FINAL MASTER PLAN FOR SOLID WASTE COLLECTION AND DISPOSAL MANAGEMENT IN NARAYANGANJ CITY CORPORATION

Volume III

Narayanganj City Corporation

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PROJECT SUMMARY

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EXECUTIVE SUMMARY

Narayanganj is characterized by a high population growth rate. Currently about 10,63,576 (Based on BBS, 2011) permanent residents live in the area. The number of seasonal laborers and commuters from Dhaka and other surrounding areas is estimated to 1.572 million people. According to the recent development the population growth rate can be estimated as 4.05 % per year. Many industrial branches provide a large number of jobs. First of all, the garment industry dominates the industrial sector of the area and generates a large amount of specific waste. The population growth and the increasing industrial sector generate fast-growing waste amounts. The raining living-standards will intensify this process. Currently the household and commercial waste amounts have been estimated to 922 Tons per day (Based on household survey, commercial survey, industrial survey and polythene beg distribution and collection survey). According to our surveys and analysis, not more than 50 % of this amount is currently collected and transported to a dumping site.

In 2025 the potential of household and commercial waste will increase to more than 1000 Tons per day. A basic regulation on waste management is given and assigned for the urban local government institutions of Narayanganj City Corporation with responsibilities regarding the removal, collection and management of waste; nevertheless, the waste management lacks in collection equipment and collection staff and environmental-friendly disposal facilities. The common illegal dumping of waste in water bodies, canals and on river banks as well as the use of uncontrolled and unsanitary dumping sites causes to heavy hazard on soil and groundwater and pollute the air with emissions of uncontrolled burning waste. The waste composition is characterized by nearly 70 % of food waste which causes to high moisture contents which is accompanied by low calorific values.

Solid waste management is one among the basic essential services provided by municipal authorities in Bangladesh to keep urban centers clean. However, it is among the most poorly rendered services. Most of the systems applied are unscientific, outdated and inefficient where population coverage is low and the poor are marginalized. Municipal laws governing the urban local bodies do not have adequate provisions to deal effectively with the ever-

growing problem of solid waste management. With rapid urbanization, the situation is becoming critical. The urban population has grown fivefold in the last six decades.

The Study covers three types of solid wastes generated in the jurisdiction of the Narayanganj City Corporation namely, Domestic waste, Commercial and Industrial waste and Medical waste. Liquid and gaseous wastes are not included in the scope of this study. The master plan has been prepared for only Domestic, Commercial, Industrial and Medical waste in of NCC Area. With regard to Industrial waste and Medical wastes, surveys were conducted to identify the problems and possible solutions will be proposed separately from Domestic waste.

Lots of the problem can be fenced if the municipal solid waste management is properly executed in Narayanganj. The activities that are usually performed as part of health care waste management involve segregation, storage, collection, transportation and disposal of Biomedical waste. It includes organizational, planning, administrative, financial, engineering aspects, legal, and human resource development and their management involves interdisciplinary relationships. Management of municipal waste requires commitment at all the levels from healthcare providers. A system that is managed by irresponsible and untrained staff, the risks and the importance of their “contribution” is dreaded.

Awareness regarding rules of disposal of municipal waste needs to be taught even among qualified personnel of commercial areas and industries, households, including hospital administrators, private and governmental institutes, hospitals, school and colleges. Knowledge regarding the significance of municipal waste, its relationship with the ecosystem, the environmental toxins used in health care industry and the impact of callousness on public health, remain very minimal. For better result we need to increase the level of training and education regarding disposal of municipal waste and environment-friendly health care with optimum priority, under rules and legislation.

ACRONYMS AND ABREVIATIONS

ADB	**Asian Development Bank**
BBS	**Bangladesh Bureau of Statistics**
BGS	**British Geological Survey**
BM	**Bench Mark**
BMD	**Bangladesh Meteorological Department**
BoQ	**Bill of Quantities**
BTM	**Bangladesh Transverse Mercator**
BUET	**Bangladesh University of Engineering and Technology**
BTM	**Bangladesh Transverse Mercator**
BWDB	**Bangladesh Water Development Board**
DEM	**Digital Elevation Model**
DGPS	**Differential Global Positioning System**
DHI	**Danish Hydraulic Institute**
DOE	**Department of Environment**
DPHE	**Department of Public Health Engineering**
FAP	**Flood Action Plan**
GDP	**Gross Domestic Product**
GIS	**Geographic Information System**
GoB	**Government of Bangladesh**
GPS	**Global Positioning System**
GSB	**Geological Survey of Bangladesh**
JICA	**Japan International Co-operation Agency**
LGRD	**Local Government and Rural Development**
LR	**Literature Review**

MIS	**Management Information System**
MoEF	**Ministry of Environment and Forests**
MSL	**Mean Sea Level (at Cox's Bazar)**
MSW	**Municipal Solid Waste**
NCC	**Narayanganj City Corporation**
NGO	**Non-Government Organization**
PCO	**Project Coordination Office**
PD	**Project Director**
PPP	**Public-Private Partnership**
PSP	**Private Sector Participation**
PWD	**Public Works Department**
RM	**Research Methodology**
SOB	**Survey of Bangladesh**
SWM	**Solid Waste Management**
TBM	**Temporary Bench Mark**
ToR	**Terms of Reference**
UNICEF	**United Nations International Children's Emergency Fund**
WM	**Waste Management**

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COMMON SWM TERMS

Commercial collection company – a private-sector company that collects garbage, recyclables, and organics from residents and businesses.

Compost – the product resulting from the controlled biological decomposition of organic waste, including yard waste, food scraps, and food-soiled paper, which is beneficial to plant growth when used as a soil amendment.

Construction and demolition debris (C&D) – recyclable and non-recyclable materials that result from construction, remodelling, repair or demolition of buildings, roads or other structures, and requires removal from the site of construction or demolition. Construction and demolition debris do not include land clearing materials such as soil, rock, and vegetation.

Landfill gas – gas generated through the decomposition of waste buried in the landfill, which consists of about 50 to 60 percent methane and about 40 to 50 percent carbon dioxide, with less than 1 percent oxygen, nitrogen, and other trace gases.

Leachate – water that percolates through garbage at the landfill and requires collection and treatment before being sent to a wastewater treatment plant.

Municipal solid waste or MSW – includes garbage (putrescible wastes) and rubbish (nonputrescible wastes), except recyclables that have been source-separated; the residual from source-separated recyclables is MSW.

Solid waste – all materials discarded including garbage, recyclables, and organics.

Special waste – wastes that have special handling needs or have specific waste properties that require waste clearance before disposal. These wastes include contaminated soil, asbestos-containing materials, wastewater treatment plant grit, industrial wastes, and other wastes.

Sustainability – an approach to growth and development that balances social needs and economic opportunities with the long-term preservation of a clean and healthy natural environment. This approach to action and development integrates environmental quality, social equity, fiscal responsibility, and economic vitality.

Waste conversion technologies – non-incineration technologies that use thermal, chemical, or biological processes, sometimes combined with mechanical processes, to convert the post-

recycled or residual portion of the municipal solid waste stream to electricity, fuels, and/or chemicals that can be used by industry.

Waste prevention – the practice of creating less waste, which saves the resources needed to recycle or dispose of it such as choosing to purchase items with less or no packaging.

Waste-to-energy technologies – recover energy from municipal solid waste and include both waste conversion technologies and incineration with energy recovery, such as mass burn waste-to-energy, refuse derived fuel, and advanced thermal recycling.

Zero waste of resources or zero waste – a planning principle designed to eliminate the disposal of materials with economic value. Zero waste does not mean that no waste will be disposed; it proposes that maximum feasible and cost-effective efforts be made to prevent, reuse, and recycle waste.

CHAPTER 10: JHALKURI LANDFILL SITE DEVELOPMENT

There are many guidelines available for selecting a landfill site. However, many contain criteria which are very onerous and restrictive, and are more appropriate for the cities like NCC. In fact, such guidelines would rule out many acceptable sites. The proposed criteria have been developed in conjunction with many international landfill design criteria as base documents. These provide some generic background and also local specifics. The following criteria are pragmatic but will still provide adequate socioenvironmental protection with a suitable landfill design and standard of operation.

10.1 Basic Site Selection Criteria

The following criteria are the basic issues that need to be addressed when siting a landfill:

i. The site selected must be consistent with the overall land use and development plan of the city corporation or municipality.
ii. The site should be large enough to accommodate the city's wastes for a long period.
iii. The site must be accessible from major roadways or thoroughfares, with strong pavements for trucks.
iv. The site should have an adequate quantity of suitable earth cover material that is easily handled and compacted.
v. The site must be chosen with regard for the sensitivities of the community's residents.
vi. The site must be located in an area where the landfill's operation will not detrimentally affect environmentally sensitive resources such as aquifer, groundwater reservoir, watershed area, ecologically sensitive area, etc.
vii. The site should be distant from airport landing and take-off paths.
viii. The site chosen should facilitate developing a landfill that will satisfy budgetary constraints, including site development, operation for many years, closure, post closure care, and possible remediation costs.

10.2 Detailed Site Selection Criteria

In addition to such general requirements, the following criteria should be followed:

a) The site should be large enough to accommodate the city's wastes for a minimum period of 20 years, including allowance for areas such as buffer areas, recycling, equipment

sheds, cover material stockpiles, buildings, internal access roads, compost processing area, etc.

b) Preferably, a site accessible within 30 minutes of travel time from the central business district is sought. At travel distances greater than 30 minutes, for collection operations to be economic, investment in either large capacity collection vehicles (5 tons per load or greater) or transfer stations with large capacity vehicles (20 tons or greater) is necessary. If transfer stations are required, the landfill should be accessible within 2 hours of travel time (one-way) by transfer trucks from the transfer station.

c) The site should be accessible from a competent paved public road which has an adequate width, slope, visibility, and construction to accommodate the projected truck traffic. To minimize landfill development costs, the requirement for new access road construction generally should be less than 10 kilometres (km) for large landfills serving metropolitan areas and less than 3 km for small landfills serving secondary cities. The site should have a gently sloped topography, amenable to development of a landfill by the ramp method. Steeper slopes are acceptable, provided that the landfill design can accommodate these slopes and still yield a suitable site life. Flat sites mean leachate management can be difficult.

d) Groundwater's seasonal high level should be at least 1.5 meters (m) below the proposed base of any cell excavation. An absolute minimum clearance of 1 m of relatively impermeable soils above the groundwater's seasonal high level should exist (preferably less than 10^ (-9) m per second permeability when undisturbed).

e) If these criteria are not met, use of impermeable clay and/or plastic liners may be required to protect groundwater quality.

f) Availability on-site of suitable soil cover material to meet the needs for daily, intermediate, and final cover, as well as bund construction must be ensured. The best soils are clayey silts which provide good cover in both wet and dry weather periods. Too little clay increases permeability so that water can enter the waste mound. Too much clay can result in trafficability issues in wet weather and cracking in dry periods. For purposes of siting, at least 10% of the final landfill volume should be assumed to be cover material. Well-run landfills are closer to 25% cover material content, but 10% is the bare minimum allowed.

g) There are no private or public drinking, irrigation, or livestock water supply wells within 500 m downgradient of the landfill boundaries, unless alternative water supply sources are readily and economically available. (Three bores as a minimum can show direction of groundwater flow if not evident on the surface.)

h) No environmentally significant wetlands of important biodiversity or reproductive value are present within the potential area of the landfill cell development. No known environmentally rare or endangered species breeding areas or protected living areas are present within the site boundaries.

i) No significant environmentally sensitive areas are within 500 m of the landfill cell development area.

j) Preferably, prevailing winds do not blow toward habituated areas from the landfill.

k) No major electrical transmission lines or other infrastructure (i.e., gas, sewer, telecoms, or water lines) are crossing the landfill cell development area.

l) There are no underlying underground mines which could be adversely affected by surface activities of landfilling.

m) No residential development within 250 m from the perimeter of the proposed landfill cell development.

n) There is no perennial stream within 200 m downgradient of the proposed landfill cell development, unless diversion is economically and environmentally feasible to protect the stream from potential contamination.

o) No significant seismic risk exists within the region of the landfill which could cause destruction of berms, drains, or other civil works, or require unnecessarily costly engineering measures.

p) No fault lines or significantly fractured geologic structure are present within 500 m of the perimeter of the proposed landfill.

q) The site must not be within 3 km of a turbojet airport and 1.5 km of a piston-type airport.

r) The site must not be within a floodplain subject to 10-year floods.

s) No major valley features are present on the site which cannot be readily diverted to prevent stormwater external to the site entering the waste mound.

t) Siting should be avoided within 1 km of socio-politically sensitive sites where public acceptance might be unlikely (i.e., memorial sites, churches, mosques, or schools) and access roads that would pass by such culturally sensitive sites.

10.3 Community Engagement

The technical and engineering aspects of landfill siting are relatively straightforward. However, the assessment of potential landfill sites will need to consider the concerns of the host community. This will allow information sharing and early identification of issues of interest that can be considered in the site screening process. Once initial meetings with the local community have been undertaken and the landfill development has been discussed and supported, a program of community participation should be continued for subsequent phases of the project. Effective engagement practices help identify potential issues, impacts, opportunities, options, and solutions for improvement and facilitate more efficient decision making. This may be part of an environmental impact study or assessment and social impact assessment, especially for larger proposed facilities. The benefits of planned and well implemented engagement

include:

- ✓ enabling the community to be better informed and encouraging local pride and active citizenship;
- ✓ reducing the amount of misunderstanding and misinformation with clear communication and very early engagement of the community;
- ✓ enabling all groups to have a better understanding of community and local needs;
- ✓ enabling greater commitment to and ownership of decision making by the community;
- ✓ building mutual understanding and ownership of problems and solutions;
- ✓ supporting more efficient and effective decisions, as actual community needs can be identified and community knowledge used throughout the business phases;
- ✓ supporting behavioural and attitudinal change in all groups; and
- ✓ enabling industry to be a good neighbour by building trust and confidence through its openness and transparency and by listening and responding to community needs.

There are numerous international guidelines for siting landfill. Many are too restrictive and would rule out suitable sites for a small or midsize city in the developing context. The guidelines presented here are pragmatic and generally suitable for siting a small to midsize facility. For very large facilities, more detailed assessments are essential.

10.4 Geotechnical Assessments

A geotechnical study is required for any controlled landfill if it is to be a large permanent facility. The scope of works specified is to adequately define the geotechnical conditions to allow the landfill design to proceed, in particular the liner requirements. This will include all works required to achieve this description. It should be noted that for very large landfills, the scope of works may have to be extended.

10.4.1 Fieldwork

The following steps should be followed in the fieldwork process:

1. Develop a grid of nine pits over the proposed base area:

✓ Locate the test pits on a grid of 3x3 pits giving a grid of nine pits equally spread over the site.

✓ Three of these nine pits (main pits) will be logged in detail, as specified below.

✓ The remaining six pits will be used to determine the soil profile, but the holes will not be logged in detail.

2. Conduct in situ infiltration tests on the surface of the clay or silty clay layer using the double-ring infiltrometer method. This should be done at three sites near the test pits where the pits are fully logged.
3. Excavate nine test pits to a depth of at least 4 meters (m). If the pit collapses due to unconsolidated and/or saturated ground conditions, then the pit should be logged to the maximum practical depth. Depths of pit wall collapse should be noted.
4. For each of the three main pits:

✓ Log and classify the soil types encountered and the strata depth according to the Unified Soil Classification system, including usual parameters such as colour and stiffness.

✓ Pay particular attention to identifying the presence, type, depth, and thickness of any impermeable layers, such as clay or clayey bands.

✓ Note features such as the presence of tree roots or other structure that may alter the gross permeability of the soil strata.

✓ Determine the standing water level in each of these three main pits, if standing water is encountered. If the water level is slow in stabilizing, the pit should be left open until a stable water level can be determined.

✓ Undertake the usual field tests to confirm the soil classifications, such as stiffness.

5. For the remaining six pits:

- ✓ Measure the depth from the surface to the top of any impermeable layers, such as clay or clayey bands, or any permeable layers such as sand or gravel.
- ✓ Measure the thickness of the soil band(s).
- ✓ There is no need for formal soil logging or sampling required in these six supplementary pits. They are just to identify any clay or highly permeable layers.

6. Backfill pits immediately upon completion of the site work. Also, compact and level them back to sensibly meet with the natural surface profile. The only reason for keeping a pit open would be while waiting for the water level in the pit to stabilize.
7. Drill one hole to a depth of at least 10 m at the centre of the site:

- ✓ Using a suitable drill rig, drill to a depth of at least 11m or until the groundwater is reached. Log and classify the soil types encountered and the strata depth according to the Unified Soil Classification system, including usual parameters such as colour and stiffness.
- ✓ Pay particular attention to identifying the presence, type, depth, and thickness of any impermeable layers, such as clay or clayey bands.
- ✓ Determine the standing water level in the drill hole. If the water level is slow in stabilizing, the pit should be left open until a stable water level can be determined.
- ✓ Undertake the usual field tests to confirm the soil classifications, such as stiffness.
- ✓ Insert three bores with piezometers to monitor water table depth over the wet and dry seasons and to allow determination of groundwater flow. These pits might be clear of the landfill footprint to become permanent water quality monitoring bores. The basic chemical constituents of the water can be monitored for 12 months to give background levels should regulations require such measures.

10.4.2 Sampling and Testing

10.4.2.1 Sampling

An undisturbed sample should be collected from a representative soil layer in each of three main pits spread over the site area. These pits should be selected so as to best represent the variations, if any, in stratigraphy over the entire site. Sufficient additional sample volume should be collected of the clay or low permeability layer from the three pits selected earlier

for laboratory analysis of the liquid limit, shrinkage and plasticity index, and Emerson pin test for dispersity.

10.4.2.2 Laboratory Testing

The three undisturbed clay samples should be tested for permeability in an oedometer test rig. The three disturbed samples from the same pits should be subjected to laboratory analysis for the liquid limit, linear shrinkage and plasticity index, and Emerson pin test for dispersity.

10.4.2.3 Fieldwork Reporting

The fieldwork report should include the following:

• A short site report describing the site activities, staff, and equipment used;

• Soils logs of the three main pits describing the features required above, printed at one log per A4 page;

• Plots from the in situ infiltrometer tests and calculated infiltration rates; and

• A table of the general soil profile in the six supplementary pits.

10.4.2.4 Laboratory Results Reporting

The laboratory results should be detailed, providing basic interpretation of soil properties, and including the results of

• liquid limit, linear shrinkage and plasticity index, Emerson pin tests;

• permeability testing in an oedometer test rig; and

• any other laboratory tests considered essential to adequately describe the soil profiles.

10.4.2.5 Double-Ring Infiltrometer Field Test

The infiltration rate is the velocity or speed at which water enters into the soil. It is usually measured by the depth of the water layer that can enter the soil in unit of time (e.g., millimetres per day, etc.). An infiltration rate of 15 mm per hour means that a water layer of 15 mm on the soil surface will take 1 hour to infiltrate. In dry soil, water infiltrates rapidly. This is called the initial infiltration rate and is dependent on the sportively of the soil. As more water replaces the air in the soil pores, the water from the soil surface infiltrates more slowly and eventually reaches a steady rate. This is called the saturated soil infiltration rate. The infiltration rate depends on soil texture (the size of the soil particles) and soil structure (the arrangement of the soil particles and tortuosity of the void flow path). It is a useful way of categorizing soils in terms of their ability to transmit water vertically. The most common

method to measure the infiltration rate is by a field test using the double-ring infiltrometer. The following table shows the typical infiltration rates for various soil types:

Table 1: Infiltration Rates of Different Soil Types

Soil Type	Basic Infiltration Rate (mm/hour)
Sand	30+
Sandy loam	20–30
Loam	10–20
Clay loam	5–10
Clay	1–5

mm = millimeters.

Source: ADB, 2017

A double-ring infiltrometer of 30 centimetres (cm) in diameter and 60 cm diameter should be used for this investigation:

(i) Hammer the 30 cm diameter ring at least 15 cm into the soil. Use the timber to protect the ring from damage during hammering. Keep the side of the ring vertical and drive the measuring rod into the soil so that approximately 12 cm is left above the ground.

(ii) Hammer the 60 cm ring into the soil or construct an earth bund around the 30 cm ring to the same height as the ring and place the hessian inside the infiltrometer to protect the soil surface when pouring in the water.

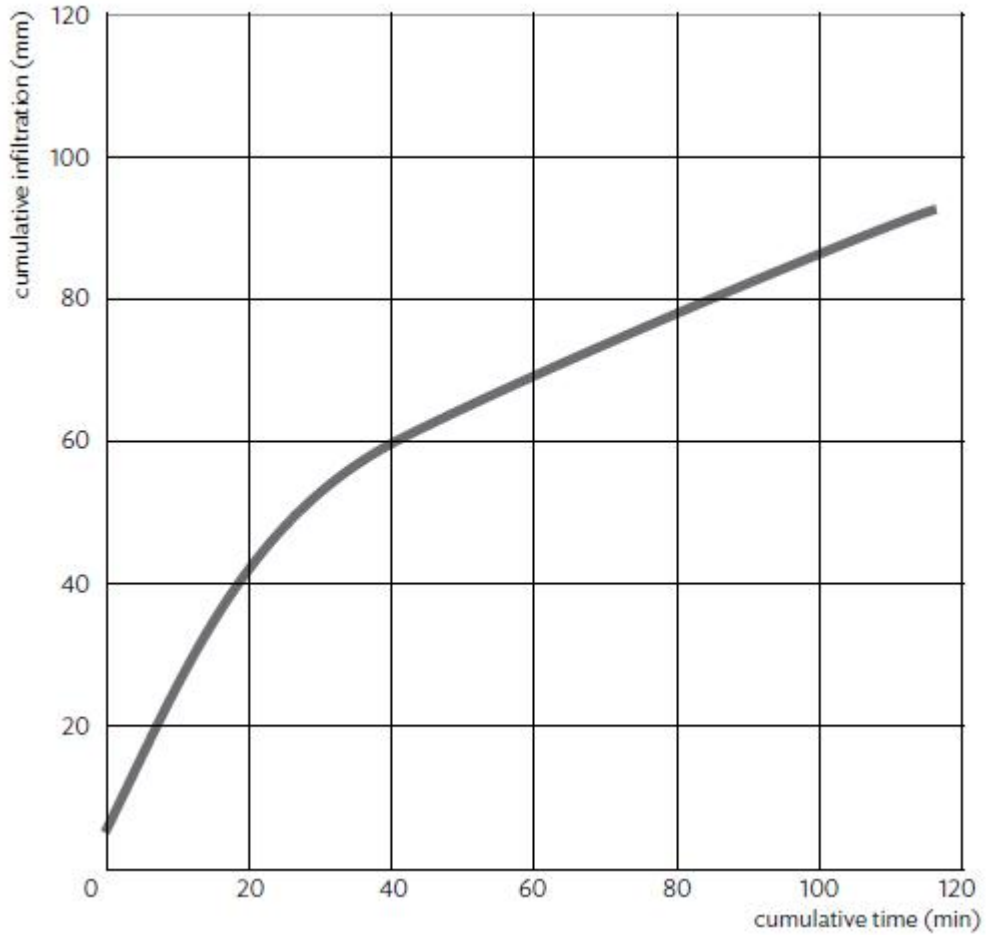
(iii) Start the test by pouring water into the ring until the depth is approximately 70–100 mm. At the same time, add water to the space between the two rings or the ring and the bund to the same depth. Do this quickly.

(iv) Record the clock time when the test begins and note the water level on the measuring rod.

(v) After 1–2 minutes, record the drop-in water level in the inner ring on the measuring rod and add water to bring the level back to approximately the original level at the start of the test. Record the water level. Maintain the water level outside the ring similar to that inside.

(vi) Continue the test until the drop-in water level is the same over the same time interval. Take readings frequently (e.g., every 1–2 minutes) at the beginning of the test, but extend the interval between readings as the time goes on (e.g., every 20–30 minutes).

The basic infiltration rate should be determined from plotting the infiltration rate to see when it has stabilized. Once the values of the infiltration rate are constant; the basic infiltration rate has been reached. The following figures shows a typical infiltration plot.



Source: ADB, 2017

Figure 1: Typical plot of cumulative Infiltration versus time

This overview of typical geotechnical assessments required for small to midsize landfills is based on a mixture of test pits as well as bore logs. Some on-site testing is required with regard to permeability and recording soil profiles. Appropriate laboratory testing procedures have also been described. The overall aim is to understand the site hydrogeology so appropriate lining systems and other leachate interventions can be developed.

10.5 Appropriate Standard for a Waste Disposal Facility

Control of waste accepted into a Landfill requires the use of protocols to routinely screen waste inflow and/or criteria to assess the admissibility of waste for handling and disposal. These criteria are aimed at determining whether a particular waste should be accepted or rejected. All acceptable wastes are classified as permitted waste and those rejected are classified as prohibited waste in relation to the operating criteria for the facility.

Table 2: Waste Disposal Facility Options

Type	Characteristics	Advantages	Disadvantages
Open dump	Poorly sited Unknown capacity No cell planning Little or no site preparation No leachate management No gas management Occasional or no cover soil No waste compaction No fence Waste burning No record keeping Uncontrolled waste picking No groundwater monitoring	Easy access Low initial cost Low operating cost Aerobic decomposition Access to waste pickers Materials recovery	High environmental impacts Unsightly Groundwater contamination Surface water contamination High risk of explosion, fire, greenhouse gases Vectors/disease transmission Reduced lifetime of dumpsite Inefficient use of landfill area Breeds vermin, rodents, flies No record of landfill content Air pollution High health risk to waste pickers, especially children
Controlled dump	Sited with regard to hydro-geology Planned cell development Grading, drainage in site preparation Partial leachate management No waste covering No compaction Fence Basic record keeping Uncontrolled waste picking Waste burning No gas management	Moderate environmental impacts Permits long term planning Improved stormwater control Less risk of leachate release Controlled access and use Access to waste pickers Materials recovery	Moderate environmental impacts Groundwater contamination Surface water contamination Moderate risk of explosion or fire due to gas Vectors/disease transmission Reduced lifetime of dumpsite Inefficient use of landfill area Breeds vermin, rodents, flies No record of landfill content Air pollution

	No groundwater monitoring		High health risk to waste pickers, especially children
Controlled landfill	Sited with regard to hydro-geology Planned cell development Grading, drainage in site preparation Improved leachate and surface water management, including provision of a low-permeability basal liner (can be compacted clay and not necessarily an artificial liner) Regular (not usually daily) cover Waste compaction Fence Basic record keeping Controlled waste picking Gas management provisions Monitoring of groundwater	Low environmental impacts Permits long term planning Improved stormwater control Reduced risk of leachate release Controlled access and use Reduced risk to waste pickers Materials recovery Waste is covered by soil Efficient use of landfill area Reduced breeding of vermin, rodents, flies Extended lifetime of landfill site	Still reduced environmental impacts Still limited potential for groundwater contamination Still limited potential for surface water contamination Still low risk of explosion, fire due to gas Still reduced risk of vectors/disease transmission Little or no record of landfill content Some air pollution Some health risk to waste pickers, no children allowed
Sanitary landfill	Site based on environmental risk assessment Planned cell development Extensive site preparation Full leachate and surface water management Full gas management Daily and final cover Daily waste compaction Fence and gate	Minimized environmental risk Permits long-term planning Improved stormwater control Minimized risk of leachate release Reduced risk from gas Vector control Improved aesthetics Extended lifetime	High initial cost High operating costs Longer development time Slower waste decomposition unless bioreactor operation used Minimized risk of vectors/disease transmission Minimized risk of vermin, rodents, flies Displacement of waste pickers Loss of recyclable resources Optimum use of landfill site

	Record waste volume, type, source No waste picking	Controlled access and use Eliminate risk to waste pickers

Waste control processes are also important in recording information about waste types that are subject to control, including:

- Establishing accurate information about deposited waste (quantities, timing)
- Recording the location of waste placement and issues around the potential environmental risk of the facility
- Details of generation point of waste to be deposited
- Waste manifest details including its detailed physic-chemical characterization studies
- Toxic chemical leachate procedure studies result with respect to its landfilling

The fundamental objective of such control methods is to ensure adequate:

- Pollution control
- Operational and public safety
- Information management
- Optimization of facility capacity
- Compliance of regulatory framework, under which permission has been granted to the facility
- Compliance of applicable environmental health and safety protocols

10.5.1 The degree of facility control achieved can be classified as a series of levels

a) Level 0: Uncontrolled

This occurs where the facility has no secure barriers to entry, which means that both users and other parties such as stray dumpers or scavengers can access the site without control. Such facilities do not have any defined physical boundaries delineation and are vulnerable to receipt of all types of waste, leading to chaos and unsafe operation. They contribute to environmental degradation as all types of wastes can end up in the facility and such sites are essentially “uncontrolled tip sites. Such sites are characterized by the presence of smoke, uncontrolled leachate release, and any anticipated fire hazards due to the dumping of

incompatible waste with varying physical, chemical, and biological properties. Such a level of operation is not consistent with modern sanitary landfill practices.

b) Level 1: Basic Site Access Control

This is when the facility is adequately delineated and secured at its perimeter, but with only unmanned entry point(s) which means such facilities can apply some access control and can be closed or suspended to use by trucks by securing those entry points.

c) Level 2: Site Access and Entry Point Control

This is considered the minimum operating standard for a modern landfill. In this situation, the site perimeter is fully secure and control of incoming waste loads is exercised at (typically) a single-entry point. In addition to overall access control, loads are allowed into the site only when the entry is open and manned. At such facilities information about the waste source, type and quantity can be acquired as part of the access control process.

d) Level 3: Site Access, Entry Point, and Operations Controls

This is considered the normal operating level for a modern sanitary landfill. In this situation, in addition to waste acceptance controls at the site entry point operations controls related to the tipping area (using a “spotter”) as well as control over the placement and compaction of waste are employed.

e) Level 4: Site Access, Entry Point, Operations, and Waste Material Controls

Level 4 requires the use of specified predetermined Waste Acceptance Criteria (WAC) to permit particular waste loads. This process is administered at the point of entry allowing only permitted waste into the facility. Detailed documentation, including inspection and when necessary on the spot testing of waste as per the details of waste manifest provided, are usually associated with this level of facility operation. These sites ensure the best compliance of any applicable Environment, Health, and Safety Protocols applicable to such facilities.

10.5.2 Waste Control Chain of Responsibility

Generator:

Waste control commences with the generator of the waste who has the responsibility of disclosing accurate information about the waste. This can be achieved with a Waste Profile

Form (WPF), or by simply packaging waste inappropriately color-coded bags as per the Universal color-coding criterion.

Carrier/Haulage Contractor:

Waste haulage contractors have the responsibility in the chain to ensure clear and correct documentation of information about the waste they are carrying to enable quick assessment at the facility. This can be transmitted with either a WCN or a Waste Manifest Form (WMF). It is an essential part of this process that waste generators endorse the haulage contractor and for corresponding waste to be delivered with the required documentation to the facility.

Landfill Manager:

The Landfill Manager effectively assumes ownership of waste admitted into the landfill and hence has final responsibility for ensuring the facility is operated in accordance with the predetermined waste control protocols. Therefore, the landfill manager must ensure that all facility Waste Acceptance Criteria are met and, all information necessary for waste traceability is acquired at the entry point (weighbridge), or via the manifest system. The landfill manager is also vested with responsibility and authority of denying access to a category of waste, which does not comply with landfilling criterion, based upon the facility defined Waste Acceptance Criteria

10.5.3 Operational Aspects of Waste Control

Security:

All security measures and operating procedures should be in place prior to commencing site operations, as detailed in the Landfill Operations Guideline.

Entry Point:

The site entry point should be manned during all hours of operation (and outside those hours as necessary) with personnel and equipment to:

- Weigh incoming waste
- Manually or automatically document waste information
- Screen incoming waste (visual inspection or automated CCTV camera screening)
- Options for decoding of any applicable waste tracking and movement bar codes

The weighbridge should be capable of recording weights accurately from the computer system and should be calibrated regularly by the appropriate authority to ensure accuracy as per applicable local legislations. Waste load weights should be recorded, together with details of the corresponding waste load. Where a weighbridge is not available, loads should be recorded in terms of truck volume. Waste density as recorded by the Waste Manifest may be used to arrive at a tentative load carried by an incoming truck to the facility.

Figure 2: Waste reception at the landfill

Internal Control:

These control processes relate to operations undertaken within the facility once the waste load has been accepted across the weighbridge.

Work Face Control:

Control at the working face by the operating personnel is targeted at not only directing traffic but also at "spotting" incorrectly described, prohibited, or potentially hazardous waste loads. This requires physical inspection and if necessary, re-direction for testing of specific loads.

Reporting:

The waste types and quantities received at the Landfill should be recorded as a Waste Reception Report (WRR). At a large landfill, such recording is usually carried out using an integrated weighing and data recording system, consisting of one or more weighbridges and compute. The recording system is often integrated with the payment and invoicing system.

Key information that should be included in the WRR includes the waste category, identification of the carrier, waste source, tonnage, and any other special load features.

Close control of waste acceptance is a key tool in ensuring a high standard of sit operations, and in meeting common license requirements that control the acceptance of hazardous and problem wastes for site design or operational reasons. A hierarchy o control measures can be applied, starting with overall site security and entry control for both personnel, and waste loads.

10.6 Dumpsite Remediation

Many municipal waste dumps are either poorly designed, poorly operated or both. This is usually blamed on funding shortcomings by municipality staff, but significant improvements are possible through a more structured approach to design and operation. Most dumpsites are operated on the generic concept of cut and fill, meaning waste is placed in shallow excavated pits which are possibly lined and then filled to establish a shallow mound often with an almost flat top surface. Municipalities often believe their disposal site is then full to capacity and after placing a thin soil cover on top of the mound the site is suitably closed. Such a design is very wasteful of landfill space and also maximizes the environmental risks given the likely quantity of leachate then generated. Leachate is predominantly the liquid formed when rainwater or runoff water enters the landfill mound, infiltrates through the waste, and becomes contaminated. Leachate is generally regarded as the primary environmental issue associated with waste disposal facilities, given that it has a high concentration of organic and inorganic pollutants and can contaminate water bodies. Most other issues such as rodents, birds, odor, and windblown litter are largely managed by the processes recommended in this section.

The contemporary approach to remediating midsize municipal dumpsites is to adopt a controlled landfill approach. The categories range from open dumping through to engineered sanitary landfills. This approach recognizes that environmental returns rapidly diminish after the basic management systems are in place, so for small to midsize cities, it is best to use a controlled landfill standard with stormwater diversion, daily or weekly compaction, shaping and soil cover application, perimeter leachate collection pipes and pump station, and leachate reinjection or irrigation systems, but without a leachate treatment plant or leachate discharge (where achievable in a given climate). These remediation interventions are usually sufficient,

provided that the existing dumpsite is not in a sensitive environmental location such as near a community water supply or on deep gravel soils. In these cases, the dumpsite may have to be relocated entirely.

Steps required for remediating dumpsites as controlled landfills include levelling and compacting existing garbage heaps, and construction of drainage canals and ditches. However, the most critical issue is that the slopes at the site should be maximized (steepened) to minimize rainfall infiltration and therefore leachate generation. The overall approach to leachate management must be to minimize the quantity formed, rather than to accept large volumes as inevitable and then provide expensive and often poorly operated leachate treatment facilities prior to discharge of the liquid. Leachate prevention not treatment is the priority. External batters should be at a slope of 1:2.5 (vertical to horizontal) as such a slope allows soil cover to still be applied by conventional equipment and, when properly constructed, is stable (even in significant earthquake events) at heights of 50 meters or more (assuming the local natural soils have sufficient bearing capacity). This is generally the case except in areas of deep weak alluvial silts or clays in floodplains, for example. A well-run controlled landfill. Retrofitting a perimeter leachate collector when remediating an open dump. The working areas on top of the mound should never be flat as is unfortunately often the case. A minimum slope of 5% should be adopted at all locations on the site. Flatter slopes allow rainwater to infiltrate and they also facilitate the formation of local depressions due to differential settlement within the waste. These depressions maximize leachate formation and must be avoided by appropriate mound sloping. In terms of site development efficiency, the common belief is that waste mounds higher than approximately 5 meters are unstable. Many well-run controlled landfills have waste at heights exceeding 40 m or 50 m and therefore are very efficient in terms of site utilization and development cost returns.

The existing landfill may not be lined to modern standards, but if the ingress of rainwater is prevented, there will be no driving force (water head) to force leachate out. Therefore, a cover and grading of the finished landfill profile will go a long way to prevent leachate emissions. This combination of maximizing slopes throughout the site, regular application of soil cover material, and cover maintenance will minimize leachate generation and reduce or obviate the need for leachate treatment plants and offsite discharges in many cases. Leachate should be collected in a network of pipes retrofitted around the waste mound base and directed into a pump station from where leachate is irrigated in dry weather on previously

worked areas to encourage grass growth or used for dust suppression. In periods of rainfall when irrigation may cause contaminated runoff, leachate should be pumped to the top of the waste mound and reinjected under the soil cover. The leachate will then be absorbed by the drier waste material in the upper levels and also retained in the waste pore space. When the upper layers of waste become saturated with the reinjected leachate, the leachate will percolate down through the mound to again reach the leachate interception pipe work. This leachate percolation accelerates biological activity within the upper waste mound and accelerates stabilization processes as a side benefit. Early in the landfill operation, there will be insufficient waste mass to accept reinjection and so a balancing storage or spray irrigation area may be needed in the interim. Full strength leachate can take up to 6 years to appear as anoxic conditions in the landfill finally cause anaerobic bacteria to break down the waste.

Remediated dumpsites should have steep sides, sloping profiled top surfaces, and regular applications of soil cover to maximize site efficiency as well as to minimize leachate generation. Collected leachate should be irrigated or reinjected depending on the season, not treated and discharged. There is usually no need for a leachate treatment plant if the site is well operated. Landfills are stable with these 1:2.5 external slopes for heights of many tens of meters which maximizes site efficiency and site life. This approach is suitable for both remediating and extending the life of old “flat” dumpsites or a new greenfield controlled landfill development.

10.7 Stormwater Runoff Management (Contour Map)

Landfills are typically subject to stormwater running on or towards the footprint from the surrounding catchment, and also generate runoff from completed cell areas. All runoff, particularly from earthworks areas that are not stabilized by vegetation, has the potential to generate sediment. Poor stormwater management can also degrade a landfill’s geotechnical components such as batters, toe bunds, or anchor trenches for geosynthetics. Poor stormwater management can impede good landfill operations by, for example, damaging roads. Runoff from active areas (where waste is being disposed, or in areas where waste is poorly controlled) has the potential to also become contaminated by organic and inorganic materials from the waste itself, and by leachate reaching surface water drains. Runoff from inactive areas where there is re-exposed waste or litter can also lead to contaminated runoff.

Significant contamination of runoff from the site can lead to contamination, ultimately, of surface water bodies and even groundwater.

The design of a Landfill stormwater system, therefore, has a number of critical functions:

- Safely conveying surface run-on and runoff from the landfill and associated catchment to the discharge point for the site
- Ensuring landfill operations not compromised by poor surface drainage
- Ensuring landfill construction not compromised by poor surface drainage
- Minimizing leachate generation by preventing surface water from entering the waste mass (to the extent practicable)
- Avoiding contamination of surface breakouts and surface flows
- Minimizing soil loss and erosion from borrow sources and completed landfill areas
- Controlling sediment discharge and surface water contamination
- Providing water storage for site use and firefighting (typically as an adjunct to sediment control using detention ponds)

At most landfills, the surface drainage system has a number of key elements. Working upstream from the receiving water/discharge point these are:

i. Stormwater detention/sedimentation/ storage ponds

Local guidelines or regulations often govern stormwater pond design. The key features normally required are:

- Ability to store runoff from moderate storm events for gravity settlement, sedimentation using chemicals (where required and appropriate) and slow discharge (usually via a siphon or other decant structure targeting the upper clear water zone)
- Ability to safely bypass overflows during larger events (service and emergency spillways)
- Provision of a Deepwater zone for sedimentation (sediment forebay) with machine access for de-silting
- A controlled slow-release outlet (decant outlet)
- Flow and water quality monitoring facilities
- Storage zones (on or offline) for surface water storage (where required)

ii. Primary drainage systems

Design requirements for primary (permanent) drainage vary greatly from location to location and are typically governed by factors such as local design regulations, site license requirements, climatic conditions, and local materials and construction methods.

Typical designs may include:

- Shotcrete and concrete-lined channels (including with energy dissipation)
- Rock-lined trapezoidal channels
- Broad, low gradient grassed channels
- Piped culverts and drains

Normally open channel structures are used for primary drainage to optimize flow capacity and to reduce the risk of blockage. Typical design criteria for primary drainage systems at landfills are the Ability to convey 1 in 100-year flow within normal flow zone (with freeboard).

iii. Secondary Drainage

Secondary drainage comprises subsidiary channels, structures, piped drains, road culverts, mechanized pumping systems, etc. that are either semi-permanent or permanent. Typically, such features are associated with major phases of Landfill development, related to cells, benches, or waste lifts, and are expected to have a required service life of 5-20 years. However, secondary drainage also includes the permanent drainage on the final cap. Such systems are usually designed to provide a balance of construction cost and risk. Under storm events more severe than the selected design life it is expected that such drainage systems may suffer drainage and require repair and reinstatement. It is also the potential for impact on the Landfill operations area (for example due to secondary drain overflow into an inactive cell).

Design requirements for secondary drains may be specified in the Landfill license, but are often determined on a site-specific basis considering climate, timing, risk, and cost.

Typically adopted design criteria are for such drains to be designed to convey the 1 in 5 to 1 in 10-year flow, with sizing for the maximum temporary catchment area that contributes to a particular drain.

iv. Tertiary (temporary) Drainage Systems

Such systems relate to active areas, earthworks areas, and areas that are being capped and rehabilitated up until the point where permanent conditions are reached. Design is usually site-specific, often based on local soil conservation/sediment control guidelines and on short-term experience gained on-site for local drainage management.

v. Active Area Drainage

Drainage in the active area where waste is being disposed of needs to be carefully managed. Features of active area drainage include:

- Slope surfaces inwards to a low point draining into the waste
- Provide ample slope to keep the tipping area from flooding
- Minimize the active area and hence stormwater ingress into the waste mass
- Apply intermediate cover regularly, and as soon as practicable to promote maximum "clean" runoff (albeit that the sediment component needs to be treated for a period of time)

vi. Landfill Cap Drainage

Landfill cap drainage is implemented progressively as the landfill is capped and rehabilitated. Timing, settlement, cap construction method, and contour are all key determinants of the final cap drainage configuration. Ultimately the cap drains are permanent secondary drainage features on the site and hence need to be:

- Durable
- Require minimal maintenance
- Able to accommodate ongoing settlement

Special cap drain configurations are adopted in areas of high rainfall or where expose geomembrane caps are used. These can comprise site-specific designs such as masonry lined channels with energy dissipation and outfall structures, corrugated steel flumes, or geomembrane gutters and channels. All such features require careful detailing and site-specific design.

The design of the stormwater drainage system at a landfill is key to optimizing operations, managing the risk of flood damage, and avoiding adverse effects offsite due to sediment, leachate and waste contamination in site runoff. The design of the stormwater system needs

to consider both the permanent (completed) landform as well as the range of intermediate conditions that will occur.

10.8 Waste Compaction

It is essential at any sanitary landfill that the waste is compacted. First and foremost, this will ensure that the available void space is maximized, but effective compaction has a range of other benefits, as follows:

- The compacted waste provides a stable surface for vehicles to move on and on which to establish access roads and tipping areas.
- Compacted waste reduces or prevents differential settlement in the waste mass and can prevent slope failures.
- Birds and rodents find it more difficult to dig into the waste to access food.
- Compaction helps to reduce wind-blown litter escape from the site surface.
- Well compacted waste inhibits and reduces odors and prevents leachate outbreaks.
- Well compacted waste reduces risks for fires.
- Compaction displaces air and increases the rate of anaerobic conditions which allow for proper generation of methane landfill gas that can be properly collected for beneficial use. Without proper compaction this practice is difficult.
- A compacted surface aids stormwater run-off and provides a good base for applying cover soil and
- Well compacted waste consumes less airspace which optimizes the landfill operation and use of the landfill disposal area.

Figure 3: Waste Being Compacted by Compactor and Dozer (Alamin Nogor Landfill Site)

10.8.1 COMPACTION METHODS

Compaction methods can include working the waste pushing “uphill”, pushing “downhill” or working on a “flat or level” area. As the fill progression in a landfill takes place, there will be a need to implement each of these fill operating practices.

Pushing “Up-Hill”

This operating practice is commonly used as pushing up allows to walk over the waste and break it/shred it better as it is being pushed and spread. Pushing uphill also allows controlling the size of the work face area as it is easier to keep it more compact. The disadvantage with this method is that the equipment has to work harder as it is climbing fill slopes all the time and pushing waste loads uphill, therefore using more fuel. The equipment tends to sink more in the waste and increases the wear on equipment and maintenance and operating costs.

Figure 4: Waste Being Pushed Uphill

Pushing "Down Hill"

This operating practice is easier on equipment as units are pushing loads downhill, using the help from gravity manage loads. Equipment operating costs and wear is lower. Some disadvantages with this method are that the work face disposal area tends to spread more as it is harder to control downslope pushing; waste compaction can have worst performance as waste can tend to roll over or cascade downward not allowing for proper spreading and walking for good compaction.

Figure 5: Waste Being Pushed Downhill

Pushing on "Flat or Level" Area

This method is the most efficient to achieve higher compaction of waste (full load for equipment unit and wheels/tracks puts downward force on the waste mass) and puts less strain on equipment, therefore having lower fuel usage and equipment operating costs. This method is hard to execute all the time due to the changes in the fill sequence as the landfill gets filled. It also requires more equipment operators training for them to work on properly setting the work face to perform waste disposal operations on flat, level areas.

Figure 6: Waste Being Pushed on Flat or Level Area

10.8.2 Compaction Techniques

The dozer or compactor, as it pushes the waste to its final point of disposal, will mix, track over, and crush or shred the waste. Once crushed/shredded and in place, the compactor or dozer should pass over the waste a number of times, but as a minimum, three to four passes are typically used to achieve effective compaction.

Good compaction operating techniques include:

1) adequate layer thickness,

2) three to four-wheel passes, and

3) adequate wheel coverage.

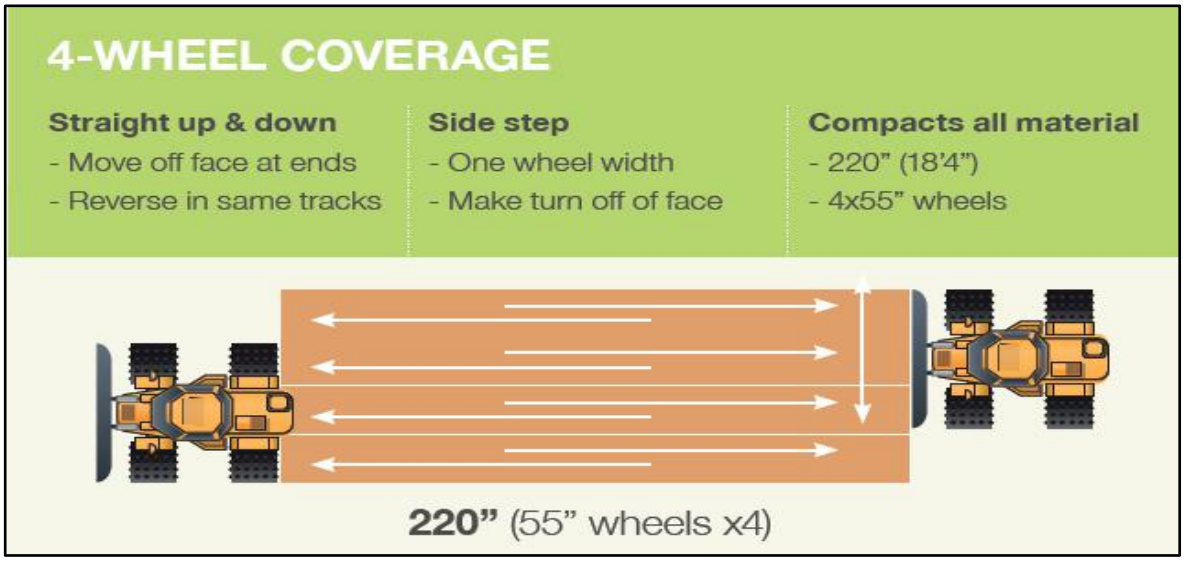


Figure 7: Wheel Coverage Pattern

Layer Thickness

The waste should be spread in layers targeted at no more than 300mm-400mm in compacted thickness as much as it can be practical. Employing this discipline ensures optimum compaction is exhorted by the compactor wheels or dozer tracks on the layered waste. This layering practice should be employed regardless of the fill method (i.e. "uphill", "downhill' or "flat or level") being employed. The technical information below is from Caterpillar literature and studies done to measure optimum landfill compaction practices.

Wheel Passes

Following proper spreading of layered waste, in order to achieve good optimum compaction, there has to be three to four-wheel/tracks passes over the layered waste. Conducting this number of wheel passes ensures the waste is not only properly layered but also properly walked to achieve good compaction. The technical information represented below is form Caterpillar literature and shows the improved performance by doing this practice. At the same time, it represents that by exceeding the number of passes beyond the four passes, the gain is minimum and it would only increase equipment operating costs.

Wheel Coverage

It is best for the compactor to work in a pattern to ensure a consistent degree of compaction. This can be achieved by making the first machine pass at one side of the working face (say left

to right), making an up and back machine pass, moving over one-wheel width, making two up and back machine passes, moving over one-wheel width, making 2 more machine passes up and back, and so o until the entire working face has been run over by the machine 4 times. This process is, however, dependent on the nature of the waste being compacted and the geometry of the working area. Waste with a high organic and moisture content (e.g. sludge waste) will likely require less than 4 machine passes to optimize compaction.

10.8.3 Compaction Measurements

A high waste density should always be targeted and this should be checked by regular surveys using airspace geometry (allowing for settlement) and waste intake tonnage data. Densities of > 0.85 t/m3 should be readily achievable with modern equipment. Densities less than 0.6 – 0.7 t/m3 significantly reduce landfill efficiency and will increase the risk of landfill fires.

The following template can be implemented and used to complete waste density calculations to measure compaction efficiency at landfill operations. Density calculations can be performed on a quarterly, semi-annual, or at a minimum on an annual basis. The table and graph provided in the report below can also be used to tack compaction performance over time.

If inbound scales are not available at landfills, the compaction efficiency can be measured by using regular surveys using airspace geometry and by tracking waste intake data based on incoming trucks metric capacity. When compaction is measuring this way, a compaction ratio from in place airspace utilized (in cubic meters) is compared to the waste intake gate cubic meters received during that same period.

This measurement is not as accurate as a density calculation having scales in place, but it does provide a reasonable compaction measurement to determine compaction efficiency at a landfill facility.

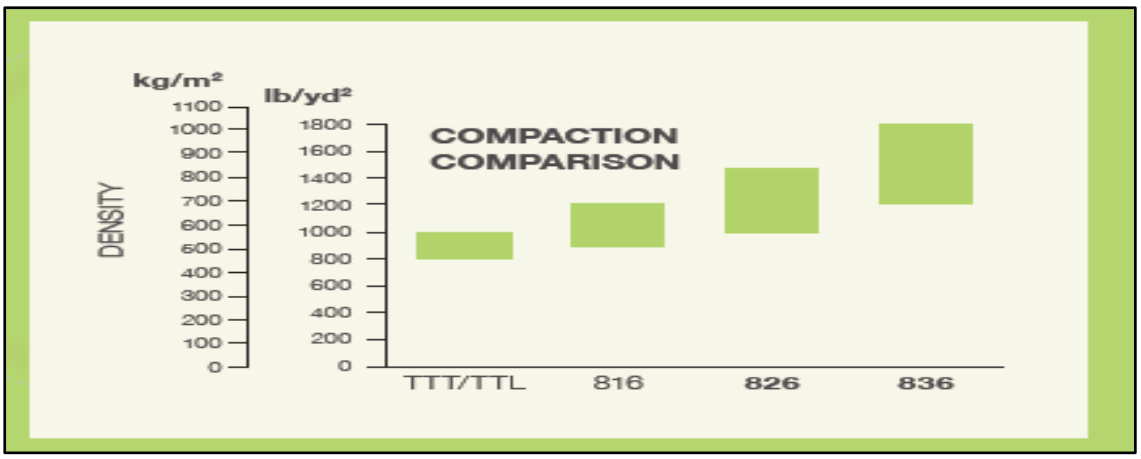


Figure 8: Compaction Performance Comparison – Track Type Dozers vs. Compactors

Figure 9: Dozer vs. Landfill Compactor – Compaction Efficiency

10.8.4 Equipment

10.8.4.1 Landfill Compactors

Waste acceptance rates at the working face should be controlled so as to ensure that there is no excessive build-up of waste in the working area. This will enable the compactor/dozer to deal with the waste as it arrives. However, at most landfills waste typically arrives at an uneven rate throughout the day, with several peak periods. The site operator must either scale his equipment fleet to meet these peak periods or, to save on machinery costs; there can be some controlled stockpiling of waste in a designated area which can then be dealt with

between peak periods that same day. This way a smaller machine fleet can often still meet the waste handling needs of a site.

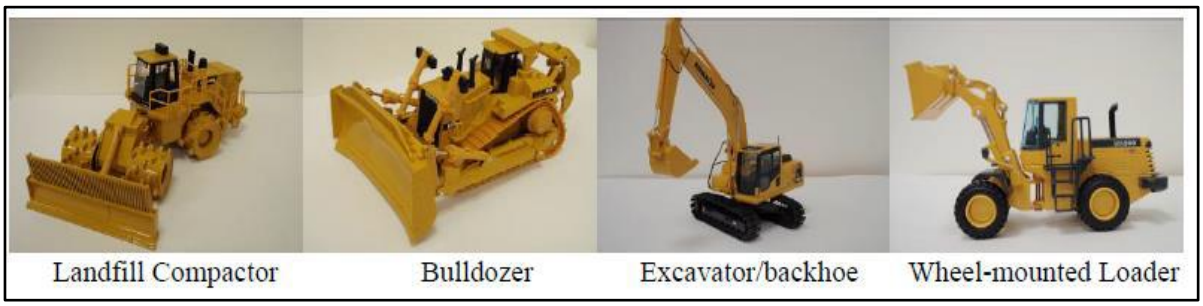


Figure 10: Typical Equipment used for Landfills

10.8.4.2 Bulldozers

Bulldozers are track-type tractors that have a lower weight and exert a lower force on the waste surface area. Landfill compactors are designed to work in the waste, have a higher weight, and exert a higher force on the waste mass as it has metal wheels with cleats. Site conditions can also be very wet, a heavy bulldozer may be used to provide the spreading and compaction of waste due to the high moisture waste. The term “compactor” in this section of the manual refers to the use of either a landfill compactor, or a bulldozer, or a combination of the two, as applicable.

Well compacted waste is an essential component of good management of a landfill. The proper selection of equipment to use for the landfill operation is important so that the landfill operating staff has adequate equipment to perform proper waste disposal operations and achieve good compaction.

10.9 Litter Management

A frequent cause for concern for sanitary landfill management is the litter. Litter is unsightly, can result in water pollution, and can be a nuisance to surrounding property. In addition, plastic litter can travel large distances via wind and water reaching our oceans. It has accumulated an alarming amount and causes harm to aquatic life. Hence issues related to wind-blown litter are a common topic at Site Liaison Committee Meetings, during the planning process for new landfills, and with regulators.

Depending on site conditions, litter can be difficult to control and manage. However, in almost all cases there are methods available that can keep the off-site impact of litter to a minimum. A site-specific strategy should be drawn up to manage the impact of litter. Importantly,

whatever strategy is introduced, it is noted that this will only be as good as its implementation.

A hierarchy of litter control measures is available, based firstly on load containment, load handling, and tipping, and moving through to secondary measures such as mobile litter screens, nets and litter picking at site boundaries. Each is expanded on from the overall range of controls that comprises. These may also vary with location on the site, or seasonally.

10.9.1 Methods of Control

10.9.1.1 Load control

While not strictly a "site-based" control it is common for litter accumulation along principal site access routes due to loss from waste vehicles to be an issue for landfill managers. This can be addressed by applying load and waste acceptance controls to site users. Typically, these include measures such as requiring all normal loads to be transported within a fully enclosed collection vehicle or a collection vehicle that is covered with nets or tarpaulins. Dry or dusty loads should also be tarpaulin-covered.

Regular inspections should also be made of incoming vehicles to ensure loads are covered, secure, and not contributing to litter. The ultimate sanction is to refuse entry to insecure loads or to operators who do not comply with load management requirements.

10.9.1.2 Waste Handling

Most of the litter lost from landfill sites results from wind acting on the waste at the point of tipping, as well as initial compaction practices. Litter loss at the point of tipping can be minimized by:

- Carefully assessing the waste type being handled i.e. dense waste is less likely to blow about than uncompact low-density waste such as plastic.
- Not tipping loose waste into the wind.
- Using previously tipped waste to cover and/or provide shelter for more vulnerable (mobile) waste streams.
- Partially compacting loose waste before pushing out.
- Using heavier waste to hold down loose waste.
- Pushing waste out carefully and compact as quickly as practicable.

- Ensuring that the entire waste load is emptied at the tip area so that no residual waste is left in the collection vehicle which would provide the potential for windblown litter on the drive out of the facility.
- Keeping the working area as tight as practicable.
- Placing a soil cover over the waste as soon as practical but no later than at the end of the operating day.

10.9.1.3 Portable Litter Screens

- Use portable litter screens routinely.
- Screens should be placed down-wind and as close to the working face as possible.
- Screens should be of good solid construction and robust enough to withstand handling and relocation by machines (preferably they should be provided with lifting eyes).
- Screens should be cleared frequently to prevent them from becoming overloaded and potentially being blown over.
- Screens need to be moved as frequently as changes in the wind direction dictate.
- Damaged screens should be repaired on a regular basis.

10.9.1.4 Semi-Permanent Litter Fencing

This type of fencing is usually semi-permanent (covering a significant landfill development area through until post-closure). Typically, it comprises a metal or nylon chicken wire/fish netting type system and should surround the entire operational area. If it is not practical to surround the entire area, fencing should at the very least cover the downwind side of the common prevailing wind direction.

10.9.1.5 Bunds

Soil bunds placed downwind of the operational area can also provide good litter control. Under most circumstances, litter rolls along the ground. In this case, it will tend to roll over the bund and deposit in the calmer space behind it. The resultant litter has to be regularly removed if the system is to remain effective.

10.9.1.6 Perimeter Fencing

Perimeter fencing is usually provided mainly for site security, but it can form a last line of defense for litter. However, cranked tops are usually provided which often consist of strands of barbed wire which can trap litter but also make it difficult to remove, so this type of design should be avoided whenever possible. For the same reason, brambles should not be allowed

to grow up perimeter fences, or immediately in front of them. Hedging should not be used as a control measure as it can often be difficult to clear.

10.9.1.7 Select Tipping Areas

In valley or quarry landfill sites it may be possible to identify different areas within the developed footprint of the site that is out of the wind, hence making it possible to have more than one working area available to cater for differing conditions. Alternative tipping areas should be identified for all sites where there is a problematic prevailing wind direction. On above ground landfill sites, the use of tipping areas that are shielded against prevailing winds must be carefully planned as there are typically higher wind gusts as you build upwards.

10.9.1.8 Netted Areas

Full netting systems that completely enclose the working face area and all loose waste are sometimes required at very windy or exposed sites. These systems can be either portable or permanent. The portable type can be moved to suit changing operations. However, this can be a costly and time-consuming task and is usually only adopted at open sites where other options are not effective. Fully netted systems can be very effective and maybe one of the most effective control options available at open, windy sites.

10.9.1.9 Designated Waste Transfer Areas

At some sites, litter control can be improved by using on-site waste transfer processes such as waste separation and waste containerization or baling. Such measures are usually only employed if conditions are particularly adverse and large volumes of one particularly difficult waste type are being handled (e.g., no recyclable plastic).

10.9.1.10 Methods for Handling for Lightweight Waste

Some lightweight wastes such as plastic (other related non-littering wastes such as ash or sawdust) can also be managed by an excavation of a pit into which they can be tipped in a controlled manner and then immediately covered to avoid wind mobilizing the wastes.

10.9.1.11 Restricting Operating Hours

At some sites, windy conditions occur at particular times of the day, or seasonally. At such sites, particularly where load control can be managed by containerizing waste, or by holding it at transfer facilities, restricting operating hours can be a particularly effective measure for litter control. Where opening hours can be restricted to morning or evening calm periods for example, or where activities can be suspended entirely on windy days, management of litter potentially can be greatly simplified.

A range of management techniques is available for litter control at landfill sites. If carefully and routinely applied there should be few sites where a high level of litter control cannot be achieved. However, there will be occasions where litter problems develop, both on and off-site and litter pickers should be deployed immediately when the windy weather abates to collect the litter. They should start from the furthest most point that litter has reached, and work back to the site boundary and then internally.

There are clearly many techniques available to us for collecting litter. Some of the simpler control measures are relatively inexpensive to implement as they relate simply to applying good operational techniques. Other measures can be much more expensive and a hierarchy of measures needs to be developed specifically to each site to provide the most effective overall solution recognizing that litter control must be given priority in order to avoid visual and environmental contamination problems from landfilling

10.10 Lining Systems

The principal functions of a landfill liner system are to limit contaminant migration to groundwater and to control landfill gas migration. This is achieved by the landfill liner slowing the vertical and lateral seepage of leachate to allow collection and removal by the leachate collection system and to contain landfill gas within the landfill for appropriate collection. The liner may also attenuate contaminants in leachate seeping through the liner. A further function of the liner is to control the infiltration of groundwater.

The primary design objective of the liner and leachate collection system is to protect the environmental values of groundwater. This includes limiting the size of any attenuation zone that extends beyond the boundary of the premises.

The outcomes of the hydrogeological risk assessment, stability risk assessment and landfill gas risk assessment will influence the containment design features; however, it will generally comprise, but not be limited to, a combination of the following components in table:

Table 3: Components and Its Functions

Component	Function
Subgrade	To provide a well-consolidated firm platform for the installation of the subsequent lining materials which will protect them from excessive strains, potentially resulting in failure of the materials, and to ensure that the drainage system drains effectively throughout the life of the landfill

Clay	A low permeability clay layer in a lining system retards water movement and absorbs exchangeable cations. Some of the properties of the soil measured to determine its suitability as low permeability liners are particle size distribution and plasticity (described by the soil plasticity index) and cation exchange capacity. A key consideration is potential for desiccation and subsequent cracking.
Geosynthetic clay liner (GCL)	To provide a low permeability layer to limit contaminant migration, reduce water ingress into the landfill, and to control landfill gas migration. They are generally used as a compliment with clay in the lining system. The assessment for the suitability of a GCL in a lining system should consider water and gas flow, contaminant transport, and stability including the assessment of hydraulic conductivity, gas permeability, chemical compatibility, diffusion, and shear strength.
Geomembrane	To limit contaminant migration, reduce water ingress into the landfill, and control landfill gas migration. Key properties to consider when selecting a geomembrane include thickness, strength, the ability to resist or accept stress and deformation, tensile strength, puncture resistance, slope stability-interface friction, long term mechanical performance, durability and resistance to degradation.
Geotextile	Installed to protect the integrity of a geomembrane. It minimizes the risk of the geomembrane being damaged/punctured during construction and operation of the landfill, and minimizes the strains in the geomembrane, and hence the risk of future punctures forming due to environmental stress cracking.

10.11 Leachate Collection and Treatment Management

10.11.1 Collection Systems and Lagoon Issues

Leachate is one, if not the biggest, environmental issue at a controlled landfill and is traditionally managed by treating in a leachate treatment plant (often incorporating a lagoon system) and then discharged. Assuming that the recommended approach for aggressively minimizing leachate, production is adopted, there is (depending on climate and mass balance) reduced or no need for leachate lagoons. These lagoons are often expected to satisfy two conflicting roles. One is to provide treatment of leachate prior to discharge, in which case the lagoon should be full to maximize the surface area and treatment capacity. However, the lagoons are often also expected to act as storage facilities, in which case the lagoon should generally be empty to maximize the storage available. In any case, the use of lagoons in wet climates inevitably results in lagoons filling with rainwater diluting the leachate and creating a major disposal and treatment issue.

Leachate Collection Network

Even with good landfill design and implementation, some leachate will form, and it needs to be managed and not allowed to saturate the entire waste mound. This is particularly so at early stages when little landfilled mass is present. The leachate collection system typically consists of a network of perforated plastic polyethylene pipes, with a minimum of 200 millimetres (mm) in diameter and a high crush strength wall thickness placed within a gravel bed on top of the landfill liner. The lateral slope of the landfill base bringing leachate across the landfill base to the leachate collection pipes should be constructed at a minimum 5% fall. Leachate pipes should be installed at a minimum slope of 1%–2% and configured such that no part of the landfill is more than 50 meters (m) from a leachate collector pipe. However, it is preferable to have the leachate pipes at separations of only 20 m

I. to provide some redundancy in case leachate pipes block or are damaged and
II. to minimize the head of leachate impounded in the waste mound (and thereby minimize the driving head for leakage).

The perforations, slots, or holes in the leachate pipes need to be small enough so that the encasement stones do not enter the pipes, and only part of the circumference of the pipe should be perforated. The pipe is laid so that the perforations are on the bottom of the pipe at about 120 degrees coverage. This arrangement minimizes the inflow of soil and dirt and other foreign objects into the pipes, which may result in blockages. The gravel bed may be protected from clogging by adding an encircling geotextile liner, but this invites the risk of slimes forming during the early acidic decomposition stage blocking the geofabric. A woven geofabric with larger pore sizes is preferable to a needle-punched geofabric. One design response is to run a lateral drain pipe to the top edge of the site so water can be flushed back down the drain. It should also be understood that local blockages will merely force liquid out into the surrounding gravel to flow past the blockage and back into downstream slots. There is support for allowing smaller fine soil particles into the drains and flushing them occasionally and pumping away until a natural grading occurs around the gravel drains. Using a finer sand over the surrounding gravel also helps this approach. Generally, the leachate gravel drain should be a minimum of 600 mm square in cross section with the 200 mm diameter slotted leachate pipe placed centrally. Some designs utilize maintenance without exhumation. Usually, the gravel drain ends up significantly wider than 600 mm at the base as the drain sits

on the liner in the shallow vee of the valley. Therefore, the edges settle to the angle of repose, meaning additional gravel has to be applied to the top of the drain profile to achieve a final depth of 600 mm for the gravel.

Leachate Lagoons or Container

As noted, leachate lagoons are often installed at landfills as they are commonly mandated by local legislation. Superficially, this seems an appropriate response to intercept the leachate, but, particularly in areas of medium to high rainfall or areas susceptible to typhoon activity, these lagoons often fill with stormwater. The resulting impounded diluted leachate then has to be managed and is often simply allowed to overflow the lagoon and discharge. A new approach is to fit a flexible roof to the storage to intercept any rainfall falling on the lagoon. This can be partly supported so that air can flow under the cover to continue evaporation (can be fan forced). In the idealized contemporary approach to leachate management, little or no treatment or storage lagoon capacity is required. Leachate is simply intercepted in a drainage network as described and directed into a leachate pumping station from where it is either irrigated to encourage grass growth on previously worked areas or onto stones to maximize evaporation area, used to suppress dust, or reinjected at the head of the mound into unsaturated accumulated waste in wet periods. There is no need to provide large volumes of balancing storage a lagoon as this is provided within the pore space of the waste within the mound (in an established landfill) and the absorptive capacity of the waste. In the wet season when irrigation is not possible, the leachate level within the mound may rise along with an increase in the moisture content of the waste in the upper levels. This can drive leakage from any weak points in the liner system, so a good liner is needed for such an approach. In dry periods, this reinjected leachate is drawn out and irrigated such that the mound moisture content decreases, as does the leachate level.

Even with the idealized contemporary approach to landfill design which aggressively minimizes leachate generation, leachate will still form at the base of the mound. This leachate can be directed to the external pump station by providing appropriate grades on the base of the landfill as well as including a suitably designed interception pipe network. Many countries still require full leachate treatment plants for small to midsize facilities. Quite often, the treatment facility includes lagoons. These are used to perform two conflicting ideals and generally do not perform well on either requirement. In many climates, lagoons merely fill with stormwater, generating a large volume of dilute leachate requiring additional

management. The idealized contemporary approach is to utilize the waste pore space and reduced moisture content of the upper levels of the landfill to act as the buffer storage, and to divert stormwater from all but the active tipping face, thereby remaining disconnected from major rain events.

10.11.2 Leachate Treatment Plants

Leachate is the liquid generated from solid waste decomposition in a landfill or from handling waste in waste treatment facilities. Leachate derives mainly from precipitation, surface run-on from adjacent areas, liquids disposed of in the waste mass, and the decomposition of organic material in the waste itself.

As leachate forms and passes through the waste, organic and inorganic compounds become dissolved and suspended in the leachate. This process can be likened to the process of passing water through coffee grounds to make coffee. This is a wanted effect in order to unload the landfill from pollutants and to reduce the environmental impact and the costs associated with it. The dissolved and suspended constituents of leachate have the potential to cause soil, groundwater, and surface water contamination if not treated properly.

Appropriate leachate management measures include:

- Adopting best practice landfill design.
- Minimization/control of polluted liquids entering the waste mass and adding to the landfill load.
- Installation and operation of an engineered leachate collection and extraction system.
- Installation and operation of a site-specific leachate treatment system, and/or shipment of leachate to an off-site treatment facility.

The leachate must be managed so as to prevent contamination of soil, groundwater, and surface water. Leachate management is best accomplished through the installation of a landfill liner (for example, compacted clay, geomembranes, or both) and the installation and operation of an engineered leachate collection/conveyance (removal) system which is presented at following figure.

Figure 11: Leachate collection and conveyance systems

Landfill liners retard the movement of leachate into adjacent soils due to their low permeability. Landfill liners are usually comprised of either in-situ or re-compacted natural clay soils or geosynthetics (flexible membrane liners [FMLs]) or some combination of the two.

Natural soil liners should be clay soils with a low coefficient of permeability and sufficient thickness to significantly retard leachate loss to groundwater. The most common material used for flexible membrane liners is High-Density Polyethylene (HDPE), but other materials such as Linear Low-Density Polyethylene (LLDPE) and polyvinyl chloride (PVC) are sometimes used.

Figure 12: Landfill with lagoons systems and a leachate treatment plant

Other materials used in liner systems are Geosynthetic Clay Liners (GCLs) and geotextiles/geo-composites. The most common high-performance liner type usually comprises (top to bottom):

- Separation geotextile;
- Leachate drainage layer;
- Protection geotextile (if required);
- HDPE Geomembrane; and
- Compacted Clay Liner (CCL)/GCL.

To prevent lateral drainage of leachate above the liner system, a leachate collection and conveyance system should always be installed. Leachate collection systems comprise perforated piping installed above the liner and sometimes in other locations within the waste mass to enable the leachate to be drained and pumped to any one of a number of leachate treatment options. Both gravity flow and pumped systems are used but pumped systems are usually preferred as they enable liner penetrations to be avoided. A leachate buffer system has to be installed to cover peaks from heavy precipitations and to balance and homogenize leachate in flow and level of pollution.

Detail about Leachate Management

Leachate is the contaminated liquid that forms when water percolates though solid waste. The generation of leachate can be from surface runoff, precipitation, groundwater, and liquid from degradation of the solid waste. Although a well-designed landfill will minimize leachate generation, it cannot be completely avoided. In some cases, local legislation may mandate the provision of a leachate treatment plant. Hence, landfill designers and operators should have at least a basic knowledge of how to treat this kind of wastewater.

When waste is first deposited, there is air (with oxygen) entrapped with the waste. When it is sealed off by further waste or capping cells, the oxygen is depleted by the high biochemical oxygen demand (BOD) and chemical oxygen demand (COD) of the waste deposited (i.e., aerobic decomposition) and slowly becomes anoxic, then anaerobic. Aerobic bacteria slowly die off, but this stage can take up to 6 years during which anaerobic bacteria increase in numbers and subsequently methanogenic bacteria start to break down the remaining BOD and COD. The initial acidic aerobic or anoxic stage is when slime production is greater (and can block any filter membranes), and it also produces odorous gases such as cadaverine and putrescine. The mass-to-gas conversion is far more efficient in the subsequent anaerobic conditions and can reduce waste volume by up to 30%, gaining airspace due to settlement. This is why most modern landfills try to accelerate the start-up of anaerobic decomposition following the bioreactor philosophy by reinjecting leachate at the top of the waste mound. Initially, leachate in a new landfill is primarily diluted waste products and can have a very high oxygen demand which can overload an aerobic treatment plant. The operating landfill eventually reaches a stable anaerobic state and the waste strength drops. Building a leachate treatment plant early in the process lifetime also makes it difficult to maintain sufficient "food" to the treatment plant.

Leachate characteristics vary depending on the type of solid waste placed into the landfill, age of the landfill, precipitation amount, and solid waste composition. Typically, leachate is characterized by a high level of COD, BOD, ammonia nitrogen as well as other ions (calcium, magnesium, sodium, chloride, and sulphate). The typical composition of landfill leachate from new and mature landfills is presented in the following table. Following table should be treated merely as an example of leachate characteristics.

Table 4: Composition of Landfill Leachate

Constituent	Value (mg/L)		
	Operating Landfill		Mature Landfill
	Range	Typical	(>10 years old)
BOD_5	2,000–30,000	10,000	100–200
COD	3,000–60,000	18,000	100–500
Total suspended solids	200–2,000	500	100–400
Organic nitrogen	10–800	200	80–120
Ammonia nitrogen	10–800	200	20–40
Nitrate	5–40	25	5–10
Total phosphorus	5–100	30	5–10
Alkalinity as $CaCO_3$	1,000–10,000	3,000	200–1,000
pH	4.5–7.5	6	6.6–7.5
Calcium	200–3,000	1,000	100–400
Magnesium	50–1,500	250	50–200
Potassium	200–1,000	300	50–400
Sodium	200–2,500	500	100–200
Chloride	200–3,000	500	100–400
Sulfate	50–1,000	60	20–200

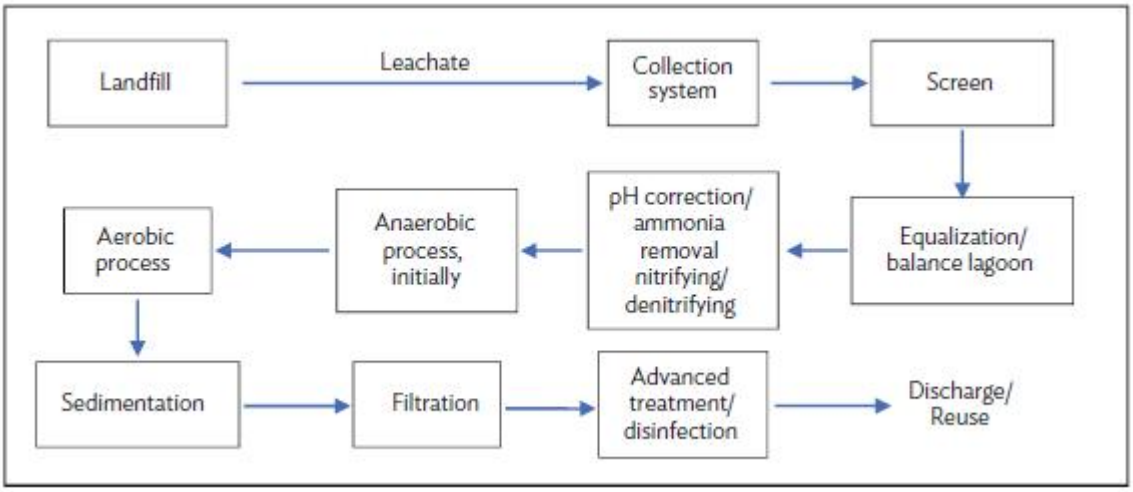
BOD_5 = 5-day biochemical oxygen demand, $CaCO_3$ = calcium carbonate, COD = chemical oxygen demand.

Source: G. Tchobanoglous, H. Theisen, and S. Vigil. 1993. *Integrated Solid Waste Management: Engineering Principles and Management Issues.* New York and London: McGraw-Hill International Edition.

Leachate is highly variable in quality, and it is almost impossible to predict leachate characteristics. If necessary, the leachate information from a nearby landfill accepting a similar kind of solid waste should be taken into consideration. However, it is not a guarantee that leachate characteristics will be identical. Many leachate treatments plants have failed to perform due to the design data not matching the actual leachate characteristics. Therefore, the designer of a leachate treatment system should take a very conservative approach when adopting design data. Some key factors must be considered before selecting the leachate treatment plants process, including whether the effluent will be discharged (or reused), effluent standards cost, and the requirement and availability of skilled labour. Usually, the discharge standard is not achievable with just biological treatment processes (e.g., aerobic treatment such as trickling filter and aerated lagoon, and anaerobic treatment such as up flow anaerobic sludge blanket).

Physical–chemical treatment processes (e.g., coagulation– flocculation, pH control and aeration/ammonia stripping, activated carbon adsorption, and reverse osmosis) are often required as a large fraction of COD in the leachate is comprised of hard to treat COD. Low BOD–COD ratio, high ions, and total dissolved solids also make it even more difficult to apply chemical treatment processes or any biological treatment process. This may well be a reason to reject some liquid waste in certain landfill operations. The following figure displays the general treatment process to be considered for a sophisticated leachate treatment system.

Figure 13: Treatment Process for a Sophisticated Leachate Treatment System



Source: ADB, 2017

The objectives of each unit process are as follows:

- ✓ Collection system: to remove leachate such as to minimize the driving head on any leakage paths through the liner.
- ✓ Screen: to remove large objects and solids that may get into the collection channels or pipes.
- ✓ Equalization lagoon or tank: to equalize and balance the seasonal variations in incoming flow and provide continuous feed to the following processes.
- ✓ Ammonia removal or pH correction: to remove ammonia nitrogen from leachate since ammonia prevents chemical precipitation and can inhibit anaerobic bacteria activity. This could be ammonia stripping or an aeration process. It also corrects the pH for later biological processes.
- ✓ Anaerobic process: to remove strong (generally >2,000 milligrams per litre) biologically degradable materials, but the process may not produce a significant amount of biogas as there are often inhibiting substances. Once anaerobic digestion

is fully established in the landfill, this process will have minimal BOD reduction effect if there is little infiltration flushing out partially degraded leachate from the waste mound.

- ✓ Aerobic process: to remove biologically degradable materials (intermittent for nitrifying and denitrifying wastewater) and achieve low BOD.
- ✓ Sedimentation: to remove settable solids and bacterial flocs, thus decreasing the suspended solids.
- ✓ Filtration: to further remove suspended solids prior to any advanced treatment system.
- ✓ Advanced treatment: to remove residual COD, colour, total dissolved solids, and ions. Examples of this process are membrane filtration (ultrafiltration or nanofiltration or reverse osmosis, adsorption using activated carbon), ion exchange, chemical oxidation, etc.
- ✓ Irrigation and spraying: to reduce leachate by evaporation and to oxidize the wastewater. Partially or untreated leachate may be reinjected back into the waste mass (bioreactor landfill) to bring waste up to field moisture content and maximize wetted area for microbial decomposition. Some plants, such as the common coconut palm, are very tolerant of high salt loads and can transpire 150 litters per tree when mature. Some grasses are also very salt tolerant and testing of treated effluent should be undertaken to expand disposal options.

Typically, the investment and O&M costs for this kind of treatment plant are so high that the effluent unit price exceeds the raw water supply cost. Therefore, it is more appropriate to reuse the effluent in the landfill operation process, for example, for truck or facility washing, dust suppression, irrigation of controlled landscaped areas, or, more effectively, in a bioreactor landfill by reinjecting into the waste mass to maximize anaerobic activity in waste breakdown. The plant

operators need to have a sound knowledge of the principles of each unit process to be able to operate and maintain the system properly. This can be overcome by seeking private sector technical input, but obviously this potentially increases O&M costs. There are not many leachate treatment plants operating correctly in the developing country context because of the high O&M costs and a lack of local operator skills. The preferred approach is always to

absolutely minimize leachate generation through proper landfill design and operation, reject difficult-to-treat wastes especially excessive liquid wastes, and adopt recirculation and irrigation of untreated leachate through the landfill mass wherever possible.

Leachate Treatment Plants

The choice of a suitable leachate treatment system for a single landfill is a question which needs to be evaluated and answered upfront site-specifically based on the following:

- Size, lifetime and possible future extension of the landfill;
- Type of waste to be disposed of (humidity);
- Climate zone – expected precipitation and temperature regimes;
- State law and local law regulations;
- Direct discharge to a receiving body of water;
- Discharge to publicly owned sewage treatment works;
- Future installation of advanced waste treatment processes like MBT;
- Organizational setup for the operation of the landfill incl. leachate treatment; and
- Budget for investment and operational costs for at least three decades.

Nowadays proven leachate treatment processes are available on the market out of worldwide experience since the 1990s. Each installation of a leachate treatment system requires a specific, detailed, and customized view on the needs of each site.

Treatment Technologies

A first step to create a suitable leachate treatment system can be the installation of a leachate collection lagoon or tank as a buffer system, which can be realized on the ground (see Figure 12.2, left). An alternative can be over-underground tanks made out of concrete or various types of bolded tanks. The volume of a buffer tank system should be min. 5 x of the expected average daily volume of leachate production – the more the better.

Find below an overview of available leachate treatment technologies:

Aerated Lagoons and Evaporation Ponds:

By adding surface aerators into the lagoons tanks oxygen will be mixed to leachate to oxidize organic compounds (COD). As expected, the elimination of organic pollution from leachate is very limited (< 20%) and inorganic pollution such as ammonia will be kept untouched. On the

surface of evaporation ponds often a silt layer generates that inhibits natural evaporation. These treatment technologies require long retention times, which can cause a lot of additional issues like aerosols or odor, etc. and consume a lot of space, which could otherwise improve the economics if used for landfilling instead.

On-site Physical-Chemical Treatment:

Various physical-chemical treatment technologies have been tested to treat leachate since the 1980s worldwide. Often good results had been achieved in laboratory tests. In most of these processes, liquid chemicals are added to leachate to partly take out organic pollution as a separate sludge, which has to be disposed of externally. Others are trying to oxidize organic pollution to uncritical carbon dioxide (FENTON, AOP, Ozone, etc.), which requires high quantities of oxidizing agents and/or energy. Also, here inorganic pollution of leachate like ammonia often remains untouched.

Figure 14: Physical-chemical treatment with chemicals (left) and ozone (right)

Until now it has been shown in full-scale installations that physical-chemical treatment processes require large amounts of consumables due to the very high concentrations in leachate in combination with its high buffer capacity. In addition, health and safety precautions for handling large amounts of chemicals are needed.

Thermal Treatment – Evaporation:

Evaporation is always a “separation” process: raw leachate will be divided into vapor and remaining residues contain all the pollution from leachate, which needs to be disposed of in an uncritical place. Evaporation of water requires a large amount of thermal energy. Low-level

evaporation processes like passive evaporation in evaporation ponds or spraying use energy from the sun for drying and is not suitable for humid climates. More sophisticated and closed evaporation units are using external energy which might be available from landfill flares, from the degassing of landfills.

Figure 15: Evaporation technologies: passive (top) and thermal (bottom)

Membrane Technology (Reverse Osmosis, Nanofiltration):

Membrane technology improved a lot since the 1980s in water science, water supply, and wastewater treatment. Similar to the evaporation process, membrane processes like reverse osmosis (RO) or nanofiltration (NF), are also always a "separation" process: raw leachate will be divided into the water to be discharged and to concentrate with remaining residues containing all the pollution from leachate, which needs to be disposed of in an uncritical place. Due to high retention rates for pollutants, using a defined barrier of a membrane with minimized pore sizes like reverse osmosis (RO), this technology was adapted to leachate treatment already in the 1980s with the first installations in a so-called "plate disc" configuration. Overall improvements and developments of membrane technology in desalination over the past led to cheaper, comparatively more advantageous, and modern spiral wounded membrane systems using standardized technical equipment. Depending on the requirements for affluent, several steps can be combined up to a 3-pass RO unit, where leachate "gets filtered three times" before final discharging.

Due to a modular configuration, suitable RO technology is available in standardized container sizes from various suppliers and can be adapted to each landfill site in the world easily and quickly. Often it is common to practice that remaining concentrate will be fed back to landfill due to missing or expensive disposal alternatives. Adequate engineering design for recirculation and infiltration of the concentrate should be done and must be site-specific. RO technology can be an effective stand-alone installation for suitable leachate treatment and to meet the highest effluent requirements.

An interesting option in membrane technology application is Nanofiltration (NF) units – using a type of membrane that allows monovalent ions (e.g. salts) to pass through while achieving high retention rates for organic pollution but slightly lower than reverse osmosis membranes. However, in this case, and unlike RO technology, NF units are not commonly used in a stand-alone model and need to be combined with other treatment steps. NF units are used principally as a polishing step for biological or physicochemical treatment step.

Figure 16: Reverse Osmosis (RO) technology: flow chart of a 2-pass unit

GAC (Granular Activated Carbon):

The use of activated carbon is well known in environmental protection worldwide – even though not available in every country. With an adsorption process driven by diffusion, activated carbon can adsorb liquid or gaseous molecules on a very large solid surface offering a broad range of pore sizes. For leachate treatment granular activated carbon (GAC) with irregularly shaped particle sizes from 0.2 to 5 mm has shown the best technical and economic

performance – used in fixed bed pressure vessels constructed in steel or plastic, ensuring enough contact time to achieve high loadings of organic adsorption on the carbon. After achieving maximum adsorption rates the carbon needs to be changed. Depending on each country and its regulations and logistics either used carbon will be disposed of externally or reactivated in special furnaces at 800°C – a service that gets offered by global suppliers of carbon. Only in combination with an MBR upfront, the use of granular activated carbon is effective and economical – supported by the solid free effluent of the MBR. The MBR "eliminates" all biodegradable pollution from leachate while the GAC polishes the effluent from MBR by adsorption of non-biodegradable organics down to the local discharge requirements.

Biological treatment SBR (Sequence Batch Reactor):

To fulfill discharge requirements for organic pollution (COD/ BOD) and water toxic ammonia

Figure 17: Stand-alone RO: plate disc (top)-spiral wounded (middle)– containerized (bottom) and Granular activated Carbon (left) – stand-alone unit (center) – in combination with MBR (right)

(NH4-N), a biological treatment process can be a sustainable solution. For nitrogen elimination, a biological process (with nitrification/denitrification) is also a suitable process. Biological treatment of leachate is always "eliminating" pollutants as much as possible. The biodegradable pollutants are effectively removed from the leachate. However, additional treatment is required for non-biodegradable COD (recalcitrant COD compounds) such as using activated carbon and/or Nano filtration, as well as handling of biological sludge that is produced in an excessive amount and needs to be disposed of in an uncritical place.

Classical biological processes like Conventional Activated Sludge processes (CAS) require large areas and substantial civil works. Therefore, more compact biological processes were applied

for the use in leachate treatment, for example, the Sequence Batch Reactor process (SBR): After adding leachate to the biological tank, several biological elimination steps (aerated, anoxic, settlement) takes place in one single reactor – with moderate elimination rates in realistic plant sizes: organic elimination increases up to 60%, nitrogen elimination up to 80%. The discontinuous process of the SBR system has limited flexibility for varying leachate loadings like a landfill is faced all over years due to precipitation. It is sensitive to temperature effects (winter, summer) and requires more or less constant concentrations of leachate in the inlet, which ends up in the need of very large buffer tanks upfront (Typ. > 10 days' daily leachate volume).

Due to the method of separation of treated leachate and biomass in a normal settlement step, SBR effluent contains small amounts of solids or biomass. This might cause further problems in post-treatment, which might be needed to fulfill discharge regulations (e.g. for separation of salts).

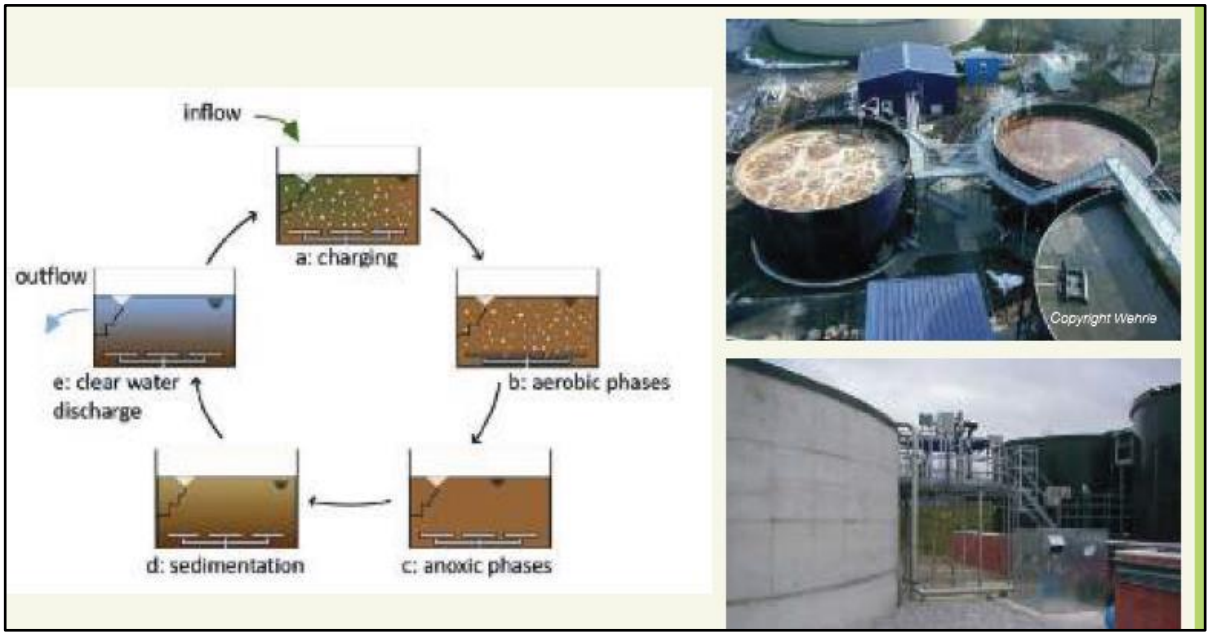


Figure 18: Biological "elimination" technologies: SBR process

Biological Treatment MBR (Membrane Bioreactor):

Further improvement of biological treatment technology was achieved by combining the advantage of a biological treatment system with the advantages of membrane technology. An MBR consists of a bioreactor system and an ultrafiltration stage, being a highly loaded

activated sludge process at the same time. Instead of a settlement process like in CAS or SBR, biomass in an MBR will be separated from treated leachate with a membrane.

MBRs achieve the highest pollutant reduction compared to other aerobic systems and require far less space and footprint using tubular side-stream or out-in submerged ultrafiltration membranes. Organic pollution will be eliminated up to a level above 80 %. Elimination rates for water toxic Ammonia of > 99.9 % are proven and shown in leachate installations worldwide on 5 continents. If needed the leachate treatment plants can be designed to eliminate also total nitrogen up to 99.9%.

The effluent of an MBR is free of solids and ideally suited for further treatment steps. MBRs are robust and handle variations of flow and concentration in leachate by dynamic and automated operation, modular design, and configuration. Out of the reasons above MBR systems are nowadays – besides stand-alone reverse osmosis units – the most implemented leachate treatment process worldwide. However, non-biodegradable COD (recalcitrant COD compounds) require additional treatment, such as using activated carbon and/or Nano filtration, as well as handling of the MBR biological sludge that is produced in excessive amount and needs to be dewatered and disposed of in an uncritical place.

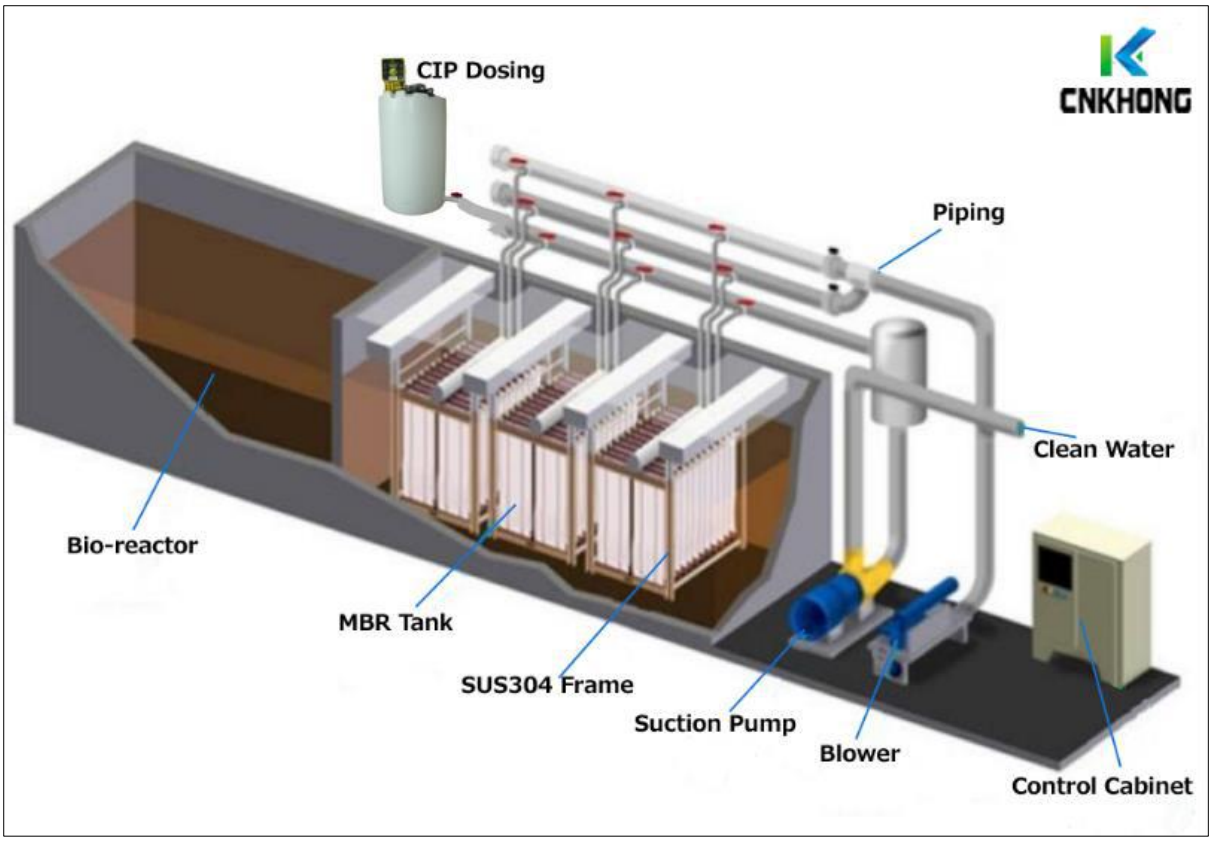


Figure 19: MBR (left) - containerized MBR systems (right)

10.12 Landfill Gas Management

Landfill gas (LFG) is generated in all landfills where organic waste is disposed of. LFG is a natural by-product of the anaerobic biological decomposition of the organic portion of solid waste. Landfill gas consists primarily of Methane (CH_4) and Carbon Dioxide (CO_2) but may contain many other constituents in small quantities, including nitrogen, oxygen, sulfides, disulfides, mercaptans, volatile organic compounds (VOCs), ammonia, hydrogen, carbon monoxide, water vapor, and many other organic gases.

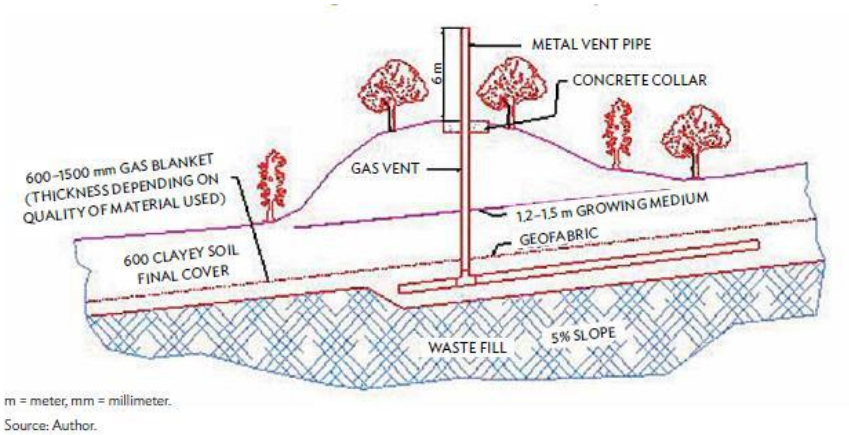


Figure 20: Landfill gas management

Figure 21: Jessore Landfill site with gas bars

10.12.1 Phases of Landfill Gas Generation

The decomposition of waste in a landfill occurs in several distinct phases, related to conditions in the landfill. The primary phases are:

- **Phase I** – Aerobic
- **Phase II** – Anaerobic Non-Methanogenic (Acetogenic)
- **Phase III** – Anaerobic Methanogenic (a non-steady phase)
- **Phase IV** – Anaerobic Methanogenic
- **Phase V** - Aerobic

Aerobic decomposition begins immediately the organic waste is disposed in the landfill and continues until all of the entrained oxygen is depleted from the voids in the refuse and from within the organic material itself. Aerobic bacteria produce a gaseous product which is characterized by relatively high temperatures, high CO_2 content, and no CH_4. Other byproducts include water, residual organics, and heat (in such a quantity to increase the landfill temperature to typically 55-70°C). Aerobic decomposition may continue for 6 or more months depending on the proximity of the waste to air at the landfill surface. This time frame for aerobic decomposition may be shortened if CH4-rich LFG from below flushes oxygen from voids in the disposed refuse. After all, entrained oxygen is depleted from the refuse, decomposition enters a transitional (autogenic) phase during which acid-forming bacteria

begin to hydrolyze and ferment the complex organic compounds in the refuse. Decomposition then enters a long anaerobic period which can be divided into several distinct phases. During this period CH4-forming bacteria, which thrive in an oxygen-deficient environment, become dominant. Anaerobic LFG production is typified by somewhat lower temperatures (35° to 55° C), significantly higher CH4 concentrations (40 to 60%), and lower CO2 concentrations (35 to 45%). Anaerobic gas production will continue until all of the biodegradable material is depleted or until oxygen is reintroduced into the refuse, which returns the decomposition process to aerobic conditions. A return to aerobic decomposition does not stop LFG production but will retard the process until anaerobic conditions resume.

10.12.2 Landfill Gas Generation Volume

LFG will be generated in all landfills containing organic (decomposable) materials, although the volume of production may vary widely over time and landfills. The total amount of LFG generated over the entire decomposition life of the landfill is mostly a direct function of the total quantity of organic material contained in the landfill, with some components decomposing rapidly, some at a moderate rate and some over a much longer period of time. Therefore, the quantity of refuse available for decomposition is the primary factor in determining the total volume of LFG that will be generated over the life of the facility.

10.12.3 Landfill Gas Generation Rate

The rate at which LFG is produced is primarily a function of the types of waste involved, e.g., rapidly decomposing food waste versus longer-lasting paper, cardboard, or other organic waste. The overall rate of decomposition for all refuse components in a given section of a landfill also is influenced by a variety of other factors, such as moisture content, temperature, refuse particle size, site configuration, compaction, and pH. Basically, the better the conditions within a landfill are for the anaerobic bacteria, the faster the decomposition will take place, resulting in a faster overall LFG generation rate build-up. The optimum moisture content for LFG generation is approximately 60%. In areas of low to moderate rainfall the moisture content of the incoming and in situ waste is typically significantly less than this optimum moisture content. Therefore, the recirculation of leachate can have significant benefits in optimizing landfill gas production. However, to avoid potential instability problems leachate recirculation should not increase pore water pressures within the waste mass.

10.12.4 Landfill Gas Composition

The typical constituents of LFG and the usual concentrations at which they are observed are:

- Methane (CH4) 40 to 60%
- Carbon Dioxide (CO2) 35 to 45%
- Oxygen (O2) < 1 to 5%
- Nitrogen (N2) <1 to 5%
- Hydrogen (H2) < 1 to 3%
- Water Vapor (H2O) 1 to 5%
- Trace Constituents < 1 to 3%

10.12.5 Landfill Migration and Emissions

Once the LFG has been generated, the forces of convection (movement from areas of higher to lower pressure) and diffusion (movement from areas of higher to lower concentration) may cause the LFG to move through and out of the landfill via the "path of least resistance". If the LFG moves out of the landfill into the surrounding soils it is called "migration". If it moves out of the landfill through the landfill cover into the atmosphere it is called "emissions". In either case, the LFG can have significant impacts on the environment and human health and safety. Some of these impacts are discussed below.

Explosion and Fire

One of the two major constituents of LFG is CH4. CH4 is a colorless odorless gas that is explosive in concentrations ranging from 5% (the lower explosive limit or LEL) to 15% (the upper explosive limit or UEL) by volume in air. At concentrations above 15% by volume, CH4 is flammable. LFG may be explosive when all of the following conditions are met:

- ✓ The concentration of CH4 is from 5 to 15% by volume in air.
- ✓ The gases are in an enclosed space.

There are documented cases of spontaneous LFG explosions and fires causing death, injuries, and property damage. The presence of carbon monoxide (CO) in landfill gas is a useful indicator of the presence of a fire.

Toxicity

LFG may contain toxic or carcinogenic compounds. Although these compounds generally do not pose a threat to human health or safety when confined to the landfill, their release into the atmosphere or the groundwater may create a potential health hazard. Therefore, LFG may present toxic hazards, both acute and chronic. Acute toxicity may be of concern if trace constituents (mostly notable H2S) are present in sufficient concentrations. Although H2S is typically found in LFG at concentrations of only a few ppm, it has been documented in some landfills at concentrations above 3,000 ppm. H2S has been shown to be deadly to humans at concentrations as low as 100 ppm. If LFG at a site has H2S concentrations anywhere near these levels, an unprotected worker entering any enclosed structure into which the LFG has migrated could result in a fatality. Chronic toxicity due to long-term exposure to LFG also may be a hazard. Many of the trace constituents of LFG are known or suspected human carcinogens. Some of the compounds that have been found in LFG at concentrations above their recommended long-term exposure toxicity thresholds and particularly at sites where industrial wastes are disposed of, this issue should be carefully examined.

Asphyxiation

Both of the major components of LFG, CH4, and CO2, asphyxiate. In closed structures or areas where LFG could potentially accumulate, LFG may present an asphyxiation hazard.

Air Pollution

Many of the trace compounds found in LFG are known as constituents commonly found in smog or as reactants in smog formation. Therefore, LFG may be a contributor to local air pollution.

Global Climate Change

CO_2 is a well-known greenhouse gas (GHG). Because landfill CO_2 is not derived from fossil fuel, but rather is part of the natural carbon cycle, it is typically not considered a contributor to global climate change. However, due to its higher infrared absorption capacity, CH4 is actually a much stronger greenhouse gas than CO_2 by a factor of 21 or even more (on a mass basis) in terms of global warming potential. Because of the CH4 contribution, uncaptured and un-combusted (fugitive) LFG is considered potentially a significant contributor to global climate change.

Odors

Odors associated with LFG are a well-documented issue. The odors are due to many of the trace compounds found in LFG, particularly mercaptans and HS.

Vegetative Stress

LFG migrating through soils can displace air in the interstitial soil spaces. If there are any plant roots in the area, the plants may suffocate and die.

Groundwater Contamination

Many of the VOCs often found in LFG are water-soluble. In addition, dissolved CO2 from LFG may form carbonic acid, which weathers formation minerals causing increases in groundwater hardness and alkalinity.

Landfill Gas and Control

Due to the potential impacts described above, all landfills of significant size (nominally >1Mt waste capacity) should have LFG collection and control systems installed that are designed and operated to minimize both LFG migration and emissions. At smaller sites, sufficient LFG control may be achieved by passive venting. However, even small sites may warrant further control measures and each site should be carefully assessed as LFG control requirements are very site-specific.

LFG control is a term that encompasses all methods for controlling the movement of LFG, including active collection, barriers, passive control, and monitoring. The purposes of a control system include:

- Controlling subsurface LFG migration
- Controlling surface emissions and nuisance odors
- Protecting groundwater
- Controlling fires/fire risk in the landfill waste mass
- Collecting LFG for its energy benefit
- Protecting structures
- Reducing vegetative stress.

A note on hazard

LFG can present very real and immediate risk and there are documented cases of fatalities due to LFG at landfill sites. Never sniff vents or wells – this could be fatal. Similarly, they never attempt to make pipe connections without assessing risk and appropriately isolating the area. LFG control methods can be divided into two separate system types, which are:

1. Passive venting and/or barrier system (sometimes with the flaring capability)

No active mechanical means are employed for a passive venting system. In the main, the pressure gradient created by gas generation within the landfill moves the gas toward a well or trench, which then intercepts the gas and conducts it to the surface.

There are two basic types of venting systems:

- Internal vents
- Perimeter trench vents.

Passive systems can be effectively used to control LFG migration, particularly at smaller or older sites. Passive venting alone should be avoided where practicable as the emissions will continue to contribute to global warming despite reducing the problems associated with LFG migration.

2. Active collection and flaring or beneficial use systems.

An active system uses a blower (extraction fan) to create a vacuum within the landfill and withdraw the LFG via a network of wells/trenches and pipework. The typical components of an active LFG control system include:

- Vertical gas extraction wells
- Horizontal gas collection trenches
- Collection piping to move the gas to a central location for processing
- Condensate traps and handling equipment
- Blowers or compressors
- Water knockout tanks, dehydrators or other scrubbers]
- “Candlestick” or enclosed flares
- Other facilities to process the gas, and gas to energy equipment.

Active systems typically provide the most effective form of control for LFG emissions and are a key feature for sanitary landfill operation at sites of significant capacity.

Figure 22: Landfill gas reception compound (Left), Landfill gas enclosed flare (Right)

LFG Monitoring

LFG Migration Monitoring

There are several aspects of LFG migration monitoring systems:

a. Surface emissions monitoring

Surface emissions monitoring using an FID or similar device is a key check on the effectiveness of the landfill cap and extraction system that together form the main control and management component for LFG at a site.

A build-up in surface emissions of LFG can provide early warning of the need for changes or improvements in cap or LFG system implementation and possible offsite odor or LFG migration issues.

b. Off-site migration monitoring systems

These systems typically are employed to monitor for CH4 concentrations at a landfill site property boundary. They typically consist of a series of monitoring wells (Figure 14.3) or probes spaced at intervals around the site. The spacing and positioning of the LFG migration monitoring wells are very important. In some places, arbitrary distance criteria (e.g., 300 meters) between probes have been mandated. However, because the probes only monitor discrete points, they may not truly indicate all migrating LFG. It is important to consider what

is to be protected and the nature of site conditions in selecting the location for LFG migration monitoring probes.

c. Structures migration monitoring systems.

Depending upon the location and construction of a structure, the risk for accumulation of LFG within it needs to be considered and may vary considerably. Structures on a landfill site, or near a landfill, particularly those involving enclosed spaces, should be evaluated for exposure to LFG migration. The factors that should be considered in the evaluation include:

- Form of construction
- Subsurface conditions
- Surface conditions
- Subsurface connections
- Existing LFG monitoring and/or control systems or devices
- Distance from LFG source

For any structure where migrating LFG poses a risk, whether an active control system is in place or not, a permanent or portable CH4 monitoring system should be employed. There are a number of permanent and portable combustible gas indicators on the market.

Landfill Gas Utilization

Though LFG can present a hazard to human health and safety and the environment, it can also be a very significant asset in relation to the energy potential of the CH4 that it contains, and hence it's potential for use as a fuel. The primary utilization modes for LFG which have been implemented successfully on a broad-scale are:

- On-site generation of electric power using LFG as a fuel within an internal combustion engine, gas turbine, or steam turbine generator.
- Fuel gas for direct sale to industrial fuel gas consumers.
- Pipeline quality gas for sale to utility companies.

Each of these technologies is discussed in more detail below:

1) Electric Power Generation

The most common energy application for LFG is the on-site generation of electricity using raw or partially processed LFG as a fuel. Typically, the LFG is used in a reciprocating internal combustion gas engine or gas turbine driving an electrical power generator. Microturbines

have been used at a number of facilities and there are a few facilities that use the LFG as boiler fuel for a steam turbine generating facility as well.

Typical LFG clean-up for electric power facilities consists of filtration and mechanical dewatering, but treatment systems to remove H2S and/or siloxanes are becoming more common in some locations as experience shows that a cleaner gas fuel can result in substantially reduced corrosion and reduced maintenance costs over the life of the equipment.

Figure 23: Gas engines

2) Direct-Use

In this application, the collected LFG typically is minimally processed and then sent to a nearby end-user, through a dedicated pipeline. The processing required to produce fuel gas from LFG is relatively minimal. It may range from selling the gas in its raw form to the removal of moisture on up to the additional removal of siloxanes, H2S, and/or non-methane organic compounds (NMOCs).

This latter procedure is approximately equivalent to the pre-treatment step that precedes the production of pipeline gas.

Figure 24: Electricity production by LFG

3) Pipeline Quality Gas

The production of pipeline quality gas from LFG requires more extensive processing in order to remove all virtual moisture, trace organic compounds, CO2, and air from the raw LFG. This results in virtually pure CH4, with a good calorific value. Of particular concern to many gas utilities companies in the presence of halogenated compounds in raw LFG. Some halogenated compounds are not destroyed by combustion and may present a danger to consumers if they are released through a home gas stove or heater.

The production of pipeline quality gas from LFG is typically performed in two steps. The first step, known as pre-treatment, is the removal of moisture and trace components by refrigeration, dehydration, filtration, adsorption, or other processes. The second step is to separate the CO2 from the CH4 by one of the many processes commonly used for that purpose in the petroleum industry.

4) Other Potential Uses of LFG

Some other potential uses of LFG are presented below:

i. **Vehicle Fuel, Compressed Natural Gas (CNG)**

Purified LFG may be compressed under pressure to approximately 3,000 pounds per square inch (psi) and is referred to as CNG.

ii. Vehicle Fuel, Liquid Natural Gas (LNG)

LFG may be purified, cooled (to approximately minus 260ºF), and compressed to a liquid form. When natural gas or LFG is compressed into a liquid form, it is known as LNG.

iii. Chemical Feedstock

To date, no practical application has been implemented using LFG as a chemical feedstock. The most likely use would be the utilization of the CO2.

10.13 Fire and Pest Management

Fire is one of the more serious risks that a landfill will face throughout its life. Fires are common at dumpsites, but serious fires are relatively infrequent at well-managed landfills. Landfill fires can cause serious damage to the infrastructure of a landfill and can be a major hazard for site staff. Additionally, landfill fires can create significant problems (in terms of health, air quality, and social acceptance) with the surrounding community. See the table below. Materials that are landfilled can be the source of both surface and subsurface fires and waste typically has a high fuel energy value. Regional landfills can represent a huge stockpile of flammable material. Understanding landfill fires requires consideration of the fire triangle: fuel, air, and an ignition source.

Table 5: Hazard of Fire

Hazard	Low severity	High severity
Uncontrolled gas and smoke emission	Additional on-site health and safety precautions required. Additional off-site receptor gas risk assessment (chronic effects)	Fire Service required. Nearby housing evacuated
Rapid settlement	Settlement causes seals around gas infrastructure to fail	Plant falls into an underground cavity-causing injury/death
Damage to landfill liner	Reduce lifespan	Immediate loss of integrity

Additional site management	Extra staff required to address subsurface fire issues and liaison with authorities.	Emergency response including 24 hours supervision and public relations/media management
Uncontrolled chemical reaction	Considerable additional on-site health and safety required. Additional off-site Receptor gas risk assessment (acute effects)	Explosion

Combustible materials are in waste such as paper, plastics, textiles, represent the main fuel but also hazardous waste mixed in co-disposal (oil, paint, solvent, a bottle of gas) are forbidden but existing in the dumpsite with no control at the entrance.

Ignition source carries on-site (e.g. hot ash), smoldering material, sparks, spontaneous combustion chemical reaction, recovery material on-site by the waste picker who recovers the metal of the electrical cables by firing the plastic sheaths, smoking on-site or even arson.

Oxygen is usually present in the waste when deposited and subsists in case of bad conditions of compaction, or it can be drawn in through the surface, large surfaces without inert material for covering is usually observed in the dumpsite.

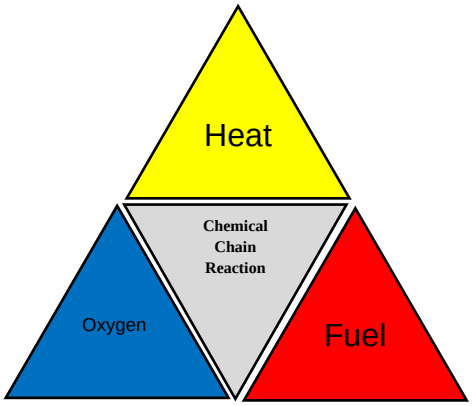


Figure 25: Chemical Chain Reaction

10.13.1 Characterization of A Fire

Fires at landfills can be classified into four categories, corresponding to the level of alert:

Level 1 Alerts: Small fires occurring on the landfill property, but not actually involving landfilled waste, compost or stockpiled recyclables, e.g. car fires, bin fires, equipment fires, office fires.

Level 2 Alerts: Small waste fires that can be contained by on-site resources within 24 hours and fully extinguished within 48 hours. Level 2 fires will typically involve less than 200 m3 of burning material.

Level 3 Alerts: Medium size waste fires or large fires at compost facilities that can be contained in less than one week and that can be fully extinguished in less than two weeks. Typically, 200 to 5,000 m3 of waste material is involved.

Level 4 Alerts: Large or deep-seated landfill fires that require more than two weeks to contain typically involving more than 5,000 m3 of burning waste.

10.13.2 Immediate Actions

Fires at Level 2 or 3 alert levels have the potential to turn into a Level 3 or 4 fire if an immediate and effective response plan is not applied. This is the reason why quick recognition and spotting of fires is essential. The prevention of the escalation of fire is related to the delineation of flammable waste, the application of immediate soil cover, and the potential for access and immediate excavation of the landfill slopes.

It is very important also, in the case of a Level 4 fire, to have ensured the exact spotting of the fire as well as an assessment of the current and potential extent it could attain. Spotting should be linked to the mobilization of fire-fighting resources from the outset.

Figure 26: Protective Equipment to be used in the vicinity of a fire

In any case, the first actions that must be taken at a landfill, during a fire of level 2 or above are:

- Shut-off of the landfill gas collection and management system (if present).
- Water services must be available for firefighting, including treated leachate if available.
- Standby electricity generators should be available for use, in case of power failure. The following actions need to be taken in the case of a landfill fire of level 2 or above:
- Immediate spotting of the fire
- Call to the fire department
- Characterization of the fire - choice of an alert level
- Appointment of an incident commander
- Application of communication plan
- Selection of the most appropriate firefighting equipment
- Activation of the alternative working face
- Monitoring of the air emissions and the course of the fire
- Application of the communication plan for the local community
- Application of the evacuation plan for residential areas if necessary
- Use of soil reserves
- Use of health and safety equipment by staff

10.13.3 Extinguishment Methods

The approach taken to extinguishing a landfill fire depends on the type of fire.

1) Water Application

Although water is an effective firefighting agent for near-surface fires, ensuring that water reaches a deep-seated fire can be problematic. Water tends to flow along paths of least resistance in the waste such as through poorly compacted pockets. This process of channeling can result in significant short circuiting, and inability of the water to reach the active burn zone at depth. Water does not readily penetrate cover layers composed of low permeability soils, especially if the cover has been compacted by vehicular traffic. Wells can be quickly drilled with a 150 to 300 mm diameter auger rig. Well, screens can be dropped into the boreholes to keep them open. Water can then be deployed into the injection wells from tank

trucks or pumped indirectly if a fire hydrant or water body is located nearby. Large volumes of water may be required as 5000 liters of water are required to absorb the energy released by the full combustion of 1 ton of garbage. The use of foam and surfactants can reduce this volume markedly. The firefighting team has to consider that the use of a large amount of water for the extinguishing of a fire can produce large amounts of leachate, which may possibly, overload the leachate treatment facility or require temporary containment or ponding. Application of a large volume of water could accelerate the instability of waste body, especially if there is poor compaction of waste (cohesion = 0) and a steep slope without good geotechnical conditions of stability (< 18° for slope is the starting point of instability)

2) Excavate and Overhaul

For deep-seated fires, where water application may not be an effective fire-fighting tool the most appropriate method for extinguishing the fire is often to excavate and "overhaul" the waste. The first step in controlling a fire in such way is the filling of parallel trenches previously excavated by the landfill operator. Next, smother the fire zone with a 2 to 3 m thick lift of refuse or soil and smooth (overhaul) the landfill surface. These actions reduce the amount of air fanning the burn, reduce the rate of burn and the amount of smoke that the fire emits, and make the landfill surface a safer work environment.

3) Oxygen Suppression

By limiting the amount of oxygen within the burn zone it is possible to extinguish a landfill fire over time, but this is usually a slow process. This method is similar to excavating and overhauling since it is based on the isolation of the burning section of waste from the rest of the landfill. Isolation is achieved by excavating around the burning mass until inflammable material (usually soil or rock) is found. The excavated trench is filled with low permeability material in order to limit the flow of oxygen through the burning waste mass.

10.13.4 Monitoring and Prevention

A. Temperature Monitoring

Monitoring of landfill internal temperature is very useful for establishing the risk of or extent of a fire, but only if the temperature is measured at depth. The best way to collect temperature measurements (and gas composition samples) is to drill a number of monitoring wells in and around the suspected fire zone. Air rotary rigs should not be considered since the

injection of large quantities of air could accelerate the fire and possibly trigger a methane explosion. In any event safety equipment, including respirators and ventilation fans, must be used by workers during such work.

To keep the holes open, the monitoring wells should be cased, preferably with slotted steel casing. Thermistors can then be lowered down the holes to measure temperatures at various depths (e.g. 5 m intervals) within the waste. To prevent convective currents between the various temperature intervals, the installation of foam baffles on the thermistor strings is recommended. A multi-channel read outbox is used to measure temperatures at the surface.

Table 6: The relation between CO concentrations and fire at the landfill

CO concentration (ppm)	Fire Indication
0 – 25	No Fire Indication
25 – 100	Possible Fire in Area
100 – 500	Potential Shouldering Nearby
500 – 1000	Fire or Exothermic Reaction Likely
> 1000	Fire in Area

Temperature monitoring has proven to be a very useful procedure in the prevention of landfill fires as well as in monitoring to confirm that the fire has been extinguished. The relation of landfill conditions and the temperature is presented.

Table 7: The relation between landfill conditions and temperature

Temperature	Landfill Conditions
< 55º C	Normal Landfill Temperature
55 – 60º C	Elevated Biological Activity
60 – 70º C	Abnormally Elevated Biological Activity
> 70º C	Likelihood of Landfill Fire

B. Gas Composition Monitoring

The monitoring of gas composition provides very useful insight fire conditions at depth and the success of firefighting measures. Parameters that must be measured at various times include methane, oxygen, carbon monoxide, and hydrogen sulfide. Of those four gases, carbon monoxide is the most useful indicator of a subsurface fire. The presence of oxygen at concentrations above 1% provides an indication that existing oxygen intrusion barriers (i.e. soil or membrane covers) are not effective in keeping oxygen out and that additional soil cover is

required. But until 5% of oxygen, it is not a real issue for the activation of a fire condition. On the other hand, a build-up of methane to levels in excess of 40% is a positive indicator that oxygen is being successfully excluded and the biological regime is reverting to cooler anaerobic conditions. During a landfill fire, sub-surface oxygen levels within the burn area are typically in the range of 15-21% oxygen. As firefighting and capping efforts progress, oxygen levels drop consistently, and when the fire is extinguished the oxygen levels typically drop below 1%.

C. Leachate Management

The application of large quantities of water will invariably produce leachate. In many cases when extinguishing landfill fires, leachate management has proven to be a significant issue. To minimize the environmental impacts of leachate, recirculation of firefighting water should be considered on projects where large volumes of water are used. Recirculation requires that leachate should be directed into settling ponds, preferably including filtration, and booster pumps may need to be brought online to enable recirculated water to augment water supplies from nearby fire hydrants.

D. Smoke and Odor Smoke

Smoke is often the first definitive evidence of a fire. In most recent fires the smoke has been seen for the first time when the gas abstraction system has been turned off for routine maintenance. Smoke, acrid, or 'cooking' odors should also be investigated if there is no visual evidence. Smokey aromas in the leachate have also been observed to correlate with a sub-surface fire. Steam on cold days has often been misconstrued as smoke. If condensation on a cold upturned bottle isn't conclusive (condensation meaning that the visible vapor cloud is steam), the definitive method of distinguishing between steam and smoke is to take a sample and look at it under a microscope. Smoke contains soot particles, while steam contains water droplets. Steam dissipates rapidly in the environment, while smoke dissipates more slowly.

E. Abnormal Settlement

Perhaps the most common association with sub-surface fires is a rapid or abnormal settlement. The abnormal settlement must be treated with caution because it is caused the removal of structural integrity at depth – if there are large sub-surface voids then there is a risk of major collapse at the surface. Rapid cylindrical settlement (bomb craters) that appear over a 2-week period was described in one case study. It is reported that the shape and size of

the settlement depend on the depth of fire, with deeper fires producing a small deep crater and shallow fires producing a shallow settlement over a larger area.

F. Fire Prevention and Control Plan

The first prevention action follows good practices to operate the landfill. But also, it is very important for every landfill to have an established and maintained fire prevention and control plan. In this plan, essential issues related to the landfill must be included such as site characteristics, Fire Fighting Resources, Landfill Fire Alert Levels, Incident Command Structure, Fire Response Actions and Responsibilities, Fire Fighting Methods, Landfill Fire Risk Reduction Strategies, Personal Protective Equipment, etc. All site personnel need to be aware of the plan and trained in its application.

G. Checklist to Prevent the Landfill Fire and Consequences of any Fire

The following checklist can help operators to assess their readiness to handle a landfill fire and identify possible gaps that have to be covered. Where "no's" is ticked in the Table remedial action must be considered.

Table 8: Checklist for monitoring landfill area

Building	Yes	No
Workplace clean and orderly		
Emergency exit signs properly illuminated		
Fire alarms and fire extinguishers are visible and accessible		
Stairway doors are kept closed unless equipped with an automatic closing device		
Appropriate vertical clearance is maintained below all sprinkler heads		
Fire extinguishers are serviced annually		
Corridors and stairways are kept free of obstructions and not used for storage		
The roads that lead to the buildings are clear and accessible to the fire engine		

Training	Yes	No
There is a specific training program for fire prevention & extinguishment		
New employees are given basic fire training		
Job-specific fire training held for employees on a regular basis		
Personnel familiar with applicable Material Fire Data Sheets		
All personnel familiar with the emergency evacuation plan		
Training documentation current and accessible		
The guests of the landfill are informed that have to follow the staff's instructions		

Landfill	Yes	No
There is a sufficient stockpile of the earth close to the working face		
There is on-site available equipment to move earth		
Alternative working face has been planned		
There is an adequate supply of water under pressure for fire-fighting purposes		
There is a water storage tank for fire-fighting purposes		
Fire-fighting equipment is readily available		
Record-keeping procedures for all fires		
Electricity generators are available for use		
There is a suitable access road for the fire engine to reach the working face and the burning mass		
All the equipment maintenance procedures are followed		
All flammable materials are stored properly		

The most dangerous locations of the landfill for fire, are signed properly		
The emergency telephone numbers (fire department, hospitals, police, etc.) are displayed in approachable places		
There is an adequate network of lightning conductors for protection from a lightning strike		

10.14 Environmental Monitoring and Management Plans

Landfills are sometimes referred to as a typical NIMBY facility. The reason for this is that people suffer many nuisances caused by landfills. Appropriate measures can minimize nuisances. The monitoring program should extend from the pre-operational monitoring through operational and post-closure monitoring of the landfill.

Odor

Odor is sometimes very difficult to manage at a landfill site. All sites will generate odor to some extent and it will generally be worse in wet, hot weather. Some measures which can be taken include:

- An immediate covering of highly odorous waste
- A regular covering of waste
- Ensure the tipping face does not pond water
- Encourage residents to store waste in a dry condition (so that when waste reaches
- The landfill is not as odorous),
- Maintain buffer zones around the landfill site (to minimize impacts on neighboring sites)

Leachate ponds can also be a source of odors. Effective operations and adequate buffers are essential for odor management. correct waste handling of known odorous waste, via special burials, together with the correct use of appropriate cover material, will in most cases manage odors from fresh deposits. Other measures that can help the management of odors may include:

- limiting waste acceptance criteria to exclude highly odorous materials/waste streams
- covering incoming odorous loads

- covering/capping odorous waste streams as soon as they are tipped on-site
- restricting the tipping of selected waste streams in certain atmospheric conditions
- limiting the tipping face
- restricting waste storage on-site (including restricting/limiting the parking of waste transport vehicles on-site)
- installing a meteorological station on-site to assist site personnel to identify and record climatic conditions
- using deodorizing/masking agents.

Operators should investigate all odor complaints as soon as practicable and are strongly advised to periodically undertake odor monitoring on-site and at site boundaries. The frequency of this monitoring will depend on site proximity to sensitive and commercial places, previous complaints, and site processes.

Litter

Municipal waste, especially plastic bags, can be spread over a wide area by the wind. This litter not only looks unsightly but might also foul drains and waterways, as well as interfere with neighboring activities.

Litter control at landfills will vary throughout the year depending on wind strength and the orientation and elevation of the tipping area. No single control option will be entirely successful for the entire life of the landfill. A litter control strategy must, therefore, be flexible and include both engineering solutions and management options.

As a minimum, a landfill should use litter screens and train staff in the appropriate placement of the screens to trap as much litter as possible. These litter screens should be portable to be able to follow the tipping area and should be capable of withstanding wind loads when loaded with litter.

Minimizing the size of tipping areas and having at least a daily litter program in which fences and surrounding areas are cleaned can assist with litter management. Contingency plans may be developed where resources are engaged to deal with extreme events that cause gross litter problems.

In areas where litter is especially problematic, this may involve a dedicated litter crew, more frequent covering, and enhanced litter screens. Such landfills may also have dedicated areas

for a waste deposition that are more sheltered from winds from particular directions, and therefore minimize litter from the landfill.

Where litter is blown or washed from the site, all reasonable and practicable actions must be made to retrieve the litter and ensure that it is disposed of in an appropriate manner.

Dust Emissions

The objective of the management of dust at the site is to prevent the release of dust. Any large area where the land has been disturbed and is subject to vehicular traffic has the capacity to generate dust. Other potential dust sources are stockpiles of earth and the delivery of dusty loads of waste.

The magnitude of the impact will depend on:

- The type and size of the operation
- Prevailing wind speed and direction
- Adjacent land use
- The occurrence of natural and/or constructed windbreaks
- Wind-abatement measures or buffers.

Dust suppression measures to be applied at the site may include:

- Vegetating or mulching of exposed areas and formation of internal roads, including sealing roads that are used regularly
- The use of water or other dust suppressants on roads or stockpiles that are not sealed or vegetated.

Noise

Landfills generally involve plant equipment that can impact detrimentally on the amenity of surrounding areas. Sources of noise at a landfill include trucks (body, engine, and exhaust noise), reversing 'beepers', external telephone bells and public announcements, mobile machinery, and equipment used for resource recovery operations such as concrete-crushing equipment.

Where noise is considered an actual or potential concern (due to changing land use), and acoustics specialist should predict the noise levels at the nearest current or future sensitive or commercial place, and recommend measures to control the noise.

Site operations must be set out to minimize noise impacts by using natural and/or constructed features such as earthen bunds and depressions as well as minimizing steep-haul roads.

Fire and Smoke

Fires should be minimized at landfill sites as burning rubbish can generate poisonous gases and be an environmental and health risk.

Figure 27: Fire Incident at Landfills

The type of control measures typically considered includes:

- regular soil covers to minimize the risk of fires
- developing a fire management plan including maintenance of an effective fire break around the perimeter of the site, and,
- developing emergency procedures for minor and major fires, including soil cover, water spray, excavation of a trench, etc.

It is therefore important to have good compaction of waste in daily operation in order to prevent the fire from spreading. For chronic smoldering in the waste layer, additional installation of a number of independent-type gas venting facilities with proper cover soil will be very effective.

The following figures explain the mechanism of fire and how it is put out by installing additional independent gas venting facilities.

Figure 28: Installation of additional independent gas venting facility

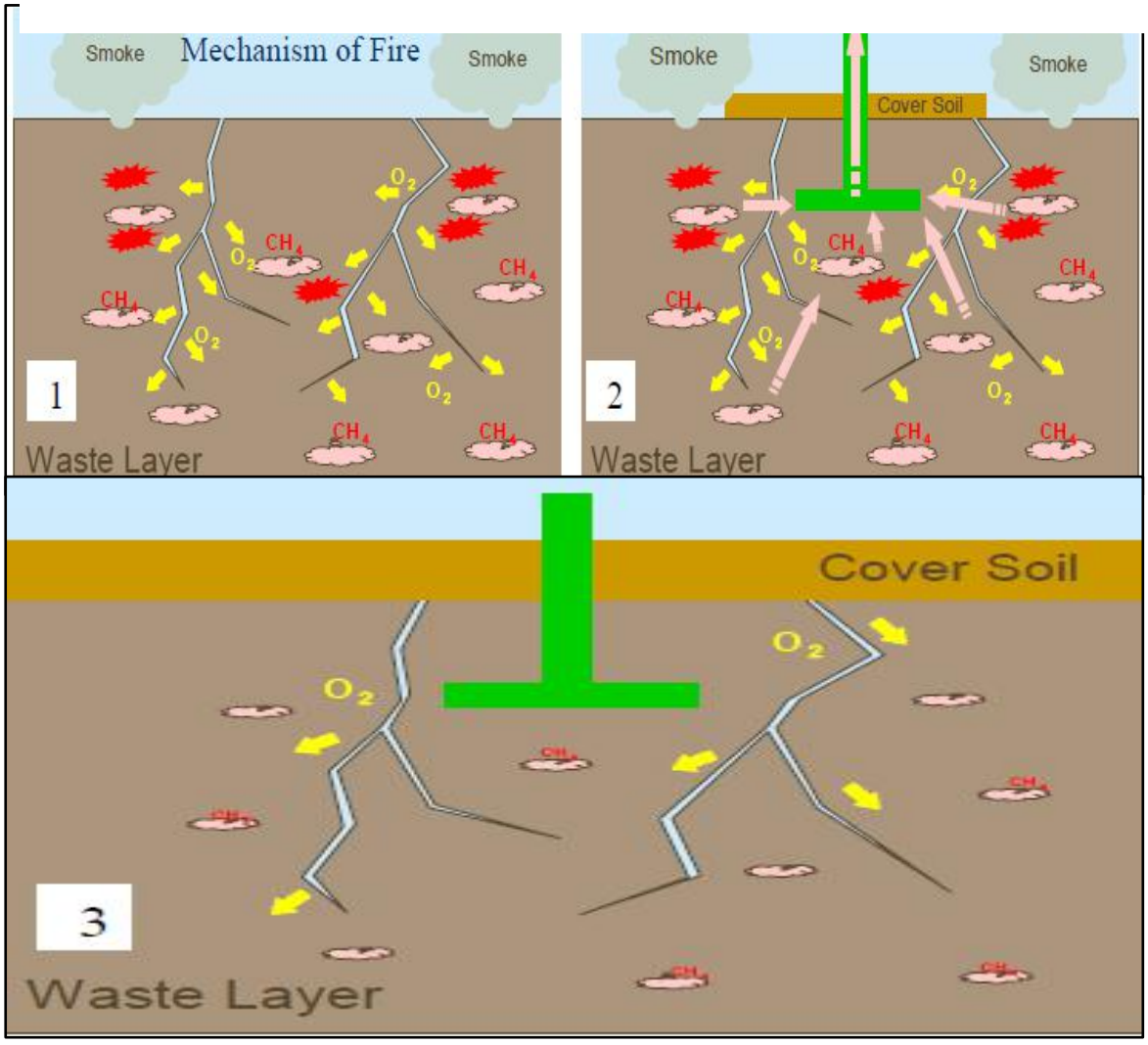


Figure 29: Fire Fighting Measure for Chronic Shoulders

Where the waste layer is in an anaerobic condition (absence of oxygen), methane is generated and contained in the waste layer. When oxygen penetrates into the waste layer from the ground, the concentration of methane enters a certain range (5–15 %) and catches fire naturally by chance or by deliberate ignition. In an anaerobic landfill, the fire continues consuming flammable materials (buried waste) in the waste layer. By installing a number of additional gas venting facilities with soil cover, quick discharge of methane is promoted and the supply of oxygen from the ground is minimized. When much methane has been released in the air, the fire (smolder) gradually becomes suppressed.

Visual Impact

Improvement of a landfill site can contribute to reducing the NIMBY syndrome against rubbish dumps. Effort should be made to try to keep waste from the view of the public employing such measures as building a buffer zone with trees, constructing bunds, installing wooden or galvanized walls or fences, etc. This can reduce some of the potential impacts of landfill operations such as noise, dust, and odor. Even simple regular covering of soil over rubbish can significantly reduce the eyesore potential.

Figure 30: Waste Dumps vicinity of Residential Area

Environmental Monitoring

Environmental monitoring can provide an indication of the severity of impacts at the waste disposal site and how effective control measures are in reducing the impacts.

Monitoring the aquifer(s) below a landfill site will provide an indication of how effective the leachate collection system is operating. Groundwater wells should be installed upstream and

downstream of the landfill so that regional concentrations (background values) can be monitored and compared to downstream values. Groundwater monitoring is quite expensive so the wells should be chosen with care and for optimum benefit.

Groundwater and surface water quality should be monitored on a quarterly (every 3 months) or bi-annual (every 6 months) frequency. It is important to account fo seasonal variations in the groundwater monitoring program. In addition, the water level at the leachate retention pond needs to be monitored so that any overflow of leachate or plugging of the outlet of the leachate collection pipe is avoided.

Gas monitoring needs to be conducted where there is the potential of gases to accumulate in high concentrations, such as the outlets of gas venting pipes. Regular monitoring of landfill gases will enable you to see if the semi-aerobic system is functioning. It must be emphasized that measuring gases is of the utmost importance when entering a deep pit or excavated place in order to avoid any accident caused by a deficiency of oxygen.

There also needs to be a mechanism for reporting and responding to complaints and problem monitoring results. Results should be reported on a regular basis to the responsible body so that decisions can be made to minimize and manage any outstanding issues.

10.15 Reporting and Complaints Register

A crucial part of correctly operating a landfill is to ensure that appropriate reporting is occurring and that these reports are passed on to the relevant managers. This provides an opportunity for managerial and external oversight. Part of this reporting involves maintaining a complaint register which provides a third-party indicator as to whether the landfill operation is being accepted by the local community. It also may be a leading indicator of potential significant problems at the site.

Daily Diary and Miscellaneous Report Sheets

The landfill diary must be completed each day before the site supervisor leaves the site. A typical diary form is presented in the Landfill Operations Manual together with all other forms mentioned. The incoming waste designation sheets, load analysis sheets, and incident record sheets should be collected at the end of each week or month. A summary report covering the number of loads, total volume of waste or fill received, and the number of incidents at the landfill should be prepared. The individual sheets and the weekly summaries should be filed and a copy

sent to the manager. The site supervisor should provide a monthly report to the manager on all aspects of the environmental management plan, including complaints and monitoring results. A summary of the operation of the landfill should be included.

DAILY LANDFILL DIARY

Date: **Day:** **Shift:**

WEATHER Temperature: Very Hot Hot Warm Cool Cold Rainfall: .....mm ..... Time Wind: Strong Light Still					
RECEIVALS: Cubic Metres/Tons ..... No. of Trucks ..... No. of Cars ..... No. of Trailers		**SAFETY INSPECTIONS:** Morning Afternoon Roads ☐ ☐ Work Area ☐ ☐ Signs ☐ ☐ Staff ☐ ☐ Amenities ☐ ☐		**DEFECTS REPORTED:**	
PLANT AND EQUIPMENT: List all major plant and equipment onsite including sub-contractors					
Description	**Unit No.**	**Hours Worked**	**Hours Idling**	**Breakdown/ Repairs**	**Comments**
Compactor Dozer Payloader/excavator Truck Chipper/crusher Other (e.g. water truck)					
SUB-CONTRACTORS: List name of sub-contractors, crew size and work area					
Name		**Hours Worked**		**Comments/Work Performed**	
VISITORS: List any visitors					
Name and Organization		**Purpose of Visit**		**Sponsor**	
TRAINING: List employees undertaking training					
INDUSTRIAL, SAFETY & ENVIRONMENTAL: List any industrial concerns, accidents, improvement notices issued on safety or environmental grounds. List verbal instructions given to workers.					
OTHER COMMENTS: List any EMP Monitoring undertaken, prohibited wastes received, OH&S issues, etc.					

Name Signature Title

Figure 31: Sample Daily Landfill Diary Entry Page

Complaints Register

The complaints register serves two purposes:

i. It identifies problems unseen or neglected by the landfill staff and will ensure that this problem is recognized and action is taken if appropriate.

ii. It enables the public to maintain an ongoing relationship with the landfill operator and enables them to have their concerns formally documented and recorded.

The complaints register applies to many aspects of the landfill operation including noise, odor, dust, mud, visual impacts, litter, water quality, and so on. The landfill staff will keep a record of all complaints made about the landfill. Generally, the gatekeeper receives the initial complaint, if it is by phone (landline or mobile) directly to the landfill, or the site supervisor if it is a written complaint.

Telephone complaints direct to the city offices must be recorded and passed on to the site supervisor immediately. The site supervisor will deal with all complaints and organize the appropriate action to be taken, assess the level of urgency, and check if the complaint is valid. The site supervisor is also responsible for informing the party who complains by letter of the outcome of their complaint, with a copy in the monthly report to the client manager.

Operating License Reporting Requirements

The external reporting requirements will be taken from the site license. They must be strictly followed or the operator (contractor) can be fined. In general, the city is required to report on at least the following issues:

- Annual quantity of different waste types accepted;
- Annual quantity of different waste types rejected;
- Annual quantity of different waste types recycled;
- Half-yearly evaluation of the overall site performance, including monitoring results, complaints handling, remaining airspace, etc. The review should involve all landfill staff and include a group section on possible environmental improvements. An external component should include feedback from neighbours and discussions with environmental agencies, etc.;
- Possible annual overview audit by external auditor;
- Possible yearly comprehensive external audit results; and
- Environmental improvement plan update, including training requirements, amendments to the policy statement, etc.

Reporting requirements provide not only the history of the landfill operation but, with the complaints register, also some indication as to whether the landfill may be subject to increasing social pressure in the future.

CHAPTER 11: PPP, IMPLEMENTATION AND FINANCIAL ASPECT

11.1 PPP Contracts in Bangladesh

The GoB has taken a two-pronged strategy for building public-private partnerships: the first is to attract investment for projects, where building new infrastructure and expanding existing infrastructure is the major component; the second is to attract innovation and sustainability of public service delivery to the citizens. The choice of the PPP arrangement for a particular project will depend on its social and economic importance and potential value for money to be generated under such an arrangement. PPP is expected to foster economic growth by developing new commercial opportunities and increasing competition in the provision of public services, thus encouraging private investment.

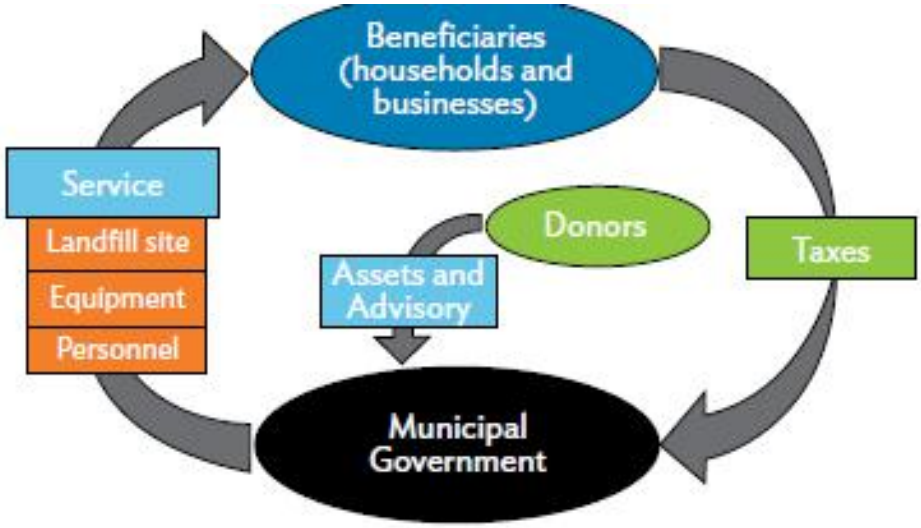


Figure 32: Municipality-Led Institutional Model for Solid Waste Management

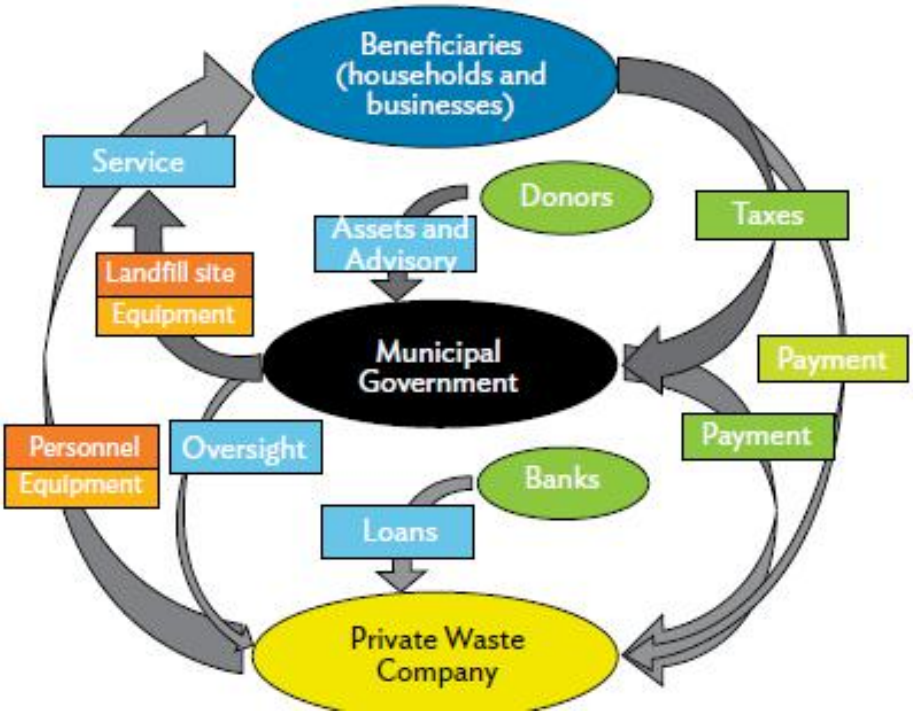
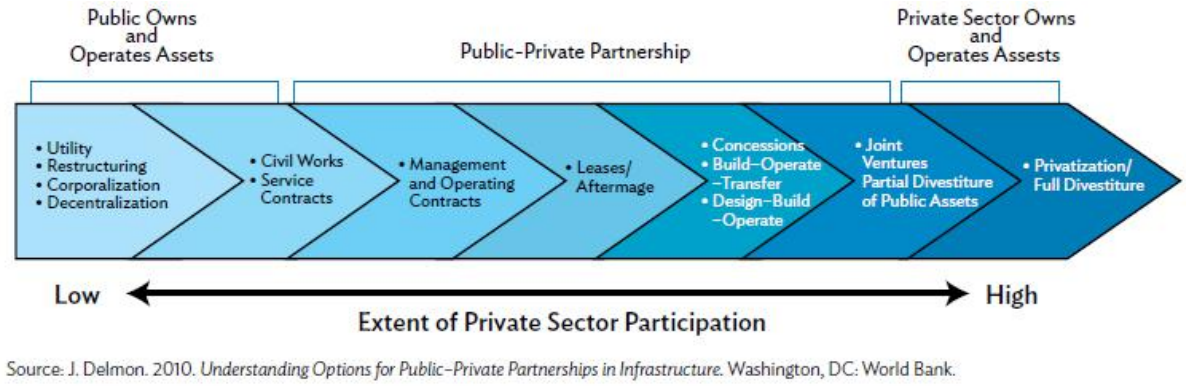


Figure 33: Public–Private Institutional Model for Solid Waste Management



Source: J. Delmon. 2010. *Understanding Options for Public–Private Partnerships in Infrastructure.* Washington, DC: World Bank.

Figure 34: Spectrum of Private Sector Participation in Infrastructure and Development Projects

11.2 Applicability of PPP

According to the Policy and Strategy for PPP, 2010, of the GoB, public-private partnership models can be considered for any project that generates public goods and services if at least one of the following circumstances exists for the project:

- The implementation of the project is difficult with the financial resources or expertise of the government alone;

- Private investment would increase the quality or level of service or reduce the time to implement compared to what the government could accomplish on its own;
- There is an opportunity for competition, where possible, among prospective private investors, which may reduce the cost of providing a public service;
- Private investment in public service provides an opportunity for innovation;
- There are no regulatory or legislative restrictions on private investment in the delivery of public service.

PPP will not be applicable to the following actions/activities: (a) Outsourcing of a simple function of public service; (b) Creating a government-owned enterprise (State Owned Company), and (c) Borrowing by the government from the private sector.

11.3 Sector Coverage of PPP

According to the Policy and Strategy for PPP, 2010, any project fulfilling one or more of the PPP applicability criteria in any economic sector, according to the International Standard Industrial Classification (ISIC) of all Economic Activities, Revision 4, specified by the United Nations, is eligible for PPP. With this coverage in perspective, the GoB has identified a number of priority sectors for e.g.

- Exploration, production, transmission, and distribution of oil, gas, coal and other mineral resources (ISIC 05-09);
- Oil refinery, and production of LPG (ISIC 19);
- Production of fertilizer (ISIC 20);
- Power generation, transmission, distribution, and services (ISIC 35);
- Airports, terminals, and related aviation facilities (ISIC 42 and 51);
- Water supply and distribution, sewerage and drainage, effluent treatment plans (ISIC 36-39);
- Land reclamation, dredging of rivers, canals, wetlands, lakes, and other related facilities (ISIC 42);
- Highways and expressways including mass-transit, bridges, tunnels, flyovers, interchanges, city roads, bus terminals, commercial car parking, etc. (ISIC 42 and 49);
- Port development (sea, river, and land) including inland container terminals, inland container depot, and other services (ISIC 52);

- Deep seaport development (ISIC 52); etc.

11.4 Eligibility of Private Sector

According to the PPP Policy and Strategy of the GoB, any for-profit or not-for-profit entity legally registered in Bangladesh or abroad at the time of submission of proposals in response to Request for Qualification or unsolicited proposals is eligible for participation in PPP projects. However, at the time of the contract award, the foreign entity is required to be registered as a legal entity in Bangladesh. The government plans to specify detailed and specific eligibility criteria in relevant Request for Qualification (RFQ) and Request for Proposal (RFP) documents for any partnership.

11.5 Classification of Projects in PPP by Investment Size

The GoB plans to carry out different sizes of projects under PPP. In order to ensure quick approval and implementation of all projects, PPP projects will be classified into three groups: Large, Medium, and Small. The threshold investment values may be reviewed, as and when required, and modified by the Cabinet Committee on Economic Affairs (CCEA).

- Large Project: A project, which is estimated to have a total investment above BDT 2.5 billion (as identified in the pre-feasibility report), excluding on-going capital for expansion, shall be classified as a Large Project.
- Medium Project: A project, which is estimated to have total investment between BDT 500 million and 2.5 billion (as identified in the pre-feasibility report), excluding on-going capital for expansion, shall be classified as a Medium Project.
- Small Project: A project, which is estimated to have total investment below BDT 500 million (as identified in the feasibility report), excluding on-going capital for expansion, shall be classified as a Small Project.

11.6 Linked Components of PPP Projects

Depending on the nature of the PPP project, the line Ministry/implementing agency may consider financing and implementation of linked activities, such as the acquisition of land, rehabilitation, and re-settlement, provision of utility services, construction of approach roads to the main highways and activities of a similar nature, in the following two forms:

- The financing will be a part of the PPP project. The implementation may be done by the private investor or by the relevant line Ministry/implementing agency, as appropriate.
- The financing, as well as implementation, will be done by the government. Necessary budgetary provision will be kept in the Annual Development Plan (ADP). Implementation will be expedited by the government.

11.7 Institutional Framework for PPP

For accelerating identification, formulation, appraisal, approval, monitoring, and financing of PPP projects, a simplified and dedicated institutional framework is required. This institutional framework is designed to streamline the approval process, to ensure a smooth and linear process of approval. Each of the following institutions is involved in the strategy development, identification, formulation, appraisal, approval, monitoring, and evaluation of PPP projects. Details on their roles are available in the Policy and Strategy for PPP, 2010.

- Public-Private Partnership Advisory Council (PPPAC);
- Cabinet Committee on Economic Affairs (CCEA);
- Office for Public-Private Partnership;
- Line Ministry/implementing agency;
- Finance Division;
- Planning Commission

The composition and role of the Public-Private Partnership Advisory Council and the role of the other institutions (as mentioned above) for PPP are available in the GoB's Policy and Strategy for PPP, 2010.

11.8 Formulation, Appraisal, and Approval of PPP Projects

- **Project Size**
  - Large Projects: The final approval authority of Large Projects is the CCEA. The detailed procedure of formulation, appraisal, and approval of Large Projects shall be proposed by the Office for PPP and approved by the CCEA.
  - Medium Projects: The final approval authority of Medium Projects is the Finance Minister. The detailed procedure of formulation, appraisal, and

approval of Medium Projects shall be proposed by the Office for PPP and approved by the CCEA.

- Small Projects: The final approval authority of the Small Projects is the respective Minister of relevant line Ministry. The detailed procedure of formulation, appraisal, and approval of Small Projects shall be proposed by the Office for PPP and approved by the CCEA.

- **Unsolicited Proposals**

  For appraisal and approval of unsolicited proposals, competitive bidding using the 'Bonus System,' 'Swiss Challenge System,' or other appropriate methods shall be followed where the options and competitiveness of the unsolicited proposals could be put to the open test by inviting competitive proposals. In the Bonus System, the proponent of the unsolicited proposal is given bonus points in relation to the evaluation. The Swiss Challenge System enables the government to attract counter proposals to an unsolicited proposal during a designated period. The original proponent then has the right to counter-match the most attractive counter-proposal.

11.9 Exit Policy

The contract for a PPP project will include an Exit Clause which specifies the terms and conditions of exit of a current private investor, possible transfer of ownership to a new investor, or partial or complete divestiture of ownership to capital markets. Such terms and conditions will identify the minimum duration after the start of commercial operations during which an exit is not allowed.

11.10 Disclosure of Information Related to PPP

The laws, rules, regulations, model documents, and short description and scope of negotiated PPP projects will be made publicly available through various channels including the internet. Each private investor participating in a PPP project (through bidding on RFQ, RFP, or through an unsolicited proposal) shall be able to track the status of processing through a secure internet site.

11.11 Investment Target through PPP in the Five-Year Plan

Infrastructure investment deficit will be identified in the Five-Year Plan and year-wise targets for financing under PPP for each relevant economic sector shall be determined. Though public

investment in infrastructure will still be predominant, the share of private sector investment will gradually be increased.

11.12 Rescind and Savings

After the adoption of the new Policy and Strategy for Public-Private Partnership (PPP), 2010, in Bangladesh, the Bangladesh Private Sector Infrastructure Guidelines (BPSIG), 2004 shall be rescinded. However, the action is already taken under the BPSIG, 2004 shall be deemed to have been taken under this Policy.

11.13 Further Details and Guidelines

The GoB's Policy and Strategy for PPP, 2010, provides more details and guidance on the way forward for PPP in the country. The document should be consulted for the following specific guidelines:

- Guidelines for Formulation, Appraisal, and Approval of Large Projects Under Public Private Partnership (PPP), 2010;
- Guidelines for Formulation, Appraisal and Approval of Medium Projects Under Public Private Partnership (PPP), 2010; and
- Guidelines for Formulation, Appraisal, and Approval of Small Projects Under Public Private Partnership (PPP), 2010.

These guidelines focus on their applicability; procedure of project identification, formulation, appraisal and approval; and time requirement.

11.14 Finding Bankable Solutions for PPP

The financial participation of the government in the PPP projects may be in at least three forms, depending on the nature of the projects and models of PPP adopted for a particular type of project.

11.15 Technical Assistance Financing

The Technical Assistance Financing is designed for the following purposes:

- Pre-feasibility and Feasibility study for projects;
- Preparation of RFQ and REP documents for projects;
- Preparation of concession contracts for projects;

- PPP related capacity building in the line Ministries/implementing agencies and other relevant agencies;
- PPP related awareness-building such as roadshow, exhibition, etc.

11.16 Viability Gap Financing

Viability Gap Financing (VGF) is meant for projects where financial viability is not ensured but their economic and social viability is high. VGF could be in the form of a capital grant or annuity payment or both. VGF in the form of a capital grant shall be disbursed only after the private sector company has subscribed and expended the equity contribution required for the project. The VGF is to be managed by the Finance Division and is for disbursement to the PPP Project Company, upon request by the line Ministry/implementing agency, as per the terms of the concession contract.

11.17 Infrastructure Financing

The infrastructure financing is an arrangement for extending financing facilities for the PPP projects in the form of debt or equity through specialized financial institutions such as Bangladesh Infrastructure Finance Fund (BIFF) and Infrastructure Development Company Limited (IDCOL). The government may participate in such financing arrangements through necessary budget provision. The detailed procedure and guidelines for all forms of financial participation by the government will be issued and specified by the Finance Division with the approval of the Cabinet Committee on Economic Affairs (CCEA).

11.18 Incentives to Private Investor

The government is keen to provide various fiscal and non-fiscal incentives to the private investors for launching PPP projects in priority sectors. All incentives in PPP, including fiscal and monetary incentives are to be considered and granted by the government, through the appropriate agencies of the government. The incentives may be in the areas of reduction of cost and protection of return to the private sector.

- **Fiscal Incentives:** All PPP projects will receive the applicable incentives, provided by the government from time to time which may, inter alia, include:
  - Reduced import tax on capital items under PPP projects; and
  - Tax exemption or reduced tax on profit from operating/managing for a specific time period.

- **Special Incentives:** Any specific project may get special unique incentives with the approval of the CCEA which shall be declared in the RFP documents. Special incentives may be extended to PPP projects targeted for rural or/and underprivileged populations. Special incentives may be given to non-resident Bangladeshis (NRBs) to invest in PPP projects.

11.19 PPP Project Stakeholders: Understanding Potential Internal Conflicts

A stakeholder is the seed of unpredictability and subjectivity in decision-making over the long-lasting, relationship-driven, life cycle of PPP projects. However, their conflicting interests, roles and responsibilities alter their level of involvement and importance leading to conflicts that may escalate into litigation, renegotiation or, even worse, project failure. This makes the PPP decision-making highly fragmented, contextual and dynamic. To deal with the interrelated issues, different conflict zones have been marked. For different phases of the project life cycle, and for different stakeholders, these conflict zones can be used to perform a more efficient stakeholder analysis and design suitable conflict prevention mechanisms for proactive stakeholder management practice integrated with contract management. This can prevent the cost and time overruns that are caused if a project goes into litigation. It must be noted that the proposed conceptualization is a generic baseline rationalization that can be sophisticated to act as a framework for conflict prevention and stakeholder integration in PPP decision-making. Expert opinion and case study demonstrations can be used to develop a PPP stakeholder analysis framework that can be directly used while making decisions at different stages of the project life cycle. Sectoral variation in the legitimacy of stakeholders, types of conflict, and their impact can also be compared in the future. The current study has employed concepts of complexity theory and stakeholder theory. To further develop this work, refined analytical tools of system dynamics, fuzzy logic, and agent-based modeling can be used to assess the robustness of the subjective rationalization as well as its further sophistication.

11.20 Financial Analysis

Financial Management

1. An independent accounting system for all solid waste management including recycling activity shall be introduced by NCC.
2. A separate charge for business premises/industries/clinic that produce large amounts of waste shall be introduced through discussion by NCC.
3. Carbon financing options for waste management project shall be explored linking this activity with 64 District Programmatic CDM project on composting of DOE. Corporate sponsorship for solid waste management activity shall be explored since SWM financing by any business can be treated as CSR and tax holiday is given by NBR.

And a simplified accounting system for actual SWM cost should be established that could be easily understood and computed by all NCC staff. For this purpose, so-called 'Standardized SWM cost' is designed as a model accounting in digitized form for NCC and the counterpart. The cost components of Standardized SWM Cost are shown below.

Table 59: Cost Component of Standardized SWM Cost

Cost component	Department-wise				Operation-wise			
	Conservancy	Transport	Mech-1	Mech-2	Cleaning	Collection /Transport	Final Disposal	Repair Works
Personnel	*	*	*	*	*	*	*	*
Repair/Maintenance	-	-	*	*	-	*	*	-
Fuel	-	*	-	*	-	*	*	-
Utility	-	*	*	*	-	*	-	*
Supply	*	*	*	-	*	*	*	-
Development	*	-	-	-	*	-	-	-
Depreciation	-	-	-	-	-	*	*	-

Privatization

To promote source separation in NCC area can increase by increasing the amount of cleaner unsoiled recyclables and fresh organic waste for composting with inclusion of private entities, those are sated here below;

Wholesaler- Wholesalers are in the higher strata of the recycling trade chain. Typically, a wholesaler supply industries and manufacturers with raw materials. Indeed, wholesalers maintain a close relationship with industry professionals and manufacturers.

Manufacturers- The final destination in the recycling trade chain is the manufacturers. Typically, a manufacturer buys a significant number of recyclables from brokers and wholesalers.

Table 60: Solid wastes supply and potential resources recovery at NCC Solid Waste Management Plant (NCC – SWMP) in Phase-1 (2021-2025)

Source of Solid Waste	Amount (tons/day)	Food & Farm Wastes (tons/day)	Non-food Wastes (tons/day)	
		Fermentable Fraction	Recyclable Fraction	Non-recyclables either hazardous or not recyclable economically
A. Household	492	366.84 (74.56 %)	89.99 (18.29 %)	35.18 (7.15 %)
B. Commercial and Industrial	340	170 (50 %)	136 (40%)	34 (10 %)
C. Warehouse of Broken Material	90	0 (0 %)	63 (70 %)	27 (30%)
Total	**922**	**537**	**289**	**96**

Basis of Plant Capacity	537 tons/day with 10% impurities (sand, soil, & packaging materials) and 70% moisture in remaining 90% = 150 tons/day dry biosolid	289 tons/day with 10% moisture and 60% direct recyclable = 86.7 tons/day	96 tons + 10% of impurities separated from Food Waste = 150 tons/day with 10% moisture, 15% inert and 75% combustible materials (non-recyclable plastics/paper/fibers) = 112 tons/day RDF with estimated LHV = 15 MJ/Kg
Technology for Resource Recovery	**Biomass Separation, Biogas-CHP,** **Composting & Biofertilizer Plant**	Direct Sale of Metals, PET & HDPE Plastics, Papers, Glass, E-Wastes after segregation by **Sorting Line**	**WTE (Gasification or Incineration) Plant** for power generation or alternatively **Pyrolysis-Distillation Plant** for diesel and charcoal production
Potential Resources Recovery	Power Generation = 3 MW Compost Production = 150 tons/day *(This production capacity can be potentially doubled with fecal & sewage sludge from NCC is co-fermented with food wastes)*	There are already few hundred small companies for recyclables-recovery in Narayanganj. If 50% of actual generation reaches the NCC-SWMP, potential sales volume = 150+ tons/day	WTE Electricity = 5 MW and Construction Materials = 35 tons/day *Alternatively,* Fuel Oil & Diesel = 50 tons/day and Charcoal + Ash = 50 tons/day (Another 1 MW can be potentially added with the treatment of medical wastes in this plant)

Potential Investment	**USD 12 15 million for first 3 MW** (Biomass Separation, Biogas-CHP, Composting & Biofertilizer Plant)	**USD 3 5 million** (Sorting Line for Recyclables & RDF Recovery form non-food wastes)	**USD 30 35 million for first 5 WTE Plant** **USD 4 5 million (Pyrolysis-Distillation)**
Land Allocation	**10 acres**	**2 acres**	**10 acres**
	1 acre for office, garage, and other common facilities. **Total = 10 + 2 + 10 + 1 = 23 acres**		

CHAPTER 12: FINDINGS, RECOMMENDATION AND CONCLUSION

12.1 Findings and Problem of Solid Waste Management

There are many problems and drawbacks of solid waste management in the NCC areas. The major ones are as follows:

- Absence of implementation of national policy to encourage recycling practice;
- Lack of proper handling rules and standard of solid waste management;
- Lack of finance, and inefficient tax collection; Inefficient practice of waste collection;
- Shortage of suitable lands for final disposal of solid waste;
- Shortage of transfer points before final transfer to disposal site;
- Lack of awareness about environmental problems associated with solid wastes and
- Lack of partnership between public sector, private sectors and community groups.

12.2 Recommendations on Solid Waste Management of NCC

SWM privatization project for 27 wards of Narayanganj has been going on since December, 2019 as "Solid Waste Management Master Plan Project of Narayanganj (Private Initiative)". A household & industrials survey was carried out for getting the initial understanding of current situation and future work plan to maintain the wastes. Recommendations on the future waste management of Narayanganj complete the study. In detail the following recommendations are suggested by the consultants:

- Segregation of wastes at source especially the household wastes through active participation of the community and in separate areas as well as a regular collection of wastes by using separate fuel-efficient vehicles according to the nature of the wastes.
- Improved community bins, storage containers for the storage of biodegradable and wet wastes and containers should be placed scientifically using GIS and GPS.
- Improvement of the collection system regarding staff and equipment is needed to increase.

- Long term contracts with substrate (waste) suppliers and collectors need to ensure to make a sustainable SWM.
- Waste collection system should support the necessary input material for the waste to energy plant.
- Informal sector should be integrated in future waste management systems.
- Adequate training to all the levels of staff engaged in solid waste management to handle respective functional aspects like collection, generation, storage, segregation of waste, etc. and medical check-ups for municipal workers and rag pickers should be mandatory at regular interval.
- Establishment of some transfer stations for the smooth operation of the SWM system at some suitable locations.
- Composting should be done with the help of dedicated technical experts and handle the bulk of waste generated everyday sanitary landfill site have to be set up to dispose of the rejects after composting.
- Encouraging effort on recycling of organic waste.
- Promotion of public participation in the SWM scheme and constitution of citizen forum in each municipal ward involving local people.
- Developing public-private-partnerships leading to privatization of some aspects of garbage collection, recovery, and disposal.
- Proper management of clinical wastes Development of Public-Private-Community - Partnership, a model of management and sharing.
- Promoting activity of civil society and environmental awareness group.
- Establishment and development of micro-enterprises in waste recovery and recycling.
- Ensuring involvement of NGOs and media in environmental awareness program.
- Effective and efficient coordination and cooperation among different divisions of City Corporation.
- To tackle various issues such as road sweeping, open dump, open burning, garbage collection, disposal etc. regular monitoring will be necessary.
- Garbage tax should be levied against large and small generators for the disposal of Wastes.
- Administrative restructuring needs to be done in order to discharge more efficiency and specific responsibilities. This requires structural changes within administration aimed at

decentralizing authority and responsibilities. This will also include periodic meetings among the staff and between the executives and elected wing of the board.

- Encouraging the involvement of local NGOs in working on various environmental awareness programs and areas related to waste management including the public about the importance and necessity of better waste management.
- Privatize solid waste management facilities or contract for waste disposal services, including recycling.
- Public awareness of the waste management should be raised through mass media for cooperation from city dwellers and
- Legal Aspect should be followed in opening a landfill. In connection with the existing landfill site, NCC should comply with Environment Conservation Act and Rules and Preservation Act.

12.3 Conclusions

Urbanization and Industrialization accompanied with population growth are the chief factors for increasing rate of solid waste generation in NCC. About 922 tons of solid waste is being generated each day from the NCC areas. The per capita waste generation is about 462 g/day. Waste management system is not very good at NCC. Efforts are being paid to improve the system of collection, transportation, recycling, incineration and land filling. However, with limited finances and organizational capacity, it has been really difficult for NCC authority to ensure efficient and appropriate delivery of solid waste collection and disposal services to the entire NCC areas.

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ANNEXURE-1

SOLID WASTE MANAGEMENT DATA SHEET

Narayanganj City Corporation

Technical Agency: Acumen Architects and Planners Ltd.

Date: ……..

Completed by……. Designation…….

1. Total Area of the City Corporation (Sq. Km) ……

2. Number of wards……..

3. Total Road length (Km) ……

Please verify the following data:

Road Type	**Length (km)**
BC	285.01
CC	67.78
RCC	12.87
HBB	13.58
WBM	4.39
Katcha	56.50
BFS	30.00
Total	470.13

4. Total length of drain (Km): …….

Please verify the following data:

Drain Type	**Length (km)**
Brick Drain	112.20
RCC Drain	49.85
Pipe Drain	21.89
Katcha Drain	0.71
Total	184.65

5. Please verify the following SWM Data:

Description of Solid waste	**Total (ton)**
Daily Generated Waste	85 ton/day
Daily Collection Waste/Disposal	73 ton/day
Collection Rate (%)	85.88%

6. Any SWM Committee Y / N; If Yes,

Who are the members (composition) of the committee?

……..

……..

What are their current activities of the committee?

……..

……..

7. Please describe City Corporation/Pourashava's organogram for SWM and show permanent and Master Role staffs:

8. Number of dustbins/ containers

Transfer Stations ……. Containers …… Brick Dustbins…….

Others (specify) …….

Word-wise numbers will be required in a separate table. Dimension of each and collection frequency will also be required. These will be required to be shown on map.

9. Any standard followed for placement of bins/containers etc.?

……

……

10. Information about landfill site:

Sl. No.	**Location**	**Area (Acre)**	Depth (m)	**Currently in operation or not**	**How long in operation**	**% filled up**

Photos of each site will be required. Locations are required to be shown on map.

11. Number of individuals involved in waste collection as:

Type of Personnel/Worker	Male		Female	
	Permanent	Master Role	Permanent	Master Role
Key Conservancy Personnel				
Truck/ tractor/ power tiller drivers				
Truck/ tractor/ power tiller helpers				
Waste collection/disposal workers				
Street sweepers				
Van drivers				
Van helpers				
Others				

12. Information about waste collection & transportation vehicles (motorized/mechanical):

Sl	Vehicle Number	*Type	Carrier Dimension (maximum)	Capacity (Tons)	Average Fuel consumption / day (Liter)	Avg. no. of trips/day	Procurement / Receiving Date	Current Condition	No. of Manpower Involved			No. of Dustbins Served	Areas (Wards) Served	Travel Route	Remarks
									Driver	Helper	Worker				

*Type: Open Truck (OT), Mini Open Truck (MOT), Hydraulic Dump Truck (DT), Compactor (C), Large Tractor Trailer (LTT), Mini Tractor Trailer (MTT), Motorized Three Wheeler (MTW), Battery Driven Van (BDV) etc.

13. Information about other SWM vehicles (manually operated/non-motorized):

Ward Number	*Type	Carrier Dimension (maximum)	Capacity (Kg)	Ownership	No.	Avg. no. of trips/ day	Manpower per vehicle		Avg. No. Served				Avg. Monthly Charge (BDT)				Avg. Income/m	NGO Name	NGO Fee/m	Garage Fee	Avg O&M Cost	Remarks
							Driver	Helper	HH	Commercial	Industrial	Medical	HH	Commercial	Industrial	Medical						

*Type: Van (V), Push Cart (PC), Hand Trolley (HT)

14. Information about other SWM equipment or vehicle:

Sl	Vehicle Number	*Type	Purpose of Use	Average Fuel consumption / day (Liter)	Avg. no. of hours of Operation/day	Procurement/ Receiving Date	Current Condition	No. of Manpower Involved		
								Driver	Helper	Worker

15. Information about Markets & Kutcha bazaar:

Type	Number	Total area
Market		
Kutcha bazar		

Sl	*Name of Market or Kutcha bazar*	Location	Ward No.	Daily Waste Generation (Kg)	
				Vegetable/ Food Waste (Organic/ Compostable)	Inorganic/ non-compostable

16. Total number of hospitals, clinics, public health centers etc.

Sl	Hospitals, Clinics, Public Health Centers (Name)	Location	Ward No.	Daily Waste Generation (Kg)		
				Vegetable/ Food Waste (Organic/ Compostable)	Inorganic/ non-compostable	Hazardous Waste

17. Do you have house to house waste collection program in your city? If yes, who is collecting it and since when and in which wards?

……

……

……

18. How solid waste is managed (collection, transportation & disposal)

……

……

……

19. How hospital / clinical waste is managed

……

……

……

20. Do you have compost plant or biogas plant or any other type of waste treatment/recycling plant in your city corporation? If yes, please mention the capacity of the plants, who is operating it & since when, and what is the process of operation?

……

……

……

21. What is the estimated amount of solid waste generation in your city? …… Tons

22. What is the quantity of solid waste collected by the city corporation? …… Tons

Composition	Collection/day (Tons)
Vegetable/Fruit/ Food	
Bones	
Paper	
Textile	
Plastic	
Grass	
Wood	
Coconut shell	
Leather	
Rubber	
Metals	
Glass/Ceramic	
Total	

23. What is the percentage of the collected waste that gets extracted for recycling?

By van drivers……% By waste pickers at dustbins or transfer stations……%

By waste pickers at the dumping site……%

Others (please specify) ……..%

24. Govt. or local govt. (public sector e.g., DPHE, LGED etc.) activities/ projects on SWM sector:

……

……

……

25. Names & activities/ projects of national, international and local NGOs working on SWM sector:

……

……

……

26. Private sector activities/ projects on SWM sector:

……

……

……

27. Do you have any mechanical workshop for repair of vehicles and equipments under your city corporation? If yes, please mention the types of equipments you have for repair and maintenance.

……

……

……

28. How the waste disposal site is being managed by the pourashava? Which facilities are available at the disposal site?

……

……

……

29. What type of personal protection equipment (PPE) is provided to which workers/van drivers by whom/which agency at which frequency?

……

……

……

30. Please fill up the Disposal Facility Inventory (Site visit – observation and KII with relevant officials)

Basic infrastructure (Yes √, No: x, N/A **and/or suitable information)**				
1. **Site selection**: Distance from flood plain, community and historical/archeological sites	< 500 meters	500 meters	>500 meters	
2. Age				
3. Design period				
4. Expected future life				
5. Distance from military and aviation service	< 20 km	20 km	>20 km	
6. Availability of buffer zone	< 500 meters	500 meters	>500 meters	
7. Prioritization of proposed site close to the existing site (Y/N)				
8. Stakeholders (<=40km) participation in decision making process of site selection				
9. **Facility:** Fencing and entrance gate **(Y/N)**	Fence	Gate		
10. Security to protect unexpected entrance (people, animal), (Y/N)				
11. Facility of excess road and quick exit after disposal (Y/N)	Quick access facility	Quick exit facility		
12. Control room/Office room (Y/N)	Control Room	Record keeping		
13. Environmental Laboratory (Y/N)				
14. Floodlight (Y/N)				
15. Occupation health safety of workers (Y/N)	Fresh water	Bath facility	Rest room	First Aid
16. Information of construction & operation plan; start and end	Construction Start	Construction End	Operation start	Operation End
17. **Specification of land filling:** Disposal, Dressing and compaction of waste	Dressing of waste	Compaction of waste		
18. Soil cover (Y/N)	Soil Cover	Thickness (Std. 7.5~10 cm)		
19. Protection for rainy season (e.g., steel plate)	Special Soil Cover	Thickness (40~65 cm)	Steel Plate	
20. Leachate collection system				
21. Leachate pond (lining)				
22. Leachate treatment	19 Important Quality Parameters Testing is urgent. Test result shall be collected and enclosed			
23. Post closure measures				
24. **Water Quality Parameters (GW within 50 meter)**	15 Important Water Quality Parameters Testing is urgent. Test result shall be collected and enclosed.			
25. **Air Quality Parameters: Facility (equipment) of gas collection and controlling**				

26. Measures to reduce the concentration of CH_4	
27. Gas burning facility	
28. Test result of Air Quality Parameters (SO_2 SPM, CH_4, NH_3, CO)	
29. Frequency of air quality testing	
30. Weighbridge	
31. National Grid Power supply	
32. Generator	
33. Car wash	
34. Water supply	
35. Toilet	
36. Drainage/rain water discharge facility	
37. Dumping plat form	
38. Cell arrangement	
39. Leachate Quality monitoring system	
40. Gas venting system	
41. Gas monitoring system	
42. Area (hectors)	
43. Accessibility	
44. Natural lining information	
45. Ground water condition	
46. Surface water condition	

47. Physical condition						
48. Environmental Acceptability	Social	SW	GW	Fire	Odor	Noise
49. **Existing operation**						
Procedure to track waste deliveries						
Record keeping system						
Reporting system						
Operation plan of disposal site (system of locating site)						

Equipment procured in Phase-1	
Number of staff and waste rate	
Environmental Control Plan (leachate, fire)	
Waste pickers number and activities	
Plan of monitoring on site waste picking and quantity of recyclables recovered	
50. Any other findings/ comments or remarks	

Annexure 2

Household Survey (HS): Questionnaire

For

Narayanganj City Corporation

This questionnaire must be filled in by a household member

Date of interview:/……/2019
Name of the interviewer
Area: **Narayanganj City Corporation**

Address:

Apartment No. (if applicable) Holding No.

House No. &/ Name Road No.

Type of House: a) Pucca b) Semi pucca c) Kacha d) Jhupri

Type of Use: a) Residential b) Mixed Use (Res/Commercial/Industrial)

Name of respondent:

Household information:

Serial no.	1 Resp	2 HH	3	4	5	6	7	8	9	10	11	12
age												
sex												
Educational level												
Profession												
Income/month												
Disease in last 1yr												
How many days remained sick in last 1yr												

Age
1) 0-4
2) 5-9
3) 10-14
4) 15-17
5) 18-34
6) 35-59
7) 60+

Sex
1) Male
2) Female

Educational level
1) Illiterate
2) Primary
3) High school
4) SSC
5) HSC/Diploma
6) Graduate
7) Masters
8) PhD

Profession
1) Service holder
2) Business
3) Worker
4) Consultant
5) Student
6) Housewife
7) Unemployed
8) Other

Income
1) Up to 5,000
2) 5,001 – 10,000
3) 10,001 – 25,000
4) 25,001 – 50,000
5) 50,001 – 100,000
6) Above 100,000

Disease in last 1yr

0) No disease
1) Diarrhea, dysenteries
2) Typhoid, paratyphoid
3) Worms
4) Malaria, dengue, chikungunya
5) Jaundice
6) eye infections
7) Scabies & other skin disease
8) Fever……
9) ……..……..
10) ……..……
11) ……..……...

Waste Related Information

1.	What type of waste is normally generated in your household?	a)	Kitchen (Fruit peel, Vegetable peel, Bread, Rice, Meat, Fish, tissue paper, dirty/food-mixed paper, dirty/blood-mixed cotton, animal wastes, meat bones, Fish bones etc.)	Kg %
		b)	Metal, cans, plastic, packaging items, containers, glass, bottles, bags, clothes, shoes, paper, cartons, paper-boxes, newspaper, books etc.	Kg %
		c)	Batteries, lamps, broken or out of order TV/PC/printer and toys, cords/cables, switchboard, screws, etc.	Kg %
		d)	Hazardous (medicine, used medical instruments (e.g. syringes, IV bags, tubing, and vials), sharp objects etc.)	Kg %
		e)	Other (Describe)	Kg %
2.	Who is responsible for waste disposal in your household?	a) b)	Family member Housemaid	c) Both (Describe)
3.	What do you use to store household waste?	a) b)	Bin/bucket Plastic bags	c) Other (Describe)
4.	Who collects waste in your neighborhood?	a) b)	Waste collector No one collects	c) Don't know
5.	Do you subscribe to a waste collection service?	a) b)	Yes No	
Applicable if they have subscribed to waste collection service				
6.	How long have you been subscribed to the waste collection service?	a) b)	Less 1 year 1 to 5 years	c) 6 to 10 years d) More than 10 years
7.	From where is your waste collected?	a)	Doorstep	b) Ground level of building
8.	When does the waste collector come to collect your waste?	a)	Morning, (____AM)	b) Afternoon, (_____PM) c) Evening, (_____PM)
9.	At what time do you dispose of your household Waste? (Put it in front of your door/take it to ground level)	a) b) c) d)	Morning, (____AM) Afternoon, (_____PM) Evening, (_____PM) Whenever waste collector comes and rings bell/whistles	
10.	Do you know what is done with your waste after the waste collector takes it?	a) b)	Yes (Describe) No	
11.	If occasionally the waste is not collected for any	a) b)	Throw out from the window Dump in the drain/street	

	reason, what do you do with waste?	c) Dispose at nearby dustbin d) I don't know, because I just dispose the waste at the ground level of my building. I never checked whether the waste was collected from there or not by the collector. e) If the answer is d, please ask the question to the caretaker or guards of the building, and fill up below:	
12.	How close is the nearest dustbin from your house?	a) Convenient distance to dispose of waste b) Too far away to dispose of waste c) Don't know where the dustbin is	
Applicable if they are not under any waste collection service or did not subscribe to waste collection service			
13.	How do you dispose of your waste?	a) Throw out from the window b) Dump in the drain/street c) Dispose at nearby municipal dustbin	
14.	How close is the nearest dustbin from your house?	a) Convenient distance to dispose of waste b) Too far away to dispose of waste c) Don't know where the dustbin is	
15.	When do you usually dispose of your waste?	a) Morning, (____AM) b) Afternoon, (_____PM)	c) Evening, (_____PM)
16.	Do you know what is done with your waste after you dispose it off?	a) Yes (Describe) b) No	
Applicable for all			
17.	Are you satisfied with the way waste is being managed/collected in your building?	a) Fully satisfied b) Partially satisfied c) Not that much satisfied d) Totally dissatisfied	e) No comments
18.	If not fully satisfied (answer to above q is b or c or d), give reasons	a) Waste collected at inconvenient time b) Waste not collected regularly c) Fees are too high d) Waste collector's behavior is not good e) Other (Describe)	
19.	Are you satisfied with waste management in your area?	a) Yes b) No c) No comments	
20.	Do you have any suggestions for improving waste management in your area?		

21.	How much do you currently pay for waste collection?	a) 20-50 BDT/month b) 51-100 BDT/month c) 101-200 BDT/month d) 201-500 BDT/month e) 501-1,000 BDT/month	f) > 1,000 BDT/month g) Nothing h) Don't know, part of service charge	
22.	What extra amount would you be willing to pay for waste collection if your current problems were completely eliminated?	a) 20-50 BDT/month b) 51-100 BDT/month c) 101-200 BDT/month d) 201-500 BDT/month e) 501-1,000 BDT/month	f) > 1,000 BDT/month g) Nothing	
23.	Do you keep any items separated from your household waste?	a) Yes b) No		
23a.	Type of item (first describe, if not mentioned, ask about paper, PET bottles, aluminum cans, electronics, metal items, other)	Method of storage (Bin/bag/ other)	Purpose of separation a) Reuse b) Resale c) Give to housemaid d) Give to caretaker	If resale, Sold to a) Ferry Wala b) Bhangari shop c) Other (Describe)
24.	Are you familiar with the term 'recycling'?	a) Yes (Describe) b) No (Surveyor should give brief description)		
25.	Do you know that compost can be made from organic waste?	a) Yes b) No		
26.	Would you be willing to use compost made from waste in your garden/potted plants?	a) Yes b) No (Describe reason)		
27.	If you were asked to segregate compostable organic waste for separate collection - would you be willing? (Examples of compostable waste: Yes - Fruit peel, Vegetable peel, Bread, Rice, Meat, Fish, tissue paper, dirty/food-mixed paper, dirty/blood-mixed cotton, animal wastes etc. No – Meat bones, Fish bones)	a) Yes b) No (Describe reason)		
27a.	If yes, what would you need to store this waste?	a) Type of container b) Type of material c) Size		

28.	Would you be willing to segregate inorganic recyclables for separate collection? If stored properly, these items can be sold by you or your maid or waste collector. (Examples of recyclables- Metal, cans, plastic, packaging items, containers, glass, bottles, bags, clothes, shoes, paper, cartons, paper-boxes, newspaper, books etc.)	a) Yes b) No (Describe reason)
28a.	If yes, what would you need to store this waste to be sold by you or your maid?	a) Type of container b) Type of material c) Size
28b.	If yes, what would you need to store this waste to be given to the waste collector?	a) Type of container b) Type of material c) Size
29.	Would you be willing to segregate e-waste for separate collection? If stored properly, these items can be sold by you or your maid or waste collector. (Examples of e-waste- Batteries, lamps, broken or out of order TV/PC/printer and toys, cords/cables, switchboard, screws, etc.)	a) Yes b) No (Describe reason)
29a.	If yes, what would you need to store this waste?	a) Type of container b) Type of material c) Size
29b.	If yes, what would you need to store this waste to be given to the waste collector?	a) Type of container b) Type of material c) Size
30.	Are you aware that certain types of waste can hurt the waste collectors or are hazardous to environment?	a) Yes (Describe items) b) No (Surveyor should describe which items)

31.	Would you be willing to segregate hazardous waste for separate collection? Examples of hazardous waste – medicine, used medical instruments (e.g. syringes, IV bags, tubing, and vials), sharp objects etc.	a) Yes b) No (Describe reason)
31a.	If yes, what would you need to store this waste?	a) Type of container b) Type of material c) Size
32.	Is there a garden or farm in the house?	a) Yes b) No
32a.	If yes, what type:	a) Vegetable/Fruits/Flowers b) Chicken/Birds/Cattle c) Fish
32b.	What do you do with the garden/farm waste?	
33.	Is your building connected to sewer line?	a) Yes b) No
33a.	If no, where the fecal sludge gets stored?	a) Septic tank b) Twin pits (with concrete rings) c) Single pit (with concrete rings) d) Dug pit e) No storage facility available, sludge goes directly to drain or canal or adjoining low lying area
33b.	If the above answer is a or b or c or d, please answer:	a) How often does the building owner empty the storage? b) Who empties the storage? c) How the owner finds the emptier? d) How much is paid for emptying each time?
34.	How do you rank your neighborhood on a scale of 1 to 10 for cleanliness?	
35.	What do you like about your neighborhood?	
36.	What do you dislike about your neighborhood?	
37.	Do you teach your children not to throw waste out in the streets/drains?	a) Yes (Describe) b) No c) No comments
38.	Have you ever received any training on waste management?	a) Yes (Describe type of training, who arranged) b) No

39.	Have you ever received any awareness material on waste management?	a) Yes (Describe type of material, who distributed) b) No
40.	What type of material/training will be useful in your opinion?	
41.	Do you need any Infrastructural support for doing proper waste management system?	
42.	Observation report by surveyor (Need to specify the requirements)	
43.	Additional Comments:	

Annexure 3

Questionnaire Survey for Commercial/Industrial Entities

Of

Narayanganj City Corporation

This questionnaire must be filled in by personnel of the Commercial/Industrial Entity

Date of interview: .../……/2019

Name of the interviewer

Area: **Narayanganj City Corporation**

Address:

Apartment No. (if applicable) Holding No.

Building No. &/ Name Road No.

Type of Building: a) Pucca b) Semi pucca c) Kacha d) Jhupri

Type of Use: a) Industrial b) Commercial c) Mixed Use *(Res/Comm/Indus)*

Name of respondent:

Information:

Age	Sex	Educational level	Profession	Income	Disease in last 1yr

Age	**Sex**	**Educational level**	**Profession**	**Income**
1) 0-4	1) Male	1) Illiterate	1) Service holder	1) Up to 5,000
2) 5-9	2) Female	2) Primary	2) Business	2) 5,001 – 10,000
3) 10-14		3) High school	3) Worker	3) 10,001 – 25,000
4) 15-17		4) SSC	4) Consultant	4) 25,001 – 50,000
5) 18-34		5) HSC/Diploma	5) Other	5) 50,001 – 100,000
6) 35-59		6) Graduate		6) Above 100,000
7) 60+		7) Masters		
		8) PhD		

Disease in last 1yr

0) No disease	4) Malaria, dengue, chikungunya	8) Fever……
1) Diarrhea, dysenteries	5) Jaundice	9) ……..……..
2) Typhoid, paratyphoid	6) eye infections	10) ……..……
3) Worms	7) Scabies & other skin disease	11) ……..……...

Total no. of staff: **Male:** **Female:**

Waste Related Information

1.	What type of waste is normally generated at your premise?	a)	Kitchen (Fruit peel, Vegetable peel, Bread, Rice, Meat, Fish, tissue paper, dirty/food-mixed paper, dirty/blood-mixed cotton, animal wastes, meat bones, Fish bones etc.)	Kg %
		b)	Metal, cans, plastic, packaging items, containers, glass, bottles, bags, clothes, shoes, paper, cartons, paper-boxes, newspaper, books etc.	Kg %
		c)	Batteries, lamps, broken or out of order TV/PC/printer and toys, cords/cables, switchboard, screws, etc.	Kg %
		d)	Hazardous (medicine, used medical instruments (e.g. syringes, IV bags, tubing, and vials), sharp objects etc.)	Kg %
		e)	Other (Describe)	Kg %
2.	Who is responsible for waste disposal at your premise?	a) b)	Male cleaner Female cleaner	c) Maid d) Other *(Describe)*
3.	What do you use to store waste?	a) b)	Bin/bucket Plastic bags	c) Other *(Describe)*
4.	Who collects waste in your neighborhood?	a) b)	Waste collector No one collects	c) Don't know
5.	Do you subscribe to a waste collection service?	a) b)	Yes No	
Applicable if they have subscribed to waste collection service				
6.	How long have you been subscribed to the waste collection service?	a) b)	Less 1 year 1 to 5 years	c) 6 to 10 years d) More than 10 years
7.	From where is your waste collected?	a)	Doorstep	b) Ground level of building
8.	When does the waste collector come to collect your waste?	a)	Morning, (____ AM)	b) Afternoon, (_____PM) c) Evening, (_____PM)
9.	At what time do you dispose of your waste? *(Put it in front of your door/take it to ground level)*	a) b) c) d)	Morning, (____AM) Afternoon, (_____PM) Evening, (_____PM) Whenever waste collector comes and rings bell/whistles	
10.	Do you know what is done with your waste after the waste collector takes it?	*a)* b)	Yes *(Describe)* No	
11.	If occasionally the waste is not collected for any	a) b) c)	Throw out from the window Dump in the drain/street Dispose at nearby dustbin	

	reason, what do you do with waste?	d) I don't know, because we just dispose the waste at the ground level of my building. I never checked whether the waste was collected from there or not by the collector. *e) If the answer is d, please ask the question to the caretaker or guards of the building, and fill up below:*	
12.	How close is the nearest dustbin from your premise?	a) Convenient distance to dispose of waste b) Too far away to dispose of waste c) Don't know where the dustbin is	
Applicable if they are not under any waste collection service or did not subscribe to waste collection service			
13.	How do you dispose of your waste?	a) Throw out from the window b) Dump in the drain/street c) Dispose at nearby municipal dustbin	
14.	How close is the nearest dustbin from your building?	a) Convenient distance to dispose of waste b) Too far away to dispose of waste c) Don't know where the dustbin is	
15.	When do you usually dispose of your waste?	a) Morning, (____AM) b) Afternoon, (_____PM)	c) Evening, (_____PM)
16.	Do you know what is done with your waste after you dispose it off?	a) Yes *(Describe)* b) No	
Applicable for all			
17.	Are you satisfied with the way waste is being managed/collected in your building?	a) Fully satisfied b) Partially satisfied c) Not that much satisfied d) Totally dissatisfied	e) No comments
18.	If not fully satisfied (answer to above q is b or c or d), give reasons	a) Waste collected at inconvenient time b) Waste not collected regularly c) Fees are too high d) Waste collector's behavior is not good e) Other *(Describe)*	
19.	Are you satisfied with waste management in your area?	a) Yes b) No c) No comments	
20.	Do you have any suggestions for improving waste management in your area?		

21.	How much do you currently pay for waste collection?	a) 20-50 BDT/month b) 51-100 BDT/month c) 101-200 BDT/month d) 201-500 BDT/month e) 501-1,000 BDT/month	f) > 1,000 BDT/month g) Nothing h) Don't know, part of service charge
22.	What extra amount would you be willing to pay for waste collection if your current problems were completely eliminated?	a) 20-50 BDT/month b) 51-100 BDT/month c) 101-200 BDT/month d) 201-500 BDT/month e) 501-1,000 BDT/month	f) > 1,000 BDT/month g) Nothing
23.	Do you keep any items separated from your waste?	a) Yes b) No	

23a.	Type of item *(first describe, if not mentioned, ask about paper, PET bottles, aluminum cans, electronics, metal items, other)*	Method of storage (Bin/bag/ other)	Purpose of separation a) Reuse b) Resale c) other (describe)	If resale, Sold to a) Ferry Wala b) Bhangari shop c) Other *(Describe)*

24.	Are you familiar with the term 'recycling'?	a) Yes *(Describe)* b) No *(Surveyor should give brief description)*
25.	Do you know that compost can be made from organic waste?	a) Yes b) No
26.	Would you be willing to use compost made from waste in your garden/potted plants?	a) Yes b) No *(Describe reason)*
27.	If you were asked to segregate compostable organic waste for separate collection - would you be willing?	a) Yes b) No *(Describe reason)*

	(Examples of compostable waste: *Yes - Fruit peel, Vegetable peel, Bread, Rice, Meat, Fish, tissue paper, dirty/food-mixed paper, dirty/blood-mixed cotton, animal wastes etc.* *No – Meat bones, Fish bones)*	
27a.	If yes, what would you need to store this waste?	a) Type of container b) Type of material c) Size
28.	Would you be willing to segregate inorganic recyclables for separate collection? If stored properly, these items can be sold by you or your maid or waste collector. *(Examples of recyclables- Metal, cans, plastic, packaging items, containers, glass, bottles, bags, clothes, shoes, paper, cartons, paper-boxes, newspaper, books etc.)*	a) Yes b) No *(Describe reason)*
28a.	If yes, what would you need to store this waste to be sold by you or your maid?	a) Type of container b) Type of material c) Size
28b.	If yes, what would you need to store this waste to be given to the waste collector?	a) Type of container b) Type of material c) Size
29.	Would you be willing to segregate e-waste for separate collection? If stored properly, these items can be sold by you or your maid or waste collector. *(Examples of* e-waste-*Batteries, lamps, broken or out of order TV/PC/printer and toys, cords/cables, switchboard, screws, etc.)*	a) Yes b) No *(Describe reason)*

29a.	If yes, what would you need to store this waste?	a) Type of container b) Type of material c) Size
29b.	If yes, what would you need to store this waste to be given to the waste collector?	a) Type of container b) Type of material c) Size
30.	Are you aware that certain types of waste can hurt the waste collectors or are hazardous to environment?	*a)* Yes *(Describe items)* b) No *(Surveyor should describe which items)*
31.	Would you be willing to segregate hazardous waste for separate collection? *Examples of hazardous waste – medicine, used medical instruments (e.g. syringes, IV bags, tubing, and vials), sharp objects etc.*	a) Yes b) No (*Describe reason)*
31a.	If yes, what would you need to store this waste?	a) Type of container b) Type of material c) Size
32.	Is there a garden or farm in the premise?	a) Yes b) No
32a.	If yes, what type:	a) Vegetable/Fruits/Flowers b) Chicken/Birds/Cattle c) Fish
32b.	What do you do with the garden/farm waste?	
33.	Is your building connected to sewer line?	a) Yes b) No
33a.	If no, where the fecal sludge gets stored?	a) Septic tank b) Twin pits (with concrete rings) c) Single pit (with concrete rings) d) Dug pit e) No storage facility available, sludge goes directly to drain or canal or adjoining low lying area
33b.	If the above answer is a or b or c or d, please answer:	a) How often does the building owner empty the storage? b) Who empties the storage? c) How the owner finds the emptiers? d) How much is paid for emptying each time?

34.	How do you rank your neighborhood on a scale of 1 to 10 for cleanliness?	
35.	What do you like about your neighborhood?	
36.	What do you dislike about your neighborhood?	
37.	Do you teach your children not to throw waste out in the streets/drains?	a) Yes *(Describe)* b) No c) No comments
38.	Have you ever received any training on waste management?	a) Yes *(Describe type of training, who arranged)* b) No
39.	Have you ever received any awareness material on waste management?	a) Yes *(Describe type of material, who distributed)* b) No
40.	What type of material/training will be useful in your opinion?	
41.	Do you need any Infrastructural support for doing proper waste management system?	
42.	Observation report by surveyor *(Need to specify the requirements)*	
43.	Additional Comments:	

Annexure-4

Photographs of all HH surveys and site visits

Picture: Survey Team

Picture: Site Visit

Picture: Site Visit

Picture: Site Visit

Picture: Waste Dumping Point at Ward-15

Picture: Dumping Ground

Picture: Waste Dumping Site at Ward-04

Picture: Waste Collection Equipment

Picture: Compost Plant

Picture: Site Visit

Picture: Site Visit

Picture: Open Dumping Point

Picture: Site Visit

Picture: Site Visit

Picture: Drone Survey

Picture: Drone Survey

Picture: Drone Survey

Picture: Drone Survey

Picture: Drone Survey

Picture: Drone Survey

Picture: Training for Survey

Picture: Household Survey

Picture: Household Survey

Picture: Household Survey

Picture: Household Survey

Picture: Household Survey

Picture: Household Survey

Annexure 5

Polythene Bag Distribution and Collection Survey

Questionnaire and Photographs

Household Data Collection and Waste Composition Data Sheet:

Format for Recording Data for Daily Generation Rate of Solid Waste at High Income Area in .....

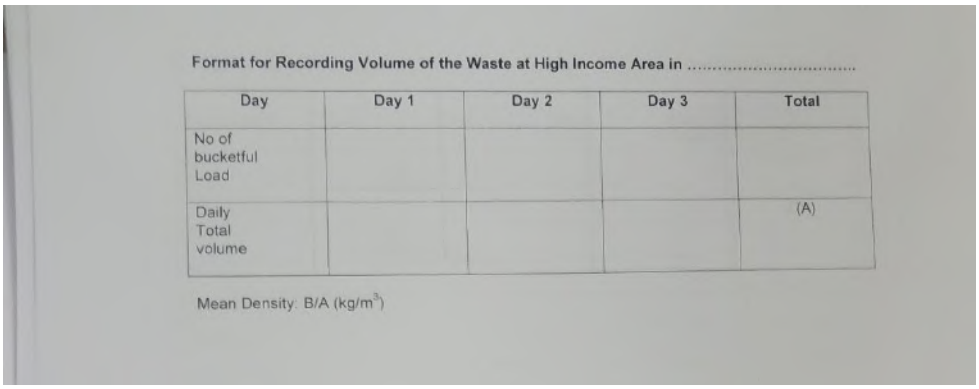
Sl	Address	Family Size	Day 1	Day 2	Day 3	Total
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						
9.						
10.						
Total		A				B

Waste Generation Rate (kg/person/day): B/A/3

Format for Recording Data for Physical Composition of Waste at High Income Area in .....

Composition	Day1	Day2	Day3	Total Weight	%
Vegetable, Food				a	a/A X100
Bones				b	b/A X100
Paper				c	
Plastic					
Styrofoam					
Tetra Pack					
Textile, Rags, Jute					
Glass					
Grass, Leafs, Wood					
Leather, Rubber					
Metals					
Ceramic					
Soil, Ash					
Medicine, Chemicals					
Miscellaneous					
Total				A	100

Waste Density Calculation Sheet:



Format for Recording Volume of the Waste at High Income Area in .....

Day	Day 1	Day 2	Day 3	Total
No of bucketful Load				
Daily Total volume				(A)

Mean Density: B/A (kg/m^3)

Detail waste generation information of high, middle and low-income groups households of Narayanganj City Corporation:

High Income Group

High Income Group									
Sl. No	Address	Family Size	Beg No	Day - 1	Day - 2	Day - 3	Total	Average (gm.)	Waste Generation (gm.) Per Person/per day/Per Household
1	55/B Poddo City Plazza - 1, 10/A	6	91	3805	3207	3927	10939	3646.33	687.98
2	55/B Poddo City Plazza - 1, 10/B	7	92	2810	3055	2185	8050	2683.33	506.28
3	55/B Poddo City Plazza - 1, 10/C1	2	93	3085	3501	2987	9573	3191	602.07
4	55/B Poddo City Plazza - 1, 10/C2	4	94	3010	2789	3129	8928	2976	561.50
5	55/B Poddo City Plazza - 1, 10/D	3	95	2530	2270	2001	6801	2267	427.73
6	55/B Poddo City Plazza - 1, 10/E	12	96	2285	3135	1764	7184	2394.66	451.82
8	55/B Poddo City Plazza - 1, 9/D	3	98	2000	1923	1788	5711	1903.66	359.18
9	55/B Poddo City Plazza - 1, 9/E	7	99	2090	2965	1890	6945	2315	436.79
10	55/B Poddo City Plazza - 1, 9/F	5	100	2505	2898	2198	7601	2533.66	478.05
Total		49	Total						4511.44
Average Family Size		5.44	Average waste generation (gm.) per person per day						501.27

Middle Income Group:

Middle income group									
Sl. No	Address	Family Size	Beg No	Day - 1	Day - 2	Day - 3	Total (gm.)	Average (gm.)	Waste Generation (gm.) Per Person/per day/Per Household
1	55/B Poddo City Plazza - 1, 8/A	4	51	3140	1870	1639	6649	2216.33	477.77
2	55/B Poddo City Plazza - 1, 8/B	4	52	4880	1920	1844	8644	2881.33	621.12
3	55/B Poddo City Plazza - 1, 8/C	5	53	1660	2026	1580	5266	1755.33	378.39
5	55/B Poddo City Plazza - 1, 7/A	6	55	6350	1877	1567	9794	3264.66	703.76
6	55/B Poddo City Plazza - 1, 7/C	4	56	1030	1678	1542	4250	1416.66	305.38
8	55/B Poddo City Plazza - 1, 7/F	5	58	3855	1950	1725	7530	2510	541.07
9	55/B Poddo City Plazza - 1, 6/A	6	59	665	700	1000	2365	788.33	169.94
10	55/B Poddo City Plazza - 1, 6/B	7	60	4305	1880	1509	7694	2564.66	552.86
12	55/B Poddo City Plazza - 1, 6/D	7	66	1205	1345	1567	4117	1372.33	295.83
13	55/B Poddo City Plazza - 1, 6/E	6	67	2265	1660	1810	5735	1911.66	412.09
14	55/B Poddo City Plazza - 1, 6/F	4	68	2745	1560	1887	6192	2064	444.93
15	55/B Poddo City Plazza - 1, 5/A	4	69	1355	1290	1190	3835	1278.33	275.56
19	55/B Poddo City Plazza - 1, 5/E	4	73	1650	1270	1456	4376	1458.66	314.44
20	55/B Poddo City Plazza - 1, 5/F	3	74	5160	2190	1500	8850	2950	635.92

21	55/B Poddo City Plazza - 1, 4/A	6	75	2080	1835	1878	5793	1931	416.26
22	55/B Poddo City Plazza - 1, 4/B	7	76	4870	1944	1860	8674	2891.33	623.28
23	55/B Poddo City Plazza - 1, 4/F	4	77	3735	1675	1540	6950	2316.66	499.40
24	55/B Poddo City Plazza - 1, 4/E	5	78	1375	1567	1265	4207	1402.33	302.29
25	H. B. + City Plazza - 1, 3/F	8	79	3845	1789	1685	7319	2439.66	525.91
26	H. B. + City Plazza - 1, 4/F1	5	80	1640	1432	1546	4618	1539.33	331.83
28	H. B. + City Plazza - 1, 4/F3	7	82	1085	1289	1178	3552	1184	255.23
29	H. B. + City Plazza - 1, 4/F4	4	83	4515	1875	1569	7959	2653	571.90
30	H. B. + City Plazza - 1, 5/F1	4	84	2895	1990	1895	6780	2260	487.18
31	H. B. + City Plazza - 1, 6/F1	3	85	1325	1159	1098	3582	1194	257.38
32	H. B. + City Plazza - 1, 6/F2	5	86	775	1075	1070	2920	973.33	209.82
34	H. B. + City Plazza - 1, 2/F1	4	88	920	1009	1209	3138	1046	225.48
35	H. B. + City Plazza - 1, 2/F2	3	89	1995	1598	1725	5318	1772.66	382.13
36	H. B. + City Plazza - 1, 2/F3	5	90	3855	2165	2010	8030	2676.66	577
Total		139	Total						11794.29
Average Family Size		4.96	Average waste generation (gm.) per person per day						421.22

Low Income Group:

Low Income Group									
Sl. NO	Address	Family size	Bag No	Day- 1	Day - 2	Day - 3	Total (gm.)	Average (gm.)	Waste Generation (gm.) Per Person/per day/Per Household
1	Dipok chowdury	4	61	1210	1011	1324	3545	1181.66	273.21
2	Anjoly chowdury - 1	4	64	915	890	1420	3225	1075	248.55
3	Gonesh chowdury	4	63	1135	965	1025	3125	1041.66	240.84

4	Chan tara	3	62	1385	895	1547	3827	1275.66	294.95
5	Muktar hosen	4	1	875	967	990	2832	944	218.26
6	Bijoy chandro das	2	2	1740	1010	1287	4037	1345.66	311.13
7	Anjoly chowdury - 2	5	3	1560	1280	1375	4215	1405	324.85
8	Hafiza	5	4	1030	925	880	2835	945	218.49
9	Shimu chowdury	4	5	1730	1459	1288	4477	1492.33	345.04
10	Hema chowdury	3	6	1275	1345	1197	3817	1272.33	294.18
11	Shilpi	1	7	556	605	765	1926	642	148.43
12	Pinky	7	8	1850	1689	1500	5039	1679.66	388.36
13	Shima chowdury	3	9	1060	1245	1176	3481	1160.33	268.28
14	Lashu chowdury	3	10	2855	2535	2789	8179	2726.33	630.36
15	Lipi	10	11	4280	2989	3299	10568	3522.66	814.48
16	Yesmin	5	12	2225	1824	1565	5614	1871.33	432.67
17	Nazma	3	13	1785	1235	1090	4110	1370	316.76
18	Happy	5	14	1910	1995	1456	5361	1787	413.17
19	Nur jahan	7	15	4355	3096	2966	10417	3472.33	802.85
21	Lotifa	6	17	2475	2505	2368	7348	2449.33	566.31
22	Jakir hosen	7	18	2225	2060	2529	6814	2271.33	525.16
23	Porimol	4	19	1678	1545	1818	5041	1680.33	388.51
24	Momota rani	5	20	1020	1236	1099	3355	1118.33	258.57
25	Basona sorkar	5	21	2200	1890	1230	5320	1773.33	410.01
26	Sumon mondol	2	22	1990	2004	1745	5739	1913	442.31
27	Bedena mondol	4	23	1470	1433	1235	4138	1379.33	318.92
28	Horidasi mondol	3	24	1035	1128	1200	3363	1121	259.19
29	Komola chakroborti	3	25	2030	1291	1070	4391	1463.66	338.42
30	Rekha rani das	6	26	1895	2125	1995	6015	2005	463.58
31	Lota mondol	3	27	1245	1387	1250	3882	1294	299.19
32	Lipi aktar	3	28	1490	1590	1275	4355	1451.66	335.64
33	shopon chondra mondol	6	29	1870	1560	1660	5090	1696.66	392.29
34	Lokki	6	30	865	1010	988	2863	954.33	220.65
35	Rajia begom	5	31	1565	1705	1678	4948	1649.33	381.34

37	Tulsi ghos	5	32	790	899	1090	2779	926.33	214.18
38	Meghia	4	33	1530	1567	1420	4517	1505.66	348.13
Total		159	Total						13147.44
Average Family Size		4.41	Average waste generation (gm.) per person per day						365.20

Average Waste Generation rate per Person per day in NCC:

Income Group	Average Family Size	Average Waste Generation rate per Person	Average Waste Generation Rate
High Income Group	5.44	501.272	429.234
Middle Income Group	4.964	421.224	
Low Income Group	4.416	365.206	
Total Permanent Resident of Narayanganj City Corporation	100,000,00		
Total Household Waste Generation per Day	429.234 Tons		

Bucket Information: Volume Calculation/Density Calculation/ Waste Composition:

	Amount of Perishable Waste (gm.)	Amount of Plastic/Polythene/ Non-perishable Waste (gm.)	Amount of Hazardous Waste (gm.)
Bucket 1	3425	1285	1425
Bucket 2	4855	1335	
Bucket 3	2825	1030	
Bucket 4	3775		
Total amount for 15 beg	14880	3650	1425
Total amount for 100	99200	24333.33	9500
Volume of the Bucket	0.0122 m^3		
Density (kg/m^3)	8131.148	1994.536	778.6885
Waste Composition (%)	74.56778	18.29116	7.141067

Information about distributed, collected and missing number of Beg:

1st day scenario:

Low Income Group:

Distributed number of beg: 40

Collected number of beg: 36

Missing number of beg: 04

Middle Income Group:

Distributed number of beg: 36

Collected number of beg: 28

Missing number of beg: 08

High Income Group:

Distributed number of beg: 10

Collected number of beg: 09

Missing number of beg: 01

Weight of Bucket

Red: 350 gm

Blue: 350 gm

Diameter at top: 26 cm

Diameter at bottom: 23 cm

Height of the Bucket: 26 cm (need to check)

Average Diameter: (26+23) = 49 cm

Radius: (49/4) = 12.22 cm or 0.1222 m

Volume V: 3.1416*0.12222*0.12222* 0.26 = 0.0122 m^3

Picture of Polythene Beg Distribution and Collection Survey

Picture: Polythene beg distribution in the high-income group household

Picture: Polythene beg distribution in the middle- income group household

Picture: Polythene beg distribution in the low-income group household

Picture: Preparation to collect distributed polythene beg

Picture: Collection of distributed polythene beg

Picture: Preparation to measure the collected waste sample

Picture: Sample measurement and analysis

Picture: Sample measurement and analysis by the experts

Picture: Picture of collected sample (polythene beg)

Picture: Picture of collected sample (polythene beg)

Picture: Waste composition, weight, volume and density measurement of the collected sample

Picture: Waste composition, weight, volume and density measurement of the collected sample

Annexure 6

Photograph of Warehouse of Broken Materials


Figure: Picture of warehouses of NCC area beside Narayanganj Rail Station and Nim Chasra


Figure: Textile or Cloth wastage and Picture of Broken materials beside Narayanganj Rail Station


Figure: Plastic Waste at Nim Chasra


Figure: Picture of Leather and Hazardous Waste

Annexure 7

Open Dumping Point and Photograph

Table: List of visited open dumping points

Location Name of open dumping point	Wand Number	Type of Area	Approx. Area (sq. feet)	Amount of waste	
				Unit: Number of Loaded Truck (3 ton)	Amount of Waste (Unit: Ton)
Nitaiganj Mor	18	Commercial	12’/6’	1	3
Nulua Road (Bongobondu extension Road, Motin Shaber Bari, beside Kamarer Shop	18	Commercial	5’/5’	1	3
Nitaigang Mor, boldeb Temple	15	Commercial	8’/6’	1/2	1.5
Nitaiganj, in front of Somrat Garments	15	Commercial	8’/5’	4	12
DIT, Jonota Super Market	15	Commercial	5’/6’	1	3
In front of F Rahman Super Market	15	Commercial	5’/7’	1	3
Ukil Para Mor	14	Commercial	8’/10’	2.5	7.5
Flower Bazar Mor	14	Commercial	8’/6’	3	9
Beside Popular Clinic	13	Commercial	8’/10’	2.5 (Evening ½ Truck)	7.5
Beside Hokers Market	13	Commercial	5’/7’	2.5 (Evening ½ Truck)	7.5
Children Park Sport	12	Residential	5’/6’	1	3
Officer’s Quarter, Khanpur	12	Commercial	10’/8’	1.5 (Evening ½ Truck)	4.5
Beside Borofcall Field	11	Commercial	5’/6’	1	3
Beside Fire Service Mor	11	Residential	10’/8’	1/2	1.5

M. Sarkas Mor	11	Industrial and Commercial	12’/10’	1	3
Beside Pathantoli Bazar Mosjod	10	Residential, Industrial and Commercial	20’/6’	1	3
Beside Metro Cinema Hall	13	Commercial	5’/6’	1/2	1.5
Beside Jahaj Office	13	Residential and Commercial	10’/12’	2	6
Beside 1 no. rail gate	15	Commercial	5’/6’	1	3
Beside Chamber Road	15	Commercial	5’/7’	2	6
Beside Amina Monjil	17	Residential	12’/8’	1	3
Beside Akhrar Mor	16	Commercial	15’/5’	1/2	1.5
Beside Jim Khana Road	17	Residential	15’/12’	1	1.5
Total (23)				32 (Approx.)	97.5 (Approx.)
Total (85)				118 (Approx.)	340 (Approx.)

Map 1: Map of the visited open dumping site

Picture of Open Dumping Points of NCC

Picture: Preparation for ODP Visit

Picture: Nitaiganj Mor

Picture: Nulua Road

Picture: Boldeb Temple Mor

Picture: Beside Somrat Garments

Picture: Beside Jonota Super Market

Picture: Beside Rahman Super Market

Picture: Beside Jonota Super Market

Picture: Ukil Para Mor

Picture: Flower Bazar Mor

Picture: Beside Popular Clinic

Picture: Beside Hokers Market

Picture: Beside Children Park Sport Field

Picture: Beside Officer's Quarter, Khanpur

Picture: Beside Borofcall Feild

Picture: Beside Fire Service Mor

Picture: Beside M. Sarkers Mor

Picture: Beside Pathantoli Bazar Mosjod

Picture: Beside Metro cinema Hall

Picture: Beside Jahaj Office

Picture: Beside 1 no. rail gate

Picture: Beside Chamber Road

Picture: Beside Amina Monjil

Picture: Beside Akhrar Mor

Picture: Beside Jim Khana Road

Picture: Beside Jim Khana Road

Picture: Industrial and Medical Waste

Picture: ODP Beside Medical

Picture: Commercial Waste

Picture: Road Waste

Annexure 8

Muza Map and Photograph of Jhalkuri Landfill Site

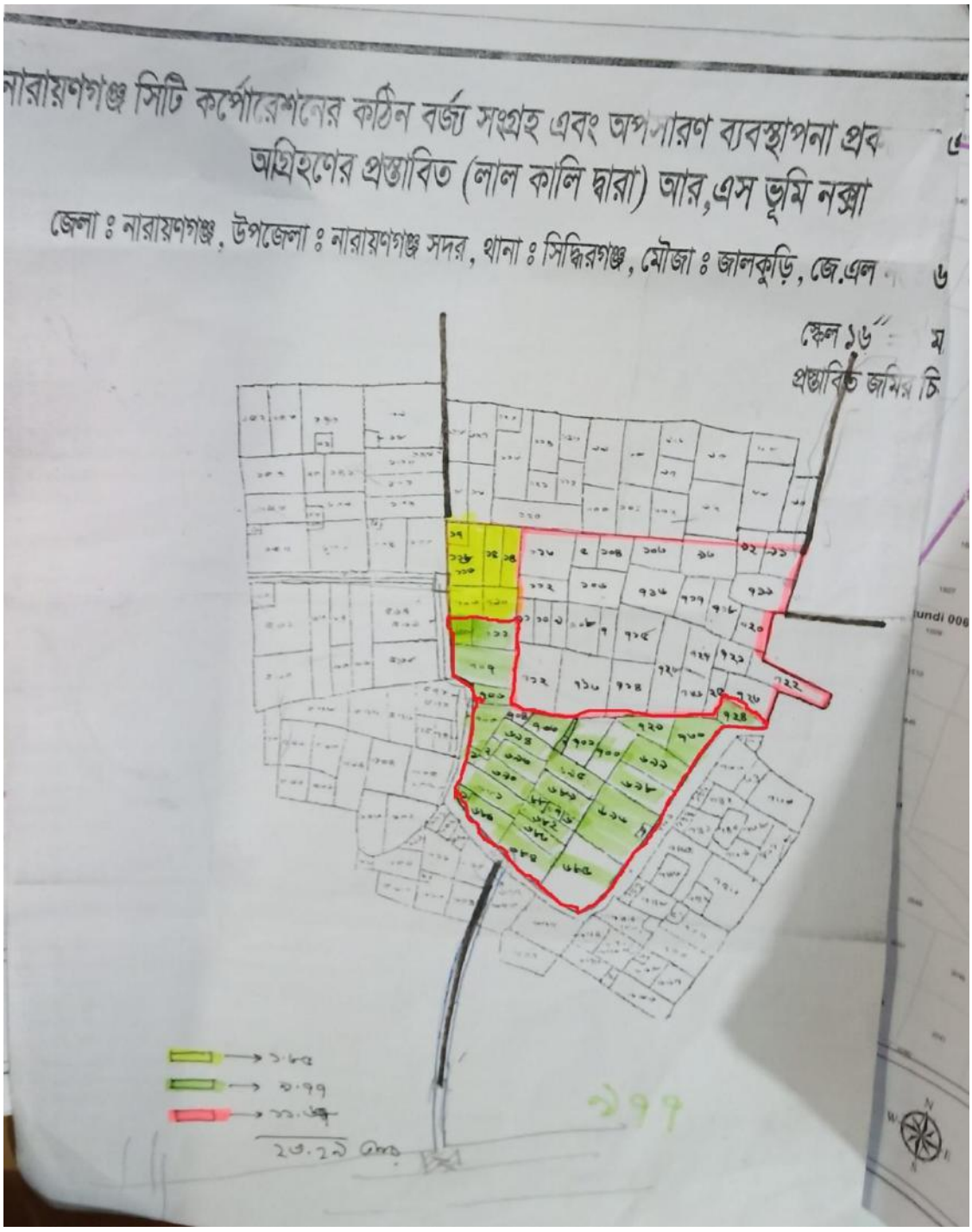


Figure: Muza map of designated land for waste to energy plan marked with red color (Source: NCC survey department)

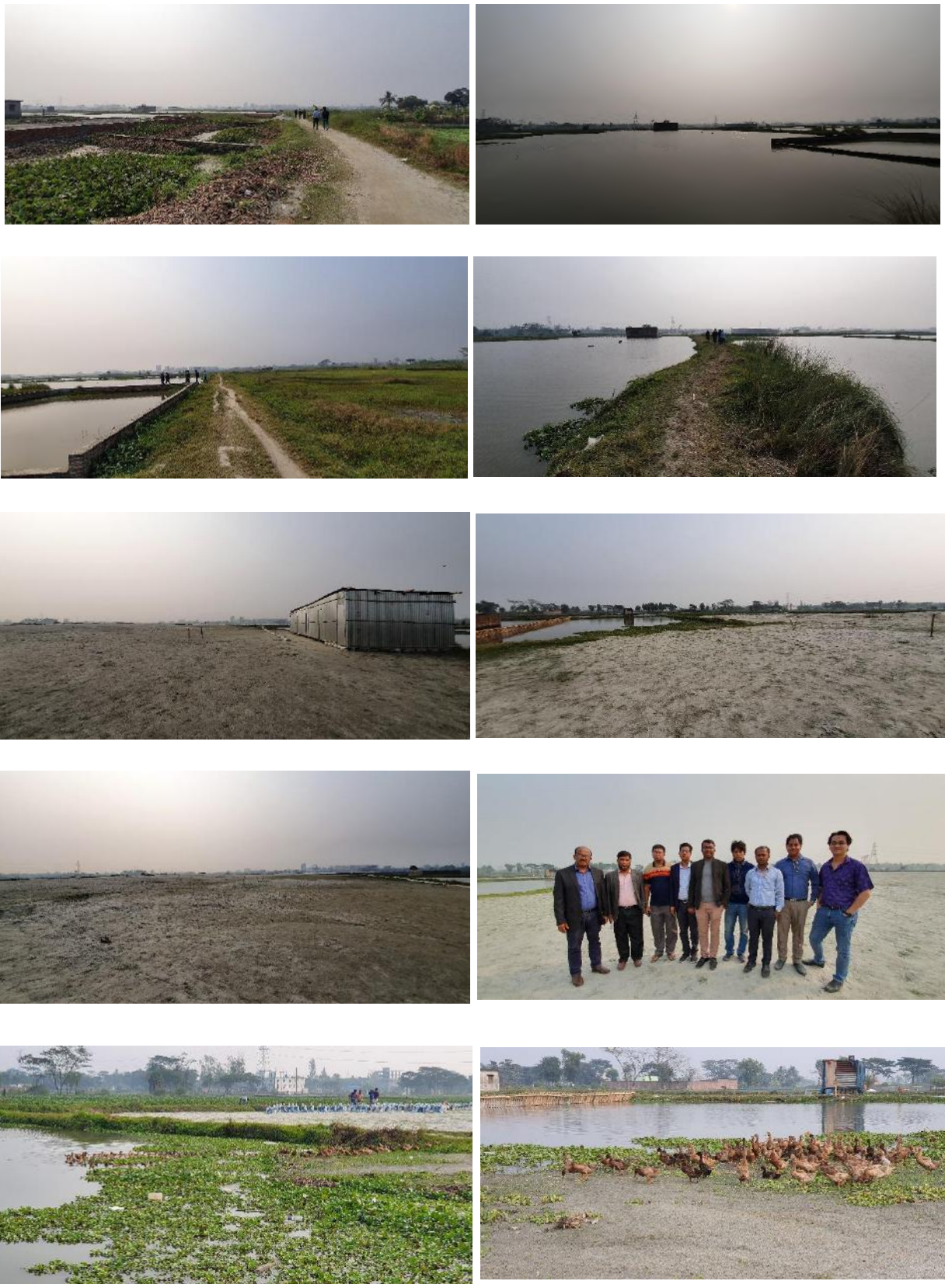


Figure: Photograph of jhalkuri Landfill Site of NCC

Annexure 9

Photograph of Jessore SWM Plant Visit

Picture: SWM Site Visit_Jossore

Picture: SWM Site Visit_Jossore

Picture: SWM Site Visit_Jossore

Picture: SWM Site Visit_Jossore

Picture: SWM Site Visit_Jossore

Picture: SWM Site Visit_Jossore

Picture: SWM Site Visit_Jossore

Picture: SWM Site Visit_Jossore

Picture: SWM Site Visit_Jossore

Picture: SWM Site Visit_Jossore

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Picture: SWM Site Visit_Jossore

Picture: SWM Site Visit_Jossore

Picture: SWM Site Visit_Jossore

Picture: SWM Site Visit_Jossore

Picture: SWM Site Visit_Jossore

Annexure 10

General Information of Waste Management Department of NCC

Narayanganj City Corporation

Waste Management Data/2019-2020

Narayanganj City Corporation belongs Narayanganj, Kadamrsul and Shiddirgonj area.

Amount of daily generated waste (Including household waste): 500 tons

The amount of daily disposed waste: 450 tons

The amount of daily disposed household waste by **NGO/CDC**: 40 tons

Percentage of disposed waste in NCC: 94 %

Temporary open waste dumping points in NCC: 80-85

Number of total garbage truck in NCC: 22

Number of garbage truck (03 ton): 19 and number of garbage truck (05 ton): 03

Total number of sweepers: 867

Every day dirt or garbage clearing time: 06.00 am to 10.00 am

Sweeper's payment scale per day:-

Serial no.	Position Name	Regular salary
01	Sweep, Dom and Latrine man	135/-
02	Sweep and Trolley man	175/-
03	Drain man	175/-
04	Trolley man	175/-
05	Truck leaver	250/-

Clinical/Hospital Waste Management:-

Total number of hospital: 02

Total number of clinic and diagnostics center: 55

Amount of waste from Clinic and Diagnostics center (Per day): 100 kg from 3 ton of total waste

[B: N: The solid waste from clinic and diagnostics center transports by "Prijom Bangladesh" and also dispose by "Prijom Bangladesh".

Total Number of NGO/CDC to manage household waste: 18

- 18 wards out of 27 are covered by Waste Management Department of NCC and rest of them (9 Wards of Kadamrsul) are in the process of SWM.
- In 2006, the Department of Environment established a compost plant at Ponchhoboti. Mega Ltd is responsible for this compost plant. They are producing 22 tons/day organic fertilizer from the compost plant.
- Narayanganj City Corporation has 23 acres land in Jhalkuri Dashpai area (Ward 09). 10 acres land will be used to prepare an electric power plant (Waste to Energy) of 5MW. There needs 500 tons waste per day to run this power plant project. 2 acres land will be used for Fecal Sludge Management by WSUP (Water and Sanitation for Urban Poor). Rest of the land will be used for sanitary dumping site.

Data from Waste Management Department of NCC:

Sl. No	Subject	Data
01	City Corporation area (square km)	72.43 sq. km
02	Total Population of Narayanganj City Corporation area	20 Million
03	Total number of Ward	27
04	Total amount of daily generated waste (Metric Ton)	400
05	Percentage of area covered by Waste Management Department NCC	94%
06	**Waste collection/management method:-**	
	a) Do they collect waste from household or institutions or others?	Yes
	b) Do they collect waste by using dustbin?	Yes
	c) Above both methods are running or not?	Yes
	d) Clinical/medical waste management method	
	e) Households/ organization septic tanker dirt removed method	
07	Are perishable and nonperishable waste collected separately or not?	No
08	a) Is there any Land fill site in NCC? b) If have, is it enough or not?	No

09	Method to produce organic fertilizer from perishable waste and their daily production and usability	Daily 22 ton organic fertilizer is produced
10	Waste treatment plant management	No
11	a) Is there any project taken for WM? If yes, what is the current situation of that project? b) Budget of that project? c) Is there any possibility for coming up new project? If yes, what is the amount of project budget? What are the major components of that Project?	Running 5 megawatt electricity production plant Jalkuri, Dospie area ward no 09
12	Is there any separate unit for waste management in NCC? If you have, describe it in brief?	No
13	**manpower/population and vehicles/machinery engaged in WM**	
	a) Number of employee?	02
	b) Number of assistant employee?	20
	c) Number of cleaning staff?	900
	d) Number of garbage truck?	21
	e) Number of waste collection van?	12
	f) Number of excavator?	5
	g) Other vehicles - machinery?	1. Vacuum tank 03 2. Pay – loader 10 3. Wheel douser 03

Short Term and Long Term Plans for Waste Management of NCC:

Serial No	Subject	Information
01	short-term work plan of waste management for the next 3 years	* Sanitary Landfill Site development * 3- R (Reduce, Reuse, Recycle) polices development and implementation * Purchase modern waste transport vehicle * Development of Secondary Transfer Station * Implementation of separately waste collection scheme from source

02	Long -term work plan of waste management for the next 3 years	* Sanitary Landfill Site development * 3- R (Reduce, Reuse, Recycle) polices development and implementation * Purchase modern waste transport vehicle * Development of Secondary Transfer Station * Implementation of separately waste collection scheme from source * Ensure technical and adequate manpower for Waste Management Department
03	Miscellaneous issues related to waste management	* Provide regular training on WM * Increase in institutional and professional capacity

Challenges and Recommendations of Waste Management Department of NCC:

Challenges in Waste Management:

01) Inadequate manpower structure

02) Inadequate vehicles and machinery

03) Secondary stations and sanitary landfill no longer available

04) Problems in household waste management and clinical waste removal

05) Inefficiency of the WM workers

06) The job of the lower performers is at risk

07) Inadequate technology and advanced technology

08) Running waste management activities in a simple and unplanned way

09) Budget shortages in waste management

10) Lack of social awareness on waste management

11) The institutional legal framework on waste management is insufficient

12) FSM (No drainage).

Initiatives to tackle waste management challenges:

01) Adequate manpower must be increased

02) Secondary stations and sanitary land fill should be constructed

03) Awareness and incentive program should be adopted for public awareness of waste management.

04) The institutional legal framework for the management of waste must be developed

05) 3-R policies need to be implemented

06) FSM (Sewage system) and a sound implementation

07) Waste management should increase the budget allocation

08) The number of modern vehicles and equipment employed for waste management should be increased

09) Sweepers or lower ranked workers need to ensure about their jobs.

Recommendation: A well organized and modern WM master plan should be formulated on waste management and implementation of the plan accordingly to improve the current WM system.

List of Waste Management NGOs and CDCs of NCC:

Sl. No	NGOs and CDC	Working area	Number of van	Expiration Date	Comment
01	Sahebpara Development Committee (01712634311) MD. Mobaruk Hossan Khan Shahabpara, Sidhergonj, Narayangonj	02 no ward	10	30/08/2018	Applying for renewal and 25,000 taka pay-order was submitted
02	Harun ar rosid, Treasurer of Bangladesh Freedom Fighter Welfare and Rehabilitation Society Shanerpar, Siddhigonj, Narayongonj	03 no ward (Partly)	05	31/08/2017	
03	MD. Shohel Rana President, "Rasulbagh Udayan Youth Association" Rosulbagh, Sanerpara Siddhigonj, Narayangonj	03 no ward (Rasulbagh and Mukte Nogor)	04	31/07/2018	Sonali Bank Limited: Nitaigonj branch, Narayangonj. Pay Oder NO-POC-8661150 Date- 31/07/2017 25,000 taka pay-order was submitted
04	MD. Ounce Ali Shojib In Conductive consciousness Kodomtoli, Admoji Nogor, Siddhigonj, Narayangonj	07 no ward	06	31/05/2018	01724573970
05	MD. Roni and MD. Mosthofa Service Association Jalkuri West para, Siddhigonj, Narayangonj.	08 no ward (Partly)	07	31/10/2017	
06	Rima Akter Madder tax Army Store Jalkuri West Para, Weaving, Siddhigonj, Narayangonj	08 no ward (Partly)	02	31/03/2018	
07	Ahsan Habib (President) Sirajul Islam (Secretary) A co-operative society, Narayangonj	09 no ward	06	30/11/2018	Agrani Bank Ltd. Bongobondhu Road C. R. R. P branch, Narayangonj Pay Oder NO-POA-0750798 Date-09/08/2017 25,000 taka pay-order was submitted
08	MD. Imran Hassan (Emon) Social Welfare Development Forum 260, Godnail, Arambagh Narayangonj	10 no ward	06		Counselor sir's oral instructions
09	Abdul Jabber Director of Public Service	11 no ward	08	31/12/2015	AL-Amin 01685035496 He works

	29, Bongobondhu Rode Narayangonj				
10	Sahida Hossain Sweety Secretary-General, Aid Bangladesh Chanmari, Narayangonj.(01673419933)	12 no ward	13	31/08/2017	
11	MD. Habibur Rahaman Mamun, Executive Director Ankur Health and Education Development Society, 126/6 Chanmare, Narayangonj	13 no ward	23	09/08/2017	
12	Kanchon Sen Vice-president(01919403507) C.D.C No-01-04-03 South Rally Gardens, Narayangonj	14 no ward	11		Related ward Councilor renowned at the behest of Mahomed
13	C. G. Committee (Tran Bazar From Bongsal)	15 no ward (Partly)	06	01/07/2019	
14	Achia Khanam Sumi Buriganga Cluster Committee (CDC Town Federation) 316 West Devogh, Narayangonj	16 no ward	09	31/10/2018	Jonota Bank Limited: Syed Ali Chamber Branch Narayangonj Pay Oder NO-POB-0810451 Date- 15/10/2017 25,000 taka pay-order was submitted
15	Salma Runa Magna cluster Community Development committee C.D.C. No-1108037 U.P.P.R.P	17 no ward	05		
16	MD. Joinal Abadin Sitolokkha Cluster Committee-03 Narayangonj.(01818703053)	18 no ward	05		
17	MD. Al- amin, President of the Port Public Service Association Welfare Service Company, Narayagonj	21 no ward	02	31/06/2017	
18	MD. Niamot Ullha President Sirajuldoilla Club, Bondr, Narayangonj	22 no ward	09	09/04/2018	Applying for renewal 25000 Taka Pay Oder Submitted
19	Selina Mahamuda Masuma Bandar Upazila Women's Cooperative Society Ltd. 128/1 Wilson Road, Nobigonj, Narayangonj.	23 no ward	06	31/08/2016	

Name of current designated driver and their working area of waste management department of NCC:

Siddhirganj Area

Serial No	Driver Name	Diver phone Number	Ward No
O1	MD. Nijamuddin	01684556353	01, 02, and 03 no ward
02	MD. Ridoy	01939853188	04, 05, and 06 no ward
03	MD. Noion	01992420772	07, 08, and 09 no ward

Kadamrsul Area

Serial No	Driver Name	Diver phone Number	Ward No
01	Nur MD. Bokul		21and 22 no ward (Partly)
02	MD. Abbul Bashar	01681262381 01921064596	19,20 no ward 21 no ward (Partly)
03	MD. Feroz		23 no ward
04	MD. Ibrahim		24, 25, 26, and 27 no ward

Comment: There are 1 payloads in the area. All the garbage is removed with the combination of pay loaders and track workers.

Pay loader Driver: 01) MD. Masud (19 no ward – 27 no ward).

Narayanganj Area

Serial No	Driver Name	Diver phone Number	Area of Action	Ward No
O1	MD. IQBAL	01835537417	AM Circus, The whole Godainaiel Ward	10
02	MD. Melon	01621755229	Iceberg, Children Park, Magistrate's Quarter, The face of the DC street and the street in front of the street, Floor Area	11 12
03	MD. Monju	01621381950	Duck bungalow bend, Jamtola, Eidgaho mat, Metro Cinema Hall, Dustbin adjacent to Kumudini Gate, Chara gope, SP Bungalow, Police line	13
04	MD. Salem Gare No-New Track-03	01987030226	B.I.W.T. Ship office, Jute office space adjacent to the old Alam cabin, The front subdivision of the city subdivision, Hawkers Market & Front	13
05	MD. Faruk Hossan Khondokar	01715588640	Ukilparar mor, Grindlays bank adjacent flower market bend, Freedom fighters in front of Parliament	14 15
06	MD. Sobuj lal Gare No- s-11-0042	01828100767	Nimtala Thousand Cottage, Turn Market is in front of Park Pursuit Pharmacy, Sweeper	15

			colony at the southern corner, Number 1 railway gate	
07	MD. Mahabub Hossan Montu Gare No-New Track-10	01720261955	Chamber Road with Toilet Mass, Dhoivog nogor Mattresonod, Dhoivog water tank Adjacent field, One day at seven o'clock Karim Market and the other on the north side of the Mathematics School	15
08	MD. Samshul Hok Gare No-New Track-03	01720261955	DIT Gulmal Cinema Hall, Digubabur Bazar Mirjumla Road	15
09	MD. Shaiful	0199108562	DIT Rizeia clinic, Digubabur Bazar Mirjumla Road, In front of the old court reb's office	15
10	Onil Chondro da	01954056075	Shaheed Bappi Road New Road, Netaigonj Twist, Rishipara dustbin, Amena Monjil Twist, The Emperor is in front of the garment, Victoria Hospital's inner dustbin	18
11	MD. Noion	01775717943	Frog gatola, Amena Monjil, Joy Gobindo schoolar back Road, Jimkhana new road twist	16 17
12	MD. Monju	01621381950	After noon all the sports on the main road of the city	
13	MD. Imran	016388810819	Dahovog Hakim Ali Market (2nd Floor),Mogen School, Lack par spot	16
14	MD. Akas\Bossier		B.I.W.T. Ship Office	13

Comment: There are 2 payloads in the area. All the garbage are removed with the combination of Pay Loaders and Track Workers.

Pay loader Driver: 01) MD. Monir (10 no ward – 14 no ward).

02) MD. Delaware (15 no ward – 18 no ward)

List of Vehicles and Vehicle Driver Engaged with SWM of Narayangonj City Corporation:

Serial No.	Car No.	Driver name
1	Long boom excavator	MD. Johir
2	Skid steer loader - 3	MD. Masud
3	Skid steer loader -1	MD. Monir
4	Skid steer loader -5	MD. Delowar
5	18 No. dump truck **(EICHER)**	Suboj das
6	2 No. dump truck **(EICHER)**	Anil
7	3 No. dump truck **(EICHER)**	MD. Nijam
8	4 No. dump truck **(EICHER)**	Not driver
9	5 No. dump truck **(EICHER)**	MD. Mahdub
10	6 No. dump truck **(EICHER)**	Not driver
11	7 No. dump truck **(EICHER)**	MD. Noyon (2)
12	9 No. dump truck **(EICHER)**	MD. Shamsul huq khandokar
13	10 No. dump truck **(EICHER)**	MD. Noyon (1)
14	11 No. dump truck **(EICHER)**	MD. Ibrahim
15	13 No. dump truck **(EICHER)**	MD. Khandokar faruq ahmed

16	14 No. dump truck **(EICHER)**	MD. selim
17	16 No. dump truck	Not driver
18	17 No. dump truck	MD. Munju ahmed
19	19 No. dump truck	Nur hossen boqul
20	20 No. dump truck	MD.Ridoy
21	21 No. dump truck	Not driver
22	22 No. dump truck	MD. Milon
23	23 No. dump truck	MD. Abul basar
24	Chain type bulldozer - 1	MD. Shakib
25	24 No. dump truck	MD .Iqbal
26	25 No. dump truck	MD. Saiful
27	26 No. dump truck	MD.Firoz
28	Narayangonj -Sa – 11- 0002 Water car	Not driver
29	Track type hydraulic boom excavator	Not driver
30	Mini excavator - 1	Not driver
31	Mini excavator -2	Not driver
32	Skid steer loader -2	Not driver
33	Skid steer loader -4	Not driver
34	8 No. dump truck **(EICHER)**	Not driver
35	15 No. dump truck **(ISUZU)**	Not driver
36	3 Ton dump truck (china)	Not driver
37	2 No. truck (709 TATA)	Not driver
38	3 No. truck (709 TATA)	Not driver
39	6 No. truck (709 TATA)	Not driver
40	Truck (407 TATA)	Not driver
41	1 No. dump truck	Not driver
42	3 NO. dump truck (china)	Not driver
43	4 No. truck (709 TATA)	Not driver
44	27 No. dump truck	MD. Akash
45	28 No. dump truck	Not driver
46	29 No. dump truck	Not driver
47	30 No. dump truck	Not driver
48	31 No. dump truck	Not driver
49	Chain type bulldozer - 2	Not driver
50	West collect truck (box) - 1	Not driver
51	West collect truck (box) - 2	Not driver
52	West collect truck (box) - 3	Not driver
53	West collect truck (box) - 4	Not driver

Total Number of Holdings in NCC:

Kadamrsul Area:

Serial No.	Ward No.	Holding number 2017-2018 (Kadamrsul)
1	19	1587
2	20	1602
3	21	1608
4	22	2218
5	23	2172
6	24	1964
7	25	1264
8	26	716
9	27	1443
Non-government	-	14,574
Government	-	62
Total	-	14,636

Siddhirganj Area:

Serial No.	Ward No.	Year	Holding number 2017-2018 (Siddhirganj)
1	01	2017-2018	3904
2	02	2017-2018	3846
3	03	2017-2018	2724
4	04	2017-2018	1194
5	05	2017-2018	1538
6	06	2017-2018	1276
7	07	2017-2018	1826
8	08	2017-2018	3725
9	09	2017-2018	3436
10	Non-government	Total	23,469
11	Government	Total	58
12		Total	23,527

Narayanganj Area:

Serial No.	Ward No.	Year	Holding number 2017-2018 (Narayanganj)
1	10	2017-2018	1169
2	11	2017-2018	1568
3	12	2017-2018	1940
4	13	2017-2018	2767
5	14	2017-2018	1624
6	15	2017-2018	1694
7	16	2017-2018	2108
8	17	2017-2018	1426
9	18	2017-2018	2552
10	Non-government	Total	16,884
11	Government	Total	306
12		Total	17,190

Budget Information on Waste management of Narayanganj City Corporation

Budget Information of Narayangonj City Corporation (Budget Year 2016-2019)

Income sector	Previous year's budget 2016-2017	Revised this year 2017 -2018	Next year's budget 2018 -2019
Dirt Drainage Tax	63884615.00	79231000.00	94113000.00
Narayangonj City Corporation Road, Drain Construction and Reconstruction			
GoB	50000000.00	900000000.00	339200000.00
NCC	0.00	9600000.00	150000000.00
Narayangonj City Corporation sweeper worker housing project			
GoB	0.00	31200000.00	257440000.00
NCC	0.00	8700000.00	64360000.00
Narayangonj City Corporation Solid waste collection and disposal management project			
Gabi	0.00	1620500000.00	237370000.00
NCC	0.00	0.00	0.00
CRDP			
Road drainage and construction	364780.00	11806000.00	0.00
Others	407447.00	20940.00	0.00

Expense sector	Previous year's budget 2016-2017	Revised this year 2017 -2018	Next year's budget 2018 -2019
Jip van, Garbage truck, Microbus, pi cup van, power tiller, Motor cycle, speed board, chain drogue, Long excavator, Hydraulic Lipter.	17529750.00	19756000.00	40000000.00
Waste Management and Fecal sludge Disposal			
Drainage and Cleaning of Garbage	4416644.00	5000000.00	15000000.00
Purchase of equipment's for daily drainage and cleaning garbage	952100.00	1000000.00	2000000.00
Conservancy vehicles fuel	0.00	8000000.00	20000000.00
Land Purchase/Acquisition of Land for dumping site	0.00	0.00	15000000.00
Waste Management Modernization	0.00	0.00	5000000.00
Trolly, van purchase and Repairing	0.00	1200000.00	5000000.00
Sweeper's remuneration	24987380.00	30000000.00	50000000.00
Implementation of sanitation activities	253620.00	50000.00	2000000.00
Electrical Equipment Purchase and Repairing	4510605.00	3500000.00	5000000.00
Total	35120349.00	48750000.00	119000000.00
Drain Construction	100737224.00	28030000.00	5000000.00
Drain Repair and Maintenance	33579075.00	12013000.00	20000000.00
Narayangonj City Corporation road and drain construction and reconstruction			
GoB	49991347.00	800000000.00	439200000.00
NCC	0.00	9600000.00	15000000.00
Subtotal	49991347.00	809600000.00	589200000.00

Budged Information of Narayangonj City Corporation (Budged Year 2013-2016)

Income sector		Previous year's budget 2013-2014 (BDT)	Revised this year's budget 2014-2015 (BDT)	Next year's budget 2015-2016 (BDT)
1.	Dirt tax	6135589.00	54733063.00	106752166.00
2.	Road and drain construction		151617000.00	121000000.00
3.	Jip van, garbage truck, microbus, pic up van, power tiller, motor cycle, speed board purchase, chain dodger, long excavator, hydraulic elevator	6582900.00	0.00	30000000.00
4.	Dumping land acquisition/purchase	0.00	0.00	50000000.00
5.	Waste management modernization	0.00	0.00	5000000.00
6.	Trolley, van purchase and repair	1274450.00	50000.00	2000000.00
7.	Sweeper's fee	16543420.00	18738500.00	28000000.00
8.	Drain construction	177542188.00	154552000.00	60000000.00
9.	Dumping center, land development and boundary wall construction	0.00	0.00	20000000.00
10.	Drain repair and maintenance	95599640.00	86550000.00	40000000.00
11.	Road and drain construction		151617000.00	121000000.00

Budget Information of Narayanganj city Corporation (Budget year 2011-2014)

Expense sector	Previous year's budget 2011 - 2012	Revised this year 2012 -2013	Next year's budget 2013 -2014
Dirt Tex	18899237.00	46821100.00	63275700.00
Drain Construction	31403158.00	400000000.00	100000000.00
Dumping Site and Land Development and Boundary Wall Construction	0.00		200000000.00
Drain Repair and Maintenance	10467710.00		400000000.00
Public Toilet/ slaughterhouse	335383.00		100000000.00
Road and Drain Construction			160000000.00
Purchase of waste management development and equipment	0.00		250000000.00

Annexure 11

Picture of Solid Waste Sample Collection

Narayanganj City Corporation


2020.07.13 14:36


2020.07.13 14:36


2020.07.13 14:36


2020.07.13 14:37

Narayanganj City Corporation

Solid Waste Collection and Disposal Management in Narayanganj City Corporation

Volume III

15/A, Holy Lane, Shyamoli, Dhaka-1207

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