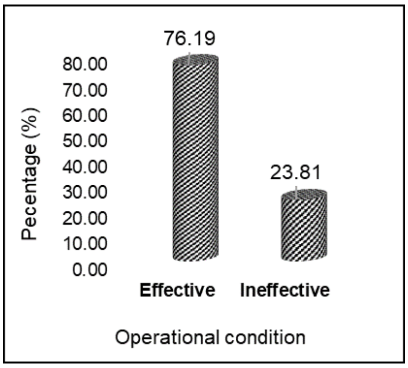


Figure 9 Physical conditions of open system SDP and Direct interview of waste workers (Tariqul, 2022)

Figure 10 Existing condition of open system SDP at (a) Nirala (b) Pujakhola (Tariqul, 2022)

In addition, the functional conditions of open-system SDPs were investigated through direct interviews and field visits. Among the existing open system SDPs, this study found that 23.81% SDPs not functioning regularly as well as not in the proper location (field visits and interviews). Ineffective or effective means considering the factors such as regularly waste is removed and the proper location for waste dumping (Figure 11).

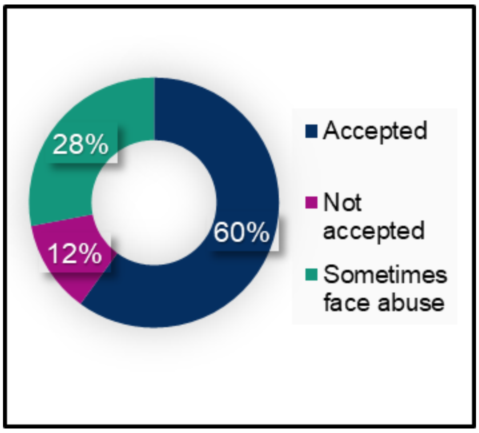


Rupsa market SDP conditions

Figure 11 Existing operational conditions (Tariqul, 2022)

Social Aspects of Waste Workers

This study evaluated the social acceptance of waste workers through direct interviews. Most waste workers answered that society cordially accepted them as waste workers and appreciated them. They and their families do not face any major problems and they get access to basic needs from society without any hamper. We interviewed 150 responders (Scavengers, waste collectors, and supervisors) among them 60% felt accepted, 28% felt not accepted and 12% sometimes faced abuse by society (Figure 12). Among the 28% of workers sometimes face challenges to knowing their problems of working place to authority. And 12% of workers and their family members sometimes face abuse from society. As well as 92% of responders said that society/KCC/organizations do not offer any special benefits and only 12% of responders get help in an emergency case as they doing challenging work (Figure 13).



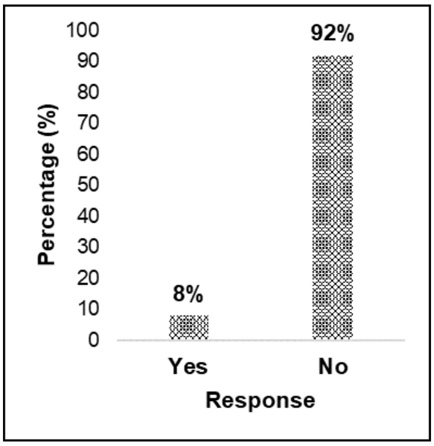


Figure 12 Waste worker's social acceptance

Figure 13 Society/organizations offer special benefits

Health Conditions of Waste Workers

Safety equipment is a major concerning issue for waste workers to protect them from affecting different kinds of health risks. We found from direct field surveys and interviews that 20% used safety boots and 80% never used safety boots while working. Also, 16% used safety gloves and never used safety gloves and 84% never used safety gloves while working (Figure 14). Although some of the organizations have provided safety equipment, they do not use it. Our study found the actual reasons behind this, they are not aware of their health and safety are not comfortable doing work wearing boots and gloves.

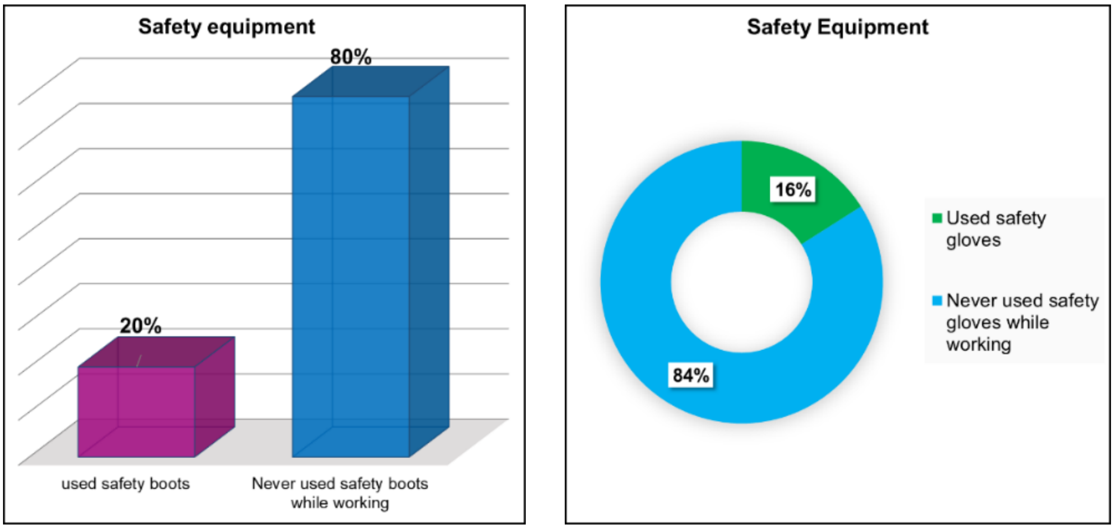


Figure 14 Safety tools used in scenarios of waste worker

Furthermore, this study investigated the health issues of waste workers that they faced in their daily life to work in waste management. During this interview, we closely observed their answers and talked to them in detail about their whole working experience. Addressing health-related issues posed a challenge. We found that they faced different kinds of problems during work such as skin problems (10%), cough/breathing problems (20%), eye problems (2%), stomach problems (15%), and being cut by sharp materials (18%) among 150 interview partners (Figure 15). Also, it was identified that some of them were affected by two or three types of diseases. This study found that those who used safety boots/ gloves get less affected by sharp materials. Some of the workers stated that concerns regarding their safety issues are well-known, but the KCC authorities are slow in their response to address them.

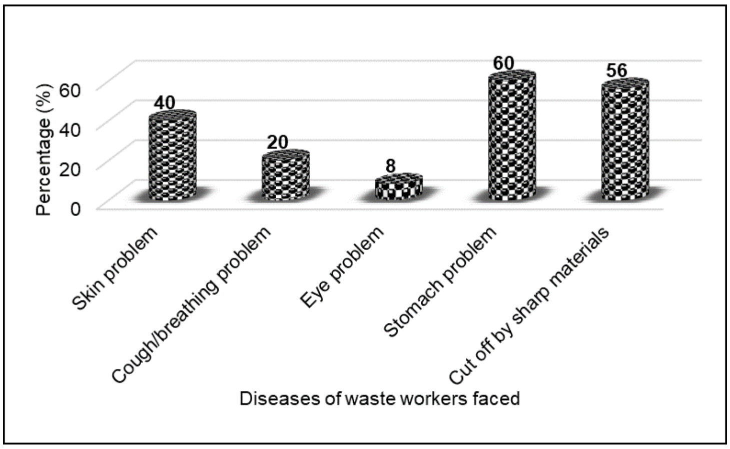


Figure 15 Challenges often faced by waste workers

Environmental Challenges

During the field survey of 21 open systems, SDPs found that 23.8% of open system SDPs have a connection with nearby drains, and wastes are spread out on them frequently (Figure 16). This waste creates a blockage of natural water flowing through drainage. Drain water overflows when a flash flood occurred or heavy rain. As a result, this flooded water caused water logging in the rainy season as well as damaged the structure of roads and SDPs. This drain water is a source of lying eggs of Aedes mosquitoes as well as many other waters contaminated diseases (Rahman et al. 2020)

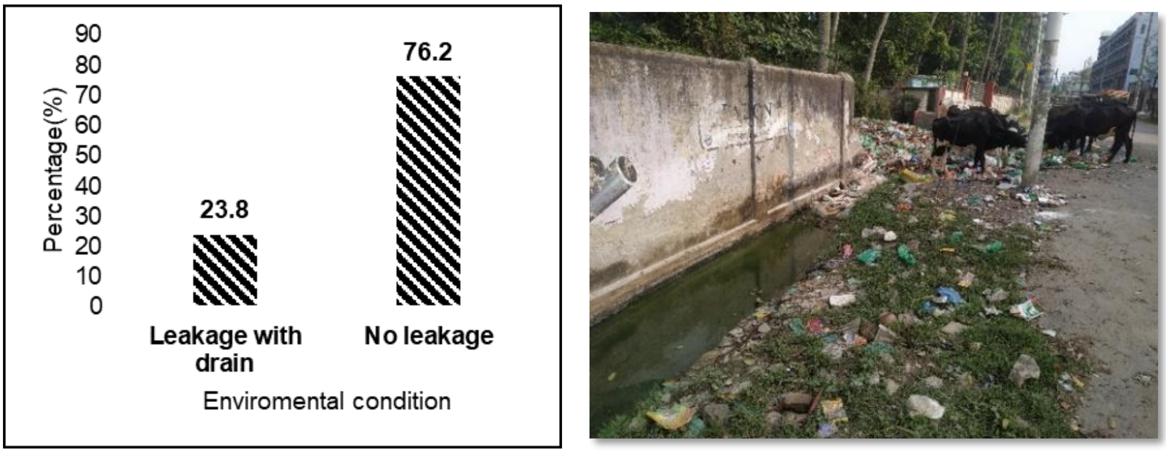


Figure 16 Environmental challenges at open system SDP (Tariqul, 2022)

However, the mismanagement of MSW is hampering the different sectors of city dwellers as well as the environment. As there has no surrounding wall 33.33% of open-system SDPs affected vehicle movement, create congestion, occurred further waste littering by animals and waste workers felt insecure condition during waste dumping. As well as having no leachate management process among 21 open system SDPs and it affected surrounding aquatic life. Some studies found that source separation is a very effective management process of MSW but in SDPs have no option for waste dumping or sorting for scavengers or waste workers. Based on the findings of this study that discussed aforementioned, some modification of open-system SDPs has been proposed to reduce the adverse impacts. Separate waste collection, leakage of waste to drainage, health safety of the waste worker, future waste generation, and space required has been considered to modify the existing open system SDPs in Khulna city.

PROPOSED MODIFICATIONS REGARDING THIS STUDY

Planning of MSW management

The space required for waste management in SDPs has been calculated based on the predicted population and waste generation shown in table 5. The population and waste generation predictions have been revealed in the previous study (Rafew & Rafizul, 2021). The bulk density was determined

542.6 kg/m3 of the municipal waste that was dumped in SDPs. The design volume of the waste-collecting rickshaw van is 0.79 m^3 and the SDP volume of 81.62 m^3 has been used to determine the space and number of trips. The number of containers required for waste management was also found out considering the waste collection container of 5 tons (10m^3). For the prediction number of container (equation 4), the number of rickshaw van (equation 5) and the volume of SDP was used. Table 4 shows the MSW management planning in ward based in KCC.

$$Number\ of\ container = \frac{Total\ waste\ generation}{Bulk\ density\ x\ container\ capacity} \tag{4}$$

$$Number\ of\ rickshaw\ van = \frac{Total\ waste\ generation}{Bulk\ density\ x\ van\ capacity} \tag{5}$$

$$Volume\ of\ SDP = \frac{Total\ waste\ generation}{Bulk\ density} \tag{6}$$

Table 4 Future waste generation prediction and space required for MSWM in Khulna city

Year	2022	2025	2030	2035	2040	2045	2050	remarks
Population (Nos.)	1542611	1607702	1722345	1845164	1976741	2117700	2268711	(Rafew & Rafizul, 2021)
Waste Generation (ton/year)	186000	225000	304000	412000	555000	792000	1210000	
Waste generation rate (kg/day)	509589	616438.4	832876.7	1128767	1520548	2169863	3315068	
Space required for SDPs (m^3)	939.16	1082.99	1463.24	1983.08	2671.38	3812.13	5824.08	
Waste collection van required (Nos.)	1189	1371	1852	2510	3381	4825	7372	
Required number of 5-ton containers (Nos)	102	123	167	226	304	434	663	
Design SDP required (Nos.)	12	13	18	24	33	47	71	

Table 5 Prediction of Waste generation, space for SDPs, and containers required in each ward of KCC

Ward no.	Population (2011)	Population (2021)	waste generation rate (kg/person/day)	Total waste generation (Kg/day)	No of container required (10m^3 = 5 ton)	Space required for SDP (m^3)
1	18900	21337	0.46	9814.83	2	18.09
2	13790	15568		7161.19	1	13.20
3	21821	24634		11331.72	2	20.88
4	15780	17814		8194.61	2	15.10
5	14835	16748		7703.87	2	14.20
6	20734	23407		10767.24	2	19.84
7	10645	12017		5527.98	1	10.19
8	9308	10508		4833.68	1	8.91
9	31882	35992		16556.43	3	30.51
10	27947	31550		14512.97	3	26.75
11	12373	13968		6425.34	1	11.84
12	21208	23942		11013.39	2	20.30
13	9287	10484		4822.77	1	8.89
14	26335	29730		13675.85	3	25.20
15	16314	18417		8471.92	2	15.61
16	29213	32979		15170.41	3	27.96
17	33163	37438		17221.66	3	31.74
18	27896	31492		14486.49	3	26.70
19	18558	20951		9637.23	2	17.76

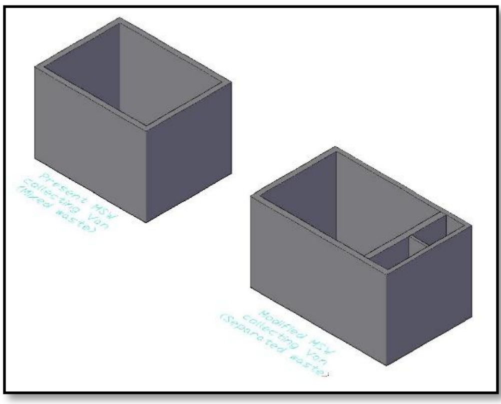
20	16623	18766	8632.38	2	15.91
21	20220	22827	10500.31	2	19.35
22	17239	19461	8952.27	2	16.50
23	13793	15571	7162.75	1	13.20
24	37889	42774	19675.89	4	36.26
25	21274	24017	11047.66	2	20.36
26	21011	23720	10911.08	2	20.11
27	30265	34167	15716.72	3	28.97
28	20148	22745	10462.92	2	19.28
29	17763	20053	9224.39	2	17.00
30	33283	37574	17283.97	3	31.85
31	33844	38207	17575.30	4	32.39
Total	**663341**	**748859**	**344475.23**	**69**	634.86

Modification of Waste-Collecting Rickshaw Van

The interview partners at household level complained that they could separate the non-degradable compositions from the degradable portion. But the waste collector mixed the waste as there was no scope to collect the waste separately in their collection rickshaw van during the management process. But in recent times waste collectors separately managed the recyclable waste in their hanging bags only that portion they can sell to recycling shops. But still, there has no separate chamber in the rickshaw van to collect the waste separately from the sources. To transport separately the collected waste the existing chamber has been modified by considering waste collector concerns. So, they can easily transfer separately to SDP. To reduce the odor problem during the transfer of the waste to the SDP cover has been provided in this modified rickshaw van (Figure 17). Table 6 shows that two trips were required by modified vans to collect the waste of 250 family's waste. Modified rickshaw vans have two separate chambers for collecting biodegradable waste and non-degradable waste separately. The mode of the rickshaw van of non-motorized has been proposed the motorized. Because the initial cost of a motorized van price is 40,000 BDT and a motorized cost 55,000 BDT, as well as the maintenance cost, is high for motorized rickshaw van (interview with waste collectors). Although the efficiency in terms of time consuming for waste transfer is lower for motorized van.

Table 6 Chamber volume and Trips required for the waste collector

No of Family	Average population/ HH	waste generation rate (kg/cap/day)	Total waste generation (Kg/day)	Volume required of rickshaw van (m^3)	Existing volume of Van (m^3)	Modified rickshaw van volume (m^3)	No of trips required by modified van to collect the waste
250	4	0.476	476	0.877	0.66	0.79	2



Modifications

- Separate chamber for recycling waste and bio-waste
- Top of the chamber will be covered by two sliding windows to solve odor problem
- Total dimension of chamber 50-inch x 32-inch x 30-inch (volume= 0.79 m^3).
- Material used for chamber stainless steel (SS).
- Incease source separation of non-degradable waste

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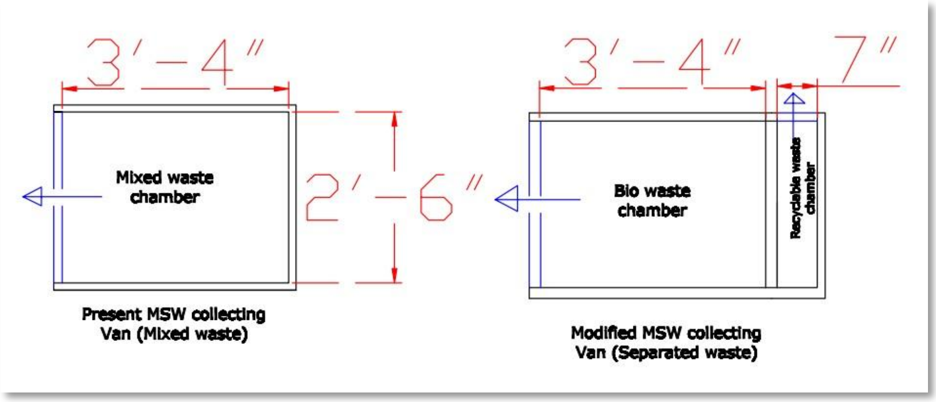
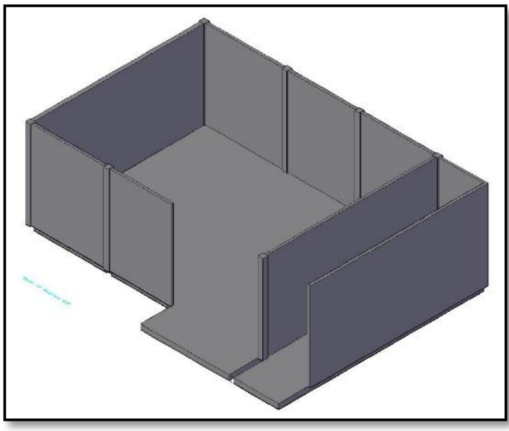


Figure 17 Modification model of waste collection van (Separate chamber, odor, and waste littering control)

Modification of open system SDPs

The modification of open system SDPs has been done basis on the findings and data analysis such as existing physical conditions, environmental conditions, leachate problem and management processes. To protect from waste outside leading to further littering and congestion of roads, the boundary wall of open system SDPs ensures. The surrounding wall also protect the waste collectors during waste dumping at SDP causing accident by moving vehicles. Two separate spaces have been considered for recyclables waste management and enough free space consider for vehicle movement (Figure 18).



Modifications

- Separate spaces for recycling waste and bio-waste.
- Total dimension of open system SDP 48 feet x 30 feet (area= 133.85 m^2) required.
- Brick walls provided to reduce the waste littering, road congestion and waste leakage to drain.
- Ensure safety of waste worker to risk of accident.

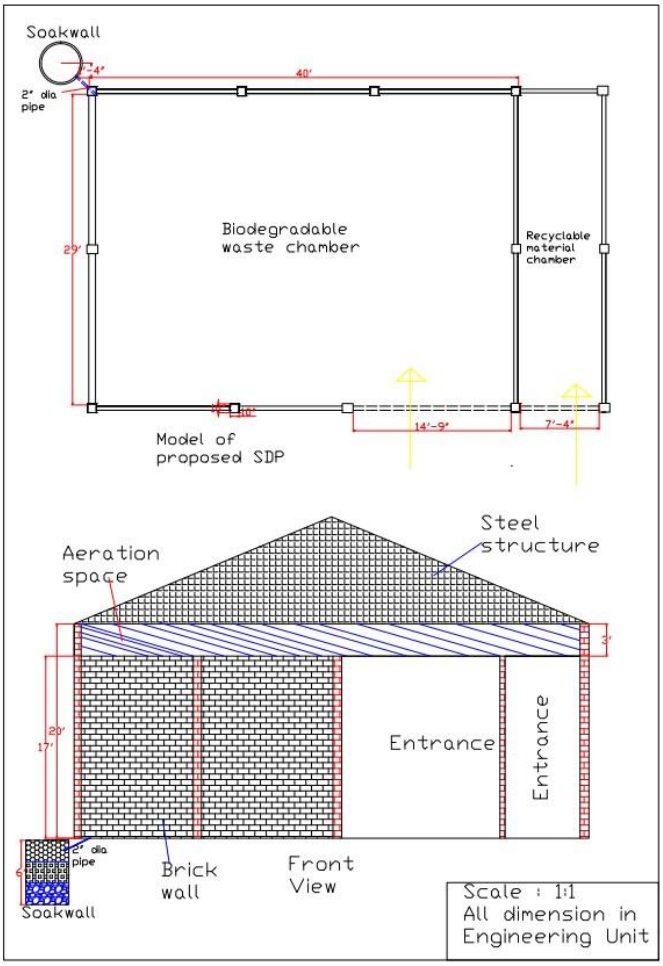


Figure 18 Proposed modified of open system SDP (separated chamber, surrounding wall, leachate treatment system and aeration process)

Table 7 Space required for Nirala SDP

No of waste collector	Families covered by waste worker / day	Average population / HH	Present population	waste generation rate(kg/cap/day) (Pankaj et al. 2020)	Total waste generation (Kg)/day	volume required (m3)
20	250	4	20000	0.476	9520	17.55

Table 7 shows the space required for one SDP on basis of the amount of waste collected by 20 persons waste collectors in the Nirala area. Each waste collector covered an average 250 number of family and an average population of 4 persons/household. The waste generation rate in Khulna city is 0.476 kg/c/day (Pankaj et al. 2020). So, at present, the space required for Nirala SDP is 16.73 m^3 for the collected waste.

CONCLUSION

The waste compositions of the MSW that is coming at Open-system SDPs daily in Khulna City from various sources, including residential, commercial, and institutional. The biodegradable fraction (Organic matter) is found at 83.02% which is greater than other compositions essentially due to the use of fresh vegetables and foods. The plastic fraction found at 4.11% is the major concerning composition. The physical conditions of all the open system SDPs are not quite good because the survey results on technical aspects found boundary walls exist only (33.3%), concrete floor (81%), waste leakage to drain (23.8%), waste littering around (66.7%), and creating congestion on roads (48%). The social aspects of waste workers are marginal, although waste management sectors created an opportunity for their livelihood. The maximum waste workers are not using the safety tools because they are not aware of health safety issues and not provide by the authority. KCC, NGOs, CBOs, and small entrepreneurs are involved in the waste management sector, but there are no concrete policies. So, the mismanagement and lack of awareness of all stakeholders are the sole concern issues to effective waste management of MSW in Khulna city. The current situation of MSW management in Khulna is not entirely adequate, according to the status of the existing MSW management layers, which include collection, storage at open system SDPs, environmental conditions, socio-economical and health conditions of waste workers, and coordination among stakeholders. So, addressing the concerning issues and future waste management process need a sustainable modification of SDPs.

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