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THE URBAN nexus

SOLID WASTE MANAGEMENT FOR NAGPUR

FEASIBILITY STUDY

NOVEMBER 2017

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ABBREVIATIONS

AD	:	Anaerobic Digestion
APTDC	:	Andhra Pradesh Technology Development & Promotion Centre
APTRANSCO	:	Andhra Pradesh Transmission Corporation Limited
ASSOCHAM	:	The Associated Chambers of Commerce and Industry of India
BII	:	Bottled in India
BMP	:	Biomethane potential
BOD	:	Biological Oxygen Demand
BOT	:	Built, Operate and Transfer
C&T	:	Collection & Transportation
oC	:	Degree Centigrade
C:N	:	Carbon: Nitrogen
CAGR	:	Compound Annual Growth Rate
CDP	:	City Development Plan
CHP	:	Combined Heat & Power
CH4	:	Methane
COD	:	Chemical Oxygen Demand
Co-Gens	:	Co- Generation
CPCB	:	Central Pollution Control Board
CPHEEO	:	Central Public Health & Environmental Engineering Organization
Crore	:	Ten Million
CSIR-NEERI	:	Council of Scientific & Industrial Research - National Environmental Engineering Research Institute
DADF	:	Department of Animal Husbandry Dairying & Fisheries
DAMP	:	Defined Aerobic Mixing Process
DO	:	Dissolved Oxygen
EBP	:	Ethanol Blending Program
EIA	:	Environmental Impact Assessment
EM	:	Emmendingen
EU	:	European Union
GEF	:	Global Environment Facility
GIS	:	Geographic Information System
GiZ	:	Deutsche Gesellschaft für Internationale Zusammenarbeit

INR	:	Indian Rupee
JnNURM	:	Jawaharlal Nehru Urban Renewal Mission
Km	:	Kilo meter
KRML	:	Kanak Resources Management Ltd
KwH	:	Kilo Watt hour
LCV	:	Lower Calorific Value
LFG	:	Landfill Gas
MBR	:	Membrane Bioreactor
MBT	:	Mechanical Biological Treatment
MCD	:	Municipal Corporation of Delhi
MIDC	:	Maharashtra Industrial Development Corporation
MIHAN	:	Multi-Modal International Hub Airport of Nagpur
MNRE	:	Ministry of New & Renewable Energy
MOAFW	:	Ministry of Agriculture & Farmers Welfare
MOEF	:	Ministry of Environment and Forest
MOSPI	:	Ministry of Statistics and Program Implementation
MPCB	:	Maharashtra Pollution Control Board
MLSS	:	Mixed Liquor Solids Concentration
ml/gVs	:	Millilitre per gram Volatile Solid
MSME	:	Micro, Small and Medium Enterprises
MSEDCL	:	Maharashtra State Electricity Distribution Company Limited
MSW	:	Municipal Solid Waste
MSWM	:	Municipal Solid Waste Management
MW	:	Mega Watt
MYT	:	Maximum Yield Technology
NEERI	:	National Environmental Engineering Research Institute
NH	:	National Highway
NIT	:	Nagpur Improvement Trust
NMC	:	Nagpur Municipal Corporation
OG	:	Ortenaukreis
PPEs	:	Personal Protection Equipment's
pph	:	persons per hectare
RDF	:	Refuse Derived Fuel
SC	:	Schedule Caste

SDG	:	Sustainable Development Goals
SH	:	State Highway
SPCB	:	State Pollution Control Board
ST	:	Schedule Tribe
STP	:	Sewage Treatment Plant
SWM Rules 2016	:	Solid Waste Management Rules, 2016
TBM	:	Temporary Benchmark
TIFAC	:	Technology Information, Forecasting and Assessment Council
TPD or t/d	:	Tons per day
TPA	:	Tons per annum
TS	:	Total Solid
TVS	:	Total Volatile Solid
UDPFI	:	Urban Development Plan Formulation & Implementation
UF	:	Ultrafiltration
ULBs	:	Urban Local Bodies
UV	:	Ultra Violet
VOCs	:	Volatile Organic Compounds
VS	:	Volatile Solid
WWTP	:	Waste Water Treatment Plant

1 EXECUTIVE SUMMARY

The Project is part of the Urban "Nexus" Project financed by the German Federal Ministry of Economic Cooperation and Development (BMZ) and implemented by GIZ, based on the concept of designing sustainable urban development solutions. The nexus approach supports the actors in identifying potential synergies between sectors such as water, energy and food security/land-use in cities. The GIZ Urban Nexus Project and Nagpur Municipal Corporation (NMC) agreed to study the solid waste management problem in detail and in an integrated manner (links to energy, water, recovery of valuables views, recover, recycling) to come up with an economically feasible solution for implementation. The characterization of municipal solid waste was one of the main components of the request to be studied.

Nagpur is the third largest city in the state of Maharashtra after Mumbai and Pune and is the largest city in central India. With a population of 2.4 million (census 2011), the city is currently generating an average of 1100-1200 tonnes of waste per day. Despite being a progressive urban local body, the city needs lot of focus and considerable improvement on waste management. According to the Swachh Sarvekshan[1] Survey, 2017, a survey to rank 500 cities in India on the basis of cleanliness and other aspects of urban sanitation initiated by Ministry of Urban Development, Government of India, Nagpur ranked 137 out of a total of 434 cities surveyed, with an overall score of 1158 as against Navi Mumbai (1705) top ranked city in Maharashtra and Indore (1808) top ranked city in India.

A study of the integrated waste management system for Nagpur was conducted along with a detailed waste characterisation of municipal solid waste. The waste characterisation exercise was undertaken by the National Environmental Engineering Research Institute (NEERI), Nagpur and Arcadis India. A total of 25 samples were collected from all the 10 zones in the city in April/May 2017 & October 2017 and tested for physical and chemical composition analysis, including bio-methane potential. Results from the waste characterisation indicate that the average waste composition for Nagpur includes organics at approximately 56%, along with plastics (15%), paper (10%), textile (6%), cardboard (3%) and inert (5%). The balance of 5% constitutes wood, thermacol, rubber, leather, metal, glass & ceramic, etc.

The MSW samples were also tested for chemical parameters, such as pH, moisture content, Total Solids (TS), Total Volatile Solid (TVS) ash, calorific value, Chemical Oxygen Demand (COD), average density and C/N ratio. The waste from Nagpur has COD at 24%; the average waste density is 440 kg/m^3, and the C:N ratio of waste is approximately 24. The average moisture content is 56 %, TS is 44 %, TVS is 70 %, ash content is 31 %, and calorific value is 1089 kcal /kg. The collected samples from all the zones in Nagpur city were also analysed for their bio-methane potential, which indicated a biogas yield of 93 m^3/ tonnes of organic waste and an average methane yield of 45 m^3/ tonne. The methane percentage in the biogas was estimated at around 49%.

Currently, the waste collection and transportation service is privatised and is being provided by Kanak Resources Management Limited (KRML). Approximately 255 vehicles of various types are deployed by KRML for the transportation of waste, along with handcarts, small tricycles and tipper trucks for primary collection from the households. Analysis of the vehicle deployment plan shared by NMC for KRML indicates that the total carrying capacity is sufficient. However, operational inefficiencies of KRML result in waste accumulation at the community bins and other secondary storage points.

Segregation of waste at source is not practiced by the generators. Segregation of waste (limited to recovery of high value recyclables) is practiced by the workers engaged in door-to-door collection of waste. The city had adopted the concept of "Bin Free City" as far back as 2008, which resulted in a significant reduction in the

[1]Swachh Sarvekshan is a *survey was conducted by the Quality Council of India (QCI) under the Swachh Bharat Abhiyan to rank 500 cities across the country with a population of one lakh and above, on cleanliness.*

number of community bins from 700 in the year 2008 to 170 in 2017 (approximately 80% reduction). Nine transfer stations have been developed in various zones for bringing more efficiency to the operations and optimising vehicle utility.

Currently, there is no working waste treatment facility in Nagpur. Waste collected from various parts of the city is dumped at the Bhandewadi dumpsite, which is approx. 10 km from the city centre. There was some previous initiative for the processing of waste in the city, which included setting up a waste to RDF/Compost facility with support from a private operator. However, this facility is not operating currently. In addition, a waste bioremediation/ bio-mining project primarily for legacy waste is being practiced by the city on the existing dump site. According to discussions with the city officials, the project has managed to process the legacy waste and reduce the height of the existing waste dump considerably. However, the project and technology is currently under question and is facing challenges because of some recent incidences of huge fire (March 2017) and odour issues.

In May 2017, NMC signed a contract for the development of a waste to energy facility of 800 TPD at the Bhandewadi dumpsite. M/s. Essel Infra Projects Ltd. Mumbai and Hitachi Zosen India have been selected as concessionaires for the project. The project is based on mass burn incineration technology and is expected to generate 11.5 MW of electricity. The scheduled commissioning date for the project is June 2019 and the total contract duration is 15 years.

The existing dumpsite at Bhandewadi is open and subject to various risks due to fire, leachate percolation, emission and is a health and safety concern for the people working on-site, as well as for people residing along the edge of the dumpsite.

A Financial Assessment of the accounts of NMC was carried out to understand its financial performance and the expense currently made for solid waste management. According to the financial records available from NMC, total expenditure (excluding capital expenditure) on management of per tonne of waste generation during the period 2013-14 and 2015-16 was INR. 3,148 and INR 4,713; and per capita expenditure was Rs. 517 and Rs. 659 during the same period.

As part of the project, a detailed assessment of various waste technologies available for the treatment and processing of waste in an environmentally sound manner was conducted. Waste processing technologies can play a significant role in an integrated waste management system by treating waste, generating power/ energy and reducing the waste volumes for disposal. Technical assessment criteria developed for selection of the most appropriate technology for Nagpur are based on factors such as waste characteristics, waste suitability, technology reliability, environmental performance of the technology, social acceptability, technology with low carbon footprints, technology with a ready market for products and by products, modular and flexible technology, and technology transferring minimal rejects to the landfill. All the prevalent waste processing technologies were accessed according to the technology assessment criteria, along with the proposed Maximum Yield Technology (MYT).

Maximum Yield Technology (MYT) is a new, innovative process for the treatment and utilisation of residual household waste. MYT aims to extract the complete raw material and energy content of waste using the energy potential as recyclable sources of energy. The technology is specifically suitable for organic-rich municipal solid waste, as in the case of Nagpur. Mechanical-biological treatment of the waste is carried out to produce biogas and refuse derived fuel (RDF). The focus of MYT is on extracting the complete raw material and energy content from municipal solid waste. In comparison to the traditional waste treatment solutions of landfilling or incineration, MYT extends the technological portfolio of waste management, allowing for optimum economic exploitation of MSW in the form of raw materials, quality-assured fuels and energy-rich biogas. A MYT plant of 100,000 metric tonnes per annum is in operation at Kahlenberg, Germany. The plant was commissioned in 2005 and has been operating successfully since 2006. MYT also came up with a small-scale technology demonstration project (plant capacity 16500-25000 TPA) in 2016 in Hangzhou (China).

MYT process involves the following stages, which include:

***Mechanical pre-treatment**: Waste after reception is transferred to Mechanical pre-treatment. Mechanical pre-treatment breaks the waste down automatically into individually defined fractions, according to the material and to differences in size.*

***Biological step:** The process involves the addition of process water to ensure appropriate and uniform consistency. After a short retention time in the mixer, presses dewater the solid material which is ideally prepared for biological drying. The new DAMP process leaves microbially convertible organic materials in the solid material for optimised drying. The resulting press water is treated in several steps for energy extraction and cleaning.*

***Biological drying** This procedure dries the waste in an energy-efficient and economical way with the energy inherent in the waste. In tightly-closed concrete tunnels, air flows through the waste evenly and provides the microorganisms with oxygen. The micro-organisms feed on organic components and produce thermal energy. This thermal energy evaporates the water contained in the solid material. After a short treatment time, a homogenous, dry and free-flowing solid material is produced. The dried solid material can be easily broken down into its components: energy sources, minerals and metals.*

***Mechanical material separation:** Mechanical material separation works fully automatically with a specially configured technology: sieving and classification systems break down the dry, very homogenous and free-flowing material into various sub-fractions. With differentiated materials handling, the energy-rich fuels, minerals and the few remaining metals flow into the loading stations. The composition of the energy-rich fuels is defined as follows: grade size range, chemical composition, heating value and biomass share.*

***Discharged air treatment:** Polluted discharged air and process air streams are captured in a targeted, individual manner and are recycled again. Discharged air with low-level pollution is fed through humidifiers and bio-filters. This biological procedure enables micro-organisms to clean the discharged air most effectively. Air washers and a regenerative thermal oxidation system clean the more severely polluted process air streams.*

***Water treatment**: It is proposed to send the process water from the biological step 400 m³/d to the newly built 130 MLD waste water treatment plant, adjacent to the proposed municipal waste treatment plant.*

The total input of 800 TPD of municipal solid waste to the system will generate following outputs with MYT

- *8.36 MW of energy*
- *Refuse Derived Fuel (RDF) - 213 TPD with a calorific value of 10,000 to 12,000 kJ/kg & 20% moisture content.*

RDF generated from the plant can be used for the generation of energy on-site or can be supplied to the cement, steel and power plants. The study has identified cement plants near the proposed MYT facility in Nagpur. RDF from the plant can be diverted to these cement plants.

An additional technical solution is also recommended for the utilisation of RDF in Nagpur. This system is recommended to address any issues in the marketing of RDF to the cement plants since RDF is a heterogeneous fuel. In this scenario, MYT process is proposed without a biological drying unit but with an additional RDF combustion unit. The recovered RDF from MYT is utilised in the combustion unit for the generation of energy. This process will generate 8.36 MW with the MYT and 35.3 MW with the combustion.

The total capital cost for 800 TPD MYT project in Nagpur is estimated to be Euro 66.36 million or INR 473.98 Crores; and the total operational cost (including manpower costs) Euro 2.69 million or INR 24.19 Crores per annum. Total estimated revenue from tipping fees, selling of RDF and electricity is estimated at Euro 5.05 Million per annum or INR 35.08 Crores.

In case RDF is utilised in an inhouse RDF combustion system, the total capital cost for 800 TPD project along with MYT process without a biological drying and including a combustion unit is estimated to be Euro 76.15 million or INR 543.95 crores and the total operation cost (including manpower costs) of the project is Euro 4.12

million or INR 29.43 crores per annum. Total estimated net revenue from tipping fees and sale of electricity is Euro 9.14 Million per annum or INR 65.29 crores.

MYT is a tried and tested technology for mixed as well as for segregated waste and aims at maximising the resource recovery from waste. In comparison to the traditional waste treatment solutions of landfilling or incineration, MYT extends the technological portfolio of waste management, allowing for optimum economic exploitation of MSW in the form of raw materials, quality-assured fuels and energy-rich biogas. The waste characterisation study conducted for Nagpur indicated a very high percentage of organic fraction (approximately 60%) and moisture content (56%), which makes it unsuitable for incineration-based processes. At the same time, the waste characteristics are extremely favourable for processing by MYT.

The incineration-based projects in India have not been very successful in demonstrating air emission standard compliances because of the high organic content of the waste and have been facing public resistance. MYT, being a state-of-the-art and an emission-free clean technology, has very high social acceptability, even from the residents residing in the immediate vicinity of the plant. The process is also odour-free in comparison to many prevalent waste processing technologies and can be recommended for Nagpur.

2 PROJECT BACKGROUND

The Project is part of the Urban “Nexus” Project financed by the German Federal Ministry of Economic Cooperation and Development (BMZ) and implemented by GIZ, based on the concept of designing sustainable urban development solutions. The nexus approach supports the actors in identifying potential synergies between sectors such as water, energy and food security/land-use in cities. In most Asian cities, the synergy effects between water, energy and food security/land-use have not been adequately utilised. The rapid population growth of Asian cities places an increasing strain on natural resources and poses the risk of supply shortages, particularly with respect to water supply & sanitation, energy, land use and food security. The national and regional planning units in Asian cities do not plan on an integrated sectoral approach and hence fail in utilizing synergies between the sectors.

The future global key development policy topics, the Sustainable Development Goals (SDG), United Nations Human Settlement Programmes HABITAT III and Climate Agreement, are being utilised to mainstream the nexus approach into an international reference system. Nexus concepts are being increasingly considered in selected Asian cities and by relevant stakeholders. Currently, twelve selected Asian cities in seven countries (China, India, Indonesia, Magnolia, Philippines, Thailand and Vietnam) are part of the Nexus project implemented by the GIZ.

The Nexus measure strengthens the relevant actors in the Nexus partner cities in cross-sectoral planning competencies through concrete measures (area of intervention 1) and by promoting the nexus approach through multi-level dialogue (area of intervention 2) widening current sectoral perspectives. By promoting cross-sectoral cooperation, the measure contributes to good governance (transparent and effective action of public sector) and peer-to-peer learning formats, thereby strengthening the south-south co-operation, as well as involving civil society. In the so-called “Nexus Mentor Cities” that particularly engage themselves in the nexus activities, the capacities of the municipal administrations are being strengthened through advisory services, seminars and training.

The measure target group is the population of Asia Nexus partner cities which are affected by the overuse and pollution of resources. In India, two cities have been selected under the Nexus programme, the city of Nagpur, (2,400,000 inhabitants) and the city of Rajkot, (1,200,000 inhabitants).

The city of Nagpur requested advisory services for the improvement of their solid waste management programme. The GIZ Urban Nexus Project and Nagpur Municipal Corporation (NMC) agreed to study the solid waste management problem in detail and in an integrated manner (links to energy, water, recovery of valuables views, recover, recycling) to come up with an economically feasible solution for implementation. The characterization of municipal solid waste was one of the main components of the request to be studied.

Arcadis has been appointed as the consultant to provide technical assistance on the project and prepare a feasibility report addressing the issue of solid waste management for Nagpur city in detail and suggesting an integrated approach for processing and disposal of municipal solid waste in Nagpur with a focus on waste characterization.

2.1 Scope of Work

The scope of work for the project includes the following tasks:

- Study and analysis of waste generation, e.g., current and future, per capita waste generation, volume estimates and its variations, and composition of waste. The analysis includes source wise generation assessment of waste (such as households, commercial establishments, vegetable, fruit, meat, fish markets, offices, hotels and restaurants, from sweeping of streets and drain cleaning).
- Waste source identification depending on the city area; and collection of waste and transfer to the treatment site
- Waste Characterization
- Physical characterization of mixed waste (in %)
  - Wood and wood products
  - Pulp, paper and cardboard
  - Food waste
  - Textiles
  - Garden, yard and park waste
  - Glass
  - Plastic
  - Metal
  - Soil/ sand etc
  - Other inert matter
- Parameters for assessment of chemical characterization of mixed waste
  - Dry density – (air dry in tons/ m3)
  - Moisture content (%)
  - Calorific value (net calorific value on dry basis, using bomb calorimeter) in Kcal/ kg
  - Organic content (%)
- Parameters for assessment of chemical characterization of organic waste
  - pH,
  - COD,
  - Total solids,
  - Volatile solids,
  - C:N ratio,
  - Bio-methane test etc.
- Material flow and energy balance from the solid waste
  - Biogas
  - Refuse Derived Fuels (RDF)

- Analysis and recommendation of the optimal treatment technology suitable for the city based on technical, legal, environmental, economic and commercial parameters.
- Conduct rapid global market study of the viable technology options for waste treatments that are suitable for Nagpur's cultural, climate and waste type and are economically viable to operate.
- Based on the analysis of alternatives of processing facilities, waste characterization studies, markets for use of processed and separated waste, likely performance of source segregation and technologies, identify feasibility for waste processing and separation plants.
- Demand study for products from waste processing and separation – provide recommendations for end use or treatment of recovered waste resources (high value recyclables, low value recyclables, compost, combustible material, waste to energy) in the region.
- For the various waste treatment technology options such as composting, waste to energy, refused derived fuels (RDF), anaerobic and aerobic digestion, conduct a comprehensive market study, based on demand for each product, quality and reliability of demand, availability and reliability of supply, availability of secondary/ancillary infrastructure to facility supply (e.g. proximity of local grid, transmission lines, etc.), proximity of demand, pricing structure and tariffs, incentive schemes, regulatory framework, inter alia.
- Based on realistic performance of source segregation and processing technologies, develop phased, conservative estimates of the potential diversion of waste to the landfill.
- For the identified processing and disposal option, map the infrastructure requirements for utilities such as power, water, land and other requirements for establishing and operating the proposed waste management systems.
- Topographic survey of the site identified for development of the facility.

  The topographical survey of the site with spot grid level of 10 m x 10 m, to prepare a contour map of the site at 0.3 m contour level. Setup local coordinate system with respect to the magnetic north and establish temporary benchmark (TBM) for future reference. The area surveyed includes main features in the adjoining area such as electric poles, overhead wires, buildings and other structures.

2.2 Structure of this Report

The report is further divided into following chapters

Chapter 1: Introduction

Chapter 2: Profile of Nagpur city

Chapter 3: Existing SWM system

Chapter 4: Waste quantification and characterisation studies

Chapter 5: Regulatory framework

Chapter 6: Review of prevalent waste processing technologies

Chapter 7: Proposed technology description

Chapter 8: Project cost and revenue assessment

3 PROFILE OF NAGPUR CITY

3.1 Project Area Description

Nagpur is the third largest city in the state of Maharashtra after Mumbai and Pune and is the largest city in central India. Nagpur is also being developed as a Smart City under the Government of India Smart City programme. Nagpur is the geographical centre of the country and is the major trade centre in the region and is well connected. Nagpur Municipal Corporation (NMC) spreads over an area of 227.38 sq. km with a total population of 24.06 lakh (2.4 million) according to the census of 2011. Nagpur city makes up 4.73% of the total urban population of the state. The city is now among the fastest growing cities in India and is rapidly emerging as commercial, retailing and logistic hub.

3.1.1 Chronological development of Nagpur city

Nagpur city is named after the River Nag and has been known since prehistoric times. Nagpur and its surrounding region are also mentioned in the Vedic and Mauryan scriptures. Nagpur city was founded by the Gond King of Deogad "Bakht Buland Shah" in the year 1703. In 1743, it became the capital of Raghoji Rao Bhonsle's kingdom.

Awareness of planned city development was raised by Sir Patrick Geddes, who visited the city in 1915. The Nagpur Improvement Trust (NIT) was established in 1936 to carry out planned development in the city. The British government made Nagpur the capital of the new state named Central Province in the mid-19th century and it remained so until 1956, after which it became the second capital of Maharashtra.

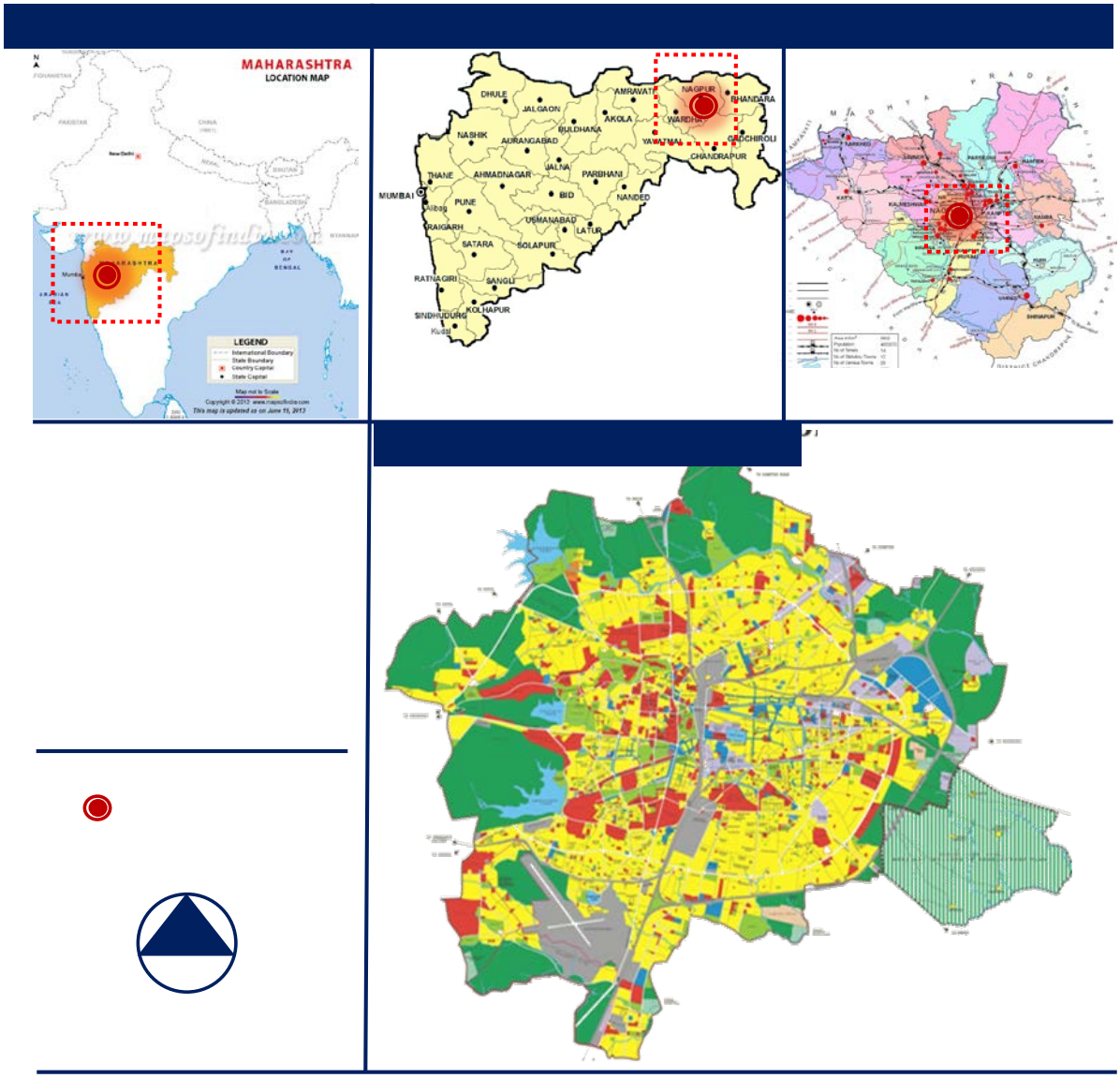
Nagpur enjoyed the status of being the administrative center of Central India during the ancient and medieval eras. It boasts a legacy of cultural and economic prosperity. Its proximity to tribal areas has also ensured the preservation of its natural resources, i.e. minerals and forests.

3.2 Geographical Location and Regional Linkages

Nagpur is situated in the eastern part of Maharashtra. The coordinates of the city lie between 78°30" to 79°30"E and 20°30" to 21°45"N. The average altitude is 310.5 m above mean sea level.

Nagpur is in the exact centre of the Indian peninsula. The city has the Zero Mile Stone locating the geographical centre of India, which was used by the British to measure all distances within the Indian subcontinent. Nagpur is well connected with the major urban centres across India.

Figure 3-1: Location of Nagpur



3.2.1 Road Connectivity

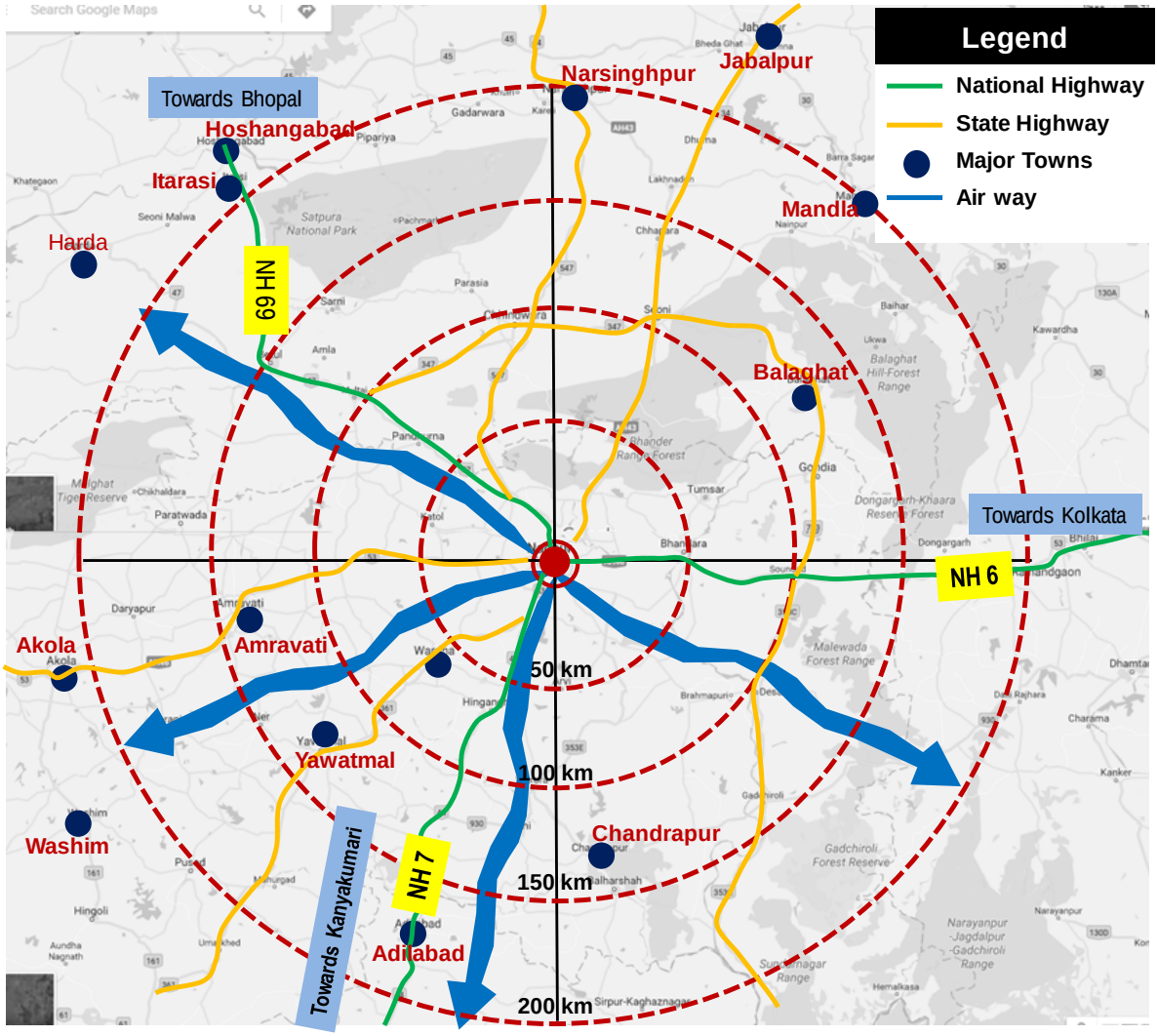
All major highways and railways pass through Nagpur. Due to the good connectivity, the city has become a major trade and transportation centre in the region. The following national highways (NH) and state highways (SH) pass through the city.

- NH 7: Connecting Varanasi-Jabalpur-Nagpur-Hyderabad-Bangalore-Kanyakumari
- NH 6: Connecting Hajira, Gujarat-Surat-Dhule-Amravati-Nagpur-Raipur–Sambalpur–Kolkata
- NH 69: Connecting Nagpur-Betul-Obedullaganj near Bhopal
- SH 9: Nagpur-Umred-Nagbhid-Chandrapur
- SH 248, SH 255, and SH 260

Table 3-1: Distance of Key Towns from Nagpur

Sl. No.	Major Towns	Distance
1	Mumbai	837 km
2	Delhi	1094 km
3	Bhopal	352 km
4	Hyderabad	501 km
5	Indore	457 km
6	Raipur	285 km

Figure 3-2: Nagpur Linkages and Connectivity



3.2.2 Rail Connectivity

In Nagpur, the railway service was established in the year 1867. Nagpur is an important railway junction and a transit for all the trains that connect the four major metropolises of Mumbai, Delhi, Chennai, and Kolkata. Within the city, there are small railway stations located at Ajni, Itwari, Kalamna, Kamptee, and Khapri. Other destinations connected include Kolhapur, Pune, Ahmedabad, Hyderabad, Jammu, Amritsar, Lucknow, Varanasi, Bhubaneshwar, Thiruvananthapuram, Cochin, Gorakhpur, Visakhapatnam, Bangalore, Mangalore, Patna and Indore.

3.2.3 Air Connectivity

The Sonegaon airport is 7.5 km south of Nagpur city, located in the Multi Modal International Hub Airport of Nagpur (MIHAN) area, and the domestic airlines connect with major cities such as Mumbai, Delhi, Ahmedabad, Pune, Bengaluru, Hyderabad, Indore, and Kolkata. Nagpur is also connected to international destinations such as Bangkok, Singapore, Doha, Dubai, and Sharjah.

3.3 Administrative Set Up

Nagpur Municipal Corporation (NMC) came into existence in March 1951. Nagpur is an important urban centre in the Vidarbha region, the administrative capital of the district and the largest urban centre in the district in terms of population and area. The city is a part of the Nagpur division. NMC is the only corporation in the district with a jurisdictional area of about 227.38 sq. km and is divided into 136 administrative wards. These 136 wards fall under 10 administrative zones.

The administrative head of the Corporation is the Municipal Commissioner supported by Addl. Commissioner, who, along with the Deputy Municipal Commissioners, carries out various activities related to engineering, health and sanitation, taxation and its recovery. Various departments such as public relations, libraries, health, finance, buildings, slums, roads, street lighting, traffic, establishment, gardens, public works, local audit, legal services, water works, education, octroi and fire services manage their own specific activities. The activities of NMC are administered by its zonal offices. There are 10 zonal offices in Nagpur – Laxmi Nagar, Dharampeth, Hanuman Nagar, Dhantoli, Nehru Nagar, Gandhi Baugh, Sataranjipura, Lakkadganj, Ashi Nagar and Mangalwari.

3.4 Physical Features

3.4.1 Geology

Nagpur's underlying rock strata is covered with alluvial deposits resulting from the flood plain of the Kanhan River. In some places, these give rise to granular sandy soil. In low-lying areas, which are poorly drained, the soil is alluvial clay with poor permeability characteristics. In the eastern part of the city, crystalline metamorphic rocks such as gneiss, schist and granites are found, while in the northern part yellowish sand stones and clays of the lower Gondwana formations are found[2].

3.4.2 Hydrology

The region is drained by the Kanhan and Pench Rivers in the center, the Wardha in the west, and the Wainganga in the east. Both these rivers later merge as tributaries into the Godavari River. In addition to these rivers, there are various natural water bodies in the form of lakes. The largest lake is Ambazari Lake. Ground water is another major source of water supply, particularly for washing, drinking and bathing purposes. The depth of the ground water table in the central part of the city is about 1.65-1.95 m, and it can rise to 16 m in the peripheral areas.

3.4.3 Climate

The climate of Nagpur follows a typical seasonal monsoon weather pattern. The peak temperatures are usually reached in May/June and can be as high as 48^{o}C. The onset of the monsoon is usually from July. The season extends up to September with the monsoons peaking during July and August. After the monsoons, the average temperature varies between 27^{o}C and approx. 6-7^{o}C right through December and January. In Nagpur, the

[2] *Source: Nagpur District Gazetteer*

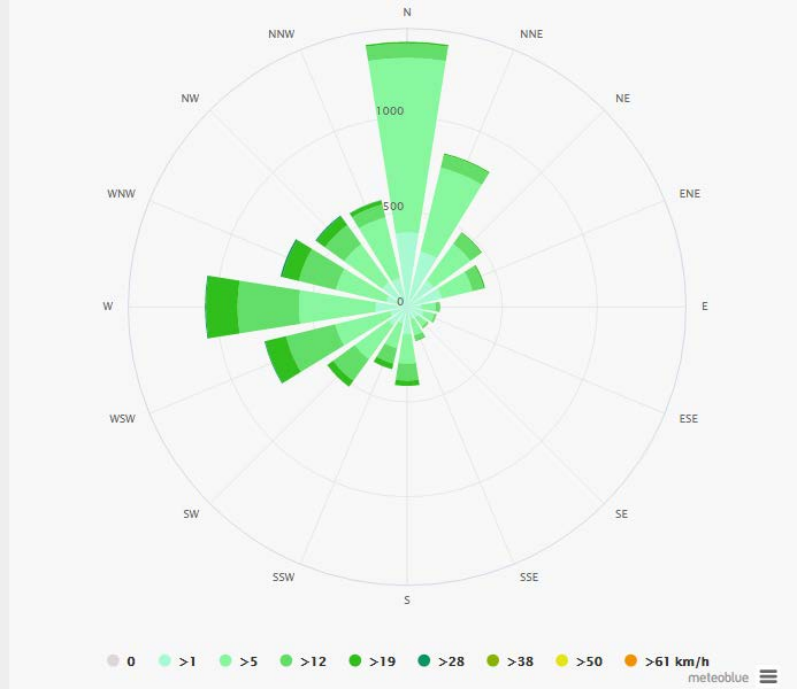
average annual rainfall is 1161.54 mm. The southwest monsoon usually reaches the city in the second week of June. Around 90% of total rainfall happens during the June to September period. The highest rainfall is reported in the month of July.

3.4.4 Wind Direction

Winds are generally light to moderate throughout the year. In the month of February and at the end of May, the Nagpur climate experiences low pressure resulting in winds blowing at a speed of 20 km per hour or more. But, for the rest of the year, the speed remains at between 5 to 6 km per hour.

Winds during the monsoon season come from the southwest. In January, winds from the northwest and northeast are common in the morning hours and change direction from the northeast to the southeast during the afternoon hours. While the winds in the morning hours during the months of February and March are similar to those in January, the afternoon winds become variable. In the rest of the summer season, the winds are mostly from southwest to northwest.

Figure 3-3: Wind Rose Diagram for Nagpur City



Source: https://www.meteoblue.com/en/weather/forecast/modelclimate/nagpur_india_1262180

3.5 Demography

Demography analysis includes details on the size, structure and distribution of populations, and spatial and or temporal changes in them in response to birth, migration, aging and death. The analysis helps in understanding the previous and present conditions of population, growth, development and uses of natural resources. The existing data used for demographic analysis would be utilized for the population projection till the year 2047.

3.5.1 Current Population

According to the provisional census data for the year 2011, Nagpur City's total population is 24.06 lakh (2.4 million). There has been an almost threefold growth in the population in the last four decades, from 8.66 lakh (0.87 million) in the year 1971 to 24 lakh (2.4 million) in the year 2011. However, the decadal growth rate has been continuously decreasing for the city. The decadal growth rate for Nagpur city's during the last decade was 17.24%, which was less than the country urban population growth rate (31.80%) and state urban

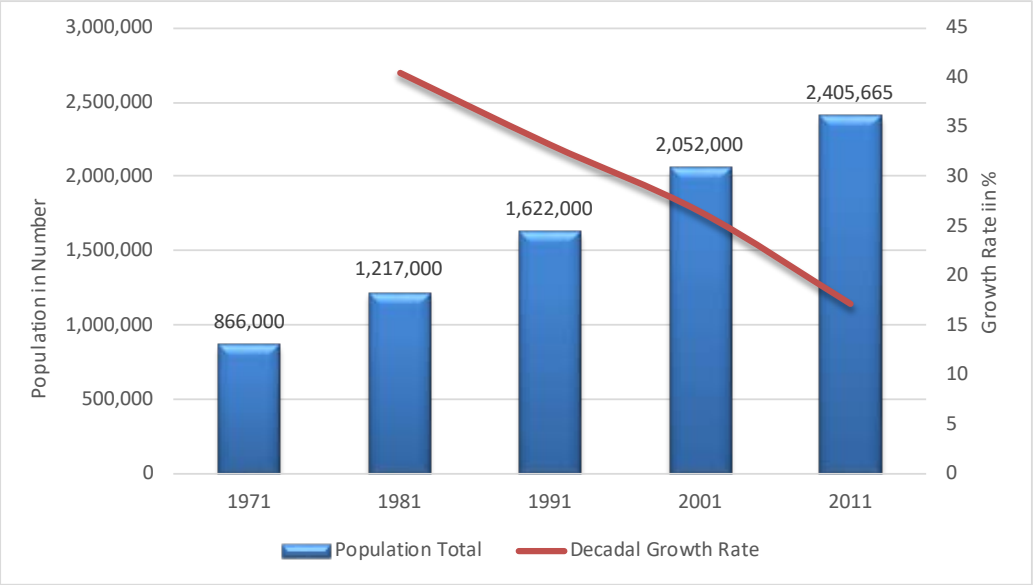
population growth rate (22.57%). The population details of Nagpur since 1971 and decadal growth in the population are shown in **Table 3-2**.

Table 3-2: Population Details for Nagpur City

Year	Population Total - NMC	Decadal Change	Decadal Growth Rate
1971	866,000		
1981	1,217,000	351,000	40.53%
1991	1,622,000	405,000	33.28%
2001	2,052,000	430,000	26.51%
2011	2,405,665	353,665	17.24%

Source: Census of India and City Development Pan for Nagpur

Figure 3-4: NMC Decadal Population Growth Rate



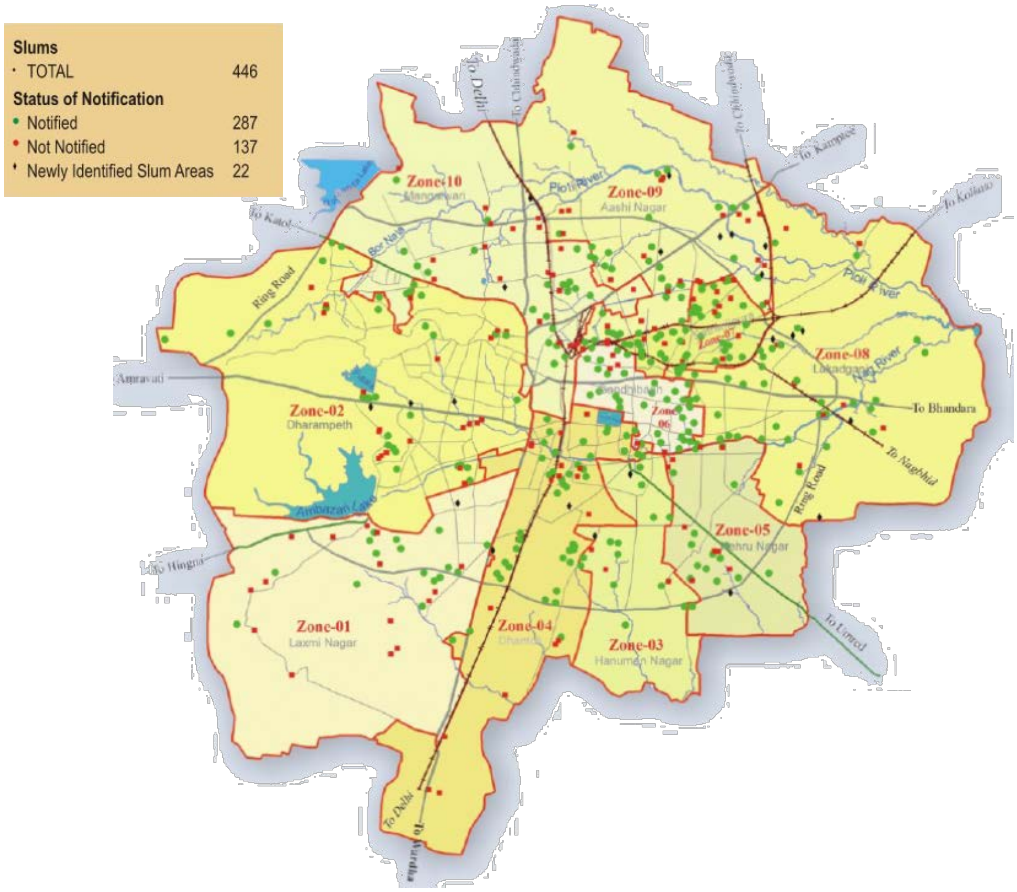
The average decadal growth rate of Nagpur city from 1971 to 2011 has been 29.39%. The demographic growth trend shows more than 40% of the growth between 1971 and 1981, the rapid growth rate during this period was due to changes in the urban morphology and the rapid migration of people from rural to urban areas. In general, decadal growth rate has been decreasing in recent decades. The reasons for the declining growth rate are stabilization in the birth rate and decreasing migration.

3.5.2 Slum Population

The growth of slum population in Nagpur in the past few decades has been huge. During 1971, the number of slum pockets in Nagpur was around 47, which increased by seven times in 1992 and, in 2008, another 50% slums were added.

In the year 2008, a slum survey was conducted in Nagpur and published in the form of Slum Atlas for Nagpur. According to the report, the total slum population in the city is 8.58 lakh (0,86 million) which is 36% of the total population. A total of 446 slums – both notified and non-notified – are scattered throughout the city area, particularly in zones 4, 7, 8 and 9. The zone-wise location of slum pockets is presented in the diagram below.

Figure 3-5: Slum Location Map for Nagpur City



Source: Slum Atlas of Nagpur, 2008

3.5.3 Population Projection

Population growth in any place depends not only on natural increase but also on in-migration. In addition to Nagpur's rapid socio-economic development that had a significant impact on the urbanization in the city, future growth is governed to a large extent by the development patterns in the city. The extent of in-migration in Nagpur city is mainly the impact of the key projects that are influencing socio-economic development in the city and peri-urban areas.

The population of NMC has been projected up to the horizon year 2047, taking into consideration the decadal population trend of the Census of India from 1971 to 2011. The population is projected using three statistical methods, viz. Arithmetic Progression Method, Incremental Increase Method and Geometric Progression Method.

The average decadal population growth rate of Nagpur city has been 29%. **Figure 3-6** given below shows the results of various population projection methods applied to Nagpur city.

Table 3-3: Population Projection for Nagpur City by the Year 2047

Year	Census Population	Arithmetic Progression	Incremental Increase	Geometric Progression	Average	Population Growth Rate
1971	866,000					
1981	1,217,000					40.53%
1991	1,622,000					33.28%
2001	2,052,000					26.51%
2011	2,405,665					17.24%
2017		2,636,615	2,675,582	2,789,967	2,700,721	12.27%
2022		2,829,073	2,868,639	3,156,716	2,951,476	9.28%
2027		3,021,531	3,061,919	3,571,676	3,218,376	9.04%
2032		3,213,989	3,255,421	4,041,184	3,503,531	8.86%
2037		3,406,447	3,449,145	4,572,410	3,809,334	8.73%
2042		3,598,905	3,643,091	5,173,467	4,138,488	8.64%
2047		3,791,364	3,837,259	5,853,536	4,494,053	8.59%

Source: Population projection by Arcadis

An average of all the three methods, i.e. the Arithmetic, Incremental and Geometric progression methods, is found most suitable for Nagpur city. As shown in **Figure 3-6,** the average population growth rate curve virtually matches the census growth rate of the city. The projected population for the years 2027, 2037 and 2047 is 3,218,376; 3,809,334 and 4,494,053 respectively for Nagpur.

Figure 3-6: Various Methods of Population Projection for Nagpur City

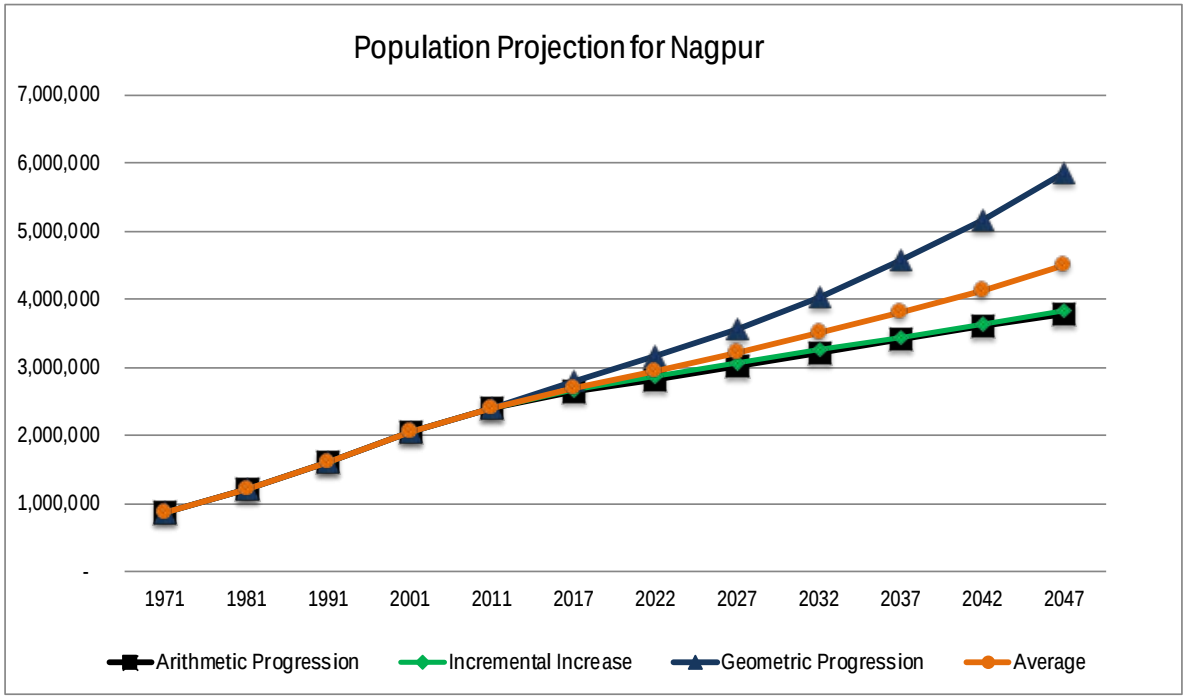


Table 3-4: Projected Population for Nagpur

Year	2017	2027	2037	2047
Projected Population	2,700,721	3,218,376	3,809,334	4,494,053

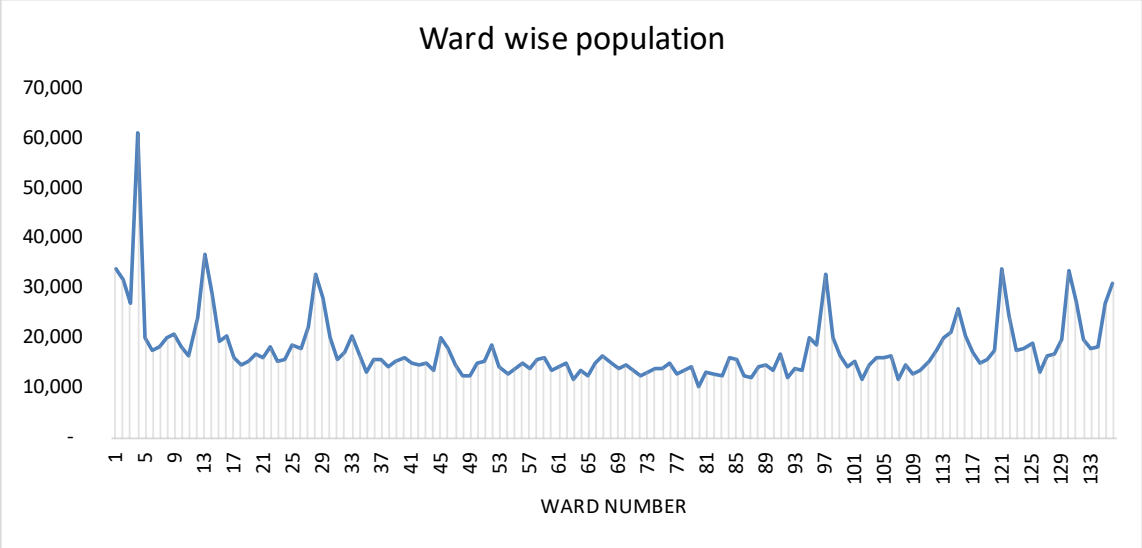
Source: Projection Analysis by Arcadis

3.5.4 Other Population Indicators

Population Distribution

The spatial distribution of population has been examined based on the ward population. NMC has 136 wards with ward population ranging from 60,949 in ward number 4 to 10,317 in ward number 80 and an average ward population of 17,700. The size and population of the wards varies in the city, with the ward areas towards the inner-city side being small. However, as one moves towards the periphery, the ward area increases. Out of 136 wards, 111 wards have a population of between 10,000 and 20,000; 16 wards have a population of between 20,000 and 30,000, and the remaining 9 wards have a population of more than 30,000. The ward-wise population distribution of NMC is shown in **Figure 3-7.**

Figure 3-7: Ward Wise Population Distribution

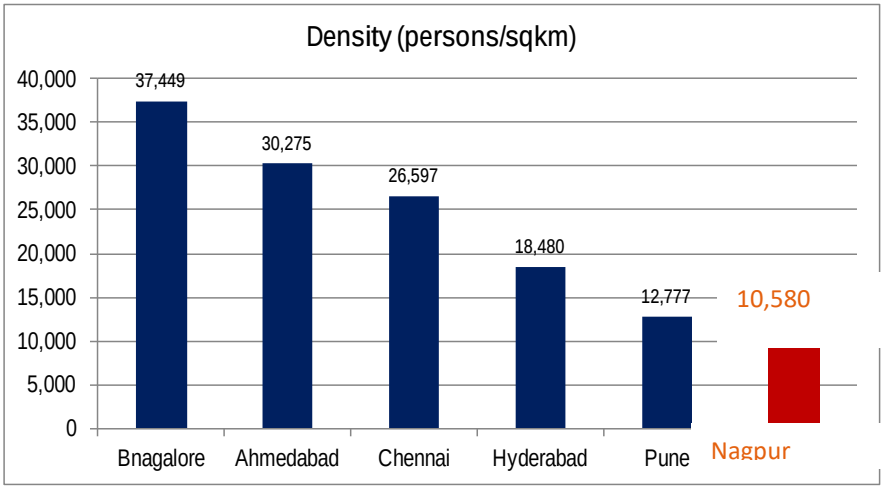


Population Density

The overall liveability of a place is dependent on the population density of that place. In case of Nagpur, according to the 2011 Census, the population density is 10,580 persons/ sq.km (density 106 persons per hectare (pph)). The average population density of Nagpur city is on the lower side of the permissible limits as given in the Urban Development Plan Formulation & Implementation (UDPFI)[3] guidelines for metropolitan cities (125-175 pph). It is also the lowest when compared to other megacities such as Bangalore, Hyderabad, Ahmadabad and Chennai as given in **Figure 3-8**.

[3]*Published by Ministry of Urban Development, Government of India*

Figure 3-8: Population Density Comparison of Nagpur



The population density of Nagpur city has grown three times between the years 1971 and 2011 due to a continuous increase in the population without any increase in the land area of the municipal corporation. The changes in population density figures and land area in Nagpur city from 1971 to 2011 have been given in **Table 3-5.**

Table 3-5: Nagpur Population Density Scenario over the Years

Year	Population Total - NMC	Area in sq. km	Density (persons/sq. km)
1971	866,000	227.38	3,809
1981	1,217,000	227.38	5,352
1991	1,622,000	227.38	7,133
2001	2,052,000	227.38	9,025
2011	2,405,665	227.38	10,580

Source: Census of India

Sex Ratio

One of the basic demographic characteristics of the population is the sex composition. Sex ratio is defined as “the number of females per 1000 males”. In any study of population, analysis of sex composition plays a vital role. The sex composition of the population is affected by differentials in the mortality conditions of males and females, sex selective migration and sex ratio at birth. According to the 2011 Census of India, the sex ratio of NMC is 963 females per thousand males, which is higher than the district (925), state (951) and national level figures, i.e. 940. The sex ratio in the city has shown improvement from the last year census, increasing from 936 females per 1000 males in 2001 to 963 females per 1000 males in the year 2011.

Literacy Rate

The literacy rate reflects the socio-economic development of any region. Nagpur city has the highest literacy rate of 91.92% when compared to the district, state and urban India literacy rate. The high literacy rate can be attributed to Nagpur city being one of the leading centres of higher education in the state. **Table 3-6** shows the literacy rate comparison of Nagpur with state and country.

Table 3-6: Nagpur Literacy Rate Comparison with Country and State

Urban Area	Literacy Rate
Urban India	80.73%
Urban Maharashtra	88.69%
Urban Nagpur District	91.37%
NMC	91.92%

Source: Census of India Data 2011

The literacy rate of Nagpur city increased from 89.28% in 2001 to 91.92% in 2011 Census. Males have a higher literacy rate at 94.44% compared to 89.31% for females. However, the gap between literacy rates for males and females has narrowed, compared to that prevailing in 2001.

Table 3-7: Literacy Rate Details in Nagpur City

Description	2001 Census		2011 Census	
	Literates	%	Literates	%
Total Literates	1,609,126	89.28	1,984,123	91.92
Male Literates	873,739	93.90	1,036,097	94.44
Female Literates	735,387	84.36	948,026	89.31

Source: Census of India, 2001 and 2011

SC & ST Population

The Schedule Caste (SC) and Schedule Tribe (ST) population are two main determinants of the social composition of any city in India. Soon after independence, the Indian government took initiatives to uplift and bring the SC and ST population to a par with society. Hence, the needs of this section of society should be considered in any developmental project to ensure inclusive and holistic development. In Nagpur city, the Scheduled Caste contributes 19.76% of the total population, while the Scheduled Tribe contributes 7.70% of the total population in the year 2011.

Table 3-8: Ward-wise SC and ST Population

Sl. No.	Name	2011			2001		
		Total	Male	Female	Total	Male	Female
1	SC Population	475,425	238,629	236,796	343,031	175,137	167,894
2	ST Population	185,281	94,638	90,643	181,975	93,509	88,466
	Share of SC	19.76%			16.72%		
	Share of ST	7.70%			8.87%		

Source: Census of India, 2001 and 2011

3.6 Socio - Economic Profile of Nagpur

This section presents a detailed assessment of the socio-economic profile of Nagpur city, such as health/education institutions, key economic drivers of the city, industrial profile, workforce participation rate, worker classification, key economic indicators with reference to the state and district, and a brief on the informal sector activity in the city. The pillars of the city's economy are trade and commerce, the service sector, industries, health, and the education sector.

Being a district headquarters and one of the major economic centres of Maharashtra, Nagpur's key economic areas are institutional and commercial activities. There has been a continuous growth in health and education institutions, commercial establishments, and service centres.

3.6.1 Industrial Scenario

India's first textile mill was established by the TATA group, formally known as Central India Spinning and Weaving Company Ltd., in Nagpur, which was part of the central province. It was popularly known as the Empress Mill and was inaugurated on 1st January 1877. The mill had spinning, weaving, and dyeing factories, and employed 4,300 operatives. At present, there are 10 major industrial areas managed by the Maharashtra Industrial Development Corporation (MIDC) within the region, which was possible due to the state's economic policies promoting industries development. The MIDCs within the region had more than 2,100 working units as of 2012-13.

3.6.2 Trade and Commerce

Nagpur has always been an important centre for commercial activities in the past, and later for the Vidarbha region and the Nagpur district. Various wholesale and retail markets in Nagpur have become an important part of the city's economy. Various daily and weekly markets in Nagpur also are a part of the trade and commercial activities in the city.

Nagpur is a hub of formal and informal commercial activities and provides employment to thousands of people. Within the formal sector, there are retail and wholesale markets and can be classified based on goods. These markets are regularised by the NMC and maintained by the market department. These markets are in the form of permanent shops, weekly markets and daily markets. Apart from this, the NMC has shopping complexes, located at various locations within city. These commercial complexes are constructed commercial spaces that are given on lease.

The informal sector in Nagpur is in the form of street vending spread throughout the city area. In addition to regular street vending, there are unauthorised weekly or daily markets set up at various places. These informal activities cater to the urban poor and daily migrants. According to the information available from the City Development Plan (CDP), Nagpur (prepared in March 2015), there are almost 90,000 street vendors in the city.

3.6.3 Health and Education

In the health and education sector, remarkable development has taken place in Nagpur. From 1991 onwards, the private health facilities in Nagpur have grown at a very high rate during last the two decades (1991-01 and 2001-11). As provided in CDP Nagpur, during 1991-01, the increase in private health facilities was 215%, and during 2001-11, it was 65%. Similarly, the growth in the education sector in the city is considerable. Both the health and education sectors have been able to attract people not only from the region but also from other parts of the neighbouring state.

Nagpur has emerged as health hub in central India. The city has several health facilities and services in the form of hospitals, nursing homes, multi-specialist hospitals and clinics. Due to presence of good connectivity and a supporting infrastructure, people from nearby rural and urban centres within and across the state come here. Some of the renowned hospitals in the city are the Govt. Medical College, Govt. Dental College, Indira Gandhi Medical College, Nagrik Sahakari Hospital, Lata Mangeshkar Hospital, Wockhardt Heart Hospital, and Rastrasanta Tukdoji Maharaj Cancer Hospital.

There has been a drastic change in the working pattern of educational institutes and the approach towards maintaining global standards. The prime reason is the shift of higher studies from government to private institutes. These private centres are attracting students from across India. Nagpur has four state universities, viz. Rashtrasant Tukadoji Maharaj Nagpur University, founded in 1923 as Nagpur University, one of the oldest in the country, having more than 600 affiliated colleges, Maharashtra Animal and Fishery Sciences University, Kavikulaguru Kalidas Sanskrit University, and Maharashtra National Law University. Nagpur has two major management institutes, viz. Indian Institute of Management, Nagpur, and Institute of Management Technology, Nagpur.

3.6.4 Workforce Participation Rate

The percentage of the dependent population is indicated by the parameter of work participation, which is 35.07% in Nagpur. Of the 843,771 total number of workers in Nagpur in 2011, the main workers comprised 92%, and marginal workers – including those seeking employment – was 8%. The work force participation rate of NMC is higher than the national level.

Table 3-9: Work Force Participation Rate Comparison Between NMC, India and Maharashtra

Particulars	Total Workers	Male Workers	Female Workers	WFPR%
Urban India	92,278,654	76,175,323	16,103,331	32.25%
Nagpur District Urban	1,120,561	878,188	242,373	35.25%
NMC	843,771	659,463	184,308	35.07%

Source: Census of India

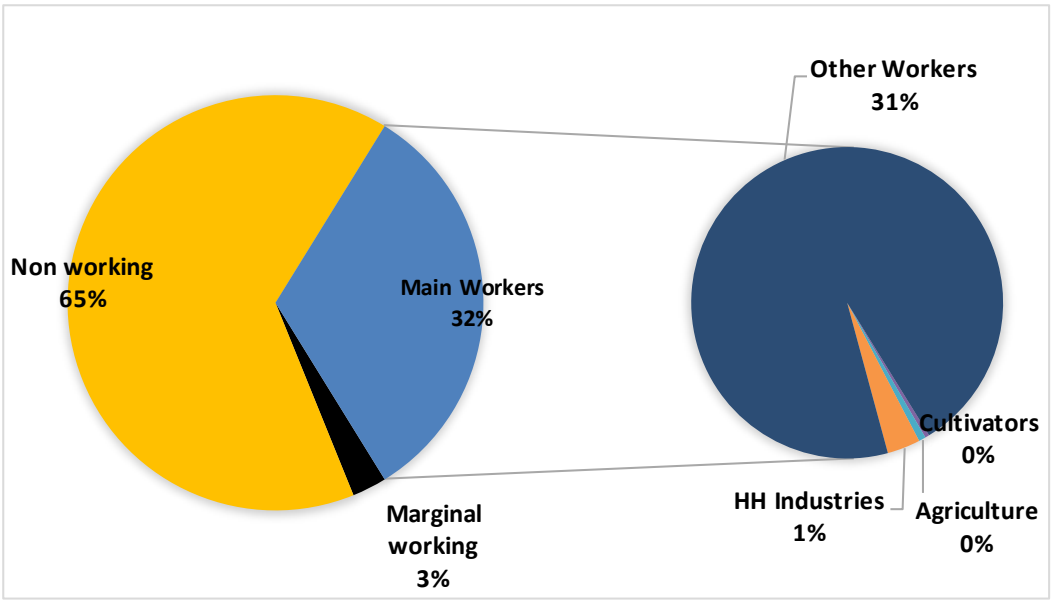
Of the total population, 32.39% are main workers and 2.68% are marginal workers and rest of the population is non-working which is 64.93% of the total. Table 3-10: shows the work participation rate for Nagpur city.

Table 3-10: Workforce Participation Rate for NMC

Category	Number of Persons	%
Main workers		
Cultivators	3,424	0.44%
Agricultural Labourers	5,683	0.73%
HH industries	26,731	3.43%
Other services	743,421	95.40%
Sub Total Main Workers	779,259	32.39%
Marginal Workers	64,512	2.68%
Total Workers	843,771	35.07%
Non-Workers	1,561,894	64.93%
Grand Total Population	2,405,665	100.00%

Source: Census of India, 2011

Figure 3-9: Workforce Participation Rate in Nagpur



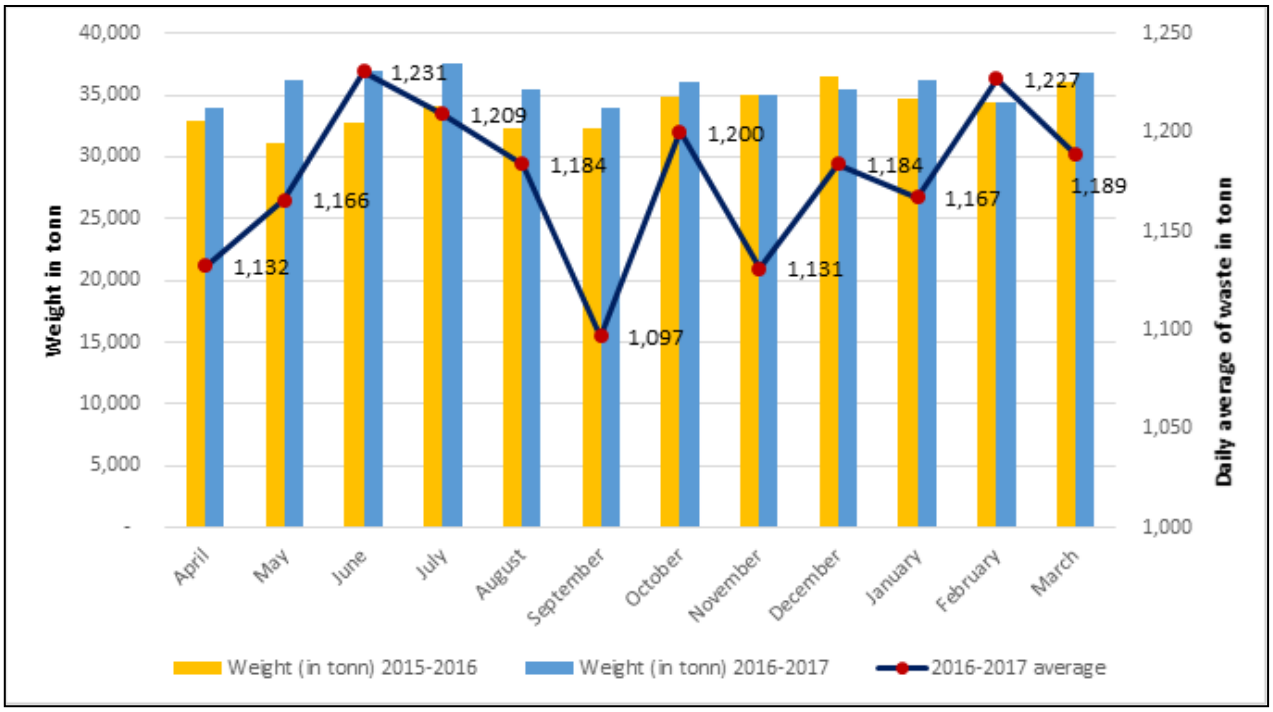
4 WASTE QUANTIFICATION & CHARACTERISATION

4.1 Waste Quantification

Municipal Solid Waste (MSW) quantification for Nagpur has been estimated based on the past records of waste transported to the dumpsite by NMC. A truck scale of 30 tonne capacity is installed at the existing dumpsite at Bhandewadi to scale all incoming waste coming to the dumpsite prior to processing or disposal.

A detailed analysis of the weighbridge data for the last two years from April 2015 to March 2017 has been carried out to estimate waste generation for Nagpur. Based on the available weighbridge record, approximately 0.43 million tonnes of waste reached the dumpsite in 2016 –17 (April-March), and 0.41 million tonnes in 2015-16 (April-March). The average daily collection of waste based on the weighbridge record for last two years is 1,143 tonnes per day; however, for all calculations in this report an average daily waste collection from January 2017 to March 2017 is assumed, which is 1193 tonnes per day. This is done to avoid inconsistency on city level and zone level data, since zone wise waste collection information is available only from January 2017 to March 2017. **Figure 4-1** and **Table 4-1** show the details on the average monthly waste received at the Bhandewadi weighbridge and provides details on the average waste generated per day in the different months of 2016-17.

Figure 4-1: Incoming Waste to Weighbridge at Bhandewadi Dumping Site



Source: Based on the data collected from Bhandewadi Weighbridge Nagpur from April 2015 – March 2017

Table 4-1: Municipal Solid Waste dumped at Bhandewadi dumpsite, Nagpur during April 2015 to March 2017

Sl. No	Year	Waste Dumped per month (in tonne)	Average Daily (in tonne)
1	Apr-15	32,907	1,097
2	May-15	31,103	1,003
3	Jun-15	32,785	1,093
4	Jul-15	34,164	1,102
5	Aug-15	32,330	1,043
6	Sep-15	32,255	1,075
7	Oct-15	34,785	1,122
8	Nov-15	34,986	1,166
9	Dec-15	36,448	1,176
10	Jan-16	34,738	1,121
11	Feb-16	34,443	1,188
12	Mar-16	36,080	1,164
13	Apr-16	33,970	1,132
14	May-16	36,140	1,166
15	Jun-16	36,923	1,231
16	Jul-16	37,483	1,209
17	Aug-16	35,511	1,146
18	Sep-16	33,999	1,133
19	Oct-16	36,007	1,162
20	Nov-16	35,068	1,169
21	Dec-16	35,517	1,146
22	Jan-17	36,181	1,167
23	Feb-17	34,349	1,227
24	Mar-17	36,848	1,189

Source: Data from Weighbridge at Bhandewadi for the years 2015-16 and 2016-17, Nagpur Municipal Corporation

Photo 4-1: Vehicles weighing and maintenance of waste record at Bhandewadi weighbridge

Photo 4-2: Dumper Placer at Weighbridge

Photo 4-3: Dump Truck at Weighbridge

4.1.1 Zone wise waste generation

Average daily waste collection for all the zones is provided in **Table 4-2**

Table 4-2: Zone Wise details on the average waste dumped at Bhandewadi dumpsite

Sl. No	Zone	Average Daily (in tonne)	Percentage Distribution
1	Zone 1	221	18.53
2	Zone 2	68	5.67
3	Zone 3	116	9.70
4	Zone 4	92	7.75
5	Zone 5	124	10.37
6	Zone 6	114	9.52
7	Zone 7	113	9.48
8	Zone 8	140	11.71
9	Zone 9	98	8.17
10	Zone 10	108	9.09
	Total	**1193**	**100**

Source: Based on zone wise waste collection data provided by NMC from Jan 2017 to March 2017, Nagpur Municipal Corporation

4.2 Waste Characterisation

A waste characterisation exercise for Nagpur city was undertaken by the National Environmental Engineering Research Institute (NEERI), Nagpur and Arcadis India. A total of 25 waste samples were collected from all the 10 zones in the city and the dumpsite. NEERI collected and analysed 15 samples from the city; and Arcadis India carried out physical waste characterisation for 10 additional samples for the waste reaching the dumpsite. Reconnaissance survey and waste characterisation work by NEERI was carried out in April/May and by Arcadis in the month of October 2017. Reconnaissance survey was undertaken and the location of the sampling points was identified based on stratified random sampling method to represent different waste generation sources such as residential (slum and non-slum areas), secondary collection points/ community bins, institutional areas[4], commercial establishments[5] and finally at the dumpsite.

4.2.1 Sampling of MSW

Waste samples were collected from all 10 zones of Nagpur city & Bhandewadi dumpsite; the general procedures followed for waste sampling for the project are presented below.

- Identification of major sample collection points from all 10 zones representing diverse types of waste generation sources, such as residential, commercial, markets (vegetable market) and slums. The economic status of the areas, representing high, middle and low-income groups, was also taken into consideration during the selection of sampling locations. In addition, samples were also collected from the dumpsite.
- 5 kg of waste were collected from each identified point and mixed thoroughly to get a homogenous sample. The quarter and coning method recommended in the Manual for Municipal Solid Waste Management, 2016[6] (CPHEEO) was used for sampling.
- The physical composition of MSW was determined at the site itself. The collected samples were separated into various major components, such as, paper, glass, plastics, etc. and weighed and expressed as a percentage of the original sample.
- For chemical analysis, the samples were packed in a plastic bag, sealed and sent to the NEERI laboratory. Each sample was in the range of 1-2 kg.
- The size determination of the samples was done using a sieve of 150 X 150 mm.

[4] Wastes generated from institutions such as schools, colleges, hospitals, research institutions.

[5] Solid wastes generated in offices, wholesale stores, restaurants, hotels, markets, warehouses and other commercial establishments. etc.

Ref: http://www.cpreec.org/pubbook-solid.htm, Published by Central Public Health & Environmental Engineering Organization (CPHEEO), Ministry of Urban Development, Govt. of India

Figure 4-2: MSW Sampling Procedure using Quartering & Coning Method

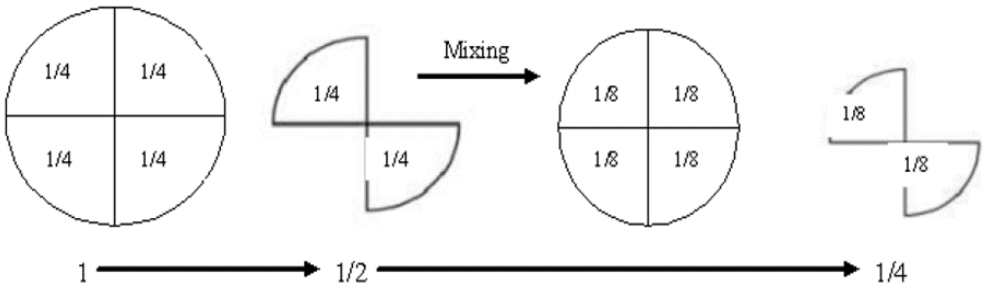


Photo 4-4: Sample Collection from Bhandewadi Dumping Site in Nagpur City

Bhandewadi Dumping Site (Old Waste)

Bhandewadi Dumping Site (Fresh Waste)

Photo 4-5: Sample Collection from Different Zones in Nagpur City

Secondary Collection Point, Zone - VII

Residential Area, Zone - V

Secondary Collection Point, Zone - V

The details of the samples collected from various sources has been provided in **Table 4-3**

Table 4-3: Details of Samples Collected for Waste Analysis

Sl. No	Particular	Number of samples	Zones
1	Zone wise Secondary Collection Point	10	All zone
2	Commercial area	2	Zone V and VII
3	Institutional Area	2	Zone I and IV
4	Dumping Site -Bhandewadi Site	11	1 Sample by NEERI (fresh waste) & additional 10 samples by Arcadis
5	**Total**	**25**	

4.2.2 Results of Physical Characterisation of Waste

Zone-wise waste composition (mixed waste from secondary collection points)

The results for the zone-wise waste characterisation are presented in **Table 4-4** and **Figure 4-3**. The results indicate a very high percentage of organic fraction in the waste (77%), followed by plastics (11.60%), and paper (7.66%). The balance (3.74 %) constitutes inerts, textile and cardboard.

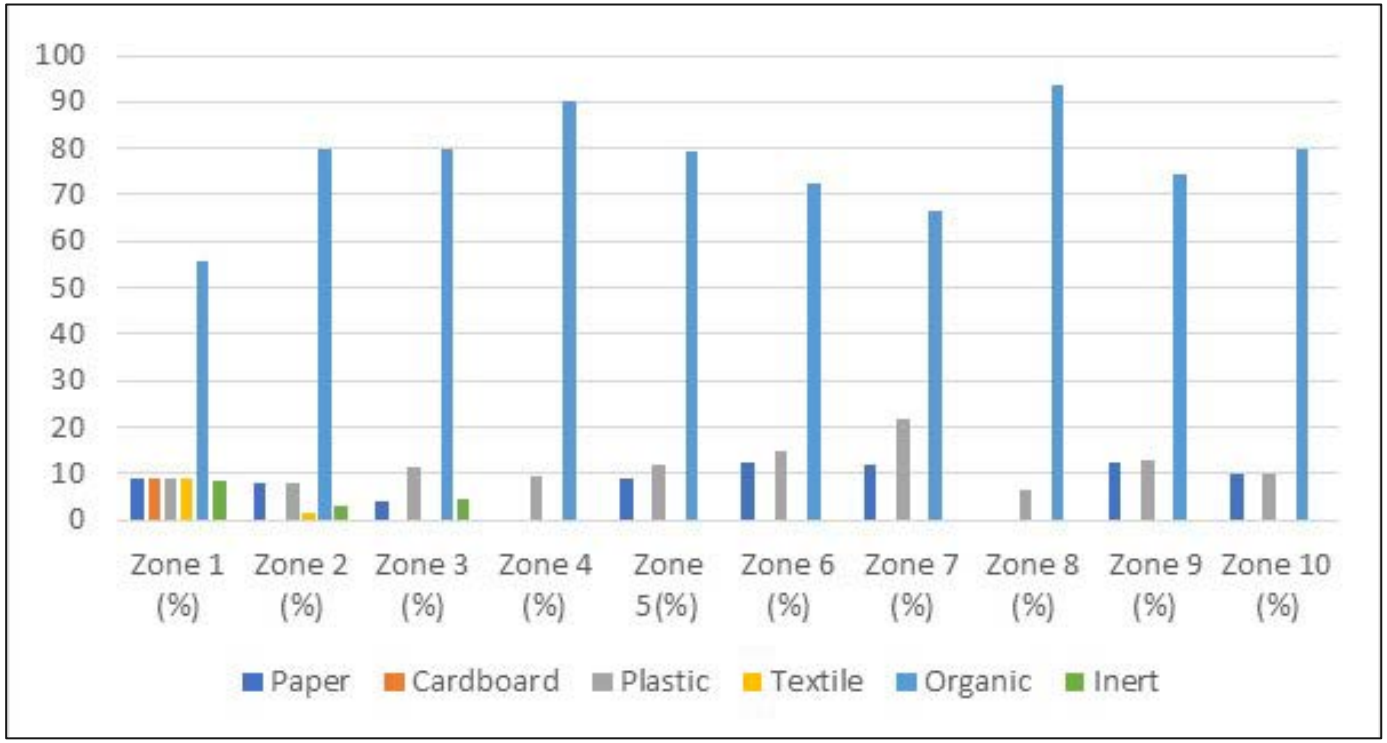
Table 4-4: Average Physical Characteristics of Solid Waste of all 10 zones in Nagpur

Sl. No.	Item	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10	Average
1	Paper	8.93	7.99	4.09	ND	8.91	12.50	11.67	ND	12.50	10.00	**7.66**
2	Cardboard	8.93	ND	ND	ND	ND	ND	ND	ND	ND	ND	**0.90**
3	Plastic	9.00	7.86	11.45	9.58	11.88	15.00	21.67	6.50	13.00	10.00	**11.60**
4	Textile	9.07	1.33	ND	ND	ND	ND	ND	ND	ND	ND	**1.04**
5	Organic	55.71	79.89	80.00	90.42	79.21	72.50	66.67	93.50	74.50	80.00	**77.24**
6	Inert	8.36	2.93	4.45	ND	ND	ND	ND	ND	ND	ND	**1.57**
7	Wood	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
8	Thermocol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
9	Metals	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
10	Glass	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

ND- Not Detectable

Source: Results of Waste Characterisation Analysis conducted by NEERI for different zones of Nagpur (samples collected from secondary collection points and residential areas), April/May 2017

Figure 4-3: Physical Characteristics of Waste Collected from the Zones



Commercial and Institutional

Samples were collected from commercial and institutional areas. The commercial area by definition includes offices, wholesale stores, restaurants, hotels, markets, warehouses and other commercial establishments7. In case of Nagpur, samples for commercial area were primarily samples from office and shopping area in zone V and VII. During field survey, it was observed that waste from vegetable market and waste from hotels & restaurants was found mixed in the secondary collection points and no exclusive sample to represent vegetable market waste or hotel waste could be identified.

Institutional waste samples for Nagpur include the waste samples from institutions such as schools, colleges, hospitals (non-biomedical waste), research institutions from zone I and IV. The results from commercial and institutional waste analysis are shown in **Table 4-5,** and **Figure 4-4.**

Table 4-5: Average Physical Characteristics of Solid Waste for Institutional & Commercial Area (in %)

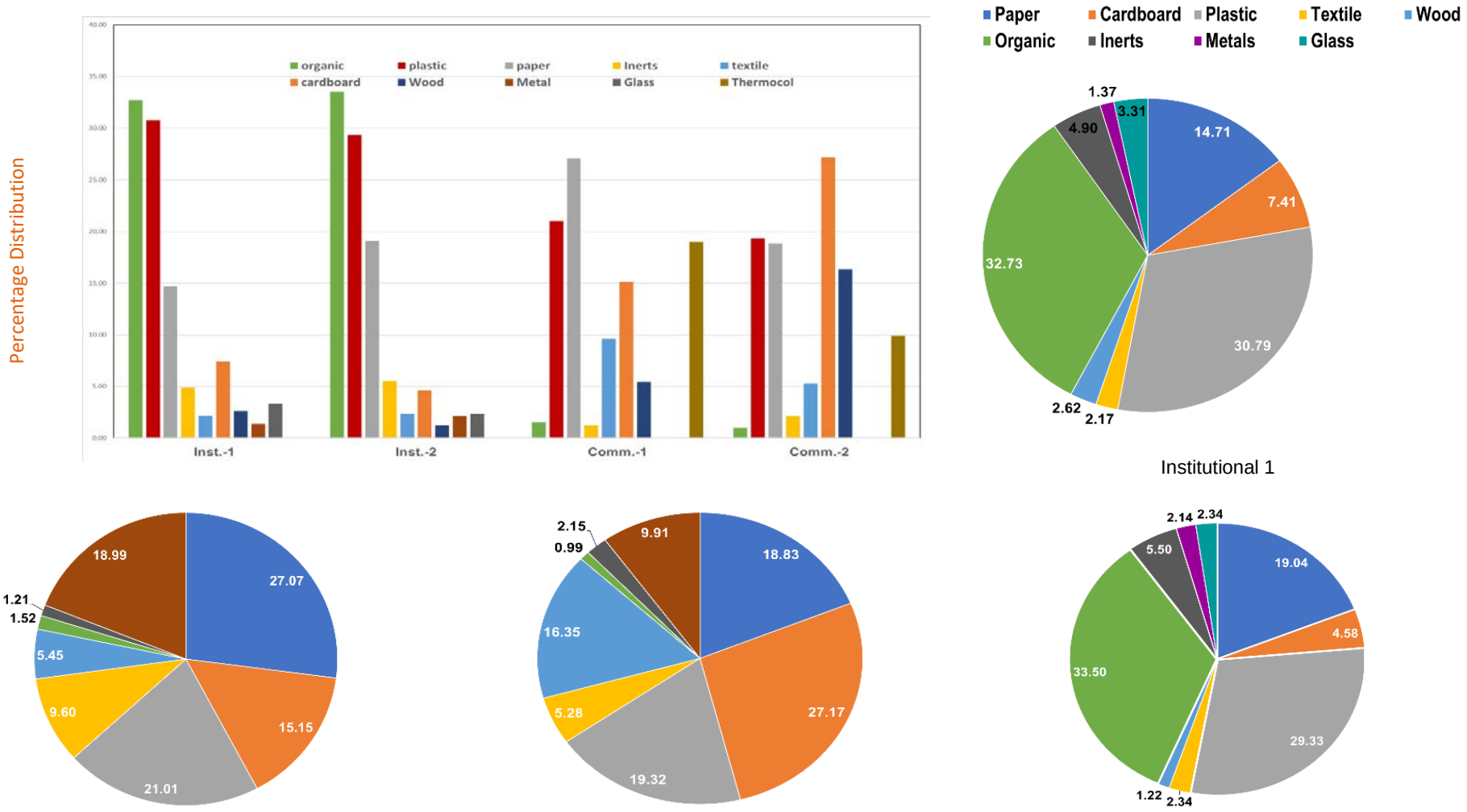
Sl. No.	Item	Commercial 1	Commercial 2	Average Commercial	Institutional 1	Institutional 2	Average Institutional
1	Paper	27.07	18.83	22.95	14.71	19.04	16.88
2	Cardboard	15.15	27.17	21.16	7.41	4.58	6.00
3	Plastic	21.01	19.32	20.17	30.79	29.33	30.06
4	Textile	9.60	5.28	7.44	2.17	2.34	2.26
5	Organic	1.52	0.99	1.26	32.73	33.50	33.12
6	Inert	1.21	2.15	1.68	4.90	5.50	5.20
7	Wood	5.45	16.35	10.9	2.62	1.22	1.92
8	Thermocol	18.99	9.91	14.45	-	-	ND
9	Metals	ND	ND	ND	1.37	2.14	1.76
10	Glass	ND	ND	ND	3.31	2.34	2.83

ND- Not Detectable Source: Results of Waste Characterisation Analysis conducted by NEERI for Commercial and Institutional Area, April/May 2017

From the commercial areas, paper (23%), cardboard (21%), plastic (20.17%) are the key components in waste; whereas for the institutional areas, organic waste (33%) is the key fraction, followed by plastics (30%) and paper (17%).

[7] *Ref: http://www.cpreec.org/pubbook-solid.htm, Published by Central Public Health & Environmental Engineering Organization (CPHEEO), Ministry of Urban Development, Govt. of India*

Figure 4-4: Physical Characteristics of Waste from Commercial and Institutional Areas



Waste from Dumpsite

Samples were collected from the fresh waste arriving from various zones at the dumpsite and analysed for their composition. The results are shown in **Table 4-6** and **Figure 4-5**

Table 4-6: Average Physical Characteristics of Solid Waste at Bhandewadi dumpsite (in %)

SN	Item	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 1 (additional sample)	Average
1	Paper	12.17	12.63	6.75	10.05	5.81	4.08	13.94	9.56	7.53	11.54	9.41
2	Cardboard	2.42	ND	2.43	ND	2.10	8.87	ND	0.53	ND	ND	1.64
3	Plastic	18.87	17.29	6.75	12.52	9.90	9.72	23.28	16.81	10.88	15.51	14.15
4	Textile	11.05	10.61	3.03	13.62	13.62	6.13	10.27	18.14	14.61	7.22	10.83
5	Organic	48.23	40.90	60.96	59.51	68.19	71.13	32.18	32.12	50.71	27.71	49.16
6	Inert	6.70	18.57	16.60	ND	ND	ND	6.03	16.46	15.06	29.87	10.93
7	Wood	ND	ND	2.27	ND	ND	ND	4.09	ND	1.03	ND	0.74
8	Thermocol	0.31	ND	ND	0.09	ND	0.07	ND	0.09	ND	ND	0.06
9	Metals	ND	ND	1.21	ND	0.38	ND	ND	1.06	0.19	ND	0.28
10	Glass & Ceramic	0.25	ND	ND	ND	ND	ND	10.20	5.22	ND	ND	1.57
11	Rubber	ND	ND	ND	4.20	ND	ND	ND	ND	ND	6.93	1.11
12	Leather	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.23	0.12

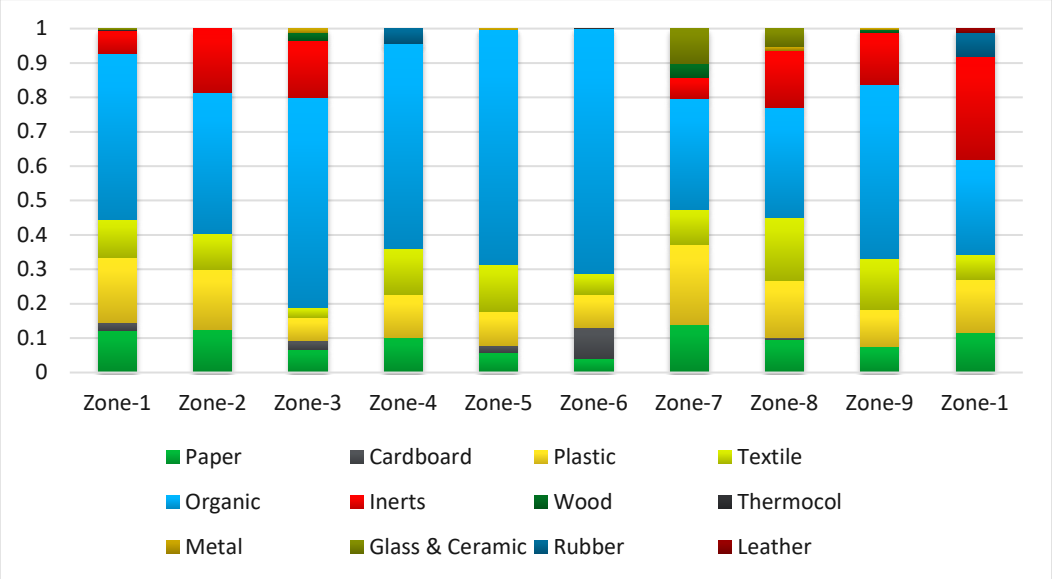
ND- Not Detectable

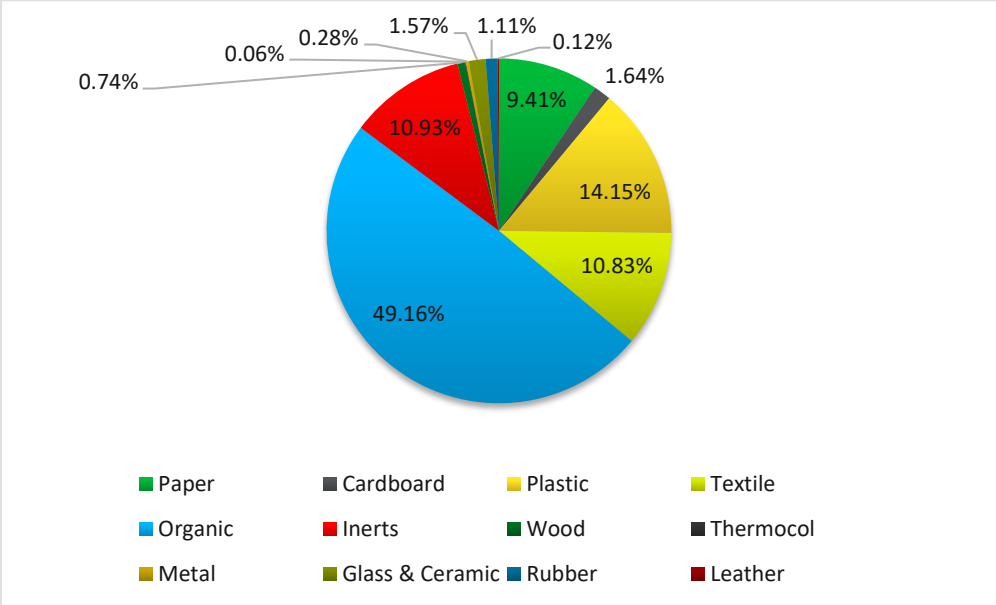
Source: Waste composition analysis conducted by Arcadis at Bhandewadi dumpsite (samples collected from vehicles coming from different zones), October 2017

Please Note: An additional sample was taken from Zone -1 as no waste trucks from Zone-10 has arrived at the during sampling duration.

Waste composition from the dumpsite shows approximately 49.16 % of organics, followed by plastic (14.15%), inerts (10.93%), textile (10.83%) and paper (9.41%). The organic content at the dumpsite is slightly lesser than the waste collected from the zones, due to mixing of street sweeping and drain cleaning waste at the transfer stations or during collection.

Figure 4-5: Physical Characteristics of Waste from Dumping Site





Based on the zone wise composition obtained at a dumpsite, total quantity of different waste types reaching the dumpsite from ten zones was calculated and presented in Table 4-7

Table 4-7: Waste arriving at dumpsite from different Zones (tonnes)

SN	Item	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10	Total (tonnes)
1	Paper	26.90	8.56	7.81	9.29	7.19	4.64	15.77	13.35	7.34	10.85	**111.69**
2	Cardboard	5.35	0.00	2.81	0.00	2.59	10.08	0.00	0.74	0.00	0.00	**21.57**
3	Plastic	41.72	11.72	7.81	11.57	12.25	11.04	26.34	23.48	10.60	10.85	**167.38**

SN	Item	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10	Total (tonnes)
4	Textile	24.43	7.19	3.51	12.59	16.85	6.96	11.62	25.34	14.24	0.00	**122.73**
5	Organic	106.63	27.72	70.53	54.99	84.35	80.80	36.41	44.87	49.44	86.80	**642.54**
6	Inert	14.82	12.59	19.21	0.00	0.00	0.00	6.83	22.99	14.68	0.00	**91.12**
7	Wood	0.00	0.00	2.63	0.00	0.00	0.00	4.63	0.00	1.00	0.00	**8.27**
8	Thermocol	0.69	0.00	0.00	0.08	0.00	0.08	0.00	0.12	0.00	0.00	**0.97**
9	Metals	0.00	0.00	1.40	0.00	0.47	0.00	0.00	1.48	0.19	0.00	**3.55**
10	Glass & Ceramic	0.55	0.00	0.00	0.00	0.00	0.00	11.54	7.29	0.00	0.00	**19.38**
11	Rubber	0.00	0.00	0.00	3.89	0.00	0.00	0.00	0.00	0.00	0.00	**3.89**
12	Leather	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
	Total	**221.09**	**67.77**	**115.71**	**92.41**	**123.70**	**113.60**	**113.15**	**139.66**	**97.50**	**108.50**	**1193**

Source: Calculated based on waste composition analysis conducted by Arcadis at Bhandewadi dumpsite, October 2017

Zone 10 data has been taken based on survey conducted by NEERI

Sieve Analysis

The collected samples were analysed for size determination. The sizing determination was carried out using a sieve of 150 X 150 mm. Sieve analysis results are presented in **Table 4-8**.

Photo 4-6: Sieving Exercise for Sizing Determination

Table 4-8: Result from Sieve Analysis

Sample Location	Sieved Waste (%)
Zone 1	8.4
Zone 2	8.58
Zone 3	8.62
Zone 4	8. 78
Zone 5	8.62
Zone 6	8.74
Zone 7	8.46

Sample Location	Sieved Waste (%)
Zone 8	8.70
Zone 9	8.52
Zone 10	8.68
Dumpsite (Fresh Waste)	13.21
Commercial 1	8.9
Commercial 2	8.8
Institutional 1	8.3
Institutional 2	8.2

Source: Results of Waste Characterisation Analysis conducted by NEERI for waste at dumpsite, April/May 2017

The above analysis reveals that less than 9% of fresh waste from various sources passed the sieve prepared for sieve analysis.

Results and Conclusion

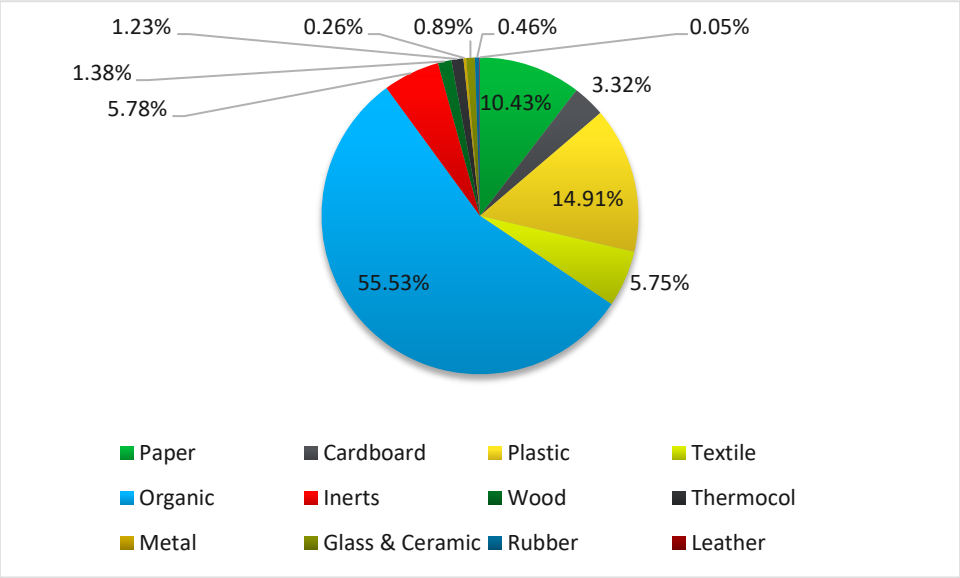
For further calculations in the report, an average of all the waste characterisation results (from secondary collection points, dumpsite, commercial and institutional area) obtained for the city has been considered. The average waste composition considered for Nagpur is presented in **Table 4-9 and Figure 4-6**

Table 4-9: Average Physical Characteristics of Solid Waste at Nagpur

Sl. No.	Component	Average Value (%)
1	Paper	10.43%
2	Cardboard	3.32%
3	Plastic	14.91%
4	Textile	5.75%
5	Organic	55.53%
6	Inerts	5.78%
7	Wood	1.38%
8	Thermocol	1.23%
9	Metal	0.26%
10	Glass & Ceramic	0.89%
11	Rubber	0.46%
12	Leather	0.05%

Source: Results of Waste Characterisation Analysis conducted by NEERI, April/May 2017 and Arcadis October 2017

Figure 4-6: Average Physical Characteristics of Solid Waste at Nagpur



The average waste composition for Nagpur includes an organic fraction of waste of approximately 56%, along with plastics (14.91%), paper (10.43%), textile (5.75%), cardboard (3.32%), wood (1.38%), Thermocol (1.23%) and inerts (5.78%). The balance of 1.67% constitutes rubber, leather, metal, glass & ceramic, etc.

4.2.3 Chemical Waste Characterisation

The MSW samples were tested for various parameters, such as pH, moisture content, total solids, loss on ignition, ash, carbon (C), calorific value, nitrogen (N), & C/N ratio. For the chemical analysis, the waste was oven dried for 48 hrs at 80 °C in a hot air oven. The oven dried samples were further grinded to fine powder and then desiccated to cool down. Extracts were prepared by dissolving 10 gm of the sample in 100 ml of distilled water and shaken for 8 hrs in a rotary shaker to ensure full dissolution of the sample into distilled water. The solution was then filtered in filter paper (Whatman No. 42) and the filtrate was used for chemical analysis. Chemical analysis was carried out using the prescribed standard methods, as presented in **Table 4-10.**

Table 4-10: Standard Methods used for Analysis of Different Parameters in NEERI Laboratory

S No.	Parameter	Methods Adopted
1.	pH	Gravimetric (IS 10158:1982)
2.	Moisture Content (MC)	Gravimetric (IS 9235:1979)
3.	Total Volatile Solids (TVS)	Gravimetric (IS 10158:1982)
4.	Ash Content	Gravimetric (IS 10158:1982)
5.	Carbon Content	Combustion (Pregal-Dumas Method)
6.	Nitrogen Content	Combustion (Pregal-Dumas Method)
7.	Calorific Value	Calorimetric (IS 1350 [Part II] 1970)

The results of the chemical analysis of mixed waste from the various sources are presented in **Table 4-11** and **Table 4-12** and **Figure 4-7** to **4-10.**

Table 4-11: Chemical Characterisation of Mixed MSW of Nagpur City

Sample location	MC* (%)	TS* (%)	TVS# (%)	Ash# (%)	Calorific value* (kcal/kg)
Zones					
Zone 1	59.16	40.84	79.02	20.98	878
Zone 2	37.10	62.90	83.60	16.40	983
Zone 3	58.13	41.87	78.20	21.80	953
Zone 4	80.95	19.05	91.67	8.33	914
Zone 5	56.86	43.14	42.40	57.60	1047
Zone 6	74.40	25.60	96.90	3.10	1009
Zone 7	66.60	33.40	79.88	20.12	1154
Zone 8	58.70	41.30	44.02	55.98	1082
Zone 9	74.40	25.60	96.90	3.10	1114
Zone 10	80.63	19.37	66.33	33.67	1059
Average	**65**	**35**	**76**	**24**	**1019**
Commercial & Institutional					
Commercial 1	12.89	87.11	45.86	54.14	1467
Commercial 2	13.23	86.77	46.23	53.77	1364
Institutional 1	57.33	42.67	61.56	38.44	1124
Institutional 2	54.87	45.13	59.86	40.14	1098
Average	**54**	**46**	**64**	**36**	**1165**
Combined average of zones, commercial and institutional	**56.1**	**43.9**	**69.5**	**30.5**	**1089.0**
Dumpsite					
Dumpsite Fresh	22.53	77.47	66.58	33.42	967

* *Wet weight basis*

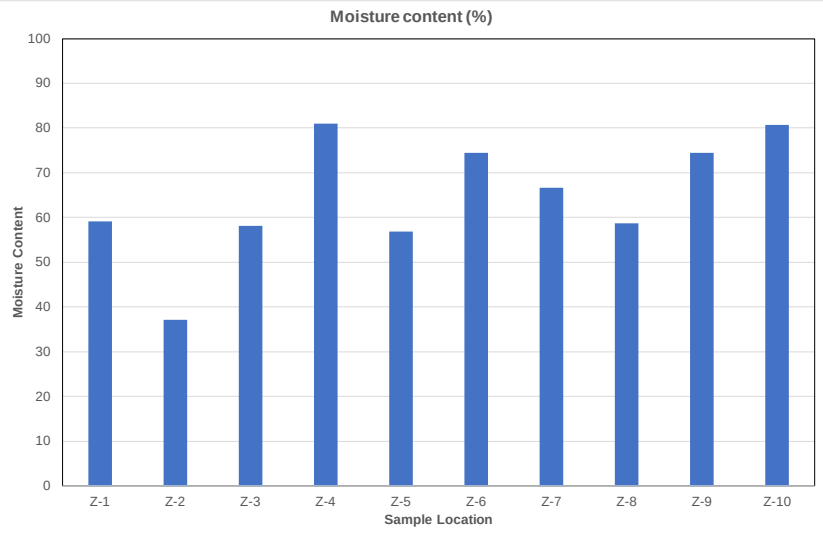
\# *Dry weight Basis*

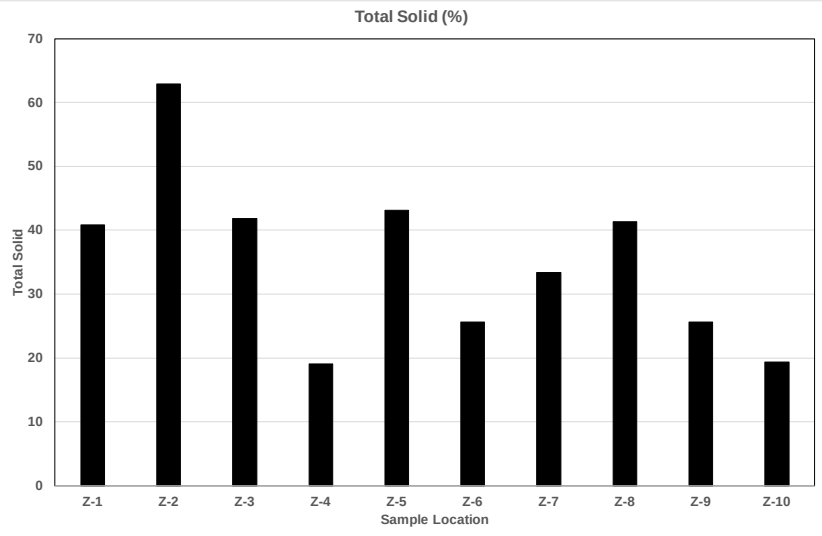
**# Values expressed are based on the results of triplicate samples collected from all locations*

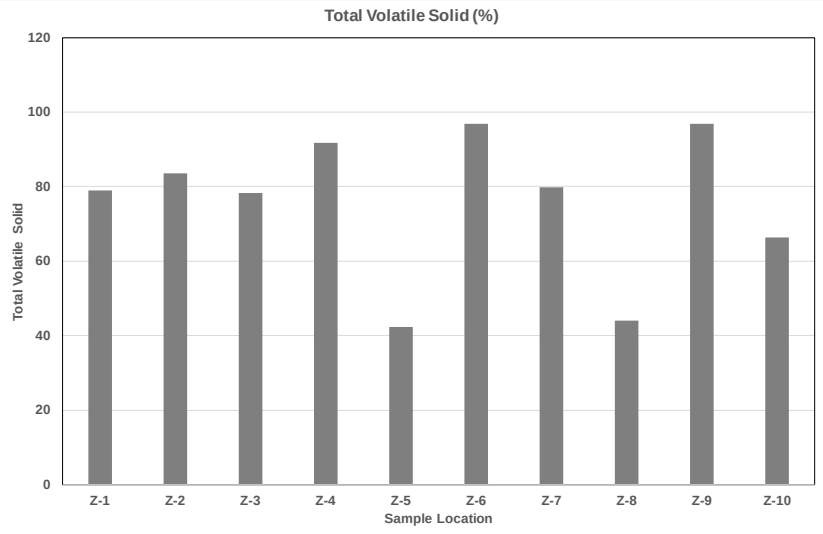
Source: Results of Waste Characterisation Chemical Analysis conducted by NEERI, April/May 2017

For further calculation in the report, an average value of various parameters obtained from zones, commercial and institutional areas have been taken into consideration. The results obtained from the dumpsite for chemical analysis though presented here, have been ignored due to limited sample size and mixing of fresh waste with the existing waste on the dumpsite. Based on the analysis carried out in **Table 4-11**, the average moisture content is 56.1%, TS is 43.9%, TVS is 69.5%, ash content is 30.5% and calorific value is 1089 kcal /kg for mixed waste in Nagpur.

Figure 4-7: Chemical Characterisation of Mixed Waste from Different Zones in Nagpur







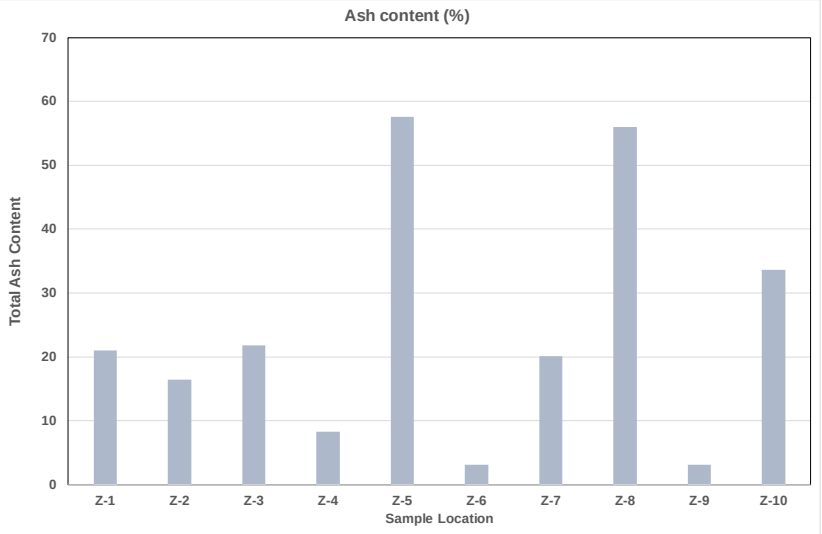
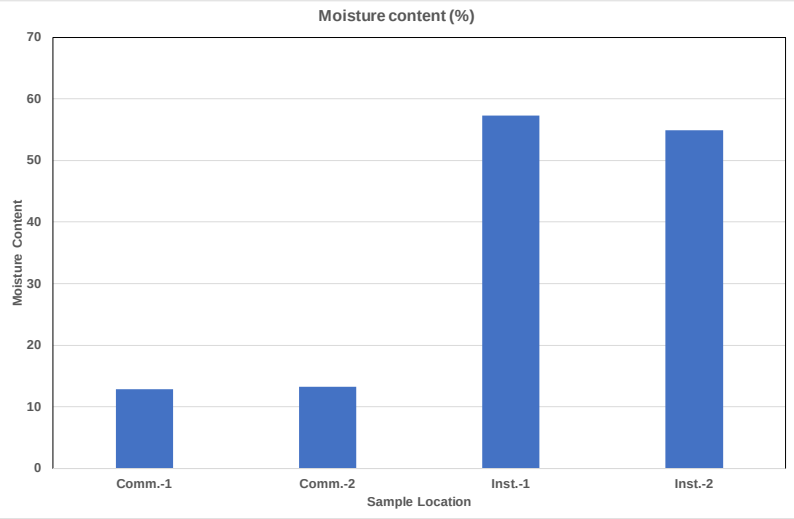
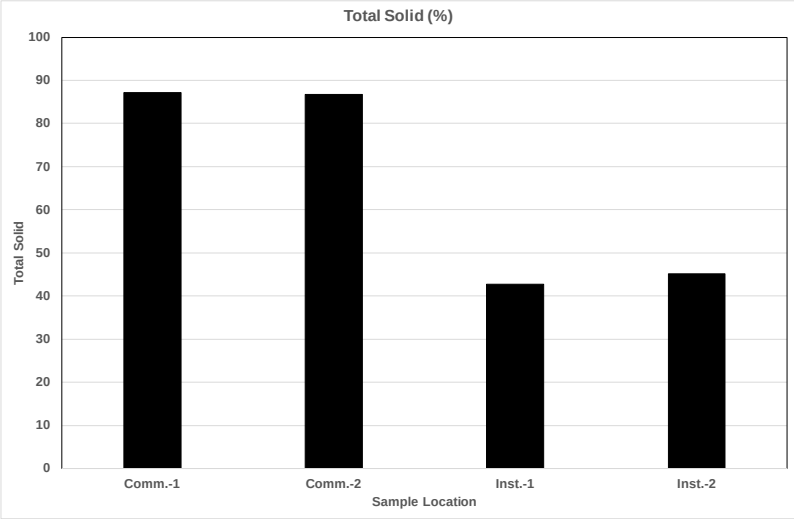
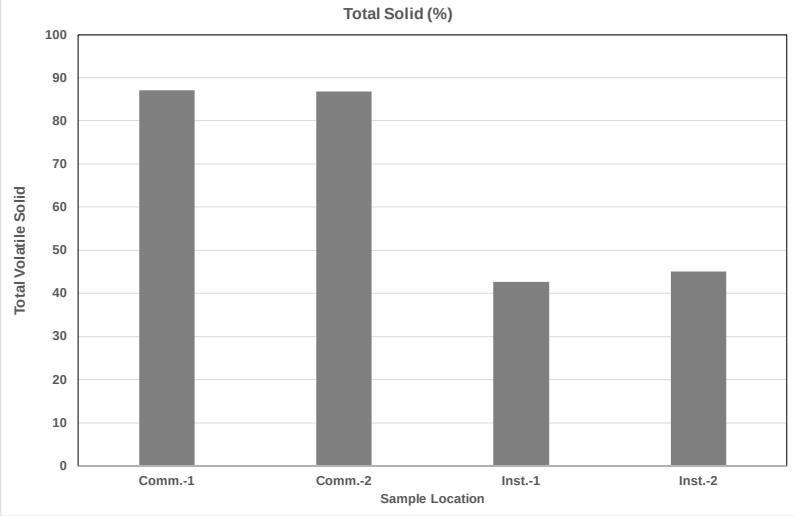


Figure 4-8: Chemical Characterisation of Waste collected from Commercial and Institutional Areas of Nagpur







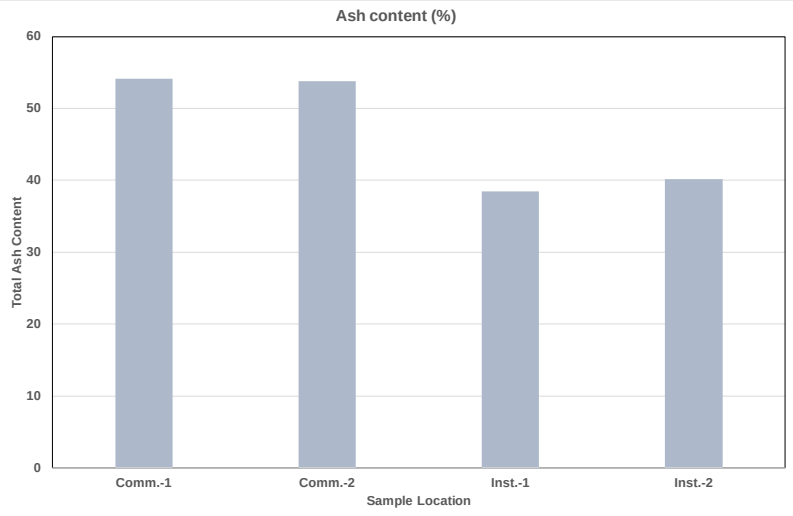
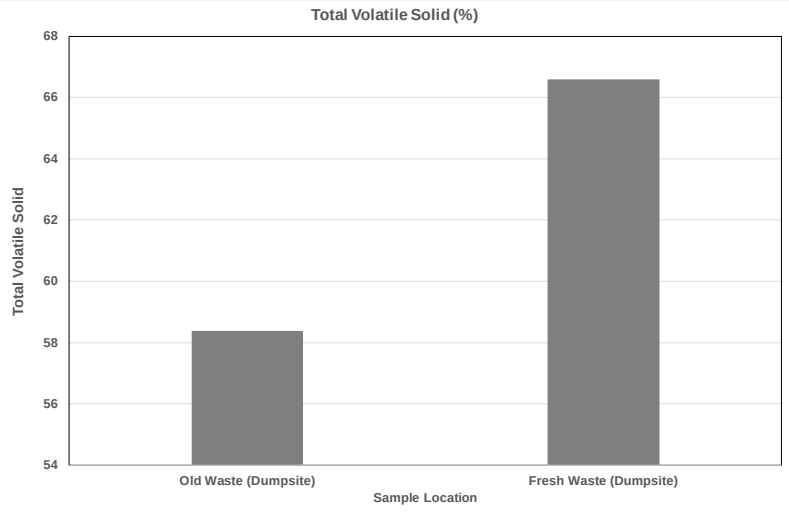
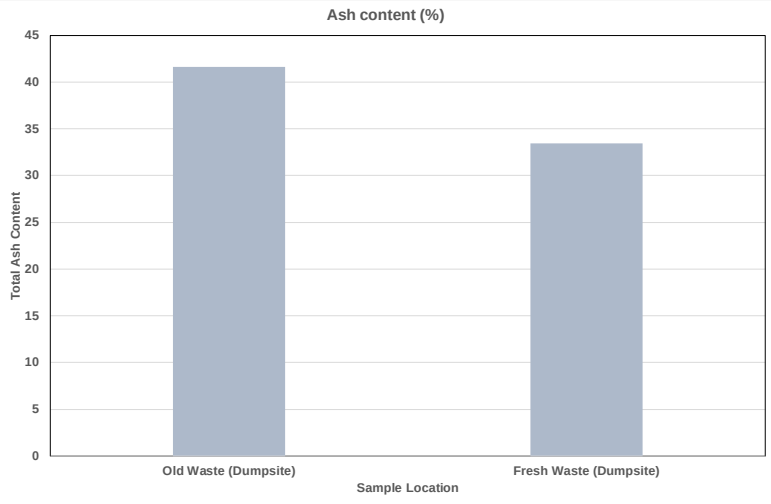
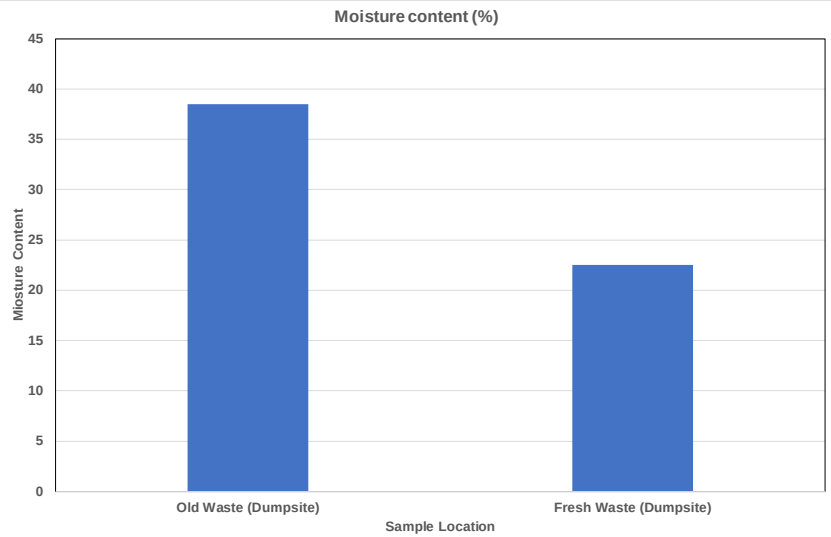


Figure 4-9: Chemical Characterisation of Waste from Dumping Site of Nagpur







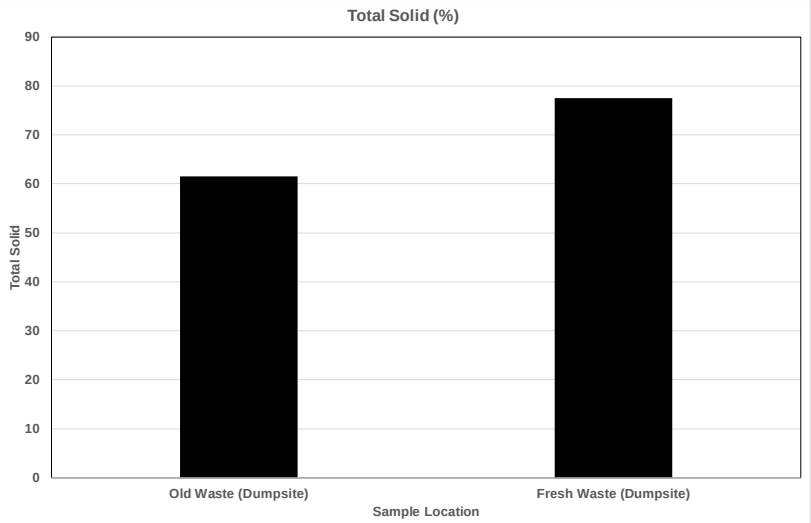
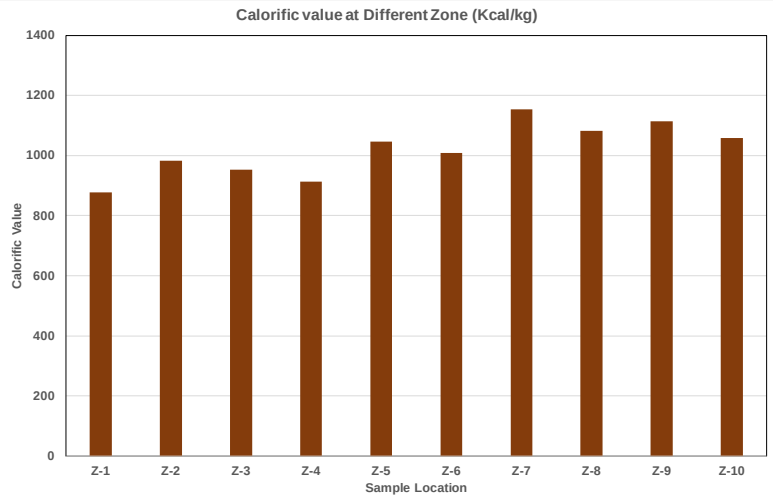
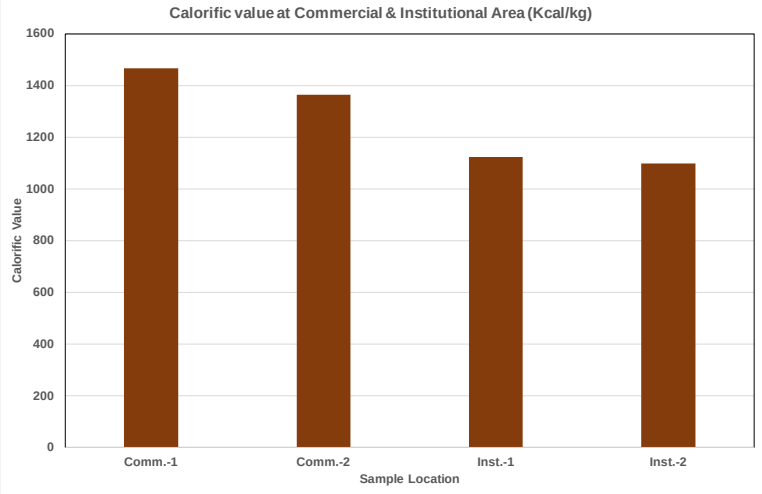


Figure 4-10: Calorific Value of Waste collected from Different Locations in Nagpur City





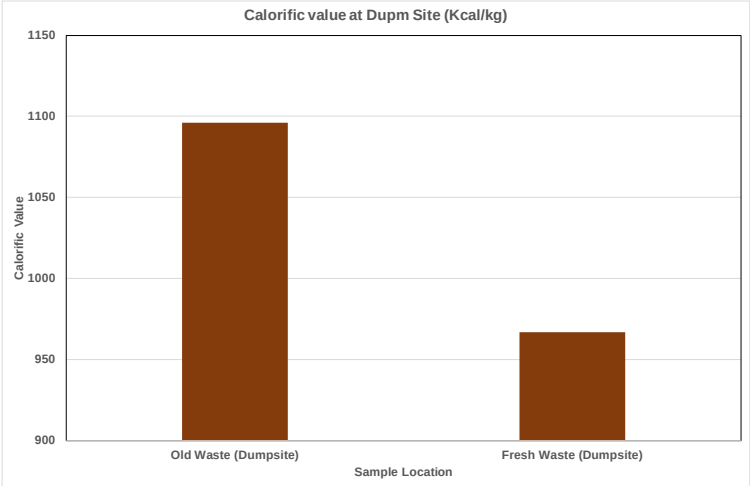


Table 4-12: Chemical Characteristics of Organic Waste in Nagpur

Sample location	pH	COD (g/kg)	Dry Density (kg/m3)	C: N ratio
Zones				
Zone 1	6.2	28.64	385	23
Zone 2	5.9	29.1	432	22
Zone 3	6.0	28.23	411	19.98
Zone 4	6.8	31.86	453	20.23
Zone 5	5.9	18.86	398	26.32
Zone 6	5.8	32.87	468	30.64
Zone 7	5.6	27.65	351	32.68
Zone 8	6.1	19.22	378	22.16
Zone 9	5.9	32.87	439	28.87
Zone 10	5.8	18.32	488	21.98
Average	**6.00**	**26.76**	**420.30**	**24.79**
Commercial & Institutional				
Commercial 1	6.7	17.12	526	14.12
Commercial 2	6.8	17.26	477	15.4
Institutional 1	7.2	18.09	467	25.54
Institutional 2	6.8	18.04	493	26.84
Average	**6.32**	**21.70**	**448.81**	**23.60**
Combined average of zones, commercial and institutional	**6.25**	**24.15**	**440.43**	**23.55**
Dumpsite				
Dumpsite Fresh waste	5.1	19.03	689	23.38

Source: Results of Waste Characterisation Chemical Analysis conducted by NEERI, April/May 2017

For further calculation in the report, an average value of the various parameters obtained from zones, commercial and institutional areas have been taken into consideration. The results obtained from the dumpsite for chemical analysis though presented here have been ignored due to limited sample size and mixing of fresh waste with the existing waste on the dumpsite. An analysis of the above table reveals that the average COD of waste is 24%, the average density of waste is 440 kg/m^3, and the C: N ratio of waste is approximately 24.

4.2.4 Biomethane Potential of Organic Fraction of MSW

The collected samples from all the zones of Nagpur city were analysed for their biomethane potential. The Biomethane potential (BMP) Assay Protocol, as discussed below, was used for evaluating biomethane production.

BMP Assay Protocol

- 10 g VS-inoculum (to obtain 80 g VS-inoculum/L of working digester volume) was taken and added to digester (125 mL Serum bottles).

- 4 g VS-waste (to obtain 0.2 g VS-waste/g VS-inoculum) was taken and homogenized with 100 mL water in blender.
- Homogenized waste was added to digester and overall volume was raised to the desired working volume (125 mL) with distilled water.
- Bottles were purged by bubbling CO_2 or a mixture of N_2/CO_2 (80/20, v/v) in the liquid mixture for 5-10 minutes.
- Bottles were incubated at 37°C with continuous shaking.

Monitoring Biogas Production

Biogas monitoring was carried out every day throughout the BMP assay run, until biogas production ceases

- Collect the gas produced with a frictionless syringe and measure total amount of gas produced.
- Transfer the collected gas from syringe into gas bag.
- If required, add air to the gas bag to raise overall volume to 300 ml. Take note of the amount of gas added to account for dilution.
- Connect methane detector to gas bag using appropriate hosing. Read and record the methane composition of gas.

The BMP results for overall biogas production and methane concentrations (CH_4%) for all 10 zones are shown in **Table 4-13** and **Figure 4-11** and **Figure 4-12.**

Table 4-13: Biomethane Potential of Organic Fraction of Waste from Different Zones in Nagpur

Sl. No.	Name of Zone	Cumulative Bio Gas Potential (ml/gVS)	Cumulative Methane Production (ml/gVS)	Cumulative Bio Gas Potential (m3/ tonne of waste)	Cumulative Methane Gas Potential (m3/ tonne of waste)	Methane percentage (%)
1	Zone 1	136	69.5	41	21	51%
2	Zone 2	271	160.1	83	49	59%
3	Zone 3	197	142.6	60	44	72%
4	Zone 4	115	46.8	35	14	41%
5	Zone 5	250	88.9	76	27	36%
6	Zone 6	447	219.0	136	67	49%
7	Zone 7	356	220.9	109	67	62%
8	Zone 8	512	240.4	156	73	47%
9	Zone 9	241	69.7	74	21	29%
10	Zone 10	515	227.9	157	70	44%
	Average			**93**	**45**	**49%**

Source:

1. *Cumulative biogas potential (ml/gVS) and cumulative methane potential (ml/gVs) – Test conducted by NEERI, April/May 2017.*
2. *Cumulative Biogas potential (m^3/ tonne of waste) and Cumulative methane potential – Calculated by Arcadis.*

Figure 4-11: Cumulative Biogas Production from Zone Waste

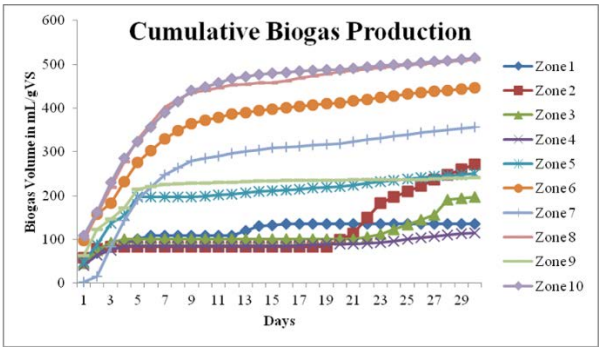
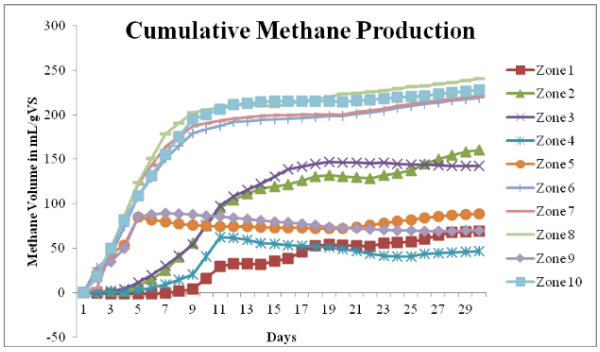


Figure 4-12: Cumulative Methane Production from Zone Waste



The following inferences can be drawn from **Table 4-13**

- Average biogas yield from organic waste - 93 m3/ tonne of waste
- Average methane yield from organic waste - 45 m3/ tonne of waste
- Methane percentage in biogas - 49%

5 EXISTING SWM SYSTEM IN NAGPUR

5.1 Overview of existing system

Nagpur Municipal Corporation (NMC) is currently generating an average of 1100-1200 TPD of waste, with an average per capita generation of 444 grams per person per day. NMC has been a progressive urban local body and has taken some measures for improvement of waste management in the city; however, there is still a need for a lot of focus and considerable improvement.

According to the *Swachh Sarvekshan*[8] survey, 2017, a survey to rank 500 cities in India on the basis of cleanliness and other aspects of urban sanitation initiated by the Ministry of Urban Development, Government of India, Nagpur ranked 137 out of a total of 434 cities surveyed, with an overall score of 1158 as against Navi Mumbai (1705), the top-ranked city in Maharashtra and Indore (1808) the top-ranked city in India.

For solid waste collection and transportation, Nagpur scored 293 as against Greater Mumbai (360), the top-ranked city in Maharashtra and Imphal (360), the top-ranked city in India in this category. Some of the initiatives by Nagpur city include privatisation of waste collection and transportation services, which involves the collection of waste from doorsteps and transportation to the dumpsite. In the year 2008, Nagpur city came up with the concept of a bin-free city and eliminated more than 80% of primary collection points/ community bins from the city. There is still scope for improvement in the collection and transportation system, including improvements in logistic management, optimal utilisation of vehicles, increasing coverage of outer city areas, and bringing efficiency to segregation practices.

For solid waste processing and disposal, Nagpur scored 82 as against Pimpri-Chinchwad (180), the top-ranked city both in Maharashtra and in India in this category. This indicates that there is surely a requirement to improve the overall processing and disposal system for waste in the city. There was previously some initiative for the processing of waste in the city, which includes setting up a waste to RDF facility with support from a private operator. However, the facility is not currently in operation.

In addition, a waste bioremediation project primarily for the existing waste is being practiced by the city on the existing dumpsite. According to discussions with the city officials, the project has managed to considerably reduce the height of the existing waste dump. However, the project and technology is currently under question and facing challenges because of recent incidences of a huge fire (March 2017) and odour issues. Other initiatives by the city include the signing of a contract with a private operator for setting up a new waste-to-energy facility.

Despite the above efforts, the processing and disposal of waste in Nagpur requires much higher level of attention to make it compliant with the Solid Waste Management Rules, 2016 (SWM Rules 2016), Ministry of Environment, Forest and Climate Change (MOEFCC), Government of India. The existing dumpsite at Bhandewadi is open and subject to various risks due to fire, leachate percolation, emission and is certainly a health and safety concern for the people working on-site as well as people residing along the edge of the dumpsite.

The existing waste management scenario is discussed in more detail further in this section.

[8]Swachh Sarvekshan is a *survey was conducted by the Quality Council of India (QCI) under the Swachh Bharat Abhiyan to rank 500 cities across the country with a population of one lakh and above on cleanliness.*

5.2 Collection& Transportation

5.2.1 Primary Collection[9]

For the effective management of waste, the city has been divided into 10 zones. Door-to-door waste collection is practiced in all wards, except outer city areas. NMC has privatised collection and transportation of the solid waste and awarded the contract to Kanak Resources Management Limited (KRML) in December 2007. KRML is responsible for the door-to-door collection of waste and transportation of waste to the dumpsite at Bhandewadi. The current contract for KRML expires in May 2018.

The vehicles deployed for door-to-door collection activities include handcarts, tricycle rickshaws, auto tippers, and small trucks (Tata 407). Under the “Bin-Free City” programme of NMC, a number of community bins have been reduced and eliminated and most of the garbage collected from various residential, commercial and institutional areas is directly transferred to the waste collection and transportation vehicles, which act as moving waste receptacles.

The door-to-door collection service does not cover the outer city areas and a few congested localities in Nagpur. The service is constrained by the reduced level of service standards and regularity. During a field visit, the study team recorded complaints from citizens about garbage spillage and related issues, and limited primary collection was observed in the following localities:

1. Rajeev Nagar, part of Kachipura in zone I,
2. Gond toli, Marar toli, New Futala Basti in zone II,
3. Kafala Basti in zone III,
4. Takiya Dhantoli in zone IV,
5. Shantinagar, Telipura in zone VII,
6. part of Pardi area, Satranjipura in zone VIII, and
7. Matatoli Basor Basti, Balabhaupeth, Korali, Mankapur, Gaddigudam in zone IX.

Photo 5-1: Primary Collection of Waste

[9] *Doorstep collection of waste from Residential, Commercial, institutional and other waste generating sources is referred to as primary collection of waste*

5.2.2 Segregation of Waste

SWM Rules 2016[10] prescribe source segregation of waste, i.e. segregation of waste by the generators but, as of now, segregation of waste at source is not practiced by the generators. Segregation of waste (limited to recovery of high value recyclables) is practiced by the workers engaged in door-to-door collection of waste. High value recyclables such as plastics, metals, papers, etc. are separated by the workers involved in door-to-door collection and sold to the local recyclers for additional income. Workers involved in door to door collection normally carry a large bag attached to their tricycle or collection vehicle for storage of segregated recyclables.

For implementing segregation at source, continuous efforts are required by NMC and KRML to raise awareness among the citizens along with making provision for segregated infrastructure for collection of segregated waste.

5.2.3 Street Sweeping

Street sweeping and drain cleaning is done by in-house staff of NMC. The total length of road for street sweeping is about 3,400 km. Street sweeping operations are carried out in the morning and evening in two shifts, i.e. 6.00 am to 11.00 am, & 3.00 pm to 6.00 pm. An average street length of 700 m (max 900 m and minimum 500 m depending upon the density of the population) per worker is swept daily.

Handcarts are generally used by sweepers for transporting silt from roads and open drains. The solid waste collected from road sweeping & drains are transported to the nearest collection centre for further transportation and disposal to the dumping site by KRML

At present, 8200 NMC staff are involved in road sweeping and drain cleaning. Approximately 44% (3613) are on regular roles and the balance 56 % (4587) are contract employees.

Photo 5-2: Street Sweeping in Operation

The key issue associated with street sweeping in Nagpur is low supervisory staff and lack of proper supervision by the existing supervisory staff.

5.3 Secondary Storage System

Nagpur had adopted the concept of a “Bin-Free City” as far back as 2008, which resulted in a significant reduction in the number of community bins from 700 in 2008 to 170 in 2017 (approximately 80% reduction). Bins/secondary collection points are provided only in the areas with continuous commercial activity. In addition, there are 9 transfer stations earmarked in various zones, which also serve as secondary storage points. The transfer station in zone 3 is mechanised, whereas the transfer stations in other zones are non-mechanised and open, resembling a large waste storage point. **Table 5-1** provides details of secondary storage points in each zone, including bins and transfer stations.

The waste collected by door-to-door activity is transferred to a refuse compactor and further transported to the dumpsite - except for the zones which are served by transfer stations. This system requires a lot of co-

[10] *Solid Waste Management Rules, 2016 (SWM Rules 2016), Ministry of Environment, Forest and Climate Change, Government of India*

ordination among the drivers of the refuse compactors and the waste collectors. The role of supervisors is also important to ensure overall co-ordination among all the operators and to ensure the timely availability of refuse compactors at designated points.

The main drawback of the system is that in the absence of coordination and non-availability of bins and other associated infrastructure, temporary roadside dumping has become prevalent.

Photo 5-3: Bins at Road Side

Photo 5-4: Bins at Community Area

Photo 5-5: Transfer Station in Open Yard

Photo 5-6: Mechaized Transfer Station

Table 5-1: Details of Secondary Storage Points in the NMC Area

Zone Number	Name of Zone	Total Number Secondary Point	Detail of Transfer stations
1	Laxmi Nagar	20	Sita Nagar (Temporary) Rahate Colony (Temporary)
2	Dharampeth	19	Ambajhari T- Point (Temporary)
3	Hanuman Nagar	14	Budhwari Bazaar, Sakkardara (Permanent)
4	Dhantoli	30	Ganesh Peth (Temporary)

Zone Number	Name of Zone	Total Number Secondary Point	Detail of Transfer stations
5	Neharu Nagar	12	Tajbag Maidan (Temporary)
6	Gandhibagh	15	Sokhta Bhawan (Temporary)
7	Satranjipura	16	
8	Lakadgang	10	Gangabai Ghat (Temporary)
9	Ashi Nagar	13	Gangabai Ghat (Temporary)
10	Mangalwari	21	Chaoni Chowk (Temporary)
		171	

Source: NMC, April/May 2017

5.4 Waste Transportation System

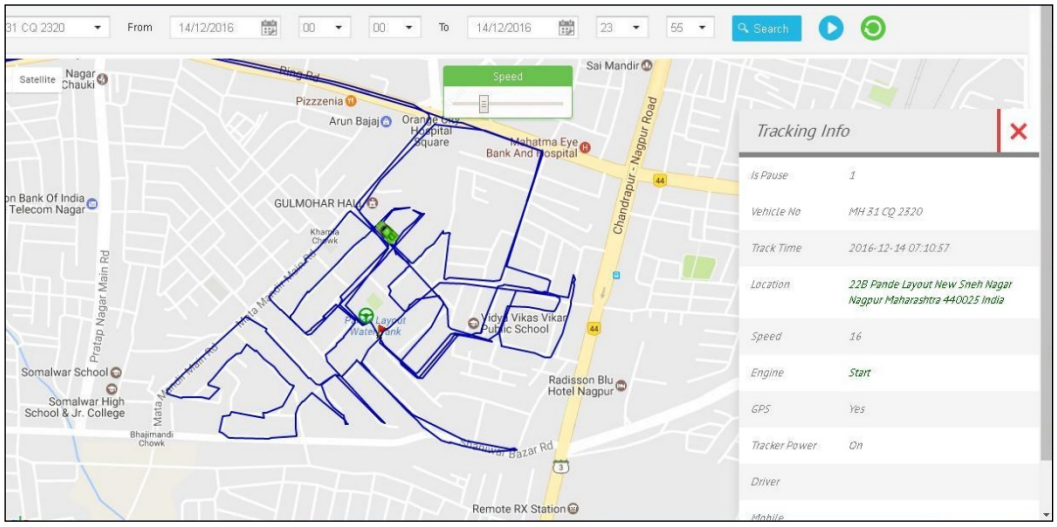
As discussed earlier, waste transportation in Nagpur is privatised with KRML providing the infrastructure and service for transportation of waste to the Bhandewadi dumping site. The vehicles deployed for transportation include tipper trucks of various sizes, dumper placers and compactors. Waste from the smaller vehicles utilised in primary collection is transferred to the larger vehicles for further transfer to the dumpsite. Transfer stations developed in various zones are utilised for optimising vehicle utility and bringing more efficiency to operations. Approximately 300-325 trips per day are made to the Bhandewadi dumpsite, with each vehicle making 3-4 trips per day. **Table 5-2** provides details of the vehicles deployed by KRML for collection and transportation of waste in Nagpur, including details on vehicles' capacity and trips undertaken. The vehicles and other infrastructure currently deployed by NMC do not have the facility to keep the dry / wet waste separate at the time of collection. With mandated segregation at source, the city requires separate vehicles for the collection of segregated waste from household/community level and other waste generation sources.

Analysis of the existing vehicle deployment plan shared by NMC for KRML indicates that the total carrying capacity for the mixed waste is approximately 2.4 times the waste generation. However, operational inefficiencies of KRML result in waste accumulation at the community bins and other secondary storage points (observed during field survey).

In 2015, NMC started developing the Geographic Information System (GIS) based-route map for waste collection and monitoring. The system was developed to bring efficiency to collection and transportation, including proper utilization of manpower, saving of fuel, reduction of time and ensuring regular collection of waste. Currently, the GIS-based monitoring system has been adopted in only a few zones and is being utilised for tracking of the vehicles involved in collection & transportation of solid waste. **Figure 5-1** and **Figure 5-2** show snapshots of the GIS-based route optimisation and tracking system for waste management in Nagpur.

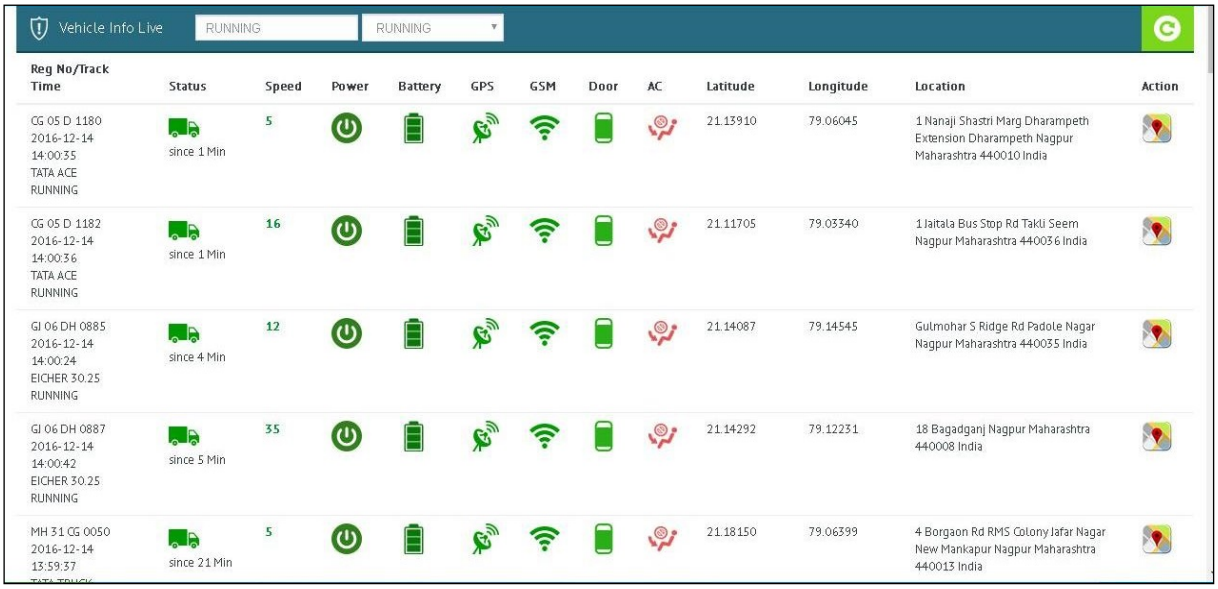
Photo 5-7: Vehicles for Collection and Transportation

Figure 5-1: GIS-Based Vehicle Route Map at Laxmi Nagar in Nagpur City



Source: NMC

Figure 5-2: GIS-Based Vehicle Tracking in Nagpur City



Reg No/Track Time	Status	Speed	Power	Battery	GPS	GSM	Door	AC	Latitude	Longitude	Location	Action
CG 05 D 1180 2016-12-14 14:00:35 TATA ACE RUNNING	since 1 Min	5							21.13910	79.06045	1 Nanaji Shastri Marg Dharampeth Extension Dharampeth Nagpur Maharashtra 440010 India	
CG 05 D 1182 2016-12-14 14:00:36 TATA ACE RUNNING	since 1 Min	16							21.11705	79.03340	1 Jaitala Bus Stop Rd Takli Seem Nagpur Maharashtra 440036 India	
GJ 06 DH 0885 2016-12-14 14:00:24 EICHER 30.25 RUNNING	since 4 Min	12							21.14087	79.14545	Gulmohar S Ridge Rd Padole Nagar Nagpur Maharashtra 440035 India	
GJ 06 DH 0887 2016-12-14 14:00:42 EICHER 30.25 RUNNING	since 5 Min	35							21.14292	79.12231	18 Bagadganj Nagpur Maharashtra 440008 India	
MH 31 CG 0050 2016-12-14 13:59:37	since 21 Min	5							21.18150	79.06399	4 Borgaon Rd RMS Colony Jafar Nagar New Mankapur Nagpur Maharashtra 440013 India	

Source: NMC

The total staff deployed by KRML for collection and transportation of waste is 1378 personnel. The zone-wise distribution of staff is provided in **Table 5-3.** The supervisory staff deployed by NMC includes 115 supervisors, 75 Sanitary Inspectors, and 10 Zonal Officers. The supervisory staff deployed by NMC for waste management is far less than the recommended staff for sanitation provided in the CPHEEO manual. There is a shortfall of approximately 77 sanitary supervisors, 114 sanitary inspectors and 14 sanitary officers/zonal officers when compared with the prescribed standards.

Table 5-2: List of Existing Vehicles for Waste Transportation in Nagpur

Zone No.	Zone Name	Ghant-agadi (Hand Cart)	Cycle Rickshaw	Small Automobile Vehicles						Dumper Placer	Compactor	Hook Loader	Private Vehicles	Tipper Truck	Back hoe Loader
				Tata Ace	Tata Ace super	Tata DI 207	Tata 407	Ashok Leyland dost	Mahindra Load King						
1	Laxmi Nagar	0	76	4	6	4	1	6	2	2	3	1	0	7	1
2	Dharampeth	1	56	12	2	0	1	0	0	2	2	0	0	4	1
3	Hanuman Nagar	9	55	14	3	0	1	2	1	1	1	0	0	2	1
4	Dhantoli	11	54	8	2	0	1	2	1	2	1	0	0	3	1
5	Nehru Nagar	0	80	17	0	0	1	0	1	2	1	1	0	3	1
6	Gandhibagh	29	67	7	1	0	1	0	1	2	1	1	3	3	1
7	Satranjipura	9	68	8	0	0	1	0	0	2	1	0	2	2	1
8	Lakadgang	0	67	12	1	1	1	0	0	1	2	0	1	3	1
9	Ashi Nagar	0	73	9	1	0	1	0	0	1	1	0	1	2	1
10	Mangalwari	21	74	8	4	0	1	3	0	2	2	0	0	3	1
Total		**80**	**670**	**99**	**20**	**5**	**10**	**13**	**6**	**17**	**15**	**3**	**7**	**32**	**10**
Capacity (in Tonne)		0.01	0.01	0.75	1.5	1.1	3.5	1.5	3.0	4.5	10.0	13.75	6.0	10.2	-
Trip per day		3	3	3	3	2	2	3	3	5	2	3	5	5	-

Source: NMC, April/May 2017

Note: In addition to the above vehicles, there are standby vehicles including:

- *Tipper truck (1 tonne capacity; Make - TATA Ace) - 1 Number*
- *Tipper truck (2 tonnes capacity; Make- Ashok Leyland Dost) - 3 Numbers*
- *Compactors - 2 Numbers*
- *Front-end Loader - 2 Numbers*
- *Tippers – 9 Numbers*

Table 5-3: Existing Manpower for Waste Management in Nagpur

Sl. No.	Name of Zone	Manpower Deployed by KRML	Manpower Deployed by NMC				
			Permanent (Sweeper and drain cleaner)	Temporary (Sweeper and drain cleaner)	Sanitary Inspector	Supervisor	Zonal Officer
1	Laxmi Nagar	236	314	347	7	15	1
2	Dharampeth	126	277	336	6	8	1
3	Hanuman Nagar	117	325	352	9	10	1
4	Dhantoli	126	353	459	7	7	1
5	Neharu Nagar	127	310	451	7	10	1
6	Gandhibagh	135	501	425	7	6	1
7	Satranjipura	132	356	403	8	16	1
8	Lakadgang	101	329	627	8	15	1
9	Ashi Nagar	108	436	665	8	13	1
10	Mangalwari	170	412	522	8	15	1
	Total	1378	3613	4587	75	115	10

Source: NMC

5.5 Treatment System

Currently, there is no working waste treatment facility in Nagpur. Waste collected from various parts of the city is dumped at Bhandewadi dumpsite, which is approx. 10 km from the city centre.

In the year 2009, NMC awarded the work of treatment and processing of municipal solid waste to M/s. Hanjer Biotech Energies Pvt. Ltd., Mumbai. Approximately 11 acres of land was leased to M/s.Hanjer Biotech Energies Pvt. Ltd. for development of the composting and Refuse Derived Fuel (RDF) based processing facility. The contract was awarded on a Build, Operate and Transfer (BOT) basis for 12 years. The first two years were for construction and development, and the remaining 10 years for operation and maintenance. The total capital cost for the project was Rs. 26 crores (Euro 3.60 million) and the tipping fee paid by NMC was Rs. 275 (Euro 3.81) per tonne. After a major fire incident in the plant in 2012, which destroyed a major part of the segregation unit & machinery, the plant became non-functional.

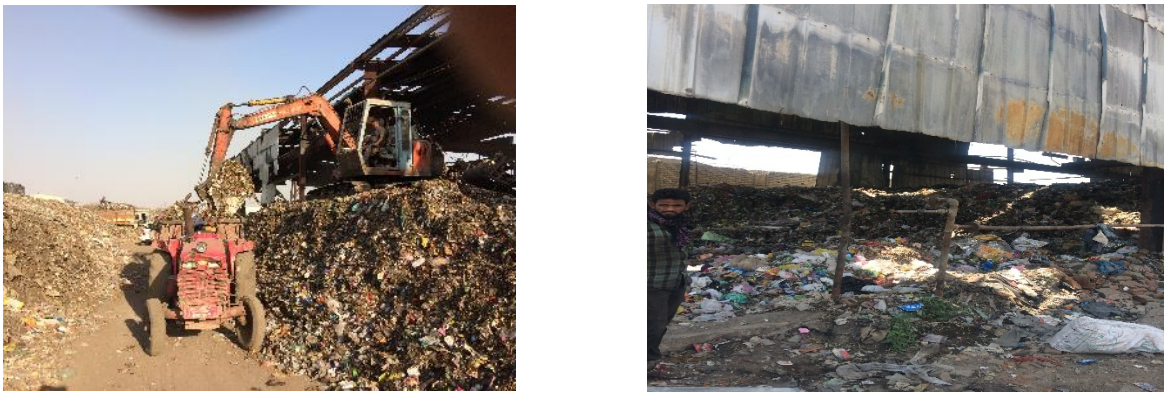


Photo 5-8: Waste Processing Facility from Hanjer Biotech Energies Pvt. Ltd, Nagpur

NMC also started processing legacy waste along with some fresh waste using bioremediation/ bio-mining technology at the existing dumpsite (since January 2017). A total of 311 windrows of five to six feet in height were created from approximately 600,000 tonnes of garbage. The process involves the bio-mining of waste, followed by segregation and harrowing of waste and spraying of bio-cultures to accelerate degradation. According to the NMC officials, the process has been successful in reducing the height of the existing dumpsite to some extent. However, a lack of market for compost and soil derived from the process has affected the project. Also, recent incidences of a huge fire (March 2017) and odour issues have questioned the reliability of the project.

Photo 5-9: Bio Remediation / Biominning at Bhandewadi Dumpsite

In May 2017, NMC signed a contract for the development of a waste-to-energy facility of 800 TPD at the Bhandewadi dumpsite. M/s. Essel Infra Projects Ltd. Mumbai and Hitachi Zosen India (JV) have been selected as concessionaires for the project. The project is based on mass burn incineration technology and is expected to generate 11.5 MW of electricity. The scheduled commissioning date for the project is June 2019 and the total contract duration is 15 years. The estimated project cost is 251 crores (Euro 35 Million), of which Viability Gap Funding (VGF) of INR 70 crore (Euro 9.7 million) is being provided by the central government under *Swachh Bharat Mission*[11] and the balance is to be invested by the private concessionaire. The estimated tipping for the project is Rs 225 (Euro 3.12) per MT, with an annual increment of 4.5% along with an electricity tariff of Rs 5.86 (Euro 0.08) per unit.

5.6 Disposal System

The Bhandewadi dumpsite is an open dumpsite in Nagpur, spread over 22 hectares or 54 acres of land. The site is surrounded by habitation on three sides (east, north and west), a sewage treatment plant to the south-east, and a composting and RDF plant developed by Hanjer to the south. The approach road to the site is also from the south end of the site. The site and surrounding features are presented in detail in Figure 5-3**.**

The Bhandewadi dumpsite has been in operation since the year 1966[12] and has been earmarked as a compost yard in all the development plans for the city since then. It is estimated that more than 18,00,000 MT of waste has been dumped on the dumpsite since its inception. However, no actual record of waste dumped at the dumpsite is available with NMC. In the year 2011, a part of the waste from the dumpsite was shifted and capping was provided over an area of 40,630 sqm (4 ha). The balance area is currently being used for the disposal of waste. NMC has earlier constructed a cell for the safe disposal of rejects from MSW processing on the existing dumpsite. However, during the site visit, the sanitary landfill cell was observed to be non-operational.

The waste is currently dumped indiscriminately with minimal compaction and no daily cover, having no system for collection or treatment of leachate leading to likely contamination of the soil and ground water resources. Many secondary studies[13] have indicated a higher level of ground water pollution in the area surrounding the Bhandewadi dumpsite. The dumpsite is subject to frequent fires during the summer season and has been causing air pollution, odour nuisance and have an adverse health impact on the nearby residents. Recently, there was a major fire outbreak on the dump site in March 2017, which has raised questions about the operations of the dumpsite.

The infrastructure provided at the dumpsite include a weighbridge of 30 tonne capacity, concrete roads, street lights and a boundary wall which is broken and dilapidated at various places, leading to unauthorised access to the site. NMC has deployed one front end loader, one excavator and one dozer at the dumpsite. Manpower at the site includes one sanitary inspector, two supervisors and twenty-six labourers of NMC.

According to the discussions with the site in charge, approximately 150 -200 ragpickers collect recyclables from waste on dumpsite. However, no proper record or data on the number of ragpickers and the quantity of recyclables collected is available from the NMC responsible. The ragpickers on the dumpsite are subject to various health and safety related hazards, which include injury and infection due to sharp objects, health impact by continuous exposure to waste, and accidents due to vehicles operating on-site. There is no major

[11] *The Swachh Bharat Mission (Clean India Mission), launched on 2nd October 2014, aims at 100% scientific management of municipal solid waste in 4,041 statutory towns in India.*

[12] *Source: Status of solid waste Management in Municipal Corporations of Maharashtra, Maharashtra Pollution Control Board ,April 2014*

http://mpcb.gov.in/ereports/pdf/Mumbai%20Booklet%20Final%20All%20171%20Pages%20new%201%20to%2084.pdf

[13] *Assessment of ground water quality in landfill area of Nagpur city, published in journal of environmental hydrology, volume 18, September 18 ,2010, by D.B. Malpe et al. (http://www.hydroweb.com/protect/pubs/jeh/jeh2010/malpe.pdf)*

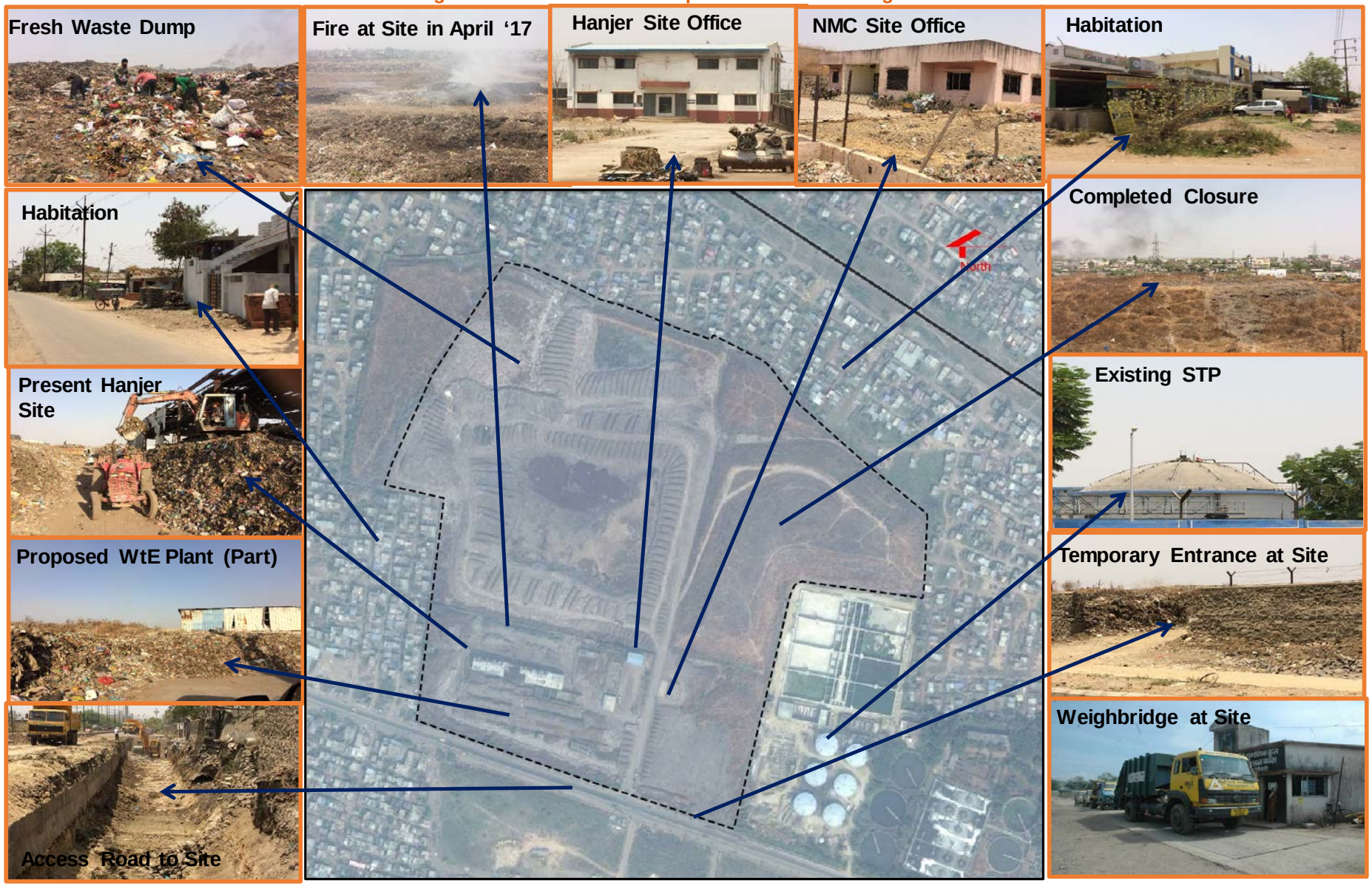
programme currently for rehabilitation of ragpickers from the site. There are some reports available from secondary sources on providing personnel protective equipment and vocational training to ragpickers by various NGO's, including the Melinda Gate Foundation in the past. However, during actual discussion with selected ragpickers on-site, this could not be confirmed.

Photo 5-10: Disposal at Bhandewadi Dumpsite

Photo 5-11: Ragpickers at Transfer Station

Photo 5-12: Ragpickers at Bhandewadi Dumping Site

Figure 5-3: Bhandewadi dumpsite and surrounding area



5.7 Financial Assessment of NMC

This section provides an analysis of the municipal finances and the past performance of Nagpur Municipal Corporation during the last four years to understand its financial capacity and provide an overview of pertinent financial issues. This is based on an analysis of actual accounts from 2013-14 to 2015-16, while results for 2016-17 are based on the estimated accounts. Further analysis has been carried out to understand the trends of income-expenditure (profit and loss) and assets-liabilities (balance sheet) by NMC under various categories and particularly for solid waste management components. The municipal finance structure comprises revenue and capital accounts, which are further divided into income and expenditure headings.

5.7.1 Financial Status of NMC

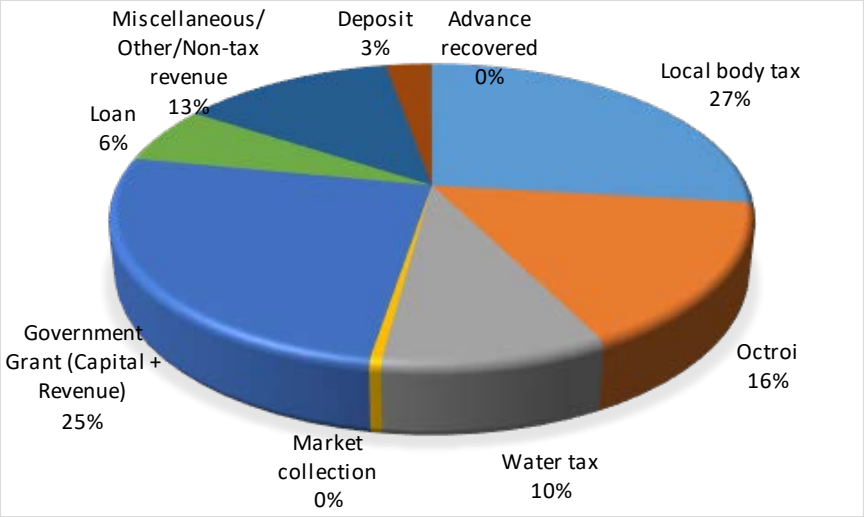
Financial reporting is a valuable tool in accountability, enabling policy makers to assess, monitor and regulate efficiency of operation. Based on the recommendations of 13th Finance Commission to Urban Local Bodies (ULBs), NMC has successfully achieved a complete transition from its single-entry accounting system to an accrual-based double entry accounting system. The double entry accounting system helps in overcoming the irregularities faced in the form of reporting faulty entries and classification of incomes and expenses under various headings. These statements help in providing a clear picture of the financial health of the municipal body and its standing at a given point in time. **Table 5-4** present details of NMC's total income and expenditure under various headings.

Table 5-4: NMC Income Statement (Revenue + Capital) (INR in million)

Sl. No.	Particulars	2013-2014	2014-2015	2015-2016	2016-2017
A	Tax revenue				
1	Local body tax	2,957.4	3,607.9	2,082.6	750
2	Octroi	1,734.8	1,580	1,740,9	3,732.3
B	Non-tax revenue				
1	Water tax	911	1,024.1	1,152	1,500
2	Market collection	48	51.9	58.1	75.5
C	Government Grant (Capital + Revenue)	1,254.7	1,324.3	5,622.1	9,336.2
D	Loan	-	600	1,400	1,000
E	Miscellaneous/Other/Non-tax revenue	1,274.1	1,987.5	905.4	3,365.1
F	Deposit	123.7	466.6	293.7	577.2
G	Advance recovered	11	6.7	3.6	70
Total		8,314.7	10,648.9	13,258.3	20,406.3

Source: Nagpur Municipal Corporation

Figure 5-4: NMC Income Headings

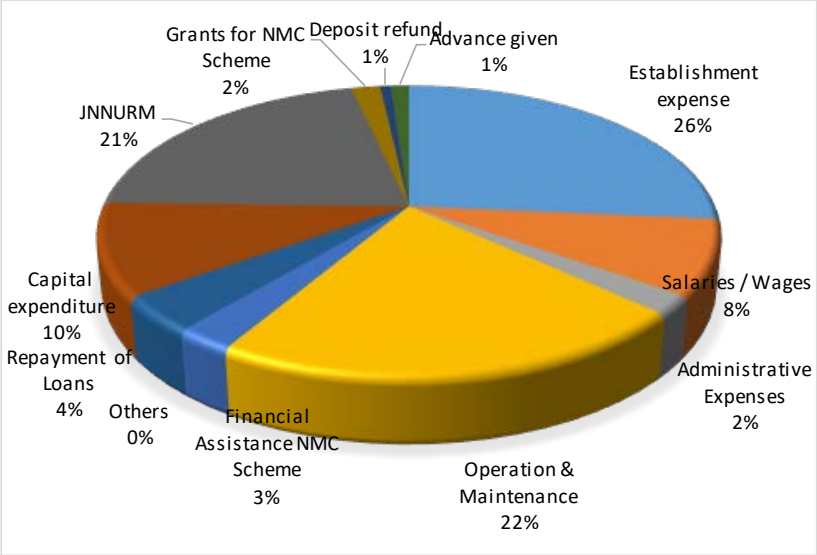


The above table indicates that for NMC, local body taxes (27%), followed by government grants-revenue and capital (25%) and Octroi (16%) are the main income sources.

Table 5-5: NMC Expenditure (Revenue + Capital) (INR in million)

Sl. No.		2013-2014	2014-2015	2015-2016	2016-2017
1	Establishment expense	2,781.2	3,204.7	3,422	3,247.9
2	Salaries/ Wages & Allowances	788	925	1,267.5	1,260
		3,569.2	4,129.7	4,689,5	4,507.9
3	Administrative Expenses	270.9	224.5	240.8	592.7
4	Operation & Maintenance	2,120.9	2,633.8	2,992,5	3,292.5
5	Financial Assistance contribution for NMC Scheme / Program	170.8	387.7	374.4	875.4
6	Others	-	-	-	0.1
7	Repayment of Loans	494.5	415.2	524.8	651.5
8	Capital expenditure	1,009.4	1,198	1,432.2	7,305.1
9	JNNURM & Other projects	2,378.2	2,581.5	2,542.6	2,376.5
10	Grants / Contribution for NMC Scheme	168.8	212.2	251.7	250.5
11	Deposit refund	36.4	52.1	138.1	562.7
12	Advance given	123.2	142.4	138.0	65
Total		10,342.3	11,977	13,324.5	20,479.8

Figure 5-5: NMC expenditure headings



On the expenditure side, the establishment expense (26%) is the key, followed by operation and maintenance expense (22%) and expenses made for capital construction under various Jawaharlal Nehru Urban Renewal Mission (JnNURM) projects (21%).

Revenue Accounts

The revenue account comprises revenue income and revenue expenditure. The revenue income sources of NMC can be broadly categorized as own sources, comprising tax and non-tax revenue, assigned revenues, grants and contributions. Revenue expenditure is classified under the establishment, mainly comprising salaries and wages, administrative expenses, operation and management expenses and repayment of loans.

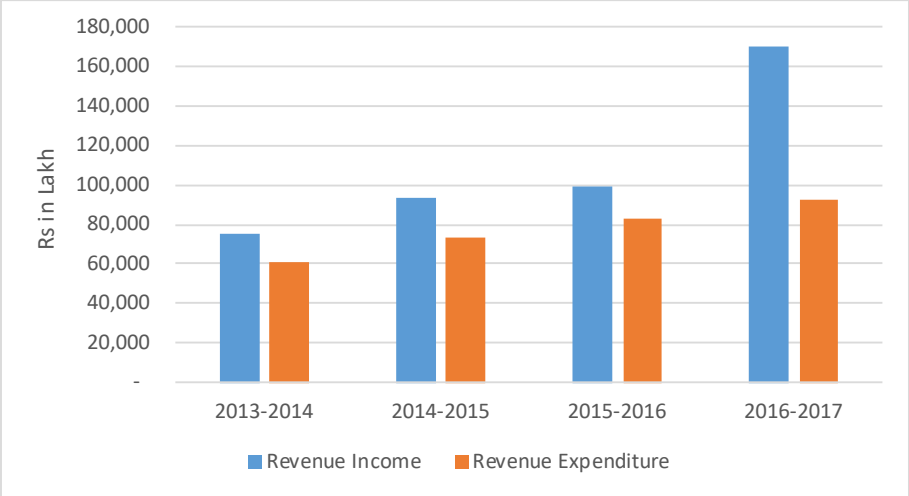
The revenue income of NMC has increased from Rs. 75,135 lakhs (INR 7513.5 million) in FY 2013-14 to Rs. 98,864 lakhs (INR 9886.4 million) in FY 2015-16. CAGR of revenue income for the same period has been 9.58%, while in terms of revenue expenditure, the growth rate has been at 10.61% CAGR during the same period. As shown in **Table 5-6,** revenue accounts for NMC has been in surplus for the last four years.

Table 5-6: Revenue Accounts for NMC (INR in million)

Revenue Account	2013-14	2014-15	2015-16	CAGR	2016-17 (estimated)
Income	7,513.5	9,358.9	9,886.4	9.58%	17,023.6
Expenditure	6,131.8	7,375.6	8,297.1	10.61%	9,268.5
Surplus/ Deficit	1,381.7	1,983.3	1,589.3	4.78%	7,755.1

Source: Nagpur Municipal Corporation

Figure 5-6: Revenue Accounts for NMC



Capital Accounts

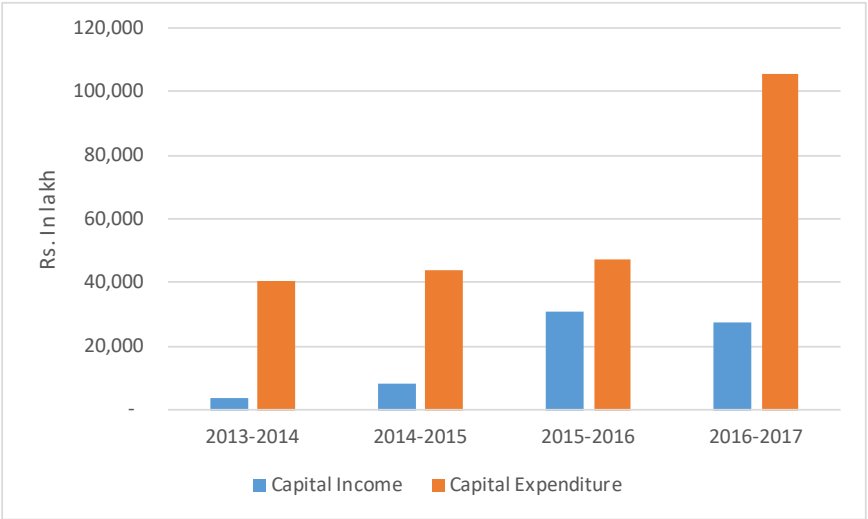
Both capital income and expenditure have shown positive growth in the period of the last four years from 2013-14 to 2016-17. However, there has been a huge deficit in capital accounts consecutively in the same period. In spite of huge growth in capital income, a deficit is clearly visible in capital accounts in the **Table 5-7**.

Table 5-7: Capital Accounts for NMC (INR in million)

Capital Account	2013-14	2014-15	2015-16	CAGR	2016-17 (estimated)
Income	376.6	816.7	3,074.6	101.36%	2,735.5
Expenditure	4,050.9	4,407	4,751.3	5.46%	10,583.6
Surplus/ Deficit	(3,674.3)	(3,590.3)	(1,676.7)		(7,848.1)

Source: Nagpur Municipal Corporation

Figure 5-7: Capital Accounts for NMC



5.7.2 Financial Performance for SWM Components

An analysis of income and expenditure for solid waste management components has been provided. The assessment has been seen with respect to revenue income/expenditure and capital income/expenditure for the last four years. Revenue income has doubled in the last four years from Rs 4,460 lakh (INR 446 million) in 2013-14 to Rs. 9,745 lakhs (INR 974.5 million) in 2016-17, whereas revenue expenditure has increased from only Rs. 12,637 lakhs (INR 1263.7 million) to Rs 16,377 lakh (INR 16377.7 million) during the same period. Income growth rate has been more than the expenditure growth for SWM services. Capital expenditure has increased manifold during the same period due to the emergence of new SWM facilities such as land acquisition for setting up new facilities and purchasing of new equipment. **Table 5-8** presents details of SWM income and expenditure for Nagpur city in terms of components.

Table 5-8: Income/expenditure - SWM (INR in million)

Income / expenditure	2013-2014	2014-2015	2015-2016	2016-2017
Revenue income - SWM				
Safai Tax - Arrear	218.1	235.7	204	285.3
Safai Tax - Current	222.4	237.9	183.7	539.2
SWM Tax	-	-	-	150
Total	440.6	473.6	387.7	974.5
Revenue expenditure - SWM				
Road cleaning / Solid waste management	687.1	773.5	843.3	800
Daily waged worker establishment	307.2	480.8	520.8	480
Insurance contribution for sanitary workers	-	-	-	0.2
Sanitary workers' uniform	5.02	0.72	0.63	2.5
Miscellaneous expenses	1.9	3.5	0.9	2.5
SWM material purchase	2.09	1.99	1.9	2.0
Garbage vehicle / disposal - transportation	258.4	346.9	524.5	350
Wheelbarrow repair	2.1	0.5	0.49	0.5
Subtotal	1,263.7	1,608	1,892.4	1,637.7
Capital expenditure - SWM				
Implementation of scientific waste management (transportation)	35.4	40.0	30.2	120
Container purchase	0	0	0	1.5
Land acquisition for construction of new dumping site	0	0	0	20
Subtotal	35.4	40.0	30.2	141.5
Total	1,299.1	1,648	1,9227	1,779.2
SWM expenditure share to total NMC expenditure	12.76%	13.99%	14.73%	8.96%
Per capita SWM expenditure	0.000517	0.000633	0.000725	0.000659
Total surplus/deficit	(858.6)	(1,174.4)	(1,535)	(804.7)
Total surplus/deficit - revenue	(823.2)	(1,134.4)	(1,504.8).	(663.2)

Source: Nagpur Municipal Corporation

The share of SWM components in total NMC expenditure has increased to 14.73% in the year 2015-16 from 12.76% in the year 2013-14. However, the budgeted account for the year 2016-17 shows a reduction in the expenditure share of SWM components in total NMC expenditure, i.e. 8.96%.

Per capita annual expenditure on SWM services has shown a positive growth pattern over the years. Per capita expenditure has increased from Rs. 517 to Rs. 659 during the assessed period. This per capita expense has been calculated based on the projected population for the respective years.

The ratio of expenditure with respect to waste quantity has also been calculated to check the growth trends and status. According to the records available from NMC, waste generation in Nagpur city is approximately 1100 tonne per day. Revenue expenditure on the management of per tonne of waste generation during the period 2013-14 and 2015-16 has increased from INR. 3,148 to INR 4,713, whereas for the budgeted period 2016-17 it is estimated at INR 4,079.

6 REGULATORY FRAMEWORK

6.1 Regulatory Framework for Waste Management in India

Historically, municipal solid waste management has received little regulatory attention in India. However, rapid population growth and an increasing trend towards urbanization over the past forty years has led to significant issues, particularly within the rapidly growing large urban population. This ultimately led to significant public concern and acted as a stimulus for regulatory reform.

There are a number of regulatory instruments (Acts and Regulations) that establish both the responsibility and requirements for management of municipal solid waste. Key regulatory requirements that are pertinent to this study include:

- *Constitution 74th Amendment* – establishes overall responsibilities for MSW management;
- *Solid Waste Management Rules, 2016:* In supersession of the Municipal Solid Waste (Management and Handling) Rules, 2000, the Central Government has issued the revised solid waste management rules, 2016. This is the primary regulation covering all functional elements of municipal solid waste management and establishes comprehensive requirements for the collection, storage, treatment and disposal of municipal waste;
- *The Water (Prevention and Control of Pollution) Act, 1974*: Under this act there are two aspects related to municipal solid waste management. Firstly, a consent to establish and operate from the Maharashtra Pollution Control Board for the establishment and operation of a waste processing and disposal facility and, secondly, no water pollution should be caused by the leachate that is emitted from the municipal waste processing and disposal facility;
- *The Water (Prevention and Control of Pollution) Cess Act, 1977* and amendments thereto. The only aspect under this act related to municipal solid waste management is the provision for levying and collection of cess on water consumed for waste processing and disposal facility;
- *The Air (Prevention and Control of Pollution) Act, 1981* and amendments thereto. The aspects to be considered under this act related to municipal solid waste management are the need for obtaining consent from Maharashtra Pollution Control Board for the establishment of the processing plants and a disposal site and, from an environmental aspect, the air pollution caused by the waste processing and disposal facility;
- *Plastic Waste Management (Handling & Handling) Rules, 2016* - provides specific rules for the manufacture and re-use of plastic bags and containers: and
- *The Environmental (Protection) Act, 1986* and its subsequent notifications. The aspect related to municipal solid waste management is the Environmental Impact Assessment (EIA) notification, 2006, which provides the requirement for environmental clearance from the statutory authorities for a municipal solid waste processing and disposal facility.

The following sections provide a summary of the key regulatory instruments related to municipal solid waste management within the project area.

6.2 Solid Waste Management Rules, 2016

Solid Waste Management Rules, 2016 (SWM Rules, 2016) are the revised set of rules issued by the Central Government to supersede the Municipal Solid Waste (Management and Handling) Rules, 2000. SWM Rules 2016 establish consistent regulations governing the collection, segregation, transportation, and disposal of all types of municipal solid wastes throughout India. The Rules are now applicable beyond municipal areas and extend to urban agglomerations, census towns, notified industrial townships, areas under the control of Indian Railways, airports, airbases, ports and harbours, defence establishments, special economic zones, state and central government organizations, places of pilgrimage, and of religious & historical importance. Specific requirements under the MSW Rules are provided in the following sections.

6.2.1 Administrative Responsibilities

There is long chain of responsibility for waste handling prescribed in the SWM Rules. The Central Pollution Control Board (CPCB) is responsible for monitoring the implementation of the rules, whereas municipal authorities are responsible for implementation. The responsibility for granting authorization for setting up of waste processing and disposal facilities lies with the State Pollution Control Board (SPCB). The distribution of jobs and the responsibilities of authorities at various levels is described below:

Central Level: Ministry of Environment, Forest and Climate Change

The Ministry of Environment, Forest and Climate Change shall be responsible for the overall monitoring of the implementation of these rules in the country. The Central Monitoring Committee formulated by the ministry shall monitor and review the implementation of these rules.

Central Pollution Control Board

- co-ordinate with relevant state authority (in this case, Maharashtra Pollution Control Board (MPCB));
- monitor the implementation of guidelines and standards;
- review standards and guidelines;
- compile monitoring data; and
- prepare a consolidated annual review report based on MPCB reports for the Central Government.

State Level: Maharashtra State Government

- The Secretary, Urban Development Department, Maharashtra through the Commissioner or Director of Municipal Administration or Director of local bodies is responsible for the overall implementation of MSW Rules in the state.

State Level: Pollution Control Board

- authorize waste processing/disposal facilities and landfills and coordinate input from other review agencies, including the Department of Housing & Urban development, Airport or Air Base Authority, the Ground Water Board or any other affected agency prior to issuing the authorization;
- monitor compliance with standards regarding groundwater, ambient air, leachate quality, compost quality and incineration standards;
- the MPCB shall issue the authorization to the municipal authority or an operator of a facility stipulating compliance criteria and standards as specified and including any other conditions as may be necessary;
- consider a new authorization after the validity of the existing authorization expires;
- coordinate with Central Pollution Control Board; and
- prepare an annual report for Central Pollution Control Board.

Local Level: Nagpur Municipal Corporation

- Nagpur Municipal Corporation is responsible for infrastructure development for the collection, segregation, storage, transportation, processing and disposal of MSW;
- apply for Grant of Authorization for setting up waste processing and disposal facilities, including landfills, from MPCB. The application should be in Form-I (MSW Rules). A private operator of the facility should also apply in a similar manner.
- notify the waste collection and segregation schedule to the generators of municipal waste, to help them comply;
- organize awareness programmes with citizens to promote reuse or recycling of segregated materials and community participation in waste segregation; and
- prepare and submit an annual report as per Form-II (MSW Rules) to the Secretary-in-Charge, Maharashtra Department of Housing & Urban Development and to the MPCB.

The Maharashtra State Pollution Control Board is responsible for monitoring compliance with the standards specified in the MSW Rules and also for issuing authorization for the setting up of waste processing and disposal facilities and landfills. Nagpur Municipal Corporation is responsible for providing solid waste management services within their jurisdiction. As such, they must provide appropriate infrastructure and services in accordance with the SWM Rules.

6.2.2 Requirements under the SWM Rules

This section provides a brief overview of the requirements under SWM Rules 2016

Segregation at Source

- The new rules have mandated the source segregation of waste in order to channelize the waste to recovery, reuse and recycle. Waste generators would now have to segregate waste into the following streams – Biodegradables, Non-Biodegradable, Sanitary waste and Domestic Hazardous waste before handing it over to the collector.
- Institutional generators, market associations, event organisers and hotels and restaurants have been made directly responsible for segregating and sorting the waste and managing it in partnership with local bodies.

Waste Collection, Storage and Transportation

The SWM Rules establish consistent requirements for the collection, storage and transportation of municipal waste with the intent of streamlining the technical and administrative methods in which solid waste is handled in the country. Requirements for the collection, segregation, storage and transportation of municipal waste are as follows:

*Collection of Waste***:** The Municipal Authority is responsible for providing door-to-door collection of segregated waste from households, including slums, informal settlements, commercial, institutional and other non-residential waste generators in compliance with the SWM Rules, and for notifying the waste collection schedule and likely methods to be adopted to the generators.

*Storage Facilities***:** The Municipal Authority is required to establish and maintain municipal waste storage facilities, taking into account the following criteria, so that unhygienic and unsanitary conditions are not created around it:

*Transportation***:** The SWM Rules specify that vehicles used for the transportation of waste should be covered and have set up compliance criteria to be taken into account to avoid visibility of waste to the public and exposure to the open environment, thereby preventing their scattering:

Treatment and Disposal of Municipal Solid Waste

The SWM Rules seek to minimize the burden on landfills for the disposal of municipal waste by adopting appropriate waste segregation and treatment technologies. The Municipal Authority has the responsibility for implementing appropriate strategies and systems to minimize disposal volumes based on the following criteria:

- Facilitate construction operation and maintenance of municipal solid processing facilities and associated infrastructure for optimum utilisation of various components of waste, adopting suitable technologies.
- Technologies proposed included bio-methanation, microbial composting, vermi-composting, anaerobic digestion or any other appropriate biological processing for the stabilization of waste and waste-to-energy processes, including refused derived fuel or combustible fraction of waste or supply as feed stock to solid waste-based power plant or cement kilns.
- Alternative, state-of-the-art technologies may also be applied, provided that the Municipal Authority or the Private Operator obtains authorization from the Central Pollution Control Board.
- The SWM Rules restrict landfill disposal to non-biodegradable, inert, and other waste that is unsuitable for either recycling or biological processing. The residues of waste processing facilities, as well as pre-processing rejects, should be land-filled. Land-filling of mixed waste should only be permitted in situations where the waste stream is unsuitable for alternative processing or when additional time is required to establish appropriate waste diversion and treatment programs and technologies.
- The SWM Rules also specify the measures to prevent pollution problems from landfill operations.
- The SWM rules also specified measures for establishing baseline and periodic monitoring of water quality and ambient air quality.

7 REVIEW OF PREVALENT WASTE-PROCESSING TECHNOLOGIES

7.1 Introduction

This chapter provides an overview of the various technologies available for the treatment and processing of waste in an environmentally sound manner. Waste-processing technologies can play a significant role in an integrated waste management system by treating waste and generating power/energy and reducing the waste volumes for disposal. Some of the associated benefits of providing suitable waste processing technology are highlighted in the following section.

- Reduce the volume of waste, thereby preserving landfill space.
- Allow for the recovery of energy from the waste stream.
- Allow for the recovery of minerals and chemicals from the waste stream which can then be reused or recycled.
- Destroy a number of contaminants that may be present in the waste stream, thereby reducing potential pollutants in the leachate and subsequent environmental pollution
- Reduce overall waste transportation for disposal.

The selection of the most appropriate technology for a city is based on the factors such as waste characteristics, needs, and resources. This report discusses the various treatment and processing technology options available for waste management and its suitability for Nagpur. Available technologies are primarily categorized into three categories.

Thermal Processing Technologies

Thermal technologies involve the thermal decomposition of waste into gaseous, liquid and solid conversion products with release of heat energy. The main thermal processing technologies adopted internationally for the treatment of municipal waste are:

- Mass-burn Incinerators;
- Pyrolysis/Gasification; and
- Plasma Arc Gasification

Biological Processing Technologies

Biological treatment involves using micro-organisms to decompose the biodegradable components of waste. The biological process can be aerobic and anaerobic, and the main biological technologies adopted internationally for the treatment of municipal solid waste are:

- Composting (aerobic processes); and
- Biomethanation (anaerobic processes)

Physical Processing Technologies

Physical technologies involve altering the physical characteristics of the municipal solid waste (MSW) feedstock. The MSW may be separated, shredded, and/or dried in a processing facility. The resulting material is referred to as refuse-derived fuel (RDF). It may be densified or pelletized into homogeneous fuel pellets and transported and combusted as a supplementary fuel in utility boilers.

Combination Technologies

These include technologies like Mechanical Biological Treatment (MBT), which is a combination of technologies including material recovery facilities, refuse derived fuels and aerobic/anaerobic digestion.

All the foresaid technologies have been reviewed in the following section and their suitability for Nagpur city have been assessed.

7.2 Overview of Municipal Solid Waste Processing Technologies

7.2.1 Massburn Incineration

Mass-burn systems are the predominant form of MSW incineration. It involves combustion of unprocessed or minimally processed refuse. The major components of a mass-burn facility include: (1) Refuse receiving, handling, and storage systems; (2) Combustion and steam generation system (a boiler); (3) Flue gas cleaning system; (4) Power generation equipment (steam turbine and generator); (4) Condenser cooling water system; and (5) Residue hauling and storage system.

Mass-burn incineration with a movable grate incinerator is a widely used and thoroughly tested technology. It meets the demands for technical performance and can accommodate large variations in waste composition and calorific value. A less common mass burning alternative is the rotary kiln.

The main advantage of a mass-burn facility is the amount of energy that it produces. However, it does have the disadvantage of producing significant amounts of air pollution, including heavy metals released during the combustion process. The ash that results from the combustion still has to be disposed. In considering the MSW incineration option, it is important to weigh the benefits of incineration against the significant capital and operating costs, potential environmental impacts, and technical difficulties of operating an incinerator.

The success of a waste incineration plant depends on the type of waste that is being treated. The following parameters and their variability are key drivers:

- The energy content of the waste, the average lower calorific value (LCV) must be at least 4000-6000 KJ/kg[14] throughout all seasons.
- Waste composition – high combustible material, low moisture, and low inert or ash.
- Waste physical composition, e.g. particle size.

Greater variability in the above parameters leads to higher costs for the pre-treatment of waste and downstream operations such as flue gas cleaning. The external costs of the pre-treatment of waste add significantly to the overall cost of waste management and to emissions from the systems. Flue-gas cleaning is often a significant contributor to overall incineration costs (i.e., approx. 30-35 % of the total capital investment).

Incineration has been adopted by many MSW management systems throughout the world as prevalent technology to treat waste and also an energy recovery option.

Indian Experience

SWM 2016 recognises incineration as one of the technology for processing of waste and many MSW based incineration plants have been proposed in last few years. However, only a selected few are operational currently. Most of the plants currently are operating at a capacity much below the installed capacity and are facing issues pertaining to compliance on the emission standards. The emission standards from Incineration and other thermal processing technologies have been revised in SWM rules 2016. The revised standards require higher level of investment and monitoring than earlier proposed incineration plants to be in compliant

[14] *Municipal Solid Waste Incineration, World Bank Technical Guidance Report, first printing August1999*

with the emission norms. Following table highlights some of the incineration plant proposed in last few years and their current status.

Table 7-1: Current Status of various incinerator plants in India (proposed and operational)

S.No.	Plant Details	Capacity	Waste Processing Capacity	Operator	Current status
1	Timarpur okhla waste management pvt ltd, New Delhi.	16 MW	1300 TPD	Jindal ITF Ecopolis	Operational with reduced efficiency. Environmental suit againt plant in NGT
2	Hyderabad Integrated Municipal Solid Waste Pvt Ltd, Hyderabad, Telangana	48 MW	2400 TPD	Ramky Enviro Engineers Ltd	Under Implementation
3	Shriram Energy Systems Pvt Ltd, Vijayawada, Andhra Pradesh.	6 MW	500 TPD	Shriram Energy Systems Pvt Ltd	Not Operational
4	Shalivahana Projects Ltd, Karimnagar, Telangana	12 MW	1400 TPD	Shalivahana Projects Ltd	Facing technical issues
5	Delhi MSW Solutions ltd, New Delhi	24 MW	3000 TPD	Ramky Enviro Engineers ltd	Recently started operations. Not much data available on plant operation
6	Srinivasa Gayatri resource recovery ltd, Mandur, Bangalore	8 MW	600 TPD	Srinivasa Gayatri resource recovery ltd	Failed to set up waste to energy plant
7	Jabalpur MSW Pvt Ltd, Jabalpur, Madhya Pradesh.	11.5 MW	600 TPD	Essel Group	Operational, with reduced efficiency. Not much data available in public domain on plant operations.
8	Essel Infra Projects Pvt Ltd, Bhubaneshwar, Orissa	11 MW	700 TPD	Essel Group	Project construction stopped due to public protest.

The three incineration-cum-power plant currently in operation in India are at Okhla (New Delhi), Jabalpur(Madhya Pradesh) and Narela-Bawana (New Delhi) . The Okhla plant is the first operating incinerator plant in India, commissioned in the year 2012; Jabalpur plant was commissioned in the year 2016; and Narela-Bawana plant was commissioned in the year 2017. Currently, all the plants are operating at a much lower efficiency and it is believed that this is due to the quality of incoming waste not meeting plant input specifications.

The Okhla plant in Delhi has been charged by the environmental rights organisations and the residents in the vicinity for posing a serious health hazard to the people living in the vicinity due to air pollution caused by it. Currently, the plant is currently facing a suit from the Green Tribunal on technology and environmental issues. The other two plants are relatively new and not much data is available in the public domain on the operation of Jabalpur and Narela- Bawana Plant.

7.2.2 Gasification

The gasification process involves the partial oxidation of carbon-based feedstock to generate a syngas, which can be used as a fuel or for the production of chemicals.

Gasification produces gases and liquids, as well as residual solids, including ash and carbon char. Inorganic materials in the feedstock are removed as bottom ash. They are usually combined with char, and can be separated out for disposal or used in making block materials.

Gasification typically relies on carbon-based waste such as paper, petroleum-based wastes such as plastics, and organic materials such as food scraps. As MSW is a heterogeneous waste stream, pre-processing of MSW is required to make the gasification process more efficient. The pre-processing includes the separation of thermally non-degradable material such as metal, glass and inerts, along with size reduction and/or densification of the feedstock, if required. If MSW has high moisture content, a dryer may be added to the pre-processing stage to lower the moisture content of the MSW to 25% or less, because lower moisture content of the feedstock increases its heating value and the system becomes more efficient. The optimal calorific value of waste should be approximately 2000 kcal/kg for proper gasification.

Gasification is not as widely applied for waste as conventional incineration and there are not many large-scale gasification plants operating on MSW globally. There is one full-scale gasification plant in Finland, in the city of Lahti, which uses MSW-based recycled fuel. It is rather expensive, and the technology is not yet mature.

Indian Experience

A gasification plant of 700 TPD to generate a 6.5 MW has been set up in Pune, Maharashtra, India. Currently, the plant is receiving about 250 TPD of MSW, segregating the waste and supplying the RDF to cement factories. The plant module for utilization the syngas and generation of electricity never started due to technical issues.

Pyrolysis

Pyrolysis involves an irreversible chemical change brought about by the action of heat in an atmosphere devoid of oxygen. Synonymous terms are thermal decomposition, destructive distillation and carbonisation. Pyrolysis, unlike incineration, is an endothermic reaction and heat must be applied to the waste to distil volatile components. The process of converting plastic to fuels through pyrolysis is possible, but yet to be proven to be a commercially viable venture.

Pyrolysis is carried out at temperature between 500 and 1000°C and produces three component streams.

- Gas: A mixture of combustible gases such as hydrogen, carbon monoxide, methane, carbon dioxide and some hydrocarbons.
- Liquid: Consisting of tar, pitch, light oil and low boiling organic chemicals such as acetic acid, acetone, methanol, etc.
- Char: Consisting of elemental carbon along with the inert materials in the waste feed.

The char, liquids and gas are useful because of their high calorific value. Part of the heat obtained by the combustion of either char or gas is often used as process heat for the endothermic pyrolysis reaction. It has been observed that even after supplying the heat necessary for pyrolysis, a certain amount of excess heat still remains which can be commercially exploited.

Though a number of laboratory & pilot investigations have been made, only a few have led to full scale plants globally.

Mainly plastics, particularly the poly-olefins, which have high calorific values and simple chemical constitutions of primarily carbon and hydrogen, are usually used as a feedstock in the pyrolysis process. More recently, pyrolysis plants are being tested to degrade carbon rich organic materials such as municipal solid waste.

Where mixed municipal solid waste is received at the processing site, sorting and pre-treatment of the waste is an essential step to ensure removal of metals, ceramics and other recyclable material. The remaining feed stock is shredded and the moisture content is reduced. Size reduction is also an essential step in pre-treatment,

to ensure appropriate size of the feedstock in relation to the feed equipment of the furnace. Maximum efficiency is achieved when the feedstock quality is homogenous.

7.2.3 Bio-methanation / Anaerobic Digestion

Bio-methanation involves controlled biological degradation of organic waste by microbial activity in the absence of oxygen. The process involves the anaerobic (without air) decomposition of wet organic waste to produce a methane-rich biogas fuel and a small amount of residual sludge that can be used for making compost. It takes place in digester tanks or reactors, which enable the control of temperature and pH levels for optimizing process control. The methane-rich gas produced is suitable as fuel for energy generation. The residual sludge is also produced, which is suitable for enriching compost materials. Input preparation or source separation is required to ensure that waste is free of non-organic contamination.

The yield of biogas depends on the composition of the waste feedstock and the conditions within the reactor. Modern anaerobic digestion treatment processes are engineered to control reaction conditions so as to optimize digestion rate and fuel production. Typically, 100-200 m^3 of gas is produced per ton of organic MSW that is digested.

The homogeneity of the feed material is an important parameter from the efficiency point of view. The waste must be sorted so that all inorganic products are removed from the refuse prior to entry into the digester. Ideally the refuse should be sorted at source. If not, it could be sorted by hand/mechanical means on delivery to the site.

The solid waste management system needs to be modified and improved to make it compatible with the requirements of bio-methanation technology covering source separation collection of solid waste. Otherwise, the applicability will be limited to highly organic and homogenous waste streams such as slaughter house waste, market waste.

Bio-methanation systems for digesting MSW are now widely used throughout the world. Anaerobic digestion of bio-waste or the mechanically separated organic fraction of residual municipal waste is well established in central Europe, with a number of technology suppliers in that region dominating the market.

Indian Experience

Many small scale biomethanation plant (5 -50 TPD capacity) are successfully operating in India from last few decades. Large scale plant currently in operation include plant set up by Organic Recycling System at Sholapur for processing 400 TPD of waste and conversion to energy. The technology is based on the principles of Thermophilic Bio-methanation (operating temperature 60^0C) with 40-50% solid content. The average biogas generation rate for the plant, according to discussions with the developer, is 110 m^3 per tonne of waste processed. The biogas from the plant is de-sulphurised in biological scrubber and fed to the gas engine. Waste heat from the engine is recovered and utilized for heating water, which is added to the digester. Currently, the first phase of the plant is operational (since July 2012) and the plant is offloading approximately 1 MW to the grid.

7.2.4 Refuse Derived Fuel Incineration

The term "refuse-derived fuel" (RDF) describes MSW that has been processed to a fairly uniform fuel for combustion. The RDF process typically includes thorough pre-separation of recyclables, shredding, drying, and densification to make a product that is easily handled. Glass and plastics are removed through manual picking and by commercially available separation devices. This is followed by shredding to reduce the size of the remaining feedstock to about eight inches or less, for further processing and handling. Magnetic separators are used to remove ferrous metals. Eddy-current separators are used for aluminium and other non-ferrous metals. The resulting material contains mostly food wastes, non-separated paper, some plastics (recyclable and non-recyclable), green wastes, wood, and other materials. Drying to less than 12% moisture is typically

accomplished through the use of forced-draft air. Additional sieving and classification equipment may be utilized to increase the removal of contaminants.

The RDF can be immediately combusted on-site or transported to another facility for burning alone, or with other fuels. It can be used in waste-to-energy plants as the primary or supplemental feedstock, or co-fired with coal or other fuels in power plants, in kilns of cement plants, and with other fuels for industrial steam production. Generally, 100 TPD generates 1 MW of power through RDF incineration route.

There are currently more than 30 RDF plants or RDF processing currently operating in the United States, with a total installed capacity of 31,000 tons per day (TPD). Many of these U.S. plants were built in the period 1981–1990. These RDF plants typically process incoming MSW to shred it and then mechanically separate out metals, glass, and other non-combustible fractions of the waste stream, leaving just the shredded combustible portion of the waste. In the United States, RDF commonly has a caloric value of 13,956–17,445 kJ/kg.

Indian Experience

One of the first waste-to-energy plant based on RDF technology was setup in Hyderabad in 1999. It was set up through technology transfer by the Andhra Pradesh Technology Development & Promotion Centre (APTDC), TIFAC and SELCO International Ltd. The installed capacity of the MSW processing plant was 700 TPD and it could manufacture 200-250 TPD of RDF fluff. The power plant based on RDF was started in November 2003 at Shadnagar, about 50 km from the processing plant. The Power Plant was using a high percentage of biomass as support fuel for combustion of the RDF. The power generated was exported to the APTRANSCO Grid. Frequent breakdowns in the grate led to the closure of the power plant operations.

As per secondary sources, there were about 25–30 operating RDF processing plants in India in year 2014, with an installed capacity of about 3,395 TPD[15]. The status of large-scale RDF plants in India is provided below.

Table 7-2: Current Status of large scale RDF plants in India

S.No.	Plant Details	Capacity	Waste Processing Capacity	Operator	Current status
1	East Delhi waste processing company pvt ltd, Gazipur, Delhi.	12 MW	1300 TPD	Joint venture of Delhi government and IL&FS	Under Implementation
2	A2Z Infrastructure Limited, Kanpur, Uttar Pradesh.	15 MW	1500 TPD	A2Z Maintenance and Engineering Services Ltd	Not Operational
3	SELCO International Ltd, Mahbubnagar, Telangana	6.6 MW	700 TPD	SELCO International Ltd	Not Operational

[15] *Dube, R. et al. (2014) 'Waste incineration for urban India: valuable contribution to sustainable MSWM or inappropriate high-tech solution affecting livelihoods and public health?', Int. J. Environmental Technology and Management, Vol. 17, Nos. 2/3/4, pp.199–214.*

S.No.	Plant Details	Capacity	Waste Processing Capacity	Operator	Current status
4	Hanjer Biotech Energies Ltd, Surat, Gujarat	15 MW	1600 TPD	Hanjer Biotech Energies Ltd	Under Implementation
5	Essel Pallavapuram and Tambaram MSW Pvt Ltd, Pallavpuram , Tamil Nadu	2.9 MW	300 TPD	Essel Infrastructure Projects private Limited	Operational- recently started
6	RDF Power Projects Ltd, Nalgonda district, Andhra Pradesh.	11 MW	1000 TPD	IL&FS	Could not be completed due to paucity of funds

7.2.5 Composting

Composting is a simple biological process in which controlled aerobic biological decomposition of organic matter by microorganisms (mainly bacteria and fungi) takes place to produce a stable humus-like product.

The process is controlled so that it is managed with the aim of accelerating decomposition, optimizing efficiency, and minimizing any potential environmental or nuisance problems that could develop. The microbes, fungi, and macro-organisms that contribute to this biological decomposition are generally aerobic. The composting of the waste generally yields 15-20% compost. The high organic content in the municipal waste stream is ideal for composting.

The size and configuration of the composting plant depends upon the quantity of materials to be processed and the duration of activities, including active composting, curing, and storage. The typical duration for composting is 45 to 60 days, while curing or maturation requires 30 to 120 days, and storage is dependent on the amount of time until the product can be marketed or removed for use.

There are two fundamental types of composting techniques: open or windrow composting, which is done out of doors with simple equipment and is a slower process; and enclosed system composting, where the composting is performed in a building, a tank, a box, a container or a vessel.

The turned windrow system is the technique most readily associated with the large-scale composting of wastes. A windrow is a pile that is generally 1.5 – 2 times as wide as its height, with its length determined by the amount of material available. Windrows are generally placed parallel to one another, with enough room in the middle for turning and power equipment to pass through. Windrow composting processes are simpler, require less capital, and use less energy. They generally rely more on land and labour and less on machinery.

In-vessel systems, such as drum or agitated bed technologies, or any technical system enclosed in a building, require complex equipment. These systems are highly engineered, capital intensive and require day-to-day management due to their automated systems and design, which has necessarily incorporated mitigation of potential worker health, environmental impact and nuisance conditions. They also use substantial amounts of energy.

The input quality flexibility of open windrow composting is limited, being only able to process organic waste. The C/N of the mixture should be in the range of 25:1 - 30:1. The initial moisture content should be between

40% and 60%. The list of materials suitable for composting is almost endless because composting is a flexible process. However, the municipal waste stream contains increasing quantities of glass, plastics, metals and hazardous materials, which make operations difficult and can contaminate the finished compost. Sand, dust and inert materials and heavy metal containing waste are to be excluded from composting to obtain quality compost.

Composting is the most commonly used waste processing technology internationally and the cost varies significantly depending upon the extent of mechanization, labour costs, and quality of input waste.

Indian Experience

In India, composting (aerobic) has been adopted by many of the municipal agencies, and it has been a mixed experience of both failed initiative and success. The main reasons for failure are:

- Poor quality of process outputs due to the use of mixed municipal waste with lot of inert
- Poor quality of finished compost resulting in problems of marketability
- Financial and marketing aspects were usually ignored, resulting in high operational costs

However, composting still remains one of the preferred methods of waste processing considering its low investment compared other processing technologies.

7.2.6 Mechanical Biological Treatment

Mechanical Biological Treatment (MBT) is a combination of technologies including material recovery facilities, refuse derived fuels and aerobic/anaerobic digestion. The selection of technologies in MBT is dependent upon the waste characteristics i.e. high/low percentage of organics/inerts/recyclables and moisture content. The MBT technology aims at reduction in the percentage of inerts to be disposed of at landfills.

Mechanical biological treatment has no/minimal demand for source segregation of waste. The technology is suitable to handle high/low organic waste with high/low moisture content. The flexibility in the technology allows better adaptation to changing waste quantities and qualities than mass burn incineration. In this technology, the organics i.e. highly putrescible waste is recovered to generate biogas and high calorific value waste is segregated for preparation of Refuse Derived Fuel (RDF). The initial waste preparation includes removal of any bulky objects like boulders, mattress, tree branches which may hinder the proper functioning of the equipment further down the line. The size reduction and separation techniques includes shredding/disc separator/ballistic separator followed by recovery of high value recyclables/fuel and aerobic/anaerobic digestion of organic waste in water to generate biogas.

The technology is internationally proven and is more acceptable among the public. MBT process configurations can vary significantly and can be designed to suit local market conditions. For e.g. if RDF is not saleable/easily marketable then it can be combusted to generate energy.

Many MBT projects are operational globally and especially across Europe, where MBT has been well established for many years. There are over 330 MBT facilities in operation throughout Europe[16]. The current MBT technologies are now second or third generation plants that are well established with proven examples of successful operation and bankable viability.

Indian Experience

[16] *The European Market for Mechanical Biological Treatment Plants', EcoProg Consultancy, December 2011.*

In India, there is no existing plants based on MBT. However, there is an operating pilot plant in China based on the technology and the waste characteristics similar to that generated in India.

7.3 Assessment of Prevalent Technologies and their Suitability for Nagpur

In order to assess the suitability of the technology for Nagpur, the following technology assessment criteria/ filters were used:

- *Waste Suitability*: Technologies that are suitable for MSW characteristics of Nagpur;
  - Technology should be capable of handling high organic waste & high moisture content - Studies conducted by NEERI in April/May 2017 show high organic (56%) and moisture content (56%).
- *Suitability of technology for mixed waste and segregated waste* – Though MSW 2016 mandates segregation of waste, putting segregation into practice requires a lot of efforts from ULB's side and is a time-consuming process to make resident adhere to waste segregation practices. In addition, it requires additional infrastructure for segregated collection and transportation and has high operation cost due increase in transportation cost and deployment of additional manpower.
- *Technology Reliability*: Technologies that are proven internationally for large-scale application for MSW and could be considered without reservations for Nagpur
- *State of Art and Clean Technology:* Technologies with low emission & low negative environmental impacts
- *Waste technology value chain assessment*: Technologies that requires value addition of the MSW chain for sustainability against following parameters
  - Technology that can process mixed waste
  - Technology that requires pre-processing of waste to make it compatible
  - Technology that requires source-segregated waste and a higher degree of pre-processing
- *Compliance with the regulatory requirement:* The technology is in compliance with the regulatory requirements (i.e., confirms to the MSW Rules, 2016 requirements);
- Rejects diversion to the landfill – technologies with low diversion of rejects to the landfill are more acceptable.
- *Social acceptability:* Technology should be socially acceptable
- Market for products and by products
- Low carbon footprint
- *Modular and flexible* plant to address the increasing waste supply in future

All the prevalent waste processing technologies were accessed as per the above-mentioned criteria and details presented in **Table 7-3**

Table 7-3: Comparison of Prevalent Waste Processing Technologies against Technology Suitability Criteria

Criteria	Composting	Incineration – mass burn	Refuse derived fuel Incineration	Mechanical Biological Treatment	Biomethanation	Gasification / Pyrolysis
Suitability as per waste characteristics	Waste contains high organic content (approximately 56%), High Moisture content (56%) – suitable	High moisture and organic content makes it non-suitable Requires waste with calorific value > 1400 kcal/kg & moisture < 40%- not applicable for Nagpur	High moisture content makes it unsuitable Calorific value requirement is 2800 -3200 kcal/kg for RDF with moisture< 20%	Most suitable technology to handle heterogeneous waste with no initial requirement of segregation at source	Suitable for waste containing high organic content (approximately 56%), and High Moisture content (56%)	High moisture and organic content makes it non-suitable
Reliability - proven internationally for large scale	Proven technology	Internationally proven Developed countries moving away from mass-burn technology to cleaner technologies	Proven technology	Internationally proven and many plants under operation	Highly sensitive process and plant performance is impacted by slight contamination	Globally, no successful case studies for large-scale MSW plants
State of Art and clean technology	High percentage of rejects i.e. upto 35-40%	High emission from waste incineration (SOx, NOx, heavy metals, Dioxins, Furans) Emission control system has high capital and operating cost	High emission from waste incineration (SOx, NOx, heavy metals, Dioxins, Furans) Emission control system has high capital and operating cost	No harmful emissions	No harmful emissions	No harmful emissions
Waste technology value chain assessment: Technology that can process mixed waste;	Requires highly segregated organic waste - not a suitable technology for mixed waste.	Suitable for handling mixed waste No pre-processing is required	Suitable for handling mixed waste Pre-processing is required	Suitable to handle heterogeneous waste with no demand for segregation requirements	Requires highly segregated organic waste - not a suitable technology for mixed waste.	Technology has not shown operational success with mixed waste

Criteria	Composting	Incineration – mass burn	Refuse derived fuel Incineration	Mechanical Biological Treatment	Biomethanation	Gasification / Pyrolysis
Requires less pre-processing of waste to make it compatible; that requires source-segregated waste and higher degree of pre-processing	Highly dependent on pre-processing				Highly dependent on pre-processing	
Social Acceptability	Odour issues in case of improper aeration Public acceptance higher than waste to energy technologies	Negative public perception & low acceptability	Negative public perception & low acceptability	High public acceptance	High public acceptance	No proven plant for high capacity
Market for products and by-products	Low acceptability for compost from mixed waste	Ready available market for energy form waste	Ready available market for energy form waste	Power generated from biogas/RDF is easily marketable	Energy is easily saleable Compost from segregated biodegradable waste has acceptability and market	Energy is the main product and market is available
Rejects diverted to landfill	High rejects diverted to SLF if not used in conjunction with other technologies	Least	Moderate	Low	Moderate	Moderate
Carbon footprints	Low	Moderate	Moderate	Low	Low	Moderate
Modular and Flexible	No	Yes	Yes	Yes	Yes	Yes

Comparison of the prevalent technologies and waste characterisation results for Nagpur indicates that incineration, pyrolysis/ gasification based technology may not be suitable considering the high moisture content and organic fraction; and composting, biomethanation and MBT are relatively more suitable technologies. Biomethanation as a technology is highly sensitive and requires highly segregated waste or pre-processing of waste to make it successful. Hence, Biomethanation cannot be suggested as a technology for processing the entire waste of Nagpur (can be used only for segregated waste from hotels and market places). Composting technology is also a proven technology, but it fares badly with respect to the amount of rejects it transfers to the landfill (40-50%) and in terms of acceptability of the compost from the mixed waste. Mechanical Biological Processing Technology is found relatively more suitable, adaptable and flexible technology for the type of waste generated in Nagpur. Mechanical Biological Processing Technology, has been further evaluated in detail in the following section for its suitability against the technology suitability criteria identified earlier in this chapter.

7.4 Mechanical Biological Processing Technology & its Suitability to Nagpur

One of the most innovative MBT process for the treatment and utilisation of residual household waste has been identified as Maximum Yield Technology (MYT) by Zweckverband Abfallbehandlung Kahlenberg (ZAK) Kahlenberg Waste Treatment Association, which has been compared in the following section. MYT aims to extract the complete raw material and energy content of waste using the energy potential as recyclable sources of energy and is specifically suitable for organic-rich municipal solid waste. Mechanical-biological treatment of the waste is carried out for producing biogas and refuse derived fuel (RDF).

An evaluation of MYT against the technological suitability criteria for Nagpur is provided in the following section.

Table 7-4: Comparison of MYT against Technological Suitability Criteria

S No	Criteria	Maximum Yield technology
1	Suitability as per waste characteristics – Technology for Nagpur should be capable of handling high organic waste & high moisture content - Recent studies by NEERI & Arcadis shows high organic (56%) and moisture content (56%)	High moisture and organic content makes biological processing technologies the most suitable technology as compared to the thermal processing technologies. MYT, which is one of the most innovative MBT technology for waste treatment, is one of the most suitable technologies due to its flexibility and range of mechanical and biological treatment provided to process various types of waste.
2	Reliability - proven internationally for large scale	MYT technology has been developed for the MBT Kahlenberg and has already been in successful and trouble-free continuous operation for several years. The technology is also operating in Hangzhou (China) which is having similar waste characteristics when compared to India. The technology is tried and tested and has high operational reliability leading to long-term operational success.
3	State of Art and clean technology	State of Art technology with emission below EU norms.
4	Waste technology value chain assessment: • Technology that can process mixed waste	The MYT process operates under flexible conditions in the case of varying waste concepts and compositions. It is developed to treat mixed solid waste, including wet and organic-rich fractions.

S No	Criteria	Maximum Yield technology
	• No requirement for source-segregated waste and a higher degree of pre-processing	In MYT process, further separation and collection of those fractions is not required, the costs of waste disposal are reduced significantly. Suitable for Mixed waste. In MYT, there is no requirement for source segregation and higher degree of pre-processing
5	Social Acceptability	Clean technology – Social acceptability very high – site acceptance high even in direct vicinity to populated areas. The process is odour-free in comparison to many prevalent waste processing technologies; involves liquefaction of odorous substances. By the encapsulated treatment provided as part of MYT, the soluble and odoriferous substances are washed out and organic waste and process water is degraded (hydrolysis).
6	Market for products and by-products	The biodegradable energy potential of municipal solid waste is converted to biogas. The utilization of biogas provides electricity and heat to cover the own energy demand of the process and excess energy for third parties. The biological drying increases the calorific value and delivers solid recovered fuel for subsequent waste-to-energy projects, e.g. industrial combustion, energy generation in power plants, cement plants. Ready market available for the energy and RDF produced from the process
7	Rejects diverted to landfill	The rejects diverted to the landfill are low in this process and are considerably reduced by biological degradation and dewatering.
8	Low carbon footprints	Carbon footprint of MYT is low in comparison to incineration. (As per the report on 'Waste Management Options and Climate Change'[17] from European Commission, MBT producing lowest greenhouse emission flux in comparison to other prevalent waste management options including incineration.)
9	Modular and Flexible	Modular plant using tried and proven machines. Small and large-sized plants economically viable.

The above table indicates that MYT as a technology fulfils most of the criteria and is suitable for the type of waste generated in Nagpur city. The technology description and other details related to MYT are provided in the next chapter.

[17] *Waste Management Options and Climate Change by European commission (http://ec.europa.eu/environment/waste/studies/pdf/climate_change.pdf)*

8 PROPOSED TECHNOLOGY DESCRIPTION

8.1 General

The focus of MYT is on extracting the complete raw material and energy content from the municipal solid waste. Hence, the energy potential of the MSW is utilized as recyclable sources of energy. Instead of using the classic waste treatment solutions as landfilling or incineration, MYT extends the technological portfolio of waste management, allowing for optimum economic exploitation of MSW in the form of raw materials, and provides output in the form of quality-assured fuels and energy-rich biogas.

Although the characteristic properties of MSW vary on a regional and international level, the key components are always the same. MYT innovative, perfectly synchronized multi-step process cascade gains the following four main components from the input MSW and extracts the maximum potential from them while utilizing synergies for each treatment step most effectively.

- Energy Sources (fuel and biogas)
- Metals
- Minerals
- Water

The conceptual overview and the general process description for MYT process are shown in **Figure 8-1** and **Figure 8-2** respectively

Figure 8-1: Conceptual Overview of MYT's Process

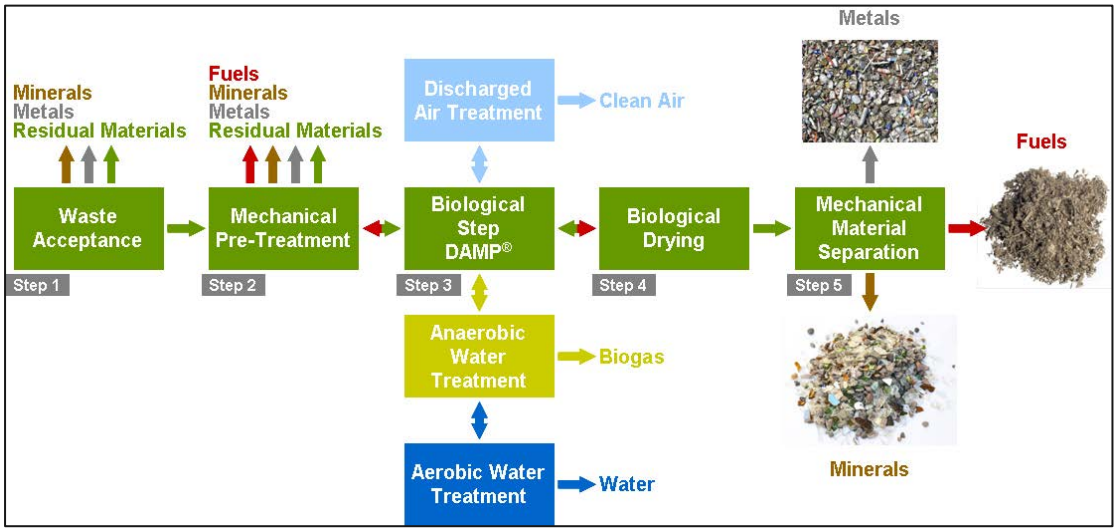
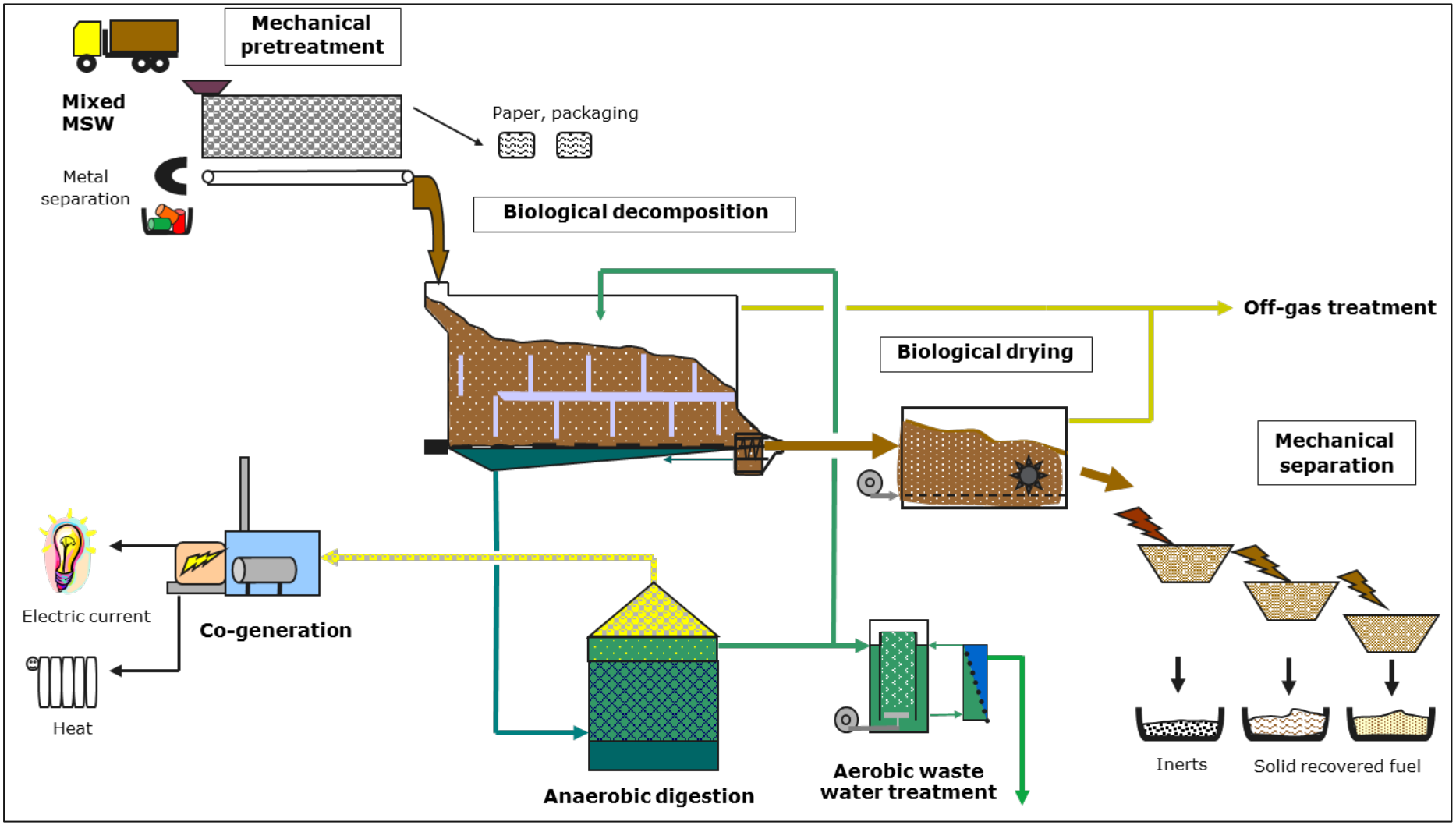


Figure 8-2: Process Flow for MYT Process



8.2 Technological Description- MYT

The system components for MYT process is discussed in the following section

8.2.1 Waste Bunker

The waste will be delivered to an underground bunker. The waste due to weight compression is drained statically in the underground bunker. The wastewater is collected in the bunkers at the lows and pumped out. Wastewater is then transported to the anaerobic stage. With its high-water content, we assume a wastewater percentage of about 25% of the delivered quantity.

Photo 8-1: Magnetic Separator

8.2.2 Mechanical Pre-Treatment

Mechanical pre-treatment includes the following components:

- Bag Opener
- 2 x Shredder for maximum particle size limitation (e.g. 300 mm)
- Magnetic Separator
- 1 x Disk separator for separation of high caloric value components > 80 mm
- Waste liquid collection system for leachate collection and treatment

Bag opener

The bag opener is provided to open waste bags from plastics and disentangle material, without shredding (size reduction) their contents. Thus, the downstream processes are provided with material easy to sort. They are double shaft shredders used to process heterogeneous waste, opening the bags without shredding and cutting the materials inside, before the selection line.

The bag opener is designed to handle all types of municipal solid waste and which does not require

frequent cleaning operations. The machine can work with the shafts in clockwise and counter clockwise. bag opener is geared to adjusting volume of incoming waste, which is obtained through the process of continuous shearing of: municipal solid waste as such, waste from waste collection, waste of twigs and other material to be composted, waste wood, pallets etc. The bag opener is designed along with a feed hopper.

Shredder

Photo 8-2: Waste Shredder (capacity: 60 t/h)

The Shredder is provided for shredding different materials such as domestic waste, industrial waste, commercial waste, etc., and has low noise generation and low wear of tools. Due to the tool heads with interlock and grip one after the other, 2-shaft Shredders provide a well draw-in and self-cleaning behaviour even for difficult-to-shred material.

The material is fed into the Shredder by a wheel loader, shredded by the tools and discharged almost equally by a feeding conveyor with smooth belt and skimmers and brought to the Magnet Station. The feeding conveyor has an approx. 17° inclination, so it is possible to use a smooth belt. It guarantees that even under extreme conditions the space below the conveyor belt is almost free of wet dribbling. The top roller of the conveyor belt consists of chromium-nickel steel. A tipping hopper is included, so it is possible to load the shredder with a wheel loader. The size of output material of the Shredder is smaller than 300 mm.

Magnetic Separator

Photo 8-3: Magnetic Separator

The Magnet Station consists of a steel construction, an overbelt magnet with length discharge and a crosswise discharge conveyor for ferrous material. The magnet is attached in the feeding direction of the shredder discharge conveyor and separates iron from the material flow coming out of the shredder. The cleaning conveyor of the magnet forwards the iron which is then thrown onto the crosswise conveyor. From there, one possibility is to throw it into a provided container and bring it back to the recycling process. The shredded and almost iron-free material is forwarded to the accelerating conveyor of the Disc Separator.

Disc Separator

The Disc Separator is a low-maintenance, high-performance equipment suitable for the screening of difficult materials as well. It is characterized by an extreme compact constructive design. Special devices allow reliable separation of different fractions from the material flow (> 7,5 mm - < 50 mm). Possible adjustments of the screen deck inclination have an effect on the resting time of material and the screening result.

Photo 8-4: Disk separator (capacity: 60 t/h) sieve overflow: > 80 high caloric waste. Sieve underflow organic material to biological step

The Screen shafts are equipped with patented sleeves and screen discs. The shafts provide an effective self-cleaning behaviour, so there will be no need for apprehensive large-scaled material wind-ups anymore.

Photo 8-5: Fine Shredder – Hammer Mill

The Separator is installed here for separating the half-rotted organics as well as the heavy fine material, which is smaller than 80 mm. The material staying above the screening deck is then only the fractions with a size between 80 and 300 mm, which contain high heat value so that they can be further reused as RDF.

The accelerating conveyor of the Disc Separator guarantees optimal feeding of the material to the screening deck. There, it is accelerated by the patented screen shafts; from shaft to shaft the material is shaken up. By this, organic material or its remains are screened optimally. Fine grain (< 80 mm) and half-rotted organics end up on the collecting conveyor installed below the screening deck and are discharged by the short and crosswise arranged transport conveyor. Here, a long dump belt can be installed that throws off the fine material into a provided container or set it up as conical debris, and then can be transported into the percolation. Further patented devices of the Disc Separator avoid rewinding and adhesion to a large extent and thus guarantee an almost trouble-free operation. At the end, the oversize material (80 – 300 mm) can be further shredded with a hammer mill to a size smaller than 60 mm.

Hammer Mill

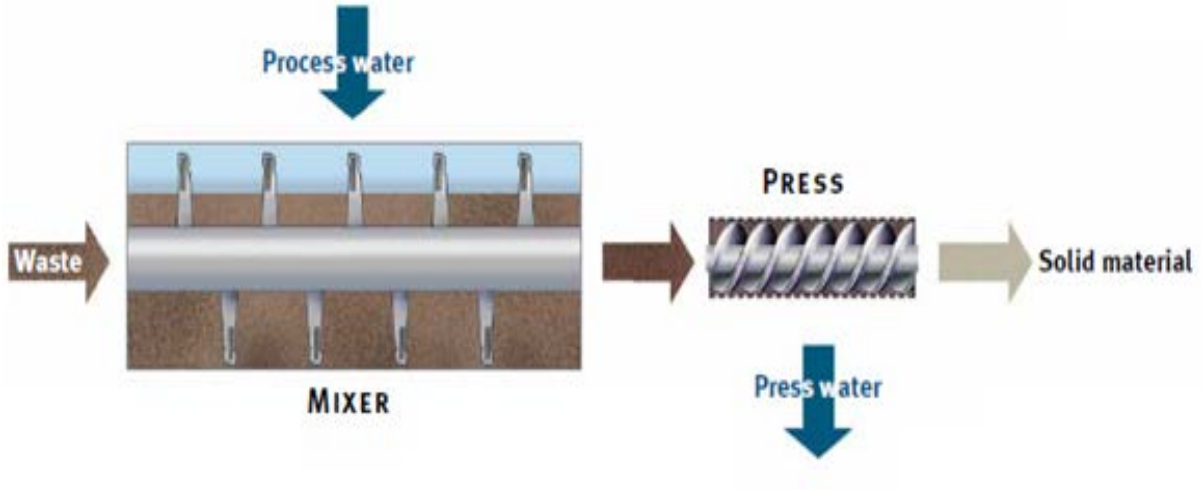
The Hammer Mill is equipped with a vibration conveyor (vibration feeder) with distributes the material to be shredded over the entire width of the rotor and feeds it horizontally into the direction of feed rollers and rotor. Because of the round rotor able to handle larger foreign bodies in connection with swinging hammers, the Hammer Mills are considerably less sensitive against foreign bodies than e.g. cutting mills with fixed tools.

The Hammer Mill here is for a further reduction of the output material size of the screen overflow (80 – 300 mm) mixed with dried material from biological drying of approx. < 80 mm. The material size of output of Hammer Mill is approx. < 60 mm.

8.2.3 Biological Step

The biological step is the *heart* of the MYT® process and includes the most innovative process: the DAMP®. DAMP is short for Defined Aerobic Mixing Process.

Figure 8-3: Illustration of the DAMP® - Defined Aerobic Mixing Process (illustration by ZAK Ringsheim)



In this process, the waste is continuously fed into lying reactors, the DAMP® Mixers, and handled and homogenized by large, robust agitators, while process water is added (refer figure 2-33). The mixers transfer the material though the reactors and also partially shred the material to allow the process water to get in maximum contact with the material.

The water washes out soluble organic matter from the waste, which is digested anaerobically in a separate fermentation stage to gain biogas from the hydrolysed organic matter in the process water.

After treatment (refer Photo 3-25) for one up to three days, depending on the waste condition, the solid material is mechanically dewatered and ready for further treatment in step 4, the biological drying.

Photo 8-6: Waste Processing: View into the operated DAMP® Mixer

Photo 8-7: DAMP Hall with the End of Six Mixers and Dewatering Presses at MYT® Plant Kahlenberg,

Photo 8-8: Anaerobic Digestion of Hydrolysed Organic Matter in the Process Water at MYT® Plant Kahlenberg,

The concept includes the following main aggregates:

- 6 x DAMP Mixer XL - for waste processing, including motors and planetary gear boxes
- 6 x Dewatering Presses - for mechanical dewatering of processed water
- 6 x DAMP Reactors and Hall - for machinery housing
- Mechanical Process Water Pre-Treatment - for sediment and floating contraries removal from process water
- 3 x Anaerobic Digesters - for biogas generation from hydrolysed organic matter
- Emergency Flare System - for burning off excess biogas
- Chemical Make Up and Dosing Stations - for production and dosing of chemical agents, e.g. polymer and chemical de-sulphurisation
- Exhaust Air Treatment System / Biofilters - for treatment of odorous air from treatment processes

8.2.4 Biogas Utilization

Due to the high loading of the process water with easy hydrolysable organics, anaerobic digestion is able to produce a high energetic biogas with methane contents of up to 70%. By dosing chemicals into the fermenters, the content on the hydrogen sulphide can be reduced to a minimum, which is good news for the subsequent Co-Gens.

The biogas is utilized in Co-Gens, producing electricity and heat from the biogas. The produced heat is used to keep the anaerobic digesters at their working temperature of ~38°C. The amount of electricity produced is sufficient to run the whole plant and even more: the remaining excess electricity can be fed to the local grit and sold.

Photo 8-9: Co-Gen Building at MYT® Plant Kahlenberg, 2013

Photo 8-10: Biogas Storage Tanks

Gas storage tanks serve the purpose of balancing out fluctuations between gas production and gas consumption; a storage capacity of two days' production volume is recommended. They must be gas-tight, secure against pressure, and impermeable to UV radiation as well as temperature and weather influences. The digester can be used as gas storage itself by using foil hoods on the reactor. The external storage tanks that are predominantly used are relatively low-cost foil tanks.

Biogas utilization is carried out in one co-generation unit (CHP) with exhaust heat recovery. The power-station is carried out as totally equipped container module and include the biogas regulation unit, emergency cooler, exhaust system and oil supply. It works automatically. Electricity is fed to the grid.

The concept includes the following main aggregates:

- Gas storage system - Biogas storage
- 3x Co-Gen 1.0 MWel. + 3x 0.5 MWel. - for electricity and heat generation from biogas
- Heat Exchangers - for engine cooling and energy recovery

Photo 8-11: Co-Gens

8.2.5 Biological Drying

One advantage of the solid fuels produced by MYT is their biochemical stability. This means that the material can be stored and transported and used on demand without risking changes of the material and its properties due to biochemical reactions. To achieve this, the material's water content is drastically reduced, to deprive any microorganisms the water required for their metabolism.

The drying of the DAMP output is performed biologically in an energy-efficient and economical way with the energy inherent in the waste. In tightly closed concrete tunnels (Refer Photo 7-12), microorganisms which are already present in the material metabolize organic matter, which is still present in the material pores, e.g. as process water, resulting in CO_2, water and heat. To enhance their metabolism and to control the temperature inside each tunnel, the air supply into each tunnel is automatically controlled and the produced heat evaporates the remaining humidity inside the processed waste. Due to those optimized conditions, a drying up water content of less than 25 % is achieved by this method and no external heat is required to fuel the drying process.

Photo 8-12: Open and Empty Drying Tunnel at MYT® Plant Kahlenberg, 2006

Many years of experience with this technology at the MYT Plant Kahlenberg have helped to fine-tune this process and to enhance it to today's condition.

Due to the high potential of odorous emission in this treatment step, all tunnels, belts, machines and aggregates are fully closed and their exhaust air is extracted and sufficiently treated to minimize the emission of odours into the environment to an absolute minimum.

The concept includes the following main aggregates:

- 12 Drying Tunnels and Machinery Hall - with walking floor installations and excess heat exchangers for the intense drying tunnels for waste drying and machinery housing
- 3 wheel loaders for tunnel charging-for optimized tunnel charging
- Air Supply System- for supplying each tunnel with the required process air amounts

8.2.6 Air Treatment

Biofilters use microorganisms to remove air pollution. The technology finds greatest application in treating malodorous compounds and water-soluble volatile organic compounds (VOCs). Compounds treated are typically mixed VOCs and various sulphur compounds, including hydrogen sulphide.

The air flows through a packed bed and the pollutant transfers into a thin biofilm on the surface of the packing material. Microorganisms, including bacteria and fungi are immobilized in the biofilm and degrade the pollutant. Trickling filters and bioscrubbers rely on a biofilm and the bacterial action in their recirculating waters.

Photo 8-13: Biofilters

8.2.7 Membrane Bioreactor

The following description is a matter of form to be listed since this step is part to the MYT process in the case that it is not possible to discharge the produced waste water to the sewer connected to the WWTP.

The waste water from the plant will be send to the waste water treatment plant, adjacent to the proposed site. There are two waste water treatment plant adjacent to the Bhandewadi dumpsite, a 100 MLD plant based on conventional activated sludge technology and a new 130 MLD plant recently constructed under PPP mode. A Special Purpose Company (SPV), Nagpur Waste Water Management Private Limited was formed in the year 2014 for the project. The treated waste water (tertiary treatment) from the plant is currently supplied to the power plant at Mauda. The demand for treated water from the waste water treatment plant is high, especially from other industries in the region.

The proposed treatment plant will provide an MBR comprising a highly efficient biological treatment and reliable ultrafiltration for biomass separation. In addition, the plant is equipped with an optional dewatering step. A brief description of the proposed treatment process and main advantages is presented.

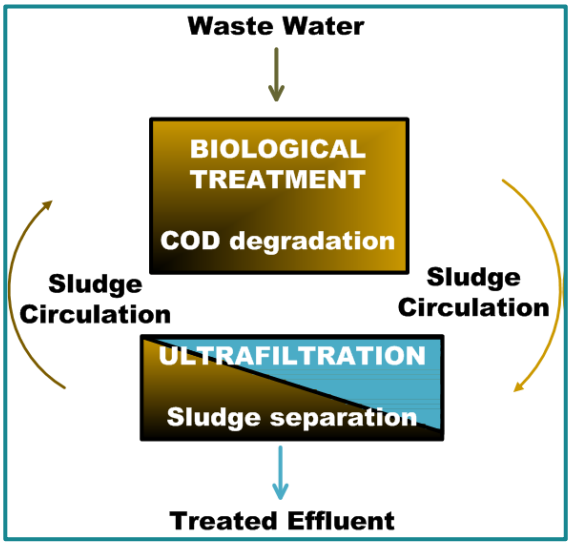
Balance tanks

The inlet system comprises one balance tank (1.500 m³) for the incoming wastewater streams.

Biological Treatment

The wastewater is pumped to the bioreactors via strainers to remove large solids. These process vessels hold a blend of water and microorganisms (activated sludge) which work on the contaminants in the wastewater to produce a high-quality treated effluent. A highly efficient oxygen transfer system, using jet aerators, provides oxygen for the biodegradation of COD/BOD and ammonia. A further description of the biological process is below.

Figure 8-4: Biological Treatment Process



The first biological process step is denitrification. This is a natural process taking place under anoxic conditions using readily biodegradable organic material. To increase the rate of denitrification, an external carbon source, in this case acetic acid, is added. Heterotrophic bacteria utilise this carbon source to reduce nitrate to molecular nitrogen. A high rate of denitrification is required in this application to meet the future total N discharge consent. However, before this comes into effect, the plant will denitrify using

Denitrification

$$4NO_3^- + 5C + 4H^+ \xrightarrow{heterotrophicbacteria} 2N_2 + 2CO_2 + 4H_2O$$

The denitrification process saves energy and caustic soda. The biodegradable matter which is consumed in the denitrification process does not need to be oxidized in the later nitrification process. This reduces aeration energy consumption. In addition, as alkalinity is recovered during denitrification, this eliminates the requirement for caustic soda for pH stabilization.

Activated sludge is transferred to the nitrification tank via a gravity flow pipe. In the nitrification tank ammonium is oxidized over nitrite to nitrate. First, ammonia-oxidizing bacteria (nitrosomonas) oxidize ammonia to nitrite. Then nitrite-oxidizing bacteria (nitrobacter) oxidize nitrite to nitrate. In the same reactor, COD is biologically removed.

The concentration of oxygen in the tank should range between 1 – 3 mg O_2/L.

An aeration system, located inside the bioreactor, continuously aerates the biomass with air being provided by an external blower.

The dissolved oxygen (DO), pH and temperature in the bioreactor are monitored and used to control operation of the blowers to maintain the desired residual DO. This ensures efficient operation with lower expenditure on energy.

Excess sludge and sludge dewatering

By definition, all biological treatment processes create excess 'sludge'. The latter, in fact, is bacteria/biomass that has grown with the waste water treatment process and is a by-product of the bio-oxidation of carbohydrates contained in the waste water. The excess sludge needs to be removed on a regular basis to maintain the desired sludge concentration and sludge age.

The produced excess sludge is pumped to the anaerobic treatment plant in front of the MBR Reactor.

Ultrafiltration (UF) Separation for the MBR

The proposed ultrafiltration plant is based on a side-stream crossflow membrane filtration process by using true UF tubular membrane modules.

The use of the tubular membrane modules provides the complete retention of biomass. The 'mixed

liquor' of activated sludge and effluent is pumped from the bioreactor through the tubular membranes in order to separate the treated waste water from the activated sludge. All bacteria and any COD due to suspended solids material, plus macromolecules and colloidal matter, is safely retained within the system and is continuously fed back, as retentate, into the ring main and returned back to the bioreactor for more biological treatment.

The tubular membrane module allows the operation at much higher mixed liquor solids concentration (MLSS) compared to other membrane systems. This can provide major cost savings, e.g. smaller bioreactors and reduced volume of the waste sludge to dewater.

The UF system typically consists of 2 - 6 tubular membrane modules connected in series to form a UF-loop. The ultrafiltration plant can consist of several UF-loops operating parallel, depending on the required throughput. In this application, one loop with space for six modules is included.

Each UF-loop has a dedicated circulation pump, sized to provide the required crossflow velocity along the membrane, to reduce fouling and maintain a high permeate flux.

The side-stream crossflow process offers very high permeate flux, compared to other membrane systems, thus requiring much less membrane area and substantial cost savings from future replacements.

Occasionally, the UF membrane modules will need to be rinsed or cleaned. This can be achieved via the wash pump by using water or permeate stored in the wash tank. Any chemicals needed to clean the membranes can be dosed into the wash tank. The rinse and clean procedure are automated and requires only minimum attention. The individual UF loops can be rinsed or cleaned while the remaining loops are in operation.

Compared to other membrane systems, the cross-flow ultrafiltration plants are designed as a closed loop system and are located inside a building or a container. Consequently, the operator does not come into contact with any activated sludge or waste water during the operation and cleaning procedure, and no aerosols are produced.

Photo 8-14: Membrane Bioreactors with External Membrane

Photo 8-15: UF System

8.3 Mass and Energy Balance

The total input is 800 TPD of municipal solid waste to the system; the outputs from the system are:

- 8.36 MW of energy (5.10 MW of thermal energy which can be used in the bio drying tunnel and 3.26 MW of electrical energy which can be used to meet the auxiliary power consumption).
- Refuse Derived Fuel (RDF) - 213 TPD with a calorific value of 12.000kj/kg& 20% moisture content. Photo 7-16 shows various RDF types generated from waste.
- 400 m^3 of waste water - proposed to be treated in adjacent Sewage Treatment Plant by Nagpur Waste Water Management Pvt. Limited (Capacity 200 MLD) operated by Vishvaraj Infrastructure Ltd. and further supplied to power plants and other industries in the region.

Figure 8-5 shows the details of the output from the process and Figure 8-6 shows the Mass and Energy balance from MYT process proposed for Nagpur.

Figure 8-5: Output from the Process

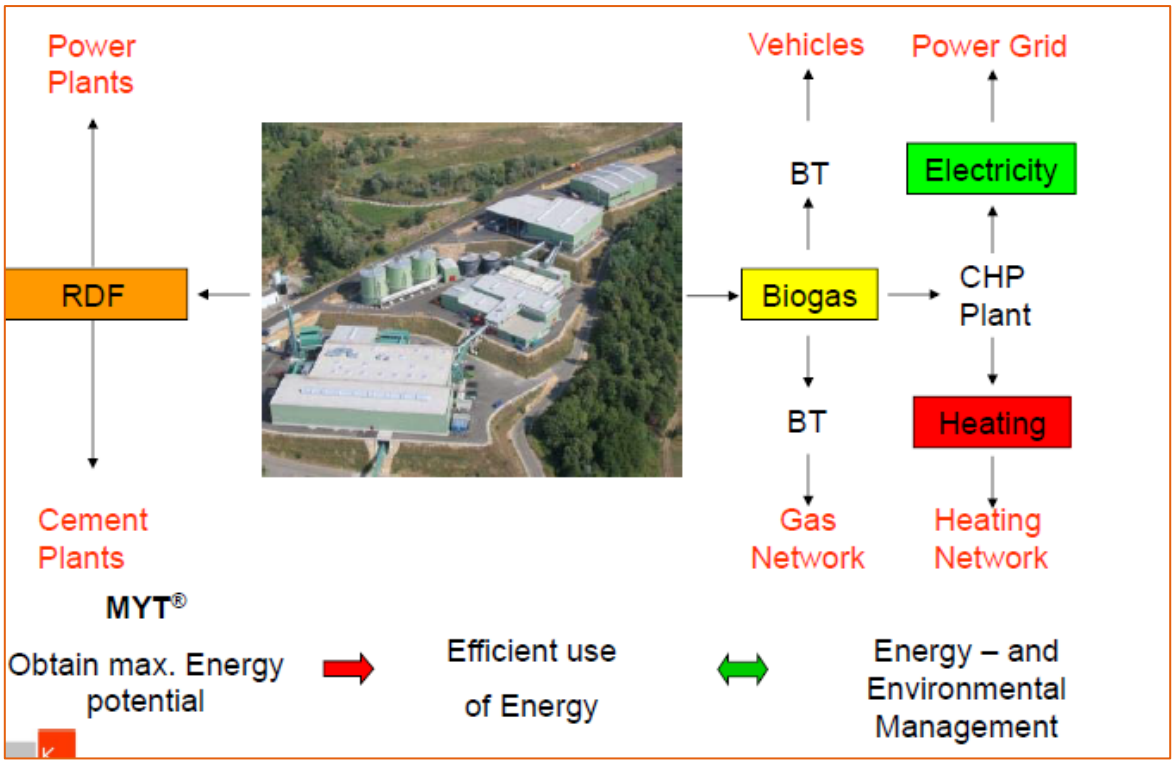


Photo 8-16: The Various Fractions of RDF are Shown in the Pictures below:

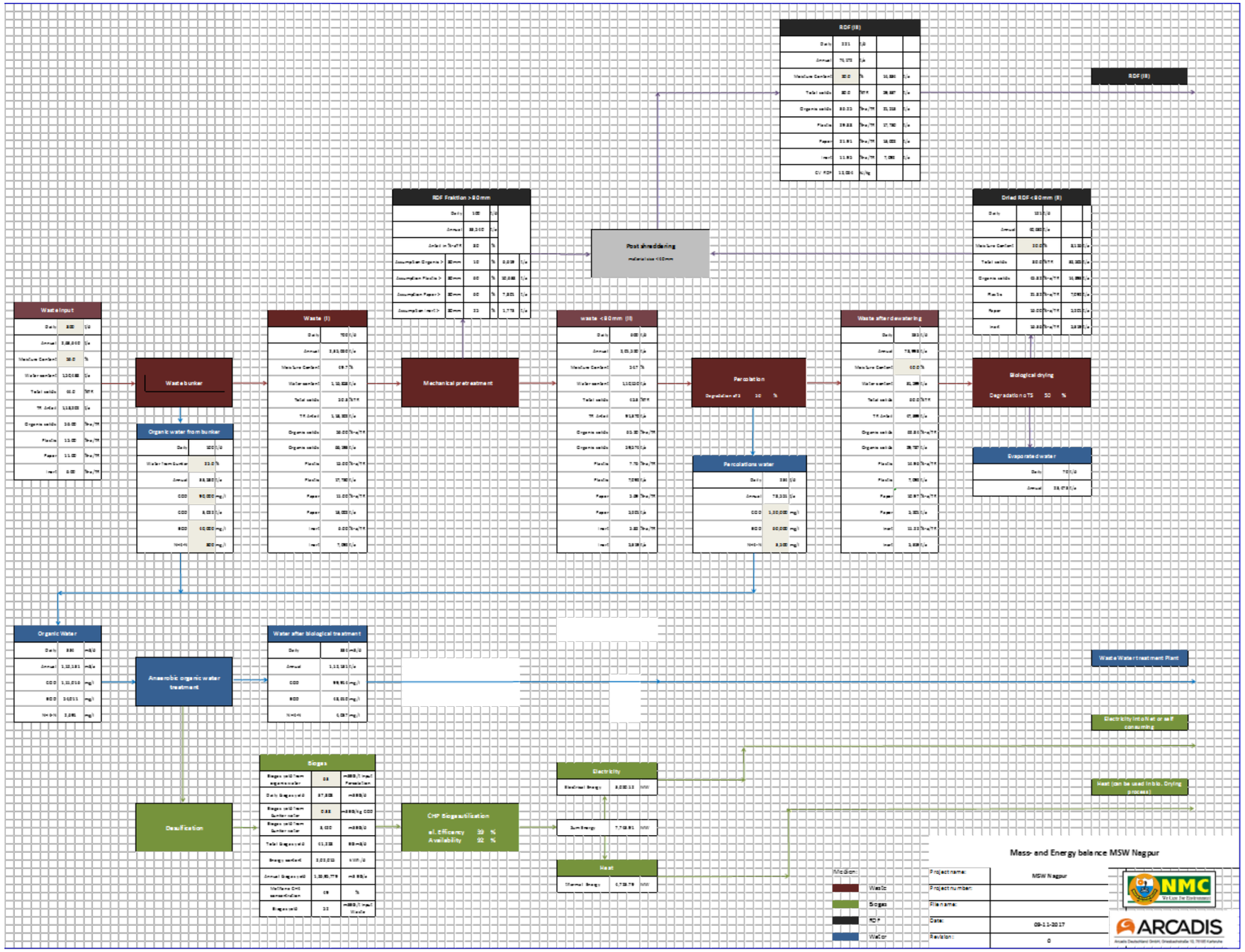
Products of the Mechanical Separation step: EBS (Refuse Derived Fuel) mid caloric range (~13,000 MJ/ton)

Products of the Mechanical Separation step: EBS (Refuse Derived Fuel) mid caloric range (~14,000 MJ/ton)

Products of the Mechanical Separation step: EBS (Refuse Derived Fuel) high caloric range (~16,000 MJ/ton)

Products of the Mechanical Separation step: Mineralstoffe (Mineral fraction

Figure 8-6: Mass and Energy Balance for MYT for Nagpur



8.3.1 Site Layout and Land Requirement

The typical land requirement is 10 acres for 800 TPD MYT plant. The site layout is shown in **Figure 8-7**. Based on site available, the MYT operations are divided into 2 land parcels, with one-part adjacent to the existing waste closure site and the other land parcel adjacent to the waste processing plant by Hanjer.

The land parcel adjacent to the waste closure site consists of the following buildings and structures:

Waste receiving pit – The waste receiving pit is designed with a capacity to hold 3 days waste, i.e. 2400 Tons of waste. The pit is designed for a volumetric capacity of 5350 m^3 of waste. The area demarcated for the waste-receiving pit is 980 m^2. The waste pit is also designed to collect the leachate generated from the fresh MSW received at site. The leachate will be transferred to the anaerobic digestion tank after pre-treatment in the leachate pre-treatment workshop (680 m^2).

Mechanical pre-treatment – The waste from the waste pit is delivered to the mechanical pre-treatment section where the waste is shredded and the +80mm is diverted to the Refuse Derived Fuel (RDF) storage area and -80mm is diverted to the Defined Aerobic Mixing Process (DAMP) unit. The total area for the mechanical pre-treatment section is 1440 m^2. This unit also includes the disc separator and magnetic separator.

Dewatering workshop - DAMP is the most important section in the total MYT process where waste is homogenized with a help of an agitator and water. The homogenized solid waste is passed through the press and dewatered. The area requirement is about 910 m^2. The organic water from the press will be transferred to the anaerobic digestion tank.

Bio drying tunnel and workshop – The dewatered waste is subjected to further drying in the bio drying tunnel. The area allocated for this section is approximately 4000m^2.

Anaerobic digester

The land parcel adjacent to the waste processing plant by Hanjer consists of the following buildings and structures:

- Anaerobic digestion (AD) tank – 2 AD tanks are proposed over an area of 875 m^2.
- Biogas Tank – 1 biogas tank is proposed over an area of 1780 m^2.

Other facilities: In addition to the above-mentioned building and structures, other facilities include an office building (800 m^2), a discharge workshop (430 m^2) and a biofilter (500 m^2).

In addition to the above-mentioned facilities, a membrane treatment workshop (580 m^2), biochemical pool (810 m^2), boiler room (144m^2), machine repair workshop (700 m^2) and desulfuration facility (530 m^2) have been provided.

Figure 8-7: Plant Layout for the Proposed MYT Facility at Nagpur

8.3.2 Marketing of End Product

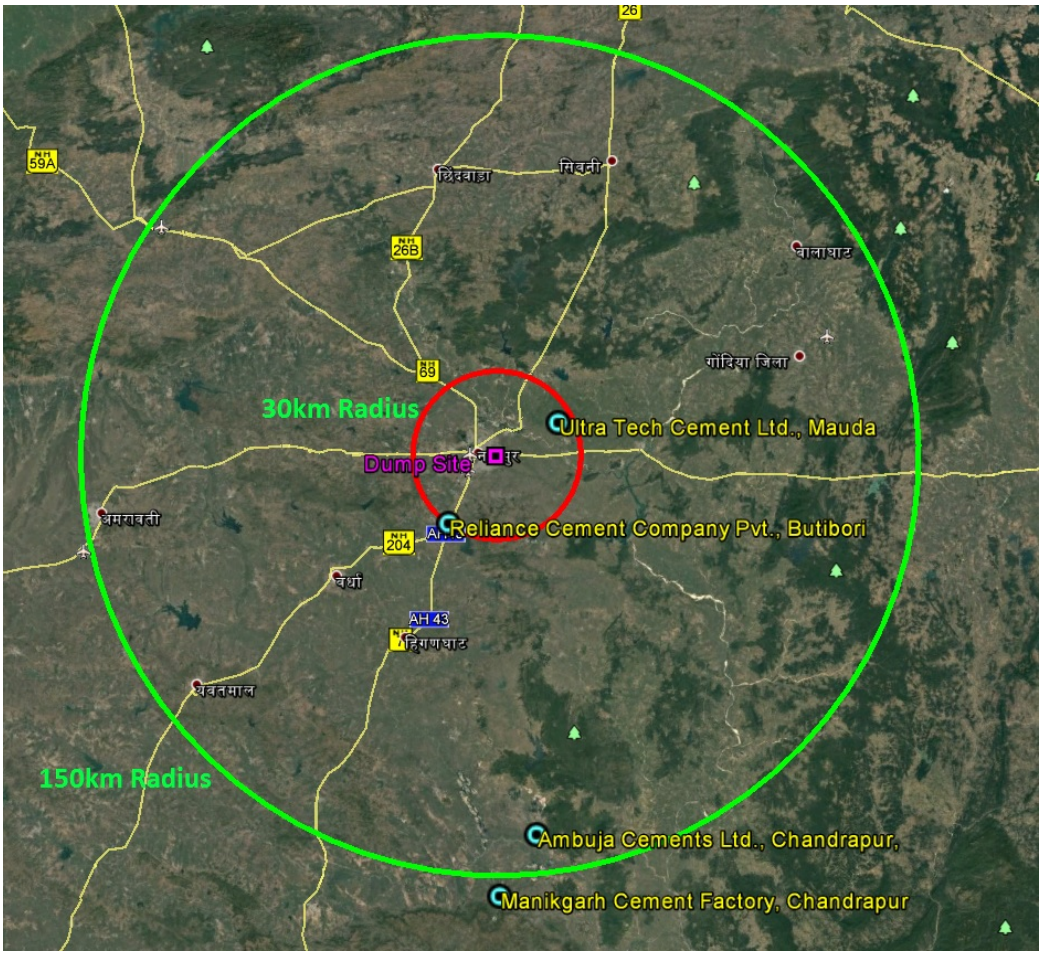
SWM rules 2016 mandate the use of high calorific value waste in the cement and power plants. They also indicate that all industrial units using fuel and located within 100 km from the solid waste based RDF plants shall plan within six months from the date of notification of the Rules to replace at least 5% of their fuel requirement with RDF so produced. RDF generated from the plant can be used for generation of energy on-site or can be supplied to the cement, steel and power plants.

Cement Plants

The study has identified cement plants in the vicinity of the proposed MYT facility in Nagpur. RDF from the plant can be diverted to these cement plants.

- Ultra Tech Cement Ltd., Mauda, Nagpur-25 - 30 km Reliance Cement Company Private Limited, Butibori - 18 - 20 km
- Ambuja Cements Ltd., Chandrapur -120 - 130 km from Nagpur
- Manikgarh Cement, Chandrapur - 120 - 130 km from Nagpur

Figure 8-8: Cement Plants near the Proposed MYT Facility at Nagpur



Power Plant- RDF Combustion system

As a developing market, there are some potential risks in terms of the operations of large thermal facilities accepting RDF from mixed waste processing as a fuel source due to the heterogeneity in the

composition of the waste. Therefore, an additional technical solution for utilisation of the RDF generated from MYT process is combustion of RDF in a RDF combustion system. This system is proposed to address the issues in marketing of RDF to the cement plants. This system will be exercised only in case there is no end user identified for the RDF generated from the MYT plant. This will be a complete system with combustion of RDF within the plant to generate power with some optional changes in the previously discussed MYT process. The following equipment are made optional in this MYT process to make it more adapt to the RDF combustion system:

- Magnetic Separator
- Disc Separator
- Dewatering Section - DAMP with 5 agitators
- Biological Drying

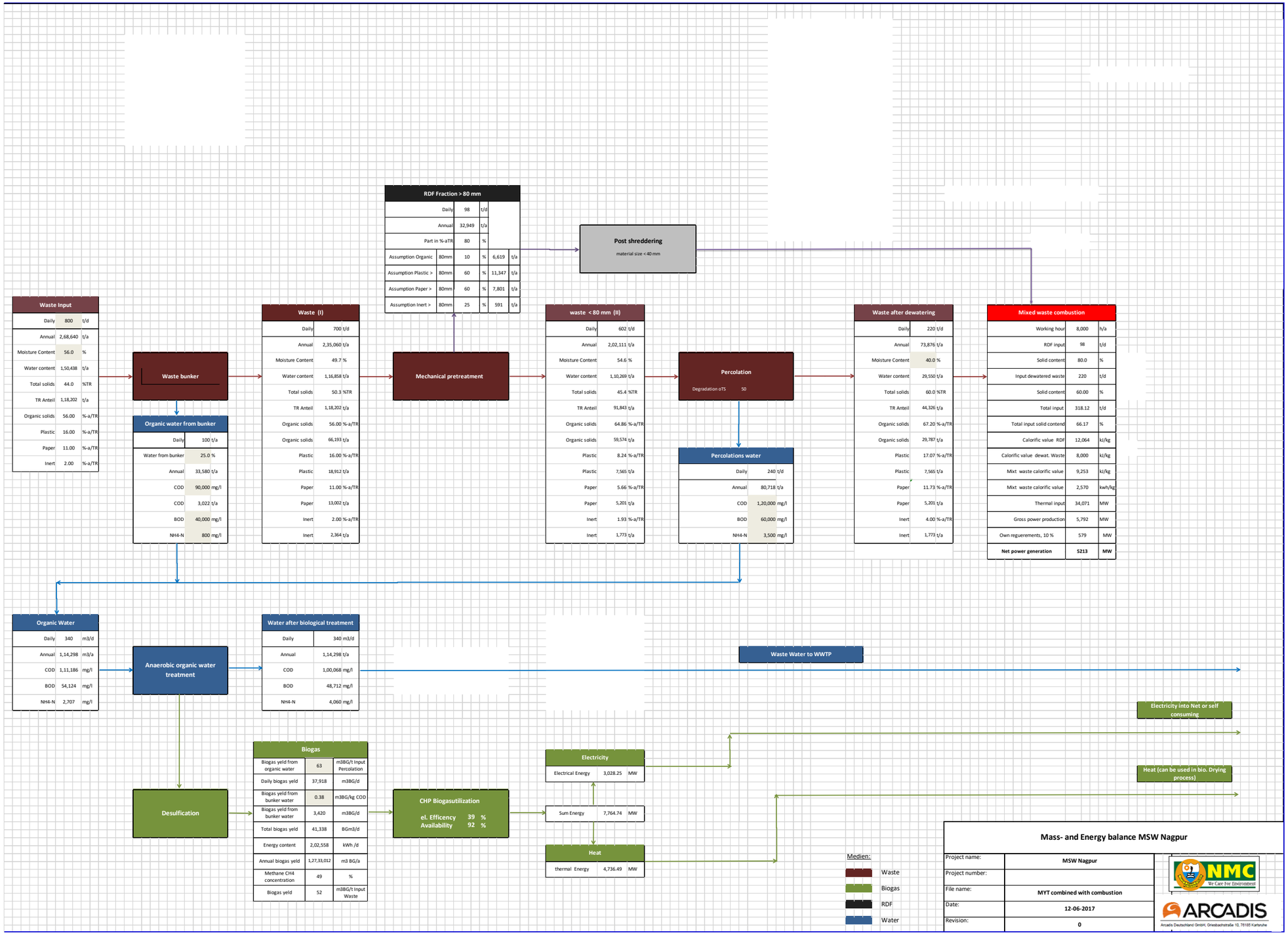
The MYT process will yield 330 TPD of mixed RDF with the calorific value of approximately 9,228 kJ/kg. The 330 TPD of RDF generated from the MYT process can be combusted in a boiler for generation of energy. The process will generate 8.36 MW with the MYT and 35.3 MW with the combustion.

The RDF combustion system consists of the following additional components to MYT:

- waste storage system,
- waste feeding and grate system,
- waste heat boiler,
- SNCR System for NOx removal,
- flue gas cleaning system,
- steam turbine and generator system,
- condenser cooling water system and
- ash storage system.

The process water from the biological treatment is proposed to be sent to the waste water treatment facility adjacent to the proposed municipal waste treatment plant.

Figure 8-9: Mass and Energy Balance for MYT-Combustion for Nagpur



8.4 Details of the Existing Operational Projects based on MYT technology

This section highlights details of some of the plants operating successfully based on the proposed MYT technology. The details of two operating plants are presented in the following section.

- MYT Plant at Kahlenberg, Germany
- MYT plant at Hangzhou (China)

8.4.1 MYT Plant - Kahlenberg, Germany

A MYT plant of 100,000 metric tonnes per annum is in operation at Kahlenberg, Germany. The plant was commissioned in 2005 and has been operating successfully since 2006, and is even able to shift the capacity limits by +20 % towards 120,000 MTA. The plant was established with the following objectives, which have been achieved in the last 11 years of successful operation.

- Material utilisation and minimising landfilling
- Energy utilisation (RDF, Biogas)
- Operational efficiency (reduction of mass, minimalization of non-treated residue and bio-waste, energy self-sufficient MBT)
- Ecology (encapsulation, air and water treatment, saving fossil fuels)

The plant currently serves approximately 570,000 residents in the two districts Emmendingen (EM) and Ortenaukreis (OG). The plant has been continuously operating for 5 days a week in two shifts. The total area for the plant is approximately 5000 m^2.

Photo 8-17: Photograph showing the location of MYT plant at Kahlenberg, Germany

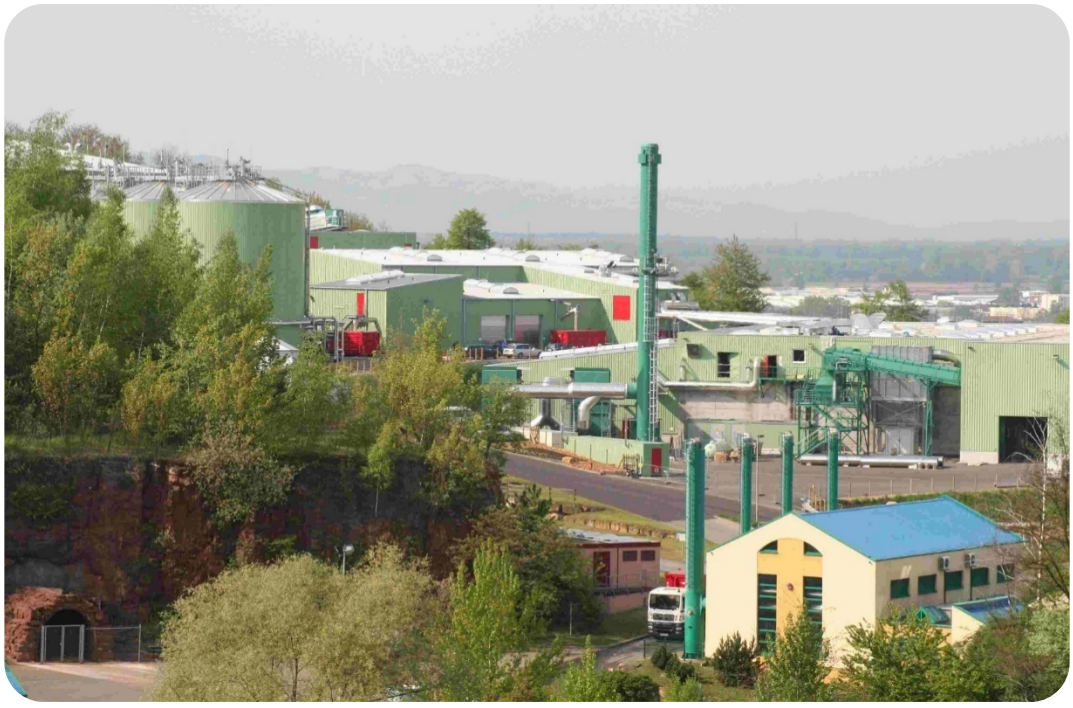


Photo 8-18: Photograph showing MYT plant at Kahlenberg, Germany

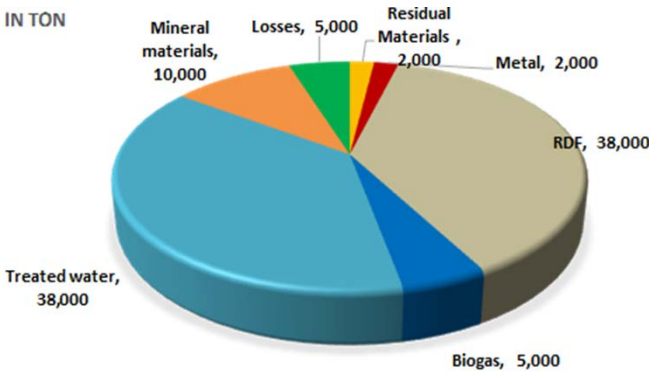
The plant is divided into five stages and the key plant stages include:

- Waste reception
- Mechanical Separation
- Biological Conversion and Waste water treatment
- Biological Drying Biological drying and off-gas treatment
- Mechanical post separation
- CHP Unit and Air Treatment

The total capital cost for the plant is 50 Million Euro (INR 3600 million).

The key output from the plant of 100,000 tonnes per annum includes:

- RDF – 38000 tonnes
- Biogas – 5000 tonnes
- Treated waste water – 38,000 m^3
- Metals – 2000 tonnes
- Mineral material – 10,000 tonnes



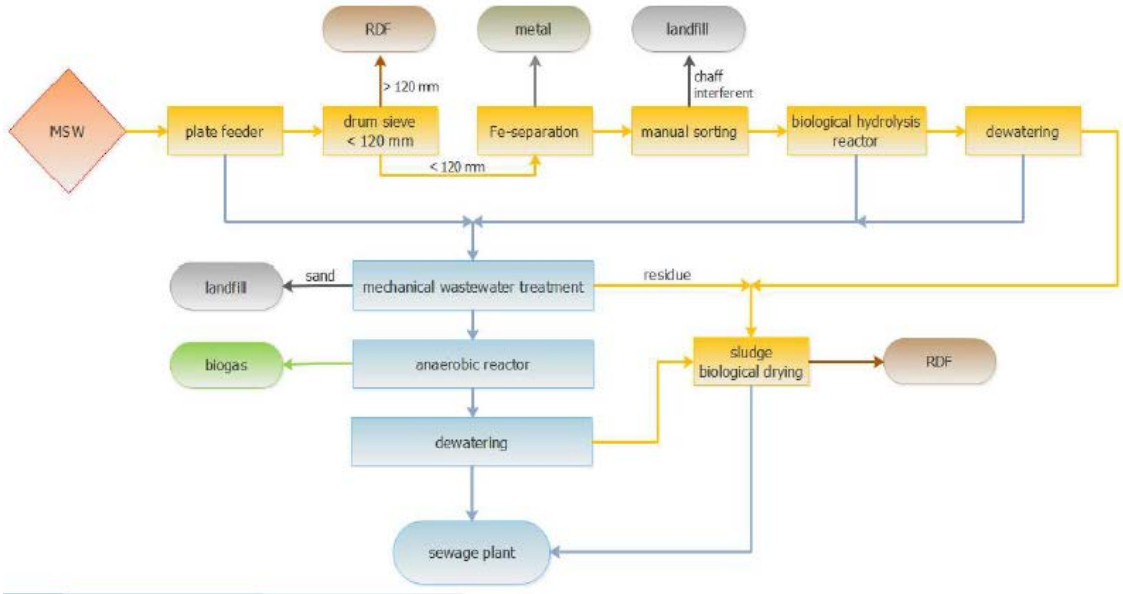
8.4.2 MYT Plant Hangzhou (China)

MYT came up with a small-scale technology demonstration project in the year 2016 in Hangzhou (China). The capacity of the plant is 16500-25000 TPA; the plant was built over an area of 5000 m2. The project cost of the plant was 50 Million RMB (6.53 Million Euro/494 Million INR).

The plant has the following components:

- Sieving
- Multi-zone-reactor (Percolation)
- Dewatering Reactor output
- Mechanical Waste Water Treatment
- Anaerobic Waste Water Treatment
- Biological Drying
- Separation process

The waste water generated from the plant for anaerobic digestion unit is 12,500 to 16,000 m3/a, with a COD of 70,000 to 120,000 mg COD/l. The Biogas yield is 50-70 Nm^3/Ton of solid waste. The plant is able to generate about 1 Million m^3/a of biogas with a methane content of 50-70%. The biogas generated is utilised to generate energy. The annual energy generation from the plant is 650,000 kwh.



9 PROJECT COST AND REVENUE ASSESSMENT

9.1 Project Cost& Revenue

9.1.1 Capital Cost

The capital costs for the MYT facility involves the costs of the following components:

- Waste Receiving Facility;
- Mechanical Separation Unit;
- DAMP
- Bio drying unit;
- Anaerobic Digestion Unit;

Table 9-1: Budget Investment Cost MYT Plant Nagpur, India - 800 t/d

S.No	Component	No	Unit Cost (€)	Cost (€)	Cost (INR-Crores)
1	Waste Bunker	1	760,000	760,000	5.49
2	Pre-Shredder	2	380,000	760,000	5.49
3	Metallic separation	2	76,000	152,000	1.10
4	Disk Separator	2	665,000	1,330,000	9.60
5	Percolation Agitators	6	855,000	5,130,000	37.04
6	Planetary gear boxes with motors	6	475,000	2,850,000	20.58
7	Dewatering Presses	6	427,500	2,565,000	18.52
8	Mechanical Process water treatment	2	332,500	665,000	4.80
9	Anaerobic Reactor	3	1,710,000	5,130,000	37.04
10	Dewatering station anaerobic sludge	2	237,500	475,000	3.43
11	Gas storage Tank	2	902,500	1,805,000	13.03
12	Desulfication	2	332,500	665,000	4.80
13	CHP Unit	4	807,500	3,230,000	23.32
14	Biological drying	12	1,045,000	12,540,000	90.54
15	Air treatment Biofilter	3	807,500	2,422,500	17.49
16	Post Shredder	2	237,500	475,000	3.43
17	Electrical Installation	1	2,850,000	2,850,000	20.58
18	Miscellaneous	1	2,000,000	2,000,000	14.44
	Mechanical Equipment(Sub-Total)			**45,804,500**	**330.71**
19	Transportation cost			1,551,000	11.20
20	Installation Cost			5,496,540	39.69
21	Start up 2px180000€/ax2a			720,000	4.86
22	Engineering Cost			4,580,450	33.07
23	Civil work			8,244,810	59.53
	Total Cost			**66,357,300**	**473.98**

The total capital cost for 800 TPD project in Nagpur is estimated to be **Euro 66.36 million** or **INR 473.98 Crores.**

9.1.2 Operational Cost

The operation cost for MYT at Nagpur has been elaborated in the following section.

Manpower costs

Table 9-2: Estimated Manpower Costs MYT Plant Nagpur, India – 800 t/d

S. No	Personal	No	Operation Cost (€/a)	Operation Cost (INR-Crores/a)
1	Waste reception	4	20,000	0.14
2	Mechanical treatment	6	30,000	0.22
3	Biological step	4	20,000	0.14
4	Wastewater treatment	4	20,000	0.14
5	Biological drying	5	25,000	0.18
6	Control station	5	25,000	0.18
7	Maintenance/Management	4	20,000	0.14
8	Sick leave / holiday replacement	6	30,000	0.22
	Total		**190,000**	**1.36**

The annual manpower costs for the project is **Euro 0.19 million** or **INR 1.36 Crores**

Plant Operation & Maintenance Cost

Table 9-3: Estimated Plant Operation & Maintenance Costs MYT Plant Nagpur, India - 800 t/d

S. No	Consumables	Operation Cost (€/a)	Operation Cost (INR-Crores/a)
1	Chemicals	804,000	5.74
2	Diesel	201,000	1.44
3	Lubricants	67,000	0.48
4	Fresh Water	26,800	0.19
5	Wear parts	804,000	5.74
6	Laboratory costs	26,800	0.19
7	Maintenance cost	643,200	4.59
	Total	**2,572,800**	**18.38**

The annual plant operational cost for the project is **Euro 2.57 million** or **INR 18.38 Crores**

9.1.3 Revenue Assessment

The key revenue sources for the project are tipping fees, sale of electricity and sale of RDF. **Table 9-4** provides details on the revenue estimated from the project

Table 9-4: Revenue Assessment for MYT plant

S. No	Consumables	Revenue Cost (€/a)	Revenue Cost (INR-Crores/a)
1	Sale of RDF	1,658,999	11.53
2	Sale of electricity	2,669,264	18.55
3	Tipping fee	6,008,688	41.76
4	Operational Expenses*	-4,095,033	-28.46
	Total	**6,241,918**	**43.38**

**Operating expense include all the operating cost including parasitic consumption*

Total estimated revenue from tipping fees, selling of RDF and electricity after deducting operating expense is estimated at **Euro 6.24 Million per annum or INR 43.38 Crores**. The assumptions taken for revenue assessment are provided in the following section.

- Estimated RDF output per day – 221 tonnes per day or 80621 tonnes per annum
- Average energy content of RDF – 12064 KJ/kg
- Sale price for RDF has been assumed at INR 1430 per tonne
- Expected biogas output – 1800 m^3 per hour
- Methane content – 49%
- Energy Content – 10 kWh/m^3CH4
- Estimated electrical conversion efficiency – 39%
- Estimated electricity generation – 3047 KWh/h or 24,379,264 kwh/annum
- Selling rate of electricity – INR 7/Kwh.
- Estimated tipping fee – INR 1430 per tonne of MSW
- Currency conversion rate 1 Euro = 72.20 INR

9.2 Project Costing under Alternative Scenario

The project cost has also been calculated for the scenario in which we install a combustion unit within the plant premises to utilise the RDF. This has been described earlier in section 7-4

9.2.1 Capital Cost

The capital costs for the MYT facility involves the costs of the following components:

- Waste Receiving Facility;
- Mechanical Separation Unit;
- DAMP
- Anaerobic Digestion Unit;
- Combustion Unit

Table 9-5: Budget Investment Cost MYT Plant with Combustion Nagpur, India - 800 t/d

S.No	Component	No	Unit Cost(€)	Cost (€)	Cost (INR-Crores)
1	Waste Bunker	1	760,000	760,000	5.43
2	Pre-Shredder	2	380,000	760,000	5.43
3	Percolation Agitators	5	855,000	4,275,000	30.54
4	Planetary gear boxes with motors	5	475,000	2,375,000	16.96
5	Dewatering Presses	5	427,500	2,137,500	15.27
6	Mechanical Process water treatment	2	332,500	665,000	4.75
7	Anaerobic Reactor	3	1,710,000	5,130,000	36.64
8	Dewatering station anaerobic sludge	2	237,500	475,000	3.39
9	Gas storage Tank	2	902,500	1,805,000	12.89
10	Desulfication	2	332,500	665,000	4.75
11	CHP Unit	4	807,500	3,230,000	23.07
12	Air treatment Biofilter	1	807,500	807,500	5.77
13	Post Shredder	2	237,500	475,000	3.39
14	Electrical Installation	1	2,850,000	2,850,000	20.36
15	Miscellaneous	1	2,000,000	2,000,000	14.29
	Subtotal (Mechanical Equipment)			**28,410,000**	**202.93**
16	Transportation			1,551,000	11.08
17	Installation cost			3,409,200	24.35
18	Startup 2px180000€/ax2a			720,000	4.86
19	Engineering cost			2,841,000	20.29
20	Civil work			4,261,500	30.44
	Subtotal (Alternative)			**41,152,700**	**293.95**
21	300 TPD Grate Combustion unit			35,000,000	250.00
	Total Cost			**76,152,700**	**543.95**

The total capital cost for the 800 TPD MYT (alternative) project along with combustion unit is estimated to be **Euro 76.15 million** or **INR 543.95 crores**.

9.2.2 Operational Cost

The operation cost for MYT at Nagpur has been elaborated in the following section.

Manpower cost

Table 9-6: Estimated manpower Cost MYT Plant Nagpur, India - 800 t/d

S. No	Personal	No	Operation Cost (€/a)	Operation Cost (INR-Crores/a)
1	Waste reception	4	20,000	0.14
2	Mechanical treatment	6	30,000	0.22
3	Biological step	4	20,000	0.14
4	Wastewater treatment	4	20,000	0.14

S. No	Personal	No	Operation Cost (€/a)	Operation Cost (INR-Crores/a)
5	Control station	5	25,000	0.18
6	Maintenance/Management	4	20,000	0.14
7	Sick leave / holiday replacement	6	30,000	0.22
	Total		**165,000**	**1.19**

The annual manpower cost for the project is Euro 0.17 million or INR 1.19 crores

Plant Operation & Maintenance cost

Table 9-7: Estimated Plant Operation & Maintenance Cost 800 t/d MYT & 300 t/d Combustion Plant Nagpur, India

S. No	Consumables	Operation Cost (€/a)	Operation Cost (INR-crores/a)
1	Chemicals	536,000	3.83
2	Diesel	201,000	1.44
3	Lubricants	67,000	0.48
4	Fresh Water	26,800	0.19
5	Wear parts	670,000	4.79
6	Laboratory costs	26,800	0.19
7	Maintenance cost -MYT	643,200	4.59
8	Maintenance cost -Combustion	1,815,000	12.96
	Total	**3,985,800**	**28.47**

The annual operational cost for the project is Euro 3.99 million or INR 28.47crores

9.2.3 Revenue Assessment

The two key revenue sources for the project are sale of electricity and tipping fees. Table 9-8 provides details on the revenue estimated from the project

Table 9-8: Revenue Assessment for MYT & Combustion plant- Alternative Option

S. No	Consumables	Revenue (€/a)	Revenue (INR-Crores/a)
1	Tipping fee	6,008,688	41.76
2	Sale of electricity	6,778,957	47.11
3	Operational Expenses*	-5,610,178	-38.99
	Total	**7,177,467**	**49.88**

**Operating expense include all the operating cost including parasitic consumption*

Total estimated net revenue from Tipping Fees and sale of electricity after deduction of operating expense is estimated at **Euro 7.18 Million** per annum or **INR 49.88 crores**. The assumptions taken for revenue assessment are provided in the following section.

- About 330 TPD of RDF generated will be utilised in the combustion plant
- Average energy content of RDF – 12064 KJ/kg
- Expected biogas output – 1870 m^3 per hour

- Methane content – 49%
- Energy Content – 10 kWh/m³CH4
- Tipping Fees is assumed at INR 1430/Ton of MSW
- Estimated electrical conversion efficiency – 39%
- Estimated electricity generation – 67,298,288 kwh/annum
- Selling rate of electricity – INR 7 /KWh.
- Currency conversion rate 1 Euro = 72.20 INR

9.3 Conclusion & Path Forward

Due to the high moisture and organic content of the MSW and taking into consideration that the MSW collection takes place as mixed waste, mass incineration is not recommended for Nagpur. We recommend an enhanced process which operates without waste segregation at the source therefore providing easy transformation to energy. According to our assessment, the mechanical-biological treatment of the MSW is the most suitable technology under the existing scenario; and the MYT process based on the technology providing maximum utilisation of waste, minimum diversion of rejects to landfill and highly flexible process for heterogeneous waste is most suitable for Nagpur.

MYT is a proven technology for mixed as well as segregated waste and aims at maximizing the resource recovery from waste. In comparison to the traditional waste treatment solutions of landfilling, composting and incineration, MYT extends the technological portfolio of waste management, allowing for optimum economic exploitation of MSW in the form of raw materials, quality-assured fuels and energy-rich biogas. The waste characterization study conducted for Nagpur indicated a very high percentage of organic fraction (approximately 56%) and moisture content (56%), which makes it unsuitable for incineration-based processes. At the same time, the waste characteristics are extremely favourable for processing through MYT.

The incineration-based projects in India have not been very successful in demonstrating air emission standard compliances and are facing public resistance. MYT, being a state-of-the-art and an emission-free clean technology, requires less land compared to other waste treatment technologies and has very high social acceptability, even from the residents residing in the immediate vicinity of the plant. The process is also odour free in comparison to many prevalent waste processing technologies and can be recommended for Nagpur.

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