TEXTE
06/2019

Annex to the final report: Resource and Climate Protection through integrated Waste Management Projects in Emerging Economies and Developing Countries – Example India

For our Environment

Umwelt Bundesamt

TEXTE 06/2019

Environmental Research of the
Federal Ministry for the
Environment, Nature Conservation
and Nuclear Safety

Project No. (FKZ) 3715 33 313 0
Report No. (UBA-FB) 002758/ANH,ENG

Annex to final report: Resource and Climate Protection through integrated Waste Management Projects in Emerging Economies and Developing Countries – Example India

by

K. Vijaya Lakshmi, Krishna Chandran, Achu R. Shekhar, Kavya Arora
Development Alternatives (DA), New Delhi, India

K P Pravinjith, Ayeesha Khanam
Ecoparadigm, Bangalore, India

Andrea Stubbusch, Regine Vogt, Claudia Kämper
ifeu – Institut für Energie- und Umweltforschung GmbH, Heidelberg, Germany

On behalf of the German Environment Agency

Imprint

Publisher:
Umweltbundesamt
Wörlitzer Platz 1
06844 Dessau-Roßlau
Tel: +49 340-2103-0
Fax: +49 340-2103-2285
buergerservice@uba.de
Internet: www.umweltbundesamt.de

/umweltbundesamt.de
/umweltbundesamt

Study performed by:
ifeu - Institut für Energie- und Umweltforschung Heidelberg GmbH,
Im Weiher 10
69121 Heidelberg

Development Alternatives
B-32, TARA Crescent, Qutub Institutional Area
New Delhi – 110016, India

Paradigm Environmental Strategies (P) Ltd.
916, 8th Floor, Oxford Towers
Kodihalli, Old Airport Road,
Bangalore – 560008, Karnataka, India

Study completed in:
August 2018

Edited by:
Section III 2.4 Waste Technology, Waste Technology Transfer
Anja Schwetje

Publication as pdf:
http://www.umweltbundesamt.de/publikationen

ISSN 1862-4804

Dessau-Roßlau, January 2019

Contents

List of figures

List of tables

Abbreviations

AMRUT	Atal Mission for Rejuvenation and Urban Transformation (second phase of JNNURM; newly launched by the Government of India for 500 cities with focus on ensuring basic infrastructure services)
BAU	Business as usual
BBMP	Bruhat Bangalore Mahanagara Palike
BDA	Bangalore Development Authority
BEL	Bharat Electronics Limited
BHEL	Bharat Heavy Electricals Limited (http://www.bhel.com/)
BMC	Bhopal Municipal Corporation
C&DW	Construction & demolition waste
CCAC	Climate and Clean Air Coalition
CDM	Clean Development Mechanism (Kyoto-Protocol)
CHP	Combined heat and power
CPCB	Central Pollution Control Board (India, national level)
CPHEEO	Central Public Health & Environmental Engineering Organization (India, national level)
CRF	Common Reporting Format (Kyoto-Protocol)
DOC	Degradable organic carbon
DOCf	DOC which decomposes
DWCC	Dry Waste Collection Center
GCF	Green Climate Fund
GCL	Geosynthetic clay liner
GDP	Gross domestic product
GHG	Greenhouse Gas
GNI	Gross national income
GoI	Government of India
GWP	Global Warming Potential
HAL	Hindustan Aeronautical Limited
HDPE	High-density polyethylene
HMT Ltd	Hindustan Machine Tools Limited
IGCS	Indo-German Centre for Sustainability (inaugurated Dec 2010 at the IIT Madras, Chennai; with Waste Management as one of six main research areas; http://www.igcs-chennai.org/
IISC	Indian Institute of Science
IIT	Indian Institute of Technology
IL&FS Ltd.	Infrastructure Leasing & Financial Services Limited

INDC	Intended Nationally Determined Contribution (submitted to UNFCCC)
IPCC	Intergovernmental Panel on Climate Change
IPMA	Indian Paper Manufacturers Association (http://www.ipma.co.in/)
ISRO	Indian Space Research Organization
JNNURM	Jawaharlal Nehru National Urban Renewal Mission (India)
KMC	Karnataka Municipal Corporation
kWh	kilowatt hour
MBT	Mechanical-biological treatment
MBS	Mechanical-biological stabilization
MCF	Methane correction factor
MNRE	Ministry of New and Renewable Energy (India)
MP	Madhya Pradesh
MoEF	Ministry of Environment, Forest and Climate Change (India)
MoUD	Ministry of Urban Development (India)
MRV	Monitoring, reporting, verification
MSW	Municipal Solid Waste
MSWI	Municipal solid waste incinerator
NAMA	Nationally Appropriate Mitigation Action (Kyoto-Protocol)
NSWAI	National Solid Waste Association (Indian ENVIS Centre)
OX	Oxidation factor
PE	polythene
RDF	Refuse derived fuel
SBM	Swachh Bharat Mission
SHG	Self Help Group
SLB	Service Level Benchmark (initiated by MoUD, GoI 2009; introduced in 30 states across 1700 ULBs); including SWM (above others goals on collection, scientific disposal)
SPCB/PCC	State Pollution Control Board / Pollution Control Committee
SWM	Solid waste management
SWDS	Solid waste disposal site
TPD	Tons per day
ULB	Urban Local Body
UNFCCC	United Nations Framework Convention on Climate Change
WtE	Waste to Energy

Annex 1: Solid Waste Management

Bangalore

1 Annex 1: Solid Waste Management Bangalore

1.1 Objective and scope

'Resource and Climate Protection through Integrated Waste Management Projects in India' is a research study commissioned by the German Environment Agency and funded by Germany's Federal Ministry for the Environment, Nature Conservation and Nuclear Safety. The project is implemented by the German ifeu (Institute of Energy and Environment Research) along with Development Alternatives and Ecoparadigm.

The objective of the study is to support decision makers in identifying potentials to optimize their waste management and simultaneously reduce greenhouse gas emissions in the waste sector in order to identify the best possible access to climate finance funds. It will show specific GHG emission saving potentials of an integrated waste sector approach for Indian cities at present and for future scenarios. The study adresses specific selected cities and the selection is done systematically with respect to the three priority criteria including availability and quality of waste data, stakeholder support to improve waste and contact network and other criteria such as population, income level and climate zone. The final selected cities were Bangalore, Bhopal and Haridwar.

This report section presents a snapshot of Municipal Solid Waste management (MSWM) in Bangalore. Secondary level data and information that is collected from government officials, MSW treatment plant operators and subject experts is analyzed and interpolated. The verification of data collected, analysis results and the data gaps were shared with different stakeholders and detailed discussions were conducted in form of a stakeholder awareness workshop, results of which are also shared in the report.

1.2 Bangalore an overview

1.2.1 Geography and Topography

The city of Bangalore (12.97°N and 77.56°E), the State capital of Karnataka is located on the southern part of the Deccan plateau at the border of two other South Indian states, Tamil Nadu and Andhra Pradesh. Bangalore is draped over the Deccan plateau at an altitude of 949 meters (3113 ft.) above sea level, which gives it possibly the best climate among all the cities in India. The Bangalore metropolitan covers an area of 223 km^2, and is the fifth largest city in India. The city apart from being the political capital of the state is also a very important commercial center with some of the major industrial establishments[1].

1.2.2 Climate

According to the Köppen Geiger climate map (Peel et al. 2007) Bangalore is classified as "Aw", tropical wet and dry or savanna climate. Bangalore is considered to be climatically a well-favored district. The climate of the district is classed as the seasonally dry tropical savanna climate with four seasons. The dry season with clear bright weather is from December to February with summer from March to May, followed by the southwest monsoon season from June to September. October and November constitute the post-monsoon or retreating monsoon season. The main features of the climate of Bangalore are the agreeable range of temperatures, from the highest maximum of 33°C in April to the lowest minimum of 14°C in January. The two rainy seasons, June to September and October to November, come one after the other but with opposite wind regimes, corresponding to the southwest and northeast monsoons. Bangalore records high temperatures during April with daily mean temperatures of 33.4°C and mean daily minimum in the month of December at 25.7°C, as the coolest month. The mean monthly relative humidity is lowest during the month of March at 44% and records highest between the months of June and October at 80 to 85%. The mean annual rainfall is 859.6 mm, with three different rainy periods

[1] http://ces.iisc.ernet.in/energy/wetlands/sarea.html

covering eight months of the year. June to September being rainy season receives 54% of the total annual rainfall in the S-W monsoon period and 241 mm during the N-E monsoons (Oct - Nov). The surface winds in Bangalore have seasonal character with the easterly components predominating during one period followed by the westerly in the other. The high wind speed averages 17 km/h during the westerly winds in the month of July and a minimum of 8-9 km/h during the months of April and October.

Bangalore grew radially from 1973 to 2010 indicating that the urbanization is intensifying from the central core and has reached the periphery of the Greater Bangalore. Urban heat island phenomenon is evident from large number of localities with higher local temperatures. The pattern of growth in Greater Bangalore has implication on local climate (an increase of ~2 to 2.5°C during the last decade) and also on the natural resources (74% decline in vegetation cover and 66% decline in water bodies), necessitating appropriate strategies for the sustainable management of natural resources.

1.2.3 Population and Urbanization

Bengaluru has a population of about 8.52 million as per census of India 2011 (Census Organization of India 2015) by covering an area of ~800 km². As one of the world's fastest growing cities, Bangalore is experiencing a steady increase in population (3.25% current annual growth rate). Its population is likely to be 10 million by 2021. The growth is spurred by the advantages conferred on the city by entrepreneurial and intellectual capacity incubated through a series of private and government actions. Besides, Bangalore enjoys a favorable climate, a high quality of life, a cosmopolitan ambience and social diversity. The city has earned the titles of "IT Hub of Asia" and "Silicon Valley of India." Since 1980s, Bangalore has enjoyed the reputation of being one of the fastest growing cities in Asia (Ramachandra & Bachamanda 2007). However, while the IT based formal sector accounts for 15% of its economy, the informal sector contributes 60-70% (BDA 2005).

On the other hand this concentrated growth has resulted in the increase in population and consequent pressure on infrastructure, natural resources ultimately giving rise to a plethora of serious challenges such as climate change, enhanced greenhouse gas emissions, lack of appropriate infrastructure, traffic congestion, and lack of basic amenities (electricity, water, and sanitation) in many localities, etc. Land use analysis show 584% growth in built-up area during the last four decades with the decline of vegetation by 66% and water bodies by 74%. Analysis of the temporal data reveals an increase in urban built up area of 342.83% (during 1973 to 1992), 129.56% (during 1992 to 1999), 106.7% (1999 to 2002), 114.51% (2002 to 2006) and 126.19% from 2006 to 2010[2].

From growth pattern analysis studies (Geospatial World 2014) it was concluded that the main urban growth concentration will be mainly in the vicinity of arterial roads and outer ring roads. This also showed that the peripheral regions and the buffer regions which include towns such as Yelahanka, Hesaragatta, Hoskote and Attibele would accommodate most of urban expansions in next decade. Further, an exuberant increase in the urban paved surface growth is observed in south east and north east due to the new industrial hubs (Bharath H Aithal 2013). The results indicate that the urban area would cover close to 50 to 60% of the total land use in and surrounding Bangalore.

1.2.4 City Structure

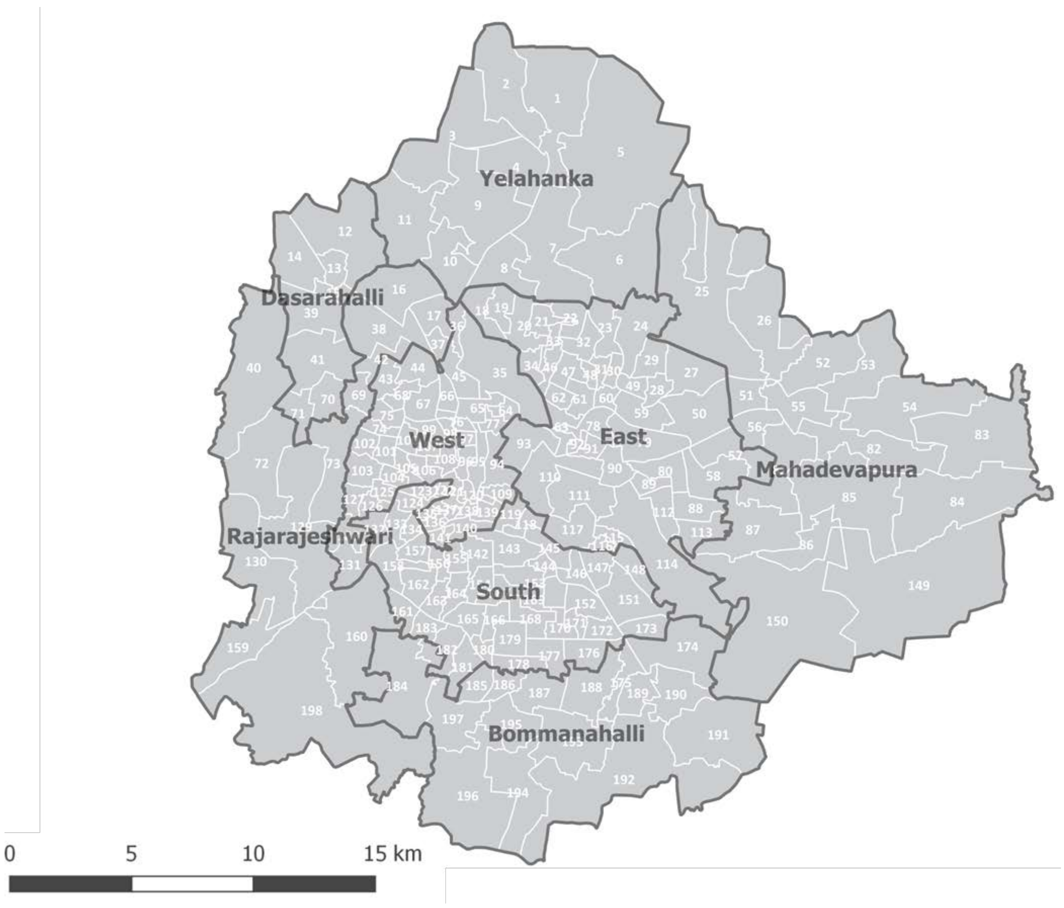
Bangalore city is under the administration of Bruhat Bangalore Mahanagara Palike (BBMP). BBMP was formed from the Bangalore Mahanagara Palike (BMP) through notification under Karnataka Government on January 16, 2007. Later in the year 2009, the Government through an amendment to KMC Act, 1976 increased the number of wards from 100 to 198 to cover a vast and growing Bangalore. For ease of administration the zones are classified into eight sub-administrative zones. The zones are namely

[2] http://ces.iisc.ernet.in/energy/wetlands/sarea.html

West zone, East zone, South zone, Bommanahalli zone, Byatarayanapura zone (Yelahanka), Dasaharahalli zone, Mahadevapura zone, Rajarajeshwari Nagar Zone (Figure 1).

The BBMP represents the third level of government (the Central and State Governments being the first two levels), and is run by a city council that comprises corporators (or elected representatives) with one corporator representing each ward of the city. Elections to the council are held once every 5 years, with results being decided by popular vote. Members contesting elections to council typically represent one or more of the state's political parties though they may also be independent. A mayor and deputy mayor of the council are also elected for a period of 1 year, though not by popular vote.

Figure 1: Zones and wards in Bangalore



Cartography: ifeu; spatial data based on CC BY-SA 3.0, http://openbangalore.org

1.2.5 Industries

Going back to history of industrial development in Bangalore, HMT Ltd, BEL, HAL, and ITI Ltd. were established by the Government of India in 1950's and 60's because of the dust free environment of Bangalore within the vicinity of IISC (Indian Institute of Science), a premier institution of India in the field of science and Technology. This initiative brought a highly talented workforce in Bangalore. Later ISRO, Government owned space research organization, opened its center in Bangalore. This initiative made Bangalore, a hub of electronic industries and also brought a pool of several other medium and small manufacturers in Bangalore. Titan Industries the fifth largest watch manufacturer in the world, opened its factory in the heart of city in 1988 (Bangalore-City 2016).

The Indian software industry get noticed but also did Bangalore as a location when Texas Instrument opened its R&D center in Bangalore. Hewlett-Packard followed the path in 1988. The primary aim in coming to India was to establish a base in the Asia/Pacific region. India was selected because of its strong educational system in theoretical sciences and engineering. And soon more and more came to Bangalore making the city as "Silicon Valley of India". Today, Bangalore contributes most of the IT export from India.

The Government policies contributed towards development of industries in Bangalore. Karnataka Government in late 80's created the Electronic City, 18 km from Bangalore, for the software and electronic industries. Several Technology parks were created in the last decade to host hundreds of companies. Most sought after parks are International Tech Park Bangalore (ITPL), Prestige Technology Parks, Prestige Blue Chip Software Park and the Cessna Business Park and cyber park. Special Economic Zones (SEZs) also under construction in Bangalore.

The city is also known as the hub of biotech industries of India with 41% of the total 265 biotech companies in India. Institute of Bioinformatics and Applied Biotechnology (IBAB), initiated by Biotechnology vision group, ICICI bank and Biocon (located at ITPL) is trying to shape revolutionary scientists in the field.

Bangalore is the 4th most developed city in India. More importantly it is growing very fast and soon it will go up in rank. Currently its total GDP is 83 Billion USD or Rs. 4,81,400 Crore. It is ranked number 84 in the world among Developed cities. The city is the third largest hub for high net worth individuals after Mumbai and Delhi[3].

With the boom of IT industries, the life style of the workforce increased the demand of hotel industries, fast-moving consumer goods industries and several other allied industries and their markets, leading to major investments being made in Bangalore and adjoining areas.

1.2.6 Energy Generation

Bangalore is powered by the same grid that supplies to the entire Karnataka state. Thermal power comes from coal, gas and diesel stations. Raichur and Bellary Thermal Power Stations (RTPS and BTPS), and Yelahanka Diesel Generating Station (YDGS) are the state's major thermal stations. In addition, the state also has 15 hydro-electric power stations that supply energy to the grid.

The state also gets power from Central Generating Stations (CGS) like Neyveli Lignite Corporation, Kaiga atomic power station in North Karnataka etc. Together, the sources have the maximum capacity to produce 12,000 MW of power, but actual generation is about 6,000 MW and the extent of generation from each source varies through the day.

Information on the grid mix in percent is not available. For the greenhouse gas balances the grid mix information known for India is used.

1.3 Municipal Solid Waste Management in Bangalore

1.3.1 Background

In Karnataka over 50% of the municipal solid waste is generated in six municipal corporations. Bangalore city generates around 3500 TPD of solid waste (KSCPCB 2014), which is 10 times higher than its next municipal corporation in the state (like Mysuru, and Hubballi Dharwad). The per capita waste generation in Bangalore city is 0.4-0.6 kilograms per capita per day. Most of the municipal waste is generated in residential and market areas. The average waste generation per households is 1.24 kg whereas it is 1.5 kg in slums[4].

[3] http://top10wala.in/top-10-most-developed-city-in-india-by-gdp/

[4] http://bbmp.gov.in/en/web/guest/swm-cell: „city statistics &infrastructure": http://bbmp.gov.in/documents/10180/512162/City+Statistics+New+Microsoft+Office+Word+Document.pdf/148f685d-58cd-402c-9c5c-bccb344eda2d; last access 17-04-2017

The general waste composition is given in Figure 2 which shows that most majority of waste is organic in nature whereas the hazardous and the biomedical portion still collected with the MSW is less than 5% of the waste quantity. According to the Waste Management Rules 2016 "waste generators shall segregate and store the waste generated by them in three separate streams namely bio-degradable, non bio-degradable and domestic hazardous waste in suitable bins" (MoEFCC 2016).

Figure 2: General waste composition in Bangalore

Waste Composition (Approximate) [For Guidance Only]

Vegetable	0.30
Paper	0.09
Plastic	0.12
Cardboard	0.04
Textiles	0.04
Grass/leaves/woos	0.06
Leather	0.00
Electronic item	0.02
Metal	0.01
Organic	0.23
Glass	0.03
Debris	0.05
Biomedical	0.02

Source: BBMP website[5]

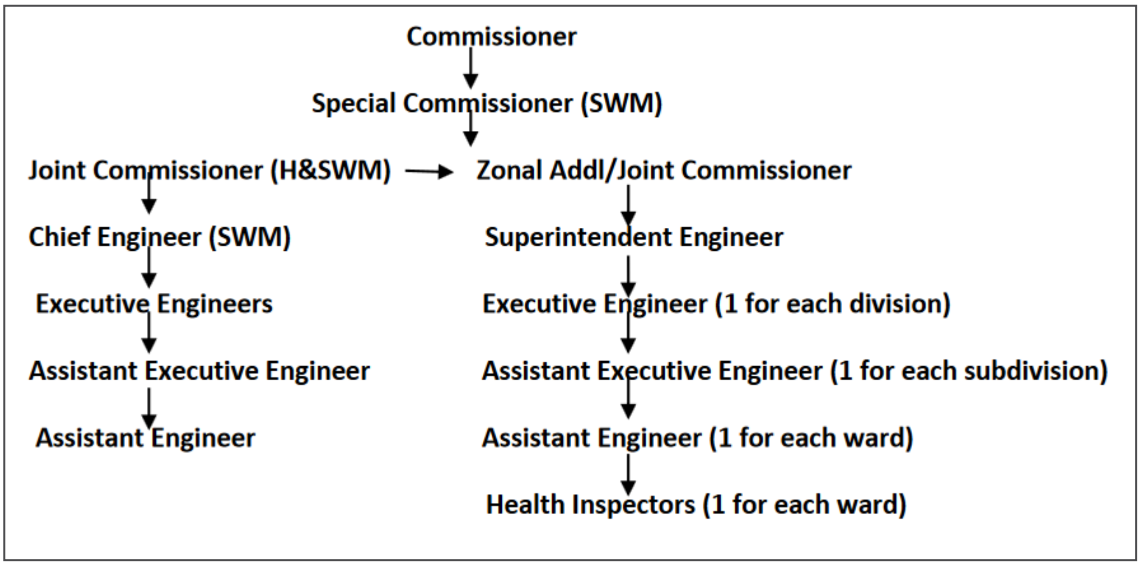
1.3.2 Organizational Structure SWM

Solid Waste Management in Bangalore is handled by the SWM Department headed by the Special Commissioner for SWM. The organizational structure of the SWM Department is shown in Figure 3. BBMP is carrying out collection, street sweeping, transportation, treatment and disposal of Municipal Solid Waste from generators. BBMP has a system of door-to-door collection for collecting the MSW. The MSW collected has to be processed before landfilling. BBMP has taken several steps to streamline the MSW management in the city. SWM is managed directly by BBMP using own staff as well as contractual staff and contractual private organizations. In addition, several NGOs and welfare groups are also involved in waste management in Bangalore.

Special budget is allocated by BBMP for waste management and Rs. 459 to 488 crores (70 to 75 million USD) have been spent in previous financial years FY 2014-15 & FY 2015-16 towards solid waste management expenses. 440 crores (68 million USD) have been allocated in the FY 2016-17. In addition, a special fund of Rs. 300.00 crores (46 million USD) are kept for solid waste management and disposal and other developmental works related to SWM.

[5]http://218.248.45.169/download/health/swm.pdf

Figure 3: BBMP organizational chart of Solid Waste Management



Source: BBMP website[6]

1.3.3 Key rules and policies concerning SWM in Bangalore

Policy support is critical for proper SWM and to enable Urban Local Bodies (ULBs) with sufficient funds, resources, infrastructure and appropriate strategies for improved solid waste management.

There are different levels of SWM rules in India which is also applicable to Bangalore, starting from recently published national level Solid Waste Management Rules, 2016 (MoEFCC 2016) in supersession of the SWM Rules, 2000, State level act, The Karnataka Municipal Corporations Act, 1976 which includes special mention of SWM and ULB level policy in form of SWM master plan for Bangalore 2008.

In addition, on a national level, there is specific rules specifying to special kind of wastes including C&D waste management rules, India 2016, Plastic waste management rules India 2016, Biomedical Waste management rules 2016 which all are applicable to SWM[7]. In addition, there are SWM support documents including the SWM manual 2000 (MoUD & CPHEEO 2000) and several SWM circulars released by the state and the local governments, like the circular on Plastic Ban Notification from BBMP[8].

1.3.4 SWM Programs in Bangalore

Several programs have been initiated in Bangalore for optimization of waste management. Programs varying from government initiatives to international support group programs to local self-help group programs and community level initiatives. Some of the notable programs are listed below.

1.3.4.1 Swachh Bharat Mission

Swachh Bharat Mission (SBM) is a national level campaign being implemented by the Ministry of Urban Development (MoUD) and by the Ministry of Drinking Water and Sanitation (MoDWS) for urban and rural areas in India for ensuring hygiene, waste management and sanitation across the nation. The mission lays down specific guidelines to be followed by governing bodies in a national level, state level and city level. As part of the project Door-to-Door (D2D) waste collection and Waste to Compost are being promoted in Bangalore city also. According to the statistics by Swatch Bharat website, D2D collection of

[6] http://bbmp.gov.in/documents/10180/512162/Organization+Chart+of+Solid+Waste+Management.pdf/2697cd91-79d5-4785-8ed2-d7ce4d0e8d7b; last access 17-04-2017; see also footnote 4

[7] http://www.nsc.org.in/index.php?option=com_content&sectionid=-1&view=article&id=168

[8] http://bbmp.gov.in/en/web/guest/swm-circulars

MSW has been implemented in 3962 wards of the total 5276 wards and 21,469 metric ton of waste has been turned into compost in India in the year 2016 alone[9].

The mission aims at 100% door to door collection of waste, 100% organic waste treatment and generation of at least 20 MW of electricity from waste to energy conversion in Bangalore by 2nd October 2019.

1.3.4.2 JN-NURM projects

Jawaharlal Nehru National Urban Renewal Mission (JNNURM), launched in 2005-06, enables the mission cities to take steps for sustainable improvements in their civic services levels, through an additional central assistance (ACA) of INR 50,000 crores (7592 Million USD) for seven years beginning from 2005-06 and an equal amount from the State Governments and ULBs. Out of the ACA, Rs. 25,500 crore (3923 Million USD) is for the submission, urban infrastructure and governance (UIG), which also includes solid waste management[10].

Among cities, Bangalore has had the highest number of approved projects. Although most of the funds in Bangalore are for infrastructure development and the metro rail development and financial support under C-BULB are extended for setting up of centers of excellence, addressing specific capacity gaps in SWM and applicable research in this sector.

The JNNURM project and funding ended in March 2015[11].

1.3.4.3 2Bin 1Bag Initiative

2Bin 1Bag – divide and conquer waste is an initiative by citizen groups that work proactively with the government at finding solutions for waste management. The movement is a combined effort of multiple citizens groups inside Bangalore including the Kasa Muktha Bellandur, HSR Citizen Forum, We Care for Malleswaram, Solid Waste Management Round Table (SWMRT) and many others where waste segregation at household level is practiced and promoted at community level. The program has also been identified and supported and further taken up by BBMP. BBMP has started collecting waste in segregated manner from house hold level in support to the program. Wet waste, dry waste and sanitary waste is collected in separate bins/bags and managed separately. The initiative is supported by court orders, public awareness campaigns and imposing penalties for non-cooperation. The high-court of Karnataka has passed an interim order on December 17, 2015 to citizens in Bangalore to mandatorily practice 2bin 1bag system[12].

1.3.4.4 Wow Program

Wealth Out of Waste (WOW), a recycling program initiated in April 2007 by the Paperboards & Specialty Papers business of ITC Ltd. This has evolved into a corporate level program with scope enhanced to "Well-being out of waste" focused on creating scalable solutions for spreading awareness about recycling, encouraging people to segregate & dispose waste responsibly and creating sustainable livelihoods for people working as rag pickers.

A pilot project on recycled compact boards made out of packaging waste collected from Indian cities has led to the development of school furniture which have been deployed in schools supported by ITC. Applications for these boards within ITC facilities are also being explored. Chennai, Bengaluru and Coimbatore, Hyderabad are some of the major cities in which the program is initiated in tie-up with the local authorities.

[9] http://swachhbharaturban.gov.in/

[10] http://indiabudget.nic.in/es2008-09/chapt2009/chap913.pdf

[11] http://timesofindia.indiatimes.com/city/pune/JNNURM-projects-to-get-funds-from-central-scheme/articleshow/47462699.cms; https://www.adb.org/projects/39645-012/main#project-overview

[12] http://www.2bin1bag.in/

In Bangalore ITC has collaborated the program along with BBMP, where strictly segregated waste from Dry Waste Collection Centers (DWCCs) is provided to ITC. The waste is purchased by ITC at a fixed rate. What started with just 10 tons collection of recyclables through the WOW collection has now swelled to over 4000 tons per month. Over 3 million citizens, 500,000 school children, 350 corporates, over 1,000 commercial establishments and about 200 industries are supporting WOW across South India[13].

1.3.4.5 Smart Cities Mission

Smart Cities Mission is an initiative to promote cities that provide core infrastructure and give a decent quality of life to its citizens, a clean and sustainable environment and application of 'Smart' Solutions. The focus is on sustainable and inclusive development and the idea is to look at compact areas, create a replicable model which will act like a light house to other aspiring cities. Even though Bangalore has not yet been identified as a smart city, BBMP has initiated a Namma Bengaluru Smart City program in order to develop Bangalore into Smart City standards[14].

A smart city strategy was announced during public consultation program organized by BBMP on 23rd June, 2016. Bangalore has adopted an area based development approach instead of an entire city development, which seems completely practical considering the huge size of Bangalore and understanding the fact that only the available fund under the smart city development program is Rs. 1000 crore (154 Million USD) over a period of 5 years. Yelahanka is the proposed smart city area and an area over 500 acres will be selected with consultation with the citizens for further development.

Main components of the program include retrofitting, i.e. to introduce planning in an existing built-up area to achieve smart city objectives, to make the existing area more efficient and livable, secondly redevelopment - to replace the existing built-up environment and enable co-creation of a new layout. Developing greenfield is the third strategy. That is to introduce smart solutions in a previously vacant area (more than 250 acre) through innovating planning, plan financing and implementation tools. In all these aspects SWM is an important aspect and even though the program is in an initial stage, if Bangalore is selected in the second round of smart cities the program will bring in development to the SWM in the city.

1.3.4.6 I got garbage

I Got Garbage is a Corporate Social Responsibility (CSR) initiative of Mindtree in the area of rag-picker livelihood and solid waste management. An important goal is to involve citizens and communities in solving the problem of managing solid waste, such that we collectively create jobs for hard working rag-pickers, and also make cities cleaner. The prime action city for the initiative is Bangalore.

I Got Garbage is basically a cloud based IT platform, and offer capabilities such as an Enterprise Resource Planning (ERP) for rag-pickers, Citizen Engagement Platform, Waste Management Services Marketplace, and a Rag-picker Benefits Tracker. Additionally, they work with social businesses towards process improvement as well as help build partner ecosystems. Since 2013 the initiative has supported the recycling of more than 9000 tons of waste in addition to creating job opportunities and green environments. The rag-pickers pick both wet waste and dry waste from their clients; the dry waste is transported to DWCCs in Bangalore whereas wet waste is converted into biogas and compost[15].

1.3.4.7 SWMRT conferences

Solid Waste Management Round Table (SWMRT) is a SWM interest group to bring the Solid Waste Management Rules and its recommendations to life for Bangalore city. The group consist of various organizations, individuals and vendors all working in the field of waste management and meet on regular time

[13] http://www.itcportal.com/media-centre/press-releases-content.aspx?id=1388&type=C&news=National-Recycling-Day

[14] http://namma-bengaluru.org/about_us.html

[15] http://www.igotgarbage.com/

intervals to exchange ideas, share experiences and come out with a common agenda for Bangalore solid waste management based on the best practices[16].

The group has been active since 2009, joining the various strengths and abilities of its members, SWMRT has created synergies and efficiencies. Through its work, thousands of households and institutions have converted to segregation at source which means that every day tons and tons of waste are being recovered and converted into renewed material instead of being dumped at the outskirts of the city.

Between 2009 and 2010 alone SWMRT converted 25,000 households, hundreds of schools, institutions and companies to segregation at source, recycling and composting, thereby saving about 650 tons a month from being dumped into landfills.

According to the organization NO_2, CO_2 calculation in 2010, SWMRT's efforts on paper recycling alone reduced the carbon footprint of Bengaluru by 4,633 tons which equals climate change mitigation of 18,530 trees.

In 2011 SWMRT set up in-house waste management systems within the campuses of the BBMP and the BDA supported by backend dry waste collection and composting of its garden wastes. Members of the group trained over 125 environment officers in BBMP.

They also worked with the Horticulture department especially in the Yelahanka and South Bangalore areas to carry out composting of leaf litter in its parks. Community composting operations have been taken up in Malleswaram (Market), Ejipura and Jayanagar.

Dozens of go-downs in various parts of the city have been set up with the support of BBMP for facilitating dry waste collection and storage from the surrounding residential areas. Dry waste collection center operations were started in Anandnagar, HSR Layout, Gottigere, Ejipura, Yelahanka, Domlur and Koramangala by the end of 2012. The concept gained more recognition and by 2016 Bangalore has established 170 DWCCs across the city out of which 124 are in working condition (BBMP 2016b).

1.3.4.8 HasiruDala

HasiruDala is a membership based non-profit organization of waste pickers and other informal waste workers in Bangalore. HasiruDala strives to integrate marginalized informal waste workers including waste pickers in the solid waste management framework by utilizing their expertise in the domain. Initiated in 2013, HasiruDala now has a membership of over 7500 waste pickers. Their work which includes collection, sorting, grading and transportation of waste for recycling which is foundational to both green and circular economies, much needed for mitigation of climate change. HarisuDala members provide service to more than 13000 households in Bengaluru[17].

1.3.4.9 The Ugly Indian Campaign

The Ugly Indian Campaign is a voluntary program run by citizens of Bangalore city, with a vision to clean the streets of the city. Volunteers gather in chosen locations in Bangalore and clean the area which is also supported by BBMP garbage staff and street cleaners.

The organizers choose to remain anonymous since they believe it is the results that matter. The campaign involves direct field implementation and does not have any lectures or group discussions. Ideas that are practical and self sustainable (without any monitoring) for a period of 90 days are considered implementable by the members[18].

[16] http://swmrt.com/

[17] http://hasirudala.in/

[18] www.theuglyindian.com

1.3.5 Status of SWM

Bangalore generates around 4000 MT of MSW per day (TERI 2015a). The BBMP is carrying out collection, street sweeping, transportation, treatment and disposal of Municipal Solid Waste from generators. Waste management involves different steps starting from collection, transportation, treatment and disposal. BBMP has taken several steps to streamline the MSW management in the city. Each step of waste management is explained in detail below.

1.3.5.1 Collection

Information on primary municipal solid waste collection in Bangalore is provided by BBMP (2016a). According to that MSW collection is practiced in form of either door step collection, litter point collection (where the community throws in waste and the collection staff collect the waste) and street cleaning where waste from streets of BBMP area is collected on a regular basis (mostly on a daily basis).

BBMP is providing daily waste collection service to all the households, slums, shops and establishment. About 80% of the collection and transportation activities have been outsourced. Auto tipper, autos and pushcarts are used for the primary collection. An Auto tipper has been provided for every 1000 households and a pushcart for every 200 households. About 20,000 Pourakarmikas are being utilized (both BBMP and contractors) in door to door collection, street sweeping and transportation of MSW. Self Help Group's (SHGs) and Residential Welfare Association (RWAs) are also involved in door to door collection, segregation & decentralized composting in some of the areas.

Separate system has been put in place or collection of waste from the large vegetable and fruit markets. The vendors are directed to store the waste in their premises to be collected by the Pourakarmikas to ensure that the market waste is transported to compost plants.

A separate system has been put in place to collect waste from large waste producers like hotels, restaurants, marriage halls, markets, offices, etc. As per the High Court directions, the BBMP has notified Bulk Generators to segregate waste into different categories and manage their waste either in-situ or to utilize the services of BBMP empanelled service providers.

Segregation at source has been emphasized. Information Education and Communication (IEC) activities are being intensified and penalties are being levied for non-compliance. The households are required to segregate their wastes into two categories namely wet and dry waste. At the later stage, household hazardous (or bio-medical or sanitary) waste like discarded medicine, sanitary napkins, diapers, batteries, paints etc. is proposed to be collected separately.

Bangalore city is a bin less city and the bins/litter bins are placed only in the commercial areas. The MSW collected from Door to Door is brought to a common point from where the waste is transferred to the treatment sites through compactors & tipper lorries.

About 670 MSW transportation vehicles including 240 compactors, 430 tipper lorries, dumper placers and mechanical sweepers are used for transportation of MSW to the treatment plants and landfill sites.

Figure 4: Door-to-Door collection (left) and tipper to compactor (right)

Figure 4 consits of 2 pictures: the left picture shows daily door-to-door collection in the streets of Bangalore. People bring their waste to workers collecting it in a small tipper.

Photos by ifeu Heidelberg

1.3.5.2 Waste treatment

Some of the observations of documented current status MSW treatment in BBMP are listed below (TERI 2015a):

- Major portion ~1200 TPD of the city's garbage is treated in Terra Firma (Integrated waste management facility) and 200 TPD in MSGP Infra Tech, respectively. These two plants at Doddaballapura are treating mixed waste after segregating at their site;
- Karnataka Compost Development Corporation (KCDC), at present processing 200 TPD segregated MSW and it is intended to increase to 500 TPD, after expansion;
- High court of Karnataka ordered Mavallipura landfill to be closed in 2012 and later in 2014 directed M/s Ramky to process 300 TPD of wet waste which is to be supplied by BBMP;
- For effective tackling of MSW and recovery of various recyclable materials, BBMP has set up Dry Waste Collection Center (DWCC)s in 170 wards, which has a receiving capacity of 1.5 tonnes of garbage per center;
- Notification has been sent by BBMP to bulk waste generators like Hotels, Restaurants, Kalyan Mantaps, Apartments etc., for establishing a separate system to scientifically manage the MSW generated in their premises or through any empanelled service providers;
- Two plants for converting food waste to Compressed Bio Gas (CBG) at Kannahalli (250 TPD) and Huskur (100 TPD) has been established by Bruhath Bengaluru Hotels Association (Noble Exchange Environment Solutions) and Maltose Agri Products Ltd respectively;
- After the High Court ordered BBMP not to dump any more garbage the way it has been and inadequate operations of earlier MSW treatment units, has forced BBMP to set up six new MSW treatment plants at Lingadheernahalli, Doddabidrakallu, Subbrayanapalya, Seegehalli, Kannenahalli and Chikkanagamangala;
- Detailed project report along with Environmental Impact Assessment and public hearing has been carried out for all these plants at an investment of Rs. 440 crore (66 Million USD);
- Although the BBMP has commissioned six new plants, it was observed that not all units are operating at their maximum potential. Around 200, 50, 80, 70 TPD of Mixed MSW are processed in Kannenahalli, Seegehalli, Doddabidarakallu and Subbarayappanapalya respectively. The Chikkanagamangala plant is yet to start functioning and temporary stay order has been issued for Lingadeernahalli, following the protest of the local people;
- Biomethanation power plants — BBMP has constructed 16 biomethanation plants across the various wards of the Bengaluru city, out of which 8-10 plants are operating and rest of them are under commissioning. Each plant has the capacity to process 5 tonnes of wet waste a day into biogas and generate around 50 KW power;

- About 1200 tonnes are open dumped at landfills in S. Bingipura and Lakshmipura (This was said to be closed recently, due to noncompliance of MSW rules);
- Apart from these, approvals have been given to waste to energy plants for M/s Satarem Enterprises (1000 TPD to 14 MW), M/s Organic Waste India – (600 TPD to 8.6 MW) and M/s Essel Infra (600 TPD). BBMP has signed an agreement with these franchises on PPP framework;
- Srinivasa Gayathri Resource Recovery Limited (SGRRL) was expected to set up an integrated MSW to energy plant at Mandur and generate 8 MW of power by treatment 1000 TPD of MSW. However SGRRL had failed to do so except few power plant machineries erected until now since the year 2005. BBMP has terminated their contract with SGRRL who is facing charges after huge sum of loan was raised pledging Mandur landfill;
- Quantity of recyclable waste diverted by scrap dealers, waste pickers, itinerant buyers, sorters and other workers in the informal sector was not available;
- It is estimated that about 30% of the processed MSW is recovered as RDF, 12%-15% yield of compost products and rest of the MSW comprising moisture and inert materials.

1.4 Study on the West Zone

A comprehensive study was conducted (Weichgrebe et al. 2016) that focuses on the 44 wards in West zone of Bangalore where the average per capita waste generation is estimated depending on the population density with 0.393-0.519 kg per day. The primary municipal solid waste collection system is by Door-to-Door collection, hence the system requires extensive involvement of manual labor. Waste is collected from the households by BBMP Pourakarmikas, private contractors or NGOs mainly through push-carts and auto tippers. Some categories of waste such as newspapers, milk covers, etc. often don't end up in this stream because they are collected separately mostly by the informal sector due to its economic value. In the study it is assumed that out of the total waste, Door-to-Door system accounts for 50%, litter spots account for 30% and 20% from street sweeping. The generation of waste may be linked to various parameters for the characterization exercise, though in Bangalore population density is the chosen criterion. A stratified random sampling exercise was carried out for the study. The statistical standards have been set for this study (based on EC SWA Tool, 2004) as follows:

- Confidence level = 95%
- Natural Variation Coefficient, Varcoeff (xi) = 45%
- Maximum allowance for random sampling error for the total results = 10%
- Confidence Coefficient, (tα; n-1) = 1.96

A thorough screening and sorting process was followed.

Figure 5: Distribution of population and waste generated according to stratification criteria

Stratification Matrix - Sampling Distribution		Low Density [%]	Medium Density [%]	High Density [%]
		29.0	28.0	43.0
Door-to-Door [%]	50	14.5	14.0	21.5
Street Sweepings [%]	20	5.8	5.6	8.6
Litter Spots [%]	30	8.7	8.4	12.9

Source: (Weichgrebe et al. 2016, Table 1)

Figure 6: Overview on the sampled waste amount from Door-to-Door stream

Strata	Weight of sampled municipal solid waste (in kg)				Population[1)]	Per-capita[1)]
	D2D	Litter Spots	Street Sweeping	Total	[sampled]	[kg/person/d]
Low Density	2,364.02	1,435.50	720.15	4,519.67	4,555	0.519
Medium Density	2,679.60	1,479.20	710.75	4,869.55	6,160	0.435
High Density	4,392.30	2,793.30	1,544.07	8,729.67	11,178	0.393
Total/Avg	9,435.92	5,708.00	2,974.97	18,118.89	21,893	0.431
% share	50	30	20	100		

1) Only refers to D2D collection

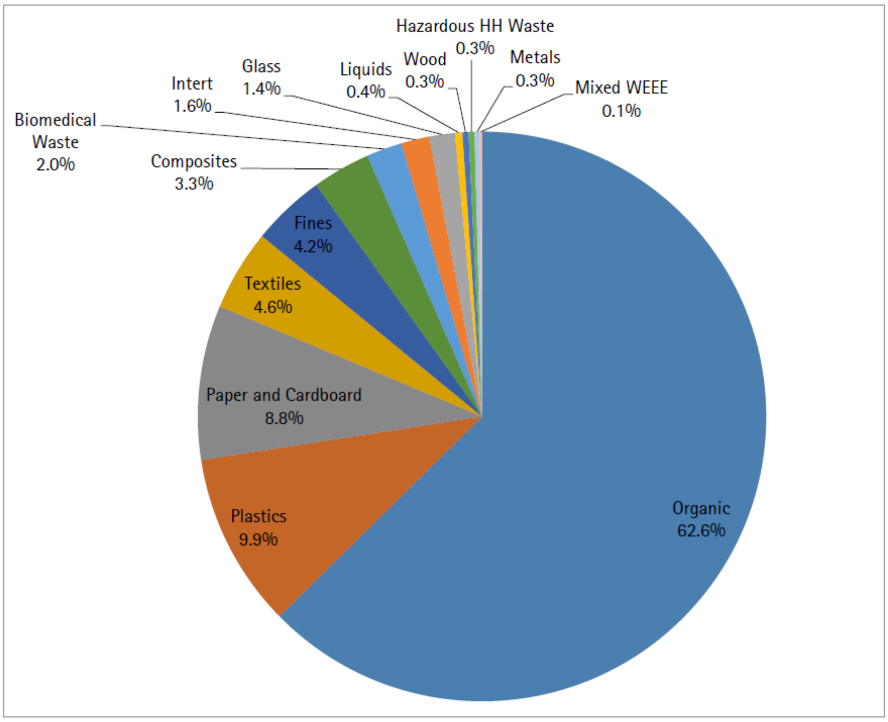
Source: (Weichgrebe et al. 2016, Table 8)

The study shows that low density areas generate more per capita waste than medium and high density populated areas (Figure 6). Based on the findings the waste generation in the West Zone was extrapolated to a total of 915.7 TPD, distinguished by source to:

- 457.85 t/d Door-to-Door collection
- 274.71 t/d litter spot collection
- 183.14 t/d street sweeping

The physical waste composition of typical household waste is depicted in Figure 7.

Figure 7: Overall MSW composition for West Zone, Bangalore



Source: (Weichgrebe et al. 2016, Figure 12)

The study also conducted a comprehensive chemical analysis. Water, organic and ash content were determined. Elemental analyses were carried out to obtain information required for designing treatment such as biological degradation, compost production, incineration and recovery potential. Figure 8 presents the values of organic dry matter (ODM), total organic carbon (TOC) and carbon available in the waste collection from door-to-door.

Figure 8: Overall MSW composition for West Zone, Bangalore

Parameters	Fraction group		
	>77 mm	14-77 mm	<14 mm
Carbon (%)	49.4	42.3	30.0
oDM (%)	59.7	55.0	57.0
TOC (ppm)	1700	1600	1200

Source: (Weichgrebe et al. 2016, Table 24)

The mixed solid waste investigated in Bangalore consists mainly (63%) of organic materials and the net calorific value of 8.1 MJ/kg (1935 kcal/kg) is considered low. This will lead to low energy production in the incinerator. Mechanical-biological treatment (MBT) process is described as the most feasible technology for waste treatment in West zone, Bangalore. It is also described that a more flexible MBT process needs to be implemented, adopting to local waste conditions and waste.

According to (Weichgrebe et al. 2016) MBT is an automated process of waste treatment in which wet/mixed waste is processed and segregated into compost, RDF, ferrous materials, recyclables and rejects.

1.5 Field data collection and analysis

Main task of this part of the study on integrated waste management in India is field level secondary data collection in form of questionnaire surveys and one to one meetings to understand in depth the actual scenario of waste management and the ground implication challenges in waste management in Bangalore.

During the initial stages of data collection in Bangalore it was observed that most critical data regarding management of waste on a climate change aspect is not available at a centralized level but available in a decentralized manner in zonal and ward levels and even treatment plant level. The original project aim to collect data on at least zonal level and selected representative treatment plants could not be realized to full extent due to certain difficulties like e.g. fluctuation of persons in power within the responsible authorities, difficulties to get appointments and clearances to visit treatment plants.

Against the background of these difficulties and the general lack of data on waste composition it was decided to focus on the West Zone where data from the ISAH report (Weichgrebe et al. 2016) could be used with respect to important information like waste composition and especially waste properties like net calorific value and carbon content which are of high importance for GHG accounting. In addition, some data were collected from other zones, especially Mahadevapura Zone, Yelhanka and South zone to assess if data for the West Zone might be transferrable.

In this study data has been collected from:

- Department of Solid Waste Management (SWM), Bangalore Municipal Corporation (Bruhat Bengaluru Mahangara Palike, BBMP, of the 8 zones in Bangalore, with more specific data from west zone and Mahadevapura zone,
- 5 dry waste collection centres (DWCC): 2 in the West Zone, 1 in Mahadevapura Zone, 2 in South Zone,

- 2 biomethanation plants: 1 in the West Zone, ward 67 and 1 in South Zone, Ward 151,
- 3 composting and/or mechanical biological treatment plants (MBT): Mavelipura, next to previous landfill site in the north of Bangalore, and Chikmangala and KCDC, both in the south of Bangalore,
- some recyclers and waste traders.

For data collection a template was used developed by ifeu. The template includes the most relevant questions from the Worldbank data tool V1.0 with regard to general information amended by data needed for GHG accounting like energy demand, waste composition and waste characteristics. The collected data in the tool has been attached as Annexure 1 (chapter 1.9.1). The description and analysis of data collected is given below.

1.5.1 General SWM

The municipal solid waste generated in Bangalore is collected by BBMP staff, private contractors and also other NGOs and housing society welfare groups. The waste collection is categorized into Door to Door collection, litter point collection (black point) and street sweepings. Even though the law states that waste needs to be collected in a segregated manner, the age old practice of mixed waste collection is practiced in many parts of Bangalore. A very small portion of uncollected waste (which officially does not exist) ends up in low lying areas, is burned or in other cases utilized by individual homes in form of home composting or home anaerobic digestion.

The collected source segregated waste is categorized into 3 categories:

- Dry waste
- Wet waste
- Sanitary waste

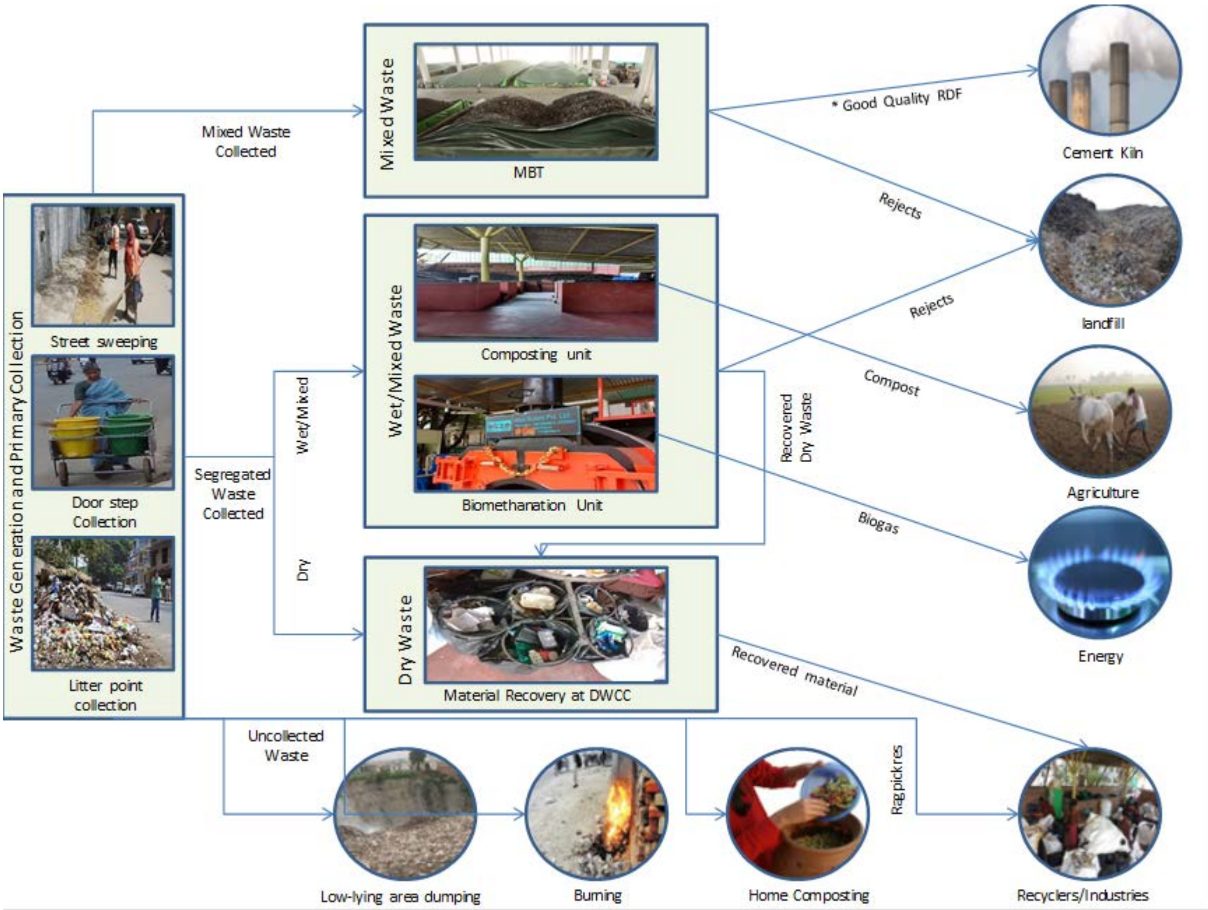
The dry waste is taken to the Dry Waste Collection Centers (DWCC) where it is further segregated into revenue generating streams and the recovered material is sold to industries or recyclers. The wet waste and a portion of mixed waste is transported to the wet waste collection and processing centers (both centralized and decentralized models exist in Bangalore) where the waste is again sorted to remove the rejects and used as a feed for composting or biomethanation. The compost is packed and made available for sale in market. The biogas is used internally for processing plant operations and if excess is available then used for public use. The rejects are converted into RDF, which – if of good quality – could be utilized by local industries.

The unutilized[19] RDF, rejects from wet and dry processing, household sanitary waste and the unsorted mixed waste usually end up in BBMP designated landfills and/or non-designated dump sites. Figure 9 shows the general flow of waste from cradle to grave in BBMP.

As seen in Table 1, the general waste composition in overall Bangalore differs from in each zonal division due to the diversity of generation sources including population density, urbanization, living standards, kind of generation source (residential waste, commercial waste etc.) hence region specific information is essential to calculate and project the GHG emission information in Bangalore. But waste composition data is not available on a region specific basis other than west zone data.

[19] Due to low quality or other managerial issues.

Figure 9: Flow of Waste in Bangalore



*Presently all RDF is sent to landfills due to lack of demand and poor quality

Table 1: Comparative waste composition in Bangalore

Waste fraction	General Bangalore [%]	West Zone [%]
Paper & Cardboard	13	8.8
Plastic	12	9.9
Composites		3.3
Textiles	4	4.6
Grass, leaves, wood	6	0.4
Electronic Item	2	0.1
Metal	1	0.3
Organic and Vegetables	53	62.6
Glass	3	1.5
Inert (debris & fines)	5	5.8
Biomedical & household hazardous waste	2	2.8

Source: Bangalore: BBMP website (see Figure 2), (Weichgrebe et al. 2016)

Some features are common in all zones which is evident from Table 1 and data collected from field. It is observed that more than 50% of the waste generated is organic in nature and hence good for composting. The share of materials like debris, biomedical waste, hazardous waste etc. are minimal and accounts to less than 10% of the total waste collected. BBMP has implemented 100% waste collection coverage and a collection frequency of 7 days a week except for special holidays in all zones. The collection system in most of Bangalore is motorized (primary collection using tipper auto-rickshaws and secondary collection using tipper trucks and compactor trucks) and landfilling is prohibited. The revenue for waste management in the city is collected through property tax and an additional charge is levied by the operator for house to house waste collection in some regions (BBMP 2016b).

Waste generation and composition is dependent on many factors including population, population density, housing typology etc. The zonal waste generation information in Bangalore and its relation to population is shown in Table 2[20] and Figure 10.

Figure 10: Zonal Population and waste generation

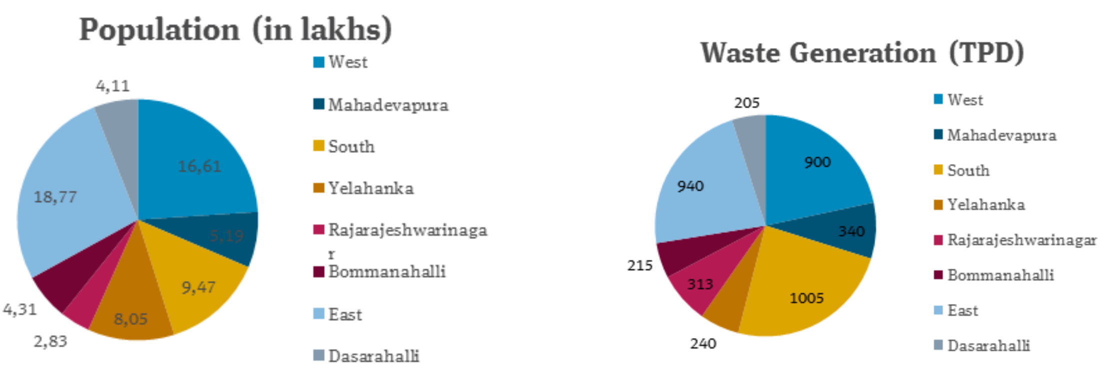


Table 2: Zonal data on SWM

Zone	Waste generated in TPD	Population
West	900	1,661,753
Mahadevapura	340	519,663
South	1005	947,169
Yelahanka	240	805,810
Rajarajeshwarinagar	313	283,936
Bommanahalli	215	431,867
East	940	1,877,635
Dasarahalli	205	411,056

Source: population-http://bbmp.gov.in/zones; Waste generation: Project Survey[21]

The data collected on waste collection and treatment in West zone, Mahadevapura, Yelahanka and Rajarajeshwari Nagar is shown in Table 3.

[20]The data marked as red is derived from per capita generation of waste in Bangalore referred from ISAH report (Weichgrebe et al. 2016) (0.5 kg/day) and the zonal population data.

[21]Project Survey (Questionnaire survey with ULBs) conducted by Development Alternatives and Ecoparadigm, 2016

Table 3: Zonal data on SWM collection and treatment

	West	Mahadevapura	Yelahanka	Rajarajeshwari-nagar
Waste collected in TPD				
Wet waste	270	140	60	138
Dry waste	90	40	12	95
Mixed waste	540	160	168[1)]	80
Waste treatment in TPD				
MBT/composting	250 Doddabidarakallu and Mavallipura	140 Chikkanagaman-gala and KCDC	55 Mavallipura	138
DWCC	90	40	12	95
Biomethanation	15		5	
OWC	5			
dumped	540	60	128 MSGP and Beli-halli quarry	80 Seegehalli
managed landfill (MSGP)		100		

1) data on 40 TPD unavailable, bulk generators

Source: (Sapna 2016), (Kumar, R. 2016), (Vasu 2016), (Poornima 2016)

The analysis of Table 2 and Table 3 reveals that the waste generated and its treatment is different in each zone. Each region is different and a study conducted in a sample location could not be representative nor easily be extrapolated to the overall situation in Bangalore.

West zone is considered an industrial area since many renowned industries have settled here, along with many residential areas and lush natural surroundings. A detailed study on SWM in the West zone has been conducted by Weichgrebe et al. (2016) which concluded an average wet and/or mixed waste generation of 915 TPD (see chapter 1.4), during the field visits under this project the BBMP officials confirms an average of 900 TPD of total waste generation in the region. Manual waste segregation for 360 TPD during initial waste collection of which a major fraction is biodegradable, composting is practiced on 250 TPD wet waste of the segregated waste whereas biomethanation is practiced on 15 TPD wet waste, and 5 TPD are treated with an Organic Waste Converter (OWC). More than 540 TPD is collected as mixed waste which is dumped off in unmanaged landfills in Mittagenahalli & Doddabidarakallu (Sapna 2016). 90 TPD of the segregated waste is dry waste sent to DWCCs for sorting.

Mahadevapura although also an industrial area, these industries are spread over a huge sprawling area within Mahadevapura making it less densely populated except for a few areas like Krishnarajapuram Railway Station area, Whitefield Road and Hindi main Road. Hence the waste generation in this region is around 340 TPD of which only 180 TPD is segregated by hand at source of which 140 TPD of wet waste is sent for composting to KCDC and Chikmangla plants. Among the mixed waste around 100 TPD is sent to MSGP managed landfill whereas roughly around 60 TPD is sent to an unmanaged landfill in Bellahalli. 40 TPD of segregated waste is dry waste sent to DWCCs inside the city for sorting.

1.5.2 Dry Waste Collection Centers (DWCC)

From Table 3 it is evident that a huge portion of waste is collected as mixed waste and hence pretreatment sorting need to be done in processing centers. Although initiatives do exist (chapter 1.3.4) which prove that pre-treatment sorting at source could be practiced successfully in Bangalore.

Altogether data from 5 dry waste centers were collected, data from 3 DWCCs in the West Zone and Mahadevapura during the field survey accomplished by Ecoparadigm (chapter 1.9.1), and data from further 2 in the South Zone during the visit of the project team Oct, 27, 2016. All of the DWCCs are equipped with a weighing machine. Nevertheless, in general weighing data is not registered digitally but noted down manually. The 5 DWCCs are briefly described in the following. Harisudala is an initiative by a social enterprise supported by BBMP for waste segregation and collection at source through which segregated dry waste collection is practiced in 3 wards in West zone, Ward 94, 95, 109. A total of almost 1.25 TPD of dry waste is collected and sorted of which 1 TPD is recovered as recyclables and 0.25 TPD are rejected and dumped (Manjunath 2016).

Stree Shakthi foundation initiative also collects segregated waste from Ward No. 82 of Mahadevapura Zone where pre-treatment sorting is practiced for 1-1.5 TPD of dry waste. 1-1.2 TPD of dry waste component is recovered and recycled through the initiative. 0.3-0.5 TPD impurities are dumped (Bhagya 2016), (Sheshgiri 2016).

BBMP operates multiple DWCCs for as part of decentralized waste management in Bangalore. The DWCC that operates in ward No. 67, West Zone, collects 1.5 to 2 TPD dry waste of which up to 1.5 TPD is recovered for recycling. Impurities of 0.3 TPD are dumped (Rajgopal 2016).

The NGO 'Samarthanam Trust for the Disabled' operates and maintains a DWCC in Ward No 151 in South Zone (Figure 11). Dry waste is collected from Households and litter points on a daily basis, 5 TPD twice every week on Wednesday & Saturday, and 1 to 1.5 TPD during other days. The waste is sorted into different components for recovery and reuse at the dry waste collection center. The different categories of dry waste are purchased under the WOW program, an ITC CSR initiative with BBMP (chapter 1.3.4). The different categories of waste recovered and their value is mentioned in Table 4.

Figure 11: DWCC maintained by Samarthanam

Photos by ifeu Heidelberg

Table 4: Purchase price of recovered materials by ITC Ltd.

	Material Category	Value in INR/kg
1	Dry Mixed Waste (paper, plastic, LVP, Tissue paper)	3/-
2	Sorted dry mixed waste (Paper & Board)	5/-
3	Pet bottles	10/-
4	Milk pouches	10/-
5	Hard plastic	13/-
6	Tetra pack	4/-
7	Kraft/Carton box	5/-
8	Old newspaper	8/-
9	Old magazines	7/-
10	Old note book/Text book	7/-
11	White record	7/-
12	Metal (iron)	8/-
13	Metal (Aluminium)	60/-
14	TIN (Metal-magnet check)	5/-
15	TIN (Aluminium)	40/-
16	Beer bottle	1/-
17	Coconut shells	1/-
18	Tyre	2/-
19	Thermocole	3/-

Source: DWCC ‘Samarthanam Trust’, Ward 151, South Zone

The NGO SAAHAS also operates a DWCC in Ward No 151 in South Zone under the ‘Trash to Treasure Project’. The project is supported by different companies, the land for the construction of the unit is provided by BBMP. Apart from dry waste sorting also wet waste is recycled, the respective biological treatment is described in chapter 1.5.3. The center’s handling capacity is 1 TPD of recyclable dry waste and 1 TPD organic waste. 16 laborers are employed for manual segregation, composting and packing. Waste is collected from Monday to Saturday from several collection points like bulk generators, apartments, schools, etc. details of which is mentioned in Table 5. For collection SAAHAS operates its own motorized vehicles (3 Autorikshas, 4 trips each a day).

Table 5: Collection points served by SAAHAS

	Waste source	No. of units
1	Appartment flats	7
2	Schools (2 days a week, 40-60 kg)	3
3	Edward Road	10
4	Companies	3

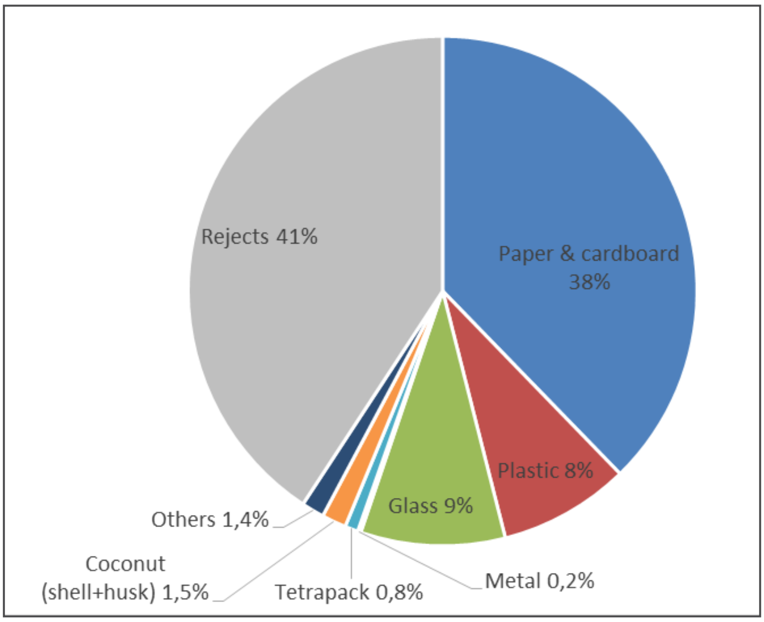
Source: (SAAHAS officials 2016)

The collected dry waste is thoroughly sorted manually (Figure 12), rejects of 0.4 to 0.5 TPD are send to landfill (Hagaduru). Different categories of waste recovered are different types of paper (white, color, tissue, newspaper, magazines), plastics (milk bags, PET bottles, cans), glass, metals (tins, aluminum foil), tetrapack, coconut residues (shell, husk), laminated sheets, E-waste and thermocole (polystyrene). Figure 13 shows an exemplary average of recyclable fractions and rejects for a three month time period (based on interview of SAAHAS officials, SAAHAS 2016).

Figure 12: DWCC maintained by SAAHAS

Photos by ifeu Heidelberg

Figure 13: Exemplary average of recyclables recovered



1.5.3 Composting

The wet waste recycling in the center in Ward No 151 maintained and operated by SAAHAS is an example for a decentralized composting treatment of source segregated organic waste. The main share of the collected organic waste is composted with the assistance of an Organic Waste Converter (OWC) (Figure 14, left side). The OWC has a capacity of 1 TPD. The composting material is introduced to the OWC with an activator (1 teaspoon for 50 kg of waste). Usually OWCs processing time is 1-3 days. The output is further composted in tanks for up to 40 days (Figure 14, right side), and turned every 3 days. Leachate is collected, the pipe is connected to the drain. The finally produced compost corresponds to approximately 25% of the input. Currently, the compost is not purchased due to lack of a compost market and capacities to market the compost. The process of composting is described in Figure 15.

Figure 14: Composting unit by SAAHAS in Ward No 151

Photos by ifeu Heidelberg

Apart from the described composting process a small share of the organic waste of about 50 kg/d is vermicomposted, and another small share of food waste (50 kg/d) is anaerobically digested. The letter provides biogas that is used for cooking.

Figure 15: Composting process Ward No 151

Source: (SAAHAS 2016)

1.5.4 Mechanical Biological Treatment

BBMP set up 7 new mechanical biological treatment plants (MBT)[22] within the last 1-2 years processing 'wet waste' (mixed waste). These plants as well as further known or reported mechanical-biological treatment plants in and around Bangalore are listed in Table 6. According to (Speier 2016) only two of the seven new MBTs were operational in midst of October 2016. Apart from the one that caught fire further four MBTs have been blocked by protesting citizens.

[22] incl. KCDC, the former composting plant, see text.

Table 6: MBTs in and near Bangalore, operational status as of Oct, 2016

MBT	operator	capacity in TPD	operational status, Oct16
Chikmangala (Chikkanagamangala)	Morgan Industries Ltd.	500	not operating
Kanahalli (Kannenahalli)	IL&FS Ltd.	500	caught fire[23]
Seegehalli	IL&FS Ltd.	200	not operating
Doddabidarakallu	UPL Services Ltd., later BBMP	200	not operating
Subrayanpalya (Subbarayappanapalya)	Morgan Industries Ltd.	200	not operating
Lingadeernahalli	IL&FS Ltd.	500	not operating
Mavallipura	Ramky Enviro Engineers Ltd.	1000	not working
KCDC, near HSR Layout	Karnataka State, now BBMP	500	operational
Doddabalapura[1)], Chigarenahalli	MSGP	(1000)[2)]	operational
Doddabalapura, Gundlahalli	Terrafirma Biotechnologies Ltd.	1000	n/a

1) about 30 km north of Bangalore

2) capacity given by workshop participant; otherwise cited with 500 TPD (TERI 2015b)

Source: (Speier 2016), visits Oct 2016, Workshop 25th October 2016 (see Workshop report), (TERI 2015b)

Visits of two plants – the one in Chikmangala and KCDC – were kindly arranged for ifeu and the German Environment Agency by members of the ISAH Hannover and K S Velankani Bangalore. The older MBT in Mavallipura was visited during field survey in May, 2016 by Development Alternatives.

The MSW Treatment facility at Mavallipura with a treatment capacity of 300 TPD is operated by government contractor organisation ‚Ramky Services'. With status, May 2016, the unit processed 150-180 TPD of segregated organic waste generating 20 TPD of compost, 40 TPD recyclables, 40 TPD of RDF and 80 TPD of rejects (BBMP 2016b). The RDF is dumped due to poor quality, not accepted by cement kiln operators for co-incineration. Farmers and local residents are the main customers for purchasing the compost which is available at a comparatively lower price than of the market price of natural compost (1000 Rs/Ton) but there is no regular purchase for the product nor is there a buyback policy by the government to ensure minimum sale of material. (Kumar, P. 2016)

Figure 16: Wet waste treatment plant Mavallipura maintained by Ramky Services Ltd., May 2016

Photos by Development Alternatives

[23] http://www.deccanchronicle.com/nation/in-other-news/151016/kannahalli-garbage-plant-still-on-fire-after-10-days.html

The newly built MBT plants are constructed in a similar way in a modular concept:

1. delivered waste is weighed on an electronic weigh bridge
2. from the waste tipping pit waste is mechanically pre-treated through a 200 mm trommel and then 100 mm trommel sieve
3. rejects are transferred to the RDF storage area
4. remaining waste (< 100 mm) is taken to the compost pad, and arranged in in the form of trapezoidal heaps (windrows), 3 m high and about 4-5 m wide
5. windrows are turned by wheel drivers about once a week, water is added if needed
6. after 4-5 weeks the semi-matured material is sieved through 40 mm and 16 mm trommel, rejects are transferred to the RDF storage area
7. throughput (< 16 mm) is stored in a section for 12 days for further stabilization
8. stabilized material is refined through 4 mm trommel, rejects are re-entered in the composting process, the finer material, the final compost product, is packed for purchase

The MBT at Chikmangala was visited in October, 2016. The plant manager informed that the MBT started operation 1 year ago. The licensed capacity is 500 TPD, the highest processing amount so far 400 TPD, processing of 500 TPD is feasible. The compost output in average is 25% of the input, the RDF about 50%. The RDF is meant to be shredded, bailed and sold to cement kiln. The calorific value of the RDF is about 1200 kcal/kg (5 MJ/kg). RDF was send to Bharathi Cement in Andrha Pradesh, Nallalingayapalli but was rejected due to low quality. It was tried to optimize the process, and currently some RDF is send to the cement kiln on free costs for the kiln and co-incinerated.

In October 2016, the plant in Chikmangala was not in operation since about 4 weeks due to villager protest[24] and power cut-off as bills were not paid. The delivered wet waste that was piled up at the entrance area is not distinguishable from mixed waste. The material includes about 2-3 m long textile and flower festoon strings (the latter being very popular in Bangalore) that are clogging the 200 and 100 mm trammel screen. Although the sieving process is stopped regularly to remove textiles and festoons, the rejects, the RDF fraction, still contains a high share of fine organic or inert material. Figure 17 (from top left zigzag to down right) shows the trapezoid windrows of the mechanically pre-treated material (< 100 mm), the trommel to refine the compost material (< 16 mm), the rejected material from the first pre-treatment step to become RDF, the RDF material after shredding, a RDF bail and the storage section for compost stabilization. It is obvious that the RDF material has a high content of fibers from textiles, bags, organics which cannot be shredded properly. Even though the shredder is equipped with two-shaft macerators which are likely to tear as to cut, the outputs are not very different from the inputs. In addition, the shredder chassis had to be exchanged after 2 ½ months. The project plans for Chikmangala include a landfill area for inert material (AECOM 2015) which was not realized at the time of the visit. The designated area is a stone quarry situated on-site the MBT plant.

[24] Possibly triggered by the fire at the Kanahalli plant where the RDF storage self-ignited, and the fact that the promised infrastructural improvements were not carried out so far.

Figure 17: MBT Chikmangala, Oct 2016

Photos by ifeu Heidelberg

Like Chikmangala also the other MBTs identical in construction face the same difficulties in processing the mixed waste collected from Bangalore, basically due to the content of textiles and strings. This also accounts for the KCDC plant. The KCDC plant used to be a composting plant owned by the Karnataka State processing organic waste with a capacity of up to 300 TPD. It was given to BBMP in 2015 and is now processing mixed waste like the other MBTs. In addition, the capacity is extended to 500 TPD, and the plant was under construction in October 2016 for this reason. Usually, the compost material from the mechanical pre-treatment is meant to be arranged in windrows 2 m high and 4 m wide. This was not possible. Instead the material was built up 4 to 5 m on the whole composting area like at a dump site. The new operator of the plant informed that composting takes place 3-4 days, then refinement is done through 40 and 16 mm trommel screens. The compost output is given to farmers, the RDF fraction was not yet refined by the new operator but is disposed of on a plant owned landfill site. The operator did not try to contact cement kiln operators but knows that cement kiln specification for RDF are maximum 10% water content and zero dust. As this is hardly to meet (see RDF bail Figure 17) cement kiln operators suggested that RDF should be washed for refinement, but this is not feasible for MBT operators. In contrast to the concept of the newly built MBTs, the KCDC plant is equipped with an aeration system, and waste gas is collected and treated via a biofilter of 15 m^2 and about 2 m height.

In general, there are still major difficulties in handling the mixed waste from Bangalore. Still a high share of the waste is dumped either directly or after treatment. Although, this is illegal, several dump sites exist in Bangalore, and often the waste is dumped in quarries with the risk of ground water contact.

1.5.5 Biomethanation

BBMP set up 16 biomethanation plants in the last 1-2 years, which are all of the same type. They have a capacity of 5 TPD and are processing source segregated food waste. In general, the plants are equipped with a combined heat and power plant (CHP) of 50 kW installed power. The output of the fermentation, the digestate, is drained. The 16 plants out of which four were actually operational in October 2016 are listed in Figure 18.

Figure 18: Biomethanation plants in Bangalore

Sl. No	BBMP ward – Area & Locality	Technology Supplier	Ward No	BBMP Zone
1	MTPD, Freedom park, Gandhinagara	Mailhem Engineers	No.94	Bagalore west
2	Rajagopalanagara, DWCC, Yeshwanthapura	Ashoka Biogreen Ltd	No.70	Bangalore North
3	MTPD, MSRIT road, Mattikere	Mailhem Engineers	No.35	Bangalore west
4	Begur, Gugutopu, Anekal	Ashoka Biogreen Ltd	No.192/ 191	Bommanahalli
5	Jayanagara, next to organic waste converter	Ashoka Biogreen Ltd	No. 168	Bangalore south
6	Jayanagara, near ACP office	Ashoka Biogreen Ltd	No.167	Bangalore south
7	S K R Market, Biomethanization plant	Ashoka Biogreen Ltd	No. 139	Bangalore west
8	Abbigere Village, Yeshwanthapura hobli	Ashoka Biogreen Ltd	No. 12	Bangalore North
9	Domlur east zone	Ashoka Biogreen Ltd	No. 112	Bangalore east
10	Kuvempunagara, Singapura	Mailhem Engineers	No. 11	Yelhanka zone
11	Nagapura near Mahalakshmi layout	Ashoka Biogreen Ltd	No. 67	Bangalore west
12	Haralakunte, near KCDC	Ashoka Biogreen Ltd	No.39,40	Bangalore west
13	Koramangala	Ashoka Biogreen Ltd	No. 151	Bangalore south
14	A Narayanapura	Ashoka Biogreen Ltd	No. 156	
15	Varthur, Mahadevapura	Ashoka Biogreen Ltd	No. 149	Bangalore east
16	Lingadheeranahalli, RR Nagar	Ashoka Biogreen Ltd	No. 198	Dasarahalli

Source: (TERI 2015b)

Data from 2 biomethanation plants were collected: the one in Nagapura, Ward No 67, West Zone (number 11 in Figure 18) during the field survey accomplished by Ecoparadigm (chapter 1.9.1), and the one in Koramangala, Ward No 151, South Zone (number 13 in Figure 18) during the visit of the project team Oct, 27, 2016.

The biomethanation plant in Koramangala, South Zone, Ward No. 151, was in full operation. The 5 TPD food waste is delivered at 5 times a day. Main sources are canteens like e.g. the canteen of the company Bosch. The food waste is sorted by deliverance to separate impurities like e.g. citrus fruits disturbing the fermentation process. The food waste is then immediately introduced into the fermentation process by adding 2 liter fresh water per kg food waste (Figure 19, top left). The main digester covered with a flexible membrane is about 1.5 m (5 feet) high and approximately 7-10 m in diameter (Figure 19, top right). The food waste is only transported by gravity and pressure from freshly fed material. The retention time within the digester is not known but with the given volume of approximately 75 m^3 may be maximum 15 days. The biogas yield seems to be low and generation only takes place when the digester is heated by the sun. Biogas is collected via a pipe and hose in a balloon. In case of overpressure one hose allows release of biogas into the atmosphere (Figure 19, bottom left). The collected biogas is used once a day for 1 or 2 hours in the installed CHP, and is dehydrated as pretreatment. The electricity generated is used for plant operation but is not sufficient to cover the total electricity demand. The digestate is transported into a covered basin (Figure 19, bottom right) which is frequently emptied by draining into the nearby waterway.

Figure 19: Biomethanation plant, Ward 151, South Zone, Bangalore

Photos by ifeu Heidelberg

The biomethanation plant in Nagapura, West Zone processed an average of 2.5-2.8 TPD of waste. 0.1-0.15 TPD are impurities which are separated before fermentation and are finally dumped. No information is available on energy demand or biogas generation (chapter 1.9.1).

1.5.6 Recyclers & Recovered material traders (Kabadiwala)

An unaccounted quantity of waste is also recovered, reused and recycled by informal recyclers and rag-pickers also known as the ‘Kabadiwalas’. The size of operation of the recycler varies from one to other but the operation mechanism remains the same.

Rag-pickers walk/cycle through the streets collecting recyclable, reusable material from households, commercial establishments etc. and other bulk generators in a segregated manner. The material is bought by the rag-pickers at a minimal price which is sold to informal recyclers. Rag-pickers usually do not take the same path each time but try their luck through different streets but in the same locality.

The recyclers receive materials from multiple rag-pickers (in addition to the material delivered to recycler shop by waste generator directly) which is bought from the rag-pickers at a marginal price higher (Figure 20, top left). The material purchased by the recycler is sold to a wholesale recycler who sells it in the secondary market. Similar wholescale recyclers are available in market areas in Bommanahalli market, Koramangala market and other regions in Bangalore. One of the major recycling market areas is Jolly Mohalla Market in the center of Bangalore. Here different recyclables are traded one sort in each street: paper & cardboard, plastics, metals, etc. and also E-waste (Figure 20).

Figure 20: Data collection from Kabadiwalas and images of Jolly Mohalla Market

Photos by ifeu Heidelberg

Information on the rate at which the recyclable/reusable material is purchased derived from an interview with a Material Trader is described in Table 7.

Table 7: Purchase price of recovered materials from Kabadiwalas by industries

Material	cost in units	quantity recovered per day
aluminum	10 Rs/kg	Not Regular
Plastic container parts	20 Rs/kg	Not Regular
Metal	13 Rs/kg	~20 kg/day
Paper	10 Rs/kg	~15 kg/day
Cardbnoard	8 Rs/kg	~40 kg/day
Plastic bottles	15 Rs/kg	~50 kg/day
Water can	10 Rs/kg	Not Regular
Beer bottles	1 Rs/bottle	~10 bottles/day
Glass bottle	20 Rs/kg	Not Regular
PV pipes	20 Rs/kg	Not Regular

Source: (Material Trader 2016)

1.6 Workshop

To validate the data collected and to make the process more efficient and realistic, a stakeholder consultation workshop was conducted in the city of Bangalore on 25th October 2016. The workshop aimed to gather different stakeholders (Government officials, NGOs, consultants and operators) operative in the city, on a common platform to discuss the data assumptions developed by ifeu as well as share possible optimization scenarios for waste management. The workshop included data and experience sharing sessions as well as brainstorming and heterogeneous group discussion sessions.

The workshop was structured around 4 central questions prepared by ifeu that surfaced from the work on the waste generation and management data collected in field by the study team.

The chronology summary of the workshop is described in detail in the workshop report for participants as separate document.

1.7 Conclusions

The study shows that SWM in Bangalore even though is efficient on the volume of waste collected and managed, it is not efficient on a climate change contribution perspective nor from a resource utilization perspective. The study clearly brings out the fact that most of the waste collected in BBMP is in mixed wet waste, mostly sent directly to landfills or illegal dumps where it contributes to the worsening carbon emission situation prevailing in India.

The lack of data availability is also highlighted in the study that brings out the need of a proper data management system as a prerequisite for a proper waste management system. Many decentralized initiatives in Bangalore show the potential of waste to wealth opportunity if proper pre-sorting, pre-treatment and treatment of waste is practiced. The study also makes a few recommendations which are mentioned below that need to be implemented in Bangalore for a better waste management scenario for future.

- Proper management of waste data through formation of a centralized data hub for BBMP where all existing initiatives and good practices need to be listed for further handholding incubation and growth.
- Formation of expert panel for SWM by the ULB and further involvement of groups like SWMRT and conduct regular meetings and brainstorming sessions to better determine the waste management practices in Bangalore and discuss and incorporate innovative ideas of waste management.
- Implement integrated waste management practices which include a hierarchy of waste management practices including recycling, composting, waste to energy etc. that result in minimal or no waste reaching the landfills.
- Proper monitoring and closure of existing landfills along with monitoring and management of landfill gases.

1.8 References Bangalore

AECOM (2015): Environmental Impact Assessment Report – Common Municipal Solid Waste Management Facility, Chikkanagamangala, Bengaluru, Karnataka. Submitted to Karnataka Urban Infrastrucutre Development and Finance Corporation. Submitted by AECOM India Pvt. Ltd, May 2015. http://kspcb.kar.nic.in/PH/Chikkanagamangala_REIA.pdf

Bangalore-City (2016): Industries in Bangalore. Retrieved from: http://www.bangalore-city.com/industries/industry.html. Accessed in Nov, 2016

BBMP (2016a): Solid Waste Management Overview. Retrieved from: http://bbmp.gov.in/solid-waste-management. Accessed in Nov, 2016. http://bbmp.gov.in/documents/10180/512162/Overview.pdf

BBMP (2016b): Personal conversation with Mr. Santosh (Technical Advisor to Additional Commissioner; Health and MMSW Management), May 2016. Health and SWM Department, Bangalore Municipal Corporation

BDA (2005): Draft Master Plan - 2015. Bangalore Development Authority (BDA), 2005. http://www.bdabangalore.org/brochure.pdf

Bhagya (2016): Personal conversation with Ms. Bhagya (member Stree Shakthi), Okt 2016. DWCC Mahadevapura Zone, Ward No.82

Bharath H Aithal (2013): Prediction of landuse dynamics in rapidly urbansing landscape using land change modeller. Retrieved from http://wgbis.ces.iisc.ernet.in/energy/water/paper/aet_land_change_modeller/results.htm

Census Organization of India (2015): Hardwar Population Census 2011. http://www.census2011.co.in/data/town/800359-hardwar-uttarakhand.html. Accessed on March 21st 2017.

Geospatial World (2014): Geo-visualisation of Urbanisation in Greater Bangalore. Retrieved from: https://www.geospatial-world.net/article/geo-visualisation-of-urbanisation-in-greater-bangalore/

KSPCB (2014): Municipal Solid Waste Annual Report 2013-14 of Karnataka State Pollution Control Board. http://kspcb.gov.in/MSW%20Annual%20Report%20%202013-14%20.pdf

Kumar, P. (2016): Personal conversation with Mr. Kumar (Plant Manager, Ramky services Ltd.), May 2016. Mavelipura, Bangalore

Kumar, R. (2016): Personal conversation with Mr. Kumar (Superintendent Engineer), 26.07.2016. Mahadevapura Zonal office

Manjunath (2016): Personal conversation with Ms. Manjunath (Supervisor), Okt 2016. DWCC West Zone, Ward No.94/95/109

Material trador (2016): Personal conversation (Trader), 27.10.2016. South Zone, Ward 191

MoEFCC (2016): Solid Waste Management Rules, 2016. Ministry of Environment, Forest and Climate Change, Notification. New Delhi, the 8th April, 2016. The Gazette of India: Extraordinary. http://www.nsc.org.in/images/MoEF/Solid_Waste_Management_Rules_2016.pdf

MoUD & CPHEEO (2000): Manual on Municipal Solid Waste Management. Constituted by the Government of India Ministry of Urban Development (MoUD) and the Central Public Health and Environmental Engineering Organisation (CPHEEO), May 2000

Poornima (2016): Personal conversation with Ms. Poornima (Superintendent Engineer), 28.07.2016. Rajarajeshwarinagar Zonal office

Rajgopal (2016): Personal conversation with Mr. Rajgopal (Contractor), Okt 2016. DWCC West Zone, Ward No.67

Ramachandra, T.V. and Bachamanda, S. (2007): 'Environmental audit of Municipal Solid Waste Management', Int. J. Environmental Technology and Management, Vol. 7, Nos. 3/4, pp.369–391. Retrieved from http://wgbis.ces.iisc.ernet.in/energy/paper/ijetm/TVR24_P9_IJETM%207(3-4)%20Paper%2009.pdf

SAAHAS officials (2016): Personal conversation with Ms. Anita (Supervisor), 27.10.16. Wet & dry waste processing unit, SAAHAS Zero Waste, Ward No 151

Sapna (2016): Personal conversation with Ms. Sapna (Superintendent Engineer), 08.09.2016. West Zonal office

Shankar (2016): Personal conversation with Mr. Shankar (Manager, Morgan Industries Ltd.), Okt 2016. Morgon Services Plant, Chikmangala, Bangalore

Sheshgiri (2016): Personal conversation with Mr. Sheshgiri (Health Inspector), Oct 2016. DWCC Mahadevapura Zone, Ward No.82

Speier (2016): Personal information Mr. Speier (ISAH Hannover), Email 17th October 2016.

TERI (2015a): Concept Paper on Power Generation from Municipal Solid Waste. Prepared for Karnataka Electricity Regulatory Commission Bangalore. The Energy and Resource Institute (TERI) 2015. http://www.karnataka.gov.in/kerc/Reports/Solid%20_Waste_Management_report_20.11.15.pdf

TERI (2015b): Appendix to (TERI 2015a). Retrieved from: http://www.karnataka.gov.in/kerc/Reports/Appendix_TERI_Report.pdf

Vasu (2016): Personal conversation with Mr. Vasu (Executive Engineer), 26.07.2016. Yelhanka Zonal office

Weichgrebe et al. (2016): Weichgrebe, D., Mondal, M.M., Vidyaranya, V., Speier, C., Zacharias, M., Murali, S., Peter, N., Urs, V., Bhaskar, U., Joseph, S., Mundkur, V. and Sivaram, R.: Municipal Solid Waste (MSW) Management Study for West-Zone Bangalore, India; available at: http://www.elcita.in/wp-content/uploads/2016/09/ISAH_Combined-Report_Bangalore_20160720.pdf

1.9 Annexure Bangalore

1.9.1 Annexure 1: Extract of secondary data collected (ifeu template, based on Worldbank tool adjusted and modified for Bangalore)

n/a = not applicable	**Governing zones:**	Mahadevapura	Dasarah-alli	Yelahanka	Bomman-ahalli	Rajarajeshwari-nagar	South	West	East	**total**
waste generated		TPD	TPD	TPD	TPD	TPD	TPD		TPD	TPD
		340		240		313	1005	900		
District information										
population		519663	411056	805810	431867	283936	947169	1661753	1877635	
housing typology		167633	132599	198405	139312	91592	696475	536049	605689	
collection										
Collection frequency	days	7		7		7	7	7		
Collection coverage	%	100		100		100	100	100		
Average distance to site	in km	24.175		10		14.8	37.1	20		
Collection fee	specify: per ton, …	0		0		0		0		
Method used for fee collec-tion		Property tax	Property tax	Property tax	Property tax	Property tax	Property tax	Property tax	Property tax	
Type of collection										
collection system	COLL-Sys	Motorized	Motorized	Motorized	Motorized	Motorized	Motorized	Motorized	Motori-zed	
Collection vehicle	COLL-Veh	Auto tip-per(385), Lorry tippers (20), Compactor (30)-Run by Diesel		Auto tipper (84), Lorry tippers (7 Nos.), Com-pactor(5 Nos.)		Auto tipper, Push-carts, Compactor, Garbage Truck(run by diesel)	Auto tipper, Pushcarts, Compactor, Garbage Truck(run by diesel)	Auto (1000+), Compactors (130),		
Waste collected		TPD	TPD	TPD	TPD	TPD	TPD		TPD	TPD
informal sector waste collec-tion	COLL (inf)									
informal sector waste collec-tion: container/street	COLL (inf)-Cont									

informal sector waste collection: door-to-door	COLL (inf)-DtD									
informal sector waste collection: landfill site	COLL (inf)-Lf	n/a		n/a		n/a		n/a		
segregated waste collected	W/segr	180		72		233		360		
segregated waste collected (informal)	W/segr (inf)									
segregated organic waste composted	W/segr-comp	140		60		138		270		
segregated organic waste anaerobically digested	W/segr-AD	0		5				15		
<u>How and when was the data collected/obtained?</u>		From Mahadevapura Zonal office (Mr. Kumar, Superintendent Engineer): 26/07/2016		From Yelhanka Zonal office (Mr. K.M. Vasu, Executive Engineer): 26/07/2016		From R.R Zonal office (Ms. Poornima, Superintendent Engineer): 29/07/2016	From South Zonal office (Ms. Mamtha, Superintendent Engineer): 30/07/2016	From West Zonal office (Ms. Sapna, Superintendent Engineer): 08/09/2016		

n/a = not applicable	**Governing zones:**	Mahadevapura	Dasarahalli	Yelahanka	Bommanahalli	Rajarajeshwarinagar	South	West	East	**total**
MSW composition		TPD	TPD	TPD	TPD	TPD	TPD		TPD	TPD
household waste	W/HH	n/a		n/a			737			
mixed waste	W/mix	160		168		80		540		
Bio-degradable waste	W/bio-degr.	140		60		138		270		
paper, cardboard		n/a		n/a				n/a		
organic waste	W/org	n/a		n/a				n/a		
Garden/green waste	W/gr	n/a		n/a				n/a		
Kitchen/Canteen Waste (households)	W/K+C_HH	n/a		n/a				n/a		
Recyclables		40		12				50		
glass (and pottery and china)		n/a		n/a				n/a		

plastics		n/a		n/a				n/a		
mixed plastics		n/a		n/a				n/a		
polyethylen	PE	n/a		n/a				n/a		
polypropylen	PP	n/a		n/a				n/a		
polystyrene	PS	n/a		n/a				n/a		
polyethylene terephthalate	PET	n/a		n/a				n/a		
polyvinylchloride	PVC	n/a		n/a				n/a		
metal		n/a		n/a				n/a		
ferrous metals		n/a		n/a				n/a		
non-ferrous metals		n/a		n/a				n/a		
aluminium		n/a		n/a				n/a		
copper		n/a		n/a				n/a		
others		n/a		n/a				n/a		
textiles		n/a		n/a				n/a		
rubber and leather		n/a		n/a				n/a		
bulky waste (furniture, mat-tresses, woody objects, car-pets/floorings, bicycleparts)		n/a	n/a	n/a	n/a			n/a	n/a	
Others		n/a		n/a				n/a		

Composting facilities / MBT		unit	A	B	C	D	D
Name			Ramky services-Mavelipura Compost plant	UPL Services - SWM processing unit, Doddabidarakallu, Bangalore	Morgon Services - SWM processing unit, Subramanyampalaya, Bangalore	Morgon Services - SWM processing unit, Chikmangala, Bangalore	Morgon Services - SWM processing unit, Chikmangala, Bangalore
Facility location - address							Chikkanagamangala
geodata							
easting							77.682179
northing							12.862943

Type of composting							
Composting of mixed waste	COMP-mix						270-300
Composting of segregated organics	COMP-segr					0	0
Vermiculture, Vemicomposting	COMP (verm)						0
Who operates the facility?			Ramky services	UPL Services	Morgon Services	Morgon Services	Morgon Services
Design capacity of the facility		TPD	300			500	500
Current quantity of waste processed		TPD	150-180	200	200		270-300
How is the waste quantified at the facility?							Weigh Bridge
Capital cost (at construction)		INR					70-80
Nominal tipping/gate fee		INR/t					460
Electricity demand		kWh/t waste					3
Fuel demand for machinery		kWh/t waste					Not available
Type of fuel							Not available
<u>Output materials:</u>							
Compost		TPD	20	25	25	50	20-25
impurities / rejects		TPD	80	50	70	175	
inert material		TPD					
RDF		TPD	40	75	40	100	25-35
Recyclables		TPD	40	50	70	175	
insert type		TPD					
insert type		TPD					

Fermentation facilities (anaerobic digestion/biomethanation)		unit	A
Facility location - address			Nagapura, West Zone
geodata			
easting			77.542824
northing			13.003988

Type of fermentation			
dry fermentation	FERM (dry)		
wet fermentation	FERM (wet)		Wet
Who operates the facility?			Ashoka Biogreen
Design capacity of the facility		TPD	5
Current quantity of waste processed		TPD	2.5-2.8
How is the waste quantified at the facility?			Weighing Machine
Capital cost (at construction)		INR	Not available
Nominal tipping/gate fee		INR/t	Not applicable
Electricity demand		kWh/t waste treated	2.6
Fuel demand for machinery		kWh/t waste treated	0.8
Type of fuel			Diesel
Is the digestate aerobically composted?			Not available
Output materials:			
Digestate		TPD	Not available
composted digestate		TPD	Not available
impurities		TPD	0.1-0.15
inert material		TPD	Not applicable
RDF		TPD	Not applicable
Other		TPD	
Destination of outputs			
Landfill		TPD	Not available
Waste-to energy plant		TPD	Not available
Compost customers:			
Farmers		TPD	Not available
Landscapers		TPD	Not available
Municipality		TPD	Not available
Retail store		TPD	Not available
other		TPD	
Prices per tonne composted digestate		INR/t	Not available
Costs per tonne of disposed of waste			Not available
insert type		INR/t	

1.9.2 Annexure 2: Waste glossary

Aerobic treatment / composting	A method of composting organic wastes using bacteria that need oxygen. This requires that the waste be exposed to air
Anaerobic digestion, here synonym to Biomethanation	A microbiological process to degrade organic waste; microorganisms involved need anoxic (O_2-free) conditions. Products are anaerobic compost or slurry and biogas (basically methane & CO_2)
Auto tipper	An Auto tipper or Auto-rickshaw tipper is an 3 wheeler vehicle fitted with a carriage body with tipping mechanism
Biomethanation from wood	A physical-chemical process to generate methane out of thermo-chemical gasification of solid biomass. Interim product is synthetic gas (carbon monoxide and hydrogen); methane is produced from the carbon monoxide
Biodegradable	A substance capable of being decomposed by bacteria or other living organisms
Compactor truck	Type of truck where the load is reduced in size through automated mechanical compression inside the truck. Usually used to reduce waste volume and space occupied inside the truck.
Energy recovery	Energy recovery from waste is the conversion of waste materials into useable heat, electricity, or fuel through a variety of processes, including combustion, gasification, pyrolysis,. This process is called waste-to-energy (WtE). Landfilling with gas collection and anaerobic digestion are not considered as WtE as only part of the waste is transferred to energy (biogas or landfill gas)
Incineration	Waste treatment process that involves the combustion of organic substances contained in waste materials. Incineration of waste materials converts the waste into ash, flue gas, and process heat. Incineration takes place with and without energy recovery. With energy recovery the process heat is used e.g. through a condensing turbine.
Leachate	Water that has percolated through a solid and leached out some of the constituents
Landfilling	Landfill site is a site for the disposal of waste materials. Unmanaged, managed, well-managed landfill sites and landfill sites with gas collection system are distinguished in the GHG mitigation context. Unmanaged landfills are synonym to dumps
Litter	Litter consists of waste products that have been disposed improperly
Litter point	A common location (designated or undesignated) at which solid waste is disposed by the generator
Material Recovery Facility (MRF)	A materials recovery facility is a plant that receives, separates and prepares recyclable materials for marketing to end-user manufacturers.
Municipal Solid Waste (MSW)	Municipal Solid Waste includes commercial and residential wastes generated in a municipal or notified areas in either solid or semi-solid form excluding industrial hazardous wastes but including treated bio-medical wastes
Open dumping	Disposal of waste in a location without any precautions taken. open dumps are synonym to unmanaged landfills

Residue	Residue is whatever remains or acts as a contaminant after a process
Stakeholder	Person, group or organization with an interest in a subject. In case of waste management it includes a huge category ranging from government, social organizations, NGOs, plant operators, recyclers, industries using waste materials, investors in waste management business, environmental groups or citizens who are effected by waste management or is interested in waste management and everyone concerned directly or indirectly

Annex 2: Solid Waste Management

Bhopal

2 Annex 2: Solid Waste Management Bhopal

2.1 Objective and scope

'Resource and Climate Protection through Integrated Waste Management Projects in India' is a research study commissioned by the German Environment Agency and funded by Germany's Federal Ministry for the Environment, Nature Conservation and Nuclear Safety. The project is implemented by the German ifeu (Institute of Energy and Environment Research) along with Development Alternatives and Ecoparadigm.

The objective of the study is to support decision makers in identifying the potential to reduce greenhouse gas (GHG) emissions in the Solid Waste Management (SWM) sector in order to plan their waste management or e.g. Nationally Appropriate Mitigation Actions (NAMAs) accordingly. It will show specific GHG emission saving potentials of an integrated waste sector approach for Indian cities at present and for future scenarios. The study conducted on specific selected cities and the selection is done systematically with respect to the three priority criteria including availability and quality of waste data, stakeholder support to improve waste and contact network and other criteria such as population, income level and climate zone. The final selected cities were Bangalore, Bhopal and Haridwar.

This report section presents the situation of Municipal Solid Waste Management (MSWM) in Bhopal. Secondary level data and information that is collected from government officials, MSW treatment plant operators and subject experts is analyzed and presented in this report.

2.2 An overview of Bhopal

2.2.1 Geography and topography

Bhopal, also known as the 'City of Lakes', is located at 23°25' north latitude and 77°42' east longitude and is the capital of the state of Madhya Pradesh. At an altitude of about 460 to 625 m above sea level (BMC 2006), the city of Bhopal spreads over 463 km^2. 10.31% of the Bhopal district's total area constitutes the city of Bhopal, which falls under the Bhopal Municipal Corporation (BMC) (Gaur et al. 2014, BMC 2006).

2.2.2 Climate

According to the Köppen Geiger climate map (Peel et al. 2007) Bhopal is located in a region classified as "Aw" climate zone. The main climate is tropical (A) with winter dry climate (w). The city's climate is considered moderate with hot summers and cold winters and temperatures between 10 and 43 °C. The average annual rainfall is 1200 mm, falling predominantly during the monsoon season from July to September. The average number of rainy days is approximately 40. (BMC 2006)

2.2.3 Population and city structure

As per Census of India 2011, the population of Bhopal city was 1,798,218. The Municipal Corporation governs 93.80% of the district's total urban population. The average population density in the city is 6,290 persons per square kilometer. Also, a significant proportion (26.68%) of the population lives in the 388 slums across the city. (Smart Cities Projects 2015)

The city structure is presented with an informative map on the BMC website (BMC n.d., a). Bhopal is divided into 85 wards, aggregated to 19 zones, and is headed by the Municipal Commissioner.

2.2.4 Importance

The city of Bhopal is the administrative and political capital of the district Bhopal as well as the state Madhya Pradesh. It is looked upon as one of the 20 most promising cities under the Smart Cities Initiative of the Government of India (Smart Cities Projects 2015).

2.3 Municipal Solid Waste Management in Bhopal

2.3.1 Waste generation and collection

The current average municipal solid waste generation in Bhopal is reported as 800 tons per day (Sharma 2016), which is consistent with other sources (Katiyar et al. 2013, Dasgupta 2016). This means a considerable increase of waste generation during the last decade of the growing city: In 2006 only 550 tons per day were reported for the then 66 wards and in 2014 700 tons per day (BMC 2006, BMC 2014).

The MSW Rules 2000 (as well as the updated SWM Rules 2016) demand door-to-door collection of waste, and the waste should be stored and collected in a segregated manner. According to the BMC website, door-to-door collection started in every ward in August 2013 (BMC n.d., b). In 2014 the Municipal Commissioner stated in an interview that waste was collected from at least more than 50% of Bhopal's households (Clean India Journal 2014), and in (CDIA 2015) it is reported that Bhopal's collection system is only capable of collecting about half of the city's waste, which is approaching 1,000 t/d, while the Bhanpura dumpsite only receives about a third of this waste, leaving the rest being dumped directly into streets, drainage channels and lakesite areas. Nowadays, collection is well implemented by the Health Department, BMC in the city, with a significantly improved efficiency over the last five years (Sharma 2016).

In 2013, segregated collection of organic and inorganic waste was only done in one ward as a pilot project (BMC n.d., b). Correspondingly, Dasgupta (2013) reported that hardly 10-15% of the generated MSW were segregated at source. To date MSW from households and commercial centers is usually unsegregated when collected. Only some items of recyclable value are extracted. Some recyclables are sold by households to the informal sector and consequently never enter the MSW stream. All in all, Bhopal's informal recycling sector includes probably more than 8,000 recyclers, where BMC employs over 4,700 personnel for solid waste management (CDIA 2015).

According to (BMC n.d., b) door-to-door collection is done using 580 cycle rickshaws and 19 auto rickshaws by employing 1,280 workers and 69 supervisors for residential and commercial properties. The waste collected by door-to-door collection and sweeping is unloaded at one of the more than 3,000 collection bins (Clean India Journal 2014, CDIA 2015). From those collection centers the waste is transported to the Bhanpura dumpsite (CDIA 2015). The transfer is done with different garbage trucks (Figure 21). At (BMC n.d., b) it is stated that each and every zone is supplied with 10 JCB[25], 14 Dumper, 7 Robots for lifting of garbage.

2.3.2 SWM programs relevant for Bhopal

2.3.2.1 Swachh Bharat Mission

Madhya Pradesh has received 10.8 billion rupees for SWM initiatives in 256 towns across the state, Bhopal being one of them. The city has now been ranked as the second cleanest city in India by the SBM Urban portal (Swachh Survekshan 2017).

2.3.2.2 JNNURM and AMRUT

The Jawaharlal Nehru National Urban Renewal Mission (JNNURM) was a national scheme launched by the Government of India under the Ministry of Urban Development to improve urban infrastructure and services and identified 65 cities for the program. It envisaged a total investment of over 20 billion US $. The seven-year mission was to end in 2011-12, but repeated extensions were given as the project was delayed for reasons like land acquisition. The scheme was closed in 2015 (TNN 2015). In Bhopal,

[25] JCB, the proprietary name, is commonly used in India for solid waste machinery.

about two thirds of projects approved by JNNURM focused on water supply and most of the other approved projects focused on urban transportation (Smart Cities Projects 2015). Consequently, this program had little impact on solid waste management in Bhopal.

AMRUT, Atal Mission for Rejuvenation and Urban Transformation, is the follow up program of JNNURM, also launched by the Government of India under the Ministry of Urban Development. The program has funds allocated of 500 billion rupees (nearly 8 billion US $) for five years from 2015 to 2020. It covers 500 cities, where Bhopal is one of. Nevertheless, AMRUT focuses even more on infrastructure creation with direct link to provision of better services to people like especially water supply, sewerage facilities, parks and urban transport. Solid waste management is not a thrust area of AMRUT. (MoUD 2015)

2.3.3 Waste composition and other properties

The composition of residential and commercial municipal solid waste in Bhopal in 2006 is depicted in Table 8 (BMC 2006). The composition is such that after segregating the compostable waste and collecting C&D waste separately, only about 40% of the total waste remains. For MSW from residential areas this remaining waste is diminished to about 30%. Fractions of the remaining waste could be diverted for recycling wherever feasible; leaving a very small quantum that would require to be landfilled.

Table 8: Waste composition of samples from Bhopal, 2006

Waste fractions and characteristics of MSW	Sample from residential/commercial area [% of weight]	Sample from residential area [% of weight]	Sample from Sabji Mandi market [% of weight]
Compostable material	28	63	72
Paper	2.9	16	6
Plastics	2.9	10	6
Glass and ceramics	2.4	1.2	0
Earth, stone and bricks	30	10	7
Moisture content	25	46	58
Carbon content	26	27	29

Source: (BMC 2006)

A more recent source from 2009 describes the composition and characteristics of Bhopal's residential MSW as listed in Table 9. The large proportion of earth is assumed to originate from unpaved areas. As in the composition from 2006, here also the main waste fractions are compostable materials. The recyclable dry waste fraction consisting of paper, plastics, textiles, metals makes up about 20% of the total waste.

Additional research in 2010 determined a moisture content of 28.1 % of dry weight, a carbon content of 26.6 % of dry weight and a lower calorific value of 2244.2 kcal/kg dry weight (Katiyar et al. 2013).

Table 9: Waste composition of samples from Bhopal, 2009

Waste fractions and characteristics of MSW	[% of weight]
Food and fruit waste	43.18
Garden trimming	3.06
Hay, straw and leaves	22.15
Paper and cardboard	11.06
Rubber, leather	0.13
Plastics, including polythene	5.72
Textiles	1
Wood	0.5
Glass, crockery	1.1
Tin cans	0.49
Stones, bricks	0.6
Coal ash, fine earth dust	9.59
Ferrous metals	0.87
Non-ferrous metals	0.21
Other waste fractions	0.26
Moisture content	31.1
Carbon content	27.02

Source: (Katiyar et al. 2013)

2.3.4 Treatment and disposal of MSW

To date MSW from households in Bhopal is basically collected unsegregated and dumped. Apart from that there are some voluntary initiatives, pilot projects and small scale plants for the treatment of organic waste and recyclables.

2.3.4.1 Dumpsite at Bhanpur Khandi

The MSW in Bhopal is collected and dumped at the disposal site at Bhanpur Khandi (also called Bhanpur khanti or Bhanpur(a) site), which is 15-16 km away from Bhopal (BMC 2006, Dasgupta 2015). Site visits in 2017 confirmed that no treatment of the collected MSW is happening at the site before dumping the MSW. Only recyclable material that is financially beneficial is extracted by the informal sector like certain types of plastic (chapter 2.3.4.2).

The Bhanpur dumpsite is the major disposal site in Bhopal with an area of about 50 acres. The site is in use for over 35 years and has reached its capacity (BMC 2014). In addition, the dumpsite is meanwhile lying inside municipal limits (Clean India Journal 2014). As a result, the dumpsite is intended for closure, possibly already within the next year (Tiwari & Rupali 2017). During the visit in March 2017 it was also explained the dumpsite as virtually overfilled, with unsegregated waste piled up not higher than 5 meters (Khare 2017). The waste is neither compacted nor covered with earth.

The collected unsegregated waste is transported to the dumpsite by different garbage trucks as shown in Figure 21. The garbage trucks are entering the dumpsite passing a weigh bridge (Figure 21, right). Approximately, at the end of 2016 digital data recording was implemented instead of the manual recording of the weighed data. The data serve for documentation purposes (Tiwari & Rupali 2017).

Figure 21: Vehicles used for transporting waste to the dumpsite and weigh bridge

Photos by ifeu Heidelberg

Figure 22: MSW dumped at Bhanpur Khandi

Photos by ifeu Heidelberg

Figure 22 gives an impression of the disposed of unsegregated MSW at the dumpsite. From visual assessment the waste mainly consists of organic or inert material, textiles and plastics bags. The picture at the bottom right expresses that especially the textiles, long stringy material, decomposes badly and would also be difficult to separate by machinery like trommel in case of pretreatment.

The digging out of the dumped waste as shown at the pictures in Figure 22 top left and bottom right is done as an attempt to minimize the dumped waste by transforming the organic fraction into fertilizer (Figure 23), also called manure.

Preparation and conditioning of the excavated waste is done in a sorting plant next to the dumpsite. This waste processing plant was set-up around 2005 by M.P. Agro Fertilizer Corporation Ltd. It has a capacity of 100 TPD, but was not in operation for some time due to technical reasons (Dasgupta 2015). During the visit in March 2017 the plant was in operation and could be visited.

Figure 23: Waste to fertilizer unit at the landfill site

Photos by ifeu Heidelberg

The input into this unit is material from the adjacent dumpsite from which non-organic material like plastics and textiles are separated as far as possible during excavating. Before treatment the input material is piled up outside the plant for drying (Figure 23, top left). The treatment consists of several mechanical steps[26]:

First the input material is lifted to the top floor of the unit (Figure 23, top right) and is then passing separator and shredding aggregates over two floors down using gravitation and conveyor belts for transport. Coarse materials and impurities like metals, stones and glass are removed (Figure 23, middle left). The mechanical treatment process emits lots of dust and is very noisy. The remaining material, the so called manure or fertilizer, is very fine and is packed into 50 kg bags (Figure 23, middle right and bottom left). According to Mr. Khare, who is in charge of this unit, about 120 bags of the manure are produced on a daily basis (Khare 2017). The so called manure is sold to M.P. Agro on request for use in agriculture at a price of approximately 300 rupees per bag. The so called manure was analyzed once with the result of rather poor nutrient content. Due to this selling of the so called manure is difficult and it is mostly stored in the storage area of the facility (Figure 23, bottom right).

In general, the plant is not operated during the rainy season as the excavated waste needs to be dry for processing. In addition, out of order periods arise from electricity failures.

2.3.4.2 Saarthak’s Plastic waste sorting unit

A small plastic sorting unit has been set up by Saarthak near the Bhanpur dumpsite and an employee of Saarthak was interviewed during a site visit in March 2017 (Rahul 2017). The center aims to retrieve different types of recyclable plastic waste, collected by the informal sector mostly from the landfill site, and sort it according to its intended use and recycling potential.

At the center itself only a presorting takes place, separating the plastic waste into three quality categories:

1. Milk pouches and similar plastics are of highest quality, these are granulated and sold as secondary products.
2. Plastic bags thicker than 40 µm are considered medium quality, this fraction is shredded and used for road construction[27].
3. Plastic bags < 40 µm are considered low quality, this fraction is compacted and sold to Satna Cement Works (MP Birla) for co-incineration in cement kilns.

Figure 24 (right) shows the secondary products derived from plastic recycling, the granules to be sold to the market, and the shreds to be used in road construction.

[26] The plant is sometimes referred to as compost plant, but the process does not include a biological treatment.

[27] Usually this does not lead to any substitution of bitumen, the benefit lies in the sure long time disposal of the plastic waste.

Figure 24: Plastic waste sorting center

Photos by ifeu Heidelberg

2.3.4.3 Biomethanation plant at Bittan Market

Since the beginning of 2017, the city has one biomethanation plant for producing biogas from organic waste of the Bittan Market Sabji (vegetable) bazaar, which happens three days a week. In addition, kitchen waste of surrounding hotels and restaurants is used. The plant has been funded by the BMC and is designed and operated by Ikos Mailhem Environment Pvt. Ltd. A member of this company was interviewed during the visit of the plant in March 2017 (Yadav 2017). The company has been contracted to maintain and operate the plant for a period of 5 years. For acquisition of the additional waste the company has contracts with hotels and restaurants within a radius of 2 km around the plant to collect and drop their kitchen waste at the center.

The biomethanation plant has a capacity of using 5 tons of waste per day to produce 300 cubic meters of biogas per day. The plant is fed between 9 am and 5 pm with the organic waste, which is shredded and introduced into the fermentation process by adding 2 liter fresh water per kg organic waste (Figure 25, top left). The mixture then flows into a basin before being pumped into the concrete fermenter (Figure 25, top right and middle left). Biogas generated is stored in two balloons (Figure 25, bottom left), and conducted through a SO_2 scrubber before being used in a 50 kW CHP unit. The CHP unit runs on demand only, generated electricity is used to light up the market area in the evening. The extra power is used for the biomethanation plant. The facility is equipped with an automatic flare, which so far ignited once or twice a month to burn excess gas. The digestate produced as a by-product of the process is stored and meant to be sold to BMC for use as manure and landscaping measures in public parks and gardens. From visual assessment the digestate stored was liquid and may not easily be used for this purpose. As the plant was only in operation for a few months, the storage tank was not yet emptied.

Altogether, the plant is well organized compared for example with similar plants in Bangalore. The construction is proper with green pipes for the fresh material feed line, brown pipes for the digestate recycle line, and yellow pipes for the biogas line. Security standards are met with the automatic flare and at least no smoking signs albeit no designated explosive areas.

Figure 25: Biomethanation plant at Bittan market

Photos by ifeu Heidelberg

2.3.4.4 Small scale compost plant at Anand Vihar Sabzi Mandi

One of the voluntary initiatives in Bhopal is the small scale compost plant at Anand Vihar Abzi Mandi. This plant was implemented by the Self Help Group (SHG) Sakaratmak Soch one month prior to the project team's visit in March 2017. The project and process were introduced by a member of the SHG (Pankaja 2017). The group consists of about 250 women volunteering for improvement of sanitization and valuable use of waste in their neighborhood. The women are organized via a WhatsApp group and managed to bring into operation a composting machine "Reddonatura" (Figure 26, left),provided by BMC, which was stored and unused for 3 years.

The composting machine utilizes the vegetable waste from the market and currently also leaves. The machine has a capacity of 300 kg. After using 200 g special bacteria from the manufacturing company for the initial inoculation of the organic waste, it is sufficient to reintroduce 15 – 20 kg compost to inoculate the process. Retention time is about one week. The produced compost (Figure 26, right) is used by the members of the SHG in their kitchen gardens, lawns and currently also donated for use in local schools and community gardens. The group is working to develop a lucrative business model around the initiative.

Figure 26: Small scale composter at a vegetable market

Photos by ifeu Heidelberg

2.3.5 Further aspects and future prospects

Apart from the small scale civil society initiatives, large scale measures to effectively manage solid waste need to be implemented by the Municipality. The slight lack of financial resources to support such measures is a bottleneck for success. More programs at the central and state level should be structured around Solid Waste Management, since currently, Swachh Bharat Mission is the sole funding and may not be enough to tackle all pertinent challenges.

One large scale measure awaiting Bhopal is closure and remediation of the Bhanpur dumpsite. Possible locations for a new landfill are 0.25 km^2 at Fatehpur Dobra (BMC 2017b) and more likely 0.26 km^2 at Adampur (also called Adampur Chavni/Chhawni/Chhawani/Chhaoni) (BMC 2014, CDIA 2015). In 2014 BMC called for tenders of private partners which would collect and transport MSW, close the dumpsite at Bhanpur Khandi, open a sanitary landfill at Adampur and install a waste-to-energy (WtE) plant near the new dumpsite (Dasgupta 2016, BMC 2014). However, BMC changed their plans and next intended to construct a sanitary landfill and a compost plant near Adampur. The compost plant should compost fresh MSW in windrows for approximately 28 days and the proposed landfill should possess a base liner and leachate collections system and after closure also a cover and a gas collection system (Dasgupta 2015, Dasgupta 2016). An Integrated Solid Waste Management plan for the city is in the draft stage. It proposes conversion of waste to electricity and a segregated collection route for green waste (garden waste, grass, trees, etc.) (Tiwari & Rupali 2017).

The idea of a WtE-plant was also mentioned during two interviews in March 2017, both times together with the WtE-plant in Jabalpur (Mishra 2017, Tiwari & Rupali 2017). According to the interviews, Jabalpur has formed a cluster with 7-8 other cities and together they combust a non-recyclable, high calorific fraction out of their MSW in the WtE-plant near Jabalpur (brief description see chapter 2.5). The WtE-plant was said to be in operation and running properly since one year. Reasons for the success are comprehensive pre-studies including waste analysis and that only a high calorific value fraction is incinerated. The same cluster concept is now envisioned for a WtE-plant in Bhopal with 10-11 cities.

This goes well with a recent initiative by the state to cluster SWM projects, thereby achieving necessary amounts of waste and improving viability (CDIA 2015). Currently, BMC is planning a WtE-plant at Adampur, but realization is under uncertainty (TNN 2017).

2.4 References Bhopal

Yadav (2017): Personal conversation with Mr. Yadav, employee of Ikos Mailhem Environment Pvt. Ltd. March 2017. Biomethanation unit at Bittan Market, Bhopal.

BMC (2006): Bhopal Municipal Corporation: Bhopal City Development Plan - JNNURM. Bhopal: Bhopal Municipal Corporation. http://www.mpurban.gov.in/Pdf/CDP/Bhopal%20CDP_Final%20.pdf.

BMC (2014): Bhopal Municipal Corporation: Request For Qualification for Municipal Waste to Energy Plant Bhopal. http://www.renewableenergyheadlines.com/index.php?option=com_k2&view=item&id=2352:madhya-pradesh-rfq-for-municipal-waste-to-energy-plant-bhopal&Itemid=272

BMC (n.d., a): Bhopal Municipal Corporation: Informative Map. http://www.bhopalmunicipal.com/city-information/informative-map.html. Access 23.06.2017.

BMC (n.d., b): Bhopal Municipal Corporation: Health and Environment. http://www.bhopalmunicipal.com/department/health-and-environment.html. Access 22.06.2017.

CDIA (2015): Cities Development Initiative for Asia: Pre-Feasibility Study – Bhopal Solid Waste Management – Executive Summary. http://www.cdia.asia/wp-content/uploads/2015/12/IND_Bhopal_ES.pdf.

Chandel et al. (2014): Chandel, P.P.S.; Sarsaiya, S.; Gautam, S.; Mandloi, G.S.; Nigam, V.; Gour, R.: Primary Inventorization of Electronic Waste in Bhopal City. Oublished in Volume 9 Number 3 of Current World Environment. http://www.cwejournal.org/vol9no3/primary-inventorization-of-electronic-waste-in-bhopal-city/.

Clean India Journal (2014): Bhopal Municipal Corporation Calls for Comprehensive Waste Solutions. Published by an unnamed editor in Clean India Journal. 21.04.2014. https://www.cleanindiajournal.com/bhopal-municipal-corporation-call-for-comprehensive-waste-solutions/. Access 22.06.2017.

Dasgupta, Tapas (2016): Proposal for Infrastructure development of Adampur Landfill Site at Bhopal in MP. Published in International Journal of Advances in Engineering & Technology. http://www.ijaet.org/media/8I30-IJAET0830233-v8-iss6-pp958-964.pdf.

Dasgupta, Tapas (2015): A Case Study on Adampur Landfill Site at Bhopal in M.P.. Published in International Journal of Advances in Engineering & Technology. http://www.ijaet.org/media/8I30-IJAET0830233-v8-iss6-pp958-964.pdf.

Dasgupta, Tapas (2013): Waste Management in Bhopal Municpal Corporation Issues and Perspectives. Published in Volume 2 Number 9 of International Journal of Scientific Engineering and Technology. https://ijset.com/ijset/publication/v2s9/IJSET_2013_901.pdf.

Gaur, A., Chourey, S., Madathil, D., & Nair, A. N. (2014): Quality analysis of drinking water in Bhopal city. Published in International Journal of Research in Engineering and Technology.

Tiwari & Rupali (2017): Personal conversation with Mr. Tiwari and Ms. Rupali, Additional Commissioner of BMC and Research Assistant of BMC (which is employed by KPMG). February/March 2017. Bhopal.

IRG (2013): IRG System South Asia Pvt. Ltd.: Inventorization of E-Waste in Bhopal, Indore, Gwalior and Jabalpur Divisions of Madhya Pradesh. http://www.mppcb.nic.in/TP/Exetive_Sum-E-Waste-I-phase.pdf.

Katiyar et al. (2013): Katiyar, R.B.; Suresh, S.; Sharma, A.K.: Characterisation Of Municipal Solid Waste Generated By The City Of Bhopal, India. Published in Volume 5 Number 2 of International Journal pf ChemTec Research. http://www.sphinxsai.com/2013/conf/PDFS%20ICGSEE%202013/CT=11%28623-628%29ICGSEE.pdf.

Prof. Mishra (2017): Personal conversation with Professor Mishra at Academy of Administration and directorate of Urban Administration. March 2017. Bhopal.

MoUD (2015): AMRUT, Mission Statement & Guidelines. Ministry of Urban Development, Government of India, June 2015. http://amrut.gov.in/writereaddata/AMRUT%20Guidelines%20.pdf

Pankaja (2017): Personal conversation with Ms. Pankaja, member of the initiative Sakaratmak Soch. March 2017. Bhopal.

Khare (2017): Personal conversations with Mr. Khare, person in charge on the dump site and of the organic manure unit at Bhanpur Khandi. February/March/April 2017. Bhopal.

Rahul (2017): Personal conversation with Mr. Rahul, employee of Saarthak. March 2017. Near Bhanpur Khandi, Bhopal.

Sharma (2016): Personal conversation with Mr. Sharma, Health Officer, Ward 15 and Deputy Chief Health Officer Bhopal city. November 2016. Bhopal

Rao (2016): Open Minds Shape the Future – HZI Community Event 2016. Hitachi Zosen India. http://www.hz-inova.com/cms/wp-content/uploads/2016/03/01b_Key-Note_K-Sreenivasa-Rao_E.pdf. Accessed on 23.06.2017.

Smart Cities Council India (2016): Garbage in, energy out – Jabalpur to use combustion technology for waste management. http://india.smartcitiescouncil.com/article/garbage-energy-out-jabalpur-use-combustion-technology-waste-management. Access 23.06-2017.

Smart Cities Projects (2015): India Smart City Profile – Bhopal. http://smartcities.gov.in/upload/uploadfiles/files/MadhyaPradesh_Bhopal.pdf. Access 22.06.2017.

Swachh Survekshan (2017): Swachh Survekshan Dashboard. Initiated by the Ministry of Urban Development. http://swachh-survekshan.in/ Access 04.07.2017.

TNN (2017): Resentment against new abbatoir at Adampur, could derail MSW plant. Published in The Times of India. TNN | Updated: Feb 28, 2017, 12.52 PM IST. http://timesofindia.indiatimes.com/city/bhopal/resentment-against-new-abattoir-at-adampur-could-derail-msw-plant/articleshow/57381767.cms

TNN (2015): JNNURM projects to get funds from central scheme. Published in The Times of India. TNN | May 28, 2015, 11.37 PM IST. http://timesofindia.indiatimes.com/city/pune/JNNURM-projects-to-get-funds-from-central-scheme/articleshow/47462699.cms. Access 21.04.2017.

2.5 Annexure Bhopal

Brief description WtE-plant Jabalpur

The WtE-plant in Jabalpur was commissioned to Hitachi Zosen India, which built the Jabalpur plant together with Essel Infra, in February 2014. An outcome of a process started in 2010, "LoCal 580", the Energy from waste concept for low calorific requirements. According to the company (Rao 2016), key issues were to bring down capital costs to meet to local economy, to involve local knowledge from combustion of fossil fuels as well as from regulations, legal requirements, and technology level. Further aspects for the viability of a WtE-project are the implementation of tipping fee and preferential electricity price.

Hitachi Zosen India with Essel Infra, offer two models of WtE-plants in India:

1. one with 11.5 MW for 600 tons per day with a calorific value of 1650 kcal/kg,
2. one with 8 MW for 580 tons per day with a calorific value of 1100-1400 kcal/kg.

The plants comply with the relevant European standards (Smart Cities Council India 2016), especially heavy metals, dioxins and furans limits are congruent (Rao 2016). Further WtE-plants are proposed to cities in India, e.g. to Bangalore.

The WtE-plant in Jabalpur is a grate combustion plant with a combustion capacity of 600 tons of high calorific MSW per day and a capacity to supply electricity of 11.5 MW. One of its important elements is the flue gas treatment. Governmental norms favor this facility — according to the guidelines issued by the Ministry of New & Renewable Energy, it is mandatory that the municipal corporation absorbs all the power generated by this plant. (Smart Cities Council India 2016).

Annex 3: Solid Waste Management

Haridwar

3 Annex 3: Solid Waste Management Haridwar

3.1 Objective and scope

'Resource and Climate Protection through Integrated Waste Management Projects in India' is a research study commissioned by the German Environment Agency and funded by Germany's Federal Ministry for the Environment, Nature Conservation and Nuclear Safety. The project is implemented by the German ifeu (Institute of Energy and Environment Research) along with Development Alternatives and Ecoparadigm.

The objective of the study is to support decision makers in identifying the potential to reduce greenhouse gas (GHG) emissions in the Solid Waste Management (SWM) sector in order to plan their waste management or e.g. Nationally Appropriate Mitigation Actions (NAMAs) accordingly. It will show specific GHG emission saving potentials of an integrated waste sector approach for Indian cities at present and for future scenarios. The study is conducted on specific selected cities and the selection is done systematically with respect to the three priority criteria including availability and quality of waste data, stakeholder support to improve waste and contact network and other criteria such as population, income level and climate zone. The final selected cities were Bangalore, Bhopal and Haridwar.

This report section presents the situation of Municipal Solid Waste Management (MSWM) in Haridwar. Secondary level data and information that is collected from government officials, MSW treatment plant operators and subject experts is analyzed and presented in this report. The verification of data collected and data gaps were shared with different stakeholders, detailed discussions were conducted in form of a stakeholder workshop, results of which are presented in a separate workshop report.

3.2 An overview of Haridwar

3.2.1 Geography and topography

Haridwar (also called Hardwar) is located at 29° 58' north latitude and 78° 10' east longitude, where the river Ganga enters the North Indian River Plain after flowing down the Himalaya. The city is headquarter and biggest city of Haridwar district in the North Indian state Uttarakhand. At an altitude of about 300 m above sea level, Haridwar spreads over 12.17 km^2 on both sides of the river Ganga with the majority of Haridwar situated northwest of the river. (GHK 2007, IPE 2009)

3.2.2 Climate

According to the Köppen Geiger climate map (Peel et al. 2007), Haridwar is located in a region classified as "Cwb", but near to "Cwa" climate zone. The main climate is temperate (C) with dry winters (w: precipitation of wettest summer month at least 10 times higher than driest winter month). "Cwb" indicates warm summers, "Cwa" hot summers (at least one month's average temperature above 22°C) with monsoon influence. Haridwar's climate is seasonal with winter season from November to February, followed by an early summer season from March to June and then a monsoon season from July to September. According to (GHK 2007), Haridwar has a humid climate influenced by the cooling river and nearby Himalaya. Humidity during summer is stated as 40 to 60% and the annual maximum temperature as 30 to 42°C, whereas in winter the humidity declines to 25% and temperature can decline to a minimum of 4°C. During rainy season the humidity is 70 to 85%. In summer hot dust raising winds with velocities of up to 15 km/h occur frequently.

3.2.3 Population

The census in 2011 determined Haridwar's population to be about 230,000 people (Census Organization of India 2015). However, the city's floating population amounts to about 160,000 people per day (IPE 2009, CPCB 2016) and consists mostly of people visiting for religious reasons or business purposes (GHK 2007). A considerable proportion of the population is living in slums, (IPE 2009) mentions

86,888 slum dwellers and (MoUD 2016) states 56,295 people living in slums in 2011. The city’s population has been increasing for decades, the census in 2001 only counted 175,000 people (GHK 2007). The population growth is predicted to continue and current projections estimate a population of 266,864 in 2019 and 293,530 in 2025 (MoUD 2016) and 424,000 people in 2041 (Urban Development Directorate of Uttarakhand 2015).

In 2016, the city was divided into 30 wards, aggregated in 4 zones (CPCB 2016).

3.2.4 Religious importance

Although Haridwar’s outskirts are among the most industrialized regions of Uttarakhand with Bharat Heavy Electricals Ltd. (BHEL) alone employing several thousand workers (IPE 2009), Haridwar is of great religious and spiritual importance. This is partly because Haridwar is one of the seven sacred cities of Hindu culture in India and one of the four places in India where the Kumbh Mela takes place every twelve years (GHK 2007). According to (IPE 2009), the average number of tourist and pilgrims visiting Haridwar is 50 million people per year, whereas (GHK 2007) mentions 8 million religious tourists per year.

3.3 Municipal Solid Waste Management in Haridwar

3.3.1 Waste generation

In this study, the current average municipal solid waste generation in Haridwar is assumed to be 237 t/d, which includes an estimated waste generation of 315 t/d during 20 days per year due to religious festivities (Nagar Nigam Haridwar 2015). While there are no accurate assessments of the current waste generation, the estimated waste generation of 237 t/d is consistent with other existing estimations of waste generation in Haridwar. The Urban Development Directorate (2015) estimated an MSW generation of 218 t/d in 2014 and the MoEFCC (2015) stated an MSW generation of 200 – 215 t/d and in peak months 250 t/d as monthly average. Newspaper articles mention 300 t/d or 350 – 400 t/d MSW generation during festivities (Azad 2015, Radhika 2016). The additional waste generation during festivities poses a challenge for waste management and (together with sanitation problems) leads to an increased number of diseases (Sharma et al. 2010).

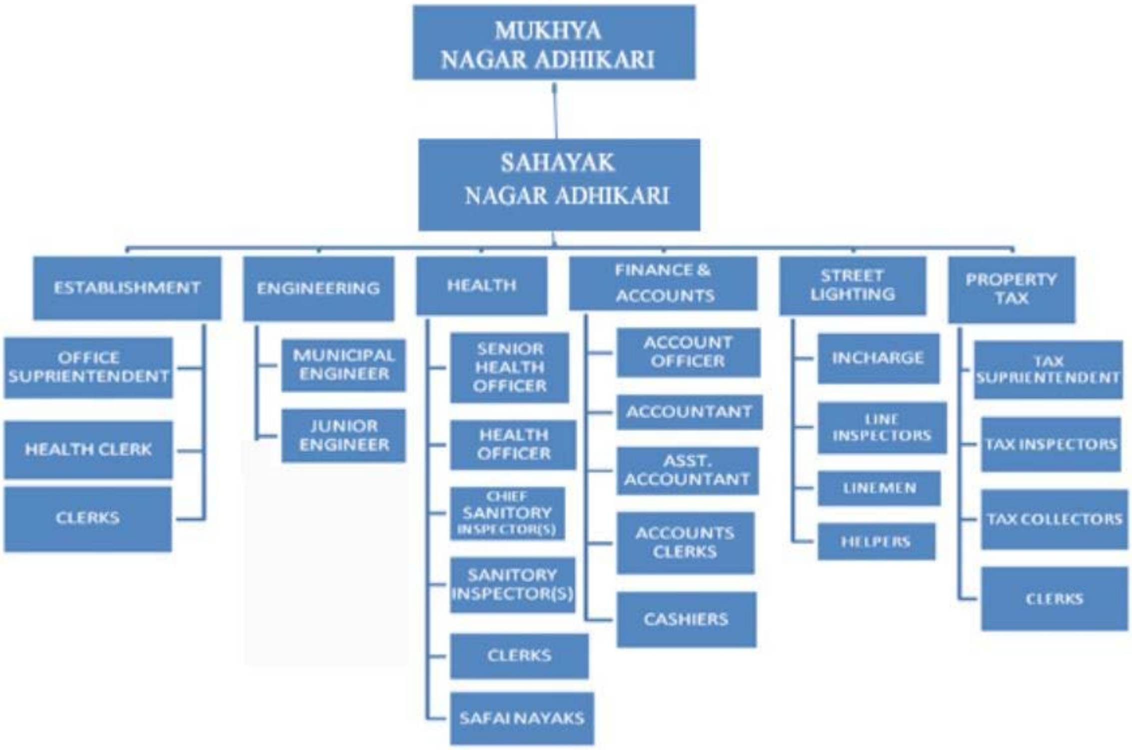
The MSW generation has been increasing for years and this trend is predicted to continue, partly because of population growth and partly because of increasing waste generation per capita (TERI 2014). Projections for MSW in Haridwar expect 278 t/d in 2025 (MoEFCC 2015) and 368 t/d in 2041 (Urban Development Directorate 2015).

The MSW includes waste from households as well as commercial waste. The city development plan from 2007 estimated household waste to make up 82% of the generated MSW, with another 6% generated by shops and commercial activities, 3% generated by fruit and vegetable markets, 2% generated by hotels, restaurants and dharamshalas, 1% construction and demolition waste and 6% other waste (GHK 2007). Another study divided the estimated waste generation into 50% collected in residential areas, 32% collected as commercial waste and 18% collected by street sweeping (IPE 2009).

3.3.2 Organizational structure of SWM

The authority in charge of SWM in Haridwar is called Nagar Nigam Haridwar. Its organizational structure is depicted in Figure 27 and shows that Nagar Nigam Haridwar has many other responsibilities, too. Among these responsibilities are city cleanliness, biomedical waste, wastewater drainage, community toilets, stray cattle management, street lightning, and property tax (Nagar Nigam 2017a). “Mukhya Nagar Adhikari” roughly translates to “Chief Municipal Officer”, and the department of Nagar Nigam Haridwar responsible for solid waste management is the health department. For some duties (such as door-to-door collection of MSW) Nagar Nigam Haridwar has contracted private organizations in public-private partnerships.

Figure 27: Organization structure of Nagar Nigam Haridwar



Source: (Nagar Nigam Haridwar 2017b)

3.3.3 SWM programs relevant for Haridwar

Waste management projects in Haridwar are supported by many different programs. Some notable programs are mentioned below, some of whom have already been described in detail in the interim report about Bangalore.

3.3.3.1 Swachh Bharat Mission

Swachh Bharat Mission (SBM) is a national level campaign being implemented by the Ministry of Urban Development (MoUD) and by the Ministry of Drinking Water and Sanitation (MoDWS) for urban and rural areas in India for ensuring hygiene, waste management and sanitation across the nation. The mission lays down specific guidelines to be followed by governing bodies in a national level, state level and city level.

Nagar Nigam Haridwar has received funds as part of the Swachh Bharat Mission (MoUD 2016, Uttaranchal High Court 2017), which intends to improve sanitation and solid waste management.

3.3.3.2 Namami Gange

Namami Gange is a program of the National Mission for Clean Ganga and intends to stop pollution of the river Ganga and to revive the river (NMCG 2017). It focuses on sewage treatment infrastructure, river-front development, river surface cleaning, biodiversity, afforestation and public awareness. In Haridwar sieve-like devices will be installed at several bridges, ghats and the opening of nullahs carrying sewage into the Ganga (Jaiswall 2017). Worshipping material and other waste collected there will be thrown out using trash skimmers. In addition, several sewerage treatment projects in Haridwar have been approved under Namami Gange: A new sewage treatment plant for 68 m^3/d in Jagjeetpur and one for 14 m^3/d in Sarai as well as supplementing the existing sewage treatment plants for 27 m^3/d in Jagjeetpur and 18 m^3/d in Sarai with tertiary treatment (Press Information Bureau 2017).

Though the Clean Ganga Mission does not target solid waste management itself, it funds systems to address floating solid waste in the river and to reduce entry of solid waste into the river as a result of poor sanitation practices in rural areas.

3.3.3.3 JNNURM and AMRUT

The Jawaharlal Nehru National Urban Renewal Mission (JNNURM) was a national scheme launched by the Government of India under the ministry of Urban Development to improve urban infrastructure and services and identified 65 cities for the program. It envisaged a total investment of over 20 billion US $. The seven-year mission was to end in 2011-12, but repeated extensions were given as the project was delayed for reasons like land acquisition. The scheme was closed in 2015 (TNN 2015). The program supported cities to improve their infrastructure services in a financially sustainable manner, to (re-)develop their area, to develop urban reforms and appropriate framework, and to make their services available to the urban poor. Haridwar’s JNNURM project was approved in 2009 with projected costs of 167.2 million rupees and includes procurement of waste management equipment (such as transport vehicles and bins), launching of door-to-door collection and construction of an integrated SWM facility (Urban Development Directorate 2015). Half of the cities covered by JNNURM are cities with more than one million inhabitants, the rest are state capitals or cities of some other importance (IPE 2009, Urban Development Directorate 2015). The only other cities in the state of Uttarakhand which participated in the JNNURM scheme are Dehradun and Nainital (Urban Development Directorate 2015).

AMRUT, Atal Mission for Rejuvenation and Urban Transformation, is the follow up program of JNNURM, also launched by the Government of India under the Ministry of Urban Development. The program has funds allocated of 500 billion rupees (nearly 8 billion US $) for five years from 2015 to 2020. It covers 500 cities, where Haridwar is one of. Nevertheless, AMRUT focuses on infrastructure creation with direct link to provision of better services to people like especially water supply, sewerage facilities, parks and urban transport. Solid waste management is not a thrust area of AMRUT. (MoUD 2015)

3.3.4 Key rules and policies concerning SWM in Haridwar

In 2007, Haridwar’s City Development Plan identified non-compliance with the Municipal Solid Waste (Management & Handling) Rules 2000 as the major problem of Haridwar’s solid waste management (GHK 2007). These rules included the following obligations for municipal authorities (IPE 2009):

- Segregated waste storage at source (and no littering)
- Door-to-door collection
- Daily sweeping of streets
- Use of covered containers for secondary waste storage
- Use of covered vehicles for transportation
- Processing of waste through biological stabilization, recycling or waste to energy
- Disposal of inert waste and rejects in Engineered Sanitary Landfills

Especially the last two aspects have had a strong influence on the plans for Haridwar’s new integrated SWM facility, which is currently under construction. Recently, the rules from 2000 were replaced by an updated version, the Solid Waste Management Rules, 2016 (MoEFCC 2016). Haridwar’s new integrated SWM facility will comply with these new rules, which also name some preferred treatment technologies for biodegradable waste: biological stabilization (such as composting or biomethanation) or waste to energy processes. Only non-recyclable, non-biodegradable, non-combustible and non-reactive inert waste as well as rejects and residues from waste processing facilities shall be deposited in landfills (MoEFCC 2016).

Another influence on Haridwar's waste management is a prohibition of using plastic for serving food, commodities and packaging in the entire city of Haridwar and especially near the river Ganga (National Green Tribunal 2015a). This ban was issued in July 2015 by the National Green Tribunal in reaction to the huge amounts of plastic waste accumulated on the riverbanks. A fine of 5,000 rupees for violation of the ban was decided. In fact, in December 2015 the National Green Tribunal extended that ban on all cities on the Ganga's riverbanks between Haridwar and the Ganga's origin at Gomukh (Gaumukh) (National Green Tribunal 2015b). This second order clarified that forbidden plastic goods were especially plastic carry bags, plates, glasses, spoons, and plastic packaging. The ban's intention is for people to replace these plastic goods by more environmentally friendly alternatives. A strict implementation of this ban by authorities could change Haridwar's waste composition and especially reduce the percentage of polythene. However, there are many businesses producing polythene products in the district Haridwar and enforcement of the ban was met with resistance by traders (Tiwari 2015, Jaiswall 2015). In August 2016, plastic in form of bags, plates and the like was still openly and frequently used in Haridwar (Trivedi 2016). Sensitizing of pilgrims was deemed especially insufficient and in the last seven months the Haridwar Municipal Corporation had confiscated 76 kg of polythene and fined different traders 250,000 rupees.

3.3.5 Waste collection

The MSW Rules 2000 (as well as the updated SWM Rules 2016) demand door-to-door collection of waste stored in a segregated manner. Back in 2007 the only door-to-door collection was carried out by private sweepers engaged by Mohalla Swachhata Samities (MSS) in a few areas. In all other areas waste was dumped in community bins/containers or onto the streets, where municipal street sweepers accumulated the waste into small heaps and then deposited it in community bins/containers or loaded it directly onto the transportation vehicles driving to the disposal site (GHK 2007). An article from 2010 mentioned a correlation of the collection system and the wealth of inhabitants: While in one wealthy colony no waste was thrown onto the street and instead a private sweeper was paid for door-to-door collection, in some other less wealthy colonies waste was thrown onto the streets and irregularly collected by municipal sweepers (Sharma et al. 2010). Under the JNNURM scheme, the private company KRL Waste Management (Haridwar) Private Limited was commissioned to carry out door-to-door collection in Haridwar. In early 2015, KRL provided door-to-door collection in 10 wards and the other wards were covered by the municipal sweepers of Nagar Nigam Haridwar (Urban Development Directorate 2015). In August 2016 KRL provided door-to-door collection in 16 wards and in early 2017 in 22 of the total 30 wards, whereas the other wards were still covered by the municipality (CPCB 2016, HMC 2016 & 2017).

For door-to-door collection, waste generators are asked to segregate biodegradable waste and non-biodegradable waste (including recyclables), which are also referred to as wet waste and dry waste respectively (MoEFCC 2016). In (UEPPCB 2006) biodegradable waste fractions listed are e.g. vegetable waste, coconut shells, non-vegetarian waste, fruit peels, ash, garden waste, kitchen waste, whereas non-biodegradable waste includes for example waste plastic, polythene covers, wooden things, bottles, waste cloth, leather items, rubber items, and fused bulbs.

During the visit to Haridwar in March 2017 a door-to-door collection tour was accompanied and explained by Mr. Dubey (2017). He is in charge for the area Kankhal, supervising about 1000 households. Collection takes place every day from about 7:30 am onwards, using bicycle rickshaws. Altogether, approximately 110 collectors visit about 200 households each, announcing their arrival by blowing a whistle. The bicycle rickshaws have four bins on each side, which are intended for separate collection of dry and wet waste (Figure 28). It was observed that full bins caused people to throw waste in other bins and some people handed in bags with mixed waste.

Figure 28: Door-to-door collection by bicycle rickshaw in March 2017

Photos by ifeu Heidelberg

When the bicycle rickshaw cannot take any more waste, the collector returns to a community container (waste storage depot). There he manually extracts marketable recyclables from the waste, using a hoe for aid (Figure 29). Afterwards, he deposits all other waste (wet waste as well as the remaining dry waste) together in the community container, from where it is transported to the current final disposal at the dumpsite (chapter 2.3.4). Bags with mixed waste were hardly opened.

The described door-to-door collection takes place in residential areas. In slum areas community bins placed at suitable locations should be used in case of lack of access or narrow lanes. The bins will be emptied into pick up vans. In private societies, multistoried buildings, and commercial complexes normally no sweepers are provided by the municipality. These establishments generally engage private sweepers (IPE 2009).

(IPE 2009) estimated that recyclables make up 25% of the MSW collected by door-to-door collection and that 15% of the collected MSW will be separated by waste collectors and sold as recyclables. This significantly decreases the amount of waste which the municipality has to transport and treat. And this does not even include the recyclables which households themselves sell instead of throwing them away. (MoUD 2016) reports that of the 237 t/d generated waste in Haridwar only 170 t/d are collected and transported.

Figure 29: Unloading and separating collected waste at community container

Photos by ifeu Heidelberg

In general, recyclables from informal collection are sold to Kabadiwallas, which are small scrap aggregators and function as intermediaries in the market for recyclables. In March 2017 one Kabadiwalla shop was visited which mostly bought commercial recyclables (Figure 30). The Kabadiwalla employes 10 - 15 people which are responsible for going door-to-door and collecting recyclable material, then segregating it into different streams at the collection point. Cardboard is sold to a recycling plant in Dehradun and other recyclables are sold to merchants. The Kabadiwalla shop was well equipped with a weighing machine for waste, a safe and a fire extinguisher. The Kabadiwalla estimated the number of Kabadiwallas in Haridwar to be 200 - 400.

Figure 30: A Kabadiwalla (itinerant trader) shop

Photos by ifeu Heidelberg

Especially in wards without door-to-door collection, much MSW is thrown onto streets or into surface drains (GHK 2007, National Green Tribunal 2015a). Waste thrown into surface drains can block them and small scrap material often ends up in the river Ganga (National Green Tribunal 2015a). Removal of stuck waste was witnessed during the visit in March 2017 (see Figure 31). Waste on streets is collected by street sweepers and usually deposited in community containers and bins, similar to the containers used for waste from door-to-door collection. Those containers and bins are placed in all wards and add up to approximately 200 (GHK 2007, CPCB 2016). An inspection team of the Central Pollution Control Board deemed their number sufficient in 2016, whereas the National Green Tribunal mentioned an unsatisfactory number of these in 2015 (National Green Tribunal 2015a, CPCB 2016). In addition, the National Green Tribunal criticized huge quantities of waste on the river banks and ghats and ordered Nagar Nigam to install more bins, which are to be emptied every day. They also directed Nagar Nigam to prevent people from throwing waste on river banks and ghats and clean those areas daily. During the inspection by members of the Central Pollution Control Board (as well as during the visit in March 2017), the waste collection gave a better impression: little waste was left on the streets, although several surface drains were littered with waste (CPCB 2016).

In 2016, street sweepers used handcarts to collect the waste, and bicycle rickshaws and wheelbarrows with PE containers were used for door-to-door collection (CPCB 2016). Tractor trolleys, tipping trucks, dumper placers, and front end loaders were used for transportation of waste.

3.3.6 Waste composition and other properties

(IPE 2009) includes an investigation of the physical and chemical composition of MSW in Haridwar. Four samples were taken from MSW transported from four economically different wards to the disposal site. The average weight of these samples was 2508 kg. The determined waste composition is summarized in Table 10.

Table 10: Waste composition of samples from four wards arriving at disposal site

Waste fraction	Portion [% by mass]	Details
Organics	50.35	Mostly kitchen waste (35.10), green leaves (7.46) and dry leaves (4.17)
Paper	5.08	
Plastic	8.40	PE bags (7.13) and plastics (1.27)
Textiles	9.60	
Glass	0.12	
Inerts	23.91	Sand/earth/soil (19.95) and construction & demolition waste (3.96), which was made up of stone, lime, bricks and ceramics
Metals	0.06	
Wood	0.38	
Others	1.24	Rubber/leather (0.53), school bags (0.5), thermocole[1)] (0.18) and human hair (0.03)

Source: (IPE 2009)
1) Indian term for polystyrene

Further testing of the samples revealed on average a moisture content of 39.75%, organic matter of 9.38% of dry weight, C/N ratio of 17.71 and calorific value of 1,838.5 kcal/kg dry weight (7.70 MJ/kg dry weight). The calorific value corresponds to 730 kcal/kg wet weight (3.05 MJ/kg wet weight).

During a project reported in (Jain & Sharma 2011), 12 samples of new and old MSW were taken at the dumpsite at Chandighat. Because of the different ages of the MSW and because each sample weighed just 1 kg, waste composition as well as other waste properties varied widely. The average calorific value was determined to be 8.217 MJ/kg wet weight, but some samples had already started drying naturally at the dumpsite and the average moisture content was consequently just 20.5%. The average fixed carbon was 17.3% of wet weight with a range of 12% to 24%, the volatile matter was 21% and the ash content 41.2%.

(Sharma et al. 2010) describes the composition of MSW which was sampled by door-to-door collection from 400 households of four economically different wards in Haridwar during one week in November 2008. Prior to the survey, the selected households were provided with two dustbins for source separation of "biodegradable" waste (including paper and coconut shells) and "non-biodegradable" waste. The results of the study are summarized in Table 11.

Table 11: Waste composition after door-to-door collection

Waste fraction	Portion [% by mass]	Details
Organics	65.7	Mostly vegetables (22.8), food (17.5), leaves (8.8) and fruit (7.0)
Paper	21.9	
Plastic	6.7	Plastic materials (4.7) and PE (2.0)
Glass	1.6	
Others	4.1	Bottles (1.2), crockery (0.9), coal (0.9), rubber (0.6) and fused bulbs (0.5)

Source: (Sharma et al. 2010)

In contrast to the results of (IPE 2009), the waste collected by door-to-door collection included no textiles, no construction & demolition waste and no sand/earth/soil. At least textiles are to be expected also in household waste, although part of the textile waste comes from pilgrims which leave their old clothes on the river banks/ghats after bathing in the holy river Ganga (National Green Tribunal 2015a, CPCB 2016). Sweeping of unpaved streets could contribute to the high proportion of sand/earth/soil, as suggested in (IPE 2009), but removing waste and associated silt from Haridwar's surface drains is said to be the main origin of the sand/earth/soil, which is illustrated by Figure 31.

For GHG calculations the waste composition given in (IPE 2009) was used, because it is more comprehensive then information from (Sharma et al. 2010) and more representative compared to the random samples of landfilled waste in (Jain & Sharma 2011). Based on this composition, the biogenic carbon content was calculated as 13.4% of wet waste and fossil carbon content as 5.7% of wet waste.

Figure 31: Waste and mud removed from open canals

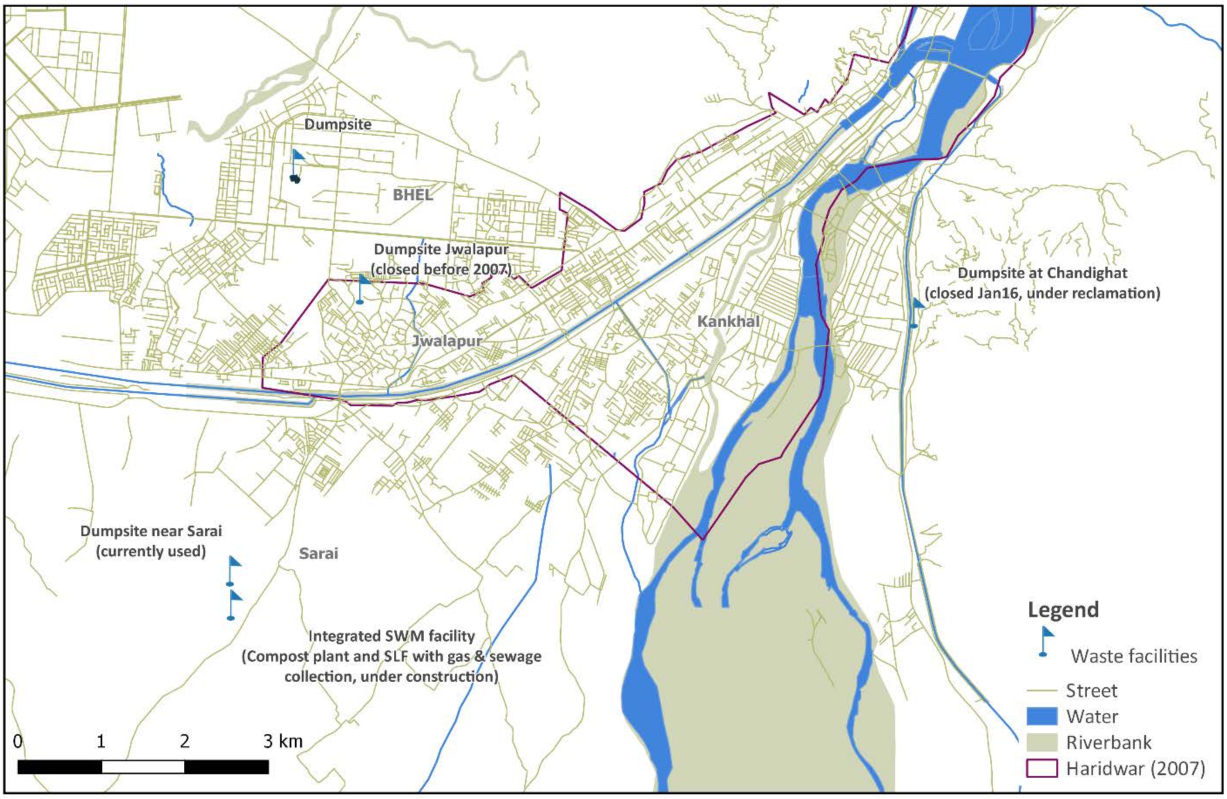
Photos by ifeu Heidelberg

3.3.7 Treatment and disposal of MSW

3.3.7.1 Overview

MSW from Haridwar is not treated before disposal at dumpsites (MoEFCC 2015, CPCB 2016). Site visits and the workshop in March 2017 confirmed this. Currently, MSW is dumped near the construction site for an integrated solid waste management facility near Sarai, which will include a sanitary landfill as well as a compost plant (CPCB 2016). Use of the old dumpsite at Chandighat has been forbidden in 2015, although a lack of alternative dumpsites prevented an immediate stop of dumping (National Green Tribunal 2015a, Tiwari 2015). Another dumpsite at Jwalapur has been abandoned already before 2007 and since then, the dumpsite at Chandighat was the only one in use until recently (GHK 2007, Jain & Sharma 2011, CPCB 2016). OpenStreetMap mentions yet another disposal site, but this one lies on the company grounds of BHEL and is mentioned by no documents concerning MSW, so that it can be assumed to be a company disposal site (OpenStreetMap contributers 2017). The location of the disposal sites can be seen in Figure 32.

Figure 32: Waste disposal sites near Haridwar



Cartography: ifeu; municipal boundary based on (GHK 2007); other spatial data based on © OpenStreetMap contributers

3.3.7.2 Currently used dumpsite near Sarai

Already in 2009 the municipal authority has reportedly dumped waste near the construction site for the integrated SWM facility, which is situated on land belonging to the municipal authority (IPE 2009).

During the visit in March 2017, the then used dumpsite near the construction site was said to be used as the only dumpsite for about a year. From observations and interviews with KRL employees at the site the dumpsite has no form of bottom sealing. Access to the site was unrestricted, as can be seen in Figure 33. New waste was brought in tippers and dumper placers (trucks carrying containers). The height of the dumped waste varied widely with an average height of about 2-3 m. While only the newly deposited waste in front areas of the dumpsite smelled, in back areas of the dumpsite several trails of smoke revealed smoldering fires. Since the smoldering waste was deposited too low and probably not long enough ago to be producing methane, the smoldering fires most likely originated from self-ignition of waste. Many birds and a few dogs were seen on the dumpsite. Although only one informal sector person was seen, there were many small heaps covered with blankets at the outskirts of the dumpsite, containing collected recyclables such as paper and plastics (Figure 34).

Figure 33: Pictures of the currently used dumpsite near Sarai in March 2017

Photos by ifeu Heidelberg

Figure 34: Sorted out recyclables at the currently used dumpsite near Sarai

Photos by ifeu Heidelberg

3.3.7.3 Dumpsite at Chandighat

This dumpsite is situated east of Haridwar near the national highway 74 and a riverbank called Chandighat or Chandi Ghat. It extends over an area of approximately 1.5 km^2 (Jain & Sharma 2011). No machinery for treatment of waste was placed at the site and neither any fencing or other visible boundary (National Green Tribunal 2015a). This allowed for animals to eat waste and for the wind to spread waste over a large area (National Green Tribunal 2015a).

In July 2015 the National Green Tribunal forbade any further dumping at this site, because it is located within the Ganga's flood plain (National Green Tribunal 2015a). Due to the site's location, floods pose the threat that waste and leachate from waste could get into the river. Despite the prohibition, continued use of the dumpsite has been reported in September 2015 due to lack of an alternative dumpsite (Tiwari 2015). According to an inspection in August 2016, more than three quarters of the dumpsite had been capped with soil and vegetation (CPCB 2016). According to the Haridwar Municipal Corporation (HMC 2016 & 2017), the dumpsite was finally closed in January 2016. The National Green Tribunal has issued that once the integrated SWM facility near Sarai is operating, the entire waste deposited at the Chandighat dumpsite shall be segregated and moved to the new integrated SWM facility (National Green Tribunal 2015b).

3.3.7.4 Integrated SWM facility near Sarai

Plans for future treatment and disposal of Haridwar's waste were significantly influenced by the Municipal Solid Waste (Management & Handling) Rules, 2000. Since door-to-door collection and segregated storage of waste at the source are demanded by these rules, at least 100 t/d of (mostly) biodegradable waste are expected to be available for separate treatment (IPE 2009). As a result, a compost plant together with an engineering sanitary landfill is under construction to provide future treatment and disposal of Haridwar's MSW. The compost plant has been designed for a capacity of 100 – 150 t/d biodegradable waste during a first phase from 2015 until 2025 and 150 – 200 t/d during a second phase from 2025 until 2040, while the landfill's capacity is planned to be 50 t/d (MoEFCC 2015, CPCB 2016) and potentially increasing with the increasing waste generation (IPE 2009). An additional storage area in the compost plant will allow for storage of biodegradable waste during times of increased waste generation, such as religious festivals (IPE 2009). Recyclables are meant to be collected separately and recycled, thus leaving only separately collected inert materials (mainly soil from road sweeping) for deposition in the landfill (IPE 2009). In addition, rejects from the compost plant will be deposited at the landfill (IPE 2009).

As a public-private partnership, KRL Waste Management (Haridwar) Private Limited has been contracted to build the integrated SWM facility (Nagrath 2016, HMC 2016 & 2017). This is the same company as the one contracted to collect waste in Haridwar.

The location of the proposed areas for both phases can be seen in the Annexure, chapter 3.5.1, and the compost plant's layout plan from 2016 for a capacity of 100 t/d in chapter 3.5.2 (IPE 2009) describes the intended composting process as follows: The daily collected segregated waste will be unloaded on the concrete yard in a heap and then formed into windrows. Leachate from the compost will flow through drains into a leachate tank from where it will be recycled back onto the windrows. Especially in summer the leachate will not be enough to keep the waste adequately moist and additional water will be needed. Excess leachate will be treated at the already existing municipal sewage treatment plant nearby (location see Annexure, chapter 3.5.1[28]). Because the waste could become too wet during rainfalls, the windrows should be covered with laminated plastic sheets. The windrows will be turned once every 7 days and after 7 - 8 weeks the compost will be sieved by several rotary screens and dispatched. Thorough separation of the biodegradable waste at its source is necessary to enable production of high quality compost.

In August 2016 the compost plant structure for the first phase was under construction. Roller compacted concrete foundations and columns for sheds were under installation, whereas the construction of the engineering sanitary landfill had not yet started (CPCB 2016). The office building and the workshop for vehicles were already constructed and one row of plantation was planted along the boundary

[28] This sewage treatment plant can also be seen on aerial photographs at 29° 53' 35'' north latitude and 78° 5' 21'' east longitude (see for example wikimapia 2017).

of the MSW facility, although the facility's environmental clearance demands at least three rows (MoEFCC 2015, CPCB 2016).

The visit in March 2017 revealed sheds and paved areas quite similar to the plan in the Annexure, chapter 3.5.2. Therefore, the names used in that plan will be used to describe the observed state of construction in March 2017 (see Figure 35). The roofs of the process shed as well as the high roof shed with the storage area were all finished and the floor of the sheds was nearly finished. Several mounts for machinery were constructed mostly in the process shed and KRL employees working on the site informed that machinery was planned to be installed a week later. The composting will take place in the open on the windrow area, which was covered with gravel. In contrast, the drying area between the windrow area and the process shed was covered with concrete. The weigh bridge had also been constructed. Construction of the sanitary landfill, however, still had not started. During the workshop HMC representatives explained that the process will include a mechanical pre-treatment, and the IT official assumed that the beginning of the operation may take another six months.

Figure 35: State of construction of the compost plant in March 2017: process shed, high roof shed, windrow area and weigh bridge (from top to bottom and from left to right)

Photos by ifeu Heidelberg

(IPE 2009) also describes the plans for the engineering sanitary landfill. The environmental clearance of the integrated SWM facility reinforces some aspects of these plans with official requirements (MoEFCC 2015). The bottom of the landfill base will be made up of compacted soil, which must be topped with a composite liner made of geosynthetic clay liner (GCL) and above it a high-density poly-ethylene (HDPE) liner. They are intended to prevent any infiltration of leachate in the soil below the landfill. On top of this will be the leachate collection system, consisting of a 30 cm gravel layer with embedded perforated HDPE pipes and covered with a geotextile separator layer. The geotextile must then be covered with a 30 cm soil layer for protection and finally a GCL to impede percolation. The

HDPE pipes will be connected to a leachate collection tank, from where the leachate should be transported to a sewage treatment plant for treatment. At the end of each working day newly deposited waste should be covered with 10 – 15 cm soil and the average final height of waste is intended to be 8.4 m. After landfill closure, 20 – 30 cm gravel with embedded passive gas vents will be placed on top of the waste. The gravel will be covered with a 60 cm compacted soil layer (mixed with Bentonite) and a HDPE liner to reduce the infiltration of water into the landfill. Above these, 15 cm gravel covered by a geotextile will help in draining infiltrated water and only a 45 cm soil layer for vegetation growth will be placed on top of them. Passive gas vents were chosen over a proper gas collection system including treatment of the captured gas because deposited waste should be (mostly) inert and produce only very small quantities of gas. Although some rejected large organics from the compost plant will be deposited in the landfill together with the inert waste, the biodegradable proportion of the deposited waste is expected to be below 5%. Consequently, no gas treatment will be installed for the predicted small amount of gas.

Furthermore, the National Green Tribunal recommended spreading disinfectant on an open landfill regularly (National Green Tribunal 2015a).

The construction of the integrated SWM facility is happening later and slower than intended because it has been delayed by lack of funding since 2015. Constructing the integrated SWM facility is part of Haridwar's JNNURM project, which was approved in 2009 with projected costs of 167.2 million rupees (Urban Development Directorate 2015). The JNNURM project and funding ended in March 2015 (TNN 2015). By then not even half the funding for Haridwar's project had been released and most of the released funding had been used to buy equipment for collection and transport of waste. Since then Uttarakhand's state government has provided some funding for the project (Nagrath 2016).

3.4 References

Azad, Shivani (2015): At end of mela, Kanwars leave Haridwar with 1400 tonnes of garbage. Published in The Times of India. http://timesofindia.indiatimes.com/city/dehradun/At-end-of-mela-Kanwars-leave-Haridwar-with-1400-tonnes-of-garbage/articleshow/48472704.cms. Access 21.03.2017.

Census Organization of India (2015): Hardwar Population Census 2011. http://www.census2011.co.in/data/town/800359-hardwar-uttarakhand.html. Access 21.03.2017.

CPCB (2016): Central Pollution Control Board: Inspection Report on Solid Waste Management at Haridwar and Integrated SW Management Facility (under construction) at Sarai, Haridwar. http://www.cpcb.nic.in/Report_on_Haridwar.pdf.

Dubey (2017): Personal conversation with Mr. Dubey, KRL Waste Management Pvt. Ltd. employee, in charge for the area Kankhal. 24.03.2017. Colony Kankhal, Haridwar.

GHK (2007): GHK International UK: City Development Plan: Haridwar – Revised – Under Jawaharlal Nehru National Urban Renewal Mission (JNNURM). On behalf of the Urban Development Department of the Government of Uttarakhand. http://nagarnigamharidwar.com/CDP_HARIDWAR.PDF.

HMC (2016 & 2017): Haridwar Municipal Corporation. Personal conversations with a HMC SWM official (Mr. Mayank Singhal), a HMC landfill engineer, and a KRL site operator and area supervisor. November 2016 and January 2017.

IPE (2009): Integrated municipal solid waste management. On behalf of the Haridwar Municipal Council.

Jain, Siddharth; Sharma, Mahendra Pal (2011): Power generation from MSW of Haridwar city: A feasibility study. Published in Renewable and Sustainable Energy Reviews.

Jaiswall, S. S. (2017): Execution of Namami Gange projects to begin shortly in Haridwar. Published in the Times of India. http://timesofindia.indiatimes.com/city/dehradun/execution-of-namami-gange-projects-to-begin-shortly-in-haridwar/articleshow/56358163.cms. Access 21.04.2017.

Jaiswall, S. S. (2015): Resisting ban on plastic, Haridwar shopkeeper tries to burn himself, raid team. Published in The Times of India. http://timesofindia.indiatimes.com/city/dehradun/Resisting-ban-on-plastic-Haridwar-shopkeeper-tries-to-burn-self-raid-team/articleshow/47977941.cms. Access 21.04.2017.

MoEFCC (2016): Ministry of Environment, Forest and Climate Change: Solid Waste Management Rules, 2016. Notification. New Delhi, the 8th April, 2016. Published in The Gazette of India: Extraordinary. http://www.nsc.org.in/images/MoEF/Solid_Waste_Management_Rules_2016.pdf.

MoEFCC (2015): Ministry of Environment, Forest and Climate Change: Environmental Clearance for Development of Integrated Municipal Solid Waste Management facility for Haridwar Cluster of Raipur Road, Village Sarai, Haridwar, Uttarakhand. http://forestsclearance.nic.in/writereaddata/FormA/ClearanceLetter/9111129121314Ecletter.pdf.

MoUD (2016): Ministry of Urban Development: Swachh Bharat Mission – City Sanitation Plan – Hardwar. Accessible via "States/Cities" -> "City Level Information" -> "Swachh City Plan" -> "Hardwar" on http://www.swachhbharaturban.in. Last updated on 05.12.2016. Access 21.04.2017.

MoUD (2015): AMRUT, Mission Statement & Guidelines. Ministry of Urban Development, Government of India, June 2015. http://amrut.gov.in/writereaddata/AMRUT%20Guidelines%20.pdf

Nagar Nigam Haridwar (2015): Environmental Clearance of Integrated Municipal Solid Waste Management Facility at Sarai Village, Haridwar. Presented to MoEFCC on 07.01.2015

Nagar Nigam Haridwar (2017a): Nagar Nigam Haridwar. http://nagarnigamharidwar.com/. Access 21.04.2017.

Nagar Nigam Haridwar (2017b): Organization Structure. http://nagarnigamharidwar.com/Organization%20Structure.php. Access 20.04.2017.

Nagrath, Radhika (2016): Haridwar to get Solid Waste Management Plant by June. Published in The Pioneer. http://www.dailypioneer.com/STATE-EDITIONS/dehradun/haridwar-to-get-solid-waste-management-plant-by-june.html. Access 21.03.2017.

National Green Tribunal (2015a): Before the National Green Tribunal, Principal Bench, New Delhi, in the matter of Indian Council for Enviro-Legal Action vs. National Ganga River Basin Authority & Ors.. July 02, 2015. http://www.greentribunal.gov.in/Writereaddata/Downloads/10-2015(PB-I)OA2-7-2015.pdf.

National Green Tribunal (2015b): Before the National Green Tribunal, Principal Bench, New Delhi, in the matter of Indian Council for Enviro-Legal Action vs. National Ganga River Basin Authority & Ors And M.C. Mehta Vs. Union of India & Ors.. December 18, 2015. http://www.greentribunal.gov.in/Writereaddata/Downloads/200-2014%28PB-I-Judg%29OA_18-12-2015.pdf.

NMCG (2017): National Mission for Clean Ganga: Namami Gane Programme. http://nmcg.nic.in/NamamiGanga.aspx. Access 21.04.2017.

OpenStreetMap contributers (2017): www.openstreetmap.org. Access 23.03.2017.

Peel MC, Finlayson BL & McMahon TA (2007): Updated world map of the Köppen-Geiger climate classification, Hydrol. Earth Syst. Sci., 11, 1633-1644. http://people.eng.unimelb.edu.au/mpeel/koppen.html; GoogleEarth layer, detailed info version. Access 04.04.2017.

Press Information Bureau (2017): Many New Projects Under Namami Gange Approved For Haridwar and Varanasi. Government of India, Ministry of Water Resources. http://pib.nic.in/newsite/PrintRelease.aspx?relid=156068. Access 21.04.2017.

Sharma et al. (2010): Sharma, Vijay; Saini, Pankaj; Gangwar, R. S.; Joshi, B. D.: Assessment of municipal solid waste generation and its management in the holy city of Haridwar, Uttarakhand State, India. Published in Waste Management.

TERI (2014): The Energy and Resources Institute: Master plan to develop Haridwar and Rishikesh as a "Solar City" – Draft Report – Prepared for Nagar Nigam, Haridwar. http://mnre.gov.in/file-manager/UserFiles/Master-Plan-Solar-City/Haridwar_solar_City_master_plan.pdf.

Tiwari, S.K. (2015): MCH flouting NGT guidelines. Published in The Pioneer. http://www.dailypioneer.com/STATE-EDITIONS/dehradun/mch-flouting-ngt-guidelines.html.

TNN (2015): JNNURM projects to get funds from central scheme. Published in The Times of India. http://timesofindia.indiatimes.com/city/pune/JNNURM-projects-to-get-funds-from-central-scheme/articleshow/47462699.cms. Access 21.04.2017.

Trivedi, Anupam (2016): Plastic ban along Ganges in Uttarakhand remains on paper. Published in Hindustan Times. http://www.hindustantimes.com/india-news/plastic-ban-along-ganges-in-uttarakhand-remains-on-paper/story-1BFM7UpMzRZsfTsi8ehbJP.html.

Urban Development Directorate (2015): Draft Urban Municipal Waste Management Action Plan for State of Uttarakhand. Dehradun, Uttarakhand. http://re.indiaenvironmentportal.org.in/files/file/draft%20urban%20municipal%20waste%20management%20of%20uttarakhand.pdf.

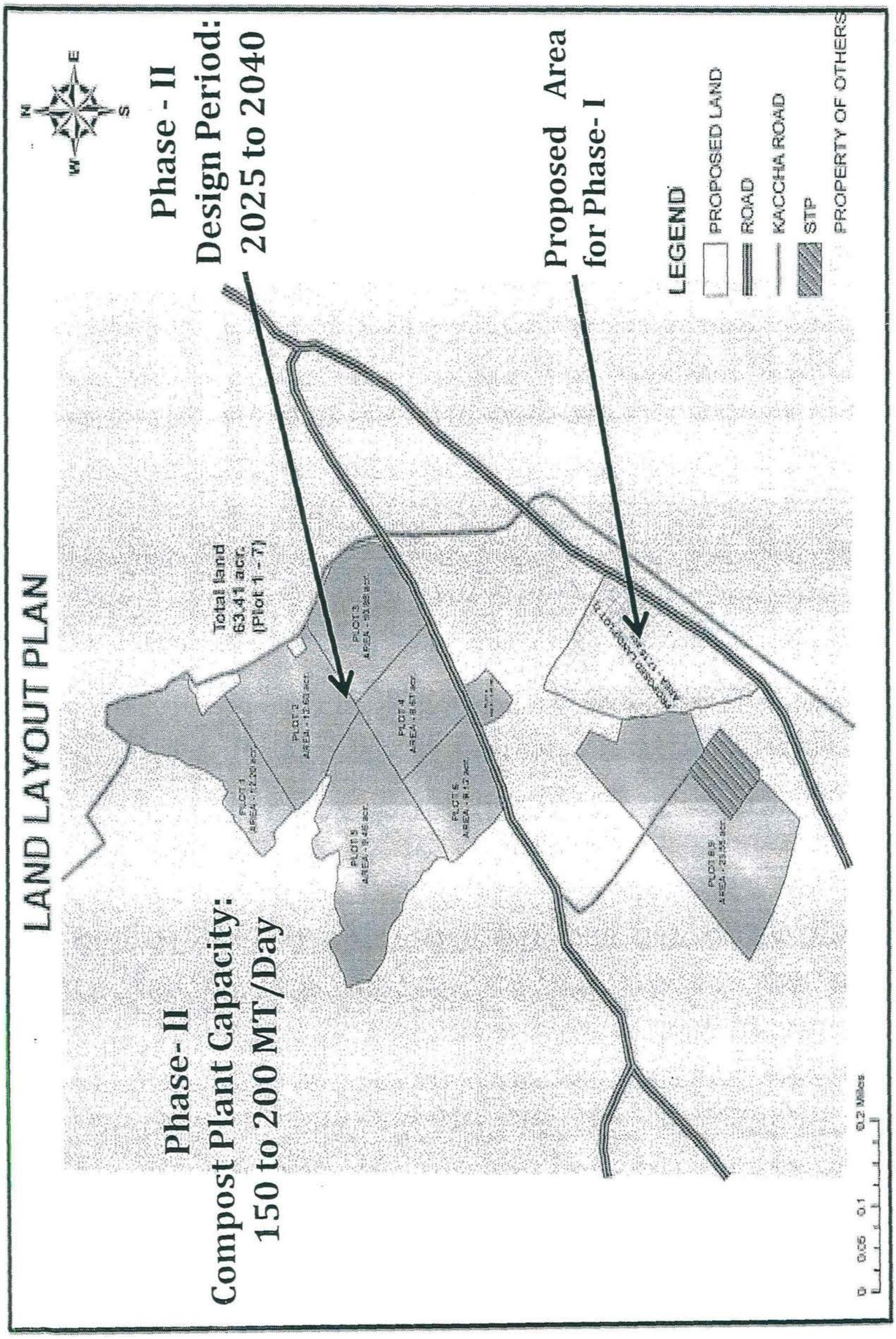
UEPPCB (2006): Uttaranchal Environment Protection and Pollution Control Board: Management of Municipal Solid Waste through Public Private Partnership. Published in ENVIS Newsletter. http://utrenvis.nic.in/data/municipal%20solid%20waste%20may%202006.pdf.

Uttaranchal High Court (2017): Shri Sai Nath Seva Mandal vs State Of Uttarakhand And Ors. on 16 March, 2017. https://indiankanoon.org/doc/47025695/. Access 21.04.2017.

Wikimapia (2017): 18 MLD STP Haridwar. wikimapia.org/#lang=de&lat=29.892909&lon=78.089597&z=18&m=b&show=/27933148/18-MLD-STP-Haridwar&search=78.089598N%09%2029.892909E. Access 21.04.2017.

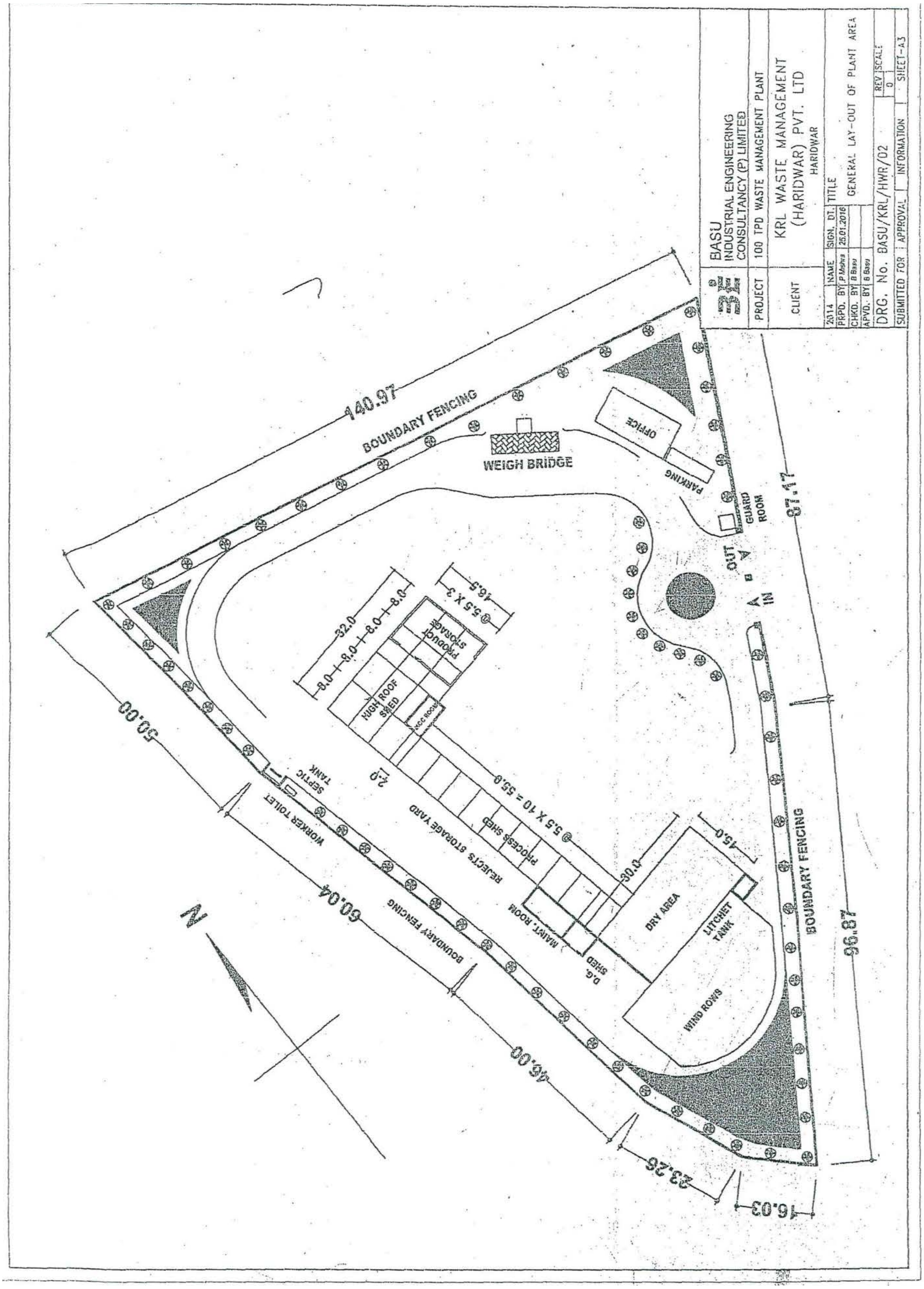
3.5 Annexure Haridwar

3.5.1 Annexure 1: Area of the integrated SWM facility



Source: (CPCB 2016)

3.5.2 Annexure 2: Layout of the future compost plant with a capacity of 100 t/d



Source: (CPCB 2016)