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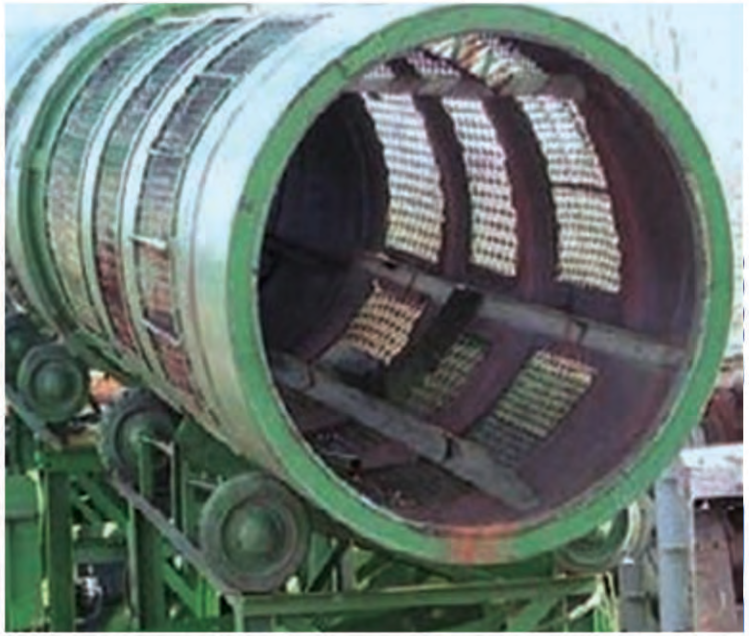

Catalog of technical options for Solid Waste Management in Bangladesh

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Contents

Acronyms & Abbreviations

APC	Air Pollutant Control
AWC	Automatic waste converter
BOT	Build own transfer
C&D	Construction & demolition
C/N	Carbon nitrogen
CC	Completion certificate
CDM	Clean development mechanism
CH_4	Methane
Co_2	Carbon di oxide
DBOT	Design Build own transfer
DG	Diesel Generator
DPR	Detailed Project Report
ECR	Environmental Conservation Rules
EHS	Environment, health and safety
EMS	Environmental management system
EPC	Engineering procurement construction
E Waste	Electronic waste
GOB	Government of Bangladesh
HDPE	High-density polyethylene
HIG	High income group
HP	Horse power
IEC	Information, education and communication
IT	Information technology
KMPH	Kilometer per hour
kWh	Kilowatt hour
LCV	Low capacity vehicle
LDPE	Low-density polyethylene
LIG	Low income group
LPG	Liquefied petroleum gas
MIG	Middle income group
MOA	Ministry of Agriculture
MOEF	Ministry of Environment & Forest
MRF	Material recovery facility
MS	Mild steel
MSW	Municipal solid waste
MT	Metric ton
NEMAP	National Environmental Management Action Plan
NGO	Non Government Organization
Nm^3	Normal cube meter
O&M	Operation & maintenance
PCC	Plain cement concrete
PPEs	Personal protection equipment
PPP	Private Public Partnership
PRSP	Poverty Reduction Strategy Paper
PWM	Plastic waste management
RCC	Reinforced cement concrete
RDF	Refuse derived fuel
RFP	Request for proposal
SAARC	South Asian Association for Regional Cooperation
SEMP	Sustainable Environmental Management Programme
SLF	Sanitary Landfill
SQFT	Square feet
SQM	Square meter
SWM	Solid Waste Management
TPD	Tons per day
ULB	Urban local bodies

Preface

The catalog of technical options for managing Municipal Solid Waste has been produced by the International Water Management Institute (IWMI) for the Technical Assistance Hub for South Asia (TA-Hub SA) located in Dhaka, Bangladesh. TA-Hub SA is managed by Development Consultants (DevCon) and supported through the Bill & Melinda Gates Foundation. One of the tasks of TA-Hub SA is to support the Department of Public Health Engineering (DPHE) on behalf of the Government of Bangladesh in activities related to the planning and implementation of Solid Waste Management (SWM) projects in over 60 cities of the country. In order to support informed decision-making among related public stakeholders, TA-Hub SA requested the production of two catalogs of selected technical options for solid waste management (SWM) and fecal sludge management (FSM) value chains currently implemented mainly in South and Southeast Asia region.

This catalog is a compilation of technical options for SWM value chains, based on brief descriptions, photographs and illustrations. The options were verified in technical sessions attended by IWMI and DevCon looking at the rationale for selecting particular technical options, including their advantages and disadvantages, and suitability in the context of Bangladesh. As requested by TA-Hub SA, detailed technical designs used to illustrate specific technical options within the SWM value chains and discussed during the technical sessions have been included as annexures in this catalog. These technical design scan be considered by relevant individual practitioners, and consulting agencies, in Bangladesh for implementation in the future.

The SWM technical catalog prepared by IWMI team focuses on waste segregation as a requirement and explores options for treatment, disposal and resource recovery. IWMI looks forward to providing assistance to TA-Hub SA as required during on-site assessments and preparation of feasibility studies for the implementation of urban SWM projects in Bangladesh once Covid-19-related travel restrictions have been lifted.

Methodology in selecting the Technical options

- Review of SWM projects & programs in Bangladesh
- Review of different publications on SWM technical options along the service chain keeping source segregation as an important parameter and targeting treatment and resource recovery within the SWM planning.
- The review was further narrowed to technical options that are currently implemented within SWM programs in South- and South East Asia
- Discussions with TA-Hub and government partners on SWM technical options in South and South-East Asian context which can be customized to Bangladesh
- Interactive and demand-based selection of technical options which can be implemented for different towns in Bangladesh
- The implementation of the technical options at city level is subjected to proper assessment and feasibility studies, availability of funds and decision by the urban local bodies (ULBs).

Overview of the Catalog

- Structured but compact overview of technical options that are currently implemented within SWM programs in South- and South East Asia
- Systematic, short and well visualized presentations of current technical SWM options including summarized considerations about planning, implementation, operation and maintenance.
- Inclusion of selected, small-scale wastewater treatment options under the category of containment.
- Description and rapid assessment of main performance indicators of technical SWM options presented.
- Description of prefabricated containment and treatment options.
- Demand-based provision of detailed technical designs of selected treatment options.

Introduction and overview

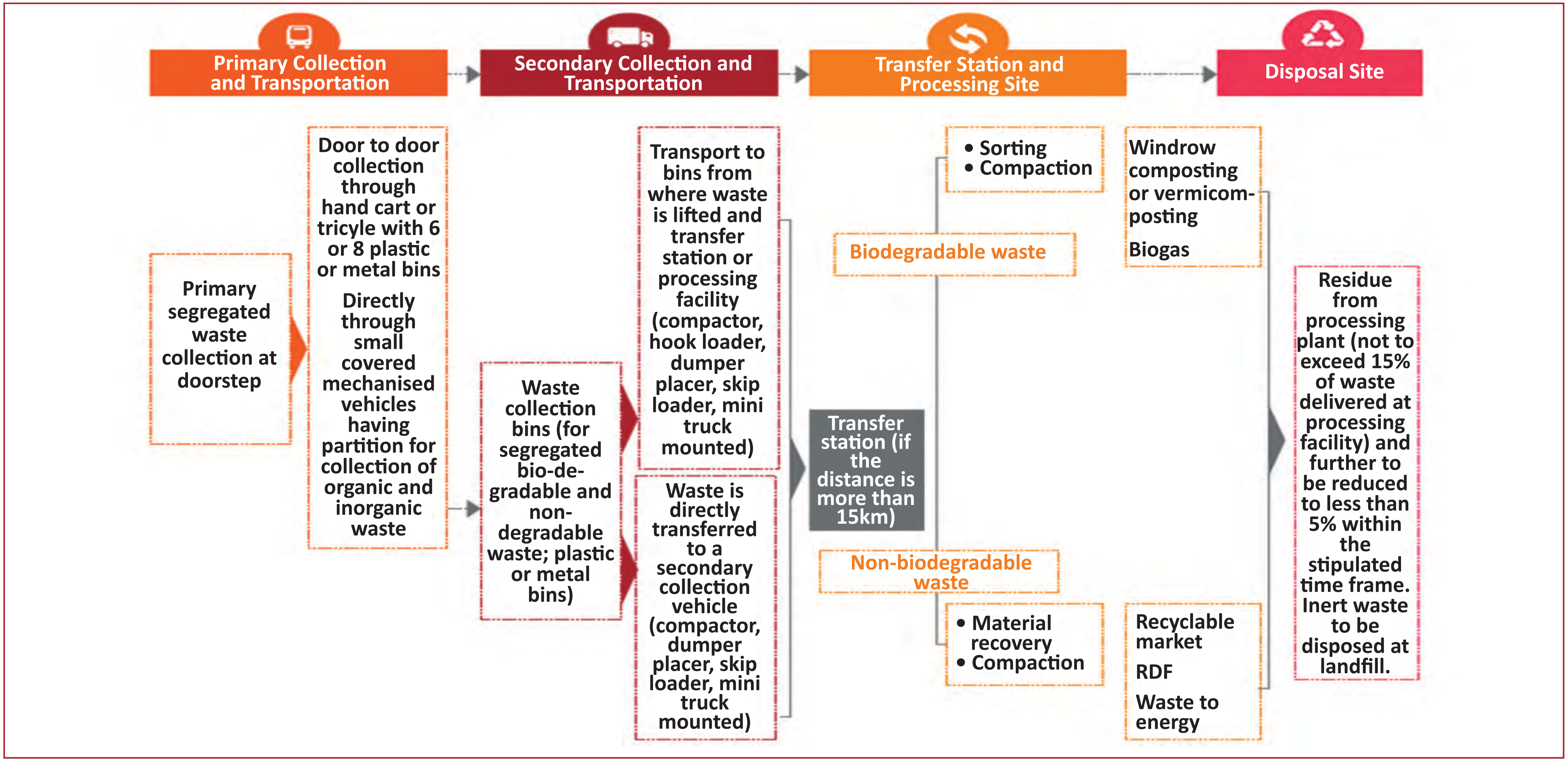
Introduction

In order to develop a framework of a robust municipal solid waste management plan, it is important to understand the existing condition of waste generation and management within a city or town. Along with this an overall appreciation of country specific national guidelines, strategies, legislations and policies are required while formulating SWM improvement plans.

Therefore, the first chapter of the catalog gives an overview about the SWM service chain and informs about the current regulatory framework for solid waste management in Bangladesh. Further, it provides a list of country specific guidelines as well as important policies. The chapter briefly outlines the current situation in the towns of Bangladesh, informs about options required to meet the sustainable development goals and technical components needed for an efficient management system.

Chapter 1: Introduction & overview

Technical Option 1.1: The SWM service chain



Source: ASSOCHAM & PwC, 2017

Chapter 1: Introduction & overview Technical Option 1.2: Regulatory framework related to SWM

Date	Title
Policy	
2006	**Draft National Urban Policy** • CDM and Recycling has been emphasized in this policy
2008	**National Renewable Energy Policy** This policy is promoting production of bio-gas and other green energy from waste and also providing incentives such CDM to promote green energy projects.
1999	**National Agriculture Policy** According to this policy the government will promote use compost/ organic fertilizer amongst the farmers to improve the soil productivity and food security
2005	**National Industrial Policy** This policy is recommended use of EMS and Cleaner Production practices amongst the industries
1998	**National Policy for Water Supply and Sanitation** • According to this policy the government shall take measures for recycling of waste as much as possible and use organic waste materials for compost and bio-gas production.
1998	**Urban Management Policy Statement** Recommend the municipalities for privatization of services as well as giving priority to facilities for slum dwellers including provisions of water supply, sanitation and solid waste disposal.
ACT	
2006	**Fertilizer Act** Under this act compost has been promoted and standard of compost has been set by the government on 2008.
1995	**Bangladesh Environmental conservation Act (ECA)** Recommends standards for disposal of different types of waste.

Chapter 1: Introduction & overview Technical Option 1.2: Regulatory framework related to SWM

Date	Title
Rules	
2008	**Biomedical Waste Management Rules** This rule recommends source separation of hospital waste as well as separate collection, transportation and treatment and disposal of all kinds of hospital and clinical waste.
2006	**Lead Acid Battery Recycling and Management Rules** Under this rules collection and recycling has been improved.
2005/ 2010	**Draft National Solid Waste Management Handling Rule** 3R principle has been used.
1997	**Bangladesh Environmental Conservation Rules (ECR)** Recommends waste disposal standards for mainly industrial wastes.
Strategy	
2005	**National CDM Strategy** This strategy is promoting pro-poor CDM projects on waste sector by harnessing carbon financing.
2005	**Poverty Reduction Strategy Paper (PRSP)** Here EMS has been promoted. To improve the solid waste management situation, special focus is given to segregation of waste at source along with the promotion of recycle, reduce and reuse of industrial and other solid waste etc.
2005	**National Sanitation Strategy** Its goal is to achieve 100% sanitation coverage by 2010. Here emphasis on resource recovery and recycling has been given as top priority to improve urban sanitation situation instead of disposal.
2014	**National Strategy for Water Supply and Sanitation** The strategy mentions about judicious management of solid waste (Strategy 6). Together with technical solutions, it is essential to promote awareness of the value of waste as a resource and promote reuse and recycling.

Chapter 1: Introduction & overview Technical Option 1.2: Regulatory framework related to SWM

Date	Title
Action Plan	
2005	**Dhaka Environment Management Plan** Waste recycling has been promoted, less land filling encouraged, EMS promoted among industries.
2005	**Solid Waste Management Action Plan for Eight Secondary Towns in Bangladesh** Under the Secondary Towns Integrated Flood Protection (Phase-2) Project of Local Government Engineering Department, GoB. This action plan is based on 4 R principle i.e. reduce, reuse, recycle and recover of the waste.
1995	**National Environmental Management Action Plan (NEMAP)** This is a plan of the Government of Bangladesh (GoB), prepared by the Ministry of Environment and Forest (MoEF) in consultation with people from all walks of life. 3R is being promoted under the Sustainable Environment Management Programme (SEMP) of NEMAP.
Other	
1995	**Circular to Promote Compost by the Ministry of Agriculture (MoA), on 23 April 2008** Ministry of Agriculture issued a circular to promote use of compost amongst the farmers to reduce the burden on the.
2004	**Private Sector Infrastructure Guideline** This guideline of the GOB has recommended private sector investment in waste management sector which includes all types of waste. It has also identified waste sector as of the priority sector for private investment.
2005	**Private Sector Housing Development Guideline** This guideline recommended to space in new housing areas for waste recycling specially composting and bio-gas generation.
2004	**Dhaka Declaration on Waste Management by SAARC countries during 10 – 12 October 2004** SAARC countries agree to encourage NGOs and private companies to establish community based composting, segregation of waste at source, separate collection and resource recovery from wastes with particular focus on composting.

Chapter 1: Introduction & overview Technical Option 1.2: Regulatory framework related to SWM

Overview of Solid Waste Management Rule 2018
• Source segregation • Storage with cover at the source of generation • Storage of waste by the bulk generators at their own premises before processing • Decentralized organic waste treatment by the bulk generators • Recycling of packaging materials • No disposal of waste to the drains • Transportation in a closed vehicle • Creation of awareness • Disposal of treated waste in sanitary landfill • Environmental monitoring of the landfill site • Environmental management plan around the sanitary landfill • Recovery of energy • Compliance of standard of emission, compost quality • Standard for incineration • Guideline on domestic hazardous waste.

Chapter 1: Introduction & overview

Technical Option 1.3: Current status of SWM in Bangladesh

Issues	
Waste generation	– Very limited segregation at source
Waste collection	– Getting mixed after generation – No 100% collection, waste lying on road – Insufficient numbers of collection point – Poor maintenance of the collection points
Waste transportation	– Inadequacy of proper vehicles, open truck – No tool (weighbridge) for quantification – No segregated transportation mechanism
Waste storage & treatment	– Open storage, no processing, or recovery
Waste disposal	– Unscientific & uncontrolled disposal – Absence of any engineered landfill, sites – Contamination of groundwater & soil – potential risk - hazardous, biomedical items
Overall waste handling	– Mostly manual handling, less manpower – No PPEs, no monitoring/ tracking

Opportunities

- 100% Door to Door collection and Source Segregation
- Efficient collection and safe transportation of wastes generated in the cities
- Opportunities for decentralized treatment system
- 100% treatment and scientific disposal facility & cost recovery
- Resource and energy recovery
- Better awareness among the stakeholders, and community mobilization/ participation
- Capacity Enhancement and Optimization of the human resources in SWM
- Strengthen the existing bye-laws for better regulation and user charges
- Encourage PPP in developing integrated treatment and treatment on Regional approach.

Chapter 1: Introduction & overview

Technical Option 1.3: Current status of SWM in Bangladesh

Sustainable Goals

Most Preferred

At Source Reduction & Reuse	Waste minimization and sustainable use/ multi use of products [e.g. reuse of carry bags/ packaging jars]
Recycling	Processing non-biodegradable waste to recover commercially valuable materials [e.g. plastic, paper, metal, glass and e-waste recycling]
Composting	Processing organic waste to recover compost [e.g. windrow composting, in-vessel composting and vermicomposting]
Waste to Energy	Recovering energy before final disposal of waste [e.g. RDF, biomethanation, co-processing of combustible non-biodegradable dry fraction of MSW, incineration]
Landfills	safe disposal of inert residual waste at sanitary landfills

Least Preferred

Source: CPHEEO, Municipal Solid Waste Management Manual, 2016

Key Indicators

- Household coverage
- Waste collection efficiency
- Segregation
- MSW recovery
- Scientific disposal
- Cost recovery
- Efficiency of user charge collection
- Compliant redressal.

Chapter 1: Introduction & overview

Technical Option 1.4: Waste generators profile

Photo credit: Medecines Sans Frontieres

Photo credit: http://bdreports24.com/markets-bangladesh-business-report-2014/

Photo credit: https://www.thedailystar.net/op-ed/dhaka-vs-kolkata-131794

Photo credit: The Business Staandard, Dhaka

Domestic	– HIG, LIG, MIG area – Slum areas – Colonies – Resident welfare associations – Gated society
Commercial	– Shops – Commercial market places – Showrooms and malls – Community areas
Institutional	– School – Colleges – Private offices – Government establishment
Bulk	– Hotels – Restaurants – Green vegetable markets – Fruit markets – Non veg markets – Slaughter house waste
Street sweeping	– Highways – Internal streets and street vendor's waste
Others	– Festivals and events

Management at the household level

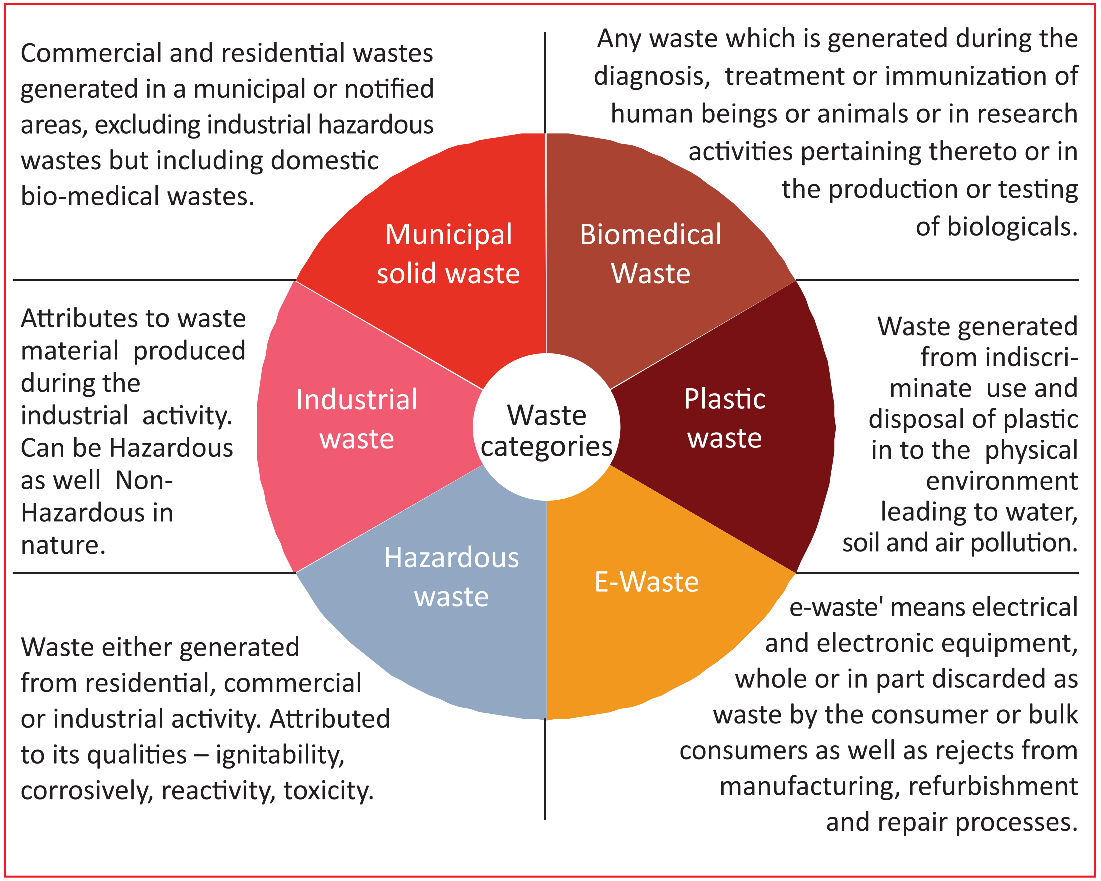
Introduction

This chapter informs about the different types of waste and its classification at household level. It provides an overview about different waste categories and stress on source segregation and subsequent storage of waste at household level. Source segregation is prioritized since this catalog contributes to technical options related to source segregation. The immediate next concern is storage of waste at the point of generation. Therefore, a detailed overview of household level segregation & storage along with community level storage of waste has been presented in this chapter. The waste quantification and sampling/ characterization protocols have been detailed out, which would further help in SWM planning.

Implementation of proper management practices at household level are considered to be essential for the functioning of all technical options presented in the following chapters of this catalog and would lead to the effectiveness and efficiency of the whole SWM service and value chains.

Chapter 2: Management at Household level

Technical Option 2.1: Types of waste



Source: ASSOCHAM & PwC, 2017

Source: GoI, 2017 (Waste to Wealth. Ministry of Housing and Urban Affairs).

Chapter 2: Management at Household level

Technical Option 2.2: Waste quantification and projection

Technical description and methodology

Household level quantification - Primary waste quantification survey needs to be carried out at all the major residential sources of generation. For this purpose, survey will be conducted for three consecutive days in residential wards comprising of different income groups including slum. From the household level survey, respective waste generation factors (gm/capita/day) for different groups such as HIG, MIG, slum etc shall be obtained and will be used to calculate the total residential waste generation in the city.

In order to quantity the waste for all residential area population projection will be carried out. To project the population, several alternative mathematical projections methods such as – arithmetic progression method, incremental increase method, geometrical progression method, decadal methods etc. should be adopted. The average population obtained from all those method will be applied to project the population for the project horizon. In case there is no decadal census data available, the growth rate of the city (from Govt. published document) shall be adopted and utilized for population projection.

Bulk generation source - Primary waste quantification should be carried out at the bulk generation sources such as vegetable markets, fruit markets, vending zones etc. The survey will be done through the visual observation on the percentage filled of the containers (Secondary Collection Points) placed in those markets. In addition to that consultation will also be carried out with the market people to understand the lifting schedule, their views on the waste generation quantity etc.

Commercial establishment - To estimate the waste quantity generated from the commercial establishments, different hotels, restaurants, eateries in the city etc. Discussions must be carried out with the establishment officials to understand the size of the establishments (bed for hotels, seats for restaurants etc.), waste generation per day and also the waste collection & disposal systems.

Disposal site - Apart from the above, the waste quantification has to be carried out by load count method at the disposal site. During this survey, the loaded and unloaded weight of all vehicles, coming to the disposal facility, should be noted for three consecutive days. By this exercise, the collection efficiency of the waste management system will also be obtained.

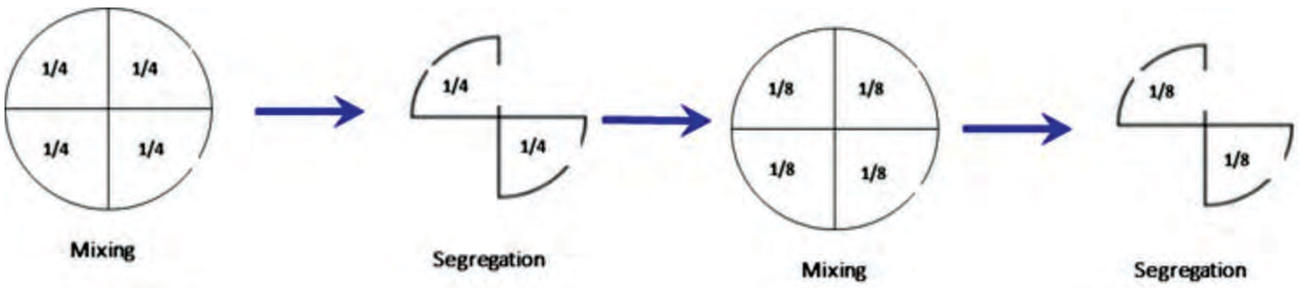
Chapter 2: Management at Household level

Technical Option 2.3: Sampling and characterization

Technical description and methodology

Selection of Sample Size and Locations - The selection of sample size and the sampling locations should be done through professional judgment and in consultation with stakeholders. The locations will be so chosen that it would give the representative characteristics of wastes at source of generation, at secondary collection points and also at disposal. For that purpose reconnaissance survey should be conducted first to identify the strategic location of sampling, which will be aimed to address different types of establishments such as, residential area (HIG, MIG, slum areas), secondary collection points, bulk generation sources such as big vegetable markets/ fruit markets and finally the garbage which are reaching landfill.

Sampling Method - For collection of municipal solid waste from representative locations, quarter conning method will be used. Considerable amount of MSW (minimum 50 kg), collected from the secondary collection points, will be flattened and quarterly conned into four equal parts. From the four equal parts, two diagonal parts will be taken out. The same procedure will be followed for a number of times and thereafter a final portion (at least 5 kg or more) will be collected from each location.



Physical Parameters (%)	Chemical Characteristics
Food waste	
Wood & wood products	
Paper and cardboard	Moisture content (%)
Textiles	Bulk Density (Ton/ m^3)
Park & garden yard	Organic content (%)
Glass, plastic, metal, inert	Calorific value (kcal/kg)
All combustible type wastes	C/N ratio

Analysis –

- Drying – to remove moisture content at 105^0 C.
- Grinding or Pulverizing - before Chemical Analysis to form homogenous mixture
- Mixing – for representative sample.

Chapter 2: Management at Household level

Technical Option 2.4: Waste segregation at source

Technical description

Source segregation of recyclables and biodegradables (organic waste) does not only provide an efficient way for resource recovery, but also substantially reduces the pressure and pollution at landfill sites. It is understood that implementation of such practices takes time and requires significant cooperation from the public. However, initiation should be made and efforts should be diverted to progressively increase the segregation practices. Community Participation indicates various actions that could increase the public participation for the management of MSW. The segregation of waste at source are primarily done for two major waste streams –

Category 1. Food & Green waste (wet waste) - Cooked/ uncooked food, vegetable, fruit, meat, borne, fish waste, leaves, grass.

Category 2. Recyclable & Non-bio-degradable (dry waste) - Paper, Plastics, glass, metal, ceramic, rubber, leather, rags, used cloths, wood, stone, sand, ash, thermocol, straw & packing materials.

Operation aspects

The household bin for food & green waste could be of 10-15 liters capacity made of plastic / reinforced plastic / LDPE or metal. Bin or plastic bags may be used for recyclables, non bio-degradable. Bins are preferred options as it is often difficult to separate the plastic bag during the waste processing and disposal. Moreover, plastic bags have a recurring expenditure, which is often difficult to overcome in a long run.

Multi-storied residences, commercial complexes, in addition to storage facilities in individual residences/shops, could also keep containers within their premises matching to collection system of the city.

Segregation of waste at source will be introduced along with door-to-door waste collection.

Hotels, offices, shops and restaurants need to keep adequate number of bins to facilitate easy handling and transfer of waste to Municipal collection system. Plastic, HDPE or reinforced fibre-glass bins are recommended for this purpose.

Hospitals and Nursing homes could use colour coded bins/ bags for storage.

Price – USD 300 for 60 lts dual bin (stainless steel

Price – USD 310 for 10 lts dual bin (HDPE)

Photo credits: Government e-Marketplace, Govt. of India; www.gem.gov.in

Chapter 2: Management at Household level

Technical Option 2.5: Storage of waste

Technical description of 120 lts bin

- Utility – Residential colony, small complexes
- Material – HDPE
- Size – 120 lts
- Lid – removable
- Towage provision – with wheel
- Wheel material - rubber
- Weight – 10 kg
- Load carrying capacity – 240 kg
- Compartments - single
- Price – USD 45

Technical description of 660 lts bin

- Utility – public, community & park area
- Material – HDPE
- Size – 660 lts
- Lid – removable
- Towage provision – with wheel
- Wheel material - rubber
- Weight – 66 kg
- Load carrying capacity – 660 kg
- Compartments - single
- Price – USD 320-340

Technical description of 1100 lts bin

- Utility – public, community & park area
- Material – HDPE
- Size – 1100 lts
- Lid – hinged
- Towage provision – with wheel
- Wheel material - rubber
- Wheel dimension – 200x50 mm
- Weight – 130 kg
- Load carrying capacity – 950 kg
- Compartments - single
- Price – USD 380-400

Photo credits: Government e-Marketplace, Govt. of India; www.gem.gov.in

Involving stakeholders for implementation

Introduction

Along with the households, it is important to include other stakeholders to reach efficient implementation of SWM planning. This chapter defines the role of different Ministries, local governance, private sector and NGOs, as well as the informal sector involved in SWM. The chapter covers a section on functional responsibility of different stakeholders towards plastic waste management. Two key stakeholders – the private sector and the informal recycling sector are discussed in the chapter. The engagement of the private sector along the collection, transportation, treatment, and disposal is provided along with different contractual arrangements.

The chapter emphasizes design of Information Education and Communication (IEC) along with Behavioral Change Communication (BCC) strategies which lead to reduction of waste, source segregation and awareness about environmental and health outcomes.

Chapter 3: Involving stakeholders for implementation

Technical Option 3.1: Implementation mechanism & public participation

Framework of responsibility				
Central	**Divisions**	**ULB**	**Private/ NGOs**	**Informal Sector**
• Ministry's overall guidance through rules regulations and notification, regulation materials. • Ministry of Urban Development. • Funding of projects through National missions. • Technical Assistance through specialized teams imparting capacity to different divisions and ULBs. • Ministry of environment. • Ministry of Finance through.	• Responsible for implementation of funding through divisional departments. • Division's responsibility – to channelize Central Funds, Co-ordination between various ULBs for central schemes, and imparting capacity to provide ULBs with knowledge and manpower.	• Implementation Responsibility. • Implement through a set of bye-laws. • Responsible for manpower and staffing. • Responsible for preparing and implementing the municipal rules. • Funding through ULB's own resource & Public Private Partnerships.	• Assist ULBs in implementation of waste management activity in the capacity of advisors, execution agencies, etc. guided by a pre-defined contract between the public entity. • Non-governmental organizations play an important role in collection and transportation and organizing the informal sector. In some cases, NGOs have done good work in end-to-end waste management.	• Scavenging and rag picking. • Informal waste recycling.

Chapter 3:
Involving stakeholders for implementation

Technical Option 3.1:
Implementation mechanism & public participation

Functional responsibility of different stakeholders for plastic waste management			
Local Bodies	**Village administration**	**Waste generators**	**Producers, Importers and Brand Owners**
• Development and setting up of infrastructure. • Ensuring segregation, collection, storage, transportation, processing and disposal of plastic waste. • Channelization of recyclable plastic waste fraction to recyclers. • Engaging groups working with waste pickers. • Setting up of system for PWM and seeking assistance from producers. • Framing bylaws.	• Operationalize and coordinate for waste management. • Ensuring segregation, collection, storage, transportation • Channelization of recyclable plastic fraction to recyclers. • Creating awareness among stakeholders. • Ensuring that open burying of plastic waste doesn't take place.	• Minimize the generation of plastic waste. • Segregated storage and handover of waste to local body. • Institutional generators to handover segregated wastes to authorized agencies. • User fee and charges payment.	• Framing of modalities for waste collection system based on Extended Producer Responsibility. • Establishing a system for collecting back the plastic waste generated and submit a plan to divisional administration. • Maintain records of the person engaged in supply of raw material to manufacture carry bags or plastic. • sheets or plastic cover or multi layered packaging.

Chapter 3: Involving stakeholders for implementation

Technical Option 3.1: Implementation mechanism & public participation

Private sector engagement & contractual arrangement			
SN	**SWM value chain**	**Private sector involvement**	**Contractual arrangements**
1	Primary collection	• Primary door-to-door collection of municipal solid waste. • Service/ management contract.	• Service/ management contract. • Service contract.
2	Secondary collection & transportation.	• Construction and management of community bins. • Transportation of waste.	• BOT and its variance and/or Separate EPC and O&M Contract. • Management contract/O&M contract
3	Transfer station management & processing site	• Processing using waste to energy/ RDF / recoverable/ recycle projects • Waste to energy.	• DBOT/ BOT (long term) EPC with 5–7 years O&M contract. • Built operate transfer (BOT).
4	Waste disposal	Disposal in an engineered landfill site	Design build operate and transfer (DBOT), EPC with O&M Contract on renewal basis.

Chapter 3: Involving stakeholders for implementation

Need for IEC / BCC

- People apprehensive to share information
- Low awareness of MSW Rules
- Absence of action plans with corporation for execution and enforcement
- Weak environmental monitoring
- Absence of bye-laws
- Lack of formal integration of waste pickers with waste management system
- Lack of knowledge on occupational municipal health hazard
- Absence of corporation level advisory body for solid waste management

Expected outcome of IEC / BCC

- Will be aware of the health and hygiene of self and community as well
- Can play important role in managing segregated waste
- Will help to communicate households about segregation
- Will help in monitoring the behavioral patter of household and help to report
- Will learn to handle the tools in scientific manner
- Learn to maintain (basic cleanliness) the tools and equipment properly

Technical Option 3.1: Implementation mechanism & public participation

STEP I – Material development for IEC/BCC

- Design a campaign with a strong them – (What – Why – How) model
- Develop an information material
  - Banners, placards, pamphlets - dos & don't
  - Posters & stickers
  - Videos (short films, dramas)
  - Audio (dialogue and speeches)
  - In local languages with attractive colors, bold, wide, visible from far
- Involve NGOs as a partner
- Involve media as a networking partner

STEP II – Action for IEC/BCC

- Roles & responsibilities of – generator and collector
- Education on
  - Domestic storage
  - Segregation
  - Littering
  - Use of proper bins (dual bins)
- Involve RWAs, market association, industry association,
- Visit to schools

STEP III – Methodology

- Street shows
- Focus Group Discussions
- Create WhatsApp group
- Facebook/ twitter (for corporation) - as an informal way of linking
- You-tube uploading of VDOs
- Locations – Youth Clubs / Open Grounds/ Courtyards, community fair
- Sit & draw competition for children
- morning, national holidays or on festival gathering

Chapter 3: Involving stakeholders for implementation

Technical Option 3.1: Implementation mechanism & public participation

IEC / BCC Consultation planning		
Stakeholder Group	**Areas of Interest/ Influence for IEC & BCC**	**IEC / BCC consultation planning**
Community around existing dumping ground	Problems faced by the community around the existing facilities due to the present nature of operation	Consultation to identify the existing issues and probable measures to redress them
Community at household level	Door to door collection	Consultations would focus on the gaps in service delivery where improvements can be made. Any reservations about the present operations would also get focused.
Rag pickers	The group which is most likely to be disadvantaged due to the implementation of any proper integrated SWM system	The consultation would focus on livelihood loss and the problems faced rag pickers. Involving in the formal chain of waste management
Municipal / Sanitary Workers of Municipal Corporation	They play an important role in the collection and transportation system	Discussions would center the present inefficiencies of the system and the improvement suggestions. Occupation health issues would also be discussed
Officials in charge of Solid Waste Management in the Corporation	Would be the key implementing authority and also the main point of contact with the community	Interactions would be held with the officials to develop an understanding of the possible areas of intervention in the existing system
Civil Society / NGOs	Door-to-door collection	Consultation would focus on the arrangements of collection and their issues and problems of being associated with the system of existing/ proposed waste management
Market Committees/ Commercial Area Associations	These are bulk waste generators	The consultations would focus on the problems faced due to the present service delivered. Their expectation from the proposed system would also be discussed.

Chapter 3: Involving stakeholders for implementation   Technical Option 3.2: Informal recycling sector

Areas of integration of informal recycling sector in SWM system

- Door-to-door collection
- Sorting of recyclable waste
- Collection and segregation of recyclable material
- Manual sorting at the conveyor belt in a material recovery facility
- Setup and management of recyclable or reusable waste take-back or buy-back facilities supported by adequate and appropriate skill enhancement arranged for by the urban local body (ULB) or other concerned departments
- Waste sorters in processing facilities (e.g., at the sorting conveyor)

Capacity and training for informal recycling sector in SWM system

- Improvement of managerial skills
- Maintenance of work ethics and organization or team work
- Training in sorting, processing, recycling techniques, and value added services
- Formalization of waste worker organizations
- Environmental and health aspects of waste management activities
- Occupational hygiene and safety
- Business support services linked to large scale formal recycling industries



Collection

Introduction

In this chapter, the waste collection at household level as well as at community level has been discussed. It includes collection of waste from different parts of the urban area – residential, commercial, institutional, bulk and others. Functioning of small-scale collection practices are relevant to enable secondary collection of waste and its transportation to disposal sites. This would also help to plan the infrastructure requirement in terms of equipment, vehicle, manpower etc. The common waste collection practices of South and South East Asia, are described, explained and visualized. This chapter also presents a roadmap of logistical arrangement towards different treatment chain for the waste.

Chapter 4: Collection

Technical Option 4.1: Door to door collection

140 lts hand cart

- Utility – Narrow lanes, slum area, congested residential and market areas
- Type - two wheel Type wheel barrow
- Material – 1.6 mm thick steel sheets
- Size – 140 lts
- Towage provision – with wheel
- Type of chassis frame - angle
- Wheel type - MS with solid rubber tyre
- Width of tyre – 50 mm
- Diameter of the wheel – 300 mm
- Price – USD 90-100

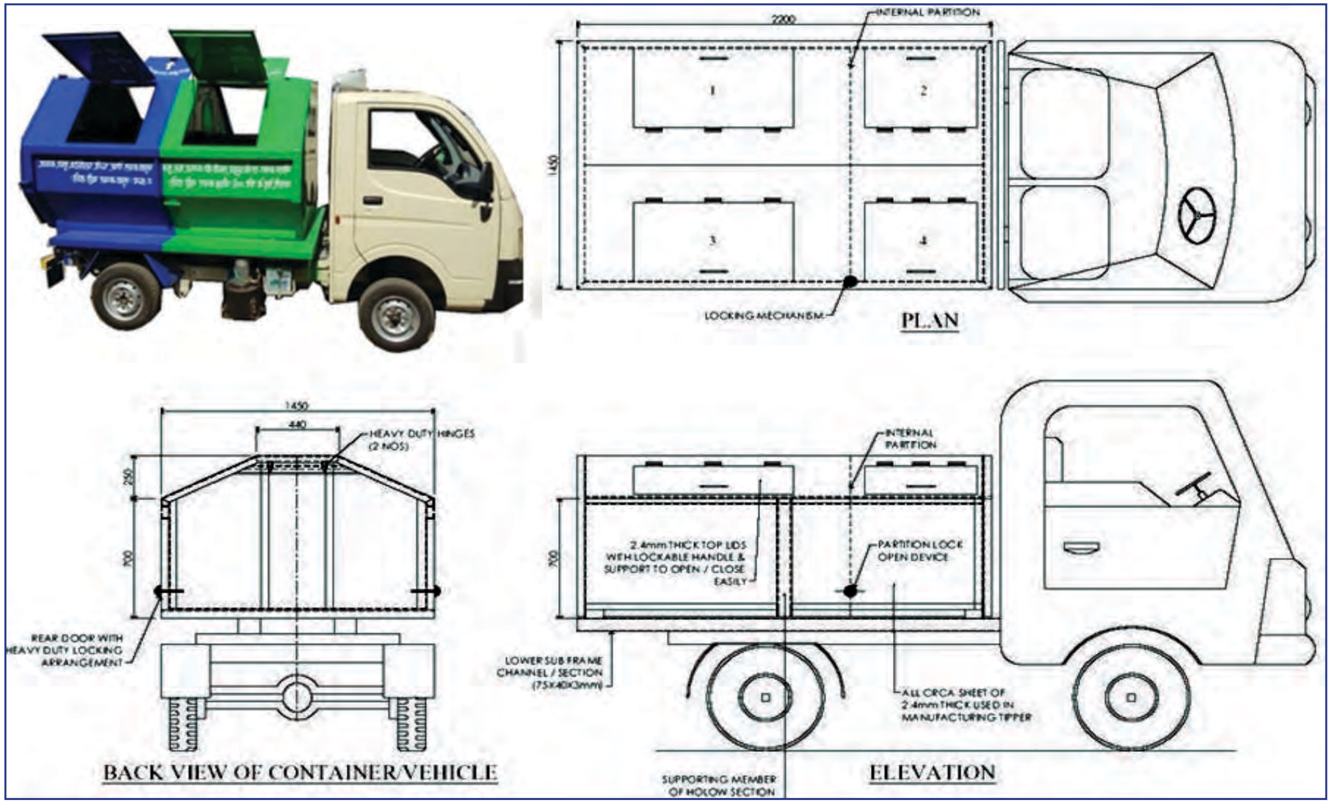
Tricycle rikshaw

- Utility – residential colonies, HIG & MIG areas, market & commercial places
- Driving mechanism – pedestal chain
- Length of tricycle – 3 m
- Cart dimension – 1350 x 800 x 300 mm
- No of containers – 6 nos (3 dry, 3 wet)
- Capacity of each container – 20 lts
- Material of container – HDPE
- Price – USD 350

Photo credits: Government e-Marketplace, Govt. of India; www.gem.gov.in

Chapter 4: Collection

Technical Option 4.2: Primary collection framework



Dual compartment auto tipper

- Utility – collection of waste from hand cart or try cycle or bins and transfer to the processing facility
- Fuel type – diesel
- Gross weight – 1700 kg
- Capacity 300-500 kg of waste
- Fuel consumption – 20 km/lt
- Compartment – dual, for wet and dry segregated waste
- Loading and unloading – hydraulically operated
- Speed – 60 kmph
- Length – 2100 mm
- Cost – USD 6000
- Design life – 10 years

Transportation

Introduction

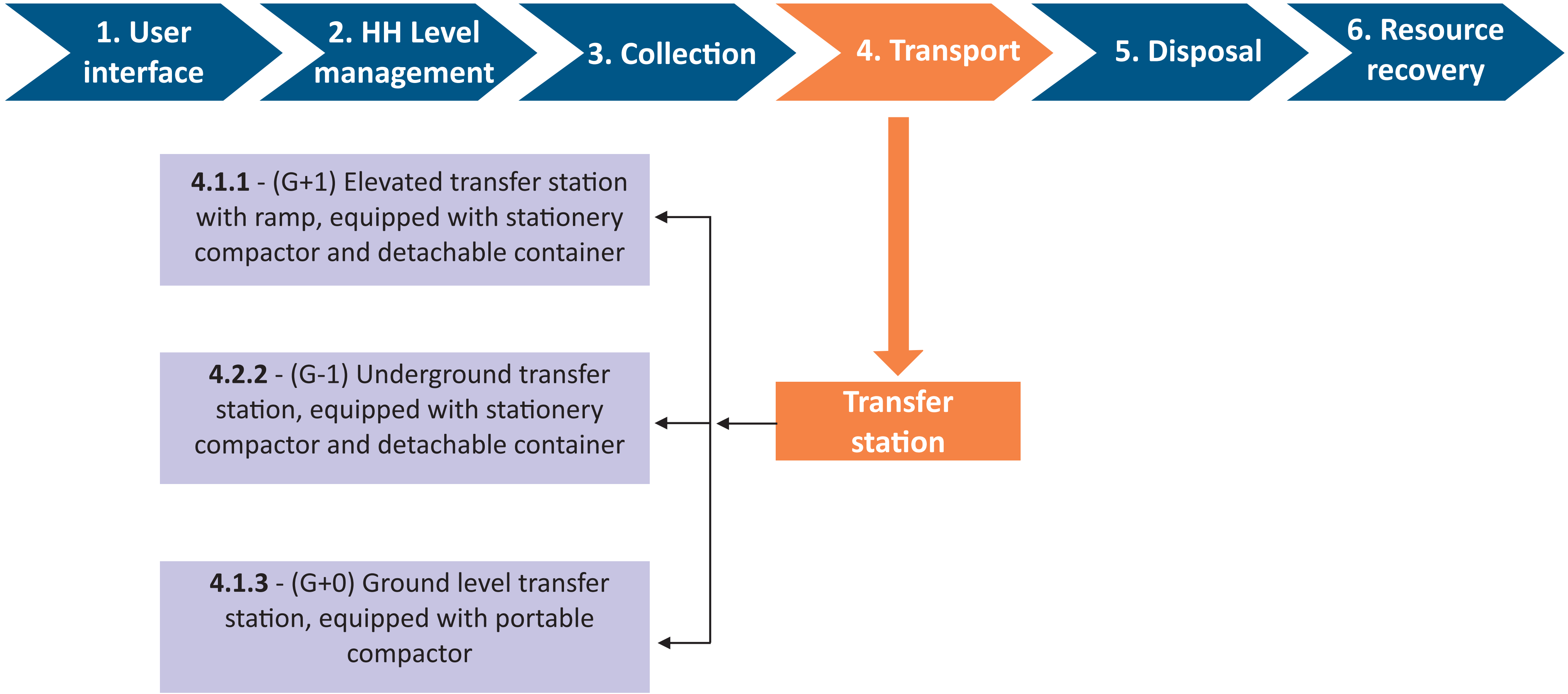
This chapter gives a detailed outline of planning and strategies of waste transportation from secondary collection point to the processing/ disposal facility. Depending upon the volume of waste and distance to treatment facility, options for intermediate storage or transfer station facility have been outlined. The vehicle fleet details, types, capacity and specification has been recommended for different cases in this chapter.

Along with the transportation, street-sweeping aspects both by manual and automated mechanisms, have also been indicated in this section.

Eventually, as overall successful implementation of SWM system depends upon a robust monitoring, Information Technology enabled monitoring frameworks and related Command Control Mechanism are being furnished.

Chapter 5: Transportation

Technical Option 5.1: Transfer station



Chapter 5: Transportation

Technical Option 5.1.1: G+1 Elevated Transfer station

Photographic visualization

Technical description, functionality & applicability

The G+1 transfer station is specially designed waste management infrastructure and highly suitable for monsoon operations. Waste from the different corner of the city is brought to the transfer station by means of low capacity vehicles or auto tippers (for example, 300-350 kg capacity). The transfer station is equipped with a ramp, a hopper system, and a compactor. The waste from the auto-tipper is transferred into the hopper from (G+1) level. A typical (G+1) transfer station could be designed to handle a waste volume ranging from (150-200) TPD to (600-650) TPD. For example, a 200 TPD capacity transfer station would require around 35 ton per hour throughput. An additional bay to house a similar compactor for future augmentation may also be provided. The flexibility is also kept to load the dumper vehicles without compaction. As the waste quantity increases in peak hours, waste could be directly loaded into dumper vehicles to match the increased waste quantity.

In Bangladesh, this kind of structure is applicable and suitable as it reduces the waste handling volume, thereby also reduces the operational cost of transportation and the time of hauling for disposal.

Chapter 5: Transportation

Technical Option 5.1.1: G+1 Elevated Transfer station

Operation and maintenance aspects

Operational Aspect -

1. Low capacity vehicles (LCVs) with uncompacted waste would be taken to the first floor, through ramp
2. From first floor, the LCV would unload the waste into the hopper/chute system, which is mounted/attached to the transfer station
3. The unloaded waste would be then transferred through the chute to the stationary compactor vehicle, standing beneath the chute at ground floor
4. Compaction will be done inside the vehicle until the compactor capacity is full
5. Compactor vehicle would be taken to the landfill

Peak hour operation –

In peak hour, when load is very high, dumper vehicles (instead of mobile compactor) could be used for transportation without compaction. Steps 1 to 3 would be followed without compaction mechanism. Then the full vehicle will be sent to landfill.

Rapid assessment

Advantages

- Centralized system advantageous for zones with large quantity of waste
- Automatic draining system
- Can cater distant locations (source of generation)
- Less chances of spread of waste, due to chute mechanism.
- In this system, almost 100% of the existing vehicles could be used.
- Compaction increases the efficiency and reduces the time & opex

Disadvantages

- Area requirement is more

Cost

- Civil - USD 0.45 million
- Stationery compactor - USD 0.5 million

(for approx. 300 TPD)

Planning, design & implementation

Civil infrastructure:

- G+1 infrastructure building
- Ground floor for compactor vehicle
- First floor for waste carrying LCVs
- Ramp

Equipment & vehicle:

- Compactor
- LCVs
- Dumper vehicles
- Hopper/ chute attached to compactor

Implementation steps:

- Feasibility study
- Survey
- Estimation of capacity and demand
- Structural design of the transfer station
- Electromechanical requirement estimate
- Preparation of DPR & RfP
- Model selection – PPP or EPC
- Procurement process
- Commercial operation

Chapter 5: Transportation

Technical Option 5.1.2: (G-1) Underground Transfer station

Photographic visualization

Technical description, functionality & applicability

(G-1) Underground transfer station is an economically designed transfer station, applicable where there is a constrain of space. It deals with the operational flexibility of both segregated and non-segregated waste. The collected waste is transported by the dual compartment garbage tippers to transfer station. It strengthens and reduces the cost of the Secondary Collection and Transportation System,

This kind of model, involves provision of segregated waste collection and transportation through Hook loaders to the disposal site. There are two hoppers one for the collection of dry waste (Blue) and second for the collection of wet waste (Green). The MSW from door to door garbage tippers is collected in two steps. At first the dry waste is off loaded in blue hopper and thereafter the wet waste is off loaded into the green hopper. These hoppers are connected to blue and green containers respectively. The segregated MSW is compressed into respective containers. When the containers are filled to capacity, they are lifted by dedicated hook loader and sent to disposal site in a segregated manner. The Hook loader carrying wet waste off load their waste directly to the green waste processing facility, whereas dry waste is off loaded to the Material Recovery Facility.

Chapter 5: Transportation

Technical Option 5.1.2: (G-1) Underground Transfer station

Operation and maintenance aspects

1. LCVs would bring waste into the transfer station and directly transfer the waste to the 'hopper-bucket' system, which is an integral part of the stationery compactor.
2. From "hopper-bucket" system the waste would be transferred to the compaction zone and will get compacted.
3. The compacted waste will remain inside the compactor container.
4. The compactor container will be lifted by hook loader and taken to the disposal site.
5. After disposal the empty compactor container will be again brought into the transfer station and placed in its position.

Rapid assessment

Advantages

- Environmental friendly option, as majority of the activities would be performed in closed system
- Less operational time
- 100% of the receiving waste would be compacted, reducing the number of trips for the vehicle to the waste landfill
- Automatic draining system.

Disadvantages

- Substantial procurement of the hook loader vehicle would be required.

Cost

- Civil & electromechanical – USD 0.2 million
- Hook loader – USD 30,000

Planning, design & implementation

Civil infrastructure:

- Ground floor with shed
- Underground pit excavation for hosting compactor
- No ramp.

Equipment & vehicle:

- LCVs
- Stationery compactor with inbuilt waste receiving mechanism ("hopper-bucket")
- Detachable compactor container
- Hook loader (to carry compactor container).

Implementa on steps:

- Feasibility study
- Survey
- Estimation of capacity and demand
- Structural design of the transfer station
- Electromechanical requirement estimate
- Preparation of DPR & RfP
- Model selection – PPP or EPC
- Procurement & Commercial operation.

Chapter 5: Transportation

Technical Option 5.1.3: (G+0) Ground level Transfer station

Photographic visualization

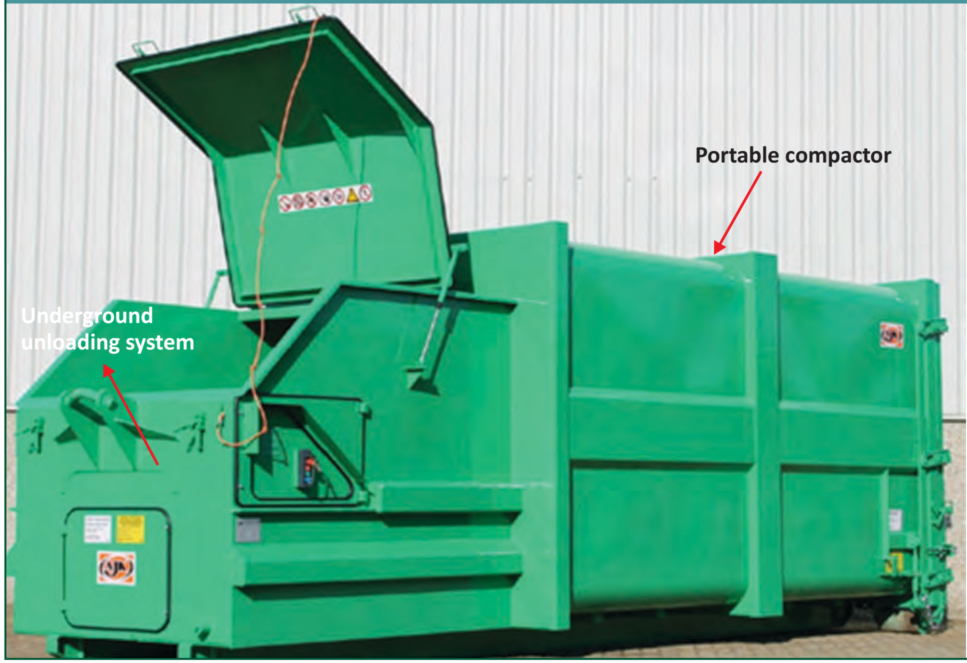


Photo credit: https://www.directindustry.com/prod/ajk-nv/product-176173-2022732.html

Technical description, functionality & applicability

(G+0) Ground level transfer station is a transfer station, which requires minimum space area and could be expandable to any capacities by just increasing number of units. It is applicable where there is a constrain of space as well as waste quantity is not substantial. The collected waste is transported by the tippers to transfer station. The transfer station contains portable compactor.

In this kind of model, the compactor after compaction acts as an container itself. It does not need any transfer of compacted waste to a separate container. The compacted waste after collection is transported through hook loaders to the disposal site.

Chapter 5: Transportation

Technical Option 5.1.3: (G+0) Ground level Transfer station

Operation and maintenance aspects

1. LCV vehicles would bring waste into the transfer station and directly transfer the waste to the portable compactor
2. Portable compactor compacts the waste with a supply of electrical power from a DG set
3. After compaction, the hook loader lifts the compactor cum compactor container and will be taken to the disposal site
4. After disposal the empty container cum compactor is placed at the same location for further operation

Rapid assessment

Advantages

- Simplest system, can be installed anywhere
- Space requirement minimum
- No additional requirement of container
- Expandable with customized addition of units
- Less and negligible civil structure required
- No foundation required
- Minimal power requirement

Disadvantages

- Cannot deal with huge amount of waste
- Waiting time more, as there is no replacement of container

Cost

- One hook loader with two portable compactor assembly - USD 0.12 million

Planning, design & implementation

Civil infrastructure (optional):

- Shed
- Concrete flooring
- Drainage system

Plant & equipment:

- Portable compactor
- Hook loader (to carry portable compactor)
- DG set

Implementation steps:

- Earmarking of location
- Estimation of capacity and demand
- Model selection
- Procurement & Commercial operation

Chapter 5: Transportation

Technical Option 5.2 Secondary collection & transportation

Secondary collection to processing facility ~ 7 Cum Refuge Compactor

Photo credits: Government e-Marketplace, Govt. of India; www.gem.gov.in

Technical specification

- Type of waste – both mixed and segregated
- Container capacity – 7 cum
- Compression ratio – 0.5.
- Emission norms: BS-VI standard
- Lifting time – 27 sec
- Operation time – 30 sec
- Discharge time – 20 sec
- Lifting capacity -1000 kg
- Compression force during compaction – 340 Ton
- Speed: 80 kmph
- Fuel tank 184 Lts
- Pay load: 7 MT
- Ground clearance: 215 mm
- Turning radius: 7200 mm
- Braking distance – 5 m
- Price – USD 435-450,000

Chapter 5: Transportation

Technical Option 5.2 Secondary collection & transportation

Transportation to sanitary landfill facility ~ 8.5 cum box tipper truck

Photo credits: Government e-Marketplace, Govt. of India; www.gem.gov.in

Technical specification

- Type of waste – Inert or process rejects
- Type of tipper – box body tipper
- Carrying capacity – 8.5 cum
- Gross vehicle weight – 18.5 MT
- Emission norms: BS-VI standard
- Fuel tank – 220 Lts
- Ground clearance: 260 mm
- Price – USD 50,000

Chapter 5: Transportation

Technical Option 5.3 Street sweeping

Operation and maintenance

Activities to perform:

- Cleaning, sweeping, mopping of identified road, curbs, sidewalks
- The sweeping should be capable of covering variety of refuses
- Shall be capable of removing pebbles up to 50 mm size & dusts
- Transportation of garbage/dust collected to specified points

Time of operation:

- It shall be mostly during non-peak hours of traffic movement, including night sweeping

Photo credits: Government e-Marketplace, Govt. of India; www.gem.gov.in

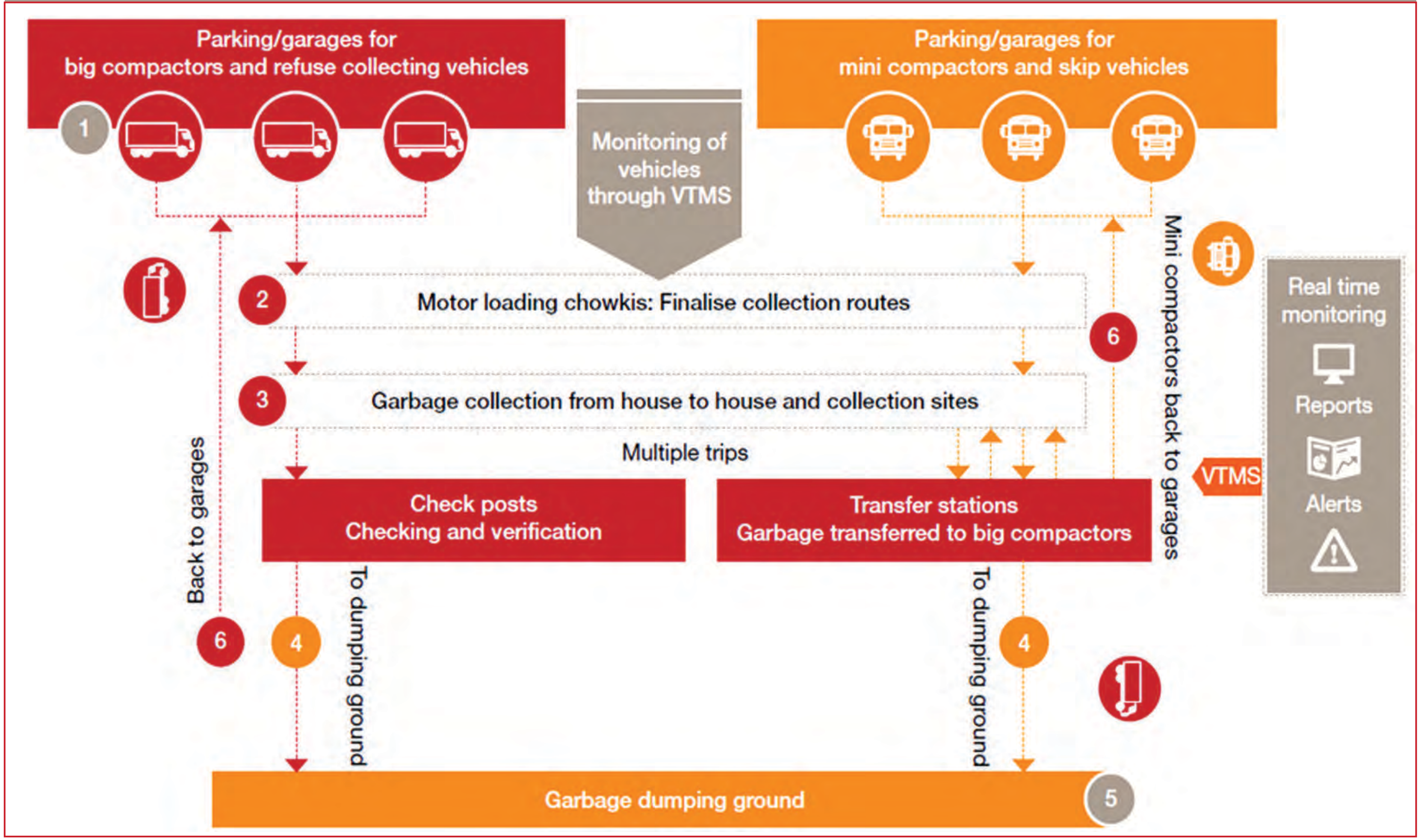
Technical specification

- Chassis Mounted Heavy Duty Vacuum Sweeper
- Engine type: double engine & with a minimum of 115 HP and two side brooms
- Emission norms: BS-IV standard
- Dust collector container 5 cum payload volume, water tank capacity
  600-1000 L
- Overall sweeping width of minimum 3000 mm in one sweep / pass
- Material of construction: Stainless Steel
- Chassis requirement: 10-12 tons
- Minimum speed: 16 kmph
- Suction Wander Hose 4 meters length
- Suction Nozzle: 750 mm
- Cleaning width all 2 brushed : 2000 – 2600 mm
- Cleaning width all 3 brushes : 2600- 3500 mm
- Suction System: Straight suction through vacuum
- Indicators system: Operation hour meter
- Steering: Hydrostatic controlled four wheel steering
- Price – USD 250-275,000

Chapter 5: Transportation

Technical Option 5.4 IT enabled monitoring

Framework



Source: ASSOCHAM & PwC, 2017

Benefits:

- Real-time bin leering status
- Viewing vehicles on duty
- Monitoring bins, vehicles and staff
- Tracking bin clearing efficiency
- Monitoring SWM disposal quantity
- Monitoring citizen complaints
- Monitoring trips of vehicles in km.

Treatment & Disposal

Introduction

Technically, treatment and disposal of solid waste depends upon its quantity, its degree of segregation and its specific physical, biological and chemical characteristics such as moisture content, bio-degradability, combustibility, toxicity and many others. In addition, centralized and decentralized waste processing systems must be distinguished.

In practice, however, the range of disposal and treatment technologies applied is largely determined by the financial means and the degree of development of environmental technologies in a country.

Accordingly, a selection of centralized and decentralized waste treatment and disposal options together with relevant treatment design parameters, and cost estimates are presented in this chapter in a summarized and highly visualized manner.

Chapter 6: Treatment & Disposal Technical Option 6.1: Innovative and modern zero waste treatment

Photographic visualization

Source: https;//slideplayer.com/slide/15477750/

Technical description and functionality

Blackhole technology is patented in US and 151 other countries. It operates on US Trade Marked Magnetically stimulated & Regulated Plasmic Temperature (THD Method). It works on Programmed Oxygenated Plasmic State that eliminates any and all kinds of environment pollutants. From 200°C (by initial firing) to 350–750°C in the equipment by plasma, ionization and thermal vibration is achieved. It is a self sustaining process with no fuel, no burning. After initial startup fire, destruction starts slowly by splitting the molecules into atoms .These atoms further ionized as electron, proton and neutron. Oxygen is induced as charged ions. The Dioxins, Difurans and Parabens are destroyed inside the machine itself. A Multi layered sprinkling system ensures pollution free emissions. Digital readers notify inner chamber temperatures. Alert system for reloading of waste as the inner chamber gets emptied. The system reduces the input waste fed into the system in the ratio of 1/200 to 1/300 fraction. For a 100 TPD plant, approximately 5635 sqft area is required.

Chapter 6: Treatment & Disposal   Technical Option 6.1: Innovative and modern zero waste treatment

Photo credits:https://teslagreen.us/the-blackhole

Applicability	
• Waste Paper • PET Bottles • E-Waste • Municipal Waste	• Butyl Tubes • Plastic Waste • Food Waste

Chapter 6: Treatment & Disposal Technical Option 6.1: Innovative and modern zero waste treatment

Rapid assessment

Advantages

- No segregation is required
- Both centralized & decentralized plant
- User friendly simple operation and easy to load,
- Multiple loading with variable quantity is possible
- Flameless technology, no combustion or electricity required
- Environmentally friendly – no flames, dioxins etc.
- Massive volume reduction (reduces the output by 1/200 – 1/300)
- By product - small volume of ceramic ash of about just 4-5 kg per ton
- By product can be landfilled and could be used as soil amendment material
- Compact, mobile system; less area footprint required.

Disadvantages

- Glass, metal, ceramic cannot be treated and need segregation from waste
- During monsoon crusher is required to remove additional moisture content from waste, as moisture reduced the performance efficiency.

Operation and maintenance aspects

Waste has to be feed into the chamber of the equipment on uniform intervals. During the commissioning process an initial start ignition is done by using camphor/ Dry-wood and destruction starts slowly by splitting the molecules into atoms. These atoms are further ionized as electron, proton and neutron and this state is called as plasma state and separated electron change to accelerated electron with strong energy.

On the other side a small amount of atmospheric air is allowed to pass through strong magnetic field into the Oxygen starved chamber. During this operation oxygen molecule split into elemental oxygen with negative charge. This atomic oxygen is to oxidize perfectly organic surface and change organic matter to desperate organic oxide. Therefore reaction is induced by exothermic phenomenon, thermal condition around 200°C is needed to accelerate reaction which can be achieved by initial decomposition. From 200°C (by initial firing) to 350–750°C in the equipment by plasma, ionization and thermal Vibration is achieved.

Cost

- **Investments** – USD 2.5 Million for 100 TPD plant
- **O&M** – USD 10,000 per month for 100 TPD plant

Chapter 6: Treatment & Disposal

Technical Option 6.2: Medical waste treatment facility

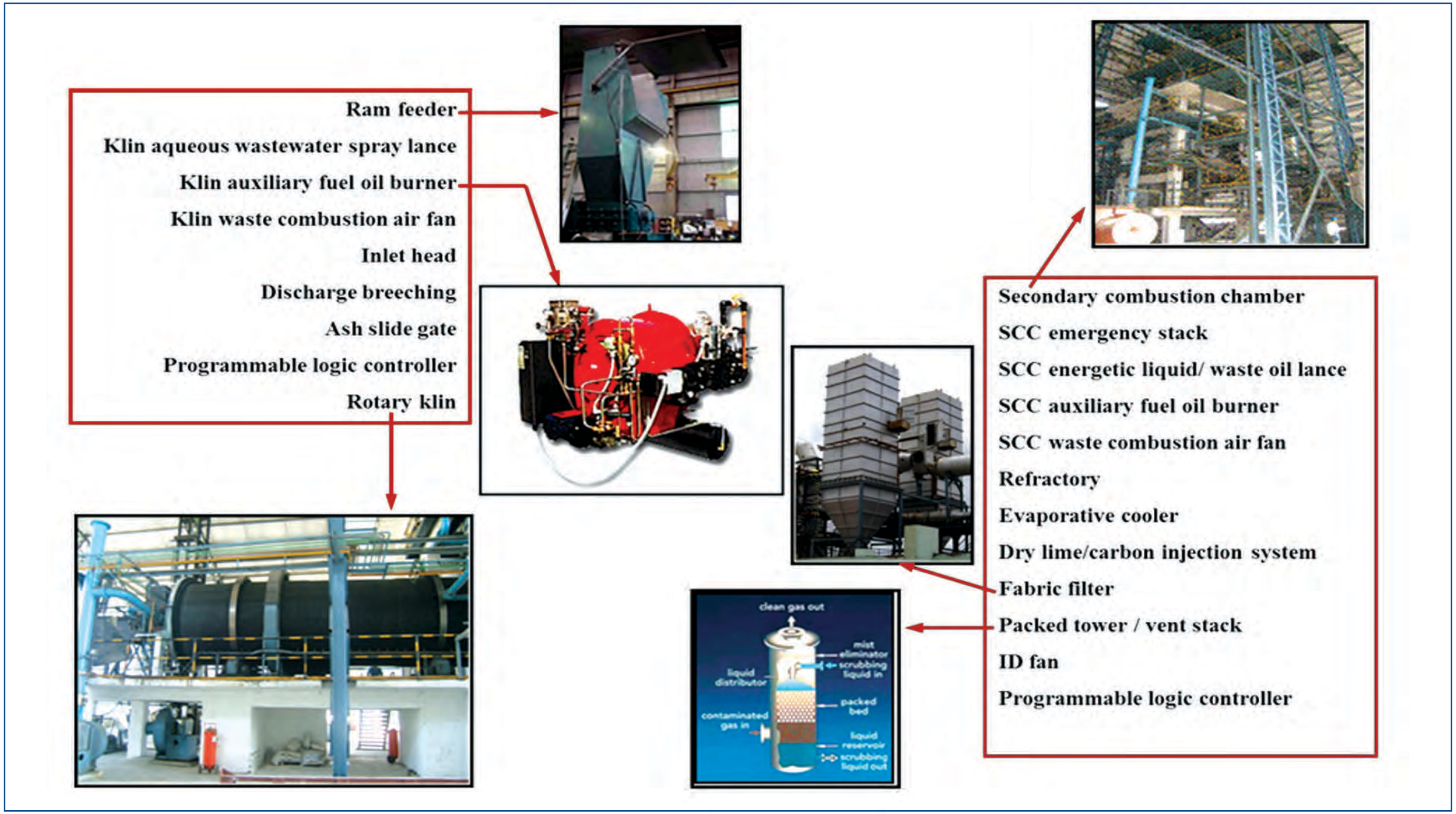
Photographic visualization

Technical description, functionality and applicability

The primary purpose of incineration is to burn the medical waste to ashes through a combustion process. The primary combustion chamber is a rotary kiln which burns the waste materials into safe end products (ash). Ash generated in the process is discharged through the discharge breech of the Kiln. The temperature within the kiln would be maintained at around 850°C, wherein wastes shall be completely destroyed. The gases generated in the process is run into a secondary combustion chamber wherein the off-gases shall be further burnt and ensure safe end products (gaseous). The secondary combustion chamber would operate at a temperature of 1050°C and above. The gases would be completely burnt and safe gases then shall be let out of the incinerator unit and shall lead into gas cleaning system. The brief components are –

- Waste reception area
- Interim waste storage area and refrigerated storage
- Waste incineration plant including air pollution control and gas cleaning equipment
- Ancillaries for waste incineration e.g oil tanks, transformers, control room etc.
- Container washing and storage area
- Administrative building and supporting infrastructure

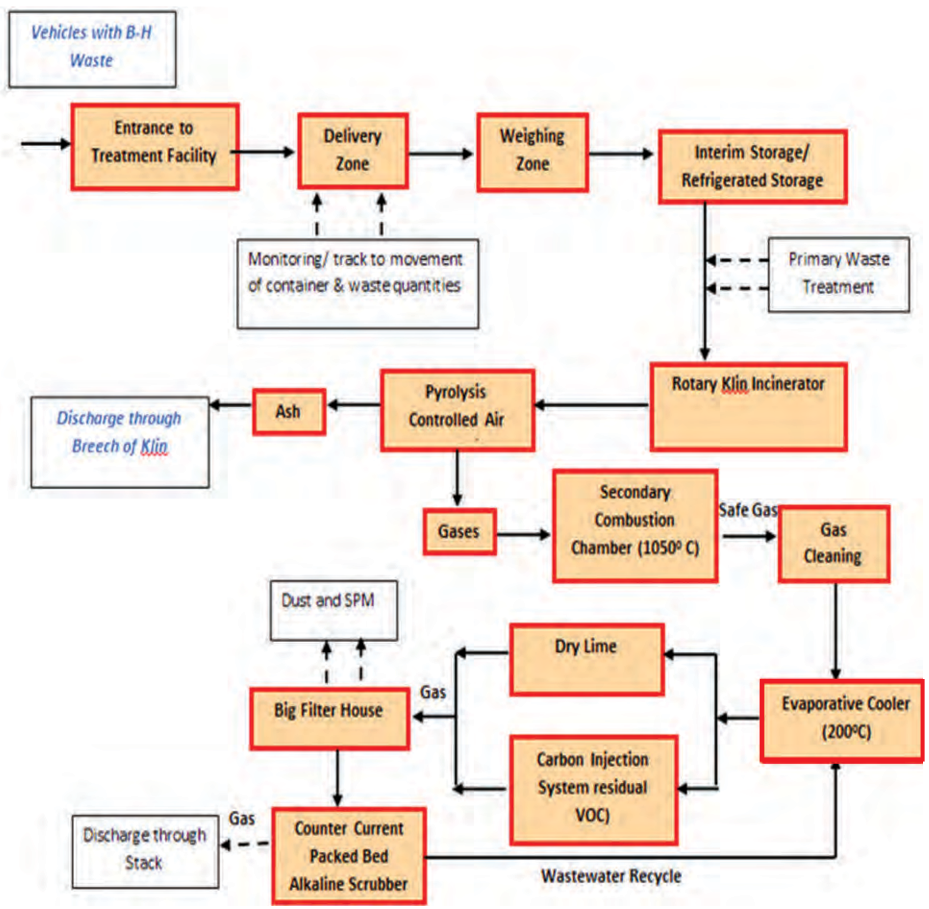
Chapter 6: Treatment & Disposal — Technical Option 6.2: Medical waste treatment facility



Chapter 6: Treatment & Disposal

Technical Option 6.2: Medical waste treatment facility

Operational aspect



Implementation planning for medical waste transfer

- Collection of waste from all point - by operator
- Closed container vehicles
- Aesthetically improved
- Environmentally safe
- Color soding system
- Occupational safety
- Vehicles dedicated for bio-medical waste transport only
- Cleaning and disinfection of the vehicle
- Measures to avoid seepage or spillage

Rapid assessment

Advantages

- Generates minimal reject quantity

Disadvantages

- Required proper control on emission
- Assured waste quantity with required calorific value

Cost

- **Investments** – USD 0.5 million for 250 kg/hr feed waste

Chapter 6: Treatment & Disposal

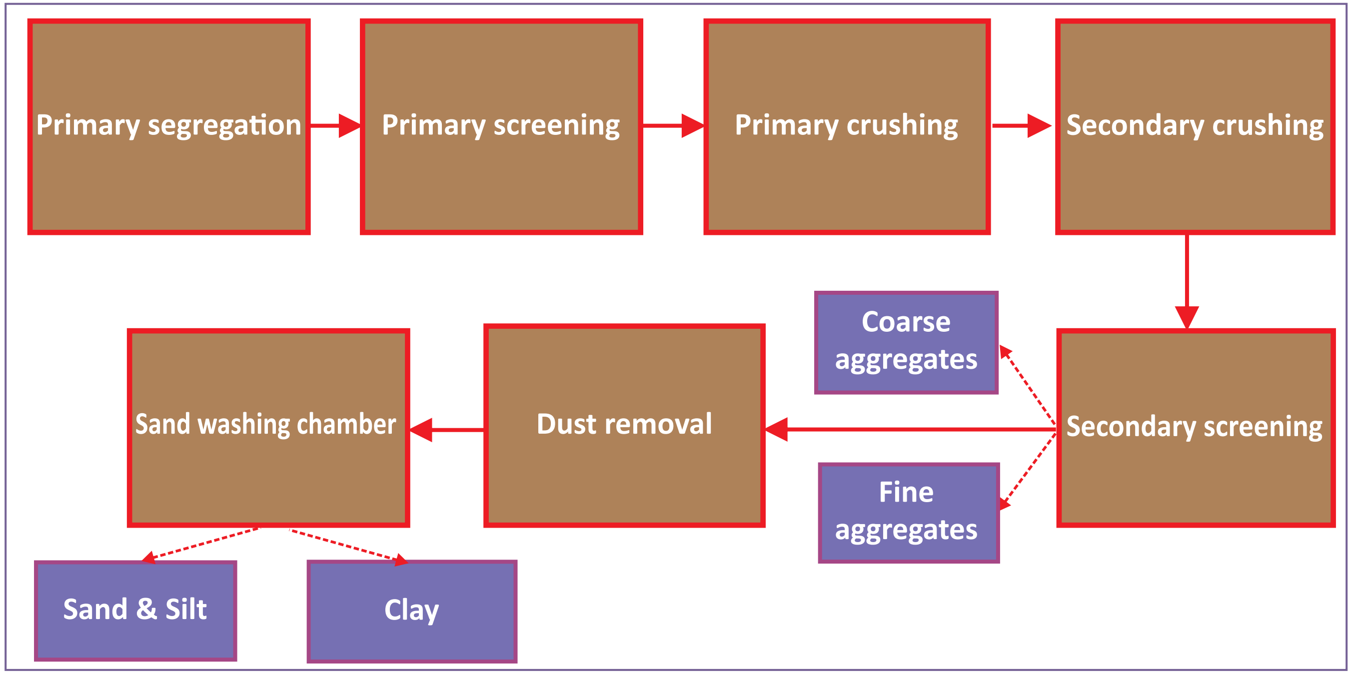
Technical Option 6.3: Overview of C&D waste treatment

Technical description, functionality and applicability

Construction and demolition waste means the waste comprising of building materials, debris and rubble resulting from construction, remodeling, repair and demolition of any civil structure. C&D waste includes bricks, tiles, stone, soil, rubble, plaster, drywall or gypsum board, wood, plumbing fixtures, non-hazardous insulating material, plastics, wall paper, glass, metal (e.g., steel, aluminum), asphalt, etc.

Construction & demolition waste processing plant is a stationery plant with an assembly of crushing, sieving and washing machinery interconnected by conveyer belts for material movement. The machinery is housed on steel/concrete platforms on a permanent basis. The crushing units have dust control systems, noise control systems, magnetic separator devices and other additional devices based on requirements. The systems are either semi-automated or completely automated units. The typical constituents of C&D waste are as per the followings:

- **Wood**
- **Bricks, Concrete and Other Masonry Products**
  Crushed and used for Fill, New Roads, Under lament for Concrete Applications, curb stone, paver block and road construction materials
- **Metals (Ferrous and Non-Ferrous)**
  Melted into New Products
- **Roofing Shingles**
  Asphalt Roads
- **Cardboard**
  Processed used New Cardboard Products
- **Plastic**
  Made into bottles, floor tile, paneling, plastic lumber, etc.



Chapter 6: Treatment & Disposal

Technical Option 6.3: Overview of C&D waste treatment

Plant visualization

Various components and instruments at C&D waste management plant. Photo credits: Saxena et al. 2018.

C&D waste handling at plant

Processed materials

Chapter 6: Treatment & Disposal

Technical Option 6.3: Overview of C&D waste treatment

Rapid assessment

Advantages

- Reduces the pressure for utilization of new construction materials
- Reduces the exploration of mining materials
- Reduces demand for energy and water in manufacture of building materials from naturals resources
- Reducing environmental impacts arising from mining, manufacturing and transportation
- Reduces transportation and disposal cost of C&D wastes
- Promotes options for reuse / recycle of products from C & D waste.

Disadvantages

- Storage space is required before transportation of C&D waste to plant.

Operation and maintenance aspects

Major operations in a C&D waste processing & recycling plant are - sorting, crushing, classification/sieving and washing. Sorting can either be done manually or using advanced devices. Before feeding the material into the crusher, a grizzly can be used to ensure the maximum feeding size of debris for the respective crusher. Generally, jaw crushers or horizontal impact crushers are used to crush the debris. Size classification is performed using appropriate screens of required sizes. Washing is done to separate fine particles (silt and clay particles). Sorted aggregates of specific sizes are stored separately

Planning, design and implementation

Planning -

- Estimation of C&D waste generation
- Identification of site and timely acquisition of land
- Necessary approval from local administration / civic bodies
- Specifications for recycled C&D waste products for quality acceptance
- List out and mandate use of recycled products from C&D wastes
- Analysis on economically viable C&D recycling options
- Awareness campaign for use of recycled processed material

Basic components of C&D plant –

- Feed Hopper with Vibrating Grizzly Feeder
- EvoScreen - Pre Screen
- RotoMax - Log Washer for aggregate cleaning
- Trash Screen for removal of light weights
- ProGrade - Sizing Screen for washed Aggregate
- EvoWash - Dual pass hydrocyclone system for sand washing
- AquaCycle - Water management system for recycling of process water

Cost

- **Investments** – USD 3000 per ton/annum
- **O&M** – USD 250-300 per ton/annum

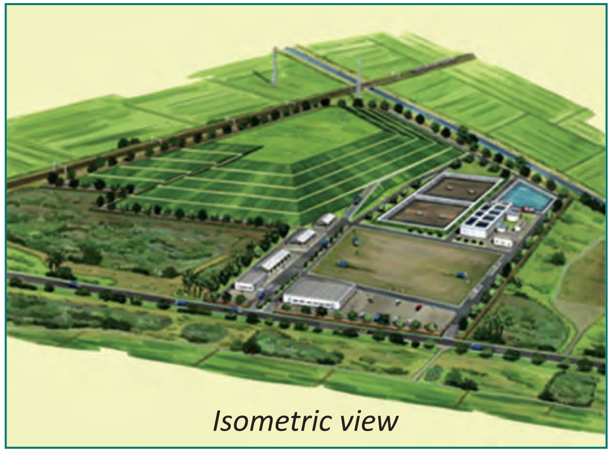
Chapter 6: Treatment & Disposal

Technical Option 6.4: Sanitary landfill

Photographic visualization

HDPE liner, drainage layer, gas wells

Leachate pond and oxidation



Isometric view

Technical description, functionality & applicability

In order to dispose the inert or reject after processing of municipal solid waste, sanitary landfill facility is developed. The basic difference of a disposal site and engineered landfill is in its protective measures in terms environmental degradation. A landfill is generally designed for a period of 25-20 years in a phased manner. Each phase consists of cell with a design life of 5 years. A typical landfill has two components – below ground and above ground. The bottom liner is laid below ground in order to restrict the leachate percolation from the disposed waste to the soil or ground water. After the operational life the landfill is closed and covered by top liner. A landfill is provided with gas collection and leachate management system, storm water management system.

During operational phase, after disposal of waste, the daily cover is put above the waste. However, a scientific landfill is expected to only receive the inert and no organic waste is supposed to be disposed off without proper treatment. A scientific landfill facility also typically includes other infrastructures, such as – weigh bridge, boundary wall, water supply system, administrative area, parking, electrification facility and power back up. Ground water monitoring well shall be installed at the up-gradient and down-gradient of the landfill site facility. Landfill could ne also integrated with the processing & treatment facility for cost optimization.

Chapter 6: Treatment & Disposal

Technical Option 6.4: Sanitary landfill

Operation and maintenance aspects

Leachate management plan
- Header pipes
- Feeder pipes
- Sump
- Submersible pump
- Solar evaporation pond

Storm water management plan

Landfill Gas (LFG) management plan
- Controlled passive venting
- Controlled collection & use/flare

Landscaping plan
- Plantation for beautification
- Plantation to absorb air pollutant
- Re-plantation

Post closure environmental monitoring plan
- Treated leachate quality
- Ambient noise level
- Ambient air quality
- Groundwater quality
- Surface water quality

Environmental Health & Safety (EHS) plan
- All records of previous incidents
- Inputs from regular Plant meetings
- All activities routine and non-routine, where substantial hazards and risk are associated
- Examination of all existing OH&S procedure and practice.

Emergency preparedness & response plan
- Maintain all fire extinguishers in working condition
- Provide training to personnel working in the landfill
- Explosion prevention
- Explosive mitigation
- Corrective and preventive action
- Avoidance of major spillage of any chemical

Cost

- Landfill – USD 35-40,000 per ton
- Infrastructure & utility – USD 500,000 (LS)

Planning, Design & Implementation

- Waste load count
- Assessment of landfill volume and area
- Landfill life and design period
- Evaluation of concept development plan
- Foot Print of landfill site
- Height of Landfill
- Depth of Landfill
- Side Slope (top)
- Side Slope (bottom)
- Design of leachate collection system
- Design of liner system
- Assessment of landfill gas generation
- Design of landfill gas collection system
- Design of final cover system

Rapid assessment

Advantages

- Scientific disposal of inert and rejects
- Avoid the contamination of groundwater
- Restricts emission of greenhouse gas emission

Disadvantages

- Area requirement is high
- Need sufficient environmental screening before selection of site

Resource Recovery

Introduction

One of the most important key performance indicators of a successful SWM system is reduction of waste at source and recycling. Reduction, recycling and resource recovery minimize the load on the waste management system, its logistical infrastructure, power requirement, manpower resources etc. as well as potential negative impacts on land utilization.

Hence, this chapter depicts different resource recovery mechanisms from solid waste, like energy, nutrients, fuel as well as material recovery. In addition to these processes, the resource recovery from the existing unscientific disposal site is also being outlined with all techno-commercial details.

Chapter 7: Resource recovery   Technical Option 7.1: Decentralized biomethannation plant for bulk generator

Photographic visualization




Technical description, functionality & applicability

Anaerobic digestion (AD) is the biological breakdown of organic materials in the absence of oxygen. The process is carried out by anaerobic micro-organisms that convert organic material into three different end product.

- Biogas, primarily consists of methane (CH_4) and carbon dioxide (CO_2), with trace amounts of other gases.
- Digested residue, which is a partially stabilized organic material, could be used as a soil conditioner/ compost after proper curing and drying.
- Nutrient rich liquid fraction, which in some cases can be used as liquid fertilizer if there is an agricultural user nearby or disposed of as wastewater.

The rejects (inert content of MSW) separated during the pre-digestion process, are sent to the landfill for final disposal.

Range of applicability

Fruits, Vegetables	Dairy Products	Bakery
Meat, Poultry, Fish	Frozen Food	Dry Goods
Paper Products Not Recycled	Milk, Juice, Beverage Cartons	Personal Hygiene Products
Disposable Diapers	Livestock Manures	Paper Based Packaging
Agricultural Wastes	Organic Sludges & Slurries	Glycol & Other Alcohols
Slaughterhouse Slurries	Food Plant Residues	Pet Wastes

Chapter 7: Resource recovery Technical Option 7.1: Decentralized biomethannation plant for bulk generator

Planning, design & implementation

SN	Specification Heads	Specification for 5 TPD
1	Area Requirement	500 SqM
2	Type of Plant	Containerized, Compact & Modular and Plug & Play
3	Type of Waste processed	Biodegradable
4	Service Water Requirement	250 Ltrs./day
5	Shredder/Crusher capacity	800 Kg/hr
6	Shredder Feed Pump capacity	5 m^3/hr
7	Main Digester Material	Stainless Steel Grade 304 (Contact Parts)
8	Anaerobic Digestion	20 days
9	Type of Anaerobic Digestion	Thermophillic Digestion
10	Capacity of Digester	100 m^3
11	Bio-gas generation per day	500-600 Nm^3/Day
12	Total Power generation	750-900 kWh/Day
13	Net Power generation	380-530 kWh/Day
14	Compost	700 kg/day

Cost

- **Investments** – USD 0.32-0.35 million for 5 TPD plant
- **O&M** – USD 3500 per month

Operation and maintenance aspects

There should be provision of minimizing odour generation, prevent off-site migration of gaseous emissions. Ambient air quality at the site and in the vicinity shall be monitored to meet the specified standards as per national rules and regulations. Dedicated vehicle would be deployed to collect and transport waste from different bulk generators to the plant. Plant run time – 16 hours a day with power backup.

- Inlet: Plant Premises.
- Rejects: Plant Premises
- Output Power Supply: 415 V AC, 3 Phase, 50 Hz at engine panel.
- Input Power Supply: 415 V AC, 3 Phase, 50 Hz at incomer of the panel.
- Service water: 1 meter flange connection from plant boundary

Rapid assessment

Advantages

- Practically no odors in enclosed system
- Can produce better quality organic compost or biogas
- No additional chemicals required to assist composting.
- Pre-engineered, prefabricated, hence less execution time at site.
- Saving in collection and transportation cost
- Saving in land due to reduction in the landfill requirement
- Saving in O&M cost as captive power can be utilized
- Less biological sludge production
- Avoidance of leachate

Disadvantages

- Requires segregation
- Requires assured waste quantity

Chapter 7: Resource recovery Technical Option 7.2: Decentralized organic waste converter for community

Photographic visualization

Technical description, functionality & applicability

- Applicable for housing societies, institutions, hospitals, office complexes, malls (food courts) etc.
- The entire composting process is natural & biological. The decomposition is done by microbes / micro-organisms which thrive in high temperature as well as in high acidic or salty atmosphere.
- When food waste is put in, moisture in the waste is sensed & the tank is heated from below.
- Microbes are activated due to high temperature & they decompose the food.
- The rate of conversion is 100% waste to 10-15% of compost.
- There is no crushing or grinding taking place in the machine & hence no wear-and-tear which contributes to the long life span of our machine.
- The compost that is formed as a result of the above process has to be removed once in a month, which can be used for the plants in the garden.

Chapter 7: Resource recovery Technical Option 7.2: Decentralized organic waste converter for community

Rapid assessment

Advantages

- No smell
- 75%-80% volume reduction could be achieved
- No major wear & tear of the machine
- Soil enricher could be used for in-house gardening
- No continuous manpower requirement
- Easy to operate
- Less operation and maintenance cost
- Reduces load for centralized system and thereby cost of transport

Disadvantages

- Need proper segregation of wet waste

Operation and maintenance aspects

- Before commencement of the operation, the area allotted for plant operations should be kept clean, with no unprocessed waste kept lying on site
- No finished products should be stored for more than a week
- The system will have scope to accept a variety of raw biodegradable materials
- The compost generated in the process need to be weed-free and rich in organic carbon contents and should be in conformity with the national/ international standards of fertilizer, for compost quality
- Once in 2 weeks the quality of the soil enricher shall be checked by the supplier and the certificate shall be issued by third party agency.

Design and specification

SN	Head	Details
1	Waste processing capacity per day	350 Kg
2	Approx. Dimension	13 ft (L) X 5.5 ft (W) X 5.5 ft (H)
3	Input	All types of organic wastes
4	Output	Soil additive
5	Volume reduction	85 – 90%
6	Power rating	9.0 Kw
7	Voltage	440V/50Hz
8	Control system	Electronic control
9	Operation	Fully Automatic
10	Heating system	Oil bath

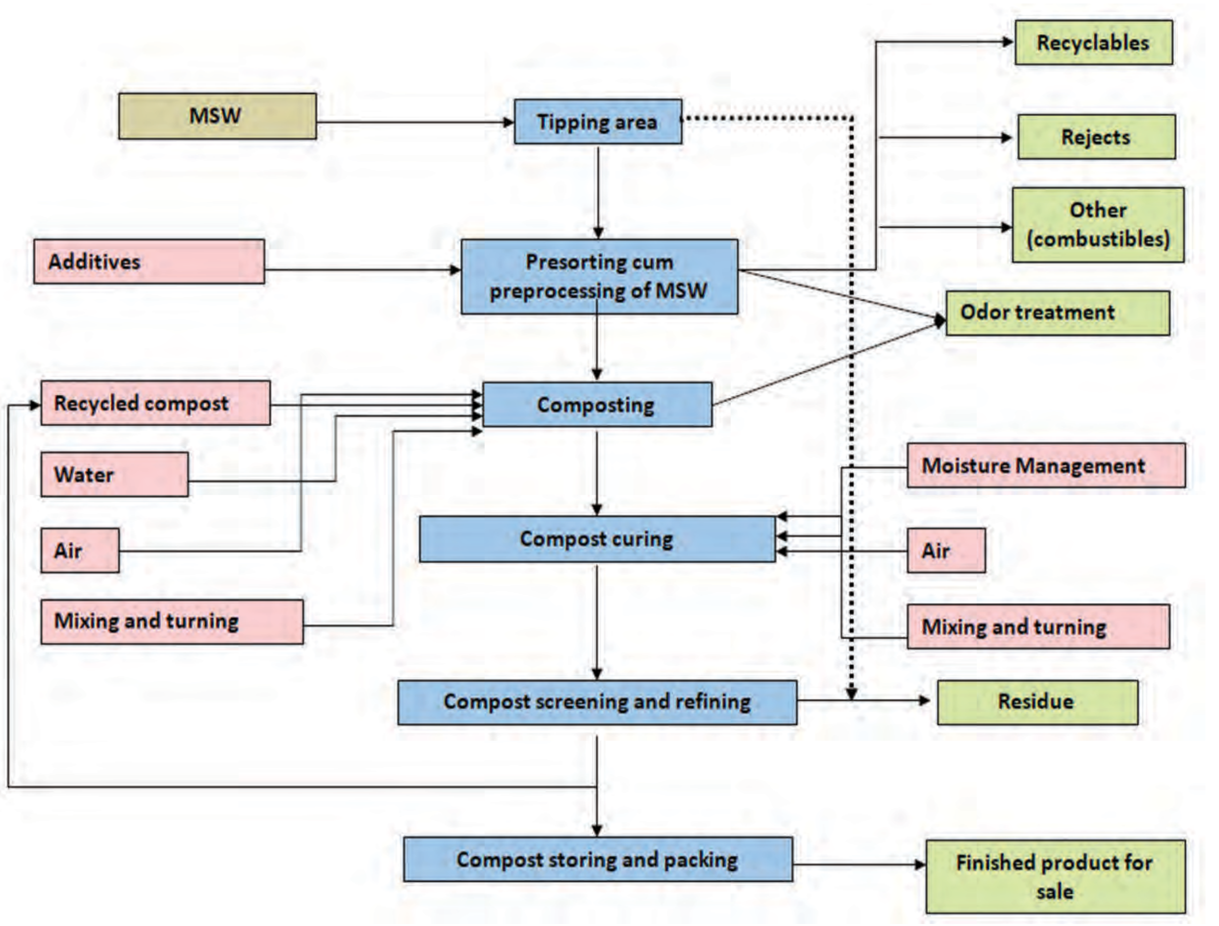
Cost (for 350 kg/day capacity)

- **Investments** – USD 20,000
- **O&M** – (power consumption)

Chapter 7: Resource recovery

Technical Option 7.3: Centralized composting facility

Technical flow diagram of the process



Applicable factors

Driving Factors	Desirable ranges
Moisture content	50% to 60% optimum
Temperature	50 to 60 ºC (for 5 to 7 days, pathogens get killed)
C/N ratio	Between 20- 40
	If C/N ratio is less -straw, saw dust, paper to be added
	If C/N ratio is more - sewage sludge, slaughter waste etc. to be added
	At the end of composting C/N =20. As per MSW regulations C/N permitted is 20-40
Aeration	Adequate oxygen through out the mass-normally ensured by turning every 5-7 days

Chapter 7: Resource recovery

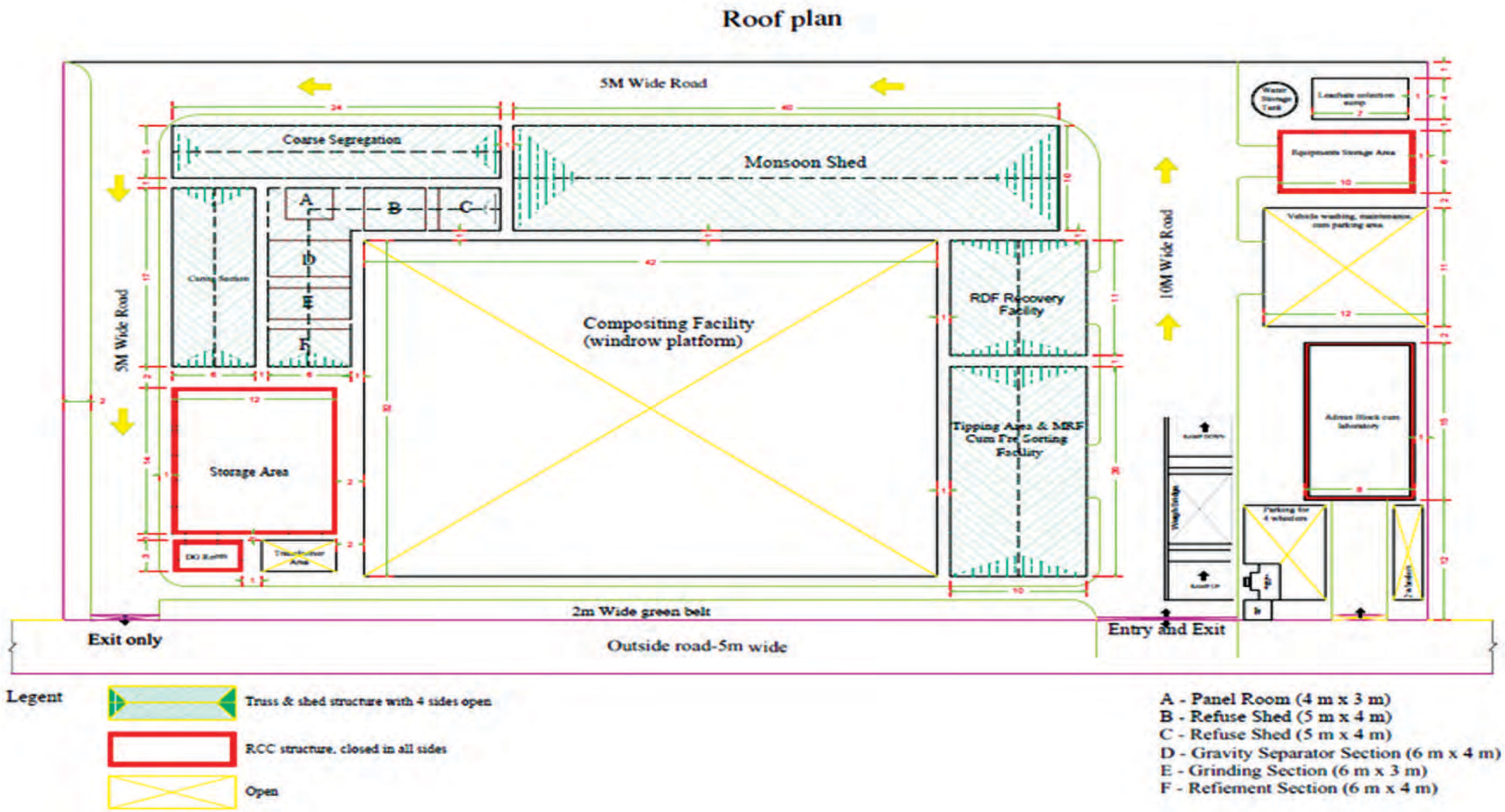
Technical Option 7.3: Centralized composting facility

Photographic visualization

Chapter 7: Resource recovery

Technical Option 7.3: Centralized composting facility

Indicative layout of the compost facility (Integrated)



Chapter 7: Resource recovery

Technical Option 7.3: Centralized composting facility

Rapid assessment

Advantages

- Economic, simple
- Keeps organic wastes out of landfills
- Provides nutrients to the soil
- Reduces the need for fertilizers and pesticides.

Disadvantages

- If C/N ratio is less, then straw, saw dust, paper to be added
- If C/N ratio is more -sewage sludge, slaughter waste etc. to be added
- Market demand linked and needs assessment
- Poor pre-sorting of incoming waste.

Operation and maintenance aspects

- Reception of raw MSW
- Visual Inspection of waste
- Weighing of Vehicle
- Manual Sorting of Inert and removal of rejected material
- Sorted material moved to Compost pad to form windrows
- Yard Management activities - Periodic Turning of Windrow & shifting
- After two weeks stabilization in monsoon shed, feeding of material to coarse segregation section
- Over sized rejects (+35 mm) to be sent to landfill
- Over sized rejects (+14 mm) sent to landfill or for windrow covering
- Undersized material (-14 mm) stocked in Curing section warehouse
- After two further weeks, cured material to be fed to refinement section
- Over sized rejection (+ 6 mm.) to be ground and mixed in curing section
- Under sized fine compost to be enriched with useful microbe
- Final Product (Compost) to be packed & stacked in finished warehouse.

Plant components and functionality

SN	Equipment	Purpose
A	**COARSE SEGREGATION**	
I)	Feeder	For feeding material at controlled rate.
2)	Dual Trommel 35/14	For screening
3)	Process conveyor	For feeding material to next trommel
4)	Reject conveyor	For removal of rejection off-line.
B	**REFINEMENT**	
I)	Drag Chain Feeder	For feeding material at controlled rate.
2)	Bucket Elevator	For lifting material & feeding to rotary screen
3)	Vibro Screen	For screening
4)	Gravity Separator with Aspirator	For separation of heavy impurities
5)	Packing Elevator	For lifting material & feeding it to add-mixer.
6)	Packing Spout	Two-way for packing material.
B	**REFINEMENT**	
I)	Hydraulic Power Pack & Control Panel	Push button station along with hydraulic system to improve efficiency and safety of equipments against fluctuating load.

Cost

- **Investments** – USD 28,000 per ton
- **O&M** – USD 1500 USD per ton per annum

Thermal plasma gasification process - Technical description, functionality and applicability

A plasma is defined as a quasineutral gas of charged and neutral particles which exhibits collective behavior. Plasma can be classified into non-thermal and thermal plasmas according to the degree of ionization and the difference of temperature between heavy particles and electrons. Electrically generated thermal plasma can reach temperature of ~10,000^{o}C or more. Over the past decade, thermal plasma process has also been regarded as a viable alternative to treat highly toxic wastes, such as air pollutant control (APC) residues, radioactive, medical wastes and municipal solid waste. It has also been demonstrated that the thermal plasma process is environmentally friendly, producing only inert slag and minimal air pollutants that are well within regional regulations. The thermal plasma process employs extremely high temperatures in the absence or near-absence of O_2 to treat MSW containing organics and other materials. The MSW is dissociated into its constituent chemical elements, transformed into other materials some of which are valuable products. The organic components are transformed into syngas, which is mainly composed of H_2 and CO and inorganic components are vitrified into inert glass-like slag. Factors controlling the technical process –

Amount of O_2

- Designed to maximize CO and H_2
- Added limited quantity of O_2
- Reducing environment
- Prohibiting the generation of NOx and Sox

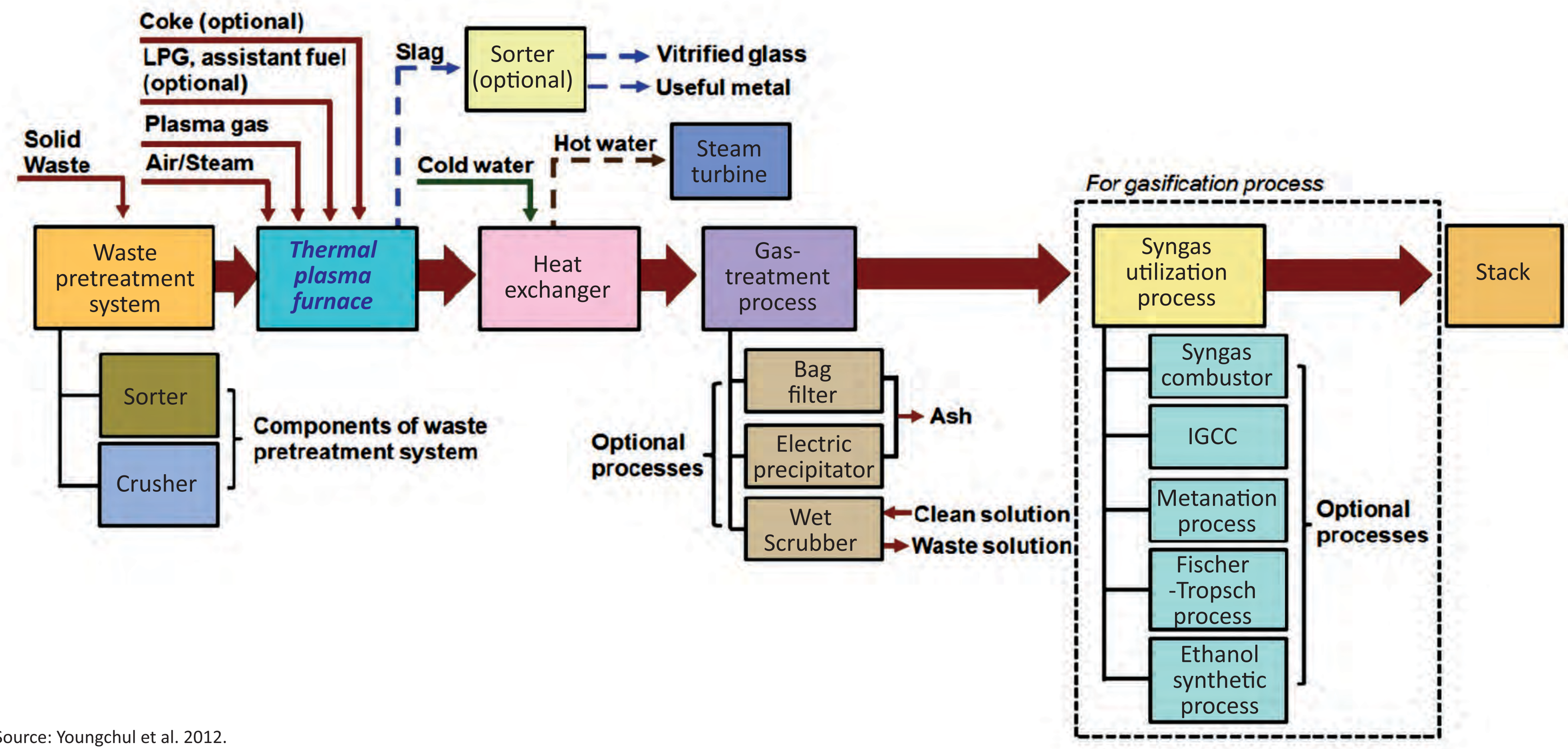
Temperature

- Operating at temperature above ash melting point
- Inorganic materials are converted to glassy slag and fine particulate
- Slag is non-leachable, nonhazardous and suitable for use in construction materials

Chapter 7: Resource recovery

Technical Option 7.4: Plasma Gasification

Thermal plasma gasification technology overview

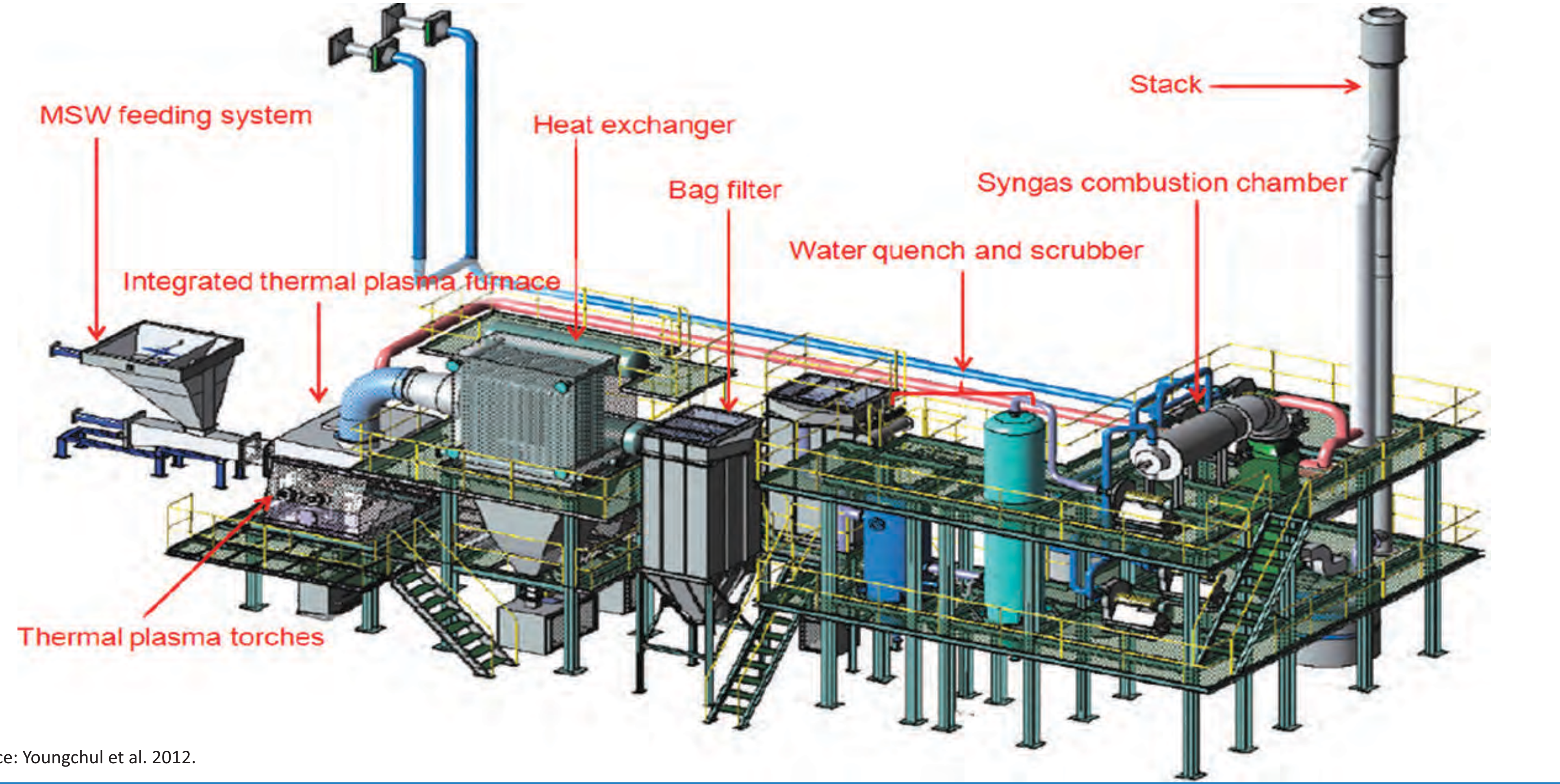


Source: Youngchul et al. 2012.

Chapter 7: Resource recovery

Technical Option 7.4: Plasma Gasification

A 3-D Schematic design of typical plasma gasification plant



Source: Youngchul et al. 2012.

Chapter 7: Resource recovery

Technical Option 7.4: Plasma Gasification

Rapid assessment

Advantages

- Feedstocks can be mixed, such as municipal solid waste, biomass, tires, hazardous waste, and auto shredder waste.
- It does not generate methane, a potent greenhouse gas.
- It does not produce leachable bottom ash or fly ash.
- It reduces the need for landfilling of waste.
- It produces raw gas, which can be combusted in a gas turbine or reciprocating to produce electricity or further processed into chemicals, fertilizers, or transportation fuels
- It has low environmental emissions.
- Comparing to traditional gasification, it doesn't generate tar during the gasification process.

Disadvantages

- It has not been proved in large scale plant, so there might be some drawbacks that are not yet known.
- The initial investment is very high.
- Plasma torches consume a lot of power.

Cost

- **Investments** – USD 0.2-0.4 million USD per ton
- **O&M** – USD 300 USD per ton per annum

Operation aspects

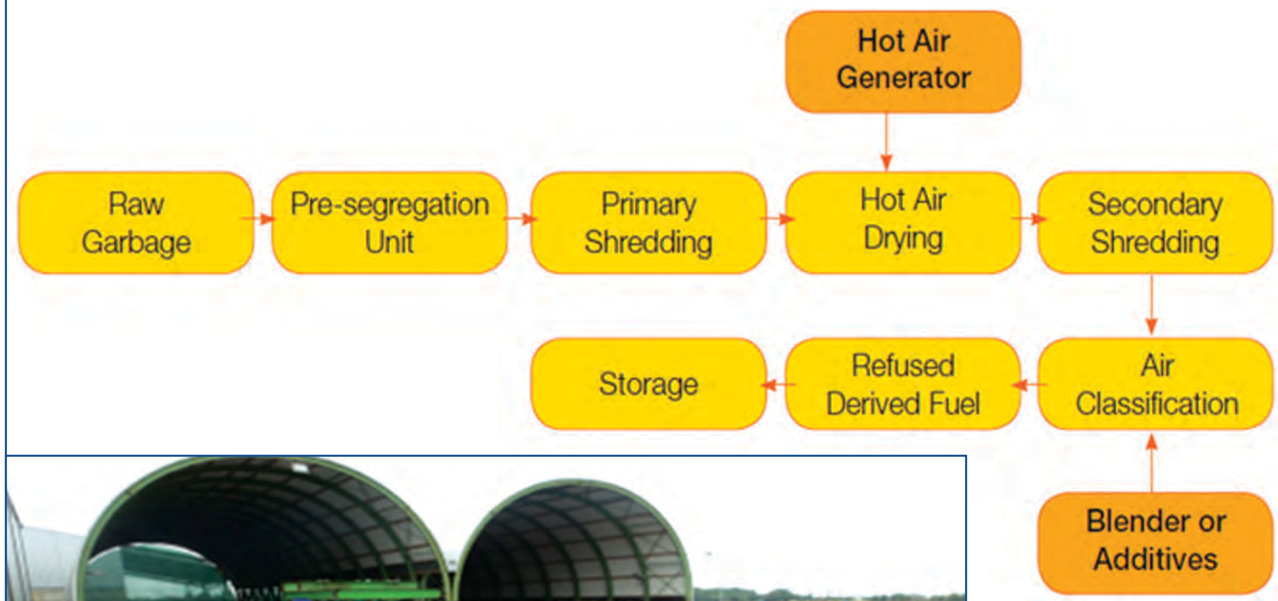
Within plasma gasification plant, inside the gasifier, plasma torches and arcs generate intense heat. This extreme heat maintains the gasification reactions, which break apart the chemical bonds of the feedstock and converts them to a raw gas. The high temperature can even increase the rate of the reaction, making gasification more efficient.

Gas treatment after the Gasifier - Raw gas is cooled down after the gasifier. Before entering the gas turbine, several steps need to be applied to clean the raw gas. Gas cleaning steps should be based on the source and composition of the waste. The raw gas mainly contains: H_2, CO, CO_2, H_2O, and N_2 and based on the feedstock it may contain: HCL, H_2S, NOx, SOx, heavy metal etc. Raw gas is cooled through a caustic venturi quench scrubber and scrubber system and then it goes to a wet electrostatic precipitator (WESP). The venturi quench and WESP can serve a purpose to remove the particulate matter in the raw gas and also convert chlorine within the raw gas into salt as well. After that, the raw gas goes through different gas cleaning processes in order to remove chlorine, sulphur, lead, cadmium, zinc and mercury.

Waste treatment after the Gasifier - Inorganic materials in the feedstock are melted in the gasifier. Due to differences in density, they are easily separated into two layers: a metal and a glassy silicate layer. The metal layer can be recycled as metal alloys, while the glassy product can be used in different commercial applications, including concrete aggregate, roadbed construction etc.

Chapter 7: Resource recovery

Technical Option 7.5: Overview of RDF treatment



Source: GoI, 2017 (Waste to wealth, Ministry of Housing and Urban Affairs)

Photo credit: GoI, 2017 (Waste to wealth, Ministry of Housing and Urban Affairs)

Technical description, functionality and applicability

Refuse derived fuel (RDF) typically consists of the residual dry combustible fraction of the MSW including paper, textile, rags, leather, rubber, non-recyclable plastic, jute, multilayered packaging and other compound packaging, cellophane, thermocol, melamine, coconut shells, and other high calorific fractions of MSW. The suitability of RDF for use as a fuel or resource is dependent on certain parameters of the constituent waste:

- Calorific value;
- Water content;
- Ash content;
- Sulphur content; and
- Chlorine content.

The required specific composition and characteristics of RDF for fuel or co-processing will be determined by the kind of boiler/ furnace, temperatures achieved in the furnace, and the associated flue gas management systems.

Chapter 7: Resource recovery

Technical Option 7.5: Overview of RDF treatment

Rapid assessment

Advantages

- Process does not associate emission or generates effluent
- No segregation or minimal segregation of waste

Disadvantages

- Highly dependent on the waste composition
- More suitable for waste with high calorific value and low moisture content;
- Very high level of pre-sorting of waste is required prior to processing for the successful operations
- Needs nearby market for utilization of RDF
- Large quantity of rejects (~35%), requiring bigger landfills.

Operation and maintenance aspects

SN	Operational aspects	Details
1	Type of waste	Mixed Combustible Waste
2	Suitability (Tonnes/ day)	Min: 0.50 , Max: 150.00
3	Area Requirement	Min: $100m^2$, Max: $1000m^2$
4	Life Duration	15 Years
5	Handling Expertise	Skilled + Semi Skilled + Unskilled
6	Reduction in Waste Volume	50%

Planning, design and implementation

The RDF production line consists of several unit operations in series to separate unwanted components and condition the combustible matter to obtain required RDF characteristics. In general, segregation and processing may include:

- Sorting or mechanical separation
- Size reduction (shredding, chipping, and milling)
- Drying (where required)
- Separation
- Screening
- Air density separation (for removing fine inert material)
- Blending
- Packaging
- Storage.

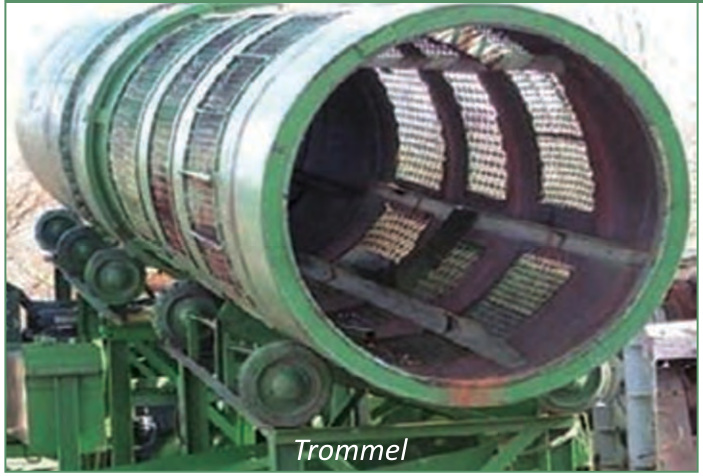
The type and configuration of unit, depend on the end use of the RDF. This is also determined by the necessary characteristics of waste (moisture, ash content, calorific value, chloride, heavy metals, etc.).

Cost

- **Investments** – USD 45,000 USD per ton
- **O&M** – USD 2250 per ton per annum

Chapter 7: Resource recovery   Technical Option 7.6: Centralized material recovery facility for dry waste

Photographic visualization



Trommel

Hopper, Screen, Conveyor

Baler

Conveyor

Technical description, functionality & applicability

The recyclable material collected is taken to the Material Recovery Facility (MRF) which houses a segregation plant. The basic principle for separation of recyclable material is moving the waste materials through a conveyor. The waste in the conveyor belt is a combination of magnetic responsive metals, magnetic non-responsive metals, glass materials and plastics. A magnetic separator removes the magnetic responsive metals. A vibrating shaker screen then receives the waste materials and by virtue of its vibration causes the smaller broken glass to pass through spaces in the screen. An eddy current separator separates non ferrous materials like aluminum etc. An air sorter including a large blower receives the waste materials and blows a stream of air across the waste materials so as to blow the lighter metals, such as the plastics, away from the remaining large glass materials, like bottles.

Chapter 7: Resource recovery Technical Option 7.6: Centralized material recovery facility for dry waste

Operation aspects

MRF units employ varying combinations of manual and mechanical operations, based on the type of facility, availability of equipment, labour availability, and associated cost implications.

Pre-sorting: Bulky and contaminated wastes hamper further sorting or processing in the facility; mechanical or manual pre-sorting is essential to separate out the wastes.

Mechanical sorting: Mechanical processes based on principles of electromagnetics, fluid mechanics, pneumatics., & used to segregate different streams in pre-sorted waste.

Screening: Screening achieves an efficient separation of particles into two or more size distributions. Two types of screens are used in MRF centre - disc screens and trommel.

Ferrous metal separation: In the second stage, electromagnets are used for separating heavy ferrous metals from mixed waste.

Air classification: The residual waste stream is passed through an air stream with sufficient velocity to separate light materials from heavy material, specifically for separating out lightweight plastics and paper from the mixed stream. Three types of air classifiers - (i) horizontal, (ii) vibrating incline (iii) inclined.

Non-ferrous metal separation: The non-ferrous metal like zinc, aluminum, copper, lead, nickel, and other precious metal from commingled waste are separated by eddy current separator.

Detect and route system: This system separates various grades of paper, plastics, and glass, which are not sorted out in the air classifier. This system works in two stages. The first stage employs programmed optical sensors to determine the nature of different materials. In the second stage, based on information received from the sensor, sorted material is routed to appropriate bins by directional air jets.

Size reduction: Sorted materials after segregation reduced to smaller sizes.

Baling: Sorted and sized material is baled for further processing or use.

Planning, design & implementation

SN	Head	Unit	Details
1	Design waste quantity (dry)	TPD	80
2	No of regular shifts	No	1
3	Duration of shift	hr	8
4	Plant capacity	TPH	10
5	Processing facility (tipping floor, processing equipment, residue transfer area, and storage)	m^2	1000
6	Scales, truck queuing and outdoor vehicle	m^2	600
7	Parking for rolling stock	m^2	1500
8	Employee parking	m^2	65
9	Site buffer allowance (10%)	m^2	320
	Total Site area requirement	**acre**	**~1**

Cost

Investments – USD 9-10,000 per ton, **O&M** – 5-7.5% of investments

Rapid assessment

Advantages

- Scientific disposal of inert and rejects
- Conserves resources for future
- Creates more jobs
- Avoids further pollution
- Saves energy
- Supplies valuable raw materials to industry
- Stimulates the development of greener technologies
- Reduces the need for new landfills

Disadvantages

- Need properly segregated dry waste

Plastic to fuel technology (PTF)

Pyrolytic Conversion Technology - A new generation of conversion technology, specifically designed to manage non-recyclable plastics, has been developed, and commercial scale facilities that use pyrolysis technology to convert plastics into oil and fuel are being established in Europe and Asia.

Pyrolysis is the thermal decomposition of materials at elevated temperatures in an inert atmosphere

Technology benefit

The benefits presented by plastic to fuel (PTF) technologies are two-fold:

(1) Transforming non-recyclable plastics into a valuable commodity

(2) Creating a reliable source of alternative energy from an abundant, no/ low cost feedstock.

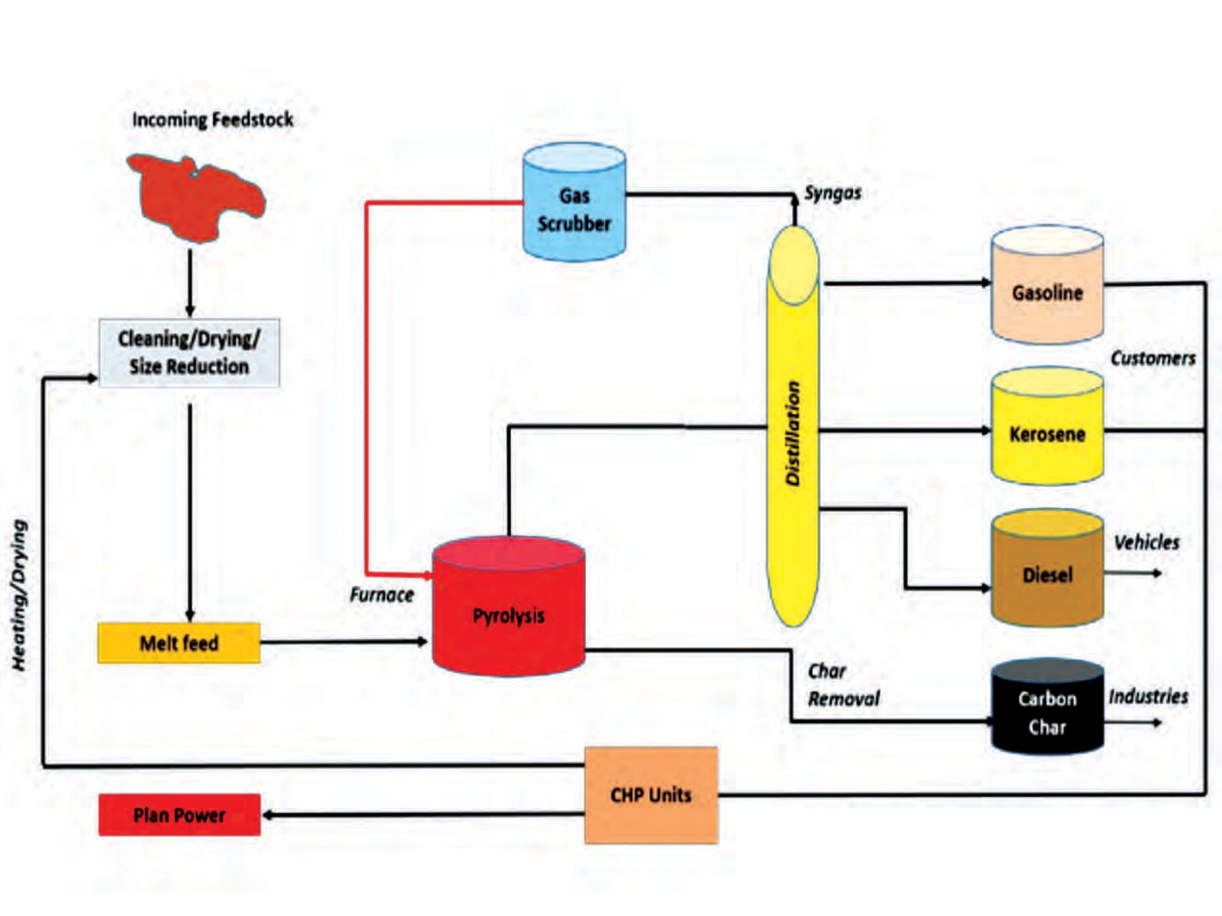
PTF technology process description

- **Segregation and Pretreatment:** Plastic waste (only HD, LD, PP and multilayer packaging except PVC) is segregated and pretreated. The pretreatment could be as minor as size reduction or as involved as cleaning and moisture removal.
- **Conversion:** Pyrolytic processes are used to convert the plastic to gas. It is undertaken in close reactor vessel where waste plastics is heated at high temperatures to convert it into vapor state. The catalyst is added whereby the pyrolysis requires less energy and results in the formation of more branched hydrocarbons. The gas generated in the process is reused as fuel in the process thus making the process economically viable and also help in minimizing air pollution.
- **Distillation:** The gas is collected in condensation chamber and is converted in the form of liquid fuel. The oil has properties similar to LDO and can be safely used as an alternative to LDO in industries thus conserving the already depleting natural resources.
- **Acid removal process:** Acids that form in the breakdown are required to be removed as they can be corrosive to the plastic to fuel systems as well as the engines that will consume the fuel.
- **Separation / final blending / refining:** It is required to be done as per the end-use.

Chapter 7: Resource recovery

Technical Option 7.7: Plastic to fuel technology

Process flow



Source: https://www.cga.ct.gov/2012/rpt/2012-R-0025.html

Output

Output	Percentage of Overall Output
Char	Ranges on average from 2% to 13% (one system claims negligible amounts of char when the system is run on a continuous feed vs a batch feed)
Natural gas	Ranges average from 8% to 10%
Fuel/ Oil	Ranges average from 80% to 90%
One gallon (3.78 liters) of oil = 138,095 BTUs (40 kWh) One pound (0.45 Kg) of mixed plastic = 15,500 BTUs (when incinerated) (4.5 kWh)	

Chapter 7: Resource recovery

Technical Option 7.8: Resource Recovery at Disposal site

Photographic visualization

Technical description

Biomining process of resource recovery involves the mechanism of recovery of combustible fraction, nutrient rich soil fraction and inert from the existing unscientific disposal sites. This process is largely applicable for the dumpsite which are being operational for many years and about to close soon. The revenue stream out of this process are – combustible fraction or RDF, ii) soil enricher, and iii) inert or rejects for (low lying area filling). The process of resource recovery through biomining method involves three stages –

Pre-stabilization – The disposal site is converted into equal sized windrows and turned frequently along with spraying of bio-culture and de-odouriser. This would ensure removal of stench, reduction of flies, and elimination of pathogenic activities, complete biodegradation and reduction of moisture.

Sorting and segregation – In this stage, mobile equipment separate and excavate waste into soil, stones and combustibles.

Disposal – In this stage soil, inert and non-combustible are disposed as construction material/ earth filling material/ soil enricher etc. and the combustible part as refused derived fuel.

Chapter 7: Resource recovery

Technical Option 7.8: Resource Recovery at Disposal site

Plant visual

Chapter 7: Resource recovery

Technical Option 7.8: Resource Recovery at Disposal site

Operation aspects

During operation, following aspects shall be taken care of -

- Automatic weigh bridge will be installed at the site for inward weighting.
- Leachate management systems will be incorporated in the plant.
- Dust management systems will be incorporated in the plant.
- Topographic survey using total station method will be done regularly to ensure volume reduction.
- Laboratory test will be conducted of all outputs using external laboratory once a month.
- All workers will be wearing safety jacket, helmets, masks etc.
- Fire extinguisher will be placed in all locations.
- Proper security arrangements will be incorporated in the site.
- Proper health checkup will be made to all employees working.

Rapid assessment

Advantages

- Has high economic revenue
- Biomining process of resource recovery leads to dumpsite reclamation, resulting in recovery of land for further use
- Revenue is also generated from the sale soil enricher, during the pre-stabilization stage of resource recovery
- Reclaimed soil after recovery process, can be used as filling material after excavation, road construction, thereby reducing the cost of filling or construction material
- Recovered combustible waste can be used for the production of refuse-derived fuel (RDF) and sold to cement or power plants

Disadvantages

- Need proper waste compaction at disposal site
- Waste slope stabilization is required before recovery process

Cost

Cost - USD 2-15 per m^3 of input waste for resource recovery

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Annexure – Selected detailed technical designs

A1 Technical design detail of transfer stations

A2 Technical design detail of centralized innovative zero waste treatment facility

A3 Technical design detail of centralized medical waste treatment facility

A4 Technical design of controlled landfill

A5 Technical design detail of decentralized biomethanation plant

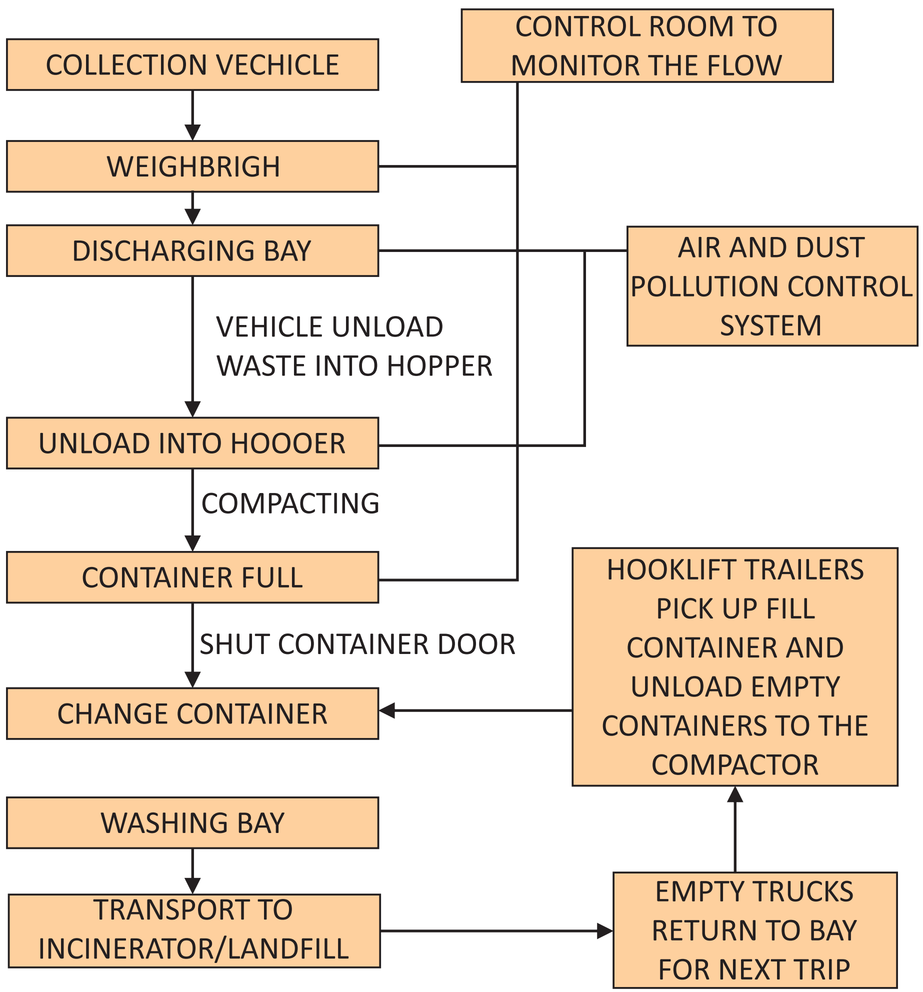
A6 Technical design detail of decentralized organic waste converter

A7 Technical design detail of MRF facility for dry waste

A8 Technical design of resource recovery at disposal site

Annexure 1 — Technical design detail of G+1 Elevated transfer station

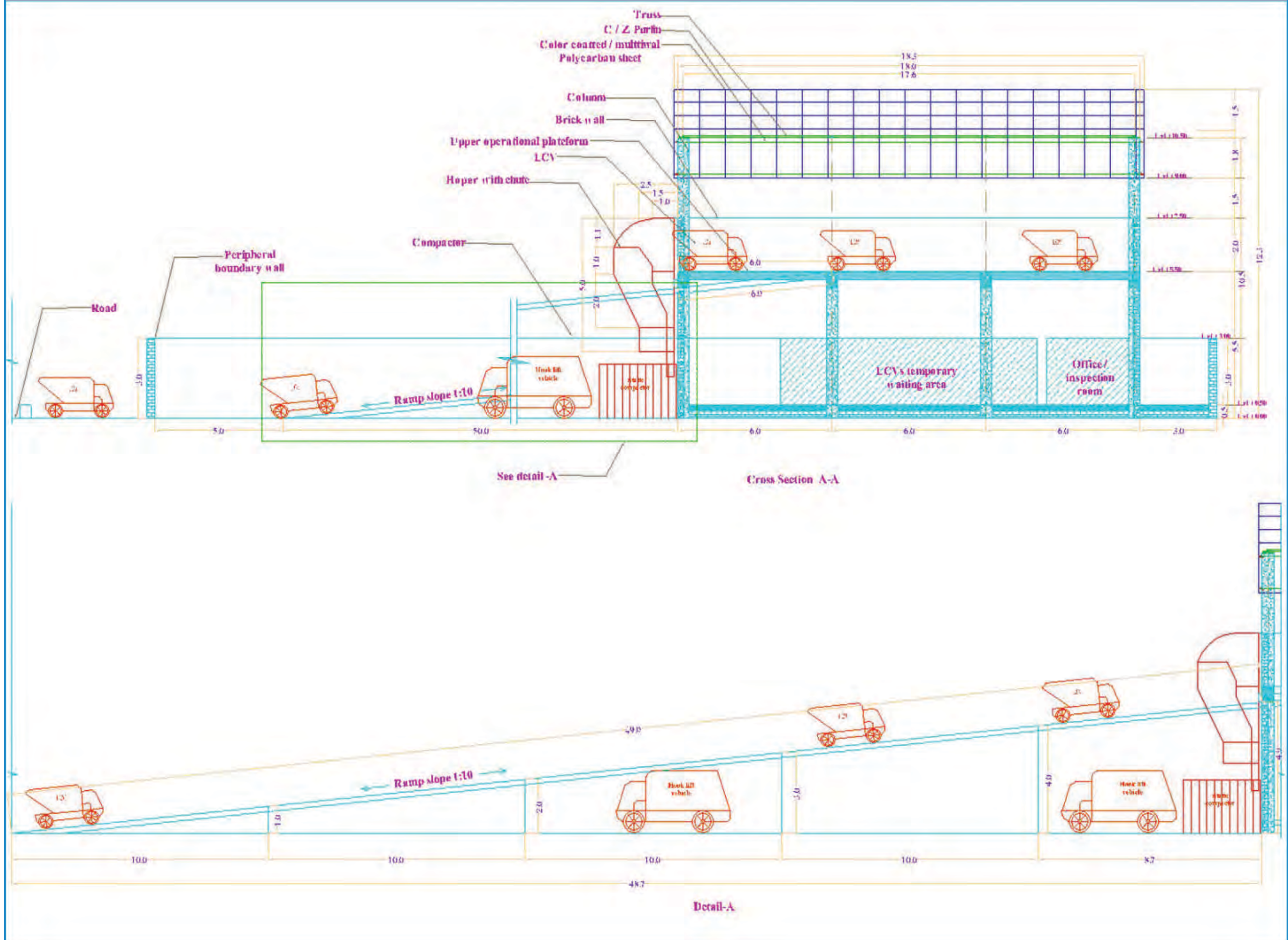
Process flow in transfer station



Operational Visualization of transfer station

Annexure 1 Technical design detail of G+1 Elevated transfer station

Scematic Design of G+1 elevated transfer station – (Cross section)



Description and functionality of Different components and Units:

- Upramp – to allow incoming tipper vehicle
- Tipping platform (G+1) – to host the vehicle to be stationed before unloading
- Hopper – to unload the waste from tipper
- Chute – to transfer waste from (G+1) to ground floor compactor
- Stationery compactor with detachable container – to compact the waste inside it
- Hook loader – to roll on and roll off the container
- Truck chassis – to carry the compactor container to the disposal facility
- Down ramp – to allow tipper vehicle to exit after unloading into the hopper.

Annexure 1 Technical design detail of G+1 Elevated transfer station

Important procedures for feasibility study

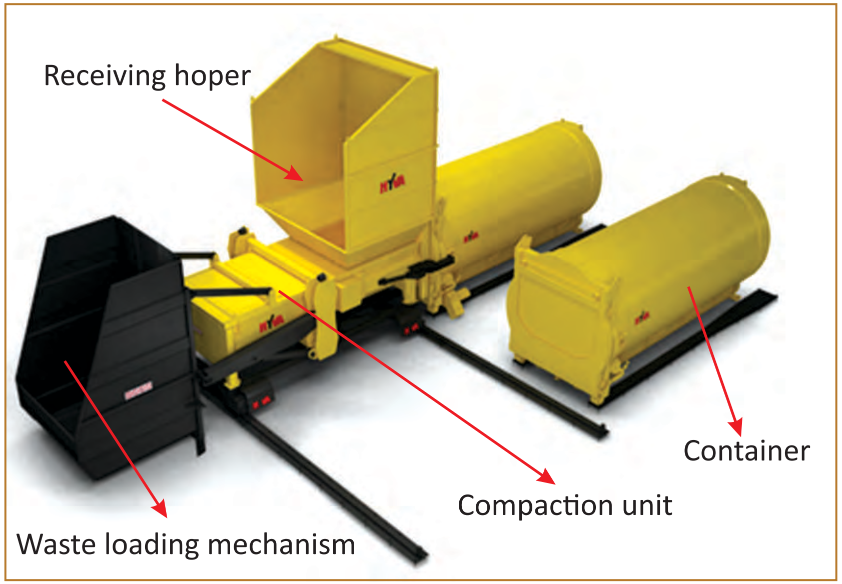
- Quantification of waste
- Characterization of waste
- Mass balance for different service chain in line with the proposed treatment and disposal mechanism
- Capacity estimation of the transfer station
- Area statement
- Identification of location for transfer station
- Environmental assessment
- Social assessment an stakeholders consultation
- Geotechnical, topographical survey and ground water quality analysis
- Schematic design and layout preparation
- Infrastructural planning
- Block costing
- Financial and investment mechanism
- Implementation mechanism
- Contract modality identification
- IEC requirement
- Monitoring framework
- Operation and maintenance aspects.

Important procedures for installation and commissioning

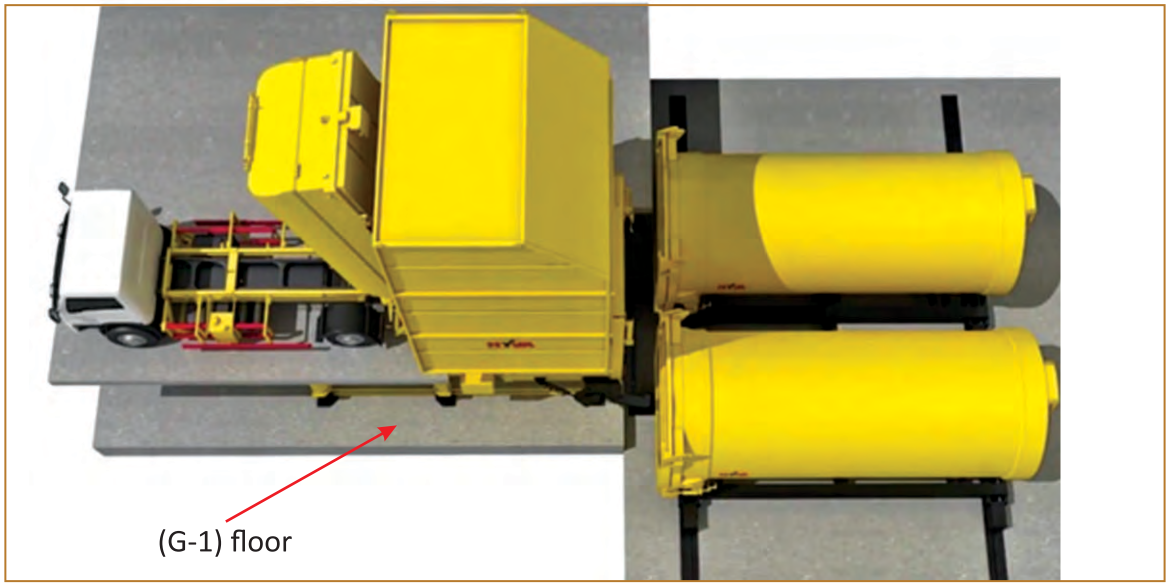
- Site clearances, cutting of bushes
- Necessary surveys, investigations, monitoring etc., as required
- Excavation, site filling, leveling work
- Earth Compacting
- Filling of Aggregate/ PCC bed
- CC & RCC Work as per drawing
- Brickwork as per drawing
- Finishing Work including Plastering ,Painting &Tile work
- MS Truss work for roofing and shed
- DG Set as per specification
- Fixing mechanism for hopper, chute, and stationery compactor
- Lower operational area
- Upper operational area
- Road base and Floor development
- Drainage system
- Boundary wall
- Leachate collection tank
- Water storage tank
- Vehicle parking (both for operational vehicles and staff vehicle)
- Drivers' room
- Electrification and solar roof installation
- Toilet, plumbing, sanitation& pit
- Office room
- Vehicle washing bay
- Minor maintenance bay
- Ramp.

Annexure 1 Technical design detail of G-1 Underground transfer station

Operational visualization of transfer station



Side view

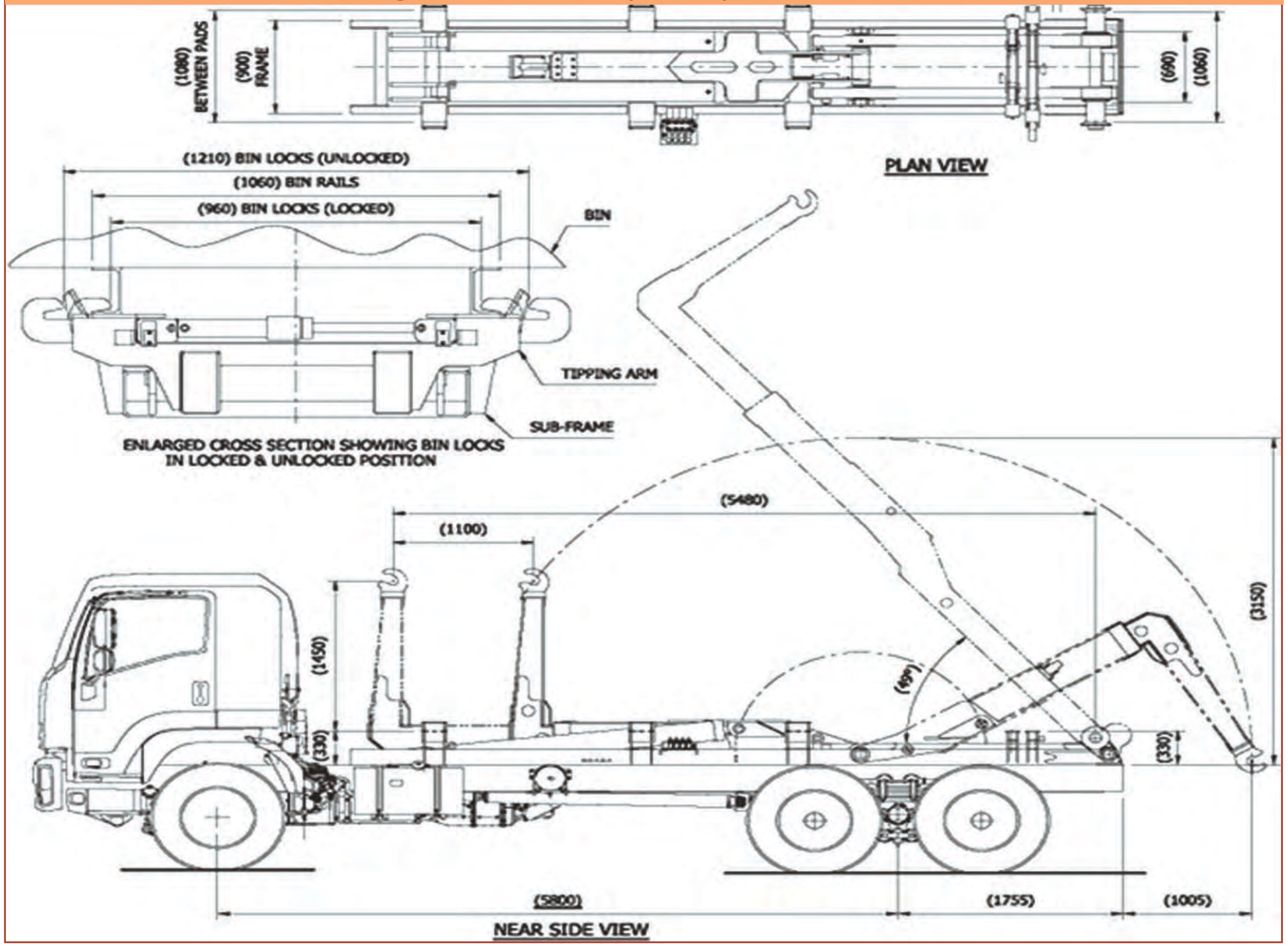


Top view

Container being lifted by the hook loader for disposal

Annexure 1 — Technical design detail of G-1 Underground transfer station

Scematic design of stationery compactor and hook loader



Description and functionality of different components and units:

- Receiving bay – to allow incoming tipper vehicle
- Underground bucket (G-1) – to receive the unloaded waste and then conveying to the porta
- Stationery compactor with detachable container – to compact the waste inside it
- Hook loader – to roll on and roll off the container
- Truck chassis – to carry the compactor container to the disposal facility
- Shed – to protect the transfer station and compactor unit from rain.

Annexure 1 Technical design detail of G-1 Underground transfer station

Important procedures for feasibility study

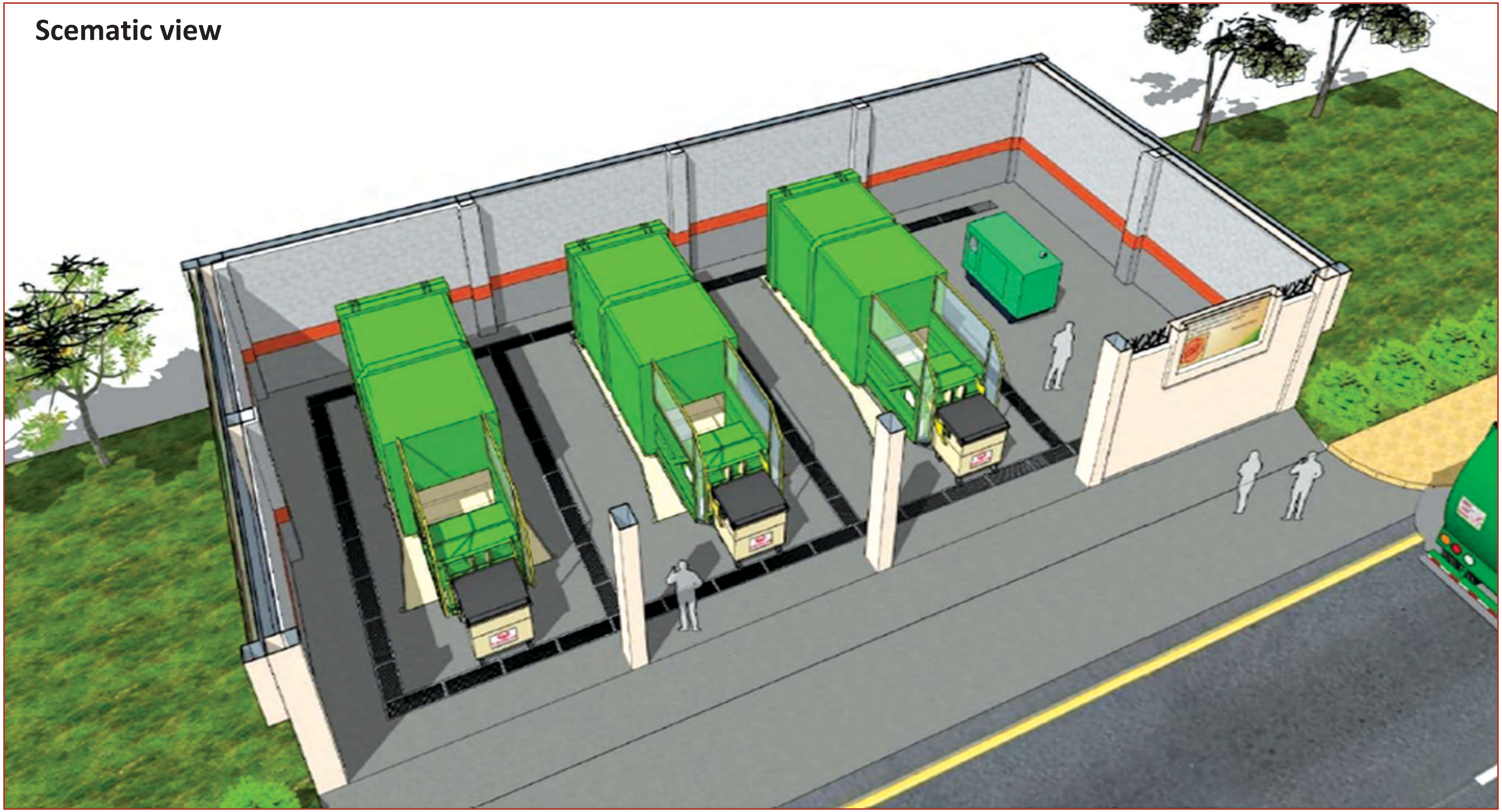
- Quantification of waste
- Characterization of waste
- Mass balance for different service chain in line with the proposed treatment and disposal mechanism
- Capacity estimation of the transfer station
- Area statement
- Identification of location for transfer station
- Environmental assessment
- Social assessment an stakeholders consultation
- Geotechnical, topographical survey and ground water quality analysis
- Schematic design and layout preparation
- Detailed assessment of subsurface condition
- Infrastructural planning
- Block costing
- Financial and investment mechanism
- Implementation mechanism
- Contract modality identification
- IEC requirement
- Monitoring framework
- Operation and maintenance aspects.

Important procedures for installation and commissioning

- Site clearances
- Necessary surveys, investigations, monitoring etc., as required
- Excavation, site filling, leveling work
- Earth Compacting
- Filling of Aggregate / PCC bed
- CC & RCC Work as per drawing
- Brickwork as per drawing
- Finishing Work including Plastering ,Painting &Tile work
- MS Truss work for roofing and shed
- DG Set as per specification
- Fixing mechanism for receiving hopper and stationery compactor
- Access road and Floor development
- Drainage system
- Electrification and solar roof installation
- Toilet, plumbing, sanitation& pit
- Office room.

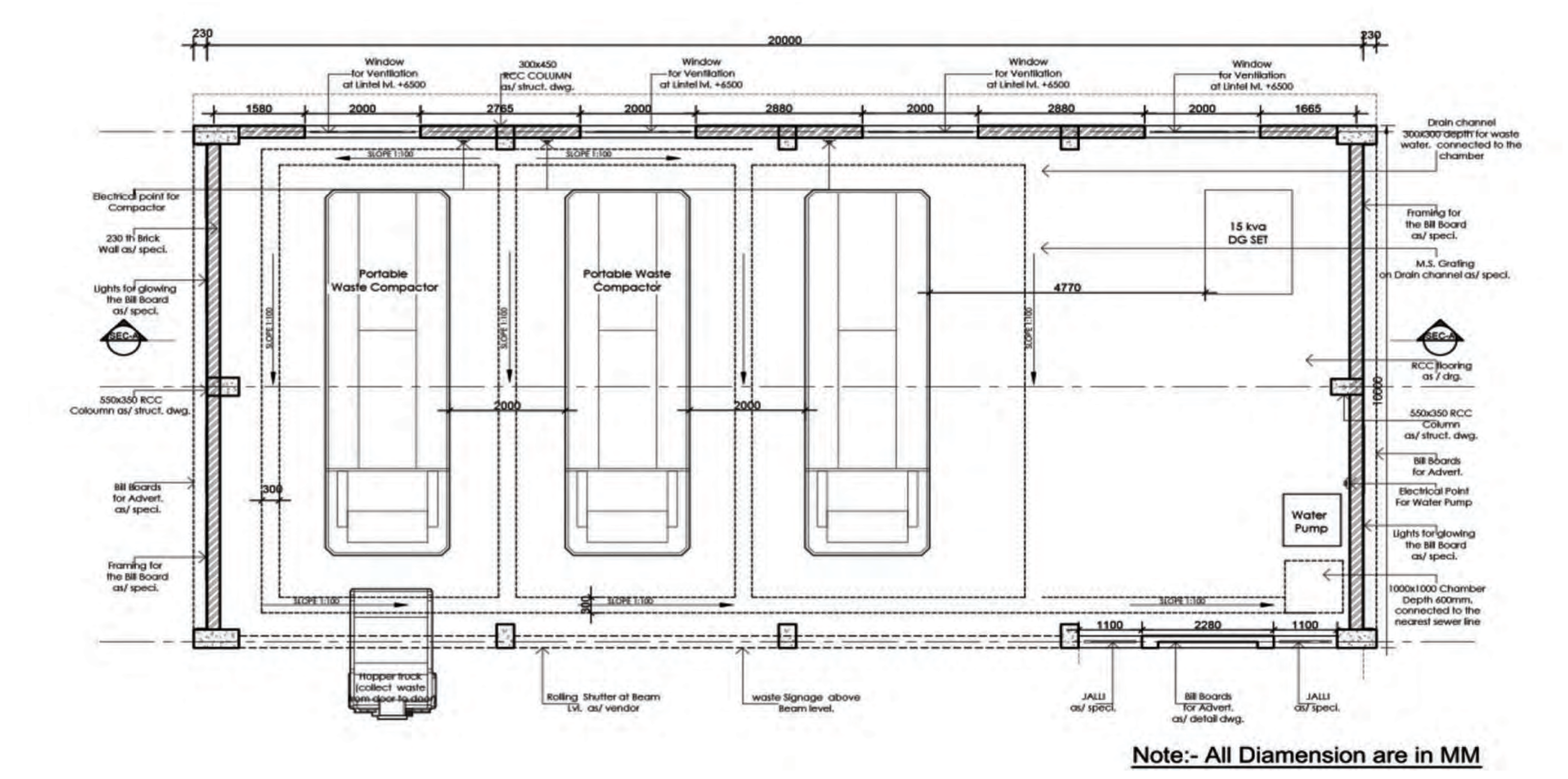
Annexure 1 — Technical design detail of G+0 Ground level transfer station

Scematic view



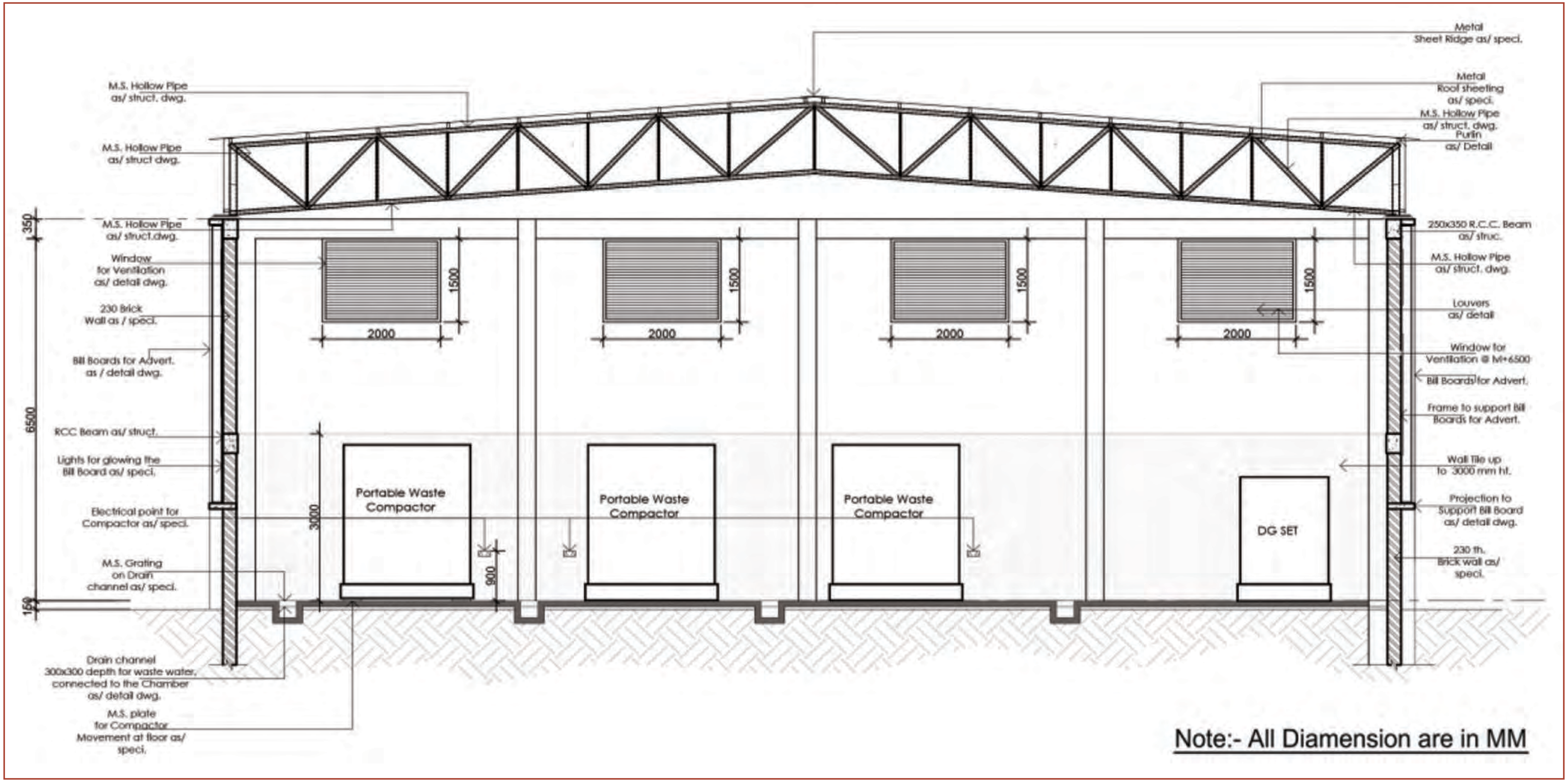
Annexure 1 Technical design detail of G+0 Ground level transfer station

Scematic view



Annexure 1 Technical design detail of G+0 Ground level transfer station

Sectional view



Annexure 1 — Technical design detail of G+0 Ground level transfer station

Description and functionality of different components and units:

- Compactor and container – compactible with hook loaded truck mounted chassis for transportation of waste
- Hook loader – with self loading/unloading mechanism to list & carry the container to the disposal site.
- DG Set – 15 Kva 3 phase to run the compactor

Optional components

- Shed – to protect the transfer station and compactor unit from rain
- Concrete flooring: designed to withstand the load impacts from the vehicles used for collection and transportation of waste
- Drainage system – to collect and convey the rainwater.

Important procedures for installation and commissioning

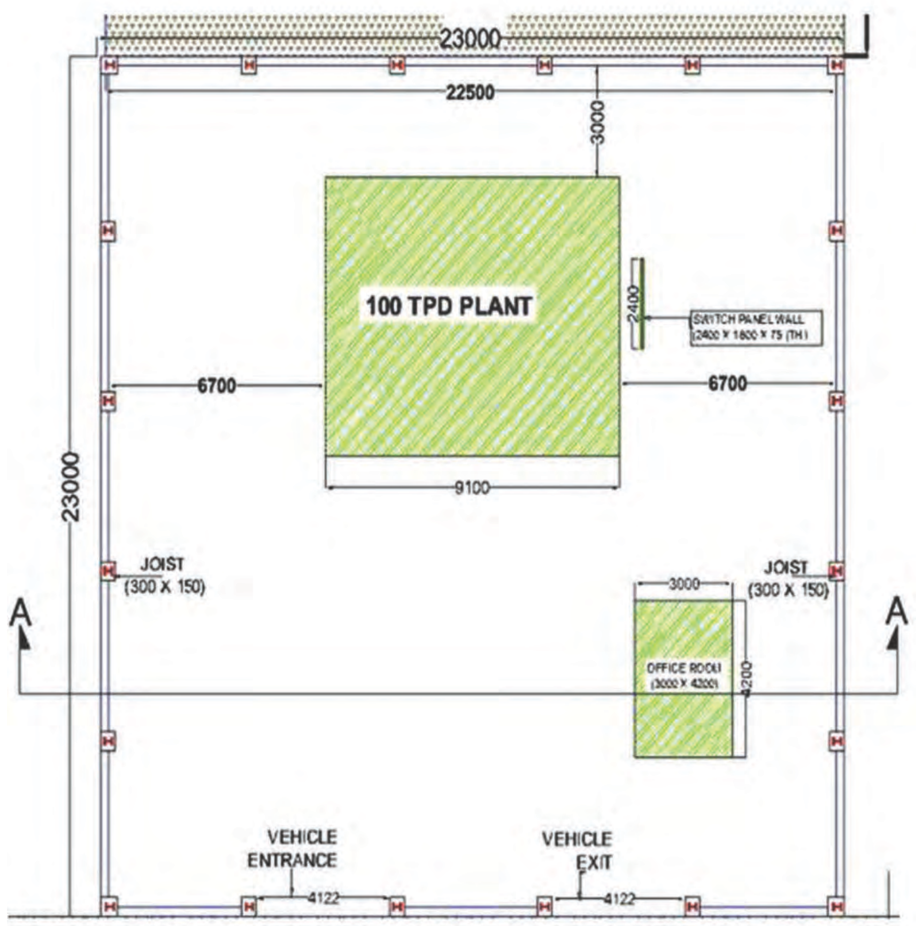
- Site clearances and earmarking
- Planning on the access road and turning radius
- Shed and brickwork (optional)
- DG Set as per specification
- Drainage system.

Important procedures for feasibility study

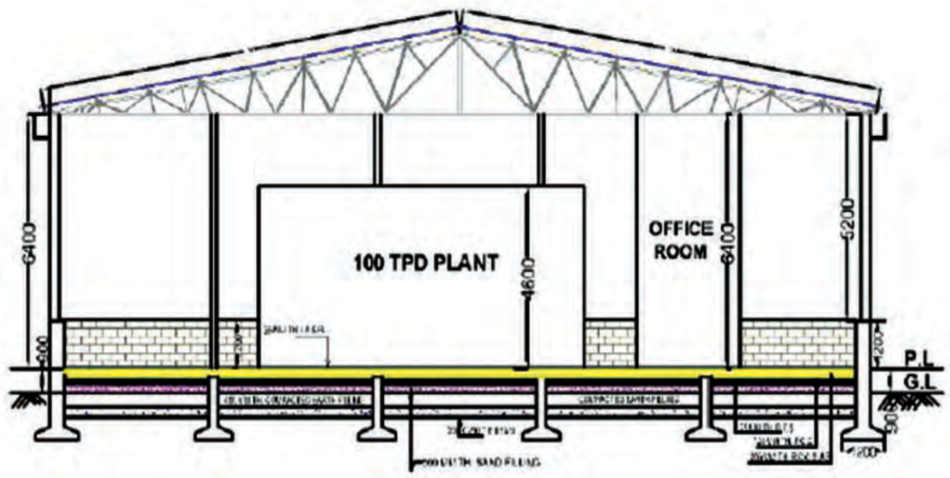
- Quantification of waste
- Characterization of waste
- Mass balance for different service chain in line with the proposed treatment and disposal mechanism
- Capacity estimation of the transfer station
- Area statement
- Identification of location for transfer station
- Planning for no of required unit, based upon the disposal location, & vehicle speed
- Block costing
- Financial and investment mechanism
- Implementation mechanism
- Contract modality identification
- IEC requirement
- Monitoring framework
- Operation and maintenance aspects.

Annexure 2 Technical design detail of centralized innovative zero waste treatment facility

Plan



Section



Description & functionality

The inner wall is made of ceramic rich refractory coating compound. Ceramic applied over inner walls of chamber to protect from corrosion and erosion. Dioxins, difurans and parabens are destroyed inside the machine itself, a multi layered sprinkling system comes along with the equipment. The equipment is made in Stainless Steel with higher grade SS 304 which is antirust and corrosion free. Prefabricated heating modules consisting of vacuum formed ceramic fibre is being used to enhance temperatures.

Annexure 2 Technical design detail of centralized innovative zero waste treatment facility

Important procedures for feasibility study

- Assessment of waste quantification
- Physical characterization of waste (especially for glass, metal and inert percentages)
- Assessment of moisture content of waste
- Identification of land
- Preliminary environmental and social screening of the site
- Preparation of drawing, layout and site infrastructure design
- Implementation timeline and contract mechanism
- O&M aspects, role of individual stakeholder, and implementing agency
- Cost recovery mechanism

Important procedures for installation and commissioning

- Design, drawing, and project implementation timeline approval
- Site investigation and surveys
- Obtaining NOC , permits etc. from the statutory governing bodies
- Water supply & Electric supply connection
- Construction of Weigh Bridge Facility for
- Measurement of MSW received at project site.
- Access road, boundary wall, site office construction
- Construction / Installation of plant will all allied equipments
- Infrastructure
- Trial run

Annexure 3 Technical design detail of centralized medical waste treatment facility

Components & functionality

Ram Feeder - Bio-hazardous Waste is loaded into the incinerator through the kiln faceplate by a horizontal, hydraulically charged ram feeder.

Rotary Kiln - The kiln is comprised of a refractory lined carbon steel shell encircled by two steel riding rings.

Discharge Breeching - The discharge breech is designed to collect the ash discharged from the rotary kiln and to allow the larger particles to drop out of the flue gas stream prior to entry into the secondary combustion chamber.

Ash Slide Gate - The bottom ash from the incinerator is discharged through a slide gate valve.

Secondary Combustion Chamber (SSC) - All gaseous products of combustion from the rotary kiln incinerator pass into the refractory-lined vertical SCC.

SCC Emergency Stack - The outlet of the SCC represents the end of the combustion reaction. Hence, it represents an ideal location for the emergency stack.

SCC Auxiliary Fuel Oil Burner - The purpose of this burner is to maintain the SCC chamber at the design operating temperature.

SCC Waste Combustion Air Fan - Combustion air for incineration of the liquid waste is blown into the SCC adjacent to the point of injection.

Evaporative Cooler - Flue gas enters the top of the evaporative cooler through a horizontal connection to the inlet plenum.

Dry Lime/Carbon Injection System - Purpose of the system is to neutralize HCl in the flue gas & to collect Dioxins, Furan & Metals via activated carbon adsorption.

Fabric Filter - The dirty or contaminated gas enters the fabric filter module through an inlet in the hopper.

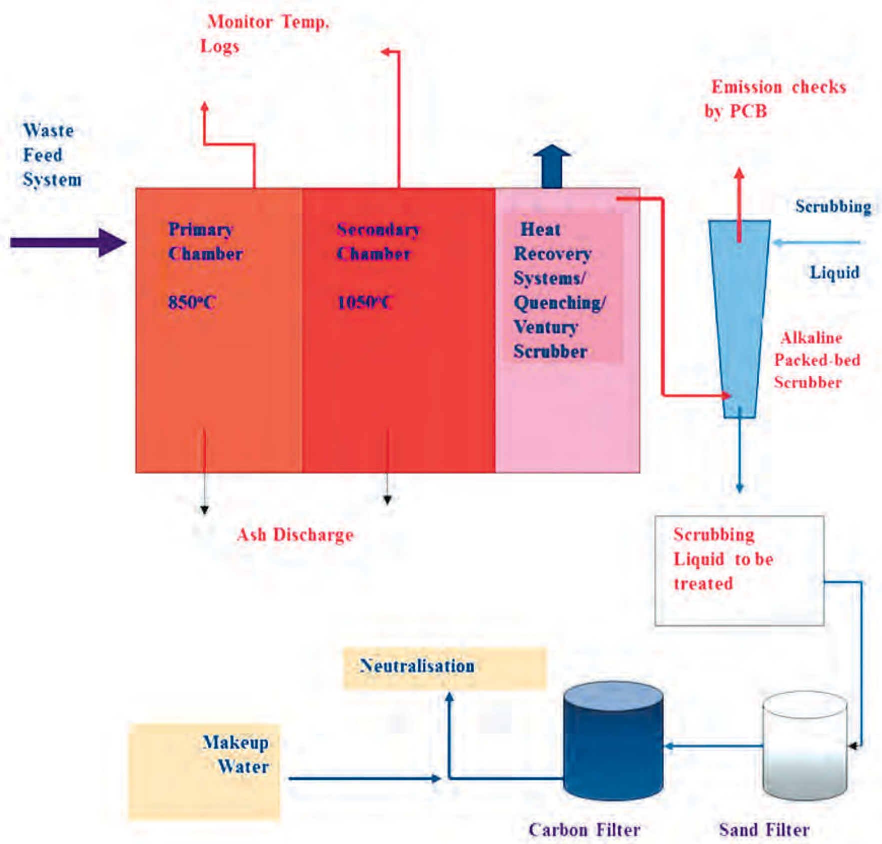
Packed Tower/ Vent Stack - A wet scrubber with integral vent stack is provided for final acid gas scrubbing prior to the discharge of the cleaned flue gases.

ID Fan - A radial blade, high pressure induced draft fan is supplied to maintain draft control in the incinerator system.

Programmable Logic Controller

Annexure 3 Technical design detail of centralized medical waste treatment facility

Process flow diagram



Important procedures for feasibility study

- Assessment of waste quantity from different medical and healthcare establishment
- Registration with concerned medical association for hand over of waste to the medical waste incinerator agency
- Segregation of autoclaving and sterilizing item from the incinerable biomedical waste stream
- Check for calorific value
- Environmental screening and assessment of the incineration site
- Provision of wash disposal in hazardous waste management disposal site.

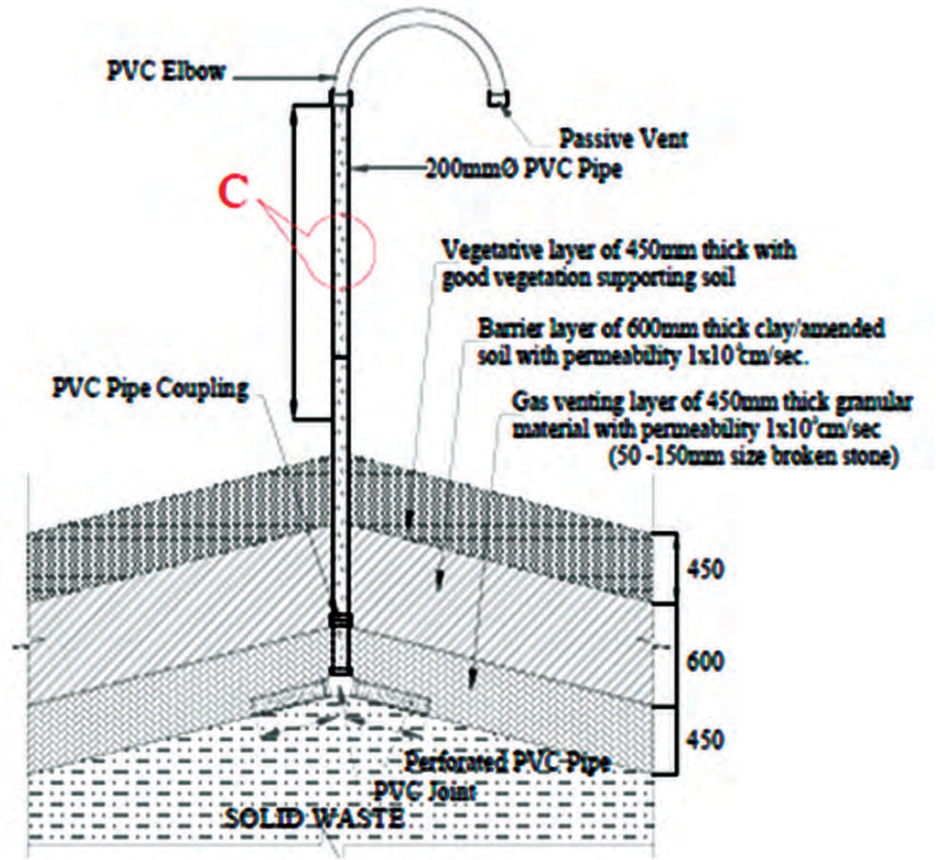
Annexure 4

Technical design of controlled landfill

Liner system	
Vegetative layer	0.45 m
Barrier layer of clay with permeability 1 X 10-7cm/sec	0.6 m
Gas venting layer of granular material with permeability 1 X 10-cm/sec	0.6 m
Municipal Solid Waste	(above G.L. and 5m below G.L.)
Drainage layer of permeability not greater than 1X10-^{7} cm/sec	0.3 m
HDPE Geomembrane liner (1.5 mm)	
Amended local soil with permeability 1X10-7 cm/sec	0.9 m

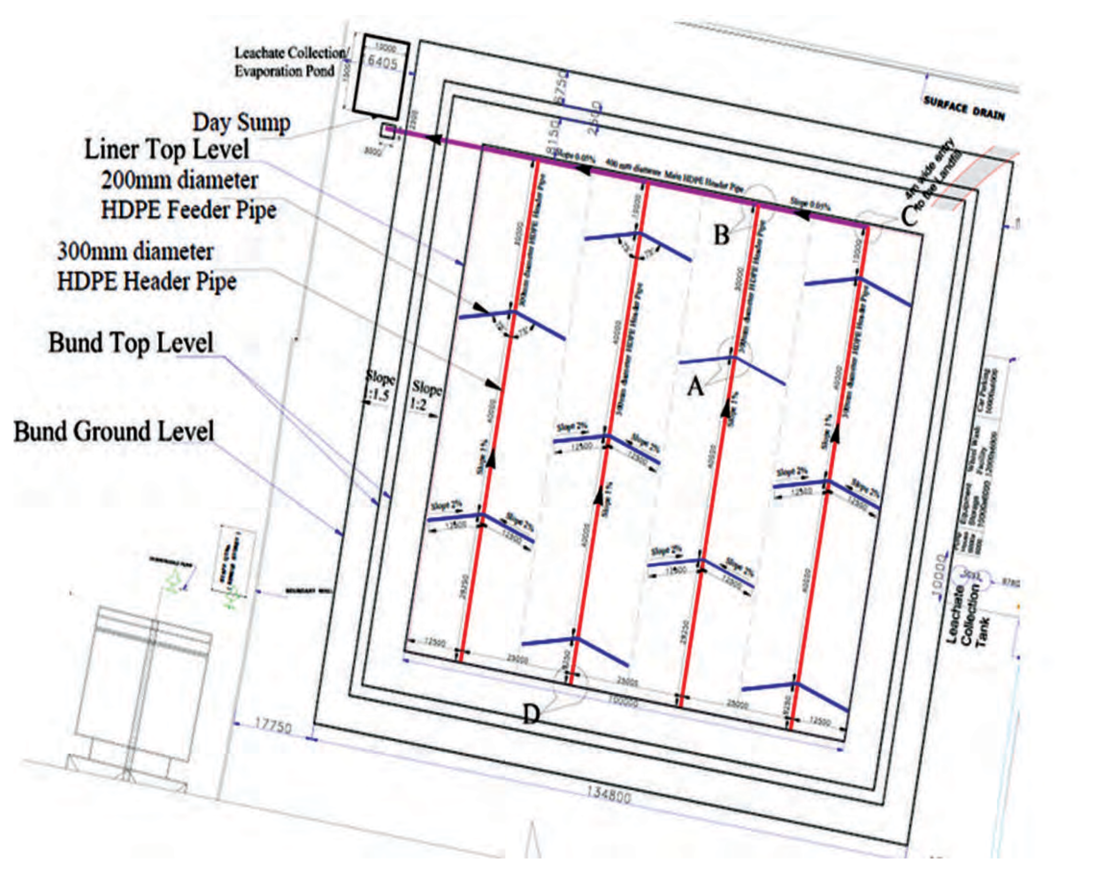
- 3.0 m (minimum), Ground water level

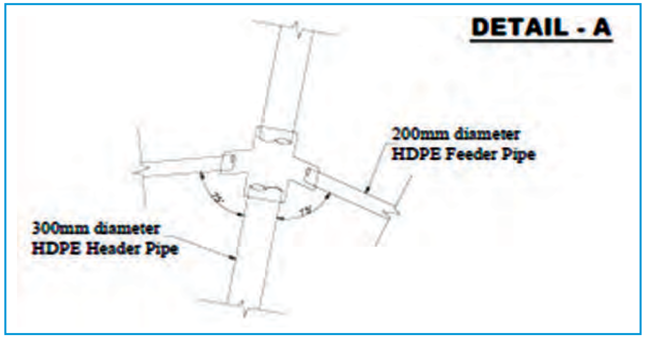
Gas venting system

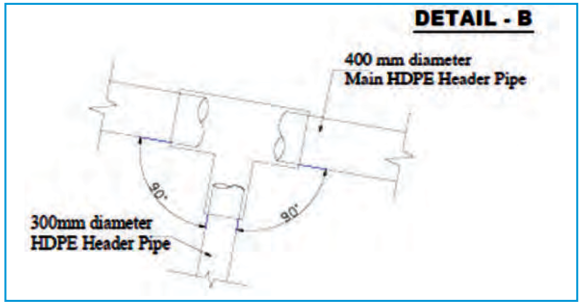


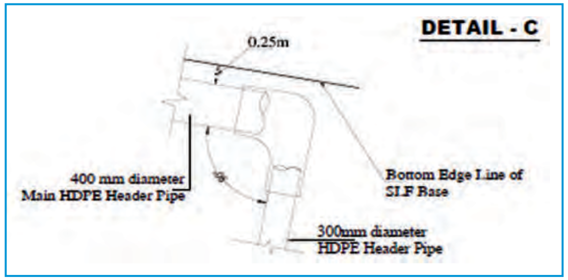
Annexure 4 — Technical design of controlled landfill

Leachate management system



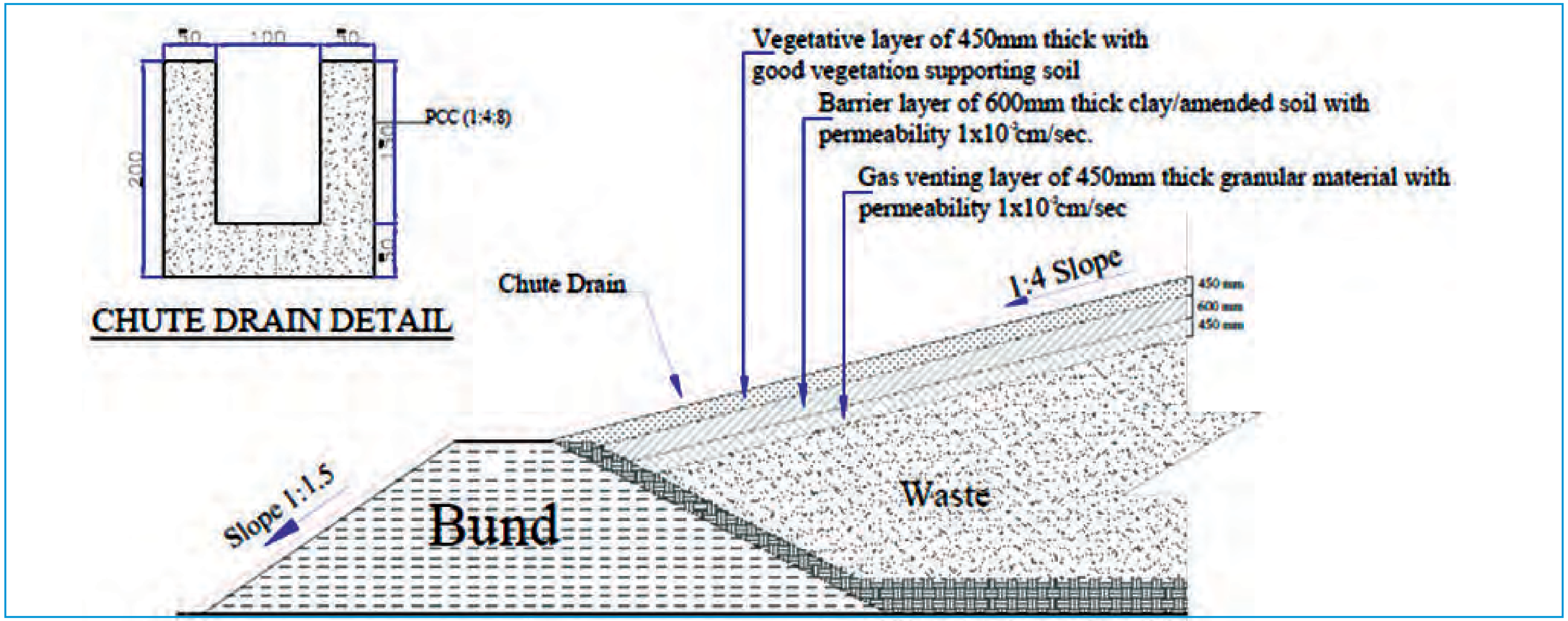




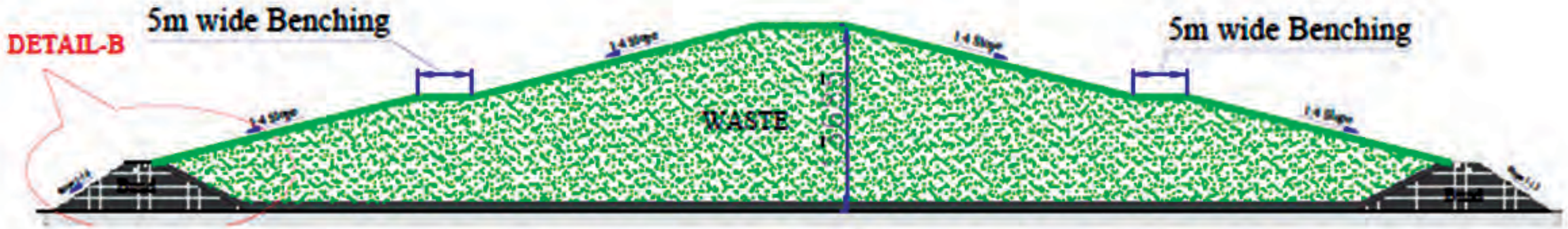


Annexure 4 — Technical design of controlled landfill

Sectional Details of Top Liner System



Closure View



Annexure 4

Technical design of controlled landfill

Important procedures for feasibility study

SN	Criteria	Feasibility
1	Lake/Pond	200 m away from the Lake/ Pond
2	River/streams	100m away from the river/ stream
3	Flood plain	No land fill within a 100 year flood plain
4	Highway	Away from 200 m highway
5	Public parks	300 m away from public parks
6	Wet lands	No landfill within wet lands
7	Habitation	500 m away from the notified habitation area
8	Ground water table	Ground water table > 3m
9	Critical habitat area, reserve forest, protected area, ecologically sensitive area	No landfill within the Critical habitat area
10	Air ports	No landfill within 20 km
11	Water supply schemes/ wells	Minimum 500 m away

Important procedures for installation and commissioning

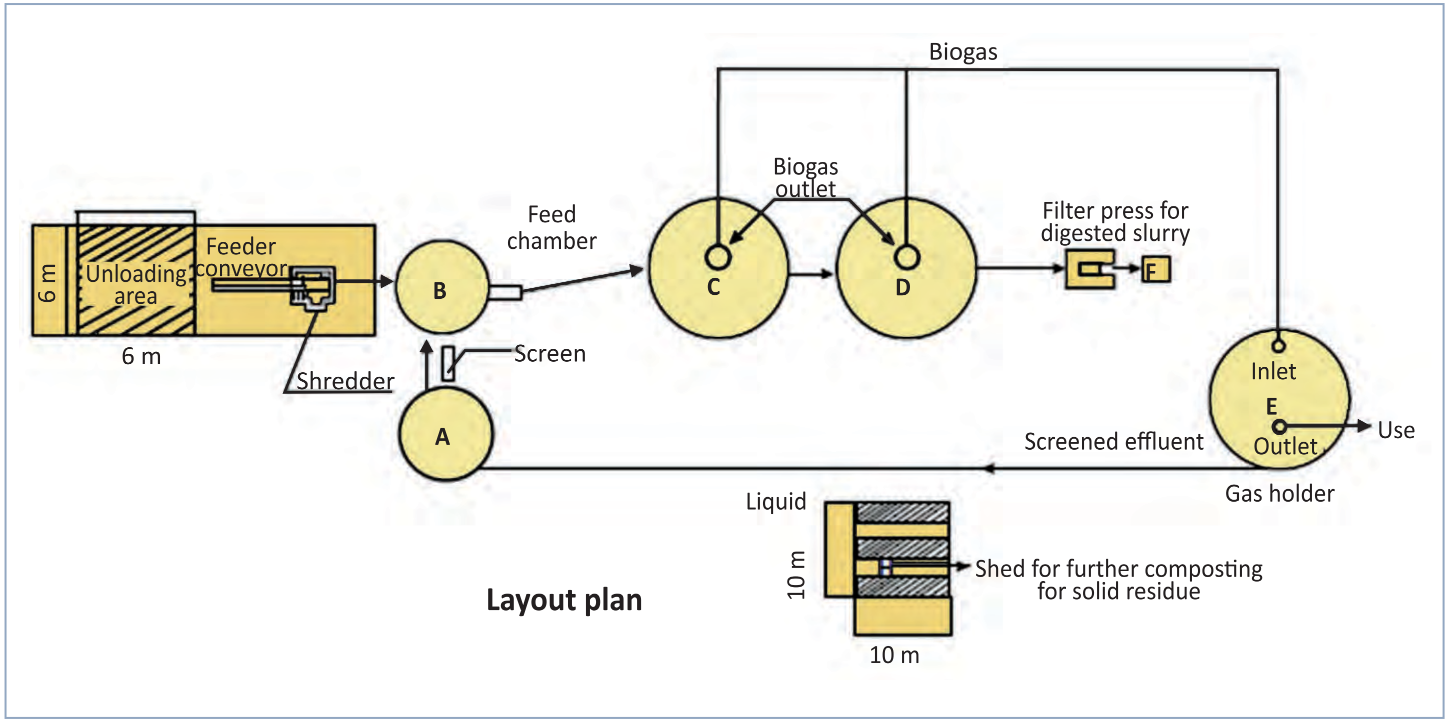
- Site earmarking and topographical survey
- Geotechnical investigation and ground water level
- Excavation and backfilling
- Bund, peripheral road, and access construction, electricity etc
- Construction of underground sump
- Construction of weighbridge
- Compaction of clay layer at the bottom
- Installation of 1.5 mm thick HDPE liner
- Testing of liner at site
- Installation of gravel layer
- Laying of header pipes
- Laying of feeder pipes
- Construction of boundary wall, admin building, water supply, utility etc
- Testing of load cell at weighbridge.

Approach for selection of landfill site

- Earmark a "Search Area" taking in to account locations of cities
- Collection of preliminary data
- Identification and Evaluation of Potential Sites
- Screening and short-listing of potential sites to arrive at best sites
- Environmental Impact Assessment
- Assessment of public perception for the selected site
- Final Selection and notification of the site.

Annexure 5 Technical design detail of decentralized biomethanation plant

Description & functionality of different components



1. Pre-treatment
The organic waste shall be fed to the Pulverizer/ Homogenizer where the material shall get homogenized and sieved /shredded for size reduction < 10 mm material. After a retention time of few hours in the Pulverizer/ Homogenizer, the waste is fed into the AD (Anaerobic Digestion) unit.

2. Digestion
The AD unit is provided with recirculation. During the anaerobic digestion process, the material passes through the AD unit. The digested residue is extracted from the AD unit from the bottom. The biogas generated is collected at the top.

3. Bio-gas Production
The bio-gas generated through Biomethanation process will be used for Power generation.

4. Power Generation from Bio-Gas
The gas stored in the gas holders is fed to Biogas engines to generate electricity. Necessary utilities, basic safety requirements and instrumentation are considered for proper operation, monitoring and control of the plant performance. The captive power will be utilized from the Gross generated power.

5. Slurry Dewatering
The residue left after the anaerobic digestion will be dewatered and dried. The dried solid can further be sold as organic compost.

Annexure 5 Technical design detail of decentralized biomethanation plant

Important procedures for feasibility study

- Identification Of source of generation and markets
- Waste quantity estimation
- Characterization of waste
- Effective segregation mechanism
- Collection mechanism
- Storage provision
- Provision of accepting waste from additional source
- Identification of market and necessary survey for end product sale (compost)
- Provision of power utilization to grid or captive
- Identification of place for installation
- Basic environmental screening of the site
- Earmark of the area
- Preliminary layout preparation
- Revenue estimation
- Financial mechanism of the project
- Implementation model.

Important procedures for installation and commissioning

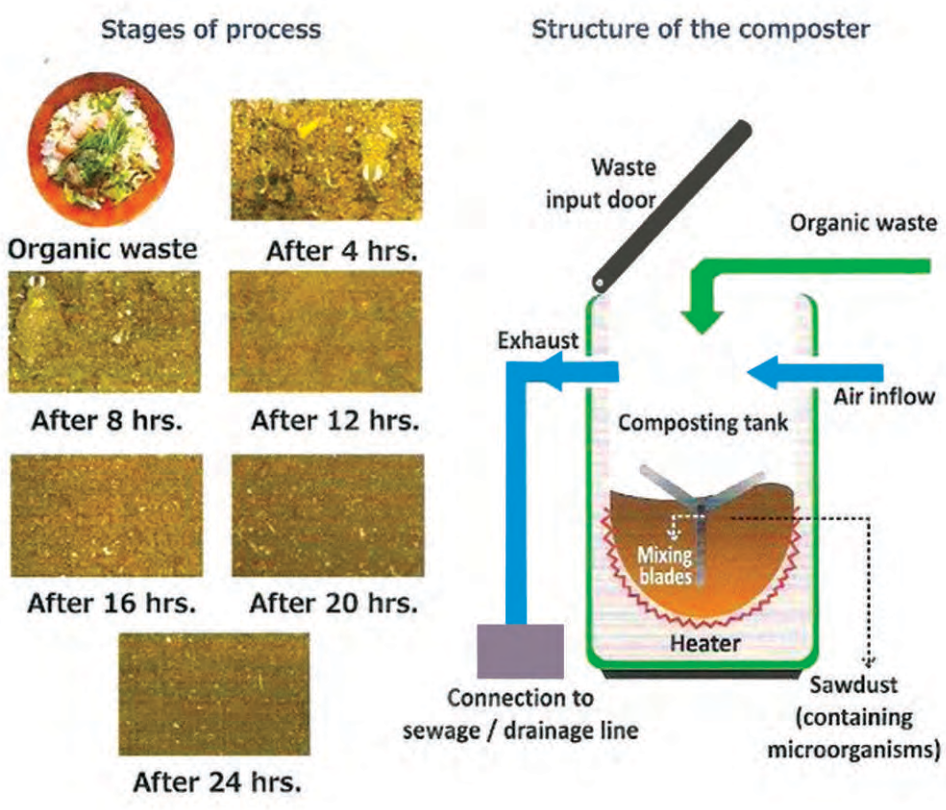
The plant should be equipped with all infrastructures including plant, building, machinery and other necessary utilities as required. There should be a weighing machine consisting of a pot for collection of the waste and weighing of the waste. There should be provision of water and electricity to be consumed during the period of Construction and O&M of the plant.

The plant should be designed, built, operated and maintained for a period of at least 10 years. The plant would produce energy and compost adhering to disposal standards. During operation, it shall follow all applicable standards as per prevailing regulations of national/ international guideline and standards. There should be a segregation unit in the area allocated for segregation. The waste from the identified market(s) would be transported to plant site. In case the designed waste quantity is completely treated in less than a stipulated period, the provision should be kept for collection and treatment of additional waste from other market sources.

The Energy produced would be transferred directly to GRID or shall be utilized for captive purpose and the compost would be packed and handed over to the implementing agency.

Annexure 6 Technical design detail of decentralized organic waste converter

Process flow diagram



Description & functionality of different components

SN	Components	Details
1	Inner tank	The tank is comprised of inner blades attached to the shaft and are designed for mixing, hammering and shredding.
2	Outer body	Outer body is made up of MS Powder coated.
3	Oil bath heating system	The oil uniformly heats the inner tank and retains the heat for a long period of time, resulting in lower power bills and better energy Management.
4	Master & Slave-heating system	Prevents downtime if a heater failure occurs, resulting in a better uptime.
5	Direct drive technology	The machine uses a direct drive technology wherein the main shaft of the machine on which the mixing blades are fixed is directly coupled to the geared motor by a planetary gearbox. This results in better load distribution to main shaft and better mixing. It also prevents main shaft breakage due to metal fatigue and stress.
6	Odor management	The ODS ensures odour removal from the hot air that is let out through the machine ventilation system.
7	Motors and controls	All motors and control equipment are of International quality, resulting in better efficiency and durability.

Annexure 6 Technical design detail of decentralized organic waste converter

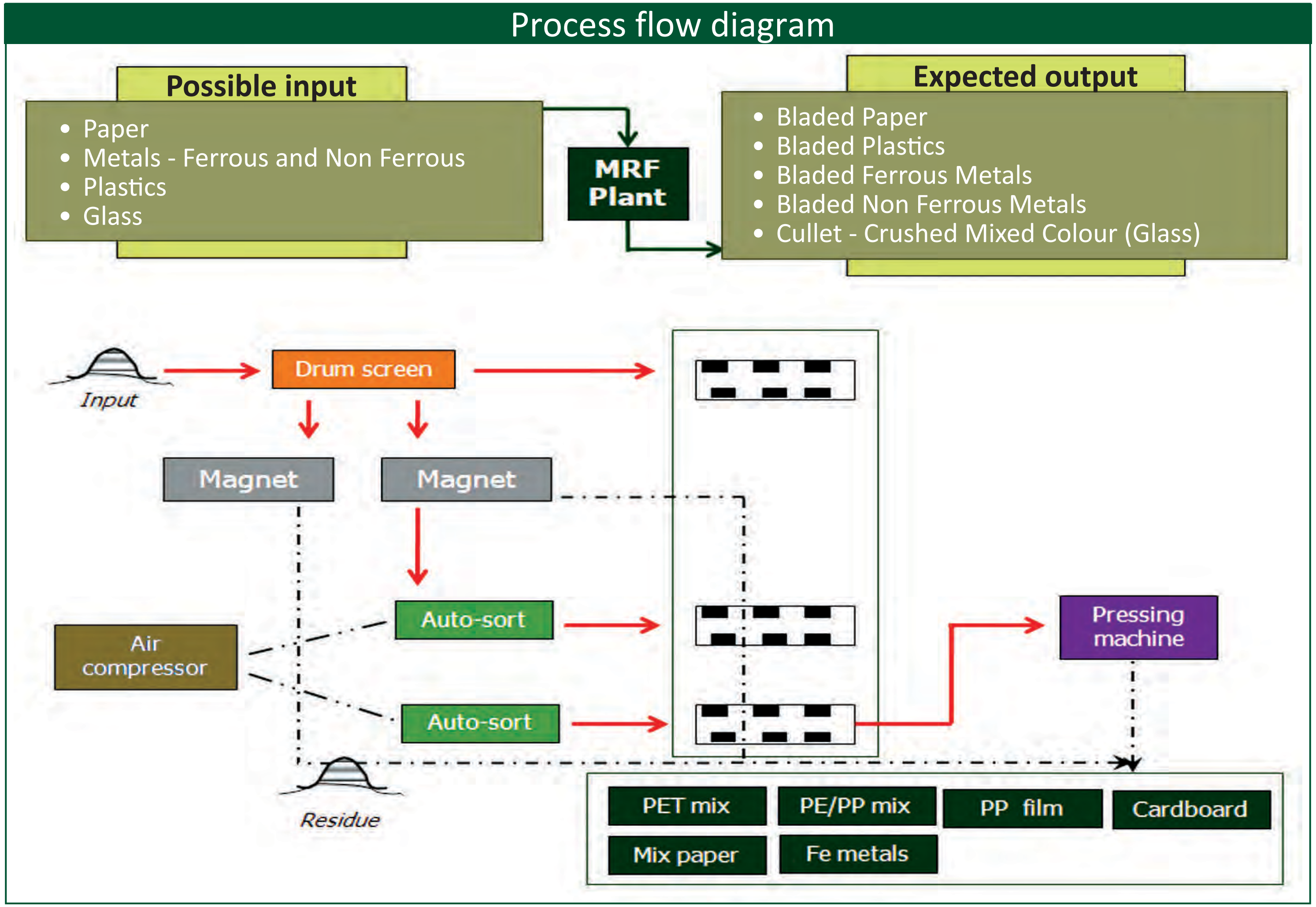
Important procedures for feasibility study

- Identification of source of generation and installation– housing societies, institutions, offices, big medical establishments, shopping malls with large food court etc.
- Assessment of status of segregation of waste into dry and wet
- Willingness and public consultation
- Quantification of assured waste quantity and commitment
- Characterization (physical) of wet waste
- Identification of area of installation
- Preliminary screening of the instalment location
- Power supply, water supply and access establishment
- Feasibility provision for installation of multiple unit, for future.

Important procedures for installation and commissioning

- The system should be equipped with shredding mechanism as part of the process to obtain the desirable finished product
- All equipment should adhere to the highest quality. Document supporting quality of systems and equipment must be provided by the supplier during installation
- Control panel should have emergency start / stop button
- The protective cover should be provided for shredder and blade parts and other important part of the system
- The mechanism used for opening / lifting of lids for loading/unloading should be easy to handle
- System should have sturdy/heavy duty construction to last for at-least ten years
- Two sets of Instruction manual should be submitted to the concerned authority
- **Biomass / waste shredder:** Suitable contact surfaces with 3 HP motor, sink & segregation tray. Shredder will be used to shred organic food waste and garden waste. The other parts should be epoxy coated
- **The motor for vessel rotation:** Should be a heavy duty geared motor, continuous duty with proper insulation. MCB (Miniature Circuit Breaker) should be of make of reputed brand
- **Weighing scale:** 1 to 100 kg capacity
- **Stand for operator:** Suitable stand may be provided for operator of suitable size
- **Other electrical components:** All remaining electrical components should be suitable for outdoor condition conforming to the best standards.

Annexure 7 Technical design detail of MRF facility for dry waste

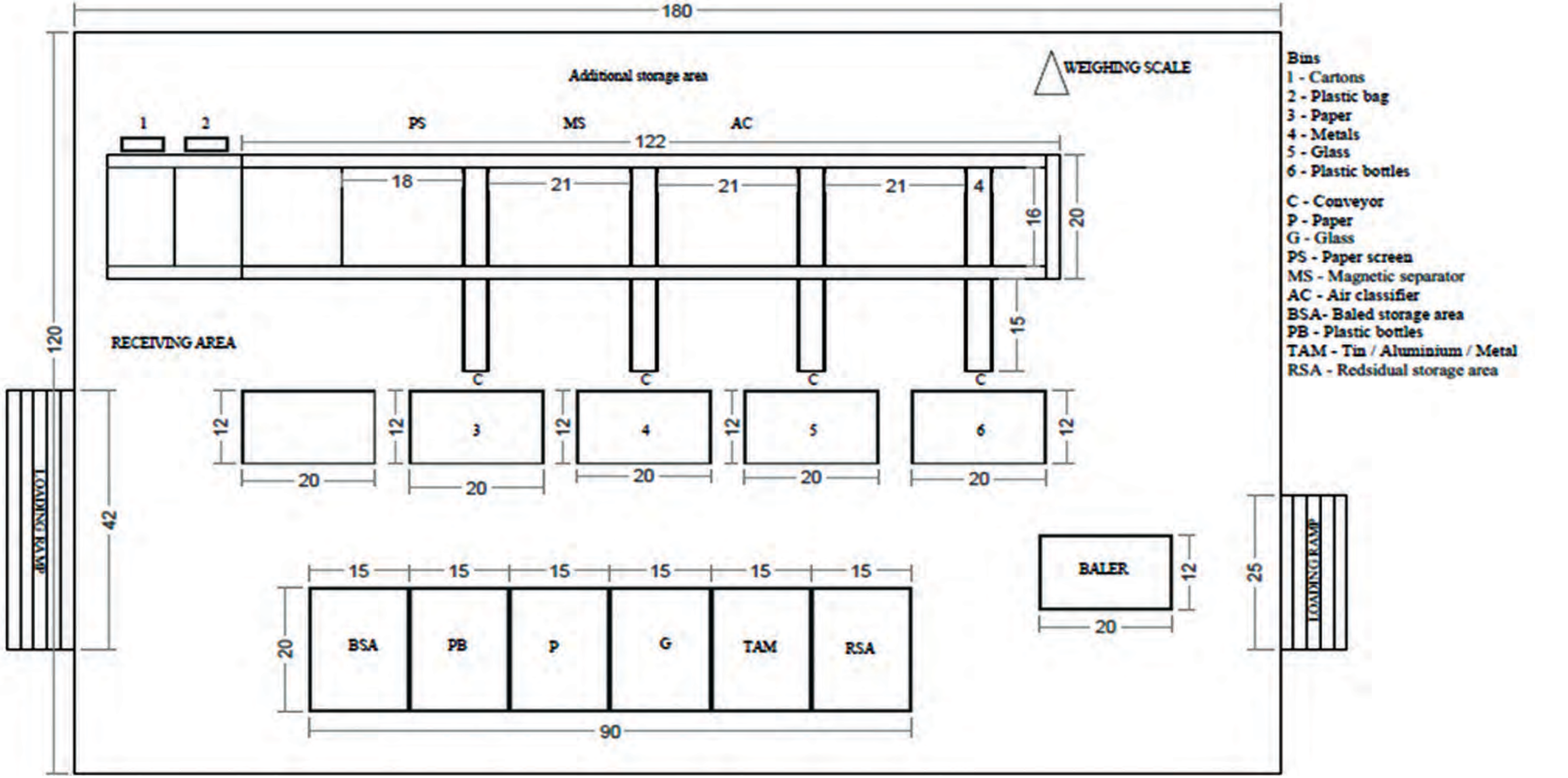


Annexure 7 Technical design detail of MRF facility for dry waste

Description & functionality of different components		
SN	**Components**	**Functions**
1	Weighing scale	Weighing of incoming waste and sorted recyclables
2	Weighbridge	Weighing of large quantities of incoming waste
3	Sorting table	Manual sorting and segregation of recyclables
4	Pay loader	Loading of incoming waste into conveyor system, sorting tables; loading of baled recyclables into outgoing vehicles; moving of residual or biodegradable waste out of the facility into the adjacent disposal site
5	Conveyor with hopper	Receipt of waste from pay loader and movement of waste for segregation
6	Conveyor system	Mechanized and regulated movement of waste for segregation
7	Trommel	Segregation of mixed waste or recyclables based on particle size
8	Magnet separator	Separation of iron-bearing materials
9	Air classifier	Separation of materials such as paper and plastic based on size, shape, and density
10	Bottle perforator	Perforation of plastic bottles prior to compaction to optimize baling
11	Baler	Compaction and binding of recyclables
12	Forklift	Movement of baled waste within MRF

Annexure 7 — Technical design detail of MRF facility for dry waste

Plant schematic layout



Annexure 7 — Technical design detail of MRF facility for dry waste

Important procedures for feasibility study

Accessibility, land use, and geology need to be considered when siting MRFs.

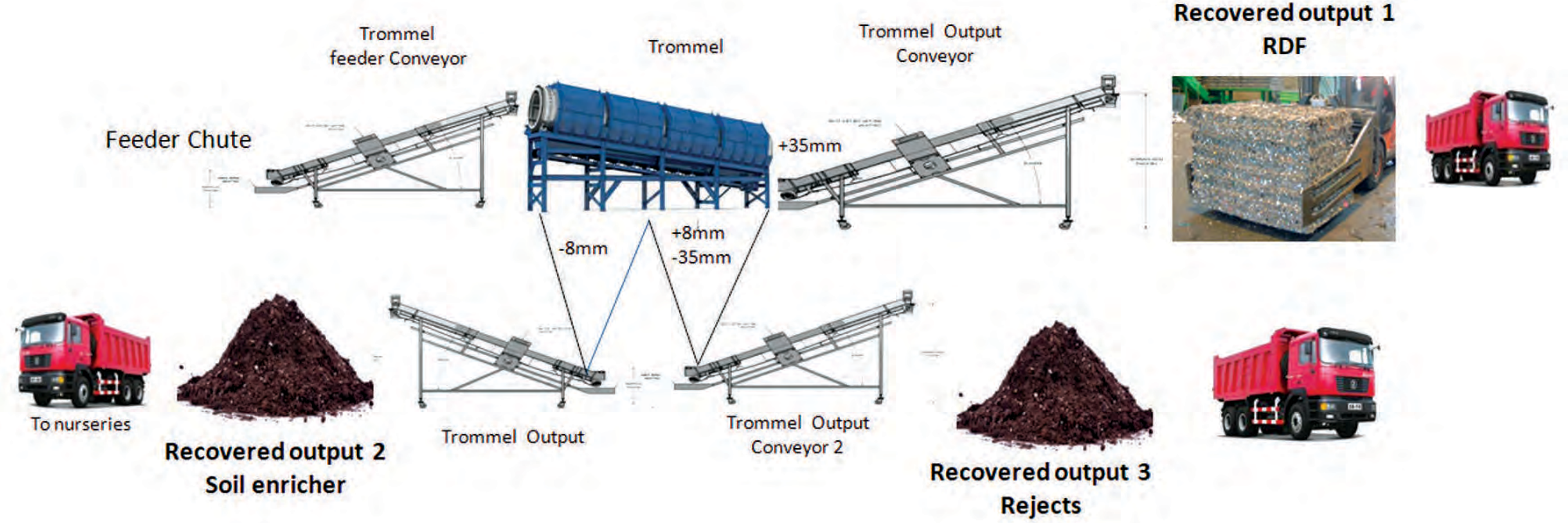
- MRFs need to be located close to existing roads, but traffic resulting from the movement of waste collection trucks should be considered.
- These facilities must be near or within urban areas that generate the inputs to be processed for recyclables.
- A minimum buffer zone of 100 meters is used for sensitive receptors such as schools, hospitals, parks, and residential areas.
- If the area is zoned, MRFs are preferably located in an industrial zone or close to a sanitary landfill to facilitate efficient movement of waste from various generators and disposal of residual or biodegradable materials.
- MRFs should be sited in flat or gently sloping, stable areas to reduce excavation cost and avoid problems of slope stability.3 Flood-prone areas should be avoided.
- Assessment of quantification and characterization of waste to understand the extent of % in the potential review stream
- Market assessment for recovered material selling.

Important procedures for installation and commissioning

A typical MRF is sited within a warehouse-type building with concrete flooring and enclosed by a perimeter fence for security. It will have the following components: (i) receiving or tipping area, (ii) sorting/processing area, (iii) storage area for recyclables, (iv) residuals storage area, (v) equipment area, (vi) space for an office, and (vii) loading area for residuals and processed recyclables. It should also be provided with the basic connections for water and electricity and adequate space for the entry and exit of waste trucks. Provisions for washing and a septic tank must be included. The warehouse design will minimize the placement of columns that could interfere with the efficient movement of materials and equipment, and facilitate the installation of higher ceilings. Receiving areas should have the capacity to receive at least 2 days’ worth of the MRF’s processing capacity in anticipation of equipment breakdown and to provide materials for the second-shift operation, if required.

Annexure 8 Technical design of resource recovery at disposal site

Process flow at disposal Site



Important procedures for feasibility study

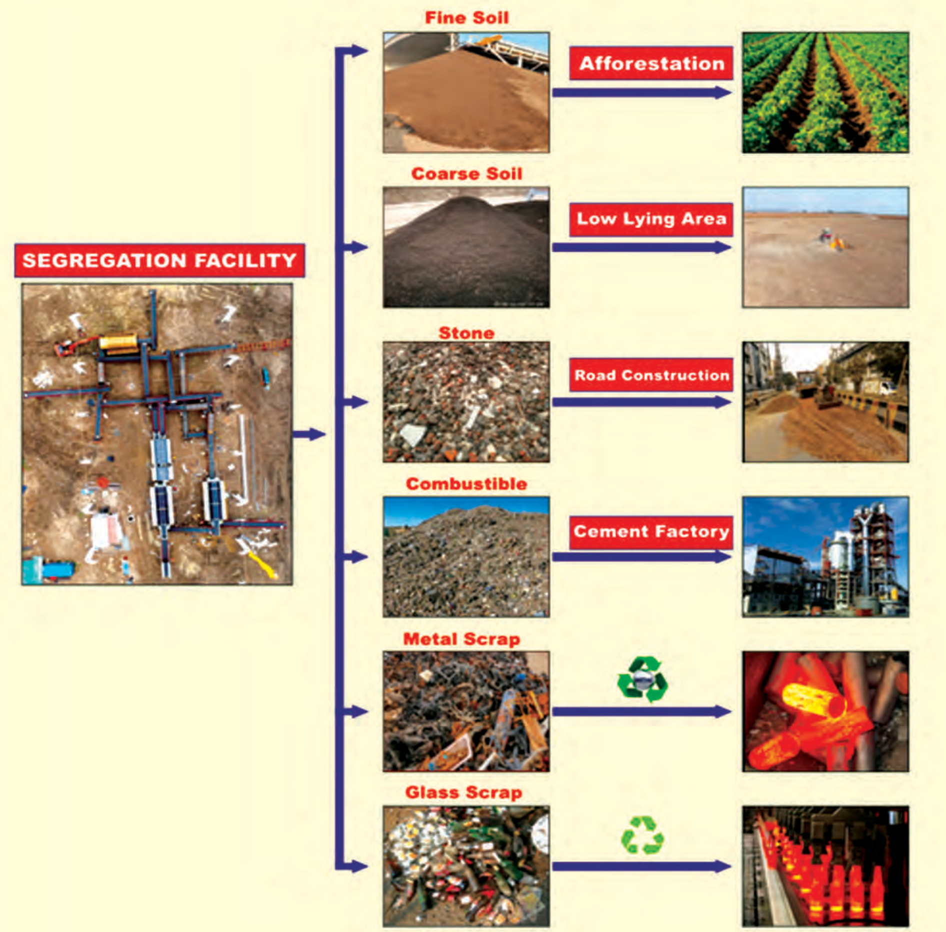
- Waste characterization study at the disposal site
- The market for RDF, i.e., cement factory should be identified and tied up prior to resource recovery operation at the disposal site
- The nurseries or potential buyers should be identified for utilization of the soil enricher, out of the pre-stabilization process
- The suitable disposal location, the low land area or should be identified for transportation and disposal of process

Annexure 8 Technical design of resource recovery at disposal site

Important procedures for installation and commissioning

- Identification and earmarking of the area to be bio-minned
- Identification of location for installation of resource recovery equipment
- Waste density analysis at representative sections and depths
- Topographical survey and volume calculation of waste
- Slope stabilization
- Windrow forming for pre-stabilization process
- Addition of additives like bio culture, raw compost or cattle dung for speedy fermentation of waste and achieving of thermophilic temperature range of 55 to 65 degree C.
- 7-10 days stabilization period for each batch or windrow
- Coarse material screening through rotary/horizontal screens.
- Separation of course material, fine aggregates, soil enricher, plastic (combustible portions)
- Bundling of combustible fraction
- Earmarking a section in the site for intermediate storage of rejects
- After resource recovery installation of equipment & machinery
- Reclaiming the land

Application feasibility



RESEARCH PROGRAM ON Water, Land and Ecosystems

LED BY: IWMI International Water Management Institute

CGIAR Research Program on Water, Land and Ecosystems (WLE)

The CGIAR Research Program on Water, Land and Ecosystems (WLE) is a global research-for-development connecting partners to deliver sustainable agriculture solutions that enhance our natural resources - and the lives of the people that rely on them. WLE brings together 11 CGIAR centers, the Food and Agricultural Organization of the United Nations (FAO), the RUAF Global Partnership, and national, regional and international partners to deliver solutions that change agriculture from a driver of environmental degradation to part of the solution. WLE is led by the International Water Management Institute (IWMI) and partners as part of the CGIAR, a global research partnership for a food-secure future.

CGIAR Research Program on Water, Land and Ecosystems (WLE)

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