M. Alamgir, S.M.T. Islam and J. A. Saju (Eds.)
ISBN: 978-984-35-4034-8

Proceedings of the Waste Safe 2023 – 8th International Conference on Integrated Solid Waste and Faecal Sludge Management
25-26 February 2023, Khulna, Bangladesh

OVERALL WASTE MANAGEMENT SCENARIO AT LANDFILL: A CASE STUDY IN KHULNA CITY

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ABSTRACT

Waste management is one of the most important and challenging municipal services of the modern era. Being the third largest city in Bangladesh, the amount of waste produced in Khulna is substantial. In Khulna city, hundreds of tons of waste are collected by the municipality and dumped at the city's sole dump site. Among all types of waste, a noticeable amount of plastic waste is found at the open dump site. If the plastic waste is not managed appropriately, it might harm the surroundings by discharging into the environment. In this study, the Rajbandh open dump site is selected as the study area. This study aims to assess the operation and management activities and identify the point source of plastic discharge at the open dump site. The overall management and operations of the site are thoroughly studied. Additionally, all the point sources on the site are identified, source categorization is done, and the plastic fractions of on-site and off-site areas are determined.

INTRODUCTION

The population of the world is still increasing and since 2022, according to the United Nations, it exceeds 8 billion people. With the increasing growth of the population and also change in the socio-economic status of the world population the generation of Municipal Solid Waste (MSW) is climbing day by day. Most of the developed countries have a substantial rate of MSW production (Jadoon et al., 2013). The MSW is the mixture of dumped homogenous and heterogenous substances mostly from city or town areas. Also, large quantities of heterogenous waste products from homes, businesses, industries, institutions, and other sources are found in MSW (Rafew and Islam, 2021). In present days with the increasing waste, waste management is one of the most challenging things all over the world. A waste management strategy without considering an extensive plan as well as poor management techniques and a lack of appropriate technology is making the situation more threatening to the environment and also the public health (Ahsan et. al., 2009). Bangladesh still uses the traditional municipal solid waste management which incorporates many outdated waste management techniques including inconsistent waste pickup and improper open dumping, which pollutes the air, soil, and water (Jerin et al., 2022). In the waste management process, the nonrecyclable waste is finally disposed of. There are two most practiced processes of final disposal for MSW landfilling and open dumping. Sanitary landfill is practiced for disposing of municipal solid waste in developed countries. The main emissions from waste disposal sites are different gases mostly methane and contaminated leachate. The landfill gas pollutes the surrounding air and the landfill leachate pollutes the soil and also ground and surface water. In the sanitary landfill, the main pollutants are managed in an environmentally friendly manner. However, unsanitary or open dumping is practiced in developing or under-developing countries. In South and South East Asia, more than 90% of MSW is disposed of in open dumps (Rafizul et al. 2009b). Being a developing country Bangladesh produces a huge amount of domestic waste in comparison with

industrial and commercial waste. Khulna is the 3rd largest city in Bangladesh and is located on the banks of the Rupsha and Bhairab rivers in the Southwest of the country covering an area of 45.65 km^2 and having a population of about 1.5 million (Basic statistics, KCC). The present study aims to identify the point sources or the potential point sources of plastic waste flow from the open dump site to the surrounding environment. Also, the ongoing site activity and management operations are going to be assessed in this study.

METHODOLOGY

Study Area

Khulna is the 3rd largest metropolitan city in Bangladesh producing a considerable MSW. This MSW is finally disposed of in an open dump site known as Rajbandh open dump site which is the only active dumpsite in Khulna city. Geographically its latitude and longitude are 22° 47' 47.87" N and 89° 29' 57.68" E respectively. It receives waste from households, markets, industries, institutions, and municipalities. The total area of the open dump site is approximately 20 acres owned by Khulna City Corporation (KCC).

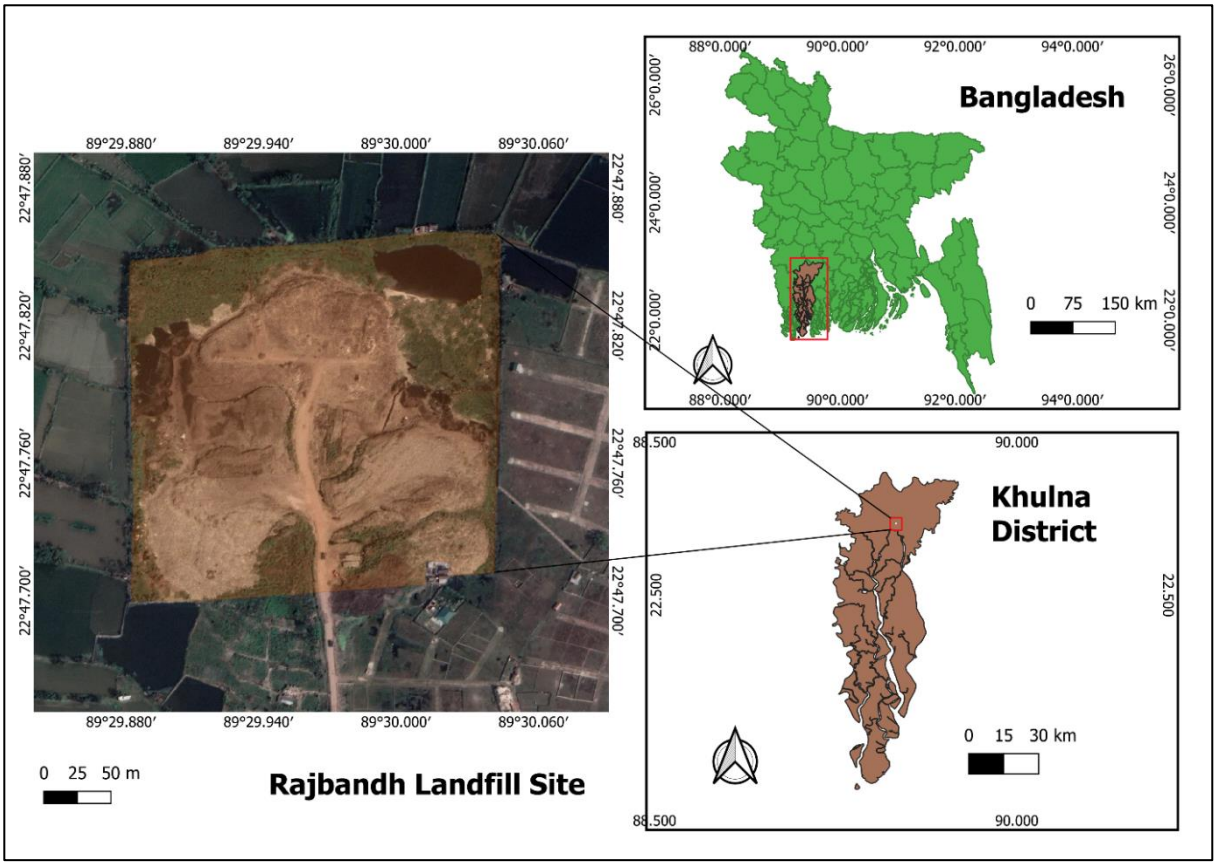


Figure 1: Open MSW dump site located in Rajbandh, Khulna, Bangladesh

Waste materials are carried here by the municipal trucks of the Khulna City Corporation. NGOs dispose of medical waste on the site. All plastic waste is directly disposed of here from secondary disposal points and other places like construction areas and clogged drains. Informal waste collectors work here to collect recyclable waste. The map of the study area is shown in Figure 1.

Overall Landfill Management Assessment

Figure 2 depicts the site's overall management activity, which has been divided into six categories in this study to identify all ongoing landfill management measures. Data on truck entry is obtained from the landfill supervisor. Supervisors record the total number of waste-carrying trucks entering the site in a log book. To gather information regarding management activity, the site's designated personnel were questioned, and their approach to dumping operations was closely observed. Photographs were taken as needed to document the dumping operation. Khulna City Corporation provided the relevant data regarding the landfill's designated staff members and the site's active facility for management activity. Additionally, several visits to the site helped to locate the operational landfill facility. The informal sector

ISBN: 978-984-35-4034-8

indicates the waste collectors, who are not appointed by Khulna City Corporation but work in the landfill. Their operation and activity on the site were thoroughly monitored, and an interview was done. For safety-related issues, the landfill's current facility and the availability of necessary safety tools were monitored by visiting the site office and interviewing the landfill supervisor. For medical waste management, the flow of medical waste at the site was identified by interviewing the responsible medical waste collector and NGO workers.

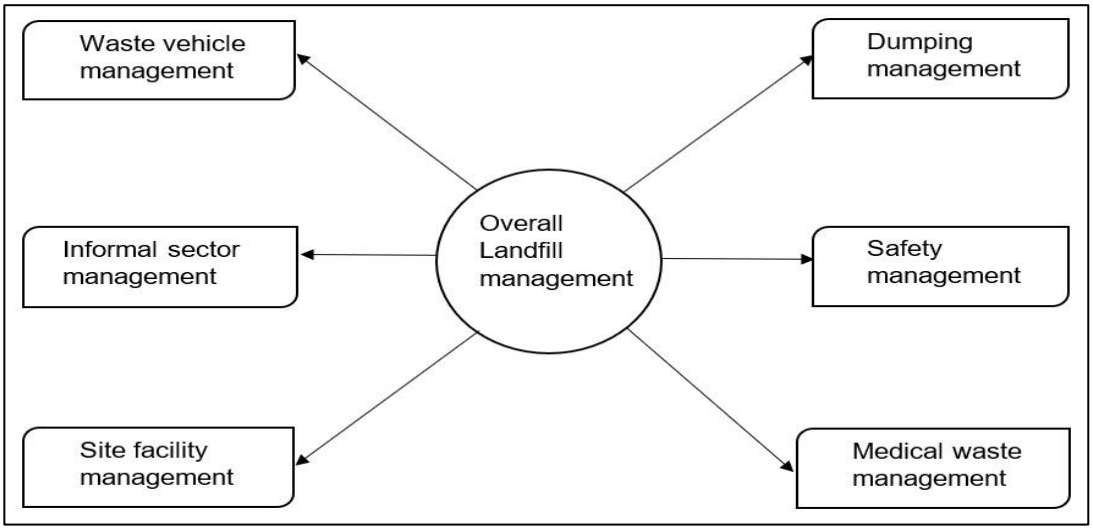


Figure 2. Overall landfill management components.

Point Source Identification

For point source identification of the open dump site, it is necessary to define the periphery of the site. A reconnaissance survey was done along the perimeter of the site. Based on waste discharge from the site to its surroundings, precise spots in the site's perimeter line were identified visually. Also, the potential point sources' location was considered in this survey. The GPS coordinates of all the points were collected using Google Maps and used by Esri QGIS 3.28.0 software to create a location map. Also, the distance and type of buffer zone between the waste pile and the point source location were considered.

Identifying Land Use Patterns Surrounding the Open Dump Site

In the study area in Figure 1, the open dumpsite area and the periphery of the site are clearly defined. As waste was being discharged into the environment, the dumpsite's surroundings needed to be investigated. The site's surroundings were observed and using Esri QGIS 3.28.0 software, a map of the site's surroundings' land use pattern was created to assist in understanding the local land use pattern.

Plastic Waste Quantification

To choose a specific location to study the type of waste discharged, a heatmap was developed in Esri QGIS 3.28.0 software. The heatmap's darker region represents more waste density. Based on that, two particular waste zones were considered. In zone-1, the three-point sources (1,2, and 3) were dumping waste in one particular pond, pond-1. In zone 2, other three-point sources (7, 8, and 9) discharged waste into ponds 8 and 9. For studying waste type, zone-1 and zone-2 were selected. Wastes were collected in both zones in on-site and off-site conditions. Fish nets were used to collect waste from ponds. Waste samples were mixed, put into a standard 35-liter bucket, and weighed in their wet state. After that, waste samples were manually sorted into two categories, i.e., plastic and non-plastic waste. The plastic portion was manually sorted into sub-categories, i.e., packaging waste, polythene, rexine, PET bottles, and other plastic waste. Each plastic fraction was weighed, and the plastic percentage was identified.

RESULTS AND DISCUSSION

Landfill Management

The overall operation and management scenario will be discussed in the following sections.

Waste Vehicle Management

Figure 3 displays the total number of trucks entering the site during the different periods of the year. It implies that the truck number varies from 76 to 132 per day. In Figure 4, the total waste amount entering the site is shown. As the Rajbandh landfill site is an open, non-sanitary landfill, weighing facilities are not available at the site. The total number of vehicles was multiplied by the respective vehicle's capacity to find the total waste amount entering the site. It gives a rough estimation of the amount of waste entering the site. It demonstrates that the daily range for total dumped waste is between 600 and 660 tons. Two landfill supervisors work from 6 am to 6 pm in two shifts each day to manage this enormous fleet of vehicles. Their main duty is to instruct the truck driver to dump the waste in a certain spot on the dumping site. Additionally, they record the number of trucks that arrive at the site each day along with the date and time. Since there is no washing facility on the site, the waste vehicles leave after disposing of the waste without doing any washing.

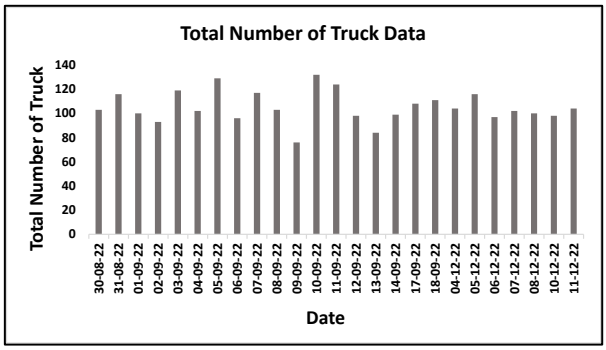


Figure 3. The total number of trucks entering the site

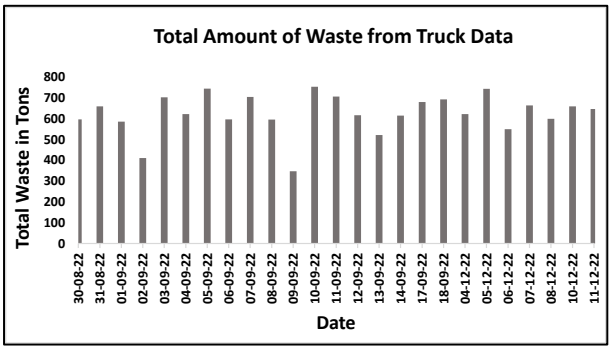


Figure 4. Total amount of wastes from truck data

Dumping management

Figure 5. Waste dumping from the truck (H.M. Nahid, 15/12/22)

Figure 6. Leveling of dumped waste by bulldozer (H.M. Nahid, 15/12/22)

The bulldozer operator begins his work after dumping the waste from the waste-carrying vehicle in a particular area of the site by the supervisor's instructions. To avoid big heaps in the waste pile, the operator's main duty is to spread the waste from the dumping point over a broader region. The operator also levels the waste heap and makes room for the next vehicle to place its waste in a particular location on the work site The site manager claims that leveling is necessary to make proper utilization of the site area. Also, compaction is done through the process, which also promotes the optimization of land use on the site. Leveling and spreading out is the core part of the dumping management in the Rajbandh open dumpsite. Figures 5 and 6 are showing dumping and leveling operations respectively.

Site Facility Management

There is only one small office room at the Rajbandh site where KCC-appointed staff members work. Visual observation and staff interviews facilitated the development of a narrative about the nature of the

activity in that room. This is the place where all the personnel take rests and have launched. Their official documentation files and logs of different site data sets, like truck logging data, are all stored here. Also, this room works as the storeroom for the site. Shovel, bucket, bulldozer chain, bulldozer oil, gumboot, fast aid box, and basic bulldozer repair tools are all available here. A drinking water tube well is also available here. This tube well is the only drinking facility on the whole site. As it is an open dumpsite, any engineered facility like a soil cover, liner, fence, or weighbridge is unavailable. Figure 7 shows the site office and Figure 8 demonstrates the inside view of that office. Table 1 shows all the KCC-appointed employees who work at the site.

Figure 7. Site office room (H.M. Nahid,15/12/22)

Figure 8. Inside view of site office room (H.M. Nahid, 15/12/22)

Table 1: KCC appointed employees at Rajbandh landfill

Employee designation	Number
Site Supervisor	2
Bulldozer operator	1
Gatekeeper	3

Informal Sector Management

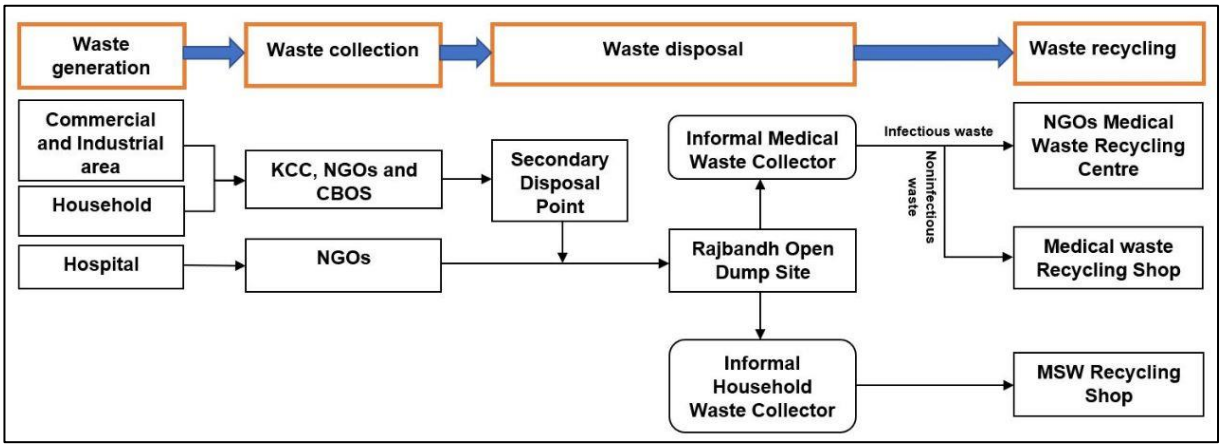


Figure 9. Waste flow diagram showing the role of informal waste collector at the dump site

The site's recyclable waste is collected by a small group of waste collectors who are not employed by KCC. The types and percentages of waste that are collected by informal waste collectors are depicted in Figure 10. The waste flow diagram showing the role of informal waste collectors at the dump site is shown in Figure 9. Since the informal sector operates on the site as a freelancer worker, no centralized management activity is carried out concerning the informal sector. Informal waste collectors come onto the site and depart as they want. The informal waste collectors are not subject to any authority from landfill employees. They claim that neither KCC nor the officials at the landfill provide any facilities for them. Figure 11 shows the interview session of the informal waste collector whereas Figure 12 depicts

waste collection at the site by the sector. Figure 13 and 14 shows the pile of collected waste and selling operation respectively.

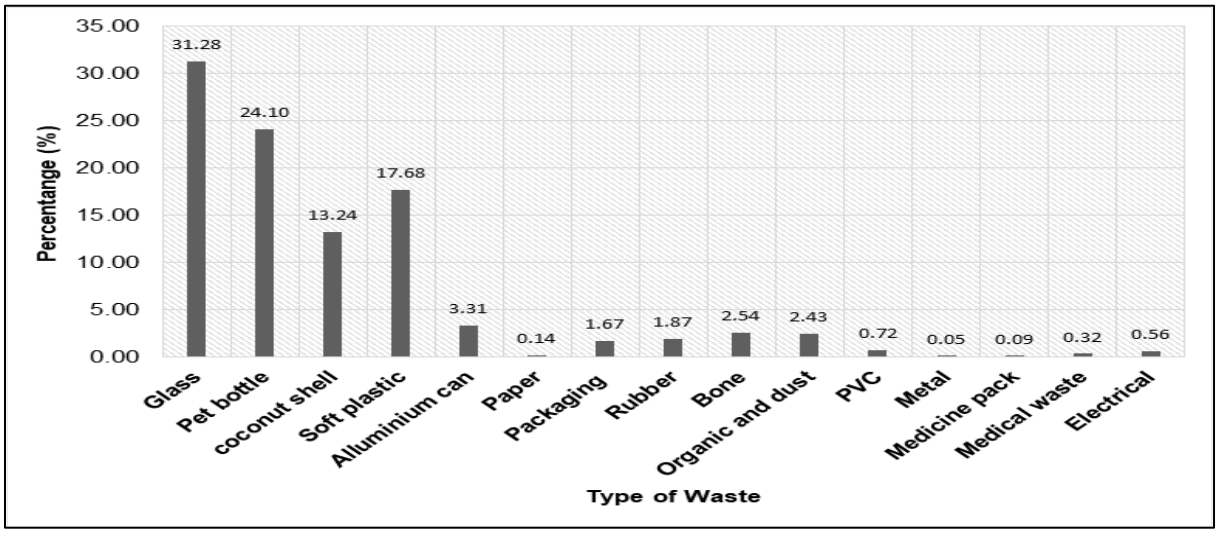


Fig. 10. Types of waste collected by the informal waste collector

Figure 11. Interview session of a waste collector (H.M. Nahid, 13/11/22)

Figure 12. Recyclable waste collection by waste collectors (H.M. Nahid,15/12/22)

Fig.13. Pile of waste sack collected by waste collectors (S. Setu, 13/11/22)

Fig.14. Waste sacks on the way to the recycling shop (S. Setu, 13/11/22)

Medical Waste Management

Several NGOs transport hospital waste to the open dump site and waste collectors collect the

recyclables from that waste. After the sorting process, they deliver some hazardous waste back to the NGOs, and the rest is sold to a designated buyer at the recycling shop. Figure 15 shows the sorting process of medical waste. Medical waste-carrying trucks are different from municipal waste-carrying trucks, owned by NGOs. But there is no specified zone for medical waste dumping on the site. Visual investigation confirms that sensitive medical wastes are spread out all over the landfill (Figure 16), which creates threats to the safety of informal workers and landfill personnel.

Figure 15. Medical wastes collected by waste pickers (H.M. Nahid, 15/12/22)

Figure 16. Medical wastes at random places on the site (H.M. Nahid, 15/12/22)

Safety Management

Rajbandh lacks the requisite safety amenities because it is not an engineered landfill. Only one first-aid box (Figure 17), which was supplied by an NGO years ago, was identified during the visit to the site office. Upon inspection, it was discovered that neither the site's workers nor the informal waste collectors were wearing any PPE, gloves, or masks, only safety shoes. The workers have no access to weather protection and are exposed to all weather conditions. There was no central safety policy for the waste collector. Additionally, the authority severely disregards the safety of informal waste collectors. Another noticeable issue identified during the site visit was that, as soon as the waste trucks dump waste, waste collectors surround the area for collecting waste. This can occasionally impede the work of the bulldozer operator and endanger the safety of the waste collectors (Figure 18).

Figure 17. First aid box at the site office (H.M. Nahid, 15/12/22)

Figure 18. Informal collectors working near the bulldozer (H.M. Nahid, 15/12/22)

Landfill Operations with Weather Variation

Activity in the landfill is not influenced by temperature variation, according to the landfill supervisor. If the waste flow is occurring, then landfill activity must be ongoing. However, during the rainy season, some activities cannot be carried out fully. The leveling activity is hampered by precipitation. According to the site's bulldozer operator, the waste heap's leveling operation is hampered by excessive water in the dumping site. Another issue is that waste cannot be spread out thoroughly to the edge of the site.

ISBN: 978-984-35-4034-8

When it rains, it spreads out over a smaller area than when it is dry. Also, the inside roads of the site are earth roads, which lead to excessive mud during rain. This hampers the truck flow as they cannot drop waste at the designated area of the site. Here in Figure 19, the total daily incoming truck numbers variation with daily precipitation of 16 days in the month of August and September is shown. Observation from Figure 19 confirms that when precipitation is higher, the number of waste-carrying trucks decreases. Even though this relationship is not always followed. According to the supervisor, if there is a special occasion, festival, or program in the city where large crowds gather, waste-carrying trucks would work in full force regardless of the weather on those days. Additionally, despite having precipitation, several dates in Figure 19 show little change in the number of daily trucks. It implies that other factors besides rainfall affect daily truck data.

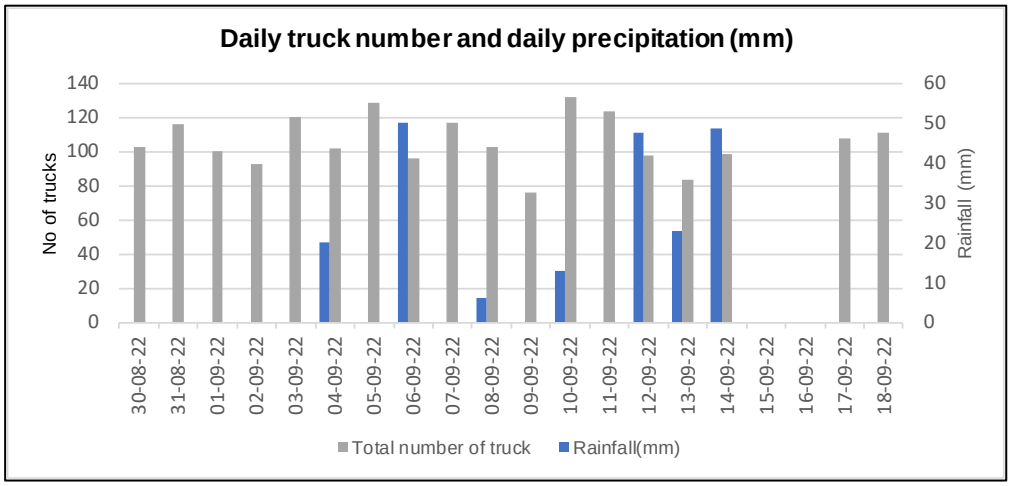


Figure 19. Variation of total truck number with daily precipitation

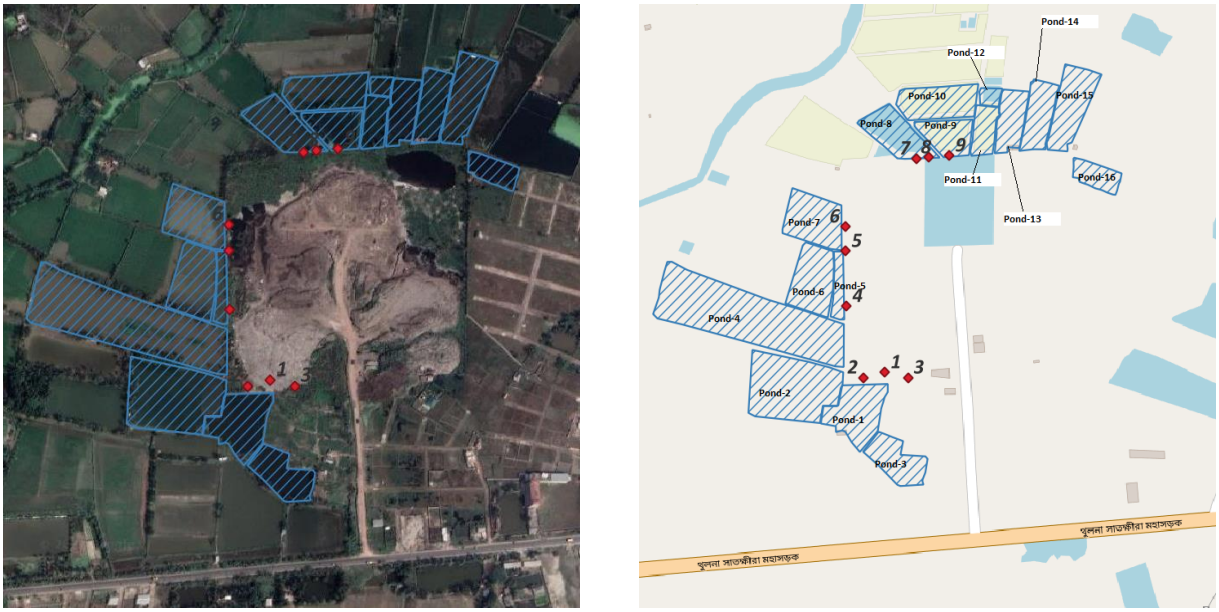
Point Source Identification and Land Use Pattern

A total of nine-point sources were identified around the open dump site through which the waste is flowing out from the dump site area. Using point sources' GPS coordinates, a location map was prepared and shown in Figure 20 where the red dot represents the point source.

Figure 20. Location map of point sources (QGIS with Google Satellite, 2022)

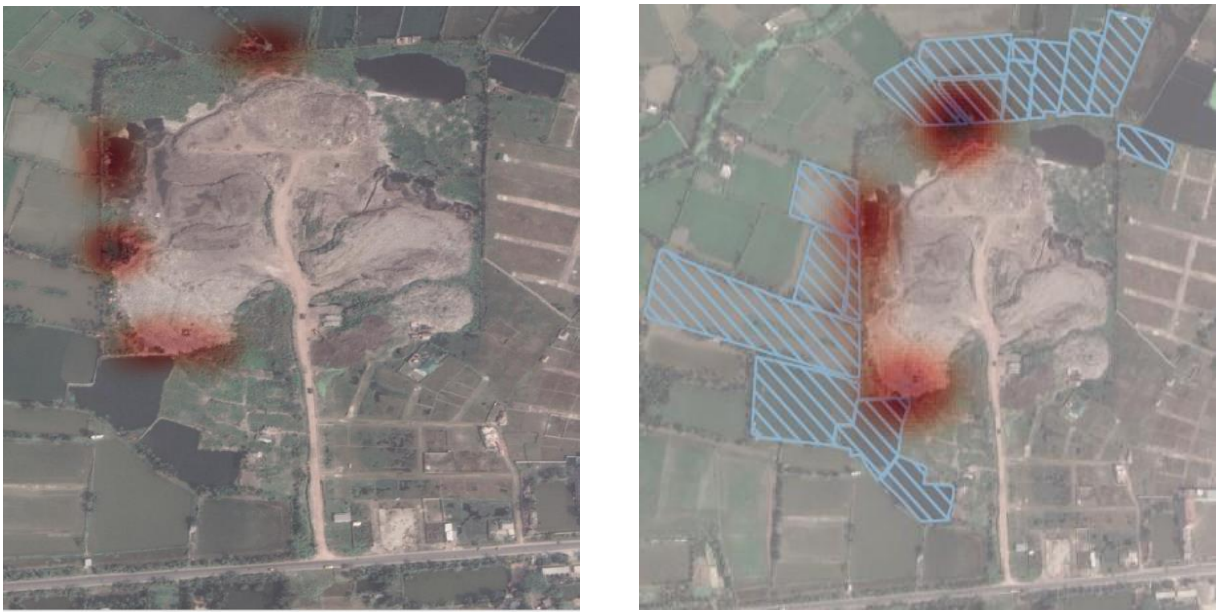
To understand dump sites surrounding land use patterns, a map is prepared showing surrounding

waterbodies and shown in Figure 21 (a) and (b). The surroundings of the site are primarily made up of waterbodies, with only a few patches of greenery. It is evident from Figure 21(b) that all specific point sources of waste disposal are located near waterbodies, primarily ponds. Wastes from all 9 points are going directly to nearby ponds. To choose a specific location to study the type of waste discharged, a heatmap was developed in Esri QGIS 3.28.0 software and shown in Figures 22(a) and (b).



(a) (b)

Figure 21. (a) Dumpsite area with surrounding waterbodies (Blue hatched area represents waterbody) (QGIS with Google Satellite, 2022) (b) Surrounding waterbody (total 16) and point source location (QGIS with Open Street Map, 2022)



(a) (b)

Figure 22. (a) Heatmap of point sources (QGIS with Google Satellite, 2022) (b) Heatmap with nearby waterbodies (Blue hatched zone) (QGIS with Google Satellite, 2022)

By analyzing the heatmap's color density, two specific zones were selected to study the type of discharged waste as shown in Figure 23. In each zone, the waste composition was studied under on-site and off-site conditions.

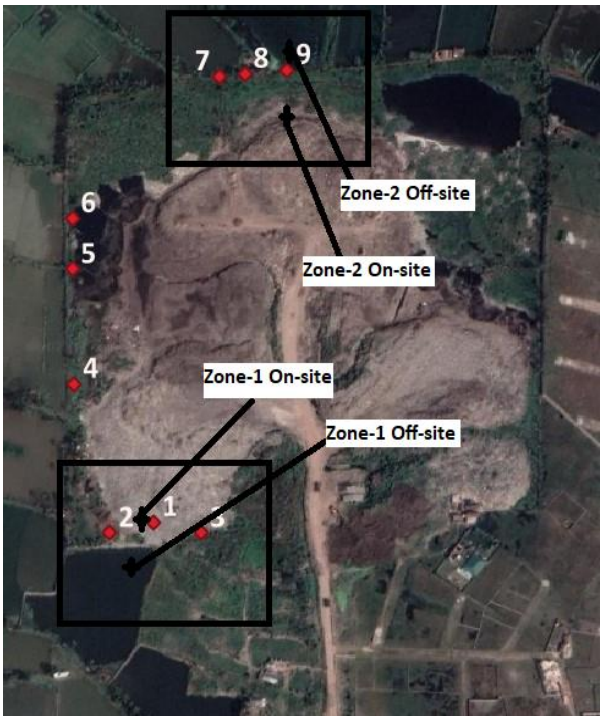


Figure 23. Selected zones for discharged waste composition study (QGIS with Google Satellite, 2022)

Point Source Categorization

All nine-point sources were split into two categories: direct and potential point sources based on the distance between each source and the closest waste pile as well as the size and nature of the buffer zone separating them. Here point source to the closest waste pile's linear distance was measured. Source categorization is shown in Table 2. Whereas potential sources have a minimum earth boundary and buffer zone between the waste pile and the point source, direct sources are those points where the earth boundary and buffer zone do not exist.

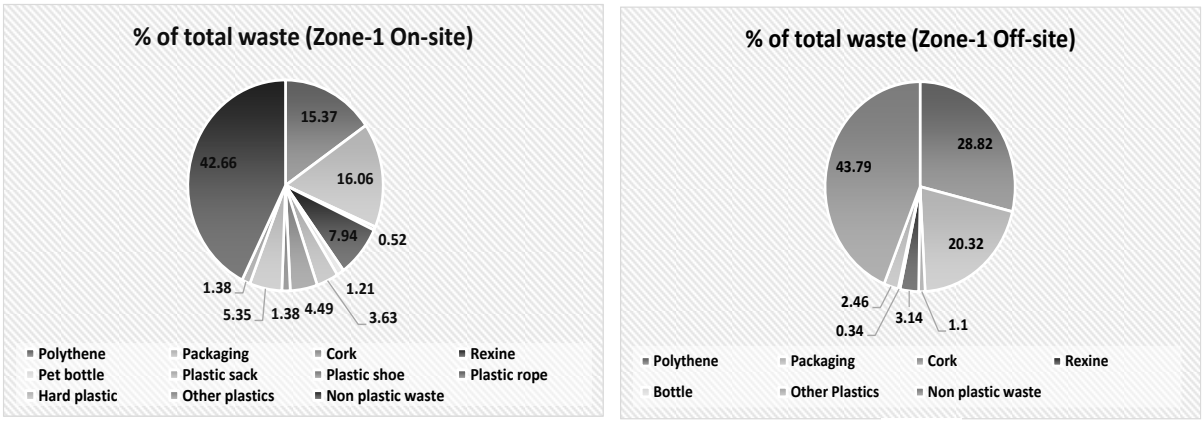
Table 2: Point source categorization

Zone	Point source	Distance from the Waste pile (m)	Earth boundary situation	Buffer Zone	Buffer Type	Source Type
1	Point 1	14.67	No earth boundary	No	No	Direct
	Point 2	32	No earth boundary	No	No	Direct
	Point 3	32.75	No earth boundary	No	No	Direct
2	Point 7	28.3	Little earth boundary	Exist	Swamp with dense vegetation	Potential
	Point 8	21.97	Little earth boundary	Exist	Swamp with dense vegetation	Potential
	Point 9	16.2	Little earth boundary	Exist	Swamp with dense vegetation	Potential

Waste Composition of Zone-1 (On-site and Off-site)

After sorting waste, every different sub-category of waste was weighed, and their percentage concerning wet waste was estimated. The data for waste sorting and the percentage is shown in the following pie charts. The waste percentage for total wet waste in Zone-1 (on-site) and Zone-1 (off-site) is shown in Figures 24 (a) and 24 (b), respectively. From here, it is clear that the total biodegradable waste is 42.66% and the rest is non-biodegradable waste, mostly plastic waste in Zone-1 (on-site). From

Figure 24 (b), the total plastic percentage of total waste in zone-1 (off-site) is 56.21%, and the rests are non-biodegradable waste. Among all the wastes in Zone-1 (off-site), polythene is the dominating fraction with an amount of 51.29% followed by packaging waste with an amount of 36.16%. The remaining fractions are cork, rexine, PET bottles, and others totaling less than 15%.

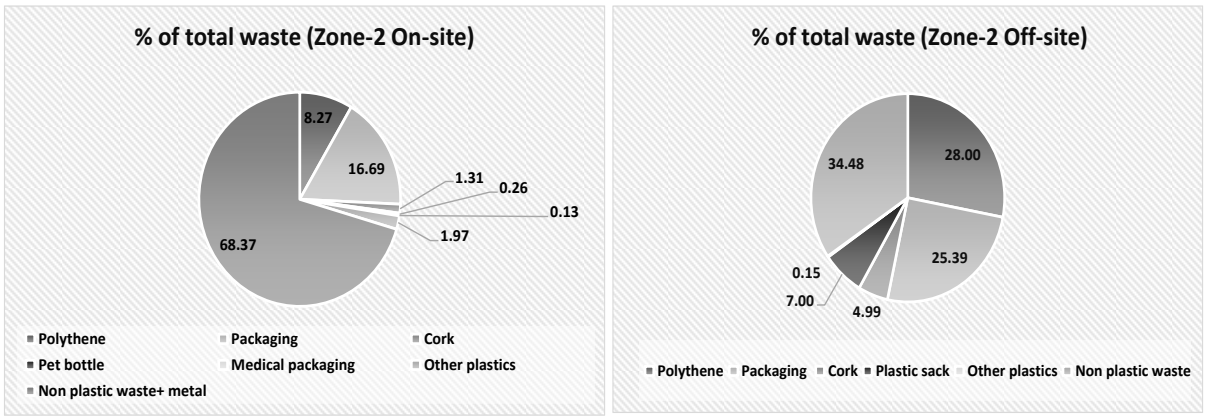


(a) (b)

Figure 24. (a) Percentage of waste in total waste in Zone-1 (on-site) (b) Percentage of waste in total wet waste in Zone-1 (off-site)

Waste Composition of Zone-2 (On-site and off-site)

From Figure 25 (a), the total plastic percentage of total waste in zone-2 (on-site) is 31.63%, and the rests are non-biodegradable waste. Figure 25 (b), the total plastic percentage of total waste in zone-2 off-site is 65.52% and the rests are non-biodegradable waste.



(a) (b)

Figure 25. (a) Percentage of waste in total waste in Zone-2 (on-site) (b) Percentage of waste in total wet waste in Zone-2 (off-site)

Plastic Fraction Comparison of Zone-1 and Zone-2 (On-site and off-site)

Figure 26. represents the percentage of plastic in total waste in zone-1 and zone-2 (on-site and off-site). It shows plastic and non-plastic fraction comparison in both zones and in both conditions. Except for the zone-2 (on-site) condition, in all cases, the plastic fraction is greater than the non-plastic fraction.

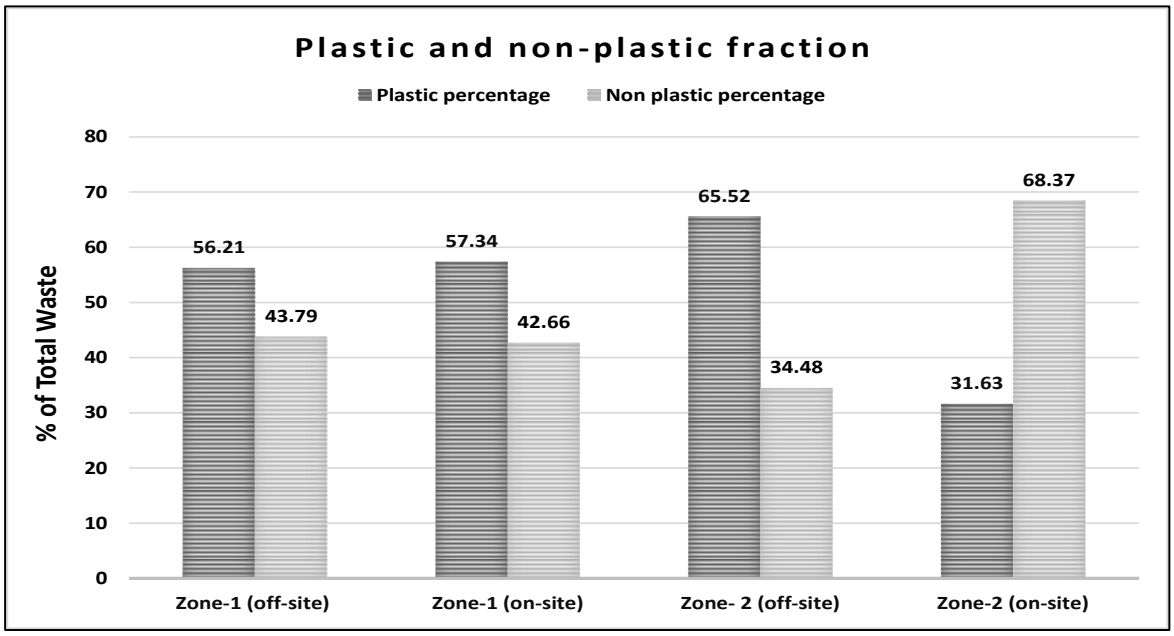


Figure 26. Percentage of plastic in total waste in zone-1 and zone-2 (on-site and off-site)

Plastic Percentage with an Average Distance from the Waste Pile

Figure 27 shows a relationship between plastic percentage (off-site) and the average distance from a point source to the nearest waste pile. Here, the width of the buffer zone was considered the distance between the point source and the waste pile. The average distance from the waste pile to the point source was calculated using Table 2. Here, the distances of three zone-1 points and three zone-2 points were picked from Table 2, and the average distances were calculated. Figure 27 implies that the plastic percentage decreases with increasing distance from the point source to the waste pile. It demonstrates a linear correlation, but if more data points were available for analysis, the correlation may be varied while still maintaining an inversely proportional relationship.

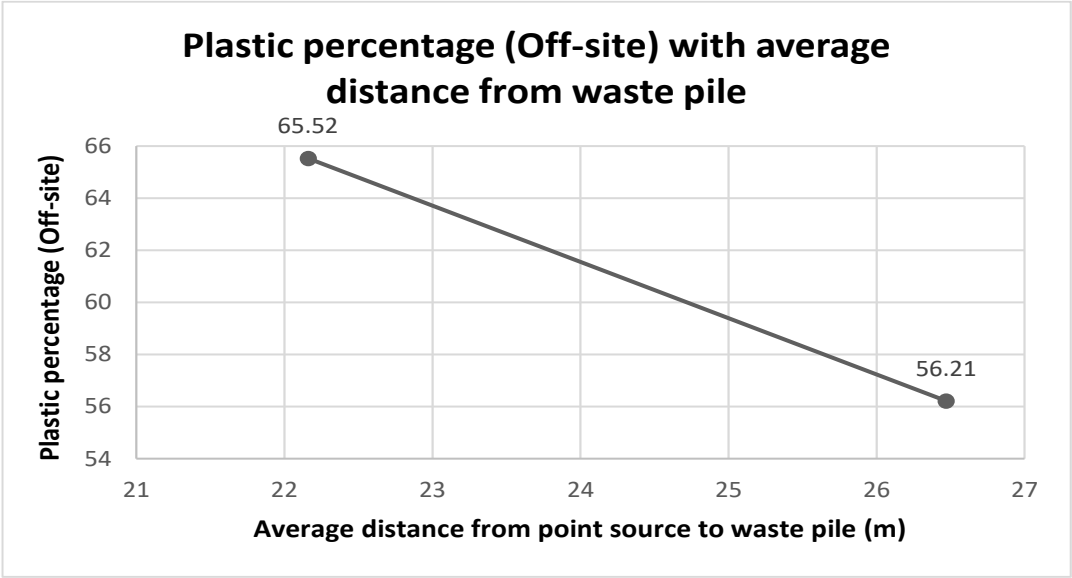


Figure 27. Percentage of plastic (off-site) with respect to an average buffer zone width.

The Driver of Waste Flow

Figure 28 exhibits the elevation of different points on the site. Google Earth Pro was used to find out the elevation of different points on the site. Different points were marked on the Google Satellite map with their respective elevations using the Esri QGIS 3.28.0 software. The red-marked points are point sources and black indicates different elevations of points on top of the waste heap in the middle of the site. Overall observation makes it clear that most of the black points are the most elevated ones and are situated in the middle of the site on top of the waste heap. Water naturally flows from the higher elevation to the lower elevation, which in this case is the middle of the site to the outside of the site. In times of outside flow, water carries a significant amount of waste and discharges through the point source, causing the overflow of the earth's boundary.

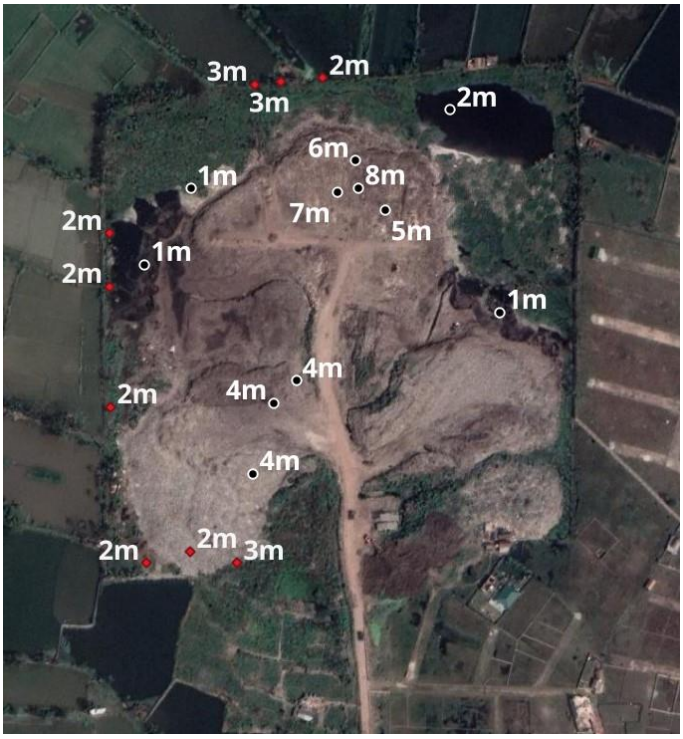


Figure 28. Elevation of different points in the site (QGIS with Google Earth Pro, 2022)

CONCLUSIONS

This study represents the present scenario of operations and management activities of the Rajbandh open dump site. This study addresses several operations and management-related topics, including vehicle management, dumping management, facility management, safety management, management of the informal sector, and management of medical waste. This study reveals how all management activities and operations are carried out at the Rajbandh open dump site. This discussion will help to comprehend all the activity and operations at the open dump site. The role and responsibility of all the formal and informal sectors of the site are explained briefly, which will also help to comprehend the overall scenario of the site. Additionally, the point source of plastic discharge from the dump site to the environment is identified. A total of nine-point sources were categorized into potential and direct point sources based on some specified criteria. Direct point sources serve as the direct waste outlet to the environment and must be addressed immediately. Potential sources work as the secondary waste discharge outlet, especially in times of rain or heavy water flow. Moreover, the plastic fractions of zone-1 and zone-2 were identified in on-site and off-site conditions, which proves the migration of plastic from the site to its surroundings. Plastic discharge is heavily influenced by the distance between the waste heap and the point source. The analysis revealed that the plastic fraction decreased as the distance between the waste heap and the point source increased. Furthermore, it is apparent from the elevation of all point sources and different points that the waste pile region of the site is higher than the perimeter of the site, causing the water to flow naturally outside the site. Besides, water was found to be the primary driver of waste transport mechanisms. In addition, the earth boundary situation should be considered to prevent waste flow from entering the environment. It is important to incorporate a new boundary strategy.

ACKNOWLEDGEMENT

The SCIP Plastics project on which this publication is based is funded by the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection under grant no. 67MM0004. Responsibility for the content of this publication lies with the author(s).

REFERENCES

Delufa Tuz Jerin a,1, Hasna Hena Sara a,*,1 , Marzuka Ahmad Radia a , Prianka Sultana Hema a , Shahriar Hasan a , Salma Akter Urme a , Camilla Audia b , Md. Tanvir Hasan a , Zahidul Quayyum (2022). An overview of progress towards implementation of solid waste management policies in Dhaka, Bangladesh

Jadoon, A., Batool, S. A., & Chaudhry, M. N. (2013). Assessment of factors affecting household solid waste generation and its composition in Gulberg Town, Lahore, Pakistan. *Journal of Material Cycles and Waste Management 2013 16:1*, *16*(1), 73–81.

Murtaza. G. 2002. Solid waste management in Khulna City. *PLAN PLUS A Journal of Planning, Development, Urbanization & Environment*. Urban and Rural Planning Discipline, Khulna University, Bangladesh. Vo. 1, N0.1. pp.6-15

Rafew, S M & Islam, Md. (2021). Application of system dynamics model for municipal solid waste management in Khulna city of Bangladesh. Waste Management. 129. 1-19. 10.1016/j.wasman.2021.04.059.

Rafizul, I. M., Alamgir, M., M. K. Howlader, E. Kraft and G. Haedrich (2009b). Construction and Evaluation of Sanitary Landfill Lysimeter in Bangladesh*. Int. Conf. on SWM, Technical, Envi. and Socio-Economical Contexts*, Nov. 9-10, WasteSafe 2009, Dept. of CE, KUET, pp. 475-484.

R. Ahsan, A.K.M. K. Islam, S. Shams (2009). Municipal Waste Management Mechanism for Khulna City: A Practice for Better Environment. *Int. Conf. on SWM, Technical, Envi. and Socio-Economical Contexts*, Nov. 9-10, WasteSafe 2009, Dept. of CE, KUET, pp. 101-108.