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

A COMPREHENSIVE STUDY OF EXISTING SOLID WASTE MANAGEMENT SYSTEM AND ITS IMPACT ON ENVIRONMENT IN A COASTAL CITY OF BANGLADESH

Israt Nahar Mona[*], Mohammad Mohinuzzaman*, Ramisa Maliyath[**], Sayed Mohammad Nazim Uddin, Shahriar M. Arifur Rahman[*] and Ohidul Alam[***]**

[*]*Department of Environmental Science and Disaster Management (ESDM), Noakhali Science and Technology University (NSTU), Noakhali, Bangladesh*
[**]*Center for Climate Change and Environmental Health, Environmental Sciences Program, Asian University for Women (AUW), Chattogram-4000, Bangladesh*
[***]*Sustainable Enterprise Project (SEP), Integrated Development Foundation (IDF), Chattogram, Bangladesh*

ABSTRACT

The indiscriminate increment of population and development poses a threat to the world in coping with and disposal of municipal solid waste (MSW). Noakhali Municipality is experiencing an enormous amount of MSW that results in a drastic trade in the environment and makes all development activities unsustainable. Improper waste management system, poorly monitored service of MSW collection vehicles, and the lack of adequate funding and awareness are liable for unsustainable MSW disposal service here. This study assessed the municipal solid waste management (MSWM) system to identify the characteristics of MSW in Noakhali Municipality through waste characterization and a questionnaire survey. The results showed that food waste was the highest percentage of total waste generated (65%) in residential areas, while the highest percentage was a plastic waste (30%), and paper and paper product wastes (27%) in commercial areas. At present, electronic wastes are also generated an alarming rate along with other wastes. An approach to undertake possible solutions to improve MSWM systems in the study area was also drafted in this study by introducing a system that would enable people to generate compost, and biogas, and usage of discarded plastics as raw material. As Noakhali is a coastal area, the application of compost will improve the organic matter content of new accredited lands (i.e. char land) and will help in reducing the salinity effects and increasing productivity. In addition, the amount of biodegradable waste per annum is 14,235 tons and the amount of methane emitted from these wastes is 877 tons, which is emitted into the atmosphere from dumping sites (landfill) that can be minimized by converting organic waste to compost. This observation reviews the methane emission estimation and the usage of IPCC default from the open sell-off yards in Noakhali, Bangladesh.

***Keywords**: Noakhali Municipality (NM), Food waste, E-waste, Methane emission, Environmental impact.*

ISBN: 978-984-35-4034-8

Executive Summary

The coastal areas of Bangladesh are in a riskier position in terms of MSW because the improper disposal of waste is posing a great threat to human health, the marine ecosystem, and the environment by polluting the surface water sources on which the coastal people are dependent for their livelihoods directly or indirectly. Noakhali is a coastal district in southeastern Bangladesh, which is becoming potential in its many development processes including industrial and commercial sectors. To utilize this potential and overcome the barriers of a fruitful MSWM system, waste characterization and a relative management strategy are crucial for Noakhali. The objective of the study is to characterize the MSW and evaluate the current management scenario to decipher the gaps in existing practices. This study also provided an SWM plan in terms of reducing the environmental health impact and economic efficiency of the MSW of Noakhali Municipality to promote the MSWM system in coastal regions.
This study was conducted based on field observations and questionnaire surveys. The primary data from three different sources were utilized in this study: i) observing the SWM system of Noakhali Municipality and taking interviews of employees and workers of the Municipality cleaning department, ii) determining the characteristics of solid waste, and iii) questionnaires from residential and commercial surveys. All wards of Noakhali Municipality were selected for observing the SWM system for 7 days, and iv) estimate the amount of methane (CH_4) emission from the landfill of Noakhali Municipality.

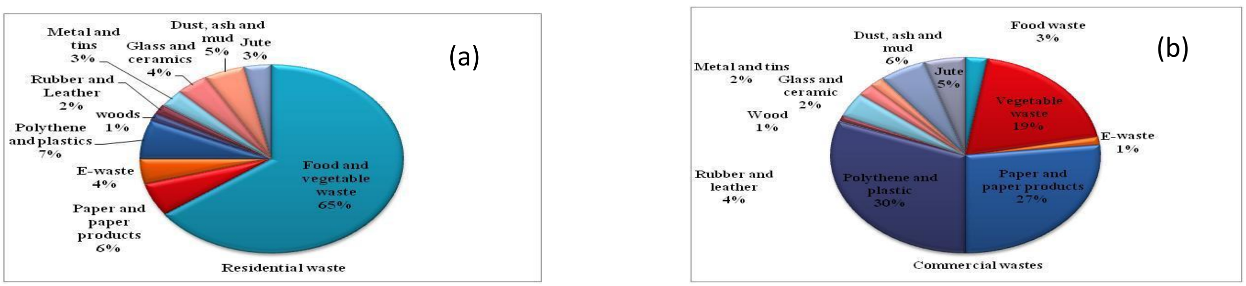


Figure 1 Characteristics of (a) residential waste (b) commercial waste

The results showed that food waste was the highest percentage of total waste generated (65%) in residential areas, while the highest percentage was plastic waste (30%), and paper and paper product wastes (27%) in commercial areas. At present, electronic wastes are also generated at alarming rate along with other wastes. An approach to undertake possible solutions to improve MSWM systems in the study area was also drafted in this study by introducing a system that would enable people to generate compost, and biogas, and usage of discarded plastics as raw material. In addition, 877 tons of methane are emitted into the atmosphere from dumping sites (landfill) that can be minimized by converting organic waste to compost. As Noakhali is a coastal area, the application of compost will improve the organic matter content of new accredited lands (i.e. char land) and will help in reducing the salinity effects and increasing productivity.
Keywords: *Noakhali Municipality (NM), Food waste, E-waste, Methane emission, Environmental impact.*

ISBN: 978-984-35-4034-8

1. INTRODUCTION

Coastal cities around the world are currently in a vulnerable position concerning the generation and management of waste while improper waste management is already a global issue, especially in urban areas, affecting public health and the environment adversely. Cities throughout the world produced 2.01 billion tons of solid waste in 2016, equating to a daily output of 0.74 kilos per person (World Bank, 2019). Municipal solid waste (MSW) is defined as waste collected by the municipality that is disposed of at the municipal waste disposal site and includes residential, industrial, institutional, commercial, municipal, and construction and demolition waste (Hoornweg et al., 2012). Residents of developing countries, particularly the urban poor are more severely affected by unsustainable solid waste management (SWM) than those in developed countries (Mmereki, Baldwin, and Li, 2016). Over 90% of waste is disposed of in unregulated dumps or burned openly in low-income countries (World Bank, 2019). Rising incomes, changing lifestyles, increasing population growth and rapidly growing but unplanned urbanization has resulted in increasing volumes and changing composition of MSW. By 2050, the global urban population is anticipated to rise by 72% (World Population Prospects - Population Division - United Nations, 2021) and this increasing population will be accountable for 3.40 billion tons of waste in 2050 (World Bank, 2019). The key objective of SWM is to minimize the adverse environmental effects caused by the indiscriminate disposal of solid wastes and convert the waste into a resource. It is to be recognized, however, that problems associated with the management of solid waste, particularly in developing countries, are complex that include several factors to be considered. The major factors include government policy, government finances, waste characterization, waste collection, and segregation (Troschinetz and Mihelcic, 2009). Considerations of these factors are important during strategizing a management system for MSW to reduce the environmental and health adversities caused by improper Municipal Solid Waste Management (MSWM).

Bangladesh is a developing country, overloaded with a large population of over 170 million producing almost 2200-2400ton waste per day per city (Rahman, 2014 Alam, and Qiao, 2020). Furthermore, in this rapid growth in population and demand, it is gradually becoming a most challenging task to manage waste being produced daily by the authorities. Open crude dumping is the most common MSW disposal system in Bangladesh which is an uncontrolled waste disposal system (Ashraf et al., 2015). Waste disposal is an integral part of the MSWM system for eliminating environmental pollution and creating economic opportunities for the region. In this regard, Alamgir and Ahsan (2007) through an in-depth field and laboratory study conducted in six major cities of Bangladesh evaluated the physical and chemical composition of municipal solid waste. The physical and chemical characterization showed high content of organic matter and some essential macronutrients in the waste which proves its high potentiality in the production of organic and oregano-mineral fertilizers.

Bangladesh has a considerable number of coastal cities. The coastal areas of Bangladesh are in a riskier position in terms of MSW because the improper disposal of waste is posing a great threat to human health, the marine ecosystem, and the environment by polluting the surface water sources on which the coastal people are dependent for their livelihoods directly or indirectly. In this regard, Sarkar and Bhuyan (2018) determined the physical and chemical composition of solid waste in Chattogram City which is a coastal city in Bangladesh. The study results portrayed fine organic materials as the major part of the produced solid waste (35.1%) and nitrogen, phosphorus, and potassium content represented the potential for conversion of the waste into good compost. Besides this, the study outcome also showed that highly polluted leachate is get entrapped in ponds with the surface wash and it poses a high degree of pollution threat to groundwater as well as surface water and subsequently causes health hazards. Khulna is another coastal district of Bangladesh whose current MSWM plan has been critically analyzed through a system dynamics (SD) model until the year 2050 by Rafew and Rafizul (2021). The study results revealed that MSW generation increased from 168 thousand tons in 2020 to 1.2 million tons in Khulna and the increasing population is working as the only linear growth factor which increases from 1.5 million in 2020 to 2.24 million by 2050. All these phenomena are adversely affecting the water sources and climate of the district resulting in environmental health hazards and environmental pollution.

Noakhali is a coastal district in southeastern Bangladesh, which is becoming potential in its many development processes including industrial and commercial sectors. Along with these developments, it is also experiencing a terrible amount of MSW in every municipality. For insufficient transfer stations, dustbins, cleaners, supervising staff, and improper monitoring of daily waste collection, municipalities are not able to get the desired level of service for SWM. For this reason, different types of pollution are taking place in various places affecting the flora and fauna detrimentally. As a result, it is causing many problems to the health and environment of living beings. In Noakhali Municipality, there are no segregation process practices for solid wastes like in other coastal cities of Bangladesh. Even though it has been asserted repeatedly that the waste characterization according to their composition is a prerequisite for planning a sustainable MSWM system (Oliveira and Turra, 2015), especially for a coastal region like Noakhali, very little focus has been given to this area. Barua, Kannon, and Munna (2020) by executing a traditional recycling practice of solid waste in Noakhali Sadar affirmed that metal, paper, tin, and plastics were the daily recyclables in the study area and the other retrieved material from solid waste are sold as raw materials. Therefore, it is seen that the MSW is not only harmful but instead could be acting as a potential for economic growth if managed sustainably. It is of the highest priority to achieve waste reduction and to decouple the link between economic growth to waste generation. To utilize this potential and overcome the barriers of a fruitful MSWM system, waste characterization and a relative management strategy are crucial for Noakhali. With this view, this study assessed the characteristics of MSW as well as their composition to draft an MSWM plan for Noakhali Municipality. The objective of the study is to characterize the MSW and evaluate the current management scenario to decipher the gaps in existing practices. Moreover, Bangladesh has noticed its methane emissions, and according to a 2018 short-lived climate pollutants-reduction plan, measures to curb methane emissions would cut them by up to 17-24% by 2030 and up to 25-36% by 2040, according to the statement from the Ministry of Environment, Forest and Climate Change. Another objective of this study is to calculate the methane emission from NM wastes. This study also provided an SWM plan in terms of reducing the environmental health impact and economic efficiency of the MSW of Noakhali Municipality to promote the MSWM system in coastal regions.

2. METHODOLOGY

2.1 Study Area

The study was conducted in the Noakhali district of Bangladesh. Noakhali district is located between 22º07` and 23º08` north latitudes and between 90º53` and 91º27` east longitudes and the total area of the district is 3,685.87 sq. km. (1423.12 sq. miles). It has eight municipalities (Paurashavas) and one of them is Noakhali Municipality or Noakhali Paurashava which was the selected area for this study.

2.2 Data Collection

This study was conducted based on field observations and questionnaire surveys. The primary data from three different sources were utilized in this study: i) observing the SWM system of Noakhali Municipality and taking interviews of employees and workers of the Municipality cleaning department, ii) determining the characteristics of solid waste, and iii) questionnaires from residential and commercial surveys. All wards of Noakhali Municipality were selected for observing the SWM system for 7 days, and iv) estimate the amount of methane (CH_4) emission from the landfill of Noakhali Municipality.

2.3 Characterization of Solid Wastes

Normally two general approaches are used to analyze solid waste stream composition, the ‘material flows approach’ and the ‘output method’. The output method was used for the characterization of the MSW of Noakhali Municipality. As hospital wastes are also dumped into the same landfill, it was hazardous to health to collect waste samples from the main landfill. For collecting samples, specific points of residential areas and commercial areas were selected based on the amount of waste. In residential areas, wastes were collected from transfer stations and households. In the commercial area, wastes are collected from shops, in front of Noakhali Supermarket, and Noakhali Municipal Market. For characterization, 30kg of waste was collected from selected points of residential area and another 30kg of waste was collected from selected points of commercial area. Two types of weight machines analog and digital, both were used for weighing the segregated wastes.

2.4 Sampling Design for Identifying Waste Management

The study was conducted in ward No-4, as it is the most populated ward in Noakhali Municipality, and most of the residences, hospitals, shops, banks, offices, restaurants, etc. are located there. Individual interviews were taken for the questionnaire survey. The data were collected using a simple random sampling method where different questions were administered to the local household and commercial area: fruit shop keepers, restaurant managers and workers, shopkeepers of cloth stores, workers of mobile and other electronic device servicing shops, and Noakhali Municipality authorities which took 10 days for completion. The survey population consisted of 120 people among whom 76 were male and 44 were female.

2.5 Data Analysis

For analyzing data, Microsoft Word and Excel programs were used to process all collected information and to prepare tables and charts. Quantitative and qualitative analyses were also conducted based on collected documents. For estimating the total methane emission from the landfill, the waste composition data were collected from the source.

2.6 Calculation of Methane Emission from MSW

The methane emission from MSW was collected using the following formula given by IPCC (IPCC, 2006):

CH_4 emission (ton/year) = (MSW* MSWF*MCF*DOC*DOCF*FM*X - RM) (1-OF)

Here,

MSW= Total waste generation (ton/year)

MSWF= Waste fraction disposal to Solid Waste Disposal Site(SWDS), national fraction MSW disposal in engineered or non-engineered landfill

MCF= Correction factor of waste fraction that generates methane gas for the sanitary landfill

DOC= Fraction of biodegradable organic carbon

DOCF= Fraction of biodegradable organic carbon that is readily available for degradation (actually converted to CH_4 and CO_2 in landfill gas)

FM= Fraction of methane in biogas

X= 16/12 – a conversion factor for converting C to CH_4

RM= Methane recovery

OF= Oxidation Factor

A description of the coefficients used in the IPCC model for the estimation of methane emission adopted in this study is given below:

Degradable organic carbon (DOC) - The DOC is the organic carbon accessible for biochemical decomposition and in this study, DOC is considered 0.15 (Noor et al., 2012).

Dissimilated degradable organic carbon under anaerobic condition (DOCF) - The DOCF is the proportion of DOC that dissimilates under anaerobic conditions, which occurs because the DOC process does not occur completely over a long period a default value of 0.77 is set for the DOCF according to IPCC guidelines.

DOC = 0.4P+0.15K+0.3W

Here,

P= Fraction of paper in MSW

K= Fraction of kitchen food/food wastes in MSW

Methane correction factor (MCF) - The MCF is the coefficient for different types of landfill practices. According to IPCC guidelines, for unmanaged and shallow landfills, the MCF is set at 0.8, and the properly managed sanitary landfill set is 1.0. (IPCC Guideline, 2006)

Fraction of CH_4 in landfill gas (F) - The CH_4 fraction F is usually taken to be 0.5 but can vary between 0.4 and 0.6 depending on several factors including waste composition (IPCC Guideline, 2006). For the landfill of Noakhali Municipality, the MCF is set to 0.8 because the landfill is in the unmanaged shallow landfill.

Methane recovery (RM) - Methane recovery is the amount of CH_4 generated at SWDS that is recovered and burned in a fare or energy recovery device. In the landfill of Noakhali Municipality, no methane is recovered either in open dumping. The default value for methane recovery is zero (0) (IPCC Guideline, 2006).

Oxidation factor (OF) - According to the IPCC Guideline, the default value for OF is also considered zero (0) (IPCC Guideline, 2006).

ISBN: 978-984-35-4034-8

2.6.1 Different Parameters of IPCC Guidelines 2006

Different parameters of IPCC Guidelines were used for the estimation of methane emission from the MSW landfill. These values are given below:

Table 1 Parameters adopted for the IPCC default method in this study (IPCC Guideline, 2006).

Parameters	IPCC value
MSWF	1
MCF	0.8
DOC	0.15
DOCF	0.77
FM	0.50
RM	0.00
OF	0.00

3. RESULT AND DISCUSSION

3.1 Socio-Demographic Characteristics of Respondents

Among 120 respondents, 63% were male and 37% were female. Respondents ranged from ≤19 years 7%, 20 to 29 years 28%, 30 to 39 years 26%, 40 to 49 years 20%, and ≥50 years 19%. The educational status of the respondents is 3% illiterate, 11% primary, 10% JSC, 19% SSC, 21% HSC, 7% graduate, 13% BSc/BA/BCS, 15% MSc/MA, and 1% above (Figure 1).

(a) (b)

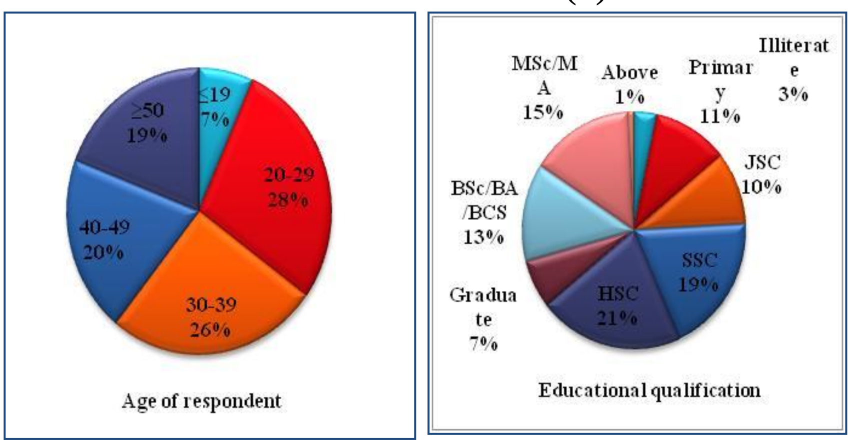


Figure 1 Percentage of socio-demographic characteristics

3.2 Municipal Solid Waste Characteristics

After the waste characterization through the output method, it was found that in the residential area, there is 65% of food and vegetable waste and 6% of paper and paper product waste. It also had 4% of E-waste, 7% of polythene and plastic, 1% of wood, 2% of rubber and leather, 4% of glass and ceramics, 5% of dust, ash, and mud, and 3% of jute. Though most of the metallic things are sold by householders 3% of metal and tins were found in wastes such as cans of cold drinks and chips, body spray, jar caps unusable metallic things, etc.

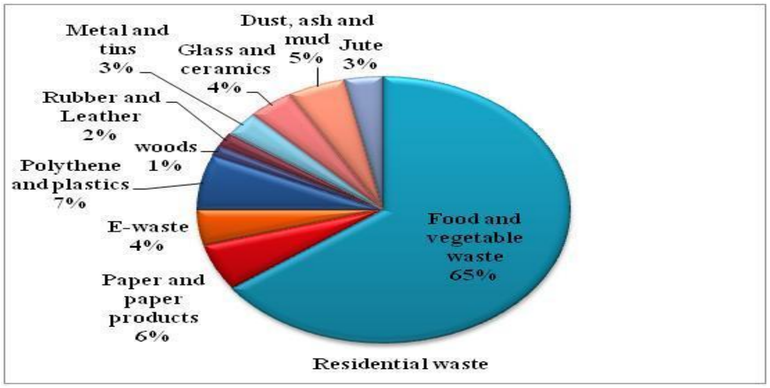


Figure 2 Characteristics of residential waste.

In the commercial area, there is 3% of food waste, 1% of E-waste, and 19% of vegetable waste. Huge amounts of polythene, plastic, and paper were present in this area. Mostly 27% of paper and paper products, 30% of polythene and plastic, 1% of wood, 4% of rubber and leather, 2% of metal and tins, 2% of glass and ceramics, 6% of dust and mud and 5% of jute were present.

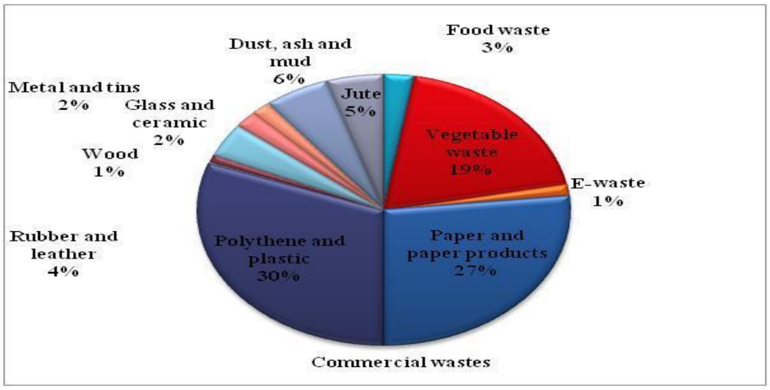


Figure 3 Characteristics of commercial waste.

The composition of waste depends on a wide range of factors such as food habits, cultural traditions, lifestyles, climate, and income. The variations due to such factors are found across different countries as well as across different regions within one country. The inter-regional variations are not as marked as those across the countries. Variation also occurs within a region like urban and rural areas over the years because of economic and social change (Gupta et al., 1998). The major differences between waste generated in the above two sources, i.e., residential and commercial waste, stand on organic and inorganic content. Food and vegetable wastes, which are organic and biodegradable waste, are highly generated from residential areas whereas inorganic, non-biodegradable, and recyclable waste like plastics and polythene are mostly generated from commercial sources. Moreover, waste that is more hazardous to health and the environment is observed to be generated from commercial sources which have the potential to be recycled if managed sustainably.

3.3 Present Scenario of Solid Waste Management System

The management of the waste disposal system is a very important facility for the inhabitants to maintain a sustainable environment. In Noakhali Municipality, SWM is extremely poor. In the issue of waste dumping, only 4.97% of the inhabitants of the Municipality use a dustbin. However, 78.3% of the residents dump their household waste beside their houses. Only 1.35% of the residents throw their solid waste into the nearby Khal and canal which is a probable contaminant of the soil and water (Nasiruddin et al., 2013). Here the present force of manpower of the conservancy department is presented. (Noakhali Municipality, 2021):

Table 2 Present scenario of manpower (NM- Current, 2021)

Designation	Number
Supervising staff	
Conservancy inspector	1
Conservancy supervisor	4
Truck driver	6
Cleaners	
Road cleaner	90
Drain cleaner	15
Refuse cleaner	41
Spray man	1
Door-to-door waste collector	25
Worker for dumping site maintenance	2
Total	185

Currently, Noakhali Municipality has 9 wards, 36 mahallas, and 1 Thana in total. It holds a total of 6 vehicles for garbage cleaning, 1 is of 5 tons, and the other 5, each is of 3-ton capacity. None of the trucks has any kind of covering. Sometimes they use tarpaulin/plastic at the time of conveying waste to the landfill. Each truck needs 12-L fuel every day. They also have 25 vans for the door-to-door waste collection system; each can hold 320kg of waste at a time. At present, Noakhali Municipality has 3 transfer stations inwards no 3, and 4 for secondary storage of solid waste. Other open transfer stations are present beside the main road of the Municipality.

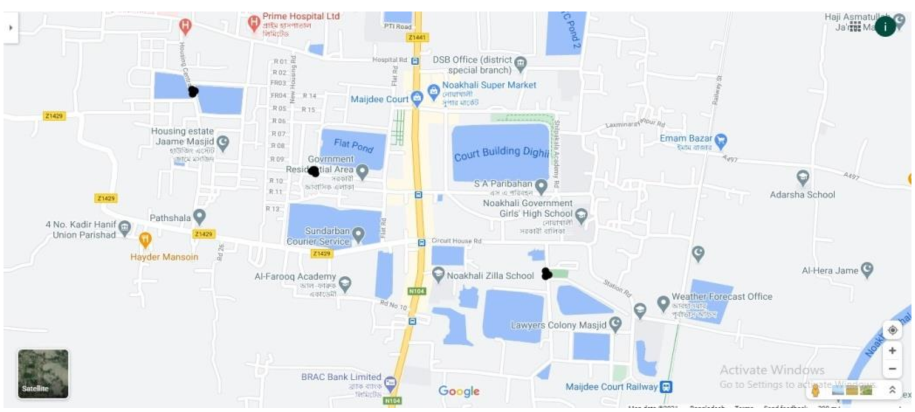


Figure 4 Transfer stations in different localities

- For collecting waste, they work in 2 shifts: Shift 1- 7.00 am to 12.00 pm
  Shift 2- 3.00 pm to 6.00 pm
- Working day: 7 days a week.
- Frequency of waste collection: Each truck collects waste 3times a day.

Door to door waste collection system is present in wards no 1,2,3,4, and 5. Each ward has 3-5 waste collectors for door-to-door waste collection in residential areas. In one mahalla (Master para) of ward no 2, they have their own Private Community Based Organized System (PCBOS) for door-to-door waste collection daily named 'Akota Poribesh Unnayan Songothon'. For door-to-door waste collection system:

- Working Time: 9 am-5 pm.
- Working day: 6 days a week. (Friday off day)
- Frequency of waste collection: Each van collects waste 3/4 times a day.

In wards, no 6, 7, 8, and 9 people throw out their trash beside roadside dustbins or in open transfer stations and waste collecting trucks collect them daily. Specific route is necessary for collecting waste. The cleaning department of Noakhali Municipality maintains specific routes for collecting daily waste. Here are some routes for waste collection and a map of the road is given below-

Route of one truck in the morning shift-

The total frequency of waste collection: 3 Times

Collection points:

Figure 5 Route of waste collection in the morning: (a) Open transfer stations beside the main roads; (b) Transfer station nearby Noakhali circuit house; (c) Transfer station of housing state

Route of one truck in the morning shift-

The total frequency of waste collection: 3 Times

Collection points:

- The residential area beside the hospital road
- Sonapur zero-point
- Master para

Route of one truck in the afternoon shift-

The total frequency of waste collection: 2 Times

Collection points: (open transfer stations beside the main road)

(a) (b)

Figure 6 Route of waste collection in the evening: (a) Dotter haat to Alipur; (b) Bishownath to Noakhali municipal market

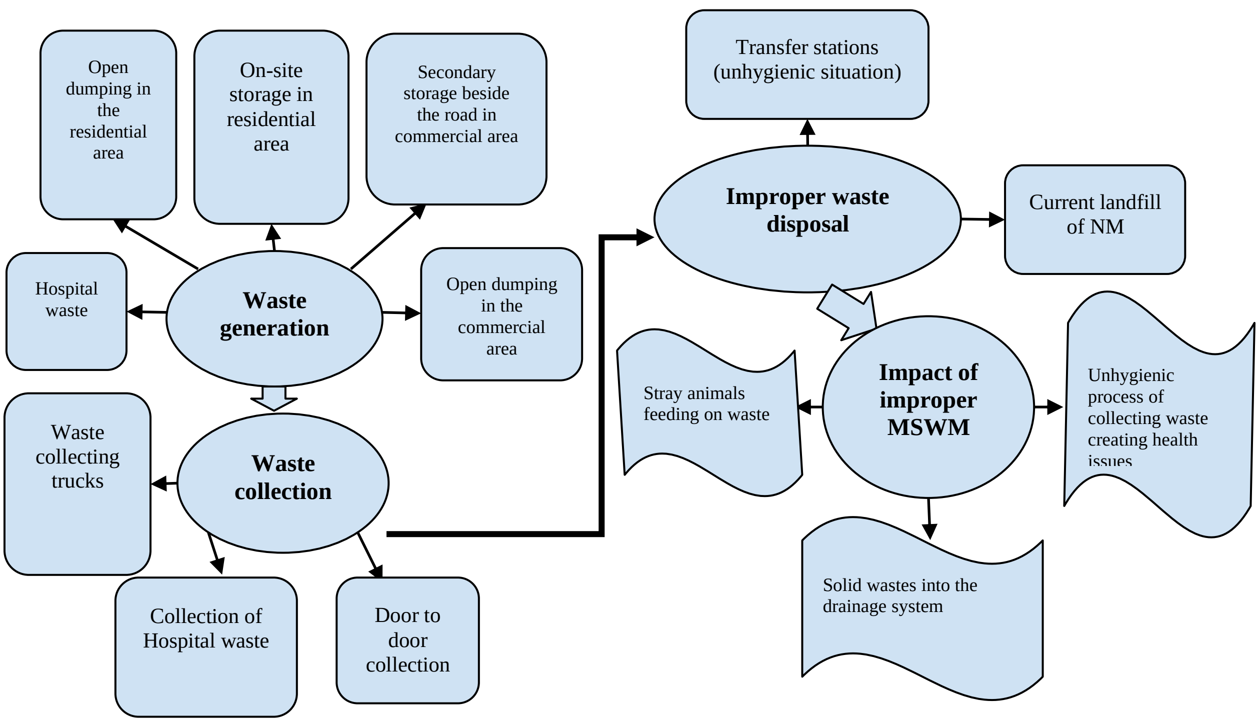


Figure 7 Flowchart for MSWM in Noakhali Municipality.

3.4 Collection of Solid Wastes and Its Unhygienic Maintenance System

Householders accumulate all types of waste in one bin/bucket/basket/polythene bag in residential areas. Then waste collectors carry out waste from households with the help of vans and take them to the nearby transfer station/open transfer station beside the roads. Residential waste, kitchen waste, food waste, paper, and plastic waste, E-waste, broken ceramics or glasses, leather things, etc. are present. Huge amounts of kitchen waste and food waste are generated from household waste. In the commercial area, shopkeepers or other people throw out their trash in accumulated conditions. Commercial wastes mainly consist of Paper, plastics, E-waste, food and vegetable wastes from fruit and vegetable markets, metallic things, jute, etc. The amount of plastic and paper is more than the other wastes in the commercial area.

NM waste collecting trucks come at a specified time and collect waste from transfer stations/open transfer stations beside the roads/dustbins. Full processing of conveying waste into trucks from the dustbin is unhygienic and not environment friendly where cleaners don't use any personal protection or safety gloves and masks but only rain boots are used by some of them occasionally. Though safety equipment is provided by the waste management authority of NM, workers do not wear them all the time. As a result, they face many difficulties like they cut their fingers with sharp metallic things or fish bones or broken glasses. For this reason, they are at high risk of getting infectious diseases.

SWM roles of Noakhali Municipality stipulated that waste collectors must collect waste from every household regularly, and from hotels, restaurants, supermarkets, office institutions, banks, and commercial areas. Temporary waste collectors, door-to-door (DtD) waste collectors, cleaners, and sweepers employed by Municipality are complained about by citizens not doing their jobs regularly.

Though the DtD waste collection system is provided by Municipality in different mahallas of 5 wards, many householders are not interested in DtD waste collection systems. They throw out their waste in an open space/beside the road/nearby canal or pond/even throw out waste into the drainage system. In this case, DtD waste collectors and householders are equally responsible for this mismanagement. Also, when waste collectors are not coming regularly, most of the time householders throw their waste here and there. Ensuring waste collectors and workers are doing their job sincerely and increasing awareness among people is more important in this situation. In the scenario of Noakhali Municipality, in most of the cases (41.80%), the distance of solid waste dumping location from the house is from 0.25 to 0.50 km. It was also found that 38.9% of the dustbins are more than 0.5 km. away from home. Only 19.3% of residents have a dustbin within 0.25 km. Thus, the condition of access to the dustbin is not very good in Municipality. In Ward 7, it was found that 99% of the houses have dustbins of more than 0.5 km. away from home which is one important reason for the open dumping of wastes from residential areas.

In the commercial area, waste is thrown out by shopkeepers or other people besides the main road/nearby secondary storage/throw out waste nearby open space/ backyard of the shops. Waste collecting trucks collect commercial wastes daily from point to point.

Dumping of solid wastes into the drainage system is a common behavioral problem observed all over the study area. Citizens are more responsible for this worse situation of drainage congestion, and sometimes waste collectors are also not doing their job regularly. As a result, the discharge of the new drainage network will create severe drainage problems in the municipal areas, particularly during the monsoon period. To solve this problem, more and more awareness campaigns are needed against the dumping of solid waste into the drainage system.

There is no sanitary landfill in Noakhali Municipality. For dumping wastes, the Municipal authority is using 2 acres of the area as a landfill/dumping site, which is located behind the Noakhali Municipal Market. One small excavator is used for maintaining dumping wastes in the landfill. It spread out wastes horizontally on the land and then sprays finial/bleaching powder on the wastes.

3.5 Hospital Waste Management System

In Noakhali Municipality, there is 1 General hospital, 39 Private hospitals, 1 TB hospital, 5 Clinics, and 58 Pathology/diagnostic centers (Noakhali Municipality, 2021). In the general hospital, there is one transfer station behind the Kidney dialysis building of Noakhali general hospital for solid waste, and for other hazardous wastes, they use different kinds of bins which are collected by hospital waste collectors. Other hospitals put their waste into black plastic bags/plastic bins.

One private organization, named Shoron Borjo Babosthapona is permitted by the municipal authority for collecting hospital wastes. One 3-ton truck is provided by the municipality for them to collect hospital wastes. They collect hospital waste from 7.00 pm-9.00 pm. The amount of hospital waste is around 3 or 4 tons daily. In Shoron Borjo Bebosthapona there is a community of 10 members including advisors, conservancy inspectors, and refuse cleaners. They have their own office, waste treatment area, and landfill in Chowmoni Bangla Bazar, Noakhali. As their waste treatment plant is in the under-construction process, they take permission to use the dumping area of the Municipality. From March 1, 2021, they are supposed to start their waste treatment plant and landfill. In their treatment plant, they are going to use Autoclave and Incineration machines for treating infectious hospital wastes, and one 3-ton covered truck would be used for conveying hospital wastes. They will collect infectious/hazardous wastes only and leave the biodegradable hospital wastes that will be collected by Municipal waste collectors.

3.6 Waste Collection System

In the study area, the DtD waste collection system is mostly used in residential areas; some also use common dustbin methods. In some commercial areas like shops, and restaurants, waste is collected by waste collecting trucks directly. Though 58% of respondents in the study area are wholly satisfied with the service of the DtD waste collection system, 42% of respondents are complaining about not collecting waste regularly.

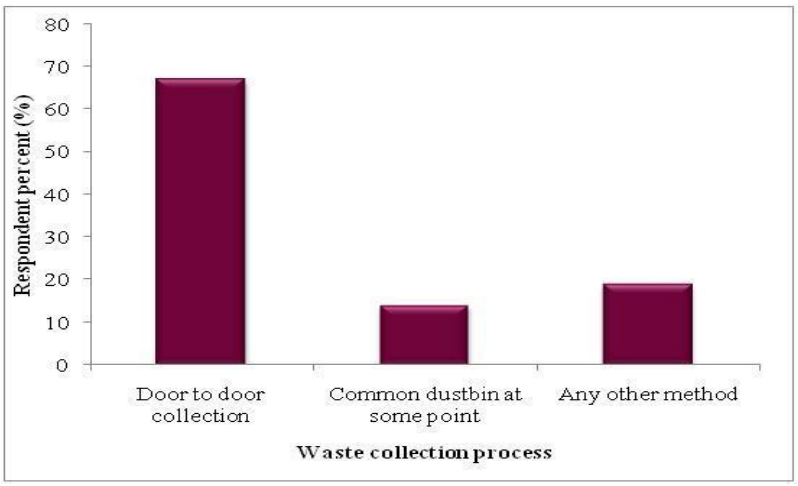


Figure 8 Waste collection process in different localities of the study area

For this service, 16% of people pay 50Tk, 31% of people pay 60/70Tk, and 53% of people among the respondents pay 100Tk.

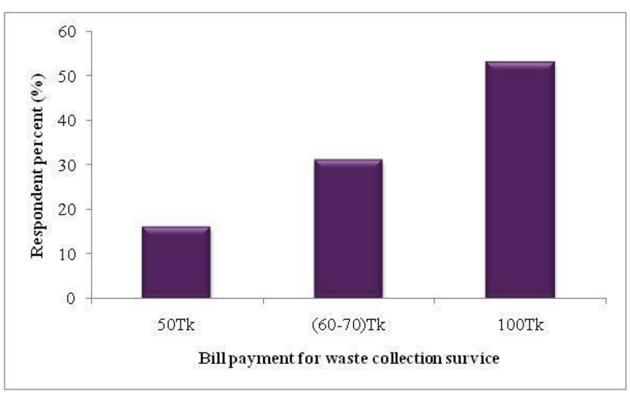


Figure 9 Monthly payment for door-to-door waste collection

In important localities of the study area, waste is collected by collectors 6/7 days per week. But 35% collection of the study area is performed irregularly. 5% collection was performed after one day, and 54% collection mostly happened six days a week (except Friday). They collect the waste once a day.

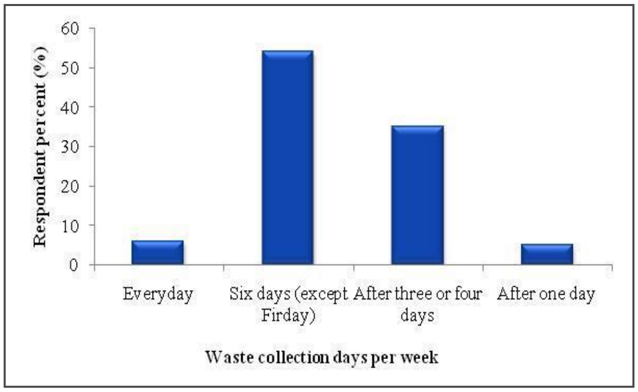


Figure 10 Frequency of waste collection per week

In the column chart, it reveals, 32 % of the respondent householders want to dispose of their waste in the morning and most respondent householders (about 53%) want to dispose of waste at noon as at this time most of the household work is finished and easy to put down waste for waste collectors. Many people want to dispose of waste in the afternoon; only 6% of people want to dispose of waste at nighttime as most of them are job holders so it's become easy to handle their household wastes.

Figure 11 Suitable time for the door-to-door waste collection process

3.7 Segregation, Storage, and Disposing Practices of Household Wastes

In the study area, most of the householders store their waste without any segregation based on its characteristics. Only 12% of respondents used to segregate their food and vegetable wastes to get organic material for their gardening, and 88% of respondents' householders dump their household wastes in accumulated/mixed condition.

Most people in the study area use provisional storage for storing wastes. In this case, buckets, baskets, and polythene bags are mostly used. Different householders use different types of storage. Among the respondents, 42% use buckets, 22% use baskets, 24% use polythene bags, 9% use plastic drums, 1% use plastic bins, and 2% use other storage.

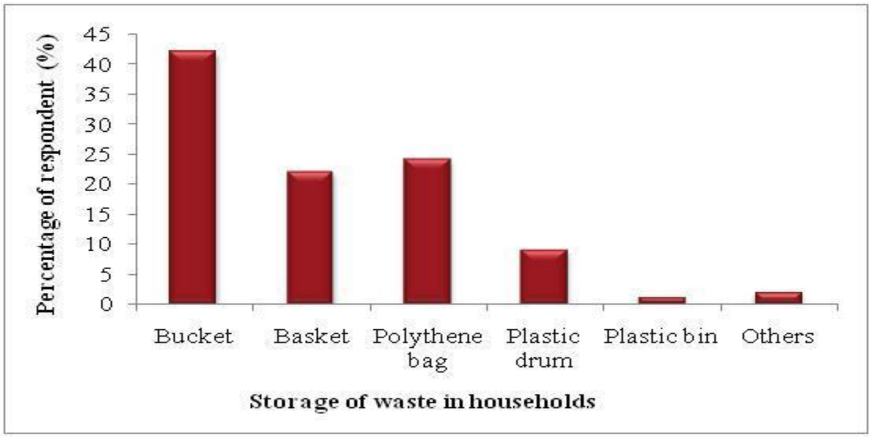


Figure 12 Provisional waste storage in households

Among respondents, 41% dispose of their wastes to the DtD waste collector of the municipality. Most respondents throw their waste here and there. Among them, 25% of respondents throw their waste in open spaces or beside the road, and 22% of respondents throw it near a pond or canal. Only 12% of respondents use a common dustbin for disposal.

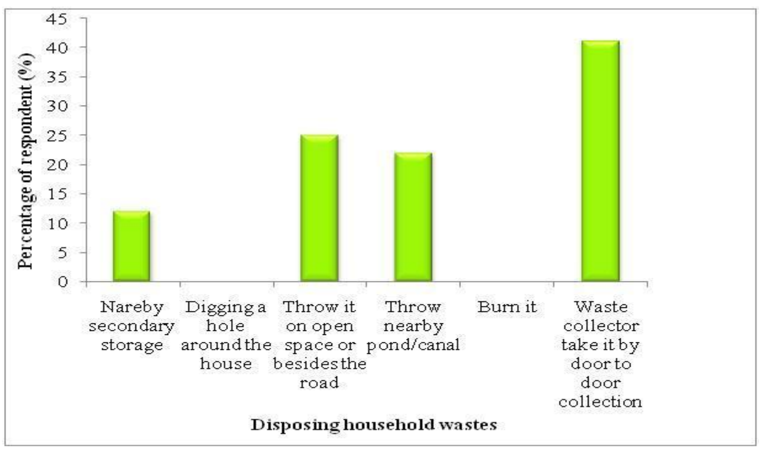


Figure 13 Process of household waste disposal

3.8 E-waste Management at the Household Level

In the present world, E-waste becomes a great problem. People are using more and more electronic devices and things in their daily life. Among 120 respondents in the study area, 65% have no idea about it. Broken mobile phones, multi plugs, chargers of different devices, earphones, ear pods, tablets, batteries, calculators, printers, switches, tube lights, bulbs, bulb holders, wires, sound boxes, power banks, smart watches, television, rechargeable light and fan, remote of television, doorbells, wifi router, computer monitor, laptop, fan, refrigerator, and air cooler are the major useable. In the study, it was revealed that 73% of householders dump e-wastes with other household wastes, and only 27% sell them when e-wastes are large like computers, television, refrigerator, laptop, and others.

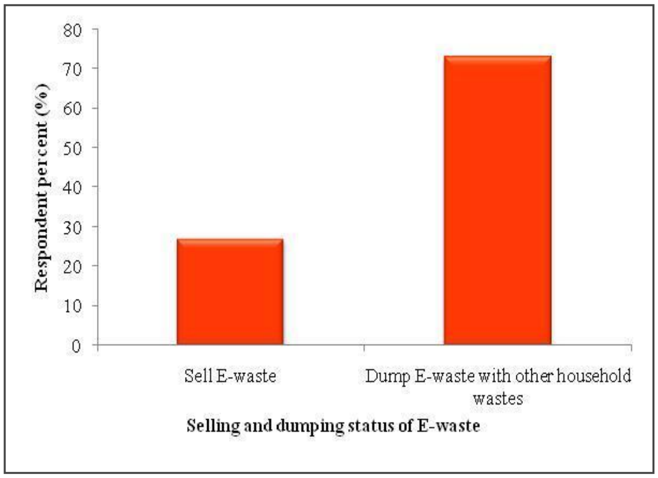


Figure 14 Selling and dumping status of E-waste in the household.

3.9 Satisfaction with the Service of SWM System of Municipal Authority

From this survey, it can be said that the present situation of the MSWM system is still poor as 41% of the respondents are not satisfied with the management system, 39% of respondents are moderately satisfied and only 20% of respondents are satisfied with the collection and disposal service of the study area. Some suggestions were also given by respondents for improving municipality waste management service which include- increasing manpower, collecting wastes properly in time, workers should use protection like gloves, and mask at the time of waste collection, regular collection of wastes from important places like municipal market and others, finding out the miss management points in the service system, ensuring workers doing their work regularly in time, making proper transfer station and increasing the number of it and also removing the open transfer stations besides the road. Citizens are facing difficulties with open waste dumping on footpaths of roads and other open spaces.

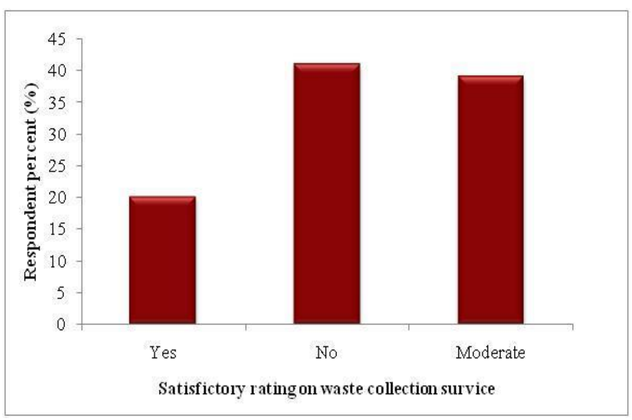


Figure 15 Satisfaction on waste collection performance

3.10 Ecological and Environmental Effects of Noakhali Municipal Solid Waste

i. Impact of solid waste on the ecosystem

Improper handling of MSW causes risks to the environment and health. As open dumping of wastes occurs in this municipality the nuisance of insects, mosquitoes, flies, etc. are increasing with time. On the other hand, these wastes are also eaten by stray animals like cows, goats, and dogs which causes harm to their health and even causes breeding defects. The offensive smell of MSW causes problems with inhalation. Burning of wastes either in open air or in landfill creates harmful smog and causes air pollution. Soil and water sources are also getting polluted continuously by this uncontrolled waste dumping, as a result, the agriculture and fishing sectors of this coastal area are facing many difficulties like harmful nutrients entering into the food chain through herbs and shrubs plant, water quality parameters: turbidity and dissolved oxygen (DO) changing constantly, nitrogen bloom and algal bloom are taking place, the growth rate of fishes decrease, microbenthos present in the bottom layer of water resources are also destroying. Many dangerous health conditions can be caused by inhaling or ingesting even small amounts of pollutants like dioxins, particles, polycyclic aromatic hydrocarbons, volatile organic compounds, carbon monoxide, hexachlorobenzene, and ash (USEPA, 2016). The emission of toxic chemicals has a more acute impact, harming flora and fauna. The most hazardous of these wastes are- hospital, electronic, and industrial wastes can be released directly into the environment if dumped or burned openly. MSW directly affects the health of oceans. Millions of metric tons of plastic enter the ocean each year (Vergara and Tchobanoglous, 2012)

Respondents of the study area are facing some environmental problems. In the survey we can see, many respondents dumped waste in the open spaces or beside the road and even nearby water sources which are affecting the environment of the study area. Improper waste management is also responsible for this harmful condition. For this reason, 35% of soil pollution, 23% of water pollution, 30% of air pollution, and 12% of other pollution is occurring in the study area.

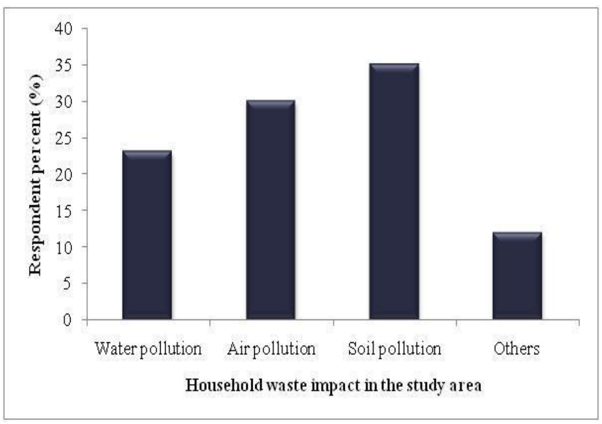


Figure 16 Household waste impact on the environment of the study area

In the survey area, among the respondents, 36% faced water logging problems during the rainy season as the drainage system is not well planned in those localities so garbage is washed away due to rain and flows through the drain also many people throw away their waste into the drainage system. As Noakhali is a coastal city, the water table level is higher than in the northern areas of our country so in the rainy season, water logging problems are seen. The drainage system is cleaned by the municipality cleaning department less often which blocks the drain time and again.

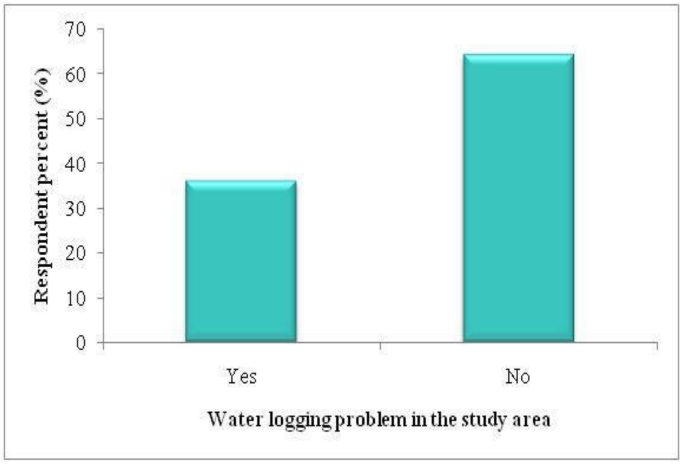


Figure 17 In the study area water logging problem facing the rate

ii. Methane emission rate and potential energy sources from MSW

In Noakhali Municipality, 60 tons of MSWs have generated daily and almost 39-nonbiodegradable wastes are generated from the residential areas. The amount of biodegradable waste in one year is 14,235 tons. The amount of methane emitted from the landfill of Noakhali Municipality in 1 year is 877 tons/year.

Methane produces energy in the form of heat when ignited through oxidative pyrolysis. The methane emissions from MSW landfills in 2020 were approximately equivalent to the greenhouse gas (GHG) emissions from about 20.3 million passenger vehicles driven for one year or the CO_2 emissions from nearly 11.9 million homes' energy use for one year. At the same time, methane emissions from MSW landfills represent a lost opportunity to capture and use a significant energy resource. When MSW is first deposited in a landfill, it undergoes an aerobic (with oxygen) decomposition stage when little methane is generated. Then, typically within less than 1 year, anaerobic conditions are established, and methane-producing bacteria begin to decompose the waste and generate methane. Landfill Gas Energy Project Types -There are many options available for converting Landfill gas (LFG) into energy. Different types of LFG energy projects are grouped below into three broad categories – Electricity Generation, Direct Use of Medium-Btu Gas, and Renewable Natural Gas (EPA, 2022). Energy derivation from MSW is a sustainable way to deal with the MSW. Waste to electricity (WtE) is adopted in many developing and developed countries. The major fraction of MSW in Bangladesh is food waste. A landfill in Bangladesh is leaking huge quantities of methane into the atmosphere, contributing to the world's mystery methane hotspot. Recently Bangladesh is trying to adopt the WtE strategy and to achieve this goal energy security issues are included in the "National Adaptation Action Plan" (NAPA) for climate change. Though these issues are addressed in NAPA no effective steps have not initiated in Bangladesh and only relying on fossil fuels for generating a little portion of electricity with the application of renewable energy technologies.

3.11 Standard SWM Practices for Noakhali Municipality

A suitable plan is proposed here for the standard management of MSW in Noakhali Municipality.

ISBN: 978-984-35-4034-8

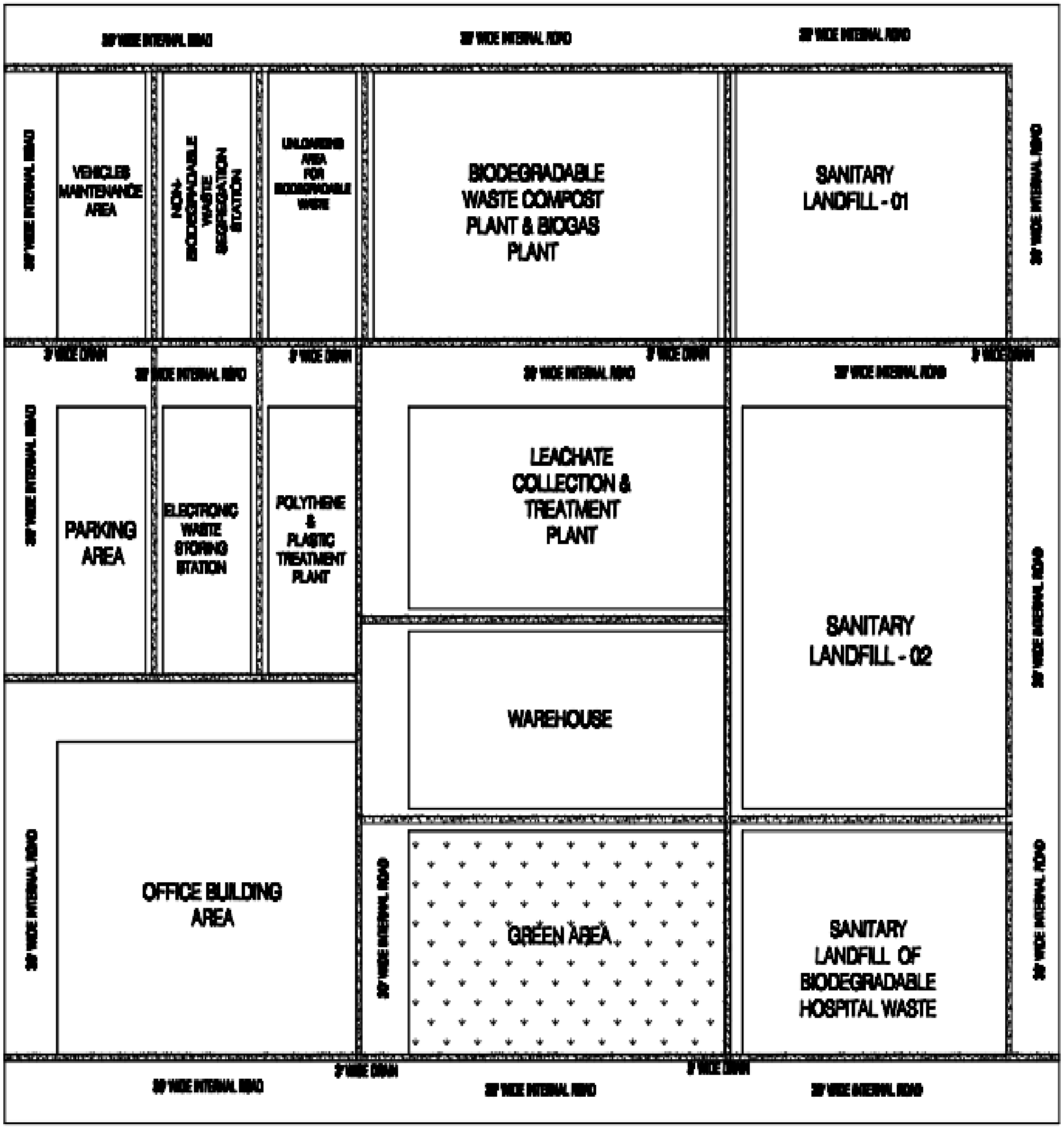
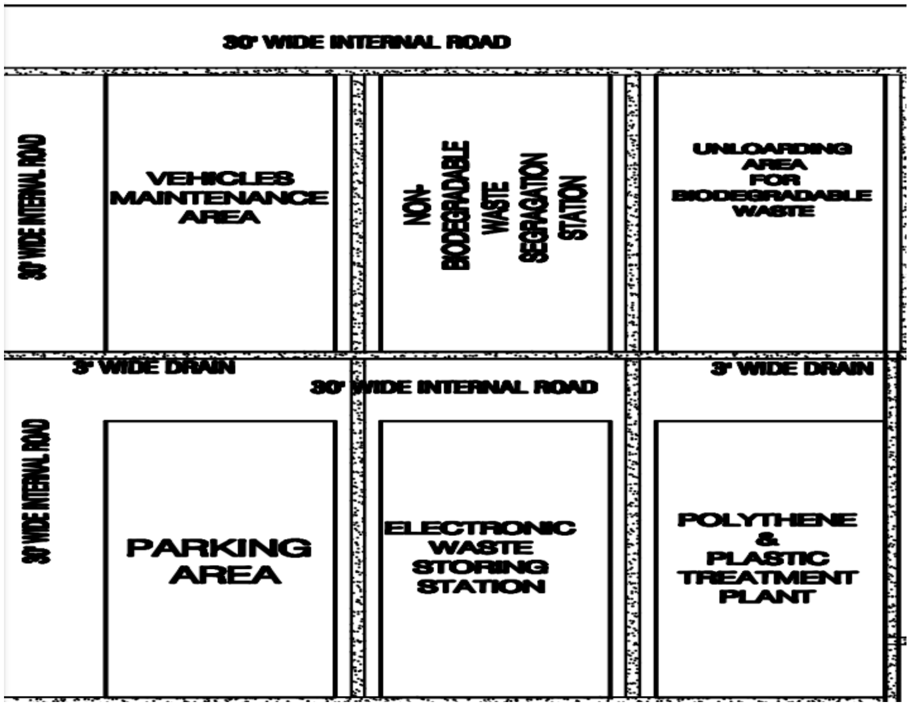


Figure 18 Proposed solid waste management system



By characterizing MSW, it was found that huge amounts of food waste, vegetable waste, and other biodegradable wastes and non-biodegradable wastes are generated daily which are dumped without any processing. Proper management of MSW can make the perfect use of all MSW except for a small amount. By the segregation of wastes, it's easy to collect biodegradable wastes and other non-biodegradable wastes. Collected biodegradable wastes can be converted into compost and biogas which is very effective for MSWM and have enormous applications like it increases the fertility of newly accreted land, reducing the use of chemical fertilizer, meet up the need for bio-fertilizer which is environmentally friendly, reducing the availability of trace heavy metals, help to reduce the salinity of coastal lands and enrich the soil health as Noakhali is a coastal city where newly accreted lands are forming known as char and most of the economic activities are dependent on its agriculture.

Biogas production helps to reduce the use of LPG gas and save money in the long term. In this way, organic waste can be turned into renewable energy. Plastics and polythene can be sold as raw materials after treatment. E-waste should be sold for recycling. After completing a sanitary landfill, it can be used as a green area. In the leachate treatment plant, leachate from sanitary landfills and other wastewater from treatment plants will be treated here. Proper management of MSW by following the 3R concept will become an earning source and will help to develop the economic condition.

The MSW sector is a major source of Methane (CH_4) emission, a Greenhouse Gas (GHG) that contributes to Climate Change. Landfills are a significant source of greenhouse gas emissions, and methane can be captured and utilized as an energy source. Organic materials that decompose in landfills produce a gas comprised of roughly 50% methane and 50% Carbon dioxide, called landfill gas (LFG). The gas is odorless and colorless, making leaks extremely difficult to detect. In a report on April 17, Canada-based emission-tracking company GHGs at Inc said that the Matuail Landfill emits around four tons of methane gas into the atmosphere every hour and is located about 8km away from Dhaka's Gulistan, the landfill is used as the disposal site for garbage collected from areas under the Dhaka South City Corporation. Municipal Solid Waste Management (MSWM) is one of the main environmental problems in Dhaka, the capital city of Bangladesh. About 5000 tons of waste is being generated in Dhaka city every day among which only more than half the portion is properly collected and dumped. So, a huge amount of waste is being mistreated every day. In Dhaka city, 67.65% of biodegradable waste is generated every day (Prodhan & Kaeser, 2020). 70% of biodegradable wastes were generated from food such as food and vegetable refuse, fruit skin, and manure which is known as organic matter and was present in the MSW of Rajshahi City Corporation in 2014 (Halder et al., 2014). In 2020, the number of biodegradable wastes in Rajshahi city increased by 1.1% and reached 71.1% (Hasan et al., 2020). That means the emission rate of methane in Dhaka city and Rajshahi city is much higher than in Noakhali Municipality as the biodegradable waste of Noakhali is 65%. The Degradable Organic Carbon (DOC) for the dry season is higher than for the wet season. But, the methane gas generated during the wet season is higher than that of the dry season. This is an appreciable quantity of methane that can contribute to the global Climate Change impact if not addressed. Therefore, these waste types should be segregated from other recyclables and processed into compost or energy resource. The quick advancement in urbanization, industrialization, and consequently improved lifestyles generate the bulk of solid wastes. As the lifestyle of human beings also has a great impact on the generation of biodegradable wastes so the emission rate of methane varies in the solid waste disposal sites from rural to urban areas.

4. CONCLUSION

Developing countries, though poor, should develop area-specific solutions to their problems in the management of MSW. In Bangladesh, this problem is terrible. Moreover, the dumping system and open disposal management are not hygienic. The improperly managed wastes causes drainage blockage during the monsoon season in Bangladesh. Poor funding is one of the main reasons for the poor collection and disposal of waste. Inappropriate design, operations, and maintenance of dumping sites and landfills have increased transfer and disposal costs. It is difficult to minimize the two variables, cost, and environmental impact, simultaneously. However, with limited finances and organizational capacity, it has been difficult for the government to ensure efficient collection and disposal of solid waste to the entire population. MSWM is indeed a complex system considering its inclusion of various stakeholders from waste generation to management, active participation of communities, and local government for a better SWM system. Proper SWM systems are needed to ensure a clean municipality, and better human health, and safety. Management authorities must be careful about their workers' health, and safety and safeguard public health by preventing the spread of disease. It can be concluded that SWM services in Noakhali Municipality are not satisfactory. The municipality should develop the concept of SWM and improve the system of entire management from top to bottom. Standardized characterization of MSW is essential for comparisons of studies made in different regions. This is important for developing countries, which will eventually allow for the implementation of more efficient SWM programs. In the future, composts that generate from biodegradable solid wastes can be used to reduce the salinity effects and make lands more productive. Landfill gas healing initiatives offer an effective way of lowering greenhouse gas emissions from landfill sites. Government along with the NGOs must take initiative to expand the existing landfill site to capture methane gas. This will assist to reduce the dependency on fossil fuel-based energy to mitigate the current power crisis.

5. REFERENCES

Ahsan, A., Alamgir, M., El-Sergany, M. M., Shams, S., Rowshon, M. K., & Daud, N. N. (2014). Assessment of municipal solid waste management system in a developing country. Chinese Journal of Engineering, 2014(12a), 1-11.

Alam, O., & Qiao, X. (2020). An in-depth review on municipal solid waste management, treatment, and disposal in Bangladesh. Sustainable Cities and Society, 52, 101775.

Ahsan, R., Islam, A. K. M. K., & Shams, S. (2009). Municipal waste management mechanism for Khulna city: a practice for better environment (Doctoral dissertation, Khulna University of Engineering and Technology).

Alam, P., & Ahmade, K. (2013). Impact of solid waste on health and the environment. International Journal of Sustainable Development and Green Economics (IJSDGE), 2(1), 165-168.

Alam, A. K. M. M., Saha, S. K., Rahman, M. M. S., Ahmed, M. F., Tanveer, S. A., &Badruzzaman, A. B. M. (2002). Aspects of solid waste management–a case study at Nirala Residential Area, Khulna. Bangladesh Environment. Bangladesh Poribesh Andolon (BAPA),Dhaka-1207, Bangladesh, 698-711.

Amirul Islam, A. K. M. (1994). Solid waste management system of Chittagong city corporation.

Alam, O., Qiao, X., (2019). An in-depth review on municipal solid waste management, treatment and disposal in Bangladesh. Sustainable cities and Society. Available at:https://www.sciencedirect.com/science/article/abs/pii/S2210670719307061#!

Alam, M. J., & Boie, D. I. W. (2001, December). Energy recovery from municipal solid waste in Dhaka City. In Proceedings of the international conference on mechanical engineering, Dhaka (pp. 26-28).

Ahsan, R., Islam, A. K. M. K., & Shams, S. (2009). Municipal waste management mechanism for Khulna city: a practice for better environment (Doctoral dissertation, Khulna University of Engineering and Technology).

Alamgir, M., & Ahsan, A. (2007). Characterization of MSW and nutrient contents of organic component in Bangladesh. Electronic Journal of Environmental, Agricultural and Food Chemistry, 6(4), 1945-1956.

A. H. M. Safayet Ullah Prodhan & Aflatun Kaeser, 2020. Solid Waste Management in Dhaka City– A Review on the Present Status and Possible Solutions.

Bhuiyan, S. H. (2010). A crisis in governance: Urban solid waste management in Bangladesh. Habitat international, 34(1), 125-133.

Barua, T., Kanon, P. S., & Munna, M. H. (2020). The Status of Recyclable Solid Wastes at Sadar Upazila of Noakhali, Bangladesh. Asian Journal of Environment & Ecology, 1-12.

Bahauddin, K. M., & Uddin, M. H. (2012). Prospect of solid waste situation and an approach of Environmental Management Measure (EMM) model for sustainable solid waste management: case study of Dhaka city. Journal of Environmental Science and Natural Resources, 5(1), 99-111.

Basic information about landfill gas, 2022, Environmental Protection Agency, https://www.epa.gov/lmop/basic-information-about-landfill-gas#.

Babu, B. R., Parande, A. K., & Basha, C. A. (2007). Electrical and electronic waste: a global environmental problem. Waste Management & Research, 25(4), 307-318.

Chowdhury, M. O. S., & Baksh, A. A. (2020). Analysis of Urban Solid Waste Management System of Bangladesh and Germany Waste Management System. International Journal of Environmental Science and Development,11(11).

Chowdhury, R. B., Sujauddin, M., Murakami, S., Chakraborty, P., & Alam, M.S.U. (2013). Current status of municipal solid waste management system in Chittagong, Bangladesh. International Journal of Environment and Waste Management, 12(2), 167-188.

EPA's Superfund Program: Making a Visible Difference,(2016).
EPA Superfund Program: PJP Landfill, Jersey city, NJ. Available at: https://19january2021snapshot.epa.gov/sites/static/files/2017-05/documents/usepa_2016b_pjp_landfill_superfund_site_profile_superfund_site_information_us_epa.pdf.

Gutierrez, K. G., Fernandes, M. A. O., & Chernicharo, C. A. L. (2019). Modelling of a sanitary landfill for developing countries to improve the reliability of Life Cycle Assessment studies. In IOP Conference Series: Earth and Environmental Science (Vol. 323, No. 1, p. 012085). IOP Publishing.

Gupta, S., Mohan, K., Prasad, R., Gupta, S., & Kansal, A. (1998). Solid waste management in India: options and opportunities. Resources, conservation and recycling, 24(2), 137-154.

Hettiaratchi, J. P. A. (2007). New trends in waste management: North American perspective.

Hargreaves, J. C., Adl, M. S., & Warman, P. R. (2008). A review of the use of composted municipal solid waste in agriculture. Agriculture, Ecosystems &Environment, 123(1-3), 1-14.

Hasan, G. M., Chowdhury, M., & Islam, A. (2006). Municipal waste management and environmental hazards in Bangladesh. Asian Journal of Water, Environment and Pollution, 3(1), 39-48.

Hoornweg, D., & Bhada-Tata, P. (2012). What a waste: a global review of solid waste management.

Halder, N. Paul, M. E. Hoque, A. S. M. Hoque, M. S. Parvez, Md. Hafizur Rahman, M. Ali (2014), Municipal Solid Waste and its Management in Rajshahi City, Bangladesh: A Source of Energy.

Islam, K. M. (2016). Municipal solid waste to energy generation in Bangladesh: possible scenarios to generate renewable electricity in Dhaka and Chittagong city. Journal of Renewable Energy, 2016.

IPCC, 2006. IPCC Guidelines for National Greenhouse Gas Inventories: volume 5- waste.

Islam, M. S., & Moniruzzaman, S. M. (2019). Simulation of sustainable solid waste management system in Khulna city. Sustainable Environment Research, 29(1), 1-8.

Josie Garthwaite, 2021, Methane and climate change.

Kumar, P. D., & Bhowmick, G. C. (1998). Solid waste management–the obvious answer. Environment Management with Indian Experience. APH publishing Corporation, New Delhi, 173-176.

Leung, A. O., Duzgoren-Aydin, N. S., Cheung, K. C., & Wong, M. H. (2008).Heavy metals concentrations of surface dust from e-waste recycling and its human health implications in southeast China. Environmental science & technology, 42(7), 2674-2680.

M. Sujauddin, S. M. S. Huda, and A. T. M. R. Hoque, “Household solid waste characteristics and management in Chittagong, Bangladesh,” Waste Management, Vol. 28, no. 9, pp. 1688-1695, 2008.

Md. Rakib Hasan , Khodadad Mostakim, Md. Shafikul Islam, Nawshin Binte Amir, Taufique Ahmmed, and Md. Rejuan Ahmed, 2020. Municipal Solid Waste Management: Scopes, Challenges of Sustainability and Treatments in Rajshahi City, Bangladesh.

Nasiruddin, M.A. Salam, & M.H.R. Azad, (2013). Master plan for Noakhali Paurashava (2013-2033). Structure plan, urban area plan and ward action plan.

Oliveira, A. D. L., & Turra, A. (2015). Solid waste management in coastal cities: where are the gaps? Case study of the North Coast of São Paulo, Brazil. Revista de Gestão Costeira Integrada-Journal of Integrated Coastal Zone Management, 15(4), 453-465.

Rahman, M. (2014). Developing the waste management system in Dhaka City, Bangladesh.

Rahman, M. and Alam, J. (2020) Solid Waste Management and Incineration Practice: A Study of Bangladesh. International Journal of Nonferrous Metallurgy, 9, 1-25. Doi: 10.4236/ijnm.2020.91001.

Salequzzaman, M., Murtaza, M. G., & Saroar, M. (1998). Evaluation study on municipal solid waste management project in Khulna City. PRODIPAN, Shaheb Bari Road, Khulna-9203, Bangladesh.

Troschinetz, A. M., & Mihelcic, J. R. (2009). Sustainable recycling of municipal solid waste in developing countries. Waste management, 29(2),915-923.

United Nations (2021). World Population Prospects - Population Division - United Nations. [online] Available at:<https://population.un.org/wpp/> [Accessed 14 August 2021].

Vergara, S. E., & Tchobanoglous, G. (2012). Municipal solid waste and the environment: a global perspective. Annual Review of Environment and Resources, 37, 277-309.

World Bank, Urban Development. (2019). Solid Waste Management. Retrieved from:https://www.worldbank.org/en/topic/urbandevelopment/brief/solid-waste-management.

Yusuf, R.O., Noor, Z.Z., Abba, A.H., Hassan, M.A.A. and Din, M.F.M., 2012. Methane emission by sectors: a comprehensive review of emission sources and mitigation methods. Renewable and Sustainable Energy reviews, 16(7), pp.5059-5070.

Zaman, A. U., & Lehmann, S. (2011). Challenges and opportunities in transforming a city into a “zero waste city”. Challenges, 2(4), 73-93.