

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

**Volume II**



**Narayanganj City Corporation**



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**PROJECT SUMMARY**

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## EXECUTIVE SUMMARY

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

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

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 Most of the systems applied are unscientific, outdated and inefficient where population coverage is low and the poor are marginalized.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

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

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

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

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

## ACRONYMS AND ABBREVIATIONS

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

<b>LR</b>	<b>Literature Review</b>
<b>MIS</b>	<b>Management Information System</b>
<b>MOEF</b>	<b>Ministry of Environment and Forests</b>
<b>MSL</b>	<b>Mean Sea Level (at Cox's Bazar)</b>
<b>MSW</b>	<b>Municipal Solid Waste</b>
<b>NCC</b>	<b>Narayanganj City Corporation</b>
<b>NGO</b>	<b>Non-Government Organization</b>
<b>ODP</b>	<b>Open Dumping Point</b>
<b>PCO</b>	<b>Project Coordination Office</b>
<b>PD</b>	<b>Project Director</b>
<b>PPP</b>	<b>Public-Private Partnership</b>
<b>PSP</b>	<b>Private Sector Participation</b>
<b>PWD</b>	<b>Public Works Department</b>
<b>RM</b>	<b>Research Methodology</b>
<b>SOB</b>	<b>Survey of Bangladesh</b>
<b>STS</b>	<b>Secondary Transfer Station</b>
<b>SWM</b>	<b>Solid Waste Management</b>
<b>TBM</b>	<b>Temporary Bench Mark</b>
<b>TOR</b>	<b>Terms of Reference</b>
<b>UNICEF</b>	<b>United Nations International Children's Emergency Fund</b>
<b>WM</b>	<b>Waste Management</b>

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## COMMON SWM TERMS

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

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

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

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

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

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

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

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

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

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

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

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

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

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

## CHAPTER 05: POPULATION AND WASTE PROJECTIONS

### 5.1 Population Projections of NCC

Population projections are the calculations of future birth rate, death rate and migration of population based on their past and present conditions. They are neither predictions, nor forecasts, nor estimates. Rather they are in between predictions and forecasts. According to a UN Study, "Population projections are calculations which show the future course of fertility, mortality and migration. They are in general purely formal calculations, developing the implications of the assumptions that are made."

#### 5.1.1 Methods of population Projection

##### Arithmetic Method:

In the arithmetic projection method, it is assumed that the annual change (increase or decrease) in population remains the same throughout the projection period and the crude birth and death rates are taken. The formula for such linear interpolation is

$$P_p = P_t + \frac{n(P_1 - P_2)}{N}$$

Where,

$P_p$  = Population projection in the future;

$P_1$  = Present population as per the recent census;

$P_2$  = Size of population in the previous census;

$n$  = Number of years between the projection year and the previous census; and

$N$  = Total number of years between the recent and previous census.

##### Geometric Method:

In the geometric method of projection, the formula is

$$P_p = P_1 (1 + r)^n$$

Where,

$P_p$  = Projected population;

$P_1$  = Population as per the recent census;

$r$  = Annual rate of increase or decrease of population; and

$n$  = Number of years.

This formula is the basis of Malthus's population projection.

### **Exponential Growth**

In the exponential growth method of projection, the formula is

$$P_t = P_0 (e^{rt})$$

Where,

$P_0$  = Initial Population

$P_t$  = Population in "t" years

$r$  = Annual Population Growth Rate

$e$  = base of the natural logarithm

$t$  = time (year)

Population Projections are important only when they are for a short period. The projections for long period are possible only in a static economy. When the economy is dynamic, and social, political and external factors affect it, the projections are rarely true.

#### **5.1.2 Population Census of NCC**

According to BBS, 2011 census, total population of Narayanganj city corporation was 7, 09, 381. Annual population growth rate of Narayanganj Zilla was 3.05% where urban population growth rate was 4.05%. Average household size of NCC was 4.22 (BBS, 2011).

Census Results at National, Divisional and Zila Level				
Key Indicators	Bangladesh	Dhaka Division	Narayanganj Zila	
			2011	2001
<b>Population (Enumerated)</b>				
Both Sex	14,40,43,697	4,74,24,418	29,48,217	21,73,948
Male	7,21,09,796	2,41,72,317	15,21,438	11,61,971
Female	7,19,33,901	2,32,52,101	14,26,779	10,11,977
Urban	2,74,68,789	1,27,15,797	9,42,354	11,33,191
Other Urban	60,94,394	28,69,038	46,602	88,764
Rural	11,04,80,514	3,18,39,583	19,59,261	9,51,993
<b>Annual growth rate (%)</b>	<b>1.47</b>	<b>1.93</b>	<b>3.05</b>	<b>2.16</b>
<b>Sex Ratio</b>				
Total	100	104	107	115
Urban	110	116	108	119
Other Urban	105	112	107	113
Rural	98	99	106	110
<b>Household</b>				
<b>Total</b>	<b>3,21,73,630</b>	<b>1,08,49,315</b>	<b>6,75,652</b>	<b>4,53,627</b>
Urban	61,33,012	29,10,693	2,22,450	2,47,978
Other Urban	13,69,028	6,69,994	10,299	17,781
Rural	2,46,71,590	72,68,628	4,42,903	1,87,868
<b>Household Size (General)</b>				
<b>Total</b>	<b>4.44</b>	<b>4.32</b>	<b>4.34</b>	<b>4.76</b>
<b>Urban</b>	<b>4.36</b>	<b>4.25</b>	<b>4.22</b>	<b>4.52</b>
Other Urban	4.42	4.24	4.48	5.01
Rural	4.46	4.36	4.40	5.05

Figure 5- 1: Population Census on Narayanganj (Source: BBS, 2011)

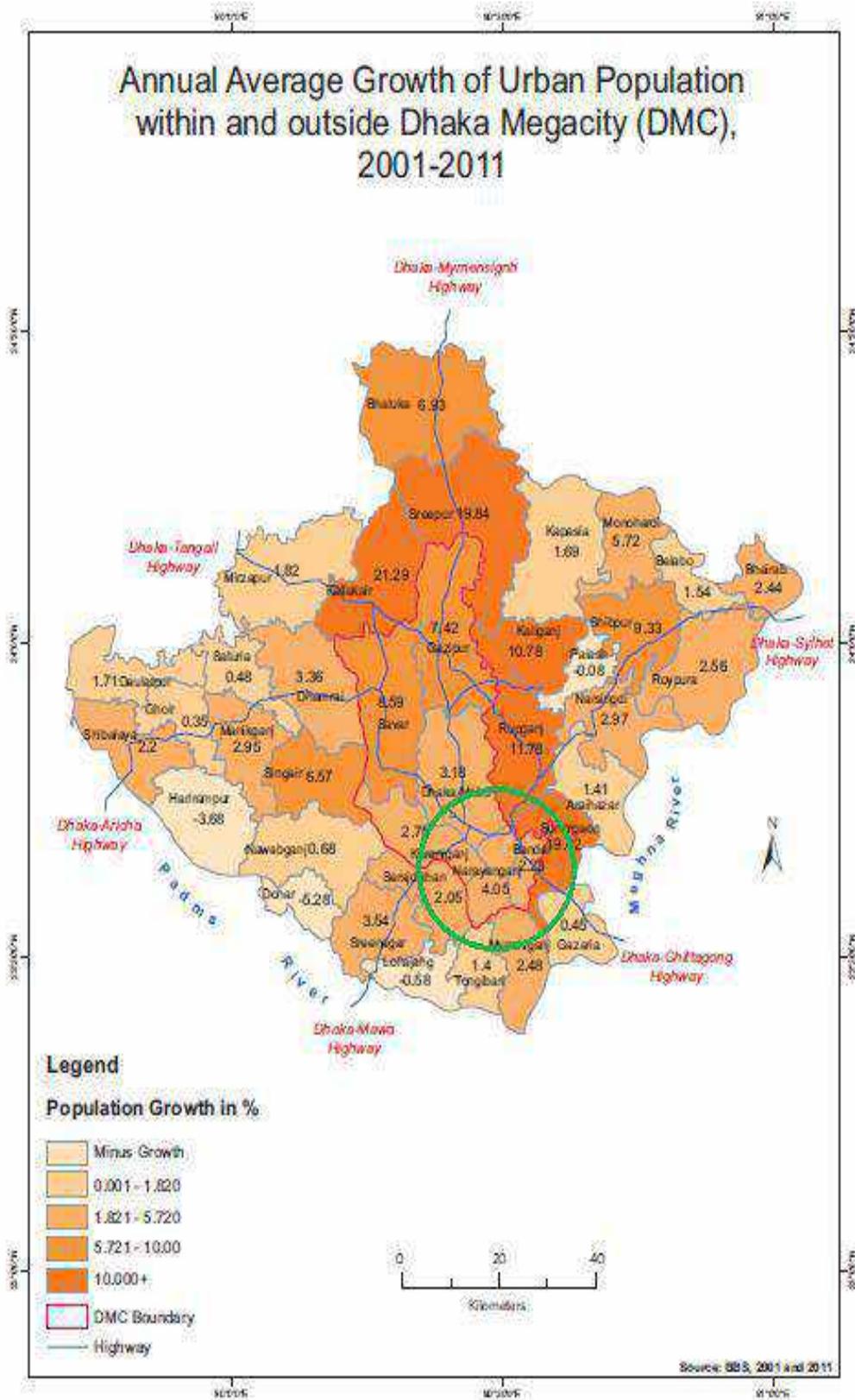


Figure 5- 2: Urban Population growth rate within Dhaka City and outside of Dhaka Mega City (DMC). Source: Urbanization and Migration in Bangladesh, 2016

### 5.1.3 Detail Calculation of Population of NCC

#### Exponential Growth

$$P_t = P_0 (e^{rt})$$

Where  $P_{2011}$  = Initial Population = 709, 381

r = Annual Population Growth Rate = 4.05 %

e = base of the natural logarithm = 2.718

t= time (year) = 10

Population in 2020 ( $P_{2020}$ ) =1, 063, 576

#### Geometric Growth

$$P_t = P_0 (1+r)^t$$

Where  $P_0$  = Initial Population = 709, 381

$P_t$  = Population in “t” years

r = Annual Population Growth Rate = 4.05 %

t= time (year) = 10

Population in 2011=7, 09,381

Population in 2020 ( $P_{2020}$ ) = **1, 055, 116**

Urban Population Growth Rate of Narayanganj: 4.05%

Source: Urbanization and Migration in Bangladesh, 2016

Population Growth Rate of Narayanganj District: 3.05%; BBS, 2011

### 5.1.4 Detail of population Projection of NCC

**Table 5- 1: Ward wise Population Projection (Geometric Growth) of NCC up to 2040**

Ward	Polation_2	Population_2	Population_2	Population_2	Population_2	Population_2
------	------------	--------------	--------------	--------------	--------------	--------------

No	011	020	025	030	035	040
1	36592	54426	69065	87642	111215	141129
2	25585	38055	48290	61279	77761	98677
3	35947	53467	67848	86097	109255	138642
4	23385	34782	44138	56010	71075	90192
5	18421	27399	34769	44120	55988	71047
6	25100	37333	47375	60117	76287	96807
7	21888	32556	41312	52424	66525	84418
8	42704	63517	80601	102281	129792	164702
9	27138	40364	51221	64999	82481	104667
10	20489	30475	38672	49073	62273	79023
11	24550	36515	46337	58800	74616	94685
12	40187	59773	75851	96252	122142	154995
13	47079	70024	88859	112759	143089	181576
14	29431	43775	55549	70491	89451	113510
15	24096	35840	45480	57713	73236	92934
16	34496	51309	65109	82622	104845	133045
17	35518	52829	67038	85070	107951	136987
18	30484	45341	57537	73013	92651	117572
19	11822	17584	22313	28315	35931	45595
20	17694	26318	33396	42379	53778	68243
21	22176	32984	41856	53114	67400	85529
22	30728	45704	57997	73597	93393	118513
23	30572	45472	57703	73223	92919	117911
24	20308	30206	38330	48640	61723	78325
25	12636	18794	23850	30265	38405	48735
26	6812	10132	12857	16316	20704	26273
27	13543	20144	25562	32437	41162	52233
<b>Total</b>	<b>709381</b>	<b>1055116</b>	<b>1338915</b>	<b>1699047</b>	<b>2156045</b>	<b>2735964</b>

Table 5- 2: Paruvashava wise Population Projection (Geometric Growth) of NCC up to 2040

Paruvashava Name	2011	2020	2025	2030	2035	2040
Siddirganj Paruvashava	256760	381899	484619	614969	780379	990281
Narayanganj Paruvashava	286330	425880	540431	685792	870252	1104327
Kadom Rasul Paruvashava	166291	247337	313864	398286	505414	641357
<b>Total</b>	<b>709381</b>	<b>1055116</b>	<b>1338915</b>	<b>1699047</b>	<b>2156045</b>	<b>2735964</b>

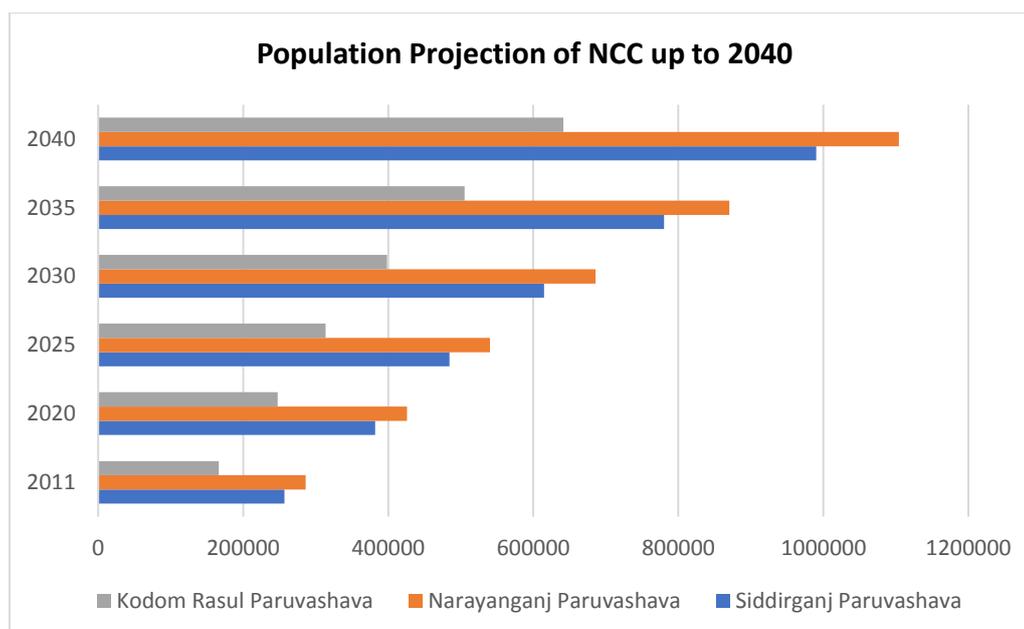


Figure 5- 3: Population Projection (Geometric Growth) of NCC up to 2040

### 5.1.5 Household number calculation based on total population

According to RAJUK, the forecasted population (P) is divided by the forecasted average household size(S) to produce the forecasted number of housing requirement (H). So,  
 $H = P/S$ .

Table 5- 3: Ward wise household number projection (Geometric Growth) of NCC up to 2040

Ward No	Household No_2011	Household No_2020	Household No_2025	Household No_2030	Household No_2035	Household No_2040
1	8623	12897	16366	20768	26354	33443
2	5739	9018	11443	14521	18427	23383
3	8044	12670	16078	20402	25890	32853
4	5655	8242	10459	13272	16842	21373
5	4278	6493	8239	10455	13267	16836
6	5845	8847	11226	14246	18078	22940
7	5196	7715	9790	12423	15764	20004
8	10568	15051	19100	24237	30756	39029
9	6342	9565	12138	15403	19545	24803
10	5094	7222	9164	11629	14757	18726
11	5843	8653	10980	13934	17681	22437
12	9565	14164	17974	22809	28944	36729
13	10004	16593	21057	26720	33907	43027
14	6552	10373	13163	16704	21197	26898
15	5453	8493	10777	13676	17354	22022

16	7920	12158	15429	19579	24845	31527
17	8198	12519	15886	20159	25581	32461
18	7416	10744	13634	17302	21955	27861
19	2723	4167	5288	6710	8514	10805
20	4109	6236	7914	10042	12744	16171
21	5039	7816	9918	12586	15972	20268
22	7289	10830	13743	17440	22131	28084
23	7114	10775	13674	17352	22019	27941
24	5028	7158	9083	11526	14626	18560
25	2954	4454	5652	7172	9101	11549
26	1655	2401	3047	3866	4906	6226
27	3391	4773	6057	7686	9754	12378
<b>Total</b>	<b>165637</b>	<b>250028</b>	<b>317278</b>	<b>402618</b>	<b>510911</b>	<b>648333</b>

Table 5- 4: Paruvashava wise household number projection (Geometric Growth) up to 2040

Paruvashava Name	2011	2020	2025	2030	2035	2040
Siddirganj Paruvashava	60290	90497	114839	145727	184924	234664
Narayanganj Paruvashava	66045	100920	128064	162510	206221	261689
Kadom Rasul Paruvashava	39302	58611	74375	94380	119766	151980
<b>Total</b>	<b>167648</b>	<b>252048</b>	<b>319303</b>	<b>404648</b>	<b>512946</b>	<b>650373</b>

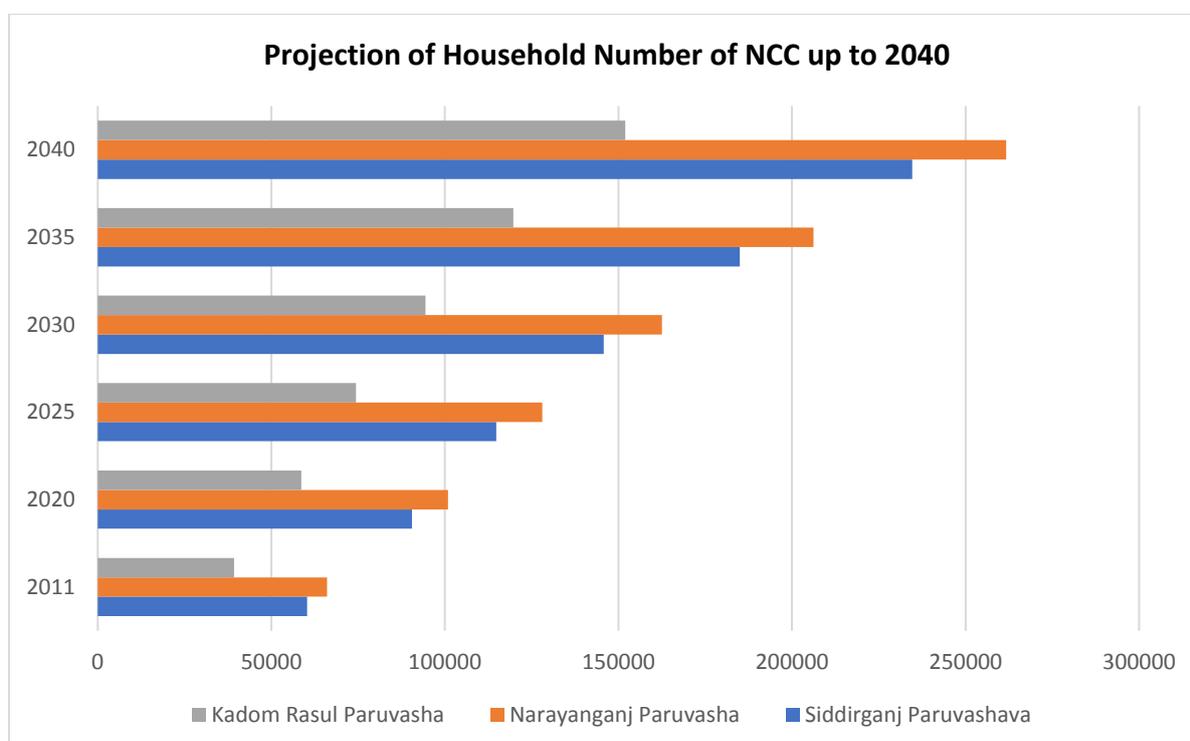


Figure 5- 4: Projection of household number (Geometric Growth) of NCC up to 2040

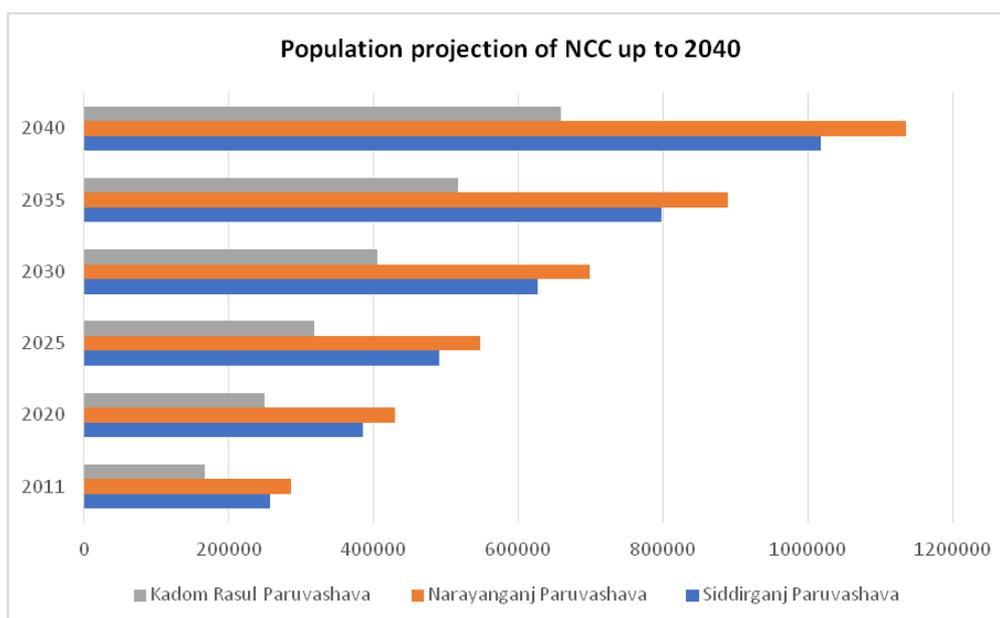
**Table 5- 5: Ward wise population projection (Exponential Growth) NCC up to 2040**

Ward No	Polation_2011	Population_2020	Population_2025	Population_2030	Population_2035	Population_2040
1	36592	54862	69953	89195	113730	145014
2	25585	38360	48911	62365	79520	101393
3	35947	53895	68720	87623	111725	142458
4	23385	35061	44705	57002	72682	92675
5	18421	27619	35216	44902	57254	73002
6	25100	37632	47984	61183	78012	99471
7	21888	32817	41844	53353	68029	86742
8	42704	64026	81638	104094	132727	169236
9	27138	40688	51880	66151	84347	107548
10	20489	30719	39169	49943	63681	81198
11	24550	36808	46933	59842	76303	97291
12	40187	60252	76826	97958	124904	159261
13	47079	70586	90002	114758	146324	186574
14	29431	44126	56264	71740	91473	116635
15	24096	36127	46065	58736	74892	95492
16	34496	51720	65946	84086	107216	136707
17	35518	53252	67900	86577	110392	140758
18	30484	45705	58277	74307	94746	120808
19	11822	17725	22600	28817	36744	46850
20	17694	26529	33826	43130	54994	70121
21	22176	33249	42394	54055	68924	87883
22	30728	46071	58743	74901	95505	121775
23	30572	45837	58445	74521	95020	121157
24	20308	30448	38823	49502	63119	80480
25	12636	18945	24156	30801	39273	50076
26	6812	10213	13023	16605	21172	26996
27	13543	20305	25890	33012	42092	53671
<b>Total</b>	<b>709381</b>	<b>1063576</b>	<b>1356132.70</b>	<b>1729162</b>	<b>2204800</b>	<b>2811271</b>

**Table 5- 6: Paruvashava wise population projection (Exponential Growth) NCC up to 2040**

Paruvashava Name	2011	2020	2025	2030	2035	2040
Siddirganj Paruvashava	256760	384961	490851	625869	798026	1017538
Narayanganj	286330	429295	547381	697948	889931	1134723

<b>Paruvashava</b>						
<b>Kadom Rasul Paruvashava</b>	166291	249320	317901	405345	516843	659010
<b>Total</b>	<b>709381</b>	<b>1063576</b>	<b>1356133</b>	<b>1729162</b>	<b>2204800</b>	<b>2811271</b>



**Figure 5- 5: Population projection (Exponential Growth) NCC up to 2040**

According to Narayanganj City Corporation, the total number of populations in Narayanganj City Corporation is about 20 lacks or 2 million including floating people. The consultant had gone through lots of literature reviews about NCC and from those studies and site observation, we think the total number of populations will be around 14 lacks or 1.4 million in NCC and we also consider this population as our study population.

### 5.1.6 Household number calculation based on total population (Exponential Growth)

According to RAJUK, the forecasted population (P) is divided by the forecasted average household size(S) to produce the forecasted number of housing requirement (H).

$$\text{So, } H = P/S.$$

**Table 5- 7: Ward wise household number Projection (Exponential Growth) of NCC up to 2040**

Ward No	Household No_2011	Household No_2020	Household No_2025	Household No_2030	Household No_2035	Household No_2040
1	8623	13001	16577	21136	26950	34363
2	5739	9090	11590	14778	18844	24027
3	8044	12771	16284	20764	26475	33758
4	5655	8308	10594	13508	17223	21961
5	4278	6545	8345	10640	13567	17299

6	5845	8918	11371	14498	18486	23571
7	5196	7776	9916	12643	16121	20555
8	10568	15172	19345	24667	31452	40103
9	6342	9642	12294	15676	19987	25485
10	5094	7279	9282	11835	15090	19241
11	5843	8722	11121	14181	18081	23055
12	9565	14278	18205	23213	29598	37740
13	10004	16726	21327	27194	34674	44212
14	6552	10456	13333	17000	21676	27639
15	5453	8561	10916	13918	17747	22628
16	7920	12256	15627	19926	25407	32395
17	8198	12619	16090	20516	26159	33355
18	7416	10831	13810	17608	22452	28627
19	2723	4200	5356	6829	8707	11102
20	4109	6286	8016	10220	13032	16616
21	5039	7879	10046	12809	16333	20825
22	7289	10917	13920	17749	22631	28857
23	7114	10862	13849	17659	22517	28710
24	5028	7215	9200	11730	14957	19071
25	2954	4489	5724	7299	9307	11866
26	1655	2420	3086	3935	5017	6397
27	3391	4812	6135	7823	9975	12718
<b>Total</b>	<b>165637</b>	<b>252032</b>	<b>321358</b>	<b>409754</b>	<b>522464</b>	<b>666178</b>

Table 5- 8: Paruvashava wise household number Projection (Exponential Growth) up to 2040

Paruvashava Name	2011	2020	2025	2030	2035	2040
Siddirganj Paruvashava	60290	91223	116315	148310	189106	241123
Narayanganj Paruvashava	66045	101729	129711	165390	210884	268892
Kadom Rasul Paruvashava	39302	59081	75332	96053	122475	156163
<b>Total</b>	<b>167648</b>	<b>254052</b>	<b>323383</b>	<b>411784</b>	<b>524499</b>	<b>668218</b>

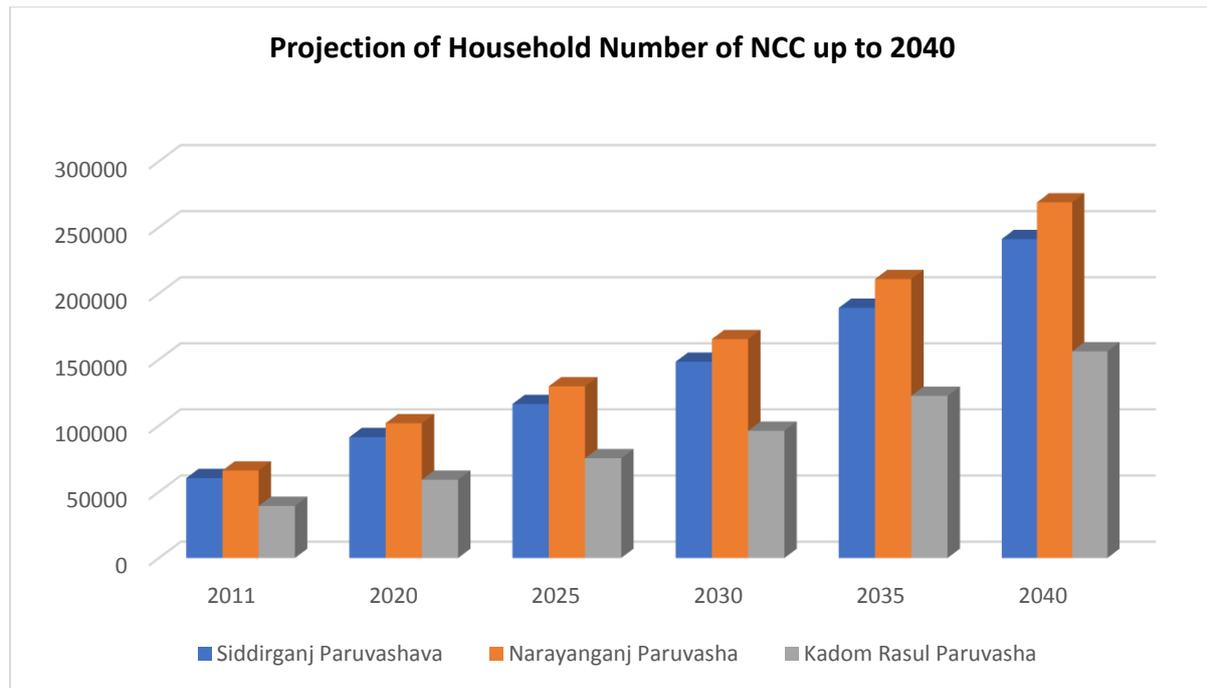


Figure 5- 6: Household number Projection (Exponential Growth) of NCC up to 2040

## 5.2 Total Amount of Waste Calculation and Waste Projection

Waste is an unavoidable by product of human activities like economic development, urbanization and improving living standards in cities which led to an increase in the quantity and complexity of generated waste. Rapid urbanization and population growth are largely responsible for increasing rate of solid waste generation in urban area line Narayanganj City Corporation. A massive volume of solid waste is generated every day in the city areas like NCC and unfortunately solid waste management is being deteriorated day by day due to the limited resources in handling the increasing rate of generated waste. Despite leaps forward in health, education and quality of life, the people of Bangladesh specially in urban area like NCC are still facing great development challenges in other areas, such as waste management and sanitation (Waste Concern, 2014). This is a big threat to the environment and public health. Due to lack of motivation, awareness, proper selection of technology and adequate financial support, a considerable portion of wastes, 40-60%, are not properly stored, collected or disposed in the designated places for ultimate disposal (Ahsan et al., 2005). As a result, this solid waste creates lots of unavoidable problems in Narayanganj City Corporation. The factors that contribute to waste composition are population density, life styles, economic conditions, fruit seasons, climate, recycling, and waste management program (Abedin & M. Jahiruddin, 2015).

Numerous national and international studies have been reviewed to calculate and project the amount of solid waste of Narayanganj City Corporation. The reviewed studies help the consultant to set the standards of calculation of amount of generated amount of solid waste in Narayanganj City.

### 5.2.1 Per Capita Waste Generation Rate in Urban Areas of Bangladesh

Acumen the consultant, has reviewed lots of studies on solid waste collection and solid waste management to prepare the master plan of solid waste collection and management of Narayanganj city Corporation. From those reviewed studies, the consultant has found different data on per capita waste generation in the urban areas of Bangladesh. The consultant uses all of the reviewed data to cross check their calculated data of per capita waste generation. Waste concern states that the total daily urban waste generation average is estimated to be 23,687.78 tons per day, or 0.56kg per capita per day (Waste Concern, 2014).

### 5.2.2 Waste Generation

From other study it is found that the per capita generation rate was ranged from 0.325 to 0.485 kg/cap/day, while the average rate was 0.387 kg/cap/day for the six major cities of Bangladesh (Abedin & M. Jahiruddin, 2015). Based on the present total urban population, per capita waste generation rate is found at 0.41 kg/capita/day in urban area of Bangladesh (Bahauddin & Uddin, 2012). The solid waste generation in urban areas of Bangladesh amounts to around 25,000 tons per day, which translates into 170 kg per capita per year. The Dhaka city produces one-quarter of all urban In 1995, per person average generation of urban solid waste was 0.49 kg/person/day but this amount is expected to increase to 0.60 kg/person/day by 2025 (Daily Star, 2019).

**Table 5- 9: Urban solid waste production in Bangladesh up to 2025**

Year	Total urban population	Urban population (% total)	Waste production rate (kg/cap/day)	Total waste production (ton/day)
1991	20872204	20.15	0.49**	9873.5
2001	28808477	23.39	0.5***	11,695
2004	32765152	25.08	0.5***	16,382
2025	78440000	40.0	0.6 **	47,064

\*\* Source: ADBI and ADB, 2000, \*\*\* Zurbrugg 2002

**Table 5- 10: Waste Generation Rate (WGR) and Total Waste Generation (TWG) in Dhaka city and other major cities of Bangladesh, 2004**

City/Town	WGR (kg/cap/day)	No. of City/Town	Total Population	Population (2005)	TWG (Ton/day)		Average
					Dry Season	Wet Season	TWG
Dhaka	0.56	1	6,116,731	6728404	3,767.91	5,501.14	4,634.52
Chittagong	0.48	1	2,383,725	2,622,098	1,258.61	1,837.57	1,548.09
Rajshahi	0.3	1	425,798	468,378	140.51	205.15	172.83
Khulna	0.27	1	879,422	967,365	261.19	381.34	321.26
Barisal	0.25	1	397,281	437,009	109.25	159.51	134.38
Sylhet	0.3	1	351,724	386,896	116.07	169.46	142.76
Paruvashava	0.25	298	13,831,187	15,214,306	3,803.58	5,553.22	4,678.40
Other Urban Centers	0.15	218	8,379,647	9,217,612	1,382.64	2,018.65	1,700.65

[Source: K. M. Bahauddin and M. H. Uddin, 2012]

In high socio-economic family, daily waste generation rates are generally higher than other lower socio-economic families. The per capita generation rate was ranged from 0.325 to 0.485 kg/cap/day, while the average rate was 0.387 kg/cap/day for the six major cities. The waste is generated from different sources viz. domestic, commercial, industrial, street sweeping, health care facilities etc., of them domestic sources is dominant. The rate of waste generation was found to be higher in the wet season and lower in the dry season, the waste generation rate per capita per day being 500 g in the wet season and 340 g in the dry season (JICA 2005).

**Table 5- 11: Per capita generation of wastes in six major cities of Bangladesh**

Income level	Per capita waste generation (kg/day)						
	DCC	CCC	KCC	RCC	BCC	SCC	Average
A	0.504	0.378	0.368	0.343	0.327	0.429	0.392
B	0.389	0.343	0.333	0.320	0.278	0.395	0.343
C	0.371	0.350	0.319	0.242	0.247	0.340	0.312
D	0.305	0.253	0.264	0.309	0.269	0.248	0.275
E	0.270	0.189	0.203	0.239	0.172	0.260	0.222
Average	0.368	0.300	0.297	0.291	0.259	0.334	0.309
SD	0.090	0.079	0.065	0.047	0.057	0.080	0.070

Source: Alamgir and Ahsan, 2007

High socio-economic (A), Middle upper socio- economic (B), Middle socio- economic (C), Middle lower socio- economic (D), Low socio- economic (E)

The consultant has conducted questionnaire survey and polythene beg distribution and collection survey to collect household waste generation data. Most of the data above mentioned is backdated but it's needed to review the previous data to cross check the consultant's calculated data. During November to December, 2019, the consultant collected all kinds of data and prepared them for further analysis. The consultant also found that in high socio-economic family, daily waste generation rates are generally higher than other lower socio-economic families. Average per capita waste generation rate in high income group was 501.272gm where in the middle- income and low-income group, it was 421.224 gm and 365.206gm.

**Table 5- 12: Per capita waste generation rate per day in NCC**

Income Group	Average Family Size	Average Waste Generation rate per Person	Average Waste Generation Rate (gm)
High Income Group	5.44	601.272	462.534 gm 0.463 kg
Middle Income Group	4.964	421.224	
Low Income Group	4.416	365.206	
Total Population of Narayanganj City Corporation at 2020	About 14 lacks or 1.4 million but according to BBS, 2011, it is about 1063576 (Based on BBS, 2011 data: Projected with exponential growth methods)		
Total Amount of Household Solid Waste Generation per Day at 2020	491975.514 kg or 491.975 tons (Based on our studies, BBS, 2011 & NCC)		

### 5.2.3 Projection of household solid waste of Narayanganj City Corporation

The consultant has projected the population of Narayanganj City Corporation based on BBS, 2011 population data of NCC. Geometric and exponential growth methods were considered as based for the population projection. According to consultant's projection, the total population of NCC is 10, 63, 576 in 2020. But the Narayanganj City Corporation says that the total population of NCC will be 20 lacks including floating people because lots of people come at NCC for various purpose and go back to their origin. As they don't stay at night in NCC, this floating people will not count to calculate the total amount of household waste. The consultant thinks that 10, 63,

576 will be the permanent resident of NCC and they were counted as waste producer for household waste generation. Another base of this projection is the per capita waste generation per day per person which is 0.463 kg. The following table shows the detail calculation and projection of household solid waste of NCC.

**Table 5- 13: Total amount of generated solid waste per day up to 2040 and projection of amount of solid waste based on existing amount of generated solid waste in NCC**

Year	Population (Based on BBS, 2011)	Total Amount of Household Waste of NCC (Unit: kg) Per capita waste generation per day: 0.463	Total Amount of Household Waste of NCC (Unit: Ton) Per capita waste generation per day: 0.463
2020	10, 63, 576	491975.51	491.98
2025	13, 56, 133	627302.83	627.30
2030	17, 29, 162	799853.86	799.85
2035	22, 04, 800	1019868.46	1019.87
2040	28, 11, 271	1300402.13	1300.40

#### 5.2.4 Total amount of Commercial and Industrial Waste in Narayanganj City Corporation

The total amount of commercial and industrial waste was calculated based on the information collected from the open dumping points of Narayanganj City Corporation. The waste from the open dumping points includes commercial waste and to some extent commercial and medical waste. Large industries and medical have their own waste management plant. But the small-scale industries and medical don't have their own waste management plant. They usually dump their generated solid waste at the city corporation's designated open dumping points. There are 80-85 open dumping points in NCC and NCC authority are responsible for those open dumping points. City corporation's trucks, vans and hand trolley are used to transfer those waste to dumping site. The consultant has visited several open dumping points and discussed with the waste management department of NCC. The total amount of commercial and industrial solid waste was calculated through the consultant observation and discussion with waste management department of NCC and which is approx. 340 tons per day. The following table shows the detail of calculation of commercial and Industrial solid waste.

**Table 5- 14: Total amount of dumping solid waste from the open dumping points (visited and not visited) of Narayanganj City Corporation which ultimately goes to dumping site**

Location Name of open dumping point	Ward No.	Type of Area	Approx. Area (sq. feet)	Amount of waste	
				Unit: Number of Loaded Truck (3 ton)	Amount of Waste (Unit: Ton)
NitaiganjMor	18	Commercial	12'/6'	1	3
Nulua Road (Bongobondu extension Road, MotinShaber Bari, beside Kamarer Shop	18	Commercial	5'/5'	1	3
NitaigangMor, boldeb Temple	15	Commercial	8'/6'	1/2	1.5
Nitaiganj, in front of Somrat Garments	15	Commercial	8'/5'	4	12
DIT, Jonota Super Market	15	Commercial	5'/6'	1	3
In front of F Rahman Super Market	15	Commercial	5'/7'	1	3
Ukil Para Mor	14	Commercial	8'/10'	2.5	7.5
Flower Bazar Mor	14	Commercial	8'/6'	3	9
Beside Popular Clinic	13	Commercial	8'/10'	2.5 (Evening ½ Truck)	7.5
Beside Hokers Market	13	Commercial	5'/7'	2.5 (Evening ½ Truck)	7.5
Children Park Sport	12	Residential	5'/6'	1	3
Officer's Quarter, Khanpur	12	Commercial	10'/8'	1.5 (Evening ½ Truck)	4.5
Beside Borofcall Field	11	Commercial	5'/6'	1	3
Beside Fire Service Mor	11	Residential	10'/8'	1/2	1.5
M. SarkasMor	11	Industrial and Commercial	12'/10'	1	3
Beside Pathantoli Bazar Mosjod	10	Residential, Industrial and Commercial	20'/6'	1	3
Beside Metro Cinema Hall	13	Commercial	5'/6'	1/2	1.5
Beside Jahaj Office	13	Residential and Commercial	10'/12'	2	6
Beside 1 no. rail gate	15	Commercial	5'/6'	1	3
Beside Chamber Road	15	Commercial	5'/7'	2	6
Beside Amina Monjil	17	Residential	12'/8'	1	3
Beside AkhrarMor	16	Commercial	15'/5'	1/2	1.5

Beside Jim Khana Road	17	Residential	15'/12'	1	1.5
<b>Total (23)</b>				32 (Approx.)	97.5 (Approx.)
<b>Total (85)</b>				118 (Approx.)	340 (Approx.)

### 5.2.5 Information about Collected Solid Waste by the Warehouses of Broken Materials, Cloth or Textile, Wood, Leather, Rubber, Plastic, Paper and others Substances of Wastages

Broken materials, cloth or textile, wood, leather, rubber, plastic, paper and other wastage substances (miscellaneous items) are basically come from households and commercial area to the warehouses of broken materials. These wastages are not only come from the Narayanganj City Corporation area but also from the outside of the city corporation area. The consultant has visited several warehouses of broken materials, cloth, wood, rubber, leather, plastic, paper and others wastage substances. The wastage of those warehouses can be recycled and reused and disposal waste also can be used in waste to energy production. This waste will also include in the total amount of solid waste of NCC.

#### 5.2.5.1 Details of warehouse of broken materials, cloth or textile, wood, leather, rubber, plastic, paper and others substances of Wastages of Narayanganj City Corporation

There are approximately 250-300 warehouses in the NCC area. This number is fixed through warehouse visit, discussion with the warehouse community/owners and consultation with waste management department of NCC. Maximum part of the waste come at those warehouses are plastic bottle, materials. The following table shows the detail of amount of solid waste which comes at those warehouses.

**Table 5- 15: Total amount of solid waste from the warehouses of broken materials**

<b>Total approx. number of warehouses</b>	<b>250-300</b>
<b>Average number of rickshaw van come per warehouses per day</b>	<b>2-3</b>
<b>The amount of waste each van contains</b>	<b>80-90 kg.</b>

The amount of waste comes at each warehouse per day by waste collector (Single Tokai)	30-40 kg.
Frequency of wastages loaded truck from each warehouse which go to Islambagh/Nawabbazar	Twice or more in a month
Percentage of useful/recyclable waste	70-80 %
Total amount of solid waste comes at each warehouse per day	250-300 kg
Total amount of solid waste comes at all warehouses of NCC	$(300 * 300) = 90000$ kg. or 90 tons

### 5.2.6 Total Amount of Solid Waste Generated in Narayanganj City Corporation in 2020

The waste from large-scale industries and medicals is not included in this calculation. Large-scale industries have their own waste management plant. On the other hand, Priso is responsible to collect and dispose medical waste of Narayanganj City Corporation. Other all types of waste sources are considered to calculate the total amount of solid waste of NCC in 2020. Total amount of generated solid waste in Narayanganj City corporation in 2020 is approx. 922 tons per day. The following table shows us the total amount of solid waste with sources.

**Table 5- 16: Total amount of daily generated Solid Waste from different sources at NCC in 2020**

Source of Solid Waste	Amount (Unit: ton)
Household	Approx. 492
Commercial and Industrial	Approx. 340
Warehouse of broken Materials	Approx. 90
<b>Total</b>	<b>Approx. 922</b>

**Table 5- 17: Daily Generation of Solid Wastes at Narayanganj City Corporation in 2020**

MSW Generation at NCC	Potential Supply of MSW by NCC to Jhalkuri Site (Basis of plant's design capacity of resources)
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		recovery)		
Source of Solid Waste	Amount (tons/day)	Food & Farm Wastes (tons/day)	Non-food Wastes (tons/day)	
		Fermentable Fraction (Biomass for Biogas & Compost Plant)	Recyclable Fraction (Direct Sale of Metals, PET & HDPE Plastics, Cardboards & Mixed Papers, E-Wastes after sorting)	Non-recyclables – either hazardous or not recyclable economically (RDF for WTE or Pyrolysis Plant)
Household	492	366.84 (74.56 %)	89.99 (18.29 %)	35.18 (7.15 %)
Commercial and Industrial	340	170 (50 %)	136 (40%)	34 (10 %)
Warehouse of Broken Material	90	0 (0 %)	63 (70 %)	27 tons/day (30%)
<b>Total</b>	<b>922</b>	<b>536.84</b>	<b>288.99</b>	<b>96.18</b>

### 5.3 Physical characteristic of Solid Waste, Waste Quantities and Composition

Solid waste generation in urban areas is increasing day by day with the growth of population. The *composition of solid waste* can be yard waste, food waste, plastics, wood, metals, papers, rubbers, leather, batteries, inert materials, textiles, paint containers, demolishing and construction materials as well as many others that would be difficult to classify. Solid waste composition varies on population density, life styles, economic conditions, fruit seasons, climate, recycling, and waste management program. Per capita waste generation and percent composition of waste components are the two most important aspects for decision makers of waste management department ( Yasmin & Rahman, 2017). This information helps identify

waste components to target for source reduction and recycling programs. The amount of waste generated in urban area is proportional to the population and the average income of the people. In addition, other factors such as climate, level of education, social and public attitude also may affect the amount and composition of solid waste ( Yasmin & Rahman, 2017).

### **5.3.1 Characteristic of Solid Waste of Urban areas of Bangladesh and Narayanganj City Corporation**

In order to identify the exact characteristics of solid wastes, it is necessary that we analyse them using physical and chemical parameters. The characteristics of solid waste depends on the following entities,

- ✓Density
- ✓Moisture Content
- ✓Size of Waste Constituents
- ✓Field Capacity
- ✓Permeability of Compacted Wastes
- ✓Compressibility
- ✓Chemical Characteristics
  - i. Chemical
  - ii. Bio-Chemical
  - iii. Calorific Value
  - iv. Toxic
  - v. Lipids
  - vi. Carbohydrates
  - vii. Proteins
  - viii. Natural Fibers
  - ix. Synthetic Organic Material (Plastics)
  - x. Non-Combustibles
  - xi. Heating Value

### **5.3.2 Solid Waste Composition of Urban areas of Bangladesh**

As reported by Alamgir and Ahsan (2007), a total of 7690 tons of municipal solid waste (MSW) is generated daily from the six major cities of Bangladesh, namely, Dhaka, Chittagong, Khulna,

Rajshahi, Barisal and Sylhet, while the Dhaka city contributes 69% of the total waste stream. The composition of the entire waste stream was about 74.4% organic matter, 9.1% paper, 3.5% plastic, 1.9% textile and wood, 0.8% leather and rubber, 1.5% metal, 0.8% glass and 8% other wastes. The major factors that contribute to waste composition are population density, life styles, economic conditions, fruit seasons, climate, recycling, and waste management program (Abedin & Anwarul, 2015).

**Table 5- 18: Generation of different categories of wastes in six major cities of Bangladesh (Alamgir and Ahsan, 2007)**

Waste category	Per capita waste generation (kg/day)						
	DCC	CCC	KCC	RCC	BCC	SCC	All waste stream
Organic matter	3647	968	410	121	105	158	5409
Paper	571	130	49	15	9	18	792
Plastic	230	37	16	7	5	8	303
Textile & wood	118	28	7	3	2	5	163
Leather & rubber	75	13	3	2	1	1	95
Metal	107	29	6	2	2	2	148
Glass	37	13	3	2	1	2	58
Others	555	97	26	18	5	21	722
Total	5340	1315	520	170	130	215	7690
Population	11.00	3.65	1.50	0.45	0.40	0.50	-
Per capita (kg/day)	0.485	0.360	0.347	0.378	0.325	0.430	0.387

DCC = Dhaka City Corporation, CCC = Chittagong City Corporation, KCC = Khulna City Corporation, RCC = Rajshahi City Corporation, BCC = Barisal City Corporation, SCC = Sylhet City Corporation

**Table 5- 19: Nature of Waste composition of urban area like Dhaka City**

Waste Composition	Dhaka (% By Weight)
Food and Vegetable	70
Paper Product	4
Plastics	5
Metals	0.13

<b>Glass and Ceramics</b>	<b>0.25</b>
<b>Wood</b>	<b>0.16</b>
<b>Garden Waste</b>	<b>11</b>
<b>Other (Stone dirt etc)</b>	<b>5</b>
<b>Moisture</b>	<b>65</b>

Source: Ahmed, M.F., & Rahman, M.M. 2000

### 5.3.3 Waste Composition of Narayanganj City Corporation

As the growth rate of the population in Narayanganj City Corporation area is going high during recent years, the amount of waste generation in NCC area is increasing. The consultant has conducted different types of surveys (Direct dumping site visits, compost plants visit, observation, questionnaire survey for household, commercial and industrial solid waste data collection, polythene beg distribution and collection survey, FGDs, KII) to explore the solid waste composition of Narayanganj City Corporation area. Generally solid waste can be categorized as solid waste can be categorized as domestic waste, commercial waste, institutional waste, industrial waste, street sweepings, medical and clinical waste and construction and demolition waste. According to the survey report which has discussed in the chapter 03, solid waste can be categorized as Kitchen/food waste, Plastic/polythene, broken materials, woods, textile/cloths, leather/rubber, street sweepings, hazardous waste like medical waste or waste which contain chemical ingredients etc. The seasonal differences in the NCC's solid waste stream are not substantial. The most seasonably variable material in the urban area's solid waste stream is food waste. Residential waste is relatively homogeneous. Although there are some differences in waste generation depending on demographic and other local factors, most households dispose of essentially similar types of wastes. Variation occurs in waste composition dependent upon income levels and category of sources. Variation also occurs based upon the extent of source reduction and recycling opportunities. According to the section 4.2 (Chapter 04), high income group produces almost double as much household waste as the lowest income group in Narayanganj City Corporation.

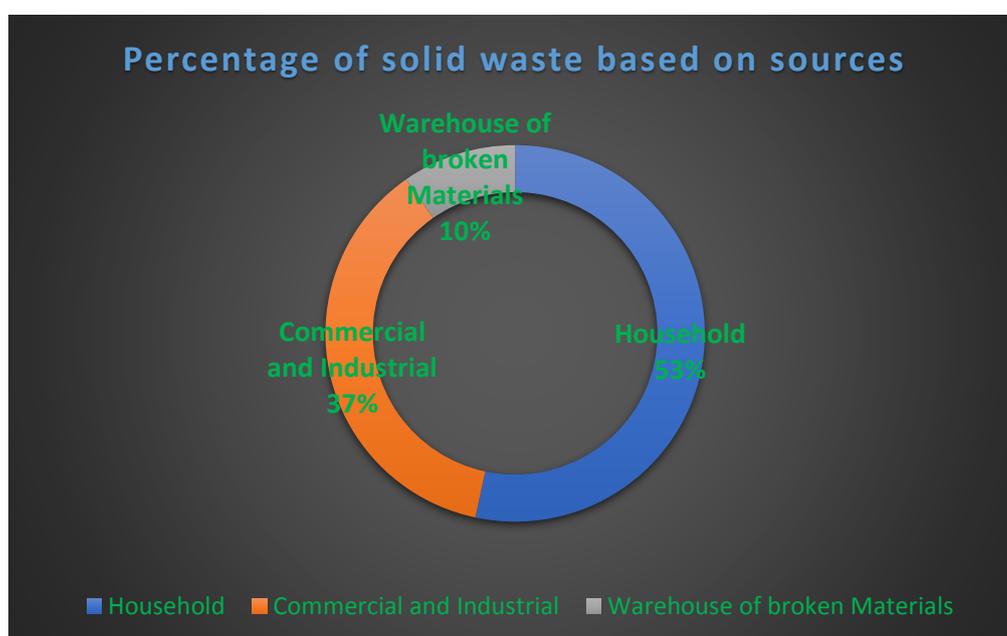
### 5.3.4 Sources of NCC's solid waste with their percentage

Total amount of generated solid waste from different sources in Narayanganj City Corporation is 922 tons where 492 tons are from household and 340 and 90 tons from commercial/industrial sector and warehouses of broken material. The contributions of different sectors to the total generation of solid waste in Narayanganj City Corporation, where nearly 54% of generated solid

waste come from the residential sector, 36.88 % come from the commercial and industrial sectors, 9.76 % from the warehouses of broken materials.

**Table 5- 20: Percentage of Solid waste generated from different sectors**

Source of Solid Waste	Amount (unit: ton)	Percentage (%)
Household	492	53.36
Commercial and Industrial	340	36.88
Warehouse of broken Materials	90	9.76
<b>Total</b>	<b>922</b>	<b>100.00</b>



**Figure 5- 7: Percentage of solid waste based on sources**

### 5.3.5 Waste composition of household solid waste in Narayanganj City Corporation

The consultant had conducted polythene beg distribution and collection household survey among different income groups in different areas of Narayanganj City Corporation to explore the existing household quantity and composition. The consultant has found from the survey that 74.56 % (3/4) of household waste was perishable like kitchen waste or food waste where 18.29 % (less than ¼) of household waste of Narayanganj City Corporation was non-perishable like plastic/polythene/paper/wood/leather/rubber etc. and 7.14 % was hazardous waste like

medicine/cosmetics/sharp materials/waste which contains chemical ingredients. The details of that survey are discussed in the chapter 03. The following table shows the solid waste composition of household solid waste of Narayanganj City Corporation.

**Table 5- 21: Bucket Information: Volume Calculation/Density Calculation/ Waste Composition**

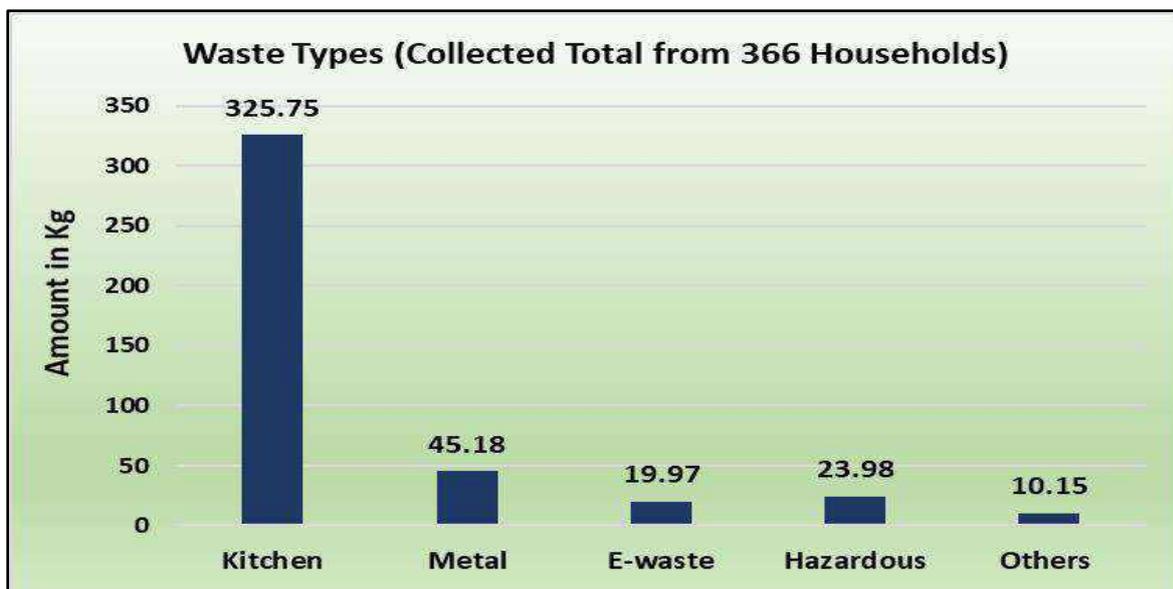
	Amount of Perishable Waste (gm.)	Amount of Nonperishable Waste Plastic/ Polythene/ Paper/ Others (gm.)	Amount of Hazardous Waste (gm.)
Bucket 1	3425	1285	1425
Bucket 2	4855	1335	
Bucket 3	2825	1030	
Bucket 4	3775		
Total amount for 15 beg	14880	3650	1425
Total amount for 100	99200	24333.33	9500
Volume of the Bucket	0.0122 m <sup>3</sup>		
Density (kg/m <sup>3</sup> )	8131.148	1994.536	778.6885
Waste Composition (%)	74.56 %	18.29 %	7.14 %



**Figure 5- 8: Waste Composition of NCC**

### 5.3.6 Household solid waste categories and composition of Narayanganj City Corporation based on questionnaire survey findings

The Consultant also has conducted questionnaire survey for 366 households to explore the current household solid waste quantity and composition of Narayanganj City Corporation. From that questionnaire survey, the consultant has found that household solid waste categories were like kitchen/food waste, metal waste, E-waste, hazardous waste and others waste. The following figures show us the amount of each category of household solid waste of 366 households of Narayanganj City Corporation.



**Figure 5- 9: Household solid waste category and amount (for 366households) of NCC**

The above figure shows that total amount of kitchen waste is much higher than other waste categories. The amount of kitchen waste of 366 households of NCC is 325.75 kg where the amount of metal is 45.18 kg, e-waste is 19.97 kg, hazardous is 23.98 kg and others are 10.15 kg. Based on the findings from questionnaire survey, the consultant has explored the waste composition in percentage for household solid waste of Narayanganj City Corporation. Following figure shows the percentage of each waste category of household solid waste of Narayanganj City Corporation which helps to have picture a picture of household waste composition of Narayanganj City Corporation.



Figure 5- 10: Household solid waste composition and categories with percentage of NCC

### 5.3.7 Commercial and industrial (small-scale industries) solid waste categories and composition of Narayanganj City Corporation based on questionnaire survey findings

The Consultant has conducted questionnaire survey to collect information about commercial and industrial (small-scale industries) solid waste. The findings from that survey help the consultant to explore the current solid waste quantity and composition of those places and institutions of Narayanganj City Corporation. From that questionnaire survey, the consultant has found that commercial and industrial solid waste categories were like kitchen/food waste, metal waste, textile/cloths, batteries, hazardous waste and others waste. Here, metal waste is much higher than other categories. The percentage of metal waste is 83 % where the percentage of kitchen, battery, hazardous and others are 9%, 4%, 2% and 2%. The following figures show us the composition/percentage of each category of commercial and industrial solid waste of Narayanganj City Corporation.

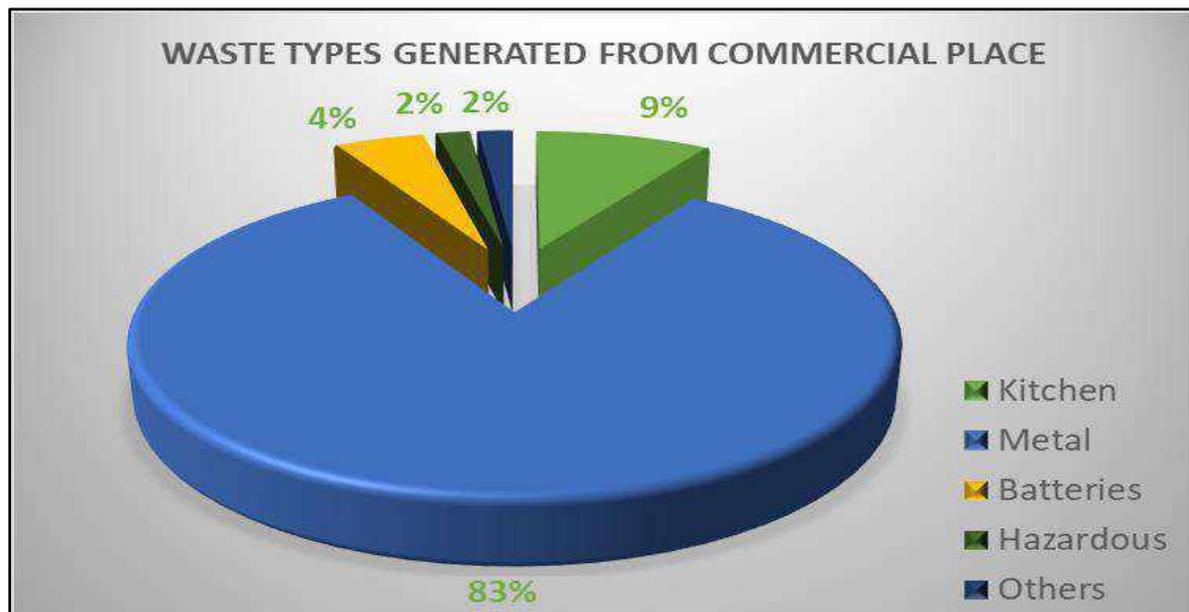


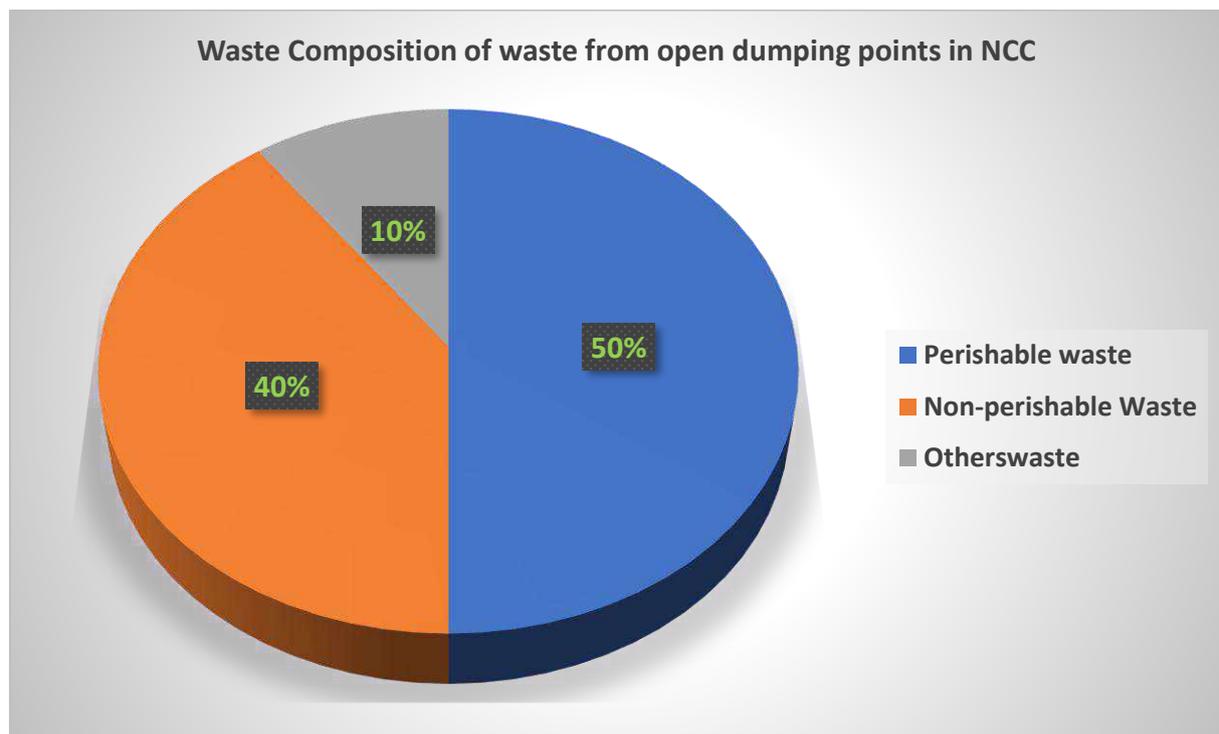
Figure 5- 11: Composition of commercial and small-scale industrial solid waste

### 5.3.8 Waste composition of solid waste dumped in the open dumping points of Narayanganj City Corporation (Commercial and Industrial Solid Waste)

The consultant has discussed about open dumping points with the waste management department of Narayanganj City Corporation. According to Waste Management Department of Narayanganj City Corporation, there are lots of open dumping point (designated and undesignated) in NCC. But Narayanganj city corporation is responsible for only 85 open dumping points which were designated and operating by the waste management department of Narayanganj City Corporation. Most of the open dumping points are along the main road and in market place of NCC. Not only the household waste but also the commercial and industrial waste even medical waste are also dumped in these open dumping points. Waste from roadside commercial, industrial, household even hospital and clinic come at open dumping points through individuals, hand trolley or rickshaw van. Every day city corporation truck comes and takes out the waste of those open dumping points at morning and sometimes evening. Acumen Architects and Planners Ltd. (The Consultant) with waste management department of NCC has visited several open dumping points and collected detail information about all of the open dumping points. This experience helps us to draw a picture about the solid waste types and composition of those open dumping points. Following table and figure show the solid waste types and composition of the solid waste from the open dumping points of NCC.

**Table 5- 22: Solid waste categories and their composition of waste from open dumping points in NCC**

Waste Category	Amount of Waste (Unit: Ton)	Waste Composition in Percentage
Perishable (kitchen/food waste from hotel, canteen, restaurant, vegetables etc.)	170	50%
Non-perishable (Plastic, polythene, leather, rubber, broken materials, paper etc.)	136	40%
Others (Hazardous waste, street sweep's etc.)	34	10%
<b>Total</b>	<b>340</b>	<b>100%</b>



**Figure 5- 12: Waste Composition of waste from open dumping points in NCC**

### 5.3.9 Waste composition of solid waste comes at warehouses of broken materials of Narayanganj City Corporation

Broken materials, cloth or textile, wood, leather, rubber, plastic, paper and other wastage substances (miscellaneous items) are basically come from households and commercial industrial sector. These wastages are not only come from the Narayanganj City Corporation area but also from the outside of the city corporation area. The consultant has visited several warehouses of broken materials, cloth, wood, rubber, leather, plastic, paper and others wastage substances. The wastage of those warehouses can be recycled and reused and disposal waste also can be used in waste to energy production. According to the community or owners of warehouses of broken materials, more than 70 % of solid waste which comes to them is reusable and recyclable. Other 30 % is disposable waste.

#### 5.3.9.1 Types of Wastages Which come from the Warehouses

Broken Materials (Iron, Glass, Silver, Steel, Tin etc.), Cloth, Wood, Leather, Rubber, Plastic, Paper, Hazardous Waste (Bottle of Medicine, Acid and other hazardous substances), Others Wastage Substances. According to an owner of a warehouse of broken material, the waste composition in 200 kg solid waste which comes to his warehouse per day is like the following table.

**Table 5- 23: Waste composition in 200 kg of warehouse’s waste per day**

Waste type	Amount (Unit: kg)	Composition/ Percentage
Broken material (Iron, steel, glass, silver, tin etc.)	31500	35
Plastic	18000	20
Textile/cloth	9000	10
Leather/rubber	9000	10
Paper	13500	15
Hazardous Waste (Bottle of Medicine, Acid, paints and other hazardous substances which contain chemical ingredients)	4500	5
Other waste	4500	5
<b>Total</b>	<b>90000 kg (90 tons)</b>	<b>100</b>

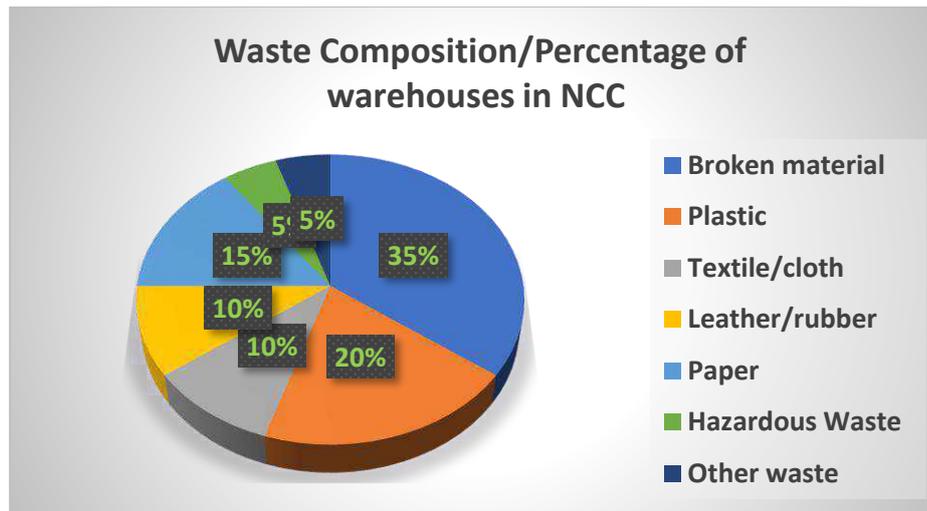


Figure 5- 13: Waste Composition/Percentage of waste from the warehouses of broken materials in NCC

#### 5.4 Waste to Energy (Calorific Value, Moisture Content, Composition)

##### 5.4.1 The Energy from Waste Process

The waste is treated as renewable resources, as well as a viable alternative to fossil fuel. The sources of primary energy are exhaustible. So, we should play a role how to get maximum benefit from the using of renewable sources. For example, over the past twenty years, awareness of the people regarding the recycling waste has been increased. Recyclable materials are being recycled. But we cannot recycle directly the most part of the waste. This part of the waste goes to the landfill whether it has value or not. This is how suitable sites for landfill are becoming more difficult to find. In this regard, incineration can give good solution. It is not only converting waste to energy but also recycles ferrous and non-ferrous metals. At the same time bottom ash would be separated. The ash produced from such plant can also be used as an inert aggregate in the construction industry, avoiding the need for disposal of the ash to landfill. Incineration, burning process of the waste is strictly controlled under conditions. Potentially harmful chemicals are destroyed at a certain temperature. The residues and flue gases are treated. Finally, there is no any significant environmental impact.

**Table 5- 24: Calorific value of different waste category**

Component	Calorific value (dry matter) MJ/kg
Organic food waste	18
Animal waste	18
Newspaper and magazines	18
Tissue paper	18
Other clean paper and cardboard	17
Other dirty paper and cardboard	18
Plastic package	40
Other plastics	40
Flower and garden waste	8
Other waste for incineration	18
Glass package	0
Other glass	0
Iron and metal package	0
Other iron and metal	0
Other waste not for incineration	0

Source: Received by fax from „Videncenter for Affald“  
DK-2830, Virum.

#### 5.4.2 Composition of solid waste of DCC

**Table 5- 25: Composition of Solid Waste in Dhaka City Corporation**

Component	Residential waste by weight (%)	Residential waste by weight (%)	Industrial waste by weight (%)
Food and vegetable waste	59.91	62.05	26.37
Paper products	11.21	6.28	7.59
Plastics, rubber and leather	17.67	4.62	6.01
Metals	0.15	0.28	---
Glass and Ceramic	---	0.37	---
Garden wastes, tree trimming and straw	8.76	2.86	4.32
Wood	---	---	---
Cloths	---	18.93	46.20

Rocks, dirt and miscellaneous	2.30	4.62	9.49
Moisture content (%)	50	54	60

### 5.4.3 Technical Possibilities

(I) Calorific value of Hamersley plant's waste.

Calorific value of household waste is calculated 10.43 MJ/kg. Researcher has learnt from Mr. Harry Hansen, plant manager that at present the delivered waste for incineration is 9.5 to 10 MJ/kg. He also said that it was 7.5 to 8.5 MJ/kg in 1993 when plant started.

(II) Calorific value of the waste in Dhaka city

Calorific value of residential waste is calculated 9.20 MJ/kg. Calorific value of Industrial waste is calculated 5.67 MJ/kg. Calorific value of commercial waste is calculated 6.94 MJ/kg.

Since,

Residential waste = 44.2%. Industrial waste = 14.7% Commercial waste = 17.7%. Street sweeping = 23.4% Therefore, street sweeping is out of our consideration. Now new percentages of waste in individual sector are: Residential waste =  $44.2 / (44.2+14.7+17.7) = 0.5770 = 57.70\%$ . Industrial waste =  $14.7 / (44.2+14.7+17.7) = 0.1919 = 19.19\%$ . Commercial waste =  $17.7 / (44.2+14.7+17.7) = 0.2311 = 23.11\%$ .

Calorific value of the waste generated in the Dhaka city is  $9.19*57.7\%+5.67*19.19\%+6.94*23.11\% = 8.00$  MJ/kg

This value is technically enough for incineration, while South East London Combined Heat and Power plant UK, is now burning the waste with the value of 8MJ/kg to 9MJ/kg. Of course, some extra fuels are necessary for burning of the waste of the Dhaka city since the moisture content of the waste is higher. Natural gas could be used as a extra fuel for burning the waste in Dhaka city while the country has own gas reserve.

### 5.4.4 Energy potential from the waste generated in the Dhaka city

The daily waste generation in Dhaka city is about 3500 tonnes per day. So, total waste generation in a year is about 1.28 million tonnes. Calorific value of waste = 8

$\text{MJ/kg}=8000\text{MJ/ton}=2222.22\text{kWh/ton}$ . Specific power output per ton of waste at a thermal efficiency 20%= $0.2*2222.22=445\text{kWh/ton}$ . Potential of electric power plant capacity from the waste in Dhaka city=  $(1280000*445)/8000\text{kW}=71\text{ MW}$ .

#### **Waste management cost per ton in Dhaka city:**

From Iftekhar Enayetullah study it is learnt that the cost of waste management in the Dhaka city is 38 US \$ / ton.

In Dhaka city, waste management is defined as the collection of waste from different areas and disposal of the waste into specific landfill. Waste management service is without any resource recovery. So, it is more expensive than in Denmark.

#### **Production cost of electricity**

(I) Cost of electricity per kWh through incineration at Hamersley plant, Denmark: Total expenses for the Electricity production is 16 685 385 Kr. Total generated electricity in 1999 is 34248.9 MWh = 34248900 kWh. Therefore, unit cost of electricity production =  $0.49\text{ Kr./kWh} = 0.058\text{ US \$ /kWh}$

(II) Unit cost of electricity production in Dhaka city: Bangladesh has own natural gas reserve. Electricity generation through gas turbine is the cheapest one in the country. Per unit cost of electricity is around TK. 0.70/kWh (Khan, S. The daily Star, 18.06.01). Unit cost of electricity production =  $\text{TK. } 0.70 /\text{kWh} = 0.013\text{ US \$ / kWh}$ .

If it is considered in the context of only electricity production, then it is not economically viable. But considering the optimum energy utilization and environmental implications it has importance. The plant can generate heat in winter and cooling in summer. The main air conditioning areas in Bangladesh are conference hall, hotels restaurants, cinema halls, office buildings, pharmaceutical factory, textile mills, food processing industry, fisheries industry etc. All these sectors are environmentally sensitive and directly related to the general population. Of course, creation of awareness is needed to the end energy user. In near future it may turn to be economically feasible in the context of generation of electricity, heat and cooling. But it needs more research and development.

#### **Calorific Value and Moisture Content Test from BUET:**

**Table 5- 26: Calorific value and moisture content of solid waste of Narayanganj City Corporation**

Parameter	Unit	Food/Kitchen Waste	Plastic/Polythene	Leather/Rubber	Paper/Rag	Methods
Moisture Content	w/w%	69.89	10.25	15.49	42.77	ASTM D 3302
Calorific Value	Kcal/Kg	2986	8649	5245	3607	ASTM D 2015



**Department of Chemical Engineering**  
 Bangladesh University of Engineering and Technology (BUET)  
 Phone: + 880-2-9665609; Mobile: +880 1753 860567; Facsimile: + 880 2 9665609  
 PABX: +880-2-55167100, 55167228-57/7326; Email: brtcuetche@gmail.com

**BRTC Date:** 14 July 2020

**BRTC No:** 110213008/CHE/20-21

**Requested by:**  
 Md Jisan Ahmed  
 Acumen Architects and Planners Limited  
 15/A, Shamoly, Dhaka-1207  
 Mobile: 01680378133

**Client's Reference and Date:**  
 Your Letter  
 Date: Not Mentioned

**Sampling done by:**  The Client  ChE Department  
**Date of Sampling:** N/A

**Sample Received:**  Sealed  Unsealed  
**Date of Testing:** 15-18 July 2020

**Table 1: Test result of Four Waste Sample supplied by Acumen Architects and Planners Limited**

SI No.	Parameter	Unit	Sample				Method
			Food/ Kitchen Waste	Plastic/ Polyethylene	Leather/ Rubber	Paper/ Rag	
1.	Moisture Content	w/w %	69.89	10.24	15.49	42.77	ASTM D 3302
2.	Calorific Value	kcal/kg	2986	8649	5245	3607	ASTM D 2015

Sample preparation: each sample was dried in an oven at 105 °C for 48 h. The dried samples were ground, sieved, and analyzed for calorific value.

**Tests Supervised by:**

*Kawnish*  
 21/07/2020

**Dr. Kawnish Kirtania**  
 Assistant Professor  
 Dept. of Chemical Engineering  
 BUET, Dhaka - 1000



**Countersigned by:**

*Shahin*  
 21/07/2020

**Dr. Md Shahinoor Islam**  
 Associate Professor  
 BRTC Secretary  
 Dept. of Chemical Engineering  
 BUET, Dhaka - 1000

Disclaimer: Test was performed as per the samples were supplied (where applicable) and valid for exactly identical samples. Wherever applicable, ChE department/BRTC BUET is not responsible for any error/omission occurred during the sampling by the client.



**Picture of Waste Sample Collection**



## CHAPTER 06: FRAMEWORK OF SWM MASTER PLAN FOR NCC

### 6.1 Master Plan Purpose

The objective of Solid Waste Management (SWM) master plan is to create economic value for solid waste by recovery of organic fertilizer, biogas, recycled materials and energy from solid waste.

Solid Waste Management is a part of public health and sanitation. The study area was supposed to undertake the task of solid waste service delivery, with its own staff, equipment and funds. The collection and disposal of solid waste is one of the pressing problems of city life of NCC, which has assumed great importance in the recent past. With the growing urbanization, problems are becoming acute and call for immediate and concerted action, here are the key development areas of SWM Master Plan for NCC:

- Detailed analyses of current SWM situation at NCC
- Future projection of waste generation at NCC
- Detailed plan for source separated waste collection, transportation and environment friendly disposal of the collected waste
- Detailed land use plan of the proposed site (three alternatives are proposed in this master plan)

Alternatives for the site include cost-benefit analyses and 3D perspective animation, from which best option are proposed with justification.

### 6.2 SWM Master Plan Framework

An integrated sustainable framework for solid waste management is developed that will serve as the basis for a sustainable waste management system. The proposed framework, presented in the below figures, depicts the integrated components of a Recycling Marketing that can be utilized to achieve sustainability. This part of the framework focuses on the economic and environmental aspects of sustainability, while social factors will be incorporated in the further development of the model.

### 6.2.1 Frameworks

1. Encourage population, including children, and the private sector to reduce waste at the source by following the 3Rs concept (Reduce, Reuse, Recycle)
2. Establish proper disposal methods for solid waste and household hazardous waste by using centralized facilities for clusters emphasizing waste utilization and waste to energy methods
3. All relevant sectors participate in the management of solid and hazardous waste

### 6.2.2 Sustainable MSW Management Goal

- ✓ **Goal 3:** Ensure healthy lives and promote well-being for all at all ages;
- ✓ **Goal 6:** Ensure availability and sustainable management of water and sanitation for all;
- ✓ **Goal 11:** Make cities and human settlements inclusive, safe, resilient and sustainable;
- ✓ **Goal 12:** Ensure sustainable consumption and production patterns.

### 6.2.3 Sustainable Solid Waste Management Policies for NCC

#### 6.2.3.1 Goal

Achieve Zero Waste of Resources – to eliminate the disposal of solid waste with economic value with an interim goal of 70 percent recycling through a combination of efforts in the following order of priority:

- a. Waste prevention and reuse,
- b. Product stewardship,
- c. Recycling and composting, and
- d. Beneficial use.

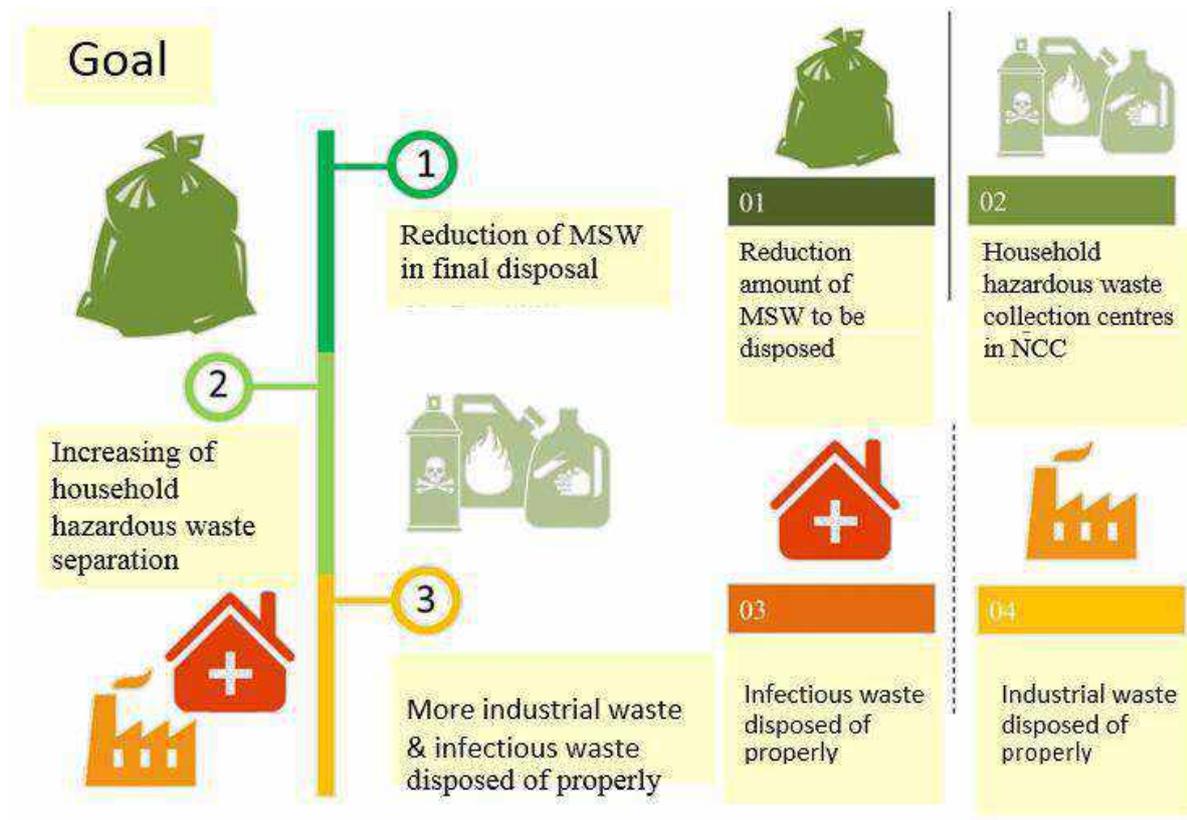


Figure 6- 1: Framework of sustainable master plan for SWM

### 6.2.3.2 Strategies

**S-1:** Set achievable targets for reducing waste generation and disposal and increasing recycling and reuse.

**S-2:** Enhance, develop, and implement waste prevention and recycling programs that will increase waste diversion from disposal using a combination of tools:

- a. Infrastructure,
- b. Education and promotion,
- c. Incentives,
- d. Mandates,
- e. Enforcement, and
- f. Partnerships.

**S-3:** Advocate for product stewardship in the design and management of manufactured products and greater responsibility for manufacturers to divert these products from the waste stream.

**S-4:** Prevent waste generation by focusing on upstream activities, including encouraging sustainable consumption behaviours, such as buying only what one needs, buying durable, buying second-hand, sharing, reusing, repairing, and repurposing.

**S-5:** Work with regional partners to find the highest value end uses for recycled and composted materials, support market development, and develop circular supply loops to serve production needs.

**S-6:** Strive to ensure that solid waste generated from NCC stream for recycling, composting, and reuse are handled and processed using methods that are protective of human health and the environment.

**S-7:** Provide for efficient collection of solid waste, recyclables, and organics, while protecting public health and the environment, promoting equitable service, and maximizing the diversion of recyclables and organics from disposal.

**S-8** Promote efficient collection and processing systems that work together to minimize contamination and residual waste, maximize diversion from disposal, and provide adequate capacity.

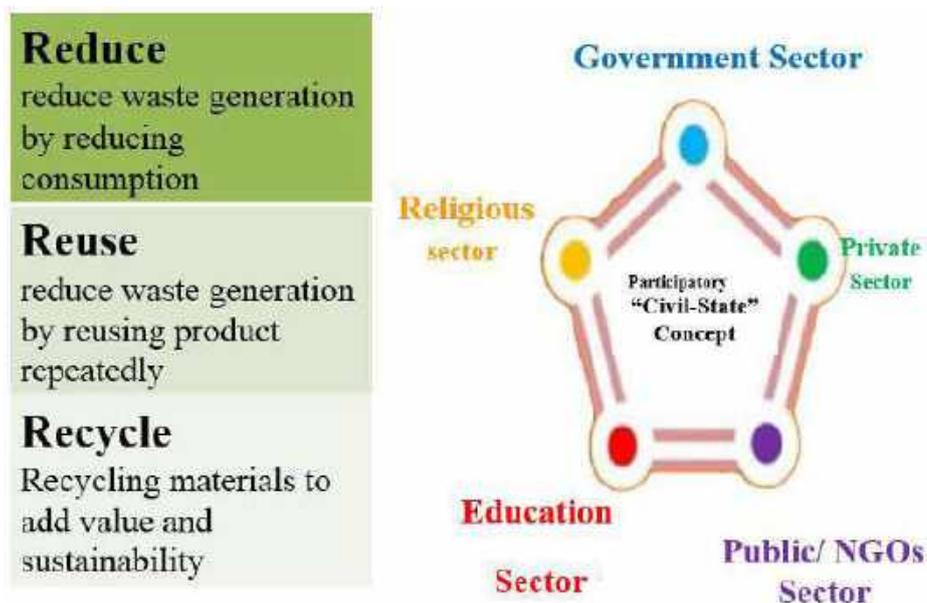


Figure 6- 2: Principle of 3Rs and Participatory "Civil-State"

### 6.3 Recycling Marketing Development Framework

For the given solid waste management system, inputs and outputs are the main elements. The inputs for the system are the municipal wastes collected from commercial and residential areas, some input energy which will be utilized for running machines used for material treatment and

recovery, and other materials that can serve as raw material for producing and manufacturing secondary products. Plastics, paper, metal, and glass are recyclable materials that can be either reused or recycled. Organic wastes can be composted, fermented, or incinerated to obtain energy. The system has useful outputs such as compost, secondary products, and energy.

There is a consensus in the literature that recycling offers a substantial benefit in material conservation that must be considered in any municipal waste management policy. Thus, the developed framework resorts to sorting wastes obtaining recyclables, and Sustainable waste management.



Figure 6- 3: Recycling Marketing Development Framework

### 6.3.1 Recycling Market Development

In Recycling processes some of the components of waste stream are segregated and turn into new, useful products. This is done to reduce the use of raw materials that would have been used. Recycling also uses less energy and great way of controlling air, water and land pollution.

Best way of recycling is to start the process from the source and recycle in the Effective recycling starts with household (or the place where the waste was created). In many countries, the authorities help households with bin bags with labels on them. Households then sort out the waste themselves and place them in the right bags for collection. This makes the work less difficult. But considering the reality of the Narayanganj, we propose to segregate them in the shed and yard in the dumping area as we shown in the master plan.

Recycling creates jobs and new entrepreneurs.

### 6.3.2 Financial and Resource Assistance

Local economic development tools to bring new recycling and reuse industries to the area - New job position will be created to promote recycling and reuse within the existing NCC's Economic Development office framework (e.g. startup highlights, innovations investment forum, etc.). The position will use the tools of the economic development community (such as the use of local industrial parks, use of economic development financial incentives, and included in local economic development promotions) to forge public/private partnerships for manufacturers that are part of the recycling supply chain.

### 6.3.3 Purchasing

**Purchasing Targets and Business Development** - NCC can use its resources to entice businesses to move in Narayanganj or launch a company to supply the chosen product made from locally generated, collected, and processed recycled materials.

**Mandated Purchasing** - Environmentally Preferable Purchasing policies can be created to require expanded use by state agencies of recycled content supplies and services to help drive demand in the recycling sector and lead to increased collection and processing of materials. Contracting language can be reviewed to eliminate barriers that make it difficult to pursue the purchasing of recycled content materials or revamp its current system to one that limits purchase choices.

## 6.4 Waste to Energy Study

The common Waste – Energy Models/Practices are shown below;

- ✓ **Waste Reduction:** Prevention, minimization, and reuse – product redesign
- ✓ **Recycling and Materials Recovery:** 3Rs Generates income and employment;  
e.g.: Construction waste
- ✓ **Composting and Biogas Production:** Composting of organic matter with oxygen (aerobic) for agricultural fertilizers or fuel; anaerobic digestion – methane collected and combusted for energy;
- ✓ **Landfill/Methane Capture:** Most common among all countries; must be done properly to protect the environment and public health. Landfill gas (LFG) from organic matter

decomposition can be recovered and the methane (about 50% of LFG) burned with or without energy recovery to reduce GHG emissions.

- ✓ **Incineration/Gasification:** Burning of waste to reduces volume of waste (up to 90%); energy recovery models with waste streams with very high amounts of packaging materials, paper, cardboard, plastics and horticultural waste. Burning without energy recovery is not recommended - results in air pollution, health.

There are two types of technology around the world for waste to energy conversion which include: - Thermal conversion (incineration, gasification, pyrolysis, plasma arc gasification, etc.) - Non-thermal conversion (anaerobic digestion, landfill gas recovery). End-use consumption such as electricity, gas, heat, compost, etc. is one of the most important parameters that influence the choice of the energy recovery system. The merit and demerits of both technologies have been elaborately addressed in the study. Gasification and anaerobic digestion (AD) are considered emerging and sustainable technologies. The advantages of gasification technology include a great reduction in waste volumes and its ability to process a variety of waste streams, small land size requirement and output energy of heat and electricity. A major disadvantage of this technology is the requirement of a constant supply of waste feedstock with less than 30% moisture content. Thus, a rotary dryer is needed to remove the moisture from wet feedstock which would result in 20 – 30% self-consumption. On the contrary, biochemical conversion techniques (anaerobic digestion) can digest wet biodegradable waste like wood and vegetables, has a low LHV with output energy of biogas, compost, and landfill. The major disadvantages of anaerobic digestion include the need for vast land areas and the cost of sanitation. However, both technologies (gasification and anaerobic digestion) are technically sustainable. Large cities where land acquisition is troublesome, gasification technology is recommended. In those cities where availability of land is not an issue and end-use consumption is primarily bio-gas (cooking & transport), compost and landfill, etc., anaerobic digestion technology is recommended. However, a composite module (integration of both technologies) is suggested in a mixed situation.

## 6.5 Numerical Frame of Master Plan

Generally, any kind of master plan is proposed for 20 years. The master plan for solid waste collection and disposal management can be for 50 years even 100 years based on its capacity. But for Narayanganj, Acumen (the consultant) think that it will not be a suitable and feasible plan

for more than 20 years. Now a days, Narayanganj is a city of hope and livelihood for about 2 million people (Including floating people; source: Town Planner, NCC). Its rapid urbanization makes it unpredictable in terms of development growth as well as urbanization rate. Rapid industrial development pulls the surrounding people as well as the people from the whole country to come here for their livelihood. There are lots of floating people who come at NCC at day time and go back after evening. These people live in the surrounding areas of NCC. Some people also come here for short period of time for the search of employments and other purposes. By considering all the above mentions issues, the consultant has come up with a 20-year time framed master plan. The consultant also proposed that this master plan will be revised and updated where necessary after every 5 years.

The revision and update will include the following issues,

**1<sup>st</sup> Revision:**

1. Revision of Waste Collection System
2. Installation of STS (Secondary Transfer Stations)
3. Garbage Vehicle needs and gaps analysis
4. Capacity Building
5. Increasement of SWM Man staff
6. New infrastructures development for SWM
7. Procurement of new Modern SWM equipment

**2<sup>nd</sup> Revision:**

1. Installation of STS (Secondary Transfer Stations)
2. Garbage Vehicle needs and gaps analysis
3. Capacity Building
4. Increasement of SWM Man staff
5. New infrastructures development for SWM
6. Procurement of new Modern SWM equipment
7. Compost production
8. Biogas Production
9. Power Generation
10. Searching for new location for Landfill site
11. Extend the service area

**3<sup>rd</sup> Revision:**

1. Garbage Vehicle needs and gaps analysis
2. Capacity Building
3. Compost production
4. Biogas Production
5. Power Generation
6. Petroliam Generation
7. Market creation for the product of waste management plant
8. Landfill site extension or preparation for new landfill site
9. Searching for new location for Landfill site
10. Extend the service area

**4<sup>th</sup> Revision:**

1. Compost production
2. Biogas Production
3. Power Generation
4. Petroliam Generation
5. Market creation for the products and bi-products of waste management plant
6. Landfill site extension or preparation for new landfill site
7. Searching for new location for Landfill site
8. Extend the service area

## **6.5.2 Develop Solid Waste Transportation and Route**

### **6.5.2.1 Waste Sources to STS**

Private waste collection organization with the help of people representation and local people will fix the time of waste collection and route plan for waste collection. This route plan will be fixed from the efficiency consideration of the all parties involved

### **6.5.2.2 STS to Final Dumping Area**

City Corporation procured trucks and the workers will collect the waste from the STS of various points of the NCC area. Proper equipment must be used to ensure the safety and the efficiency of the work. Collected waste will be transport to the shed and yard at final dumping area where

mixed waste will be segregated according to the characteristics of the waste. An efficient cost-effective route plan will be designed by the city officials considering the road condition, distance and transport cost.

According to the character and nature of the waste, they will be sending to;

- Waste to energy unit
- Composting unit
- Recycling unit
- Sanitary Land Fill

#### 6.5.2.3 Composting Plant and Segregation Yard

Composting is nature's way of recycling. Waste transported from the residential and commercial areas will be segregated in the dumping yards (as shown in the diagram). We found from the filed survey that around 73% of the waste in Narayanganj is of biodegradable organic waste. i.e. kitchen waste, restaurant waste, food waste, manure, leaves, paper, wood, crop residue etc., and turns it into a valuable organic fertilizer.

Composting is relatively simple and a natural biological process that carried out under controlled aerobic conditions (requires oxygen). In this process, various microorganisms, including bacteria and fungi, break down organic matter into simpler substances. The effectiveness of the composting process is dependent upon the environmental conditions present within the composting system i.e. oxygen, temperature, moisture, material disturbance, organic matter and the size and activity of microbial populations.

By composting we convert organic matter into stable compost that is odor and pathogen free, and a poor breeding substrate for flies and other insects. In addition, it will significantly reduce the volume and weight of organic waste as the composting process converts much of the biodegradable component to gaseous carbon dioxide.

#### 6.5.2.4 Recycling Unit

Things to Recycle:

- ✓ Paper waste: Paper waste items include books, newspapers, magazines, cardboard boxes and envelopes.

- ✓ Plastic waste: Items include plastic bags, water bottles, rubber bags and plastic wrappers.
- ✓ Glass Waste: All glass products like broken bottles, beer and wine bottles can be recycled.
- ✓ Aluminum Waste: Cans from soda drink, tomato, fruit cans and all other cans can be recycled. Recycling just 1 ton of aluminum cans conserves more than 207 million Btu, the equivalent of 36 barrels of oil, or 1,665 gallons of gasoline

When these are collected, they are sent to the recycling unit, where all the waste from each type are combined, crushed, melted and processed into new materials.

- ✓ Recycling helps protect the environment and reduce the Pollution of the air, land, water and soil etc. Recyclable waste materials would have been burned or ended up in the landfill.
- ✓ Recycling conserves natural resources and reduce the resource depletion
- ✓ Recycling saves energy as recyclable materials need less energy to produce new one
- ✓ Recycling creates jobs and new entrepreneurs.

#### 6.5.2.5 Preparation and Construction of Dumping Site

Dumping is a method of waste disposal where the waste is buried either underground or in large piles. In this method it is necessary that waste disposal should be controlled and monitored very closely for the sake of environmental hazards.

For dumping, the process starts by digging a large hole in the ground that is then lined with thick plastic (normally 2-4 feet thick) and a layer of impervious clay. The bottom of the landfill is also lined with a network of plumbing that functions as a collection system for any liquids. Leachate is the term used to describe liquids that leach or leak from the landfill, and this system collects the leachates. These components of the sanitary landfill help prevent materials and liquids from spreading to the surrounding ground and waterways.

Once the landfill is set up, waste can then be added to the landfill. Instead of simply filling the landfill completely with waste, the landfill is organized in layers. The layers alternate between waste and soil. This alternation of materials reduces odors and allows for more rapid decomposition, which is the breakdown of materials. When a landfill is full, it is sealed and covered in a thick layer of clay. Once the landfill has been evaluated and considered safe, it can

be converted into a park or open space for human use. It is interesting to think that a location where we put our unwanted materials can then be turned into a location for recreation and fun.

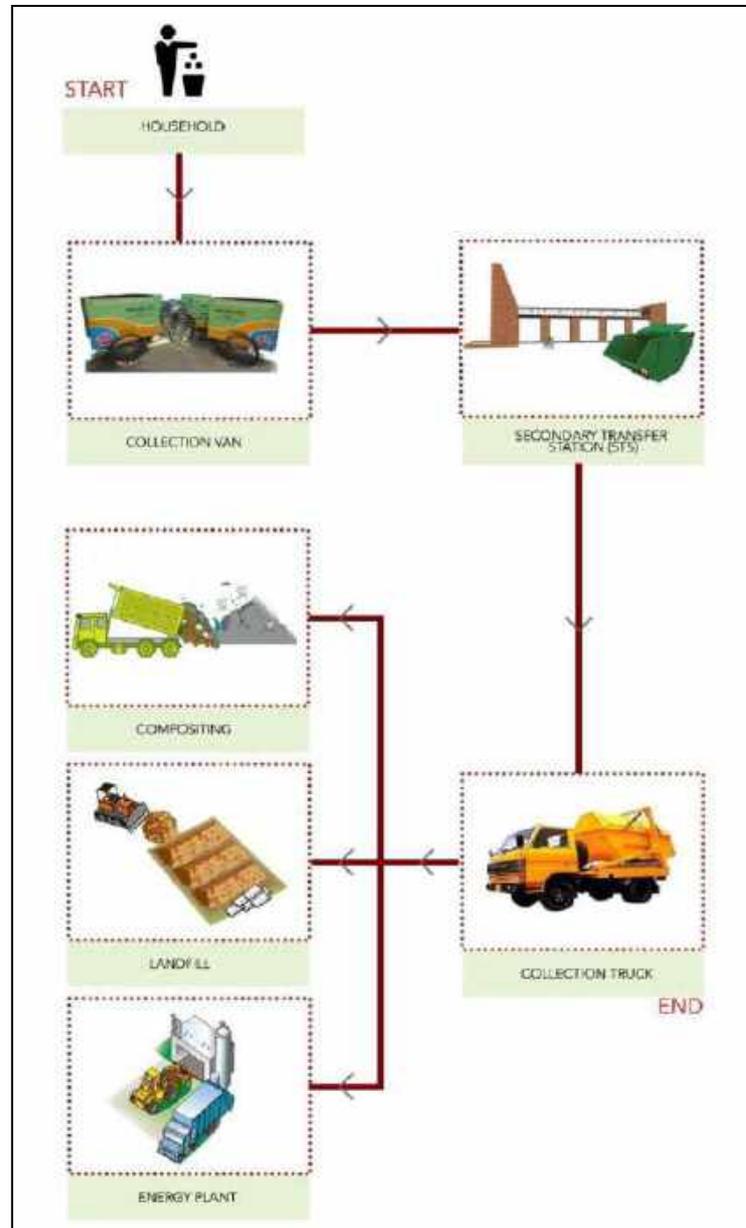


Figure 6- 4: Diagram of Solid Waste Transportation System

### 6.6 Financial Analysis Framework

A financial analysis has been exercised separately with and without environmental cost and revenue into consideration. The actual cost estimation for a pilot project with regards to Bangladesh became difficult due to limited time and was estimated based on experience gained in Bangladesh. Due to the limitation of cost estimation of commercial projects, developing a

decision-making financial business model proved difficult. A practical approach to cost estimation using more local resources is highly recommended. In order to do so, a small-scale demo project using both technologies (gasification and anaerobic digestion) would need to be undertaken. Based on the result of a demo project, a sustainable financial model should be developed comprising of soft loans, grants, and owner's equity. The Life Cycle Cost (LCC) with Net Present Value (NPV), Internal Rate of Return (IRR) and Pay Back Period (PBP) are to be formulated to evaluate the financial viability of the commercial project. This is the critical time for GOB to make appropriate policies for waste management. Electricity generation from municipal solid waste (MSW) is the most environmentally friendly solution for this existing issue. The overall result of this study is considered as a major step forward in the development of sustainable solutions to address the huge solid waste challenge in the NCC.

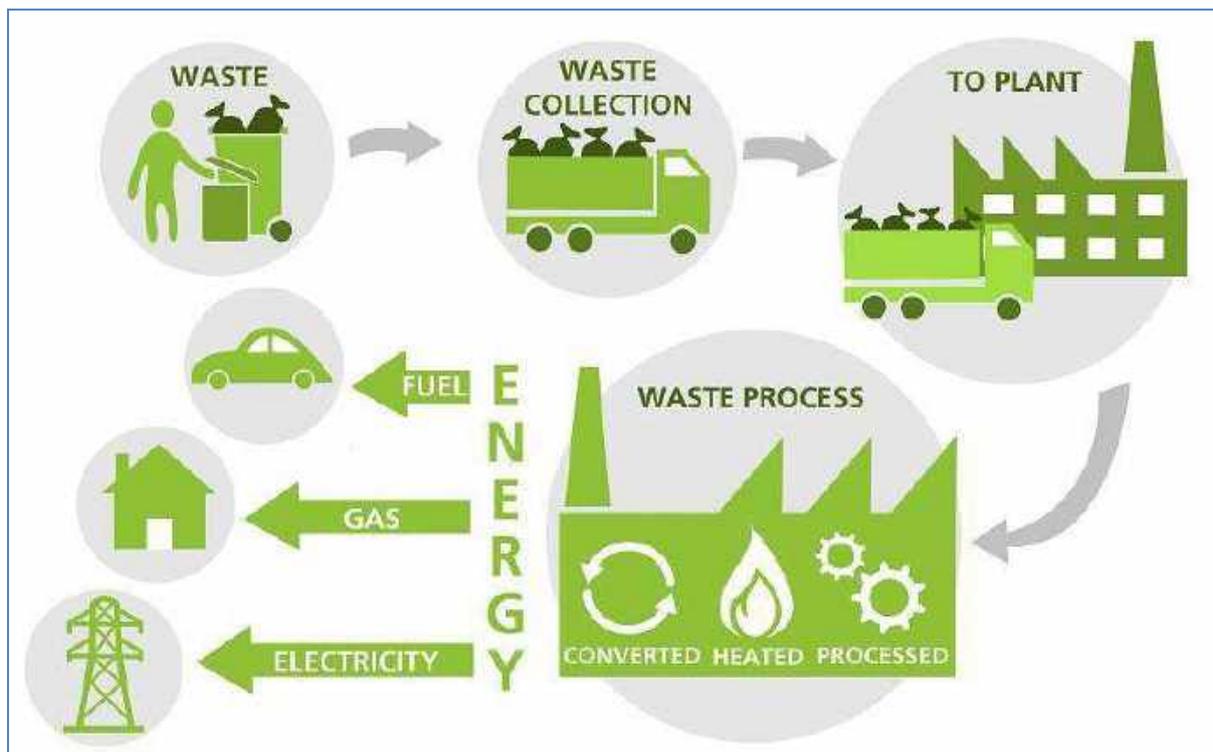


Figure 6- 5: Uses of products generated from Solid Waste

## CHAPTER 07: MASTER PLAN of SWM FOR NCC

This document is the Master Plan (MP) prepared for the Narayanganj Solid Waste collection and disposal management project. It is based on a feasibility level study and preliminary engineering design and will be updated at the final detailed engineering stage. The MP is prepared in accordance with the ADB Safeguard Policy Statement, 2009 (SPS), Government of Bangladesh's (GOB) swm policies.

### 7.1 Solid Waste/Municipal Waste

The production of unwanted materials as a by-product of economic processes. Waste (or wastes) are unwanted or unusable materials. Waste is any substance which is discarded after primary use, or is worthless, defective and of no use. A by-product by contrast is a joint product of relatively minor economic value. A waste product may become a by-product, joint product or resource through an invention that raises a waste product's value above zero. Examples include municipal solid waste (household trash/refuse), hazardous waste, wastewater (such as sewage, which contains bodily wastes (feces and urine) and surface runoff), radioactive waste, and others.

#### 7.1.1 Sources of Solid Waste

Residences and homes of NCC, where people live are some of the major sources of solid waste. Garbage from these places include food wastes, plastics, paper, glass, leather, cardboard, metals, yard wastes, ashes and special wastes like bulky household items like electronics, tires, batteries, old mattresses and used oil. Waste also comes from commercial areas, industrial areas, medical institutes construction debris etc. in Narayanganj City Corporation.

#### Major sources of solid wastes in NCC

**Residential Sources:** From households and residential areas. These are the major sources of solid waste in almost all cities and towns in Bangladesh as well as NCC.

**Commercial Sources:** From businesses such as food and drink establishments, shops, banks, etc.

**Institutional Sources:** From public and government institutions e.g. offices, religious institutions, prisons, schools, universities, etc.

**Open Areas:** Waste from street sweepings, roadside dustbins, ditches and other public places.

**Industrial Sources:** From various types of industrial processes.

**Health Facilities:** From hospitals and other health facilities.

**Construction and Demolition:** From various types of construction and demolition activities in urban areas such as the construction of apartments, the demolition of urban slums, etc.

**Agricultural Sources:** From farming — more common in peri-urban areas of small and medium towns like NCC.

**Electronic and Electrical waste (e-wastes):** Waste electronic devices (computers, phones, radios, etc.) and household appliances (cookers, washing machines, etc.).



Figure 7- 1: Major sources of Solid Waste

### 7.1.2 Solid Waste Production/Generation and projection up to 2040 in NCC

Total amount of generated solid waste of Narayanganj City Corporation depends on NCC's population growth, urbanization growth, industrial growth, commercial growth, institutional growth, medical/hospital/clinic growth, local life style, season, economic development, food habit etc. Most of the generated solid waste of NCC comes from household and commercial areas. The following table (Table 7.1) shows the current household waste generation and future waste generation projection up to 2040 in Narayanganj City Corporation.

**Table 7- 1: Total amount of generated solid waste per day up to 2040 and projection of amount of generated solid waste based on existing amount of generated solid waste in NCC**

Year	Population (Based on BBS, 2011)	Total Amount of Household Waste of NCC (Unit: Ton) <b>Per capita waste generation per day: 0.463</b>	Population (Based on Consultant Study, NCC)	Total Amount of Household Waste of NCC (Unit: Ton) <b>Per capita waste generation per day: 0.463</b>
2020	10, 63, 576	491.98	14, 00, 000	648.2
2025	13, 56, 133	627.30	17, 20, 957	796.80
2030	17, 29, 162	799.85	21, 15, 496	979.47
2035	22, 04, 800	1019.87	26, 00, 485	1204.02
2040	28, 11, 271	1300.40	31, 96, 660	1480.05

## 7.2 Solid Waste Collection

### 7.2.1 Types of Collection System

- Refuse Collection Systems - Household waste removed from the home
- Commercial Waste Collection - Commercial waste removed primarily using dumpsters
- Recyclable Material Collection - Collection of recyclable materials separated at the source of generation

### 7.2.2 Collection System Develop and Options

There are many waste collection systems which are following by cities and municipalities. It's basically depends on local resource, budget, capacity, behaviour, connectivity, efficiency of waste management department etc. It's also depended on physical characteristics and it's uses (If any). In Narayanganj City Corporation, private waste collection system is going on to collect and disposal the generated waste of NCC. Following discussion shows the advantages and disadvantages of different waste collection systems.

#### A. City-Run Collection

- More control over collection

- City owns and operates all equipment
- City manages personnel
- Funded from property tax, user fees, or utility bill

**Disadvantages**

1. Municipalities tend to be less efficient than private companies
2. Capital expenditures can be difficult
3. May require passage of bond
4. Tendency to minimize short-term spending without considering long-term implications

**Advantages**

5. Non-profit
6. Centralized operation
7. City maintains complete control over waste

**B. Private Collection**

City gives contract to firm(s) as a set fee based on bidding process, users are billed directly

**Non-Exclusive Franchises**

- Multiple contractors competing for service in community

**Exclusive Franchises**

- One contractor is responsible for a given area

**Advantages**

- No capital expenditure for city
- Long-term lower costs
- Impose order on collection (exclusive franchise)
- Regular pickup schedules (exclusive franchise)
- Trash cans/trucks on street one or two days per week (exclusive franchise)
- Lower costs due to improved routing and technology (exclusive franchise)

**Disadvantages**

- Difficult to compete with large haulers
- Leads to domination by a few haulers (exclusive franchise)

- Citizens provide a profit to waste hauler
- City can become overly dependent
- Requires oversight by city

The consultant suggests public and private partnership waste collection system in Narayanganj City Corporation. The running waste collection system is also private waste collection system but the NCC's waste management authority have control over this collection system. NCC's should develop a modern public and private partnership (PPP) waste collection system.

### Problems and Concerns of Waste Collection system

#### a) Labor

- Labor intensive
- Labor unskilled
- High turn-over rates
- Few prospects for mechanical replacement of manual labor
- Injuries and poor working conditions
- Limited career opportunities

#### b) Customer Service

- Frequency of service
- Container and storage issues particularly for commercial and industrial
- Location of pickup
- Special wastes

#### c) Management and Financing Issues

- Low priority
- Resistance to change and new technologies
- Lack of quality management
- Inflation
- Changing with new regulations

#### d) Technological Issues

- Collection of multiple streams (recyclables, yard waste, special wastes)
- Single stream vs. commingled recyclables
- Yard waste containers - bagged material must be debagged prior to composting
- Automated collection (still requires an operator)
- Development of efficient routes

- Vehicle weight restrictions
- Vehicle turning radius and clearance

### 7.2.3 Frequency of Collection

Collection frequency can be daily collection, once per week (1/wk) collection, twice a week collection (2/week) etc.

Reasons for declining collection frequency include;

- Proportion of putrescible waste declined (food grinders)
- Better design of collection vehicles controls odors and flies
- Service costs increased
- Time between collection and disposal decreased
- Better management

**Table 7- 2:** Advantages and Disadvantages of Different Collection Frequencies

Alternative	Potential Advantage	Potential Disadvantage	Favoring Condition
Once per week or less	Less expensive	Odor and Vector Problem	Cold to Moderate Climate
Twice per week	Reduce storage equipments	More expensive	Warm Climate
More than twice per week	Reduce storage equipments	More expensive	Dense Population

## 7.2 Primary Collection and Public Involvement

House-to-house primary collection will be implemented in Narayanganj City Corporation, geared towards collecting up to 500-600 tons of domestic waste per day from all households, using simple segregation at the source approach. In total, about 400 to 500 tons of solid waste including commercial, industrial and medical waste will be collected as well through the same process. Private sector operators, licensed by the City Corporation will collect waste from houses and commercial places using tricycle vans. An additional 300 to 400 vans would be required to cover the solid waste generated in Narayanganj. The household service will be extended to the whole of

City Corporation including the markets and other commercial and community facilities gradually. No involuntary resettlement impacts are expected from primary collection activities.



Figure 7- 2: Picture of primary solid waste collection Rickshaw Van in NCC

### 7.2.3 Establishment of Ward Wise Solid Waste Management System

**a) Formation of Local Organization at Ward Level:** From a legal point of view, primary collection belongs to the responsibility of residents or business entities. It is essential to formulate an orderly manner of waste discharge for every individual resident and business entity in this connection. This is self-evident but, in general, people do not know their responsibility and do not want to take any responsibility. The plan proposes to form a special organization and encourage residents through the movement envisaged by the organization to change their behavior of waste discharge to the well-managed primary collection. The stakeholders of the primary collection are expected to form a partnership with the others as shown in below figure.

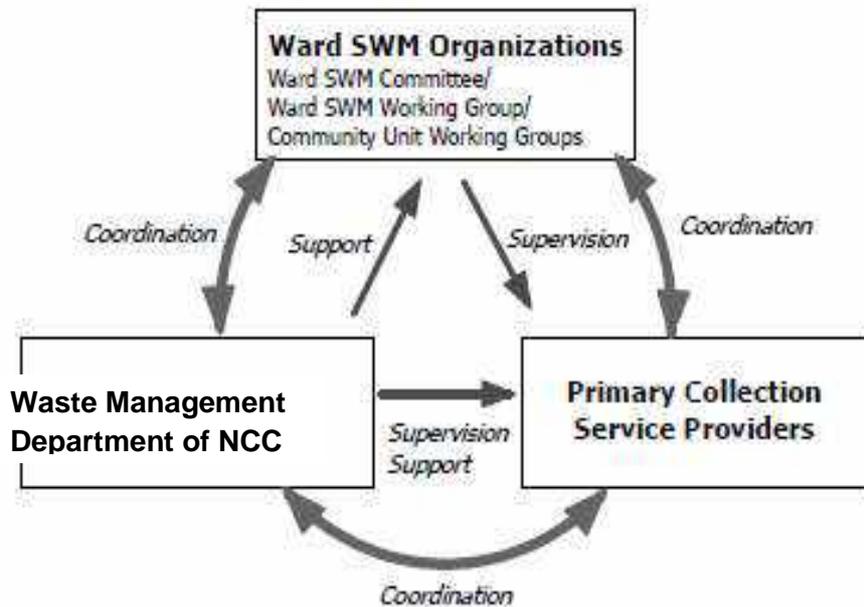


Figure 7- 3: Partnership of Stakeholders in Primary Collection

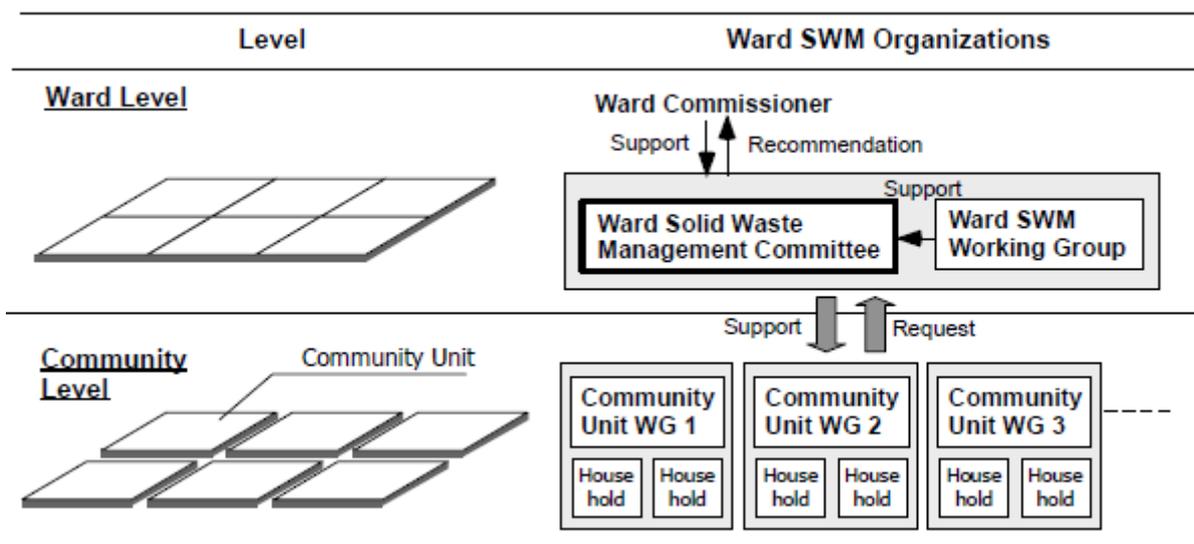


Figure 7- 4: Structure of Ward Solid Waste Management Organizations

**b) Ward Solid Waste Management Planning:** A bottom-up approach will be taken in the planning process; planning workshops will be held by the Committee to be supported by the Working Group. Ward Solid Waste Management Plan will be formulated based on a result of workshops.

**c) Development of Primary Collection through Community Based Approach:** A suitable method of primary collection based on the town structure will be developed at the community level. NCC Conservancy Department should coordinate by responding to the plan in the distribution of NCC

containers and adjustment of waste collection time and frequency. The conceptual primary collection System is presented in the below figure.

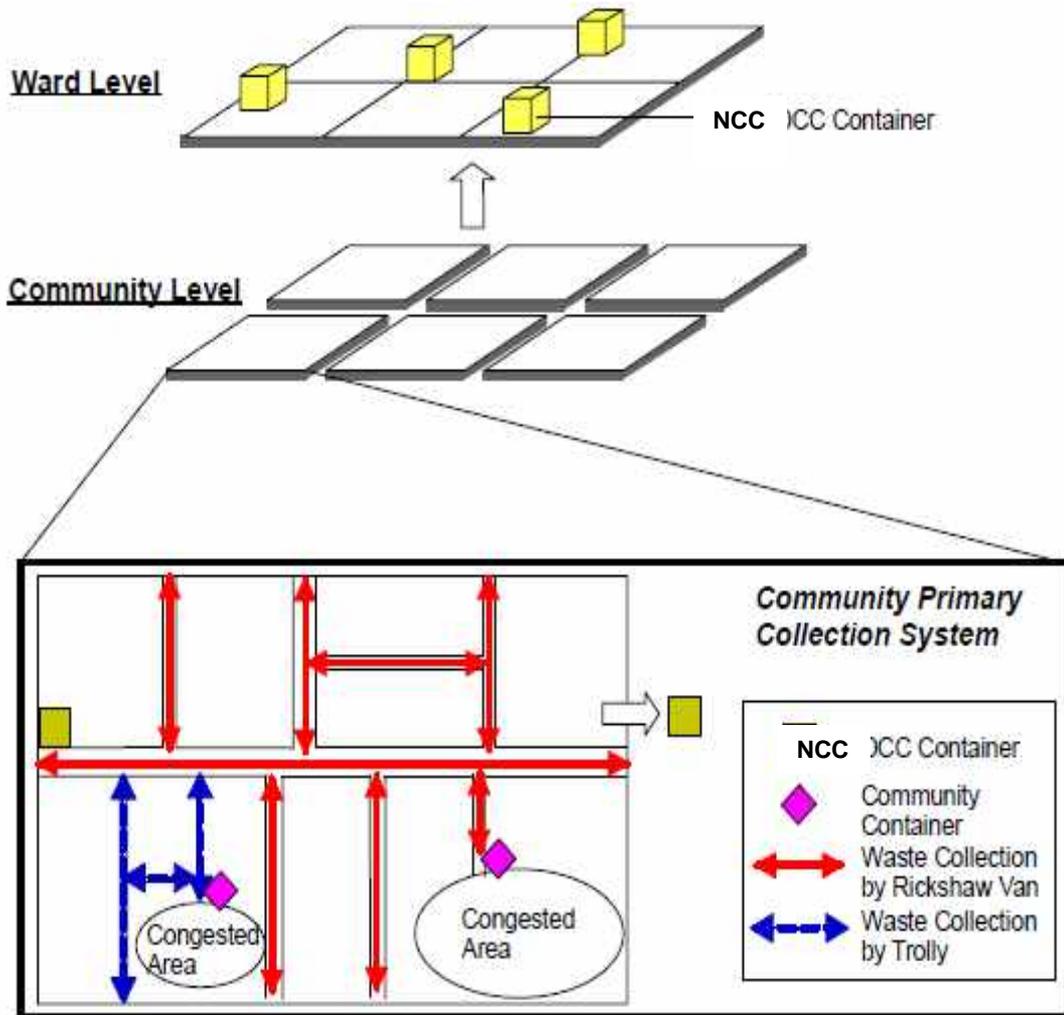


Figure 7- 5: Community Level Primary Collection System

### 7.2.4 Source Separated Primary Waste Collection

Source separation is the segregation of different types of solid waste at the location where they are generated (like household or commercial, industrial, medical etc.). The most common reason for separating wastes at the source is for recycling. Recyclables that are segregated from other trash are usually cleaner and easier to process.

Modernized Solid Wastes Collection System

There are two types of collection system:

1. Conventional based
2. Community based



Figure 7- 6: Source Separation Waste Collection Bucket Sample

### 7.2.5 Strengthening the Function of NCC in Primary Collection and Community Involvement

**a) Short Term Action:** A special section (Community Solid Waste Management Section) with full-time staff should be set up in the Waste Management Division in order to develop and expand the Ward Solid Waste Management System and support primary collection activities.

**b) Medium-Term Action:** Functions of NCC in primary collection and community involvement should be further strengthened according to the phased organizational reform as shown in the below figure.

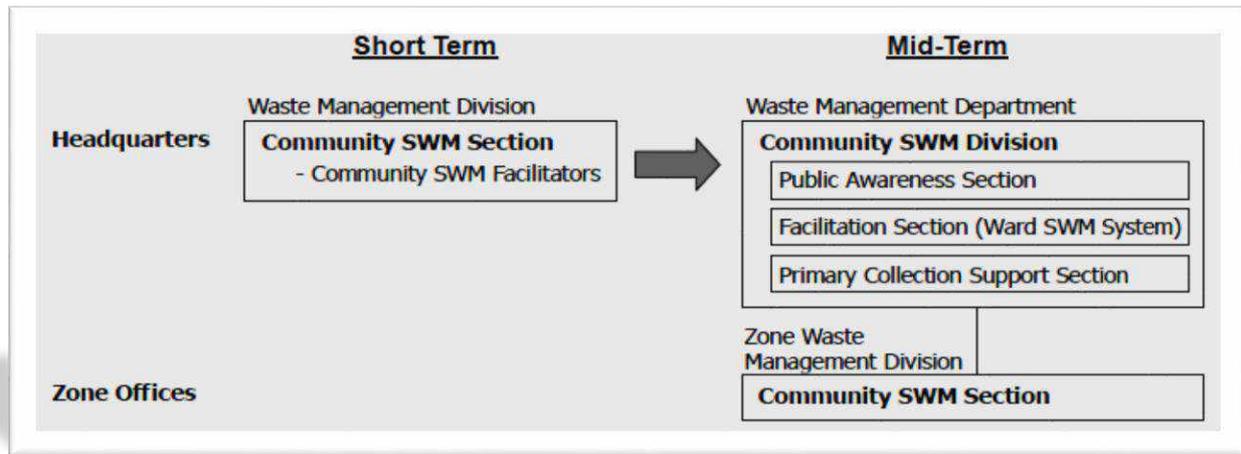


Figure 7- 7: Proposed Evolution of Competent Section in Community Involvement

### 7.2.6 Support for Primary Collection Service Providers

Most primary collection service providers are facing difficulties to invest in further expansion of the activities because of the lack of funds. On the other hand, it is difficult for NCC to provide a collection of equipment/facilities free of charge since the primary collection is a private activity. The two-step loan through NCC and/or establishment of loan scheme by Bangladeshi NGOs for investment in a primary collection might be worth examination for a possible solution.

### 7.2.7 Technical Development of Primary Collection

NCC will make continuous efforts to develop the primary collection methods in order to improve efficiency and cleanliness. Pilot projects are proposed to test some alternative equipment/facilities for primary waste collection. The highest priority is the harmonization of the design of rickshaw vans and NCC containers. At present, the transfer of waste from rickshaw vans to containers takes too long and the waste is scattered around containers. An alternative design of rickshaw vans and containers is expected in cooperation with users including primary collection service providers and NCC. Another priority is to develop a primary collection system in congested areas with narrow roads where even trolleys cannot enter.

### 7.2.8 Raising Public Awareness

Establishment of a Section in Charge of IEC (Information Education and Communication) Activities: Community Solid Waste Management Section will be established under NCC immediately. The

Community Solid Waste Management Section should implement IEC activities for the promotion of people's understanding, awareness, and behavior.

### 7.2.9 Education of Young Generation

It is expected that the young generation can raise awareness and adapt to modest behavior more firmly than adults. Therefore, education for the young generation should be started immediately although it takes time to change the entire society. As the first step, education of schoolteachers is indispensable because most of the schoolteachers are not familiar with solid waste management and have never visited solid waste management facilities. NCC can give the lessons on solid waste management and the opportunity to visit the relevant facilities.

#### 7.2.10 Raising Awareness of Decision Makers and NCC Staff Members

**a) Decision Makers:** In Narayanganj, decision-makers such as mayor, NCC high ranking officers, and ward commissioners will have important roles in solid waste management. It is indispensable that decision-makers are familiar with the issues of solid waste management as the priority policy. Waste Management Division will coordinate and implement the following events in order to keep them more closely to SWM:

- I. Sharing actual information
- II. Bangladesh Solid Waste Management Conference

**b) Enlightenment of NCC Staff Members:** NCC will undertake the following with suitable material:

- I. Make people understand a cleaner's job
- II. Boost cleaner confidence and pride in their work by letting them know that they are doing a precious job and are contributing to clean Narayanganj.

### 7.3 Secondary Collection

The Narayanganj city corporations are responsible for secondary waste collection to remove waste from its open dumping points or containers, and transport the waste to final disposal sites. Primary collectors bring segregated solid waste to transfer stations/secondary transfer stations where the waste will be transferred from the tricycle vans or truck to conventional trucks, after which the trucks will transfer the waste to the proposed sanitary landfill site. This will provide the means to achieve the transfer efficiently and without significant environmental impact. Each transfer station will require a dedicated land area of around 50X30 square feet (size of transfer

station will depend on site-specific dimensions which are to be decided at detailed design). As the sites are within government-owned land, no land acquisition is required. However, involuntary resettlement impacts can include impacts on hawkers /street vendors.

### 7.3.1 Secondary Transfer Station (STS)

A secondary transfer station (STS) is a building or processing site for the temporary deposition of waste, often called Waste Transfer Stations. Secondary Transfer stations are often used as places where local waste collection vehicles will deposit their waste cargo prior to loading into larger vehicles or to dump into final dump yard.

Study Based on Narayanganj City Corporation:

There is no specified transfer station in Narayanganj City Corporation.

Need for a transfer station is indicated by the following,

Presence of illegal dumps and litter

Remote disposal sites (> 10 miles)

Small capacity collection vehicles (< 20 yd<sup>3</sup>)

Low density residential areas

Widespread use of medium sized commercial containers



Figure 7- 8: Picture of Secondary Transfer Points in Dhaka

Waste from Household and others can be carried to Big Compactor Vehicle. These larger vehicles will transport the waste to the end point of disposal in an incinerator, landfill, or hazardous waste facility, or for recycling.



**Figure 7- 9: Picture of Big Compactor Vehicle**

Today almost everywhere Motorized Vehicle is used for transferring waste.

It can be Categorized as:

- I. Compaction vehicle
- II. Semi-compaction vehicle
- III. Non-compaction vehicle
- IV. Container handling systems

Picture of Transfer Vehicle:



Compaction vehicle



Semi-Compaction vehicle



Container Holding vehicle



Open vehicle

Standard Collection and Transfer System:



Figure 7- 10: Standard collection and transfer system

STS Proposal for Narayanganj City Corporation:

There are already 80-85 designated open dumping points in Narayanganj City Corporation which should be converted into secondary transfer station. There need 80-90 secondary transfer stations in Narayanganj City Corporation. This number will be revised after each five year.

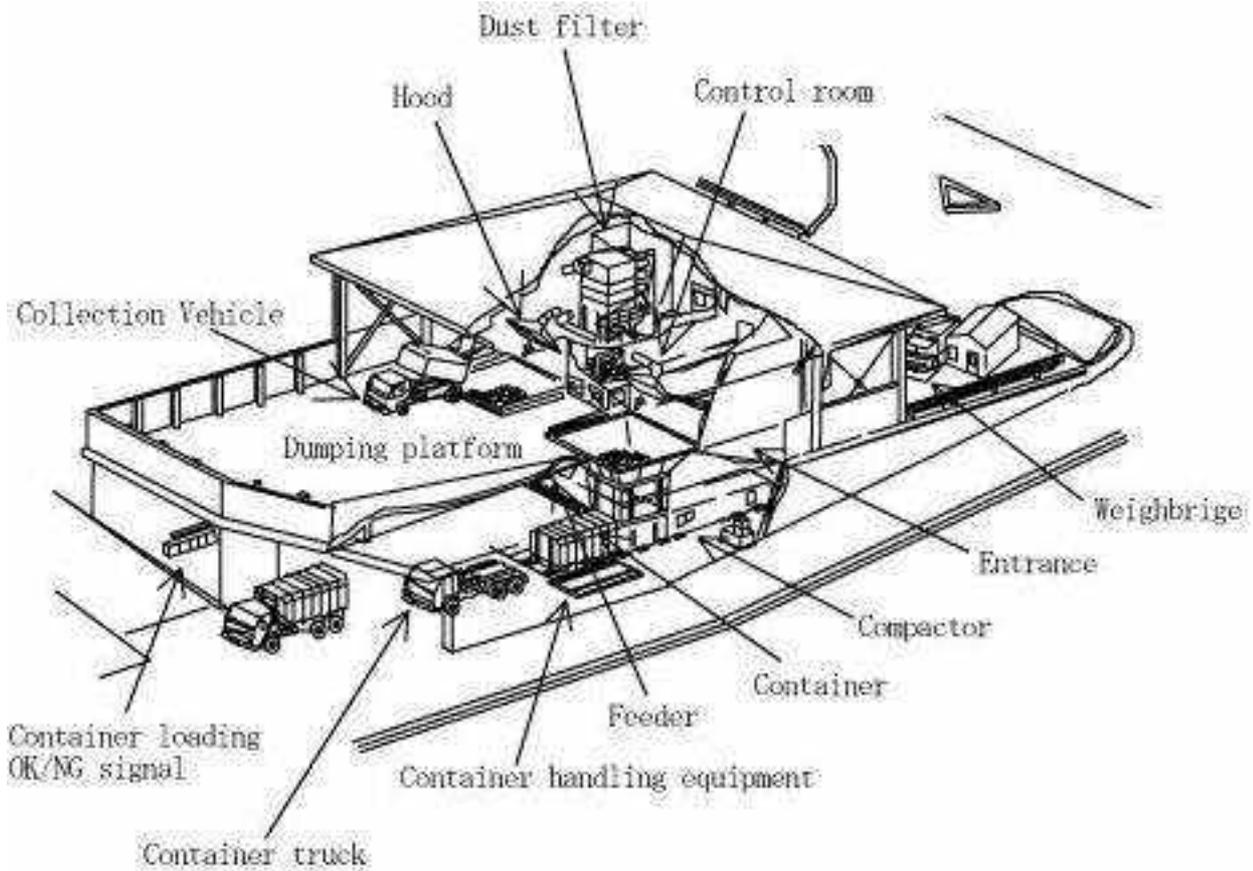


Figure 7- 11: Layout Plan of STS

Typical design of a secondary transfer station:

### Elements in Transfer Station

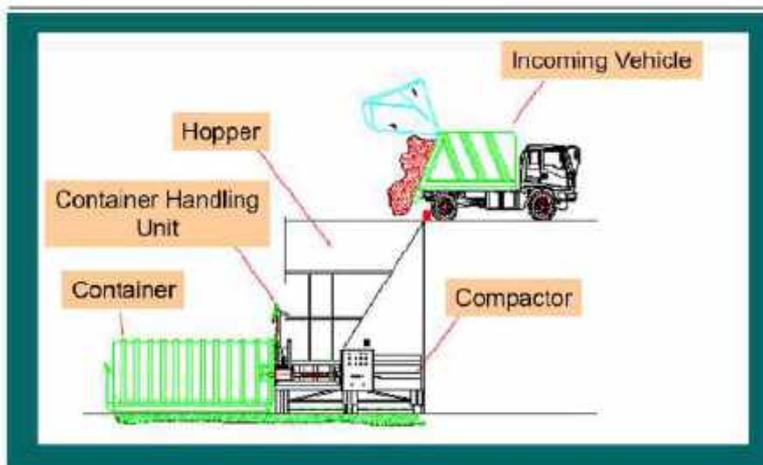


Figure 7- 12: Elements of STS

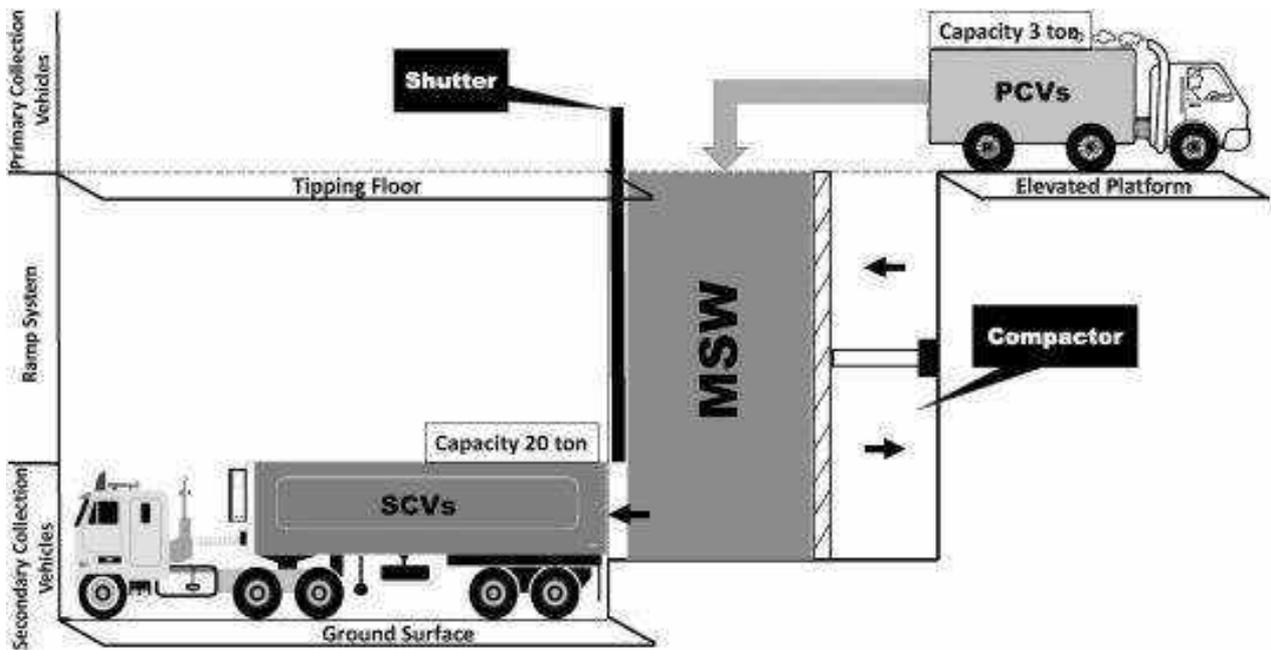


Figure 7- 14: Loading and unloading system of STS

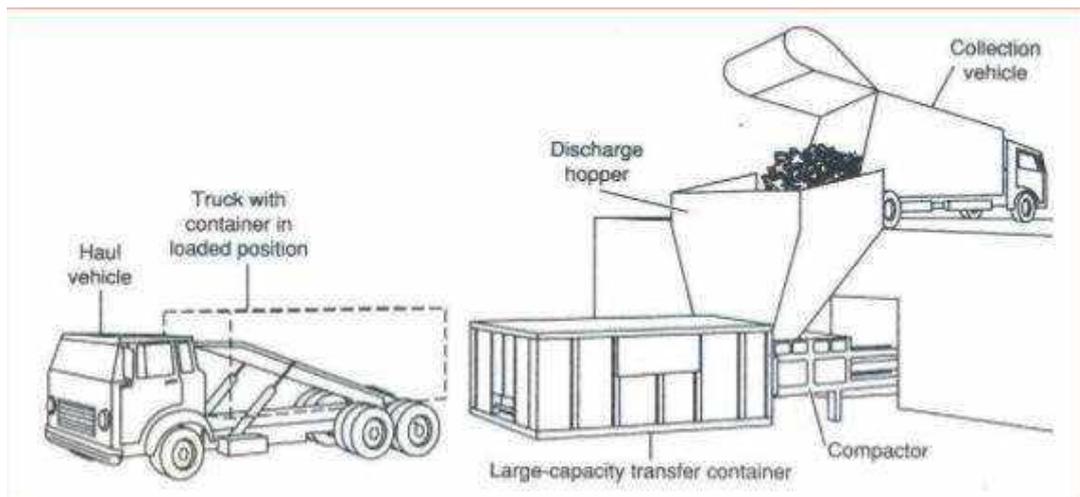
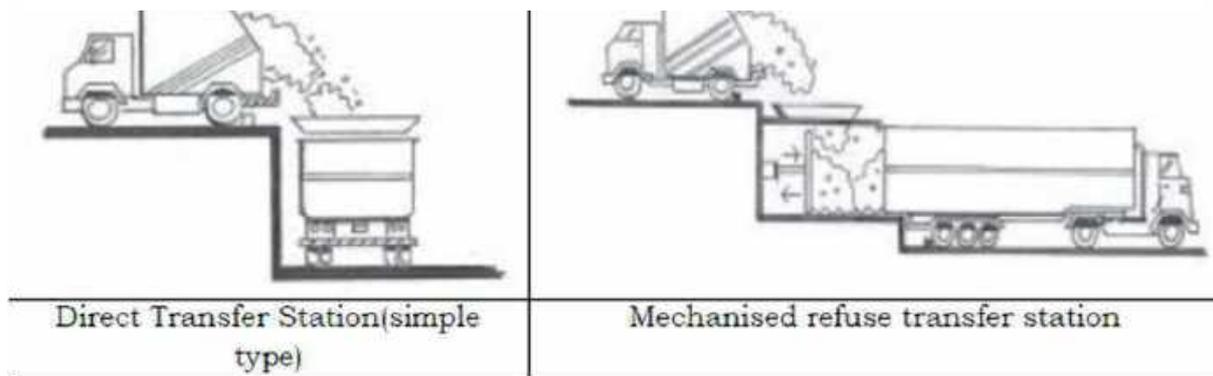


Figure 7- 13: Direct and mechanized refuse transfer station

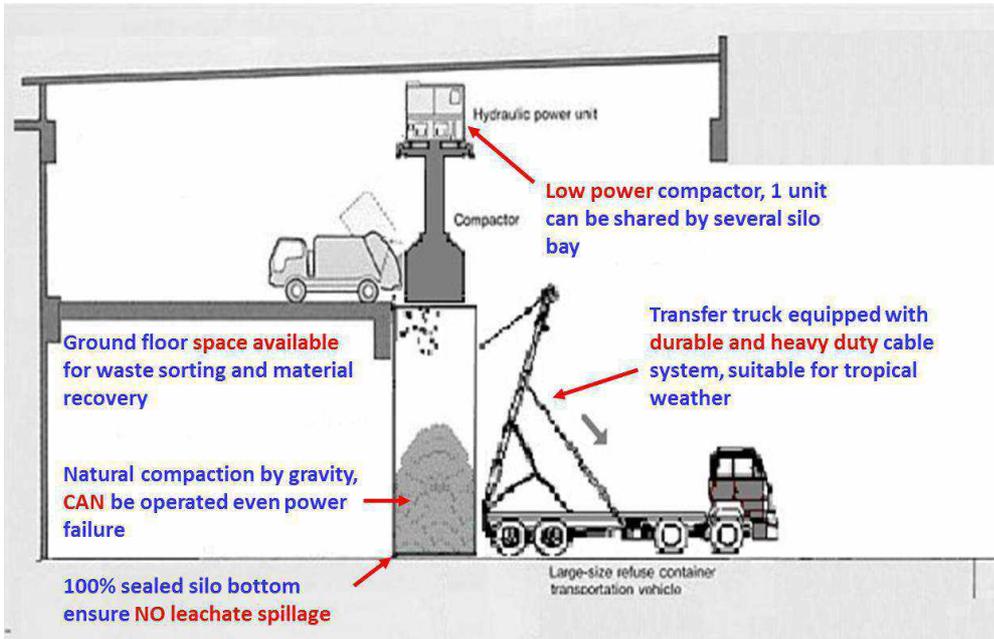


Figure 7- 15: Details of mechanized STS

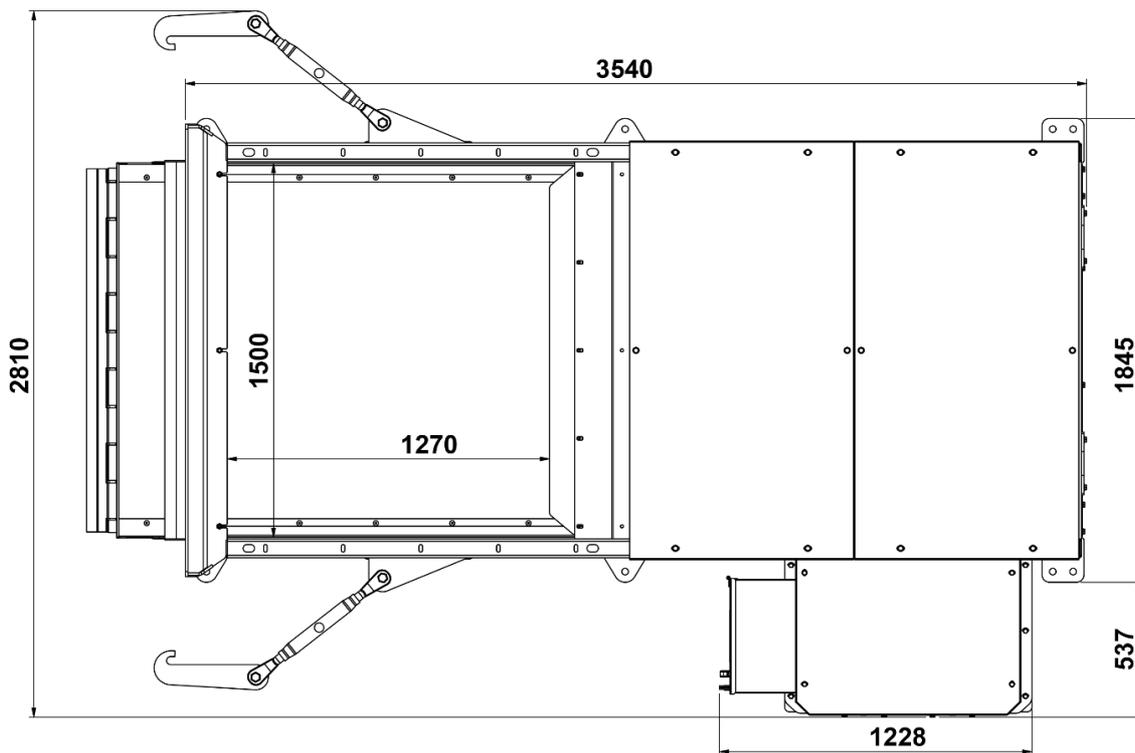


Figure 7- 16: Dimension of Compactor of STS

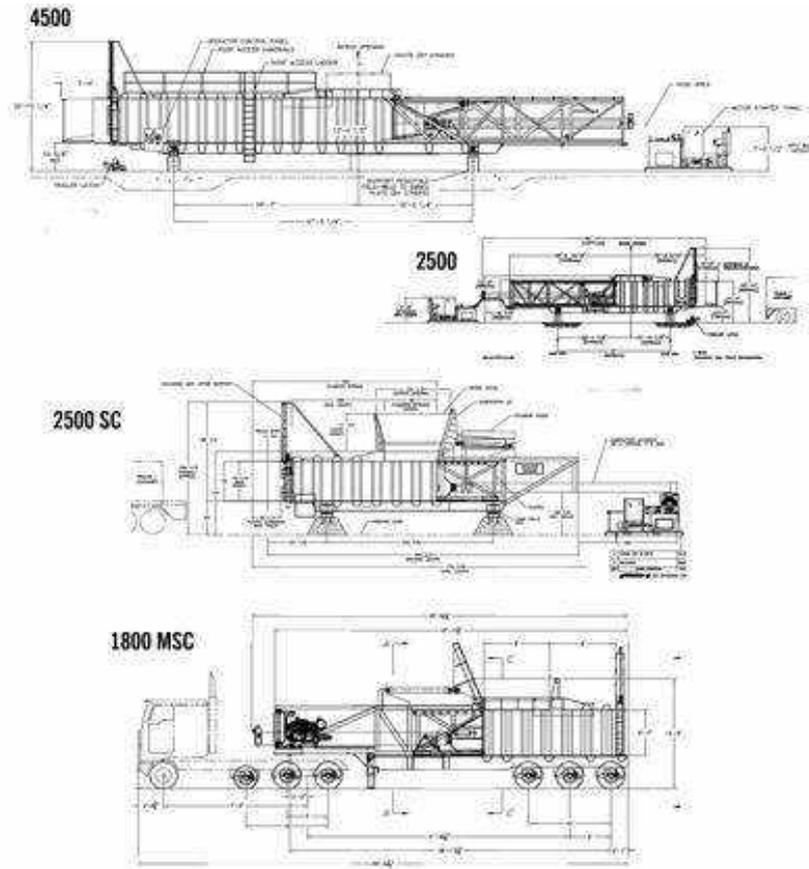


Figure 7- 17: Section of STS compactor



Figure 7- 18: Picture of STS vehicle

### 7.3.2 Procurement of New Vehicles and Waste Containers for Waste Collection in NCC

#### A. Recommendable Type of Vehicle

From viewpoints of efficiency and cost-performance, the following principle is recommended for the future composition of collection and transport trucks.

1.5-ton Truck: Need to keep the present quantity

3-ton Truck: Need not to renew

5-ton Truck: Need to keep the present quantity

10-ton Truck: Need to increase as many as necessary to meet the demand in any year in the planning period

20-ton Truck: Need to increase as many as necessary to meet the demand in any year in the planning period

#### B. Consideration of Aging of Garbage Trucks and Containers

Trucks are costly goods but have limited lifetime. In planning future line-up of collection and transport trucks, the following residual ratio should be adopted for estimation of service life of every type of trucks.

**Table 7- 3: Adopted Residual Ratio of Trucks by Age**

Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Rate (%)	100	100	100	100	100	94	86	79	71	64	56	48	41	33	26	0

#### C. Assumption of Truck Operation in NCC

Trucks are assumed to operate with the following frequency of dumping and loading rate.

**Table 7- 4: Assumption of Truck Operation at NCC**

Type of Truck	Frequency of Dumping	Loading Rate
1.5 ton	4 trips/d	80 %
3 ton	4 trips/d	80 %
5 ton	2 trips/d	70 %
10 ton	2 trips/d	70 %
15 ton	2 trips/d	60 %
20 ton	1 trips/d	60

Source: Estimated by the Acumen Study Team

#### D. Procurement Plan of Trucks and Waste Containers for NCC

The required number of trucks and containers to be procured is estimated at 135 units and 95 pieces respectively during the planning period. The numbers to be procured is summarized in the following table by year and type.

**Table 7- 5: Procurement Plan of Trucks and Containers**

Year	1.5 ton	3 ton	5ton	10 ton	20 ton
'20	5	10	15	15	5
'22	5	4	10	0	0
'24	5	1	5	0	0
'26	0	0	5	5	5
'28	0	0	5	0	0
'30	0	0	4	0	5
'32	0	0	4	5	0
'34	0	0	3	0	0
'36	0	0	3	0	5
'38	0	0	1	5	5
'40	0	0	0	0	0
total	15	20	50	30	25

Source: Estimated by the Acumen Study Team

#### E. Staffing Plan and Assumed Operation Manner for NCC

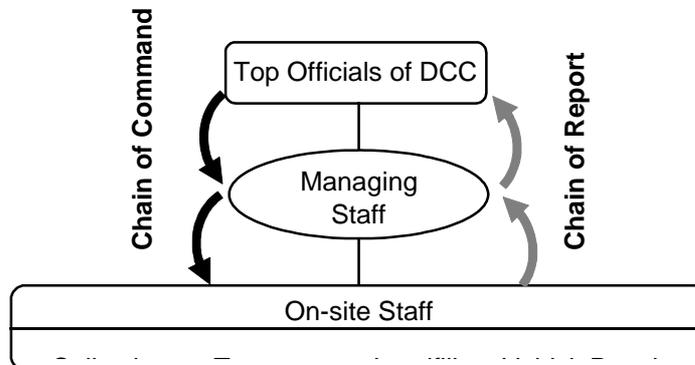
The required number of drivers and cleaners is estimated under the following conditions by type of trucks.

- 1.5-ton Truck: (1 crew consists of 1 driver + 2 cleaners) 4-shift a day
- 3-ton Truck: (1 crew consists of 1 driver + 2 cleaners) 2-shift a day
- 5-ton Truck: 1 crew consists of 1 driver + 2 cleaners (truck and special cleaners)
- 10-ton Truck: 1 crew consists of 1 driver + 4 cleaners (truck and special cleaners)
- 15-ton Truck: 1 crew consists of 1 driver + 5 cleaners (truck and special cleaners)
- 20-ton Truck: 1 crew consists of 1 driver + 5 cleaners (truck and special cleaners)

Two-shift aims at ensuring 4 trips a day to dump site because present achievement of container carrier is 3 trips at most and it needs a special measure to increase the frequency by one more trip. The number of truck cleaners is set minimum 2 persons in a crew and becomes larger number as the size of truck becomes bigger in order to save time for loading waste.

#### F. Formation of Chain of Management in SWM of NCC

The chain of management consists of two actions in opposite directions: the chain of command and the chain of report as show in following figure. With this chain of management, the SWM can be executed effectively and efficiently.



**Figure 7- 19: Structure of Management Chain in SWM**

NCC currently has a well-connected chain of command; however, it does not have the opposite direction, the chain of report.

In line with formation of the chain of report, it is recommended that NCC should determine job descriptions for those sections engaged in solid waste management. The job description should be authorized as the standard for every NCC staff to follow. The standard is the basis for NCC to acquire the following abilities:

- a. To adopt safe and effective manner of cleaning
- b. To evaluate the contribution of individual staff,
- c. To make maximum use of resources,
- d. To solve uneven burden of work among staff

For the standardization of cleaning work, a committee should be established to discuss all the aspects of works by reflecting interests of concerned staff. In principle all the jobs of those sections which handle waste are regarded as the target of the job description. However, it is recommended at first to start determination of job description with the following two groups considering the larger size of budget allocation:

1. Secondary collection/transport job (workers and managing staff)
2. Road/drain cleaning job (workers and managing staff)

### G. Setting up of Operation and Management Plan

The following technical alternatives are to be examined to set up Operation and management plan under the initiatives.

- a. Improvement of waste container,
- b. Phase-out of dustbins and appropriate setup of waste container network,
- c. Development of Geographic Information Systems (GIS) for SWM,
- d. Introduction of mechanized cleaning equipment
- e. Shortening time for vehicle repair

### H. Capacity Development of Cleaners and Drivers

Capacity development of the staff, not only collection and transport staff but also all the staff engaged in SWM services, shall be carried out based on the authorized job description.

### I. Mitigation of Health Risks to Cleaners/Drivers

Measures shall be taken to address the following issues for the sake of protecting the cleaners from health risks:

- a. preventing cleaners from getting injured during daily cleaning work,
- b. preventing cleaners from getting hit by vehicles during daily cleaning work,
- c. raising awareness for sanitation,
- d. supplying the appropriate tools and working clothes & outfits periodically, and
- e. assisting/compensating cleaners suffered from occupational disease.

### J. Coordination with Recycle Industry

NCC should open a channel to recycle industry for having periodical dialogue with them. The topics of major concern with SWM are:

- a. Time sharing between secondary collection and recycle activity
- b. Work sharing in cleaning the place of NCC container/dustbin after recycling
- c. Coordination with compost makers
- d. Provision of information to waste pickers on vocational health.

## 7.4 Final Disposal

NCC is using dumping sites (Alamin Nogar, Jhalkuri etc.) in the manner of open dumping without covering soil. It is crucial that Alamin Nogar and Jhalkuri dump yards are used without Environmental Clearance Certificate (ECC) that is enforced by Environmental Conservation Rule of 1997. Even for Jhalkuri, it will become necessary to obtain the ECC because it will be used as dumpsite.

### 7.4.1 Establishment of Management Organization for Final Disposal

#### i. Temporary Organization

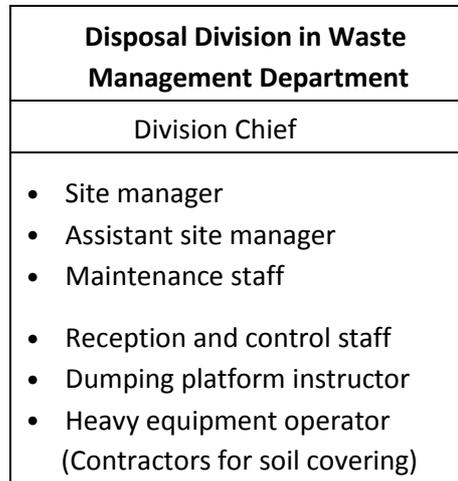
As a temporary management organization, a special task force shall be set up for landfill operation. The staff should be basically recruited from those are now engaged in landfill operation: for example, Conservancy Department and operators of Mechanical Division. The necessary staff is assumed as shown in the following table.

**Table 7- 6: Necessary Manpower of Taskforce at Jhalkuri Landfill Site**

Assignment	Role	Required number
Chief (Site manager)	Site manager (Engineer)	1 person
Assistant staff to manager	Give assistance to site manager (technician)	2 shifts x 1 person
Maintenance staff	Mechanical technician (Temporary)	1 person
Reception and control staff	Measurement of weight and check of waste	2 shifts x 2 persons
Dumping platform instructor	Instruction to trucks	2 platforms x 2 shifts x 2 persons
Heavy equipment operator	Operator	2 shifts x 10 persons
Guard	entrance control	2 shifts x 2 persons

**ii. Permanent Organization**

The task force for Jhalkuri landfill site shall be developed in the permanent organizations for future landfill sites as shown below.



**Figure 7- 20: Future Organization for Management of Final Disposal**

**iii. Capacity Building for Final Disposal**

Capacity building for final disposal shall be executed through actual improvement of Jhalkuri landfill site. Training programs shall be prepared by DCC in collaboration with the international agency that has suitable experience in the said field.

**7.5 Legal Aspects**

Proper Disposal and Compliance with Environmental Conservation Act/ Rules and Preservation Act

**a) Responsibility of NCC for Proper Disposal**

Responsibility of NCC for proper disposal of domestic waste as well as street/drain waste should be clearly stipulated in the Ordinance and (Municipal) Solid Waste (Management) Handling Rules.

As is currently done, for the determination of the proper locations of containers, discussion with Commissioners and/or Ward SWM Committees is inevitable. Since containers may cause some nuisance to the residents nearby, close discussion with residents and primary collection service providers are required. Before discussion with Commissioners or Ward SWM Committees, NCC has to prepare standards for the allocation of containers among wards. A number of containers per

Population and Longest Distance to Containers from a Building will be the indicators for the standards.

**b) Responsibility to Remove and Dispose of Business Waste**

The NCC Ordinance of 1983 does not make any difference in responsibility allocation by type of waste generators. It is recommended that NCC should transfer the responsibility to business entities in the long term because NCC will have to cope with the huge volume of waste in the future.

**c) Environmental Management Plan**

NCC should immediately start preparation of Environmental Management Plan (EMP) according to the Rules and Guidelines for Environment Impact Assessment under Environmental Conservation Rules of 1997.

**d) Compliance with Preservation Act**

It would be better for NCC to ask RAJUK for judgement/recommendation on the compliance after design of civil works is fixed.

**e) Establishment and Implementation of Procedure for Punishment against Illegal Throwing and Dumping**

Prevention of throwing garbage may require three measures;

- i) community activities, including door-to-door collection,
- ii) environmental education, and
- iii) enforcement.

The legal task group proposes establishment of a by-law regarding the punishing procedure and “administrative charge”.

## f) Legal Training to NCC Staff

The following program is recommendable.

**Table 7- 7: Legal Training Program**

Target Trainee	Topic	Duration
Top Managers (Members of Waste Management Committee)  (around ten persons)	<ul style="list-style-type: none"> <li>* Basic Concept on Environmental Conservation Act (1995), Rules (1997) and Guidelines for Environmental Impact Assessment</li> <li>* Basic Concept on Preservation Act (2000) and Required Procedure for the Compliance</li> <li>* Basic Concept on Relevant Part of the Ordinance</li> <li>* Basic Concept on (Draft) (Municipal) Solid Waste (Management) Handling Rules</li> <li>* Discussion and Determination on What to do to Comply with the Laws/Regulations</li> <li>* Discussion on Responsibility Demarcation on Business Waste and DCC Strategy for Responsibility Re-allocation</li> </ul>	One Day Seminar
Conservancy Officers, Supervising Inspectors and Inspectors, etc.  (Around 120 persons)	<ul style="list-style-type: none"> <li>* Basic Concept on Relevant Part of the Ordinance, including the Part of Offense and Punishment</li> <li>* Basic Concept on Environmental Conservation Act (1995), Rules (1997) and Preservation Act (2000)</li> <li>* Required Procedure for the Compliance of the Ordinance</li> <li>* Planning for Implementation of the Procedure for Relevant Areas and Presentation of the Result</li> </ul>	One Day Seminar and  One Day Workshop
Junior Engineers and Officers in charge of SWM  (around 50 persons, two circles, around 25 persons)	<ul style="list-style-type: none"> <li>* Basic Concept on Environmental Conservation Act (1995), Rules (1997) and Guidelines for Environmental Impact Assessment</li> <li>* Basic Concept on Relevant Part of the Ordinance</li> <li>* Basic Concept on Preservation Act (2000) and Required Procedure for the Compliance</li> <li>* How to Prepare Environmental Management Plan</li> <li>* Required Procedure for the Compliance of the Ordinance</li> </ul>	One Day Seminar and  One Day Workshop

## 7.6 Organization

### Strengthening Planning/Coordinating/Monitoring/Evaluation Capability

Since the functions for implementation of SWM components are scattered in several departments in NCC, consolidated planning and monitoring/evaluation will be adopted. In addition, the

procedure should be in accordance with the budget compilation procedure. NCC objectives in the master plan have to be broken down into department-wise objectives and then into objectives of divisions/zones. Division/zone-wise objectives will further be broken down into smaller units if necessary. Lower level organs will at first prepare the concrete operation plans. The upper-level organs have to check the consistency among different operation plans of the lowers within the authority. Inter-departmental operation is to be negotiated at the competent higher level of respective departments.

### Improvement of Field Organizations

**a) The shift of Collection and Transport Functions to Zone Office:** Vacant posts of Conservancy Inspectors and Conservancy Supervising Inspectors in zonal offices will be fully assigned immediately. Plans for container installation and re-deployment of cleaners will be formulated by the initiative of zone personnel assisted by a staff of the headquarters. It is recommendable to create posts of 'Conservancy Sub-inspectors', one for 20-30 road cleaners. The control of drivers /conservancy trucks as well as refueling will be transferred to Zone Offices where each driver has to report starting/finishing collection of waste in assigned area(route) and getting fuel tickets.

**b) Improvement in Vehicle and Equipment Maintenance:** Waste Management Division will start the preparation of manuals for the inspections as well as procurement plans for a periodical change of spare parts. After the preparation of the inspection manual, a few mechanics, as well as helpers, will have to move to the conservancy pool from the workshop. For accelerating the approval process of outsourcing, the following measures are recommendable:

- Past records on repair works should be analyzed at first.
- The mechanical workshops should prepare a conservative annual
- Procurement plan based on the analysis.
- Repair service can be outsourced with short-cut procedure within the limit of
- The approved plan and budget
- After a few years, the possibility for packaged contracts for maintenance and
- Repair service of a group of the same type of vehicle should be discussed.
- The frequency of bid for contracting should be increased to once a month.

### Plan of Organization Reform

**a) Phased Development of the Future Organization:** To enhance NCC's capability for integrated SWM, scattered functions will be combined into one department. The following phased development is recommended.

**Phase I:**

- To change the name of the Department
- To organize Administrative, Planning and Community Solid Waste Management Divisions
- To enhance zone office for cleaning and collection

**Phase II:**

- To merge Conservancy Pool and to organize Zone Management Support Division, Zone Waste Management Division.
- To enhance maintenance functions

**Phase III:**

- To organize Disposal Division.

**Phase IV:**

- To include functions of vehicle/heavy equipment purchase and repair (to organize Mechanical Sections in Zone Management Support and Disposal Divisions)

**b) Change in Composition of Waste Management Committee:** The Waste Management Committee (WMC) will take its functions as a deliberative organization. Accordingly, the composition of WMC is to be varied as the circumstances require. The possible range of members is representative from academic institutes, Ward Commissioners/Ward SWM Committees, RAJUK, business associations, residents near disposal sites, and NGOs.

**c) Transition to the New Department and Divisions:** NCC will execute the organizational transition by using existing human resources to the maximum extent and by enhancing the capacity of existing staff in the fields which are new to them.

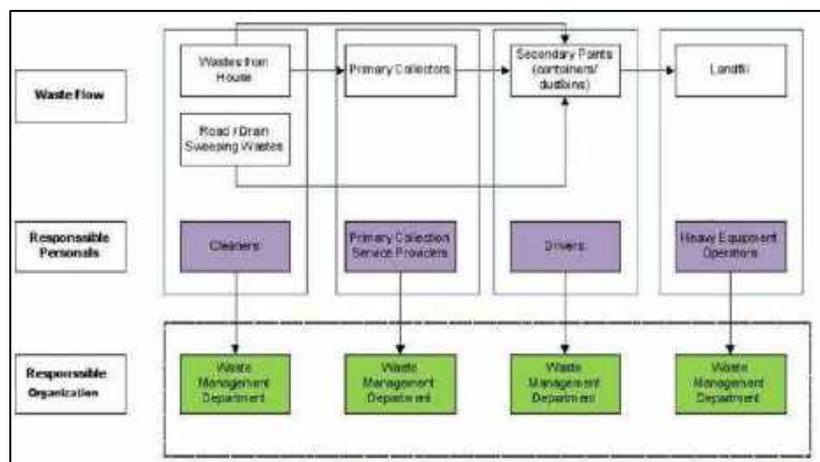


Figure 7- 21: Waste Management Responsibility

Master Plan of Solid Waste Collection and Disposal Management of Narayanganj City Corporation

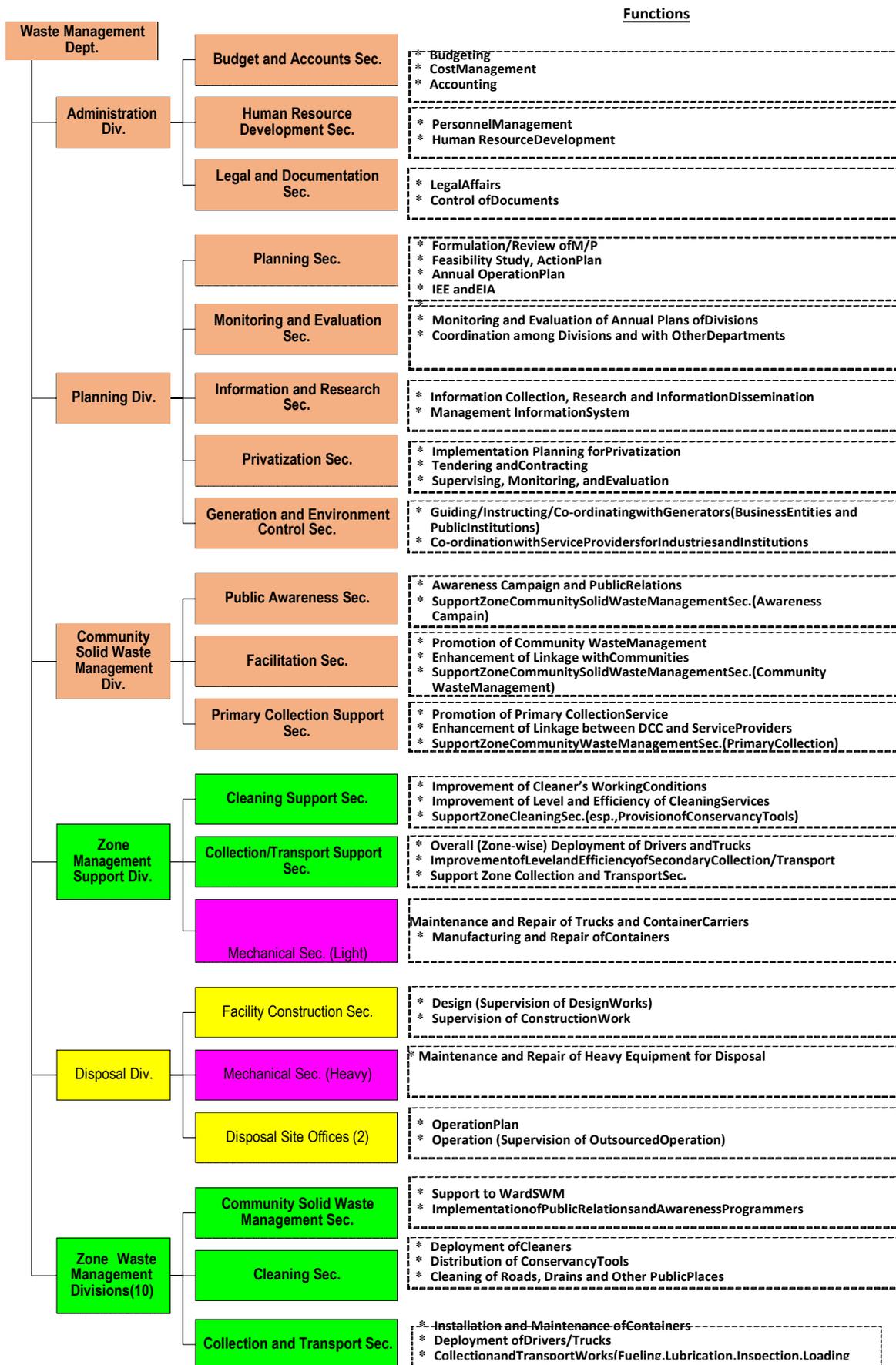


Figure 7- 22: Proposed Future Organization Structure of Waste Management

## 7.7 Financial Management

### Simplified Accounting System for Actual SWM Cost (Standardized SWM Cost)

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

**Table 7- 8: Cost Component of Standardized SWM Cost**

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

Note: Marked \* means respective cost component.

### Financial Planning for Master Plan

**a) Financial Consequence of Overall SWM Cost:** Primarily, overall SWM Cost must be covered entirely by NCC’s own SWM revenues. However, the financial situation of SWM is characterized by a negative balance to a considerable amount every year.

**b) Sources of Funds for Development and Procurement Cost:** Development and Procurement Cost should be also primarily covered by NCC's own SWM revenues and then, if difficult, other sources can be taken into account as alternatives.

## 7.8 Privatization

During the continuation of the outsourcing pilot project, the following items are to be examined. Based on the results of the evaluation of the pilot project, the privatization projects have to be improved and expanded.

- Period of Contracts
- Scope of Contract
- Area of Outsourcing
- Survey on Capability of the Private Sector
- Performance Monitoring/Evaluation

## 7.9 Assessment of Potential System Alternatives

Waste is an unavoidable by-product of human activities. Economic development, urbanization, and improving living standards in cities, have led to an increase in the quantity and complexity of generated waste. The rapid growth of population and industrialization degrades the urban environment and places serious stress on natural resources, which undermines equitable and sustainable development. Inefficient management and disposal of solid waste is an obvious cause of degradation of the environment in most cities of the developing world. Municipal corporations of the developing countries are not able to handle increasing quantities of waste, which results in uncollected waste on roads and in other public places. There is a need to work towards a sustainable waste management system, which requires environmental, institutional, financial, economic, and social sustainability.

### 7.9.1 Alternatives

This section presents a quantitative comparison of the environmental, economic, and social impacts of the current waste disposal program being practiced worldwide and of three waste management alternatives:

- (i) expansion of the organics collection program with biogas recovery,
- (ii) expansion of the recycling program, and
- (iii) incineration with energy recovery for the Jhalkuri Landfill Site.

This project explores alternative approaches to municipal solid waste (MSW) management and estimates the cost of waste management in NCC. Two alternatives considered in this project are community participation and public-private partnership in waste management.

### 7.9.2 Assessment of Alternatives

Environmental impacts were evaluated by performing a life cycle analysis using the US EPA's Waste Reduction Model. Economic impacts were quantified using cost-benefit analysis; social impacts were evaluated using a previously developed scoring scheme. Finally, the overall impacts were ranked and analyzed using Saaty's Analytical Hierarchy Process (AHP) to determine an optimal alternative to landfill disposal. Results indicate that incineration with energy recovery is ranked the highest overall in all three evaluation criteria categories. Incineration results in the greatest gas reductions (86%) and the lowest cost to implement. Incineration also ranks the highest in the social impacts ranking due to reductions in foul odors, the potential for attracting disease vectors, and land requirements. Expanding the recycling collection improves greenhouse gas emissions by 41% of the current method; it also reduces disposal costs. Overall, all three alternatives are better than the current waste disposal method, and incineration is deemed the optimal waste management option for NCC.

### 7.9.3 Alternatives Selected for Detailed Analysis

Overall, all three alternatives are better than the current waste disposal method, and waste to energy is deemed the optimal waste management option for NCC. Bangladesh Power Development Board (BPDB) has already signed a memorandum of understanding (MoU) with Narayanganj City Corporation (NCC). The PDB will implement the 3MW-5MW waste-based IPP power project at Jhalkuri in Narayanganj.

The following suggestions were obtained from a focused group discussion on Solid waste management issues, with stakeholder and elite groups.

**Table 7- 9:Existing SWM facilities in NCC**

Outcome of discussions	Suggestions
<ul style="list-style-type: none"> <li>▪ There are no systematic waste collection and disposal systems in NCC and people through it here and there in the drain which creates water logging due to lack of awareness.</li> <li>▪ There are no dust bins or STSs in the residential area and fixed place for Garbage disposal. Major garbage is collected from market places by four nos. of sweepers.</li> <li>▪ Garbage is deposited near Canals</li> </ul>	<ul style="list-style-type: none"> <li>▪ Construction of dustbins in residential areas.</li> <li>▪ A fixed place for dumping garbage (landfill)</li> <li>▪ More sweepers are needed</li> <li>▪ Willing to pay for better sanitation.</li> <li>▪ NGO may be involved for awareness-raising</li> <li>▪ Recruitment of more staff for the conservancy section and more training for skill.</li> </ul>

After rigorous field visits, household surveys, consultations with the stakeholders, we finalize our plan to adopt for the waste management of NCC. An adopted plan will be presented and discussed among the city officials of NCC too. Eventually, the final adopted plan consists of the following stages.

**Table 7- 10: Tasks/Activities of the SWM**

Steps	Tasks/Activities	Mechanisms	Performers
1	<ul style="list-style-type: none"> <li>▪ Door-to-door waste collection</li> </ul>	<ul style="list-style-type: none"> <li>▪ Formation of area-based private organizations</li> <li>▪ City Corporation office with the consultation with the stakeholders assign the necessary number of wastes collecting organization for a fixed area</li> <li>▪ Household or the sources of waste will be collected by one Van</li> <li>▪ A private organization that collects the waste will charge an amount to the household/sources for this service in consultation with the Citi Corporation office</li> </ul>	<ul style="list-style-type: none"> <li>▪ Ward Councilor</li> <li>▪ Local Government</li> <li>▪ Local organizations</li> <li>▪ Bazar committees</li> <li>▪ Market Committees</li> <li>▪ Area-based Building Owners associations</li> </ul>

Steps	Tasks/Activities	Mechanisms	Performers
2	<ul style="list-style-type: none"> <li>Transport the collected waste to the nearby secondary transfer stations</li> </ul>	<ul style="list-style-type: none"> <li>The collected waste will be carried by the “waste-collecting vans” by the private organization</li> </ul>	<ul style="list-style-type: none"> <li>Private waste-collecting organization</li> <li>Households/ sources of waste</li> </ul>
3	<ul style="list-style-type: none"> <li>Preliminary segregation of the waste in the Secondary transfer stations (STS)</li> <li>Loading the Trucks to transport them to the dumping area</li> </ul>	<ul style="list-style-type: none"> <li>Preliminary sorting and segregation are done by the waste collectors</li> <li>Using the machinery and equipment waste will be loaded in the truck and ready to move</li> </ul>	<ul style="list-style-type: none"> <li>Private waste collectors</li> <li>Truck drivers and helpers</li> <li>City Corporation office</li> </ul>
4	<ul style="list-style-type: none"> <li>Bringing the waste to dumping area/ shed or the waste yard</li> <li>Segregation of waste before selecting waste for final destinations; recycling/ composting/ waste to energy/ sanitary landfills</li> </ul>	<ul style="list-style-type: none"> <li>Segregation of waste according to the character of the waste</li> <li>Sending them to the appropriate places for the next action</li> </ul>	<ul style="list-style-type: none"> <li>Workers of waste segregation</li> <li>People of Composting plant units</li> <li>People of waste to energy units</li> <li>People of the recycling unit</li> <li>Residue to the sanitary landfills by the above-mentioned units</li> </ul>
5	<ul style="list-style-type: none"> <li>Monitoring of environmental and social threats from the dumping area</li> </ul>	<ul style="list-style-type: none"> <li>Regular monitoring the activities and finding the problems of the activities or performances as designed</li> </ul>	<ul style="list-style-type: none"> <li>City Corporation assigned technical people</li> </ul>

## 7.10 Future Landfill Site Selection Criteria

### 7.10.1 Location

- Near center of collection area

- Convenient to good haul routes
- An area zoned industrial or commercial
- Minimum public objections
- Costs of land and construction
- Avoid flood plains, historical/archeological sites, wildlife habitats
- Closed landfills or incinerators are good sites

### 7.10.2 Economics

Compare direct haul and transfer costs

### 7.10.3 Considerations

- Cost of disposal
- Fixed transfer station costs - cost to build, own, operate, and maintain
- Transport cost - cost/ton/min of transport time

Plot cost/ton vs. difference between round trip to transfer station and disposal site.

## 7.11 Mechanical Equipment for waste sorting

### Vertical waste transfer station:

- ✓ Vertical waste transfer station is composed of vertical garbage compactor and waste transfer vehicle. It's utilized for the collection, compaction, and enclosed transfer for domestic wastes and solid wastes in municipal residences, factories and mines, and institutions and universities.
- ✓ The vertical garbage compactor adopts the vertical compacting technology to compact, dehydrate, and reduce volume of loose wastes into blocks and then transfer into the waste transfer vehicle. This equipment can forcibly compact the loose wastes for dehydration and volume reduction into blocks and transfer them to the waste transfer vehicle for transport.
- ✓ Characteristics: High waste compacting ratio and clean dehydration, without sewage leakage or secondary pollution during transport.
- ✓ With small occupation area, it's especially suitable for the construction of small stations and the reconstruction of old stations.
- ✓ Civil construction requirements of equipment:
- ✓ Internal height at >7m for building

- ✓ Internal height at >6.5m for building
- ✓ Width at >4m and free height at >5m for doors of building.
- ✓ If a highway is available on the front the waste station, the highway can be used to hoist the equipment. The land acquisition requirement is shown in above diagram.
- ✓ If there is no highway (through highway) on the front of the waste station, a front ground in size of at least 15m x 15m is required on the front of the waste station.

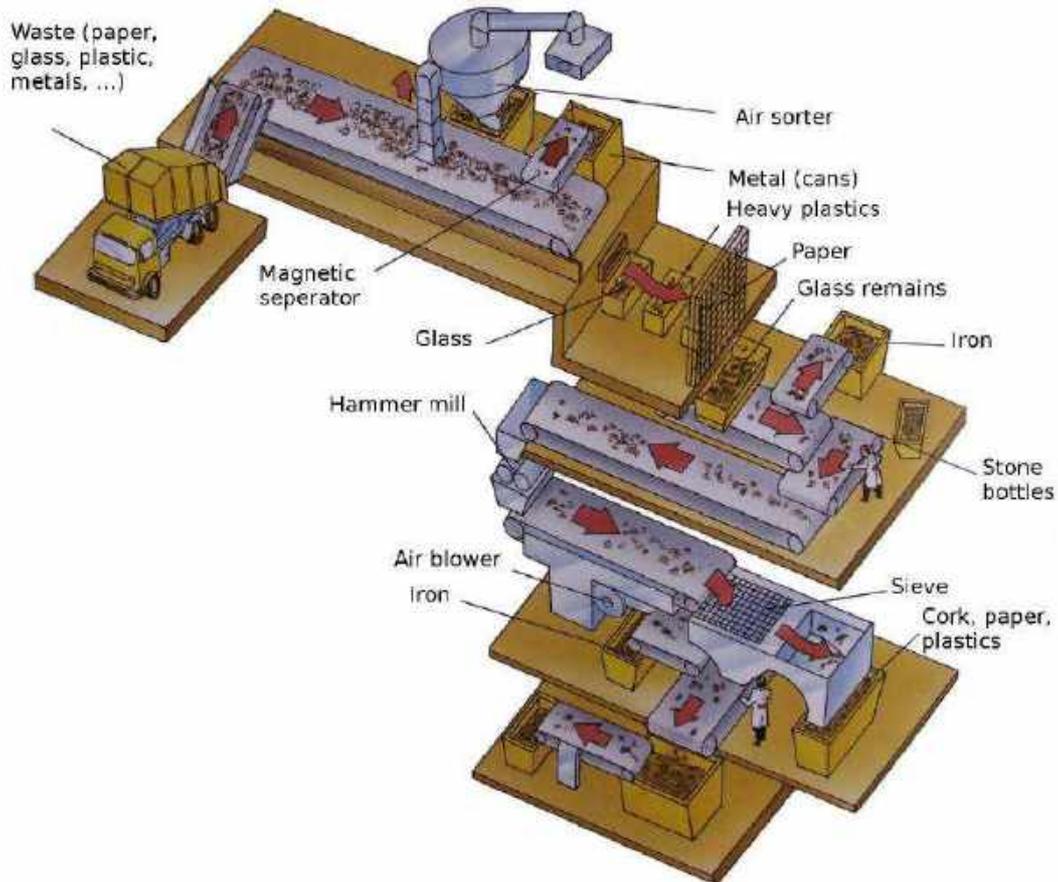


Figure 7- 23: Waste sorting procedure



Figure 7- 24: Waste Sorting Procedure (Source: Unanimous Online)



Figure 7- 25: Picture of Hydraulic Lifter (Source: Rajput Plant, India)

## 7.12 Compost Plant and Composting

### Compost:

Compost is the stable end product derived from the biological degradation of organic material, which can vary from dead leaves and roots to kitchen waste and vegetable remains. Finished compost looks like soil– dark brown, crumbly and smells like a forest floor.

Positive effects of compost are shown below:

- ✓ Enlarge the air spaces in the soil, improving its permeability for air and water circulation
- ✓ Enhances and improves the soil texture
- ✓ Lowers the degree of pH
- ✓ Helps to retain moisture
- ✓ Adds nutrients and trace materials to the soil, stimulating biological activity and encouraging vigorous plant rooting systems
- ✓ Helps to bind nutrients, preventing them from being leached out of the soil

- ✓ Reduces soil erosion
- ✓ Reduces emission of methane (a greenhouse gas)

**Basics of Composting:**

Naturally, the slow decomposition of organic matter by different microorganisms and invertebrates produces a black-brown earthy material called humus – a valuable component of good soils. Composting runs along the same lines, but is accelerated by optimized and controlled process parameters like input material, temperature, moisture, and pH. This distinguishes composting from natural decomposition. The quality of the input materials and certain biological and physical parameters has a major influence on the quality of the compost and on the occurrence of operational problems with the composting facility. A properly constructed compost pile can be compared to an interactive biological and ecological system. It contains various microorganisms dependent on the nutritional and environmental condition of the pile. It is important for composters to understand the physical, chemical and biological processes involved in the decomposition of biodegradable organic material. Any well-managed compost heap contains water and air in the pore spaces between the solid particles, as shown in Plate 7.26.



**Figure 7- 26:** Compost contains solid, liquid and gaseous phases – all play an important role during composting(IRRC, 2012)

The solid material is the biodegradable waste, the moisture inside and outside of the waste is the liquid part and the air in the gaps between the solid particles is the gaseous phase. All three constituents play a key role in the composting process, as the main activity of microorganisms can be observed at the interfaces of these three phases. Microorganisms can only make use of dissolved nutrients found in the liquid phase. However, they require oxygen for their metabolism, which they draw from the air in the gaps (IRRC, 2012).

### **Aerobic Composting**

Aerobic composting is the aerobic, or oxygen-requiring, decomposition of organic materials by microorganisms under controlled conditions. During composting, the microorganisms consume oxygen (O<sub>2</sub>) while feeding on organic matter. Active composting generates considerable heat, and large quantities of carbon dioxide (CO<sub>2</sub>) and water vapor are released into the air. The CO<sub>2</sub> and water losses can amount to half the weight of the initial materials, thereby reducing the volume and mass of the final product.

Understanding the fundamentals of composting enables operators to manipulate the process to maximize the rate of decomposition of the organic material and meet other environmental or quality specifications. The means to control composting conditions differ from site to site depending on the type of technology employed, the types of materials being processed, environmental considerations, the desired end product and the preference and experience of the site operator (IRRC, 2012).

### **Aerobic "hot" composting:**

The composting process can be divided into three phases:

1. Degradation phase
2. Transformation phase
3. Synthesis or maturation phase

As natural microorganisms such as bacteria, actinomycetes, fungi, and some protozoa are already present in organic waste, the degradation phase starts directly after piling. These aerobic microorganisms degrade carbohydrates and amino acids present in food and yard waste into simpler compounds, carbon dioxide and water. Under favorable conditions, they multiply exponentially and generate a large amount of heat as a result of oxidative processes. The temperature within the heap rises to over 60°C. If high temperatures are maintained for one week, and all of the material experiences such temperatures (the cooler outer layer being relocated to

the warm interior as a result of the turning process) pathogens and weed seeds are destroyed during this phase. To ensure a favorable environment for aerobic microorganisms, it is important to control the oxygen supply during this phase. After about one month, the process slows down and temperatures drop slightly. Different species of fungi become predominant in the compost pile and develop a white or grey color just under the surface of the compost heap. Fungi are important for the decomposition of proteins and cellulose substances. During this phase, the compost process has to be controlled and adjusted frequently to ensure optimum conditions for the microorganisms.

After about 45-50 days, the temperature drops to 30-40°C and the compost heap enters the transformation phase. The heap becomes populated with various invertebrates, such as mites, millipedes, beetles, earwigs, earthworms, slugs, and snails. As the material is a nutrient source to them, they continue the degradation process and cut down the coarse compost material into a crumbly soil-like substance. Though the material looks like compost, it is not yet stable and chemical substances (e.g. nitrite) may inhibit plant growth if applied directly to the flora.

The compost heap enters the synthesis or maturing phase after approximately ten weeks when the insects abandon the compost. Ongoing chemical processes transform nitrite to nitrate and slowly link the short-chained hemic substances into stable and nutrient-rich humus. Depending on the local conditions (e.g., temperature and input material), the compost is mature after 3-6 months (IRRC, 2012).

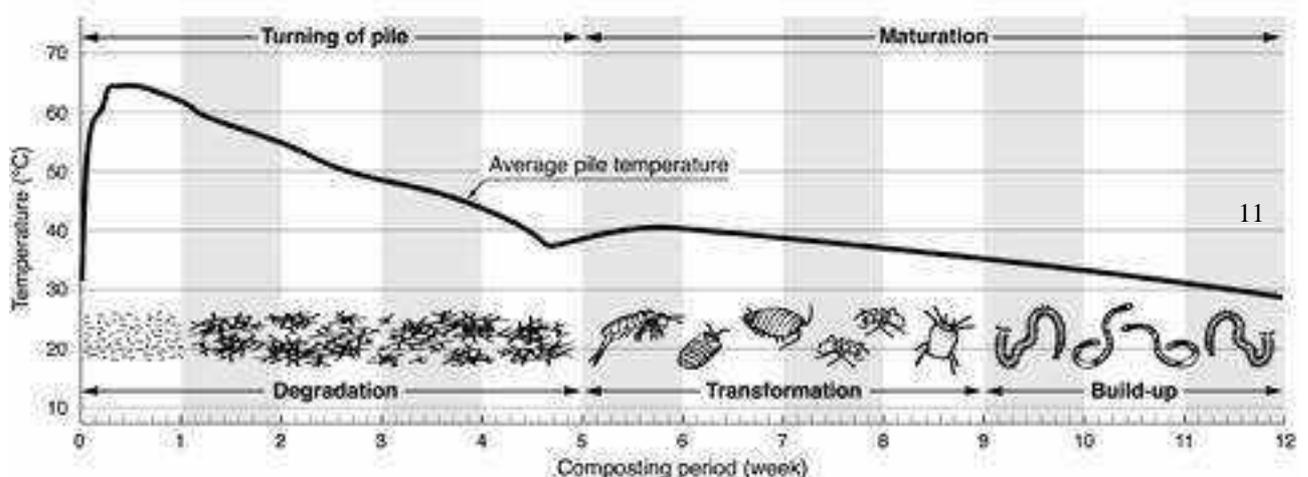


Figure 7- 27: Temperature and processes during composting(IRRC, 2012).

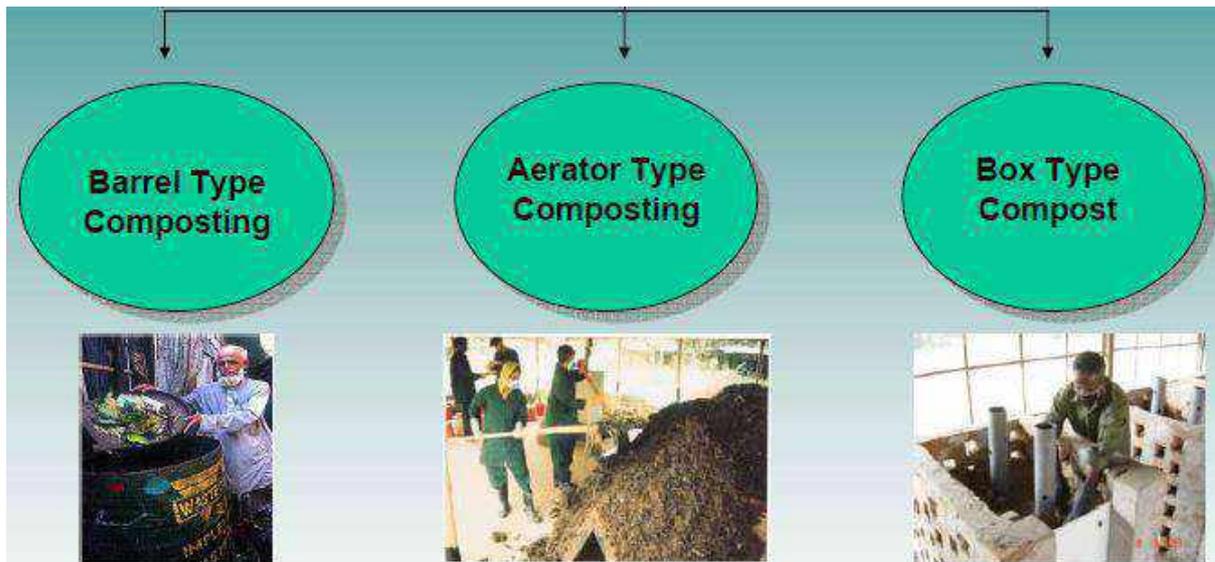


Figure 7- 28: Composting Methods (Waste Concern, 2014).

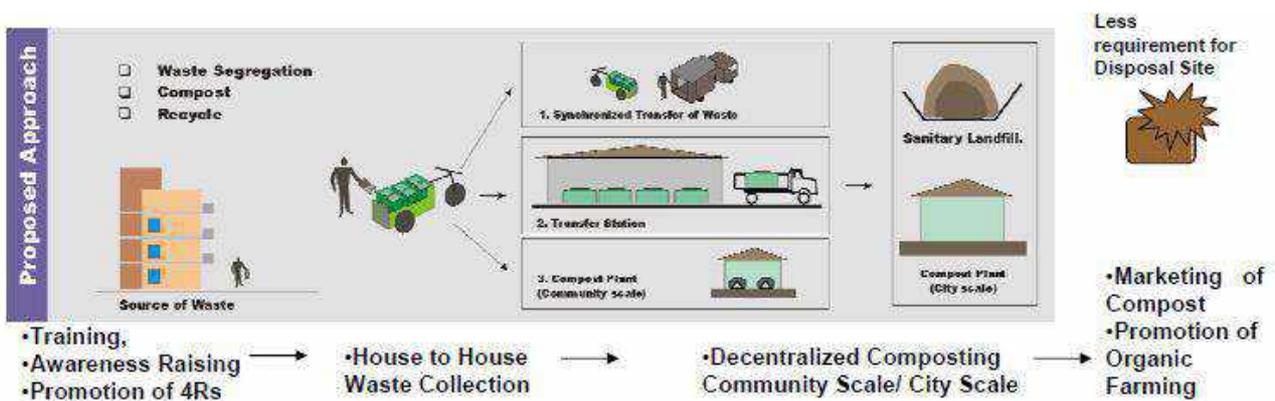


Figure 7- 29: 3R Approach for composting (Waste Concern, 2014).

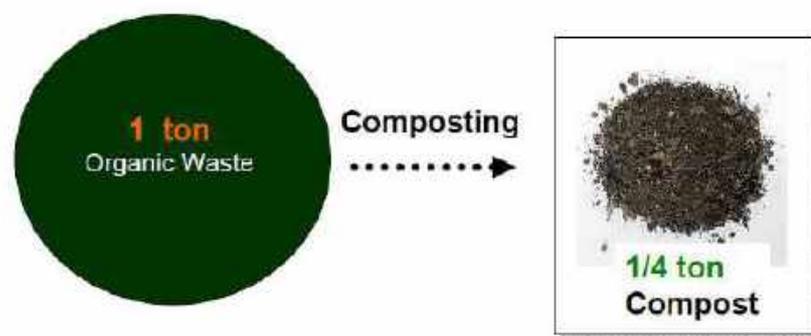


Figure 7- 30: Amount of compost from 1-ton organic solid waste

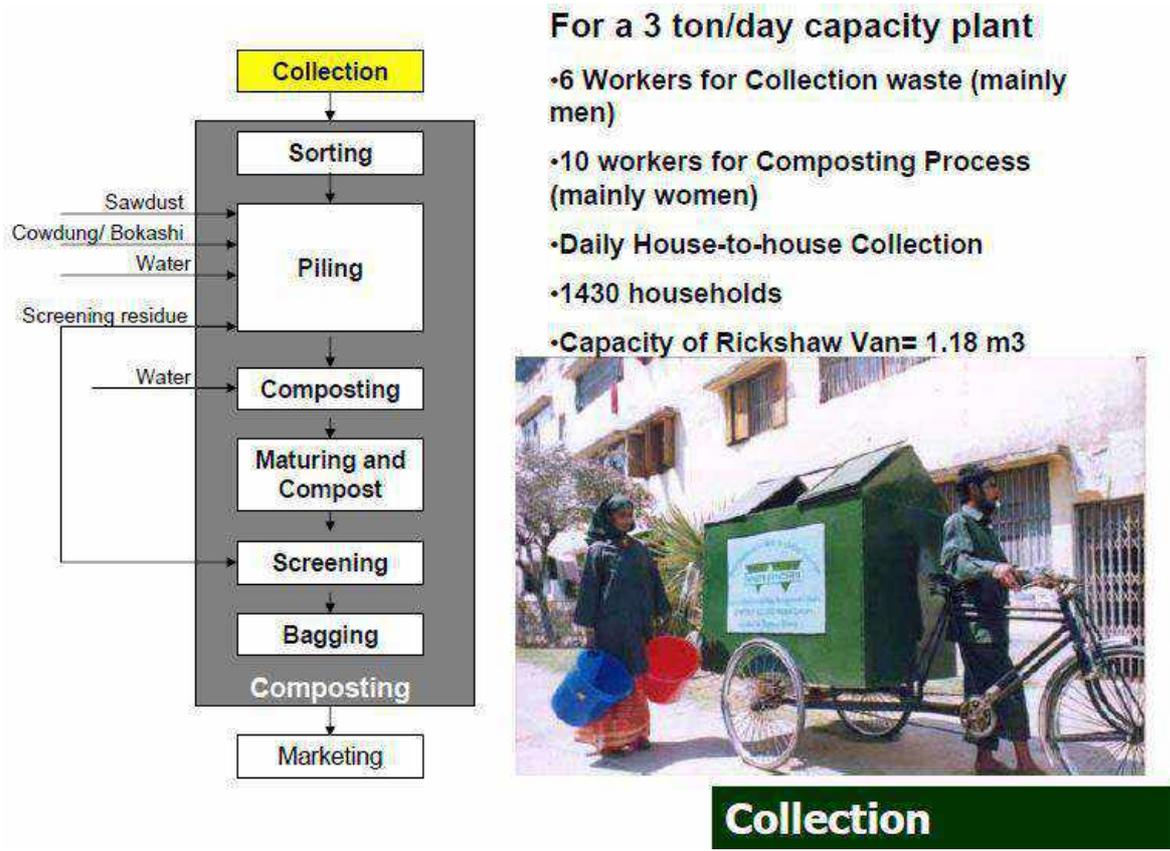


Figure 7- 31: Different Steps of Composting Process-Collection (Waste Concern, 2014)

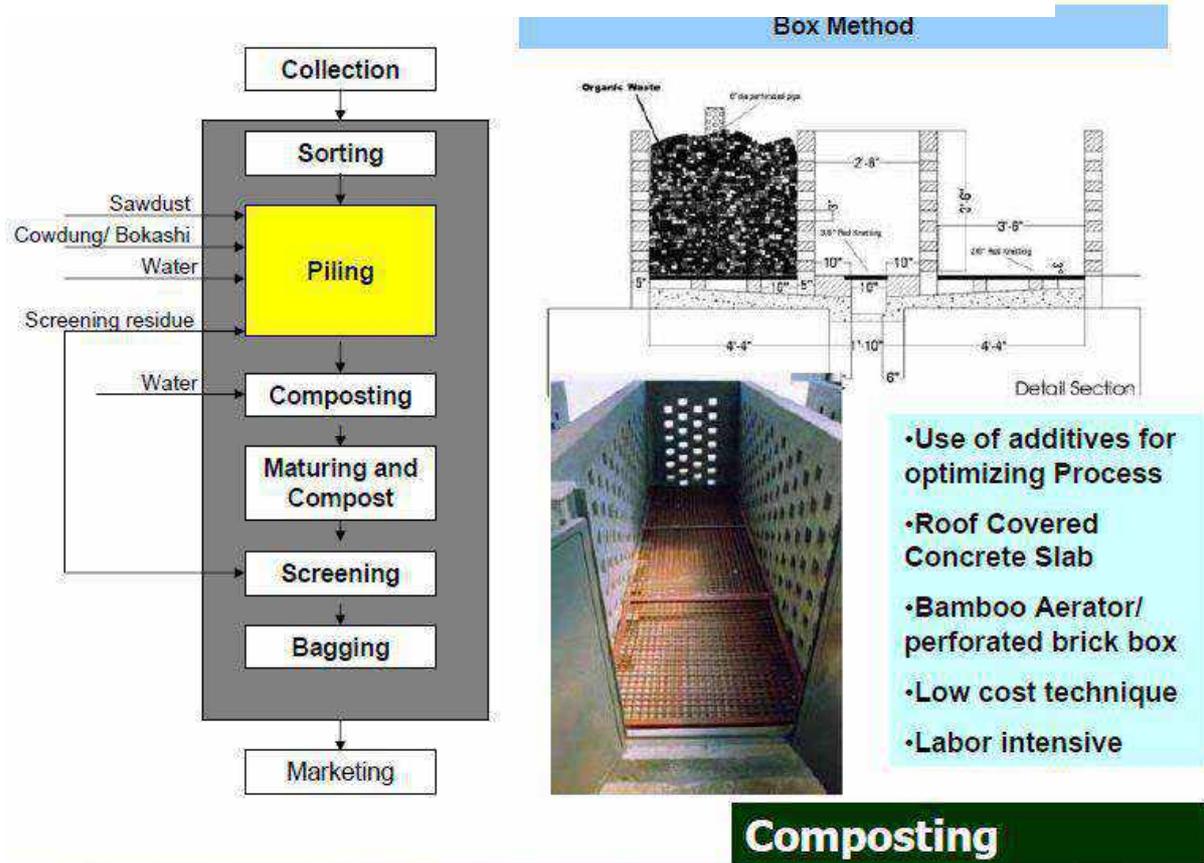


Figure 7- 32: Different Steps of Composting Process-Piling(Waste Concern, 2014)

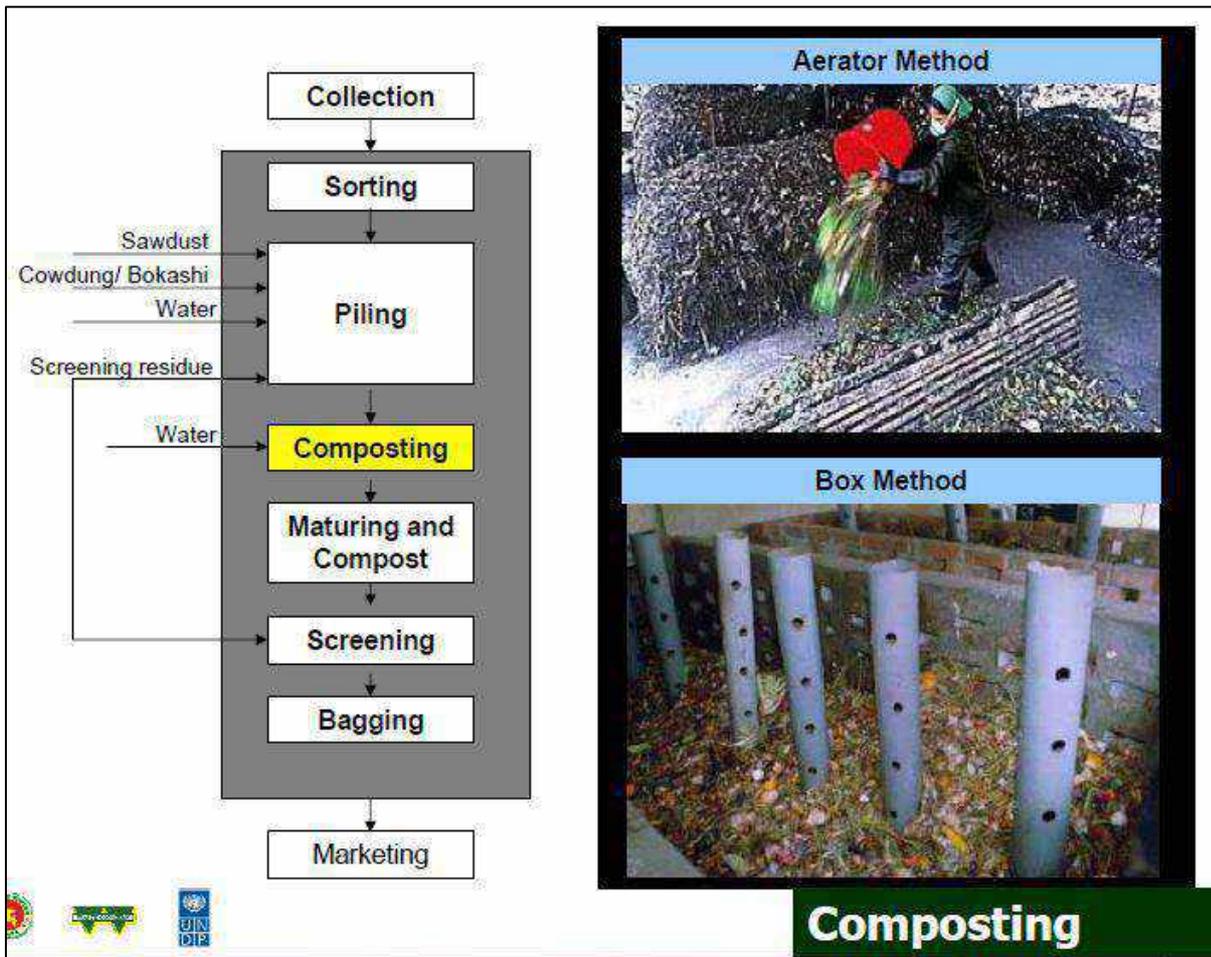


Figure 7- 33: Different Steps of Composting Process-composting(Waste Concern, 2014)

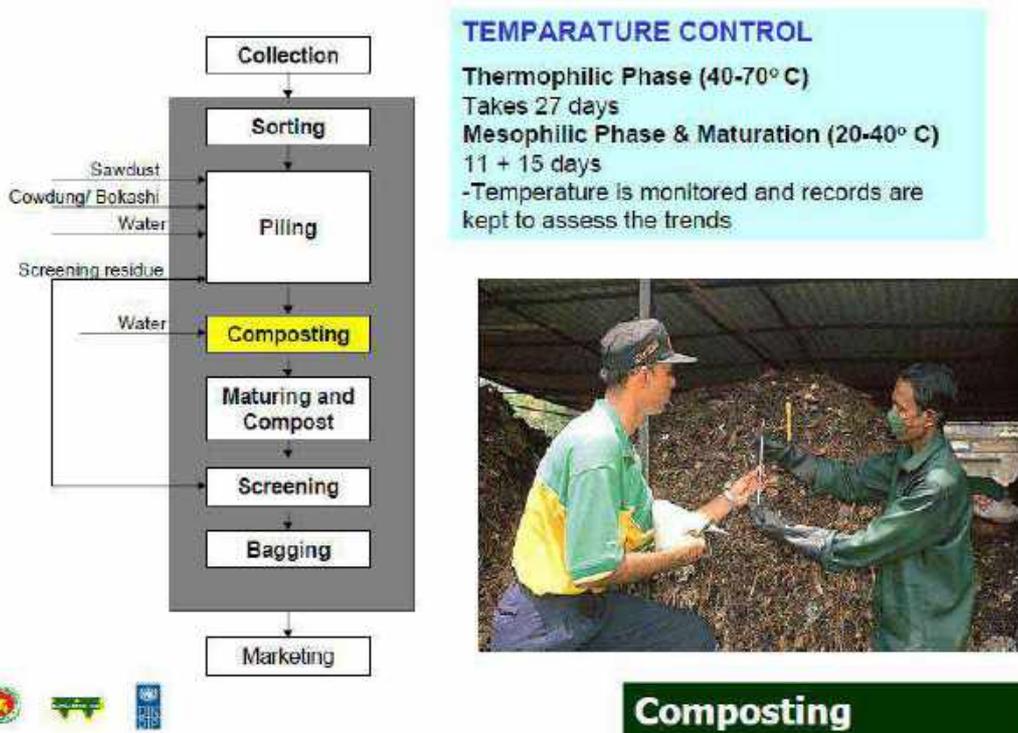


Figure 7- 34: Different Steps of Composting Process-composting(Waste Concern, 2014)

Table 7- 11: Survival time (in days) of Pathogen by Different Treatment Method

Types of Treatment	Bacteria	Virus	Protozoa	Helminths
Night soil, faeces at 20-30 C	90 days	175 days	10 days	Many months
Composting (anaerobic) septic tank/ pit latrine	60 days	60 days	30 days	Many months
Thermophilic Composting 50-60°C	7 days	7 days	7 days	7 days
Waste Stabilization Pond Retention time >20days	20 days	20 days	20 days	20 days

Source: IDA (1990)



**Screening and Bagging**

Figure 7- 35: Screening and Bagging of Compost



Figure 7- 36: Different steps of Composting-Marketing(Waste Concern, 2014)

This section highlights an innovation in compost marketing. It features a photograph of a man and a woman working with a large green wheelbarrow. To the right, another photo shows a person using a small-scale processing machine. Below these, a photograph displays several white bags of compost. A cyan box titled 'Innovation' describes the 'Marketing of nutrient enriched compost ( compost blended with fertilizers)'. To the left, a cyan box lists the activities of a 'FERTILIZER COMPANY': Grinding, Enriching, Screening, Distribution through own retail channels, Directly to Farmers and nurseries, and Own use for demonstration plot. At the bottom, three circular samples of compost are shown: 'Compost (8mm)', 'Compost (4mm)', and 'Enriched & Granular'.

Figure 7- 37: Marketing of compost by private sector

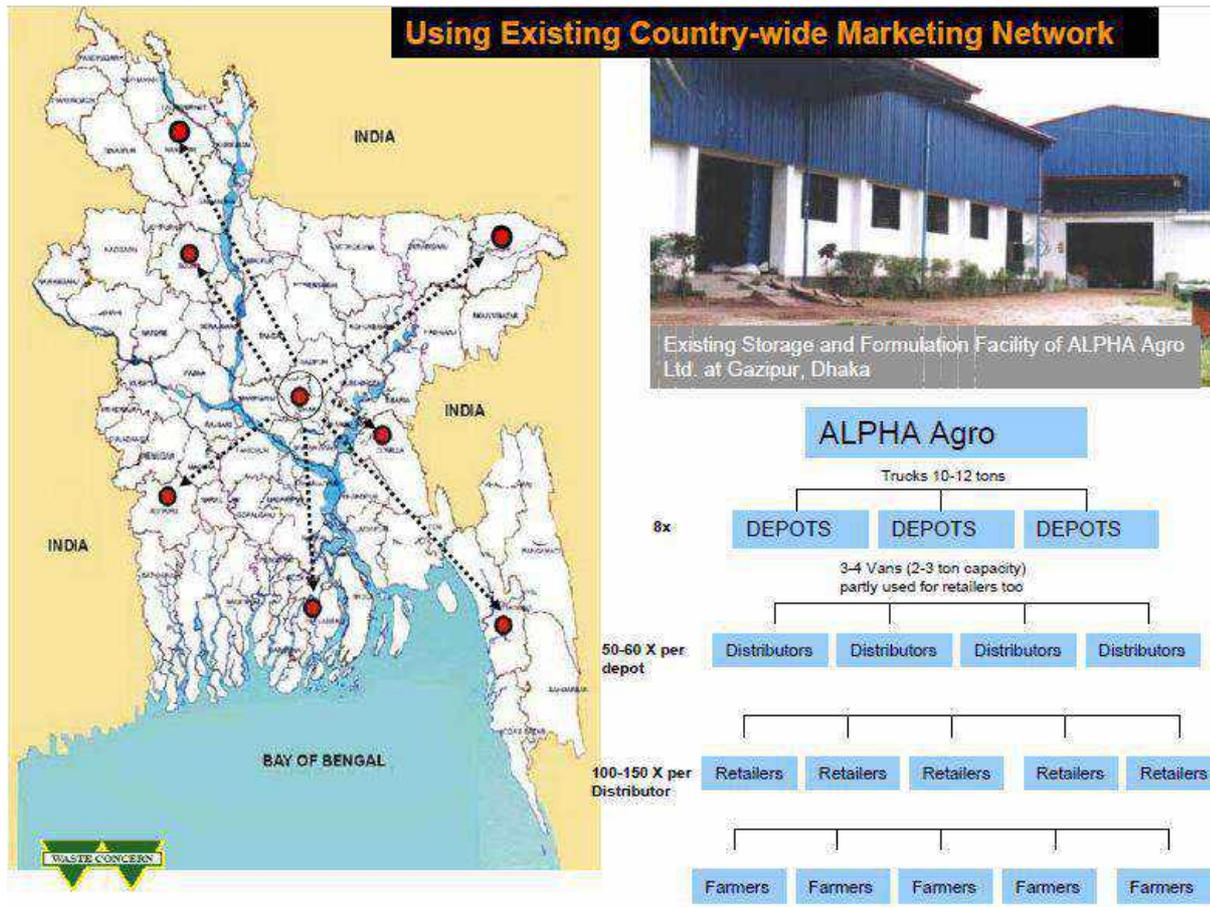


Figure 7- 38: Example of Country wide marketing (Waste Concern, 2014)

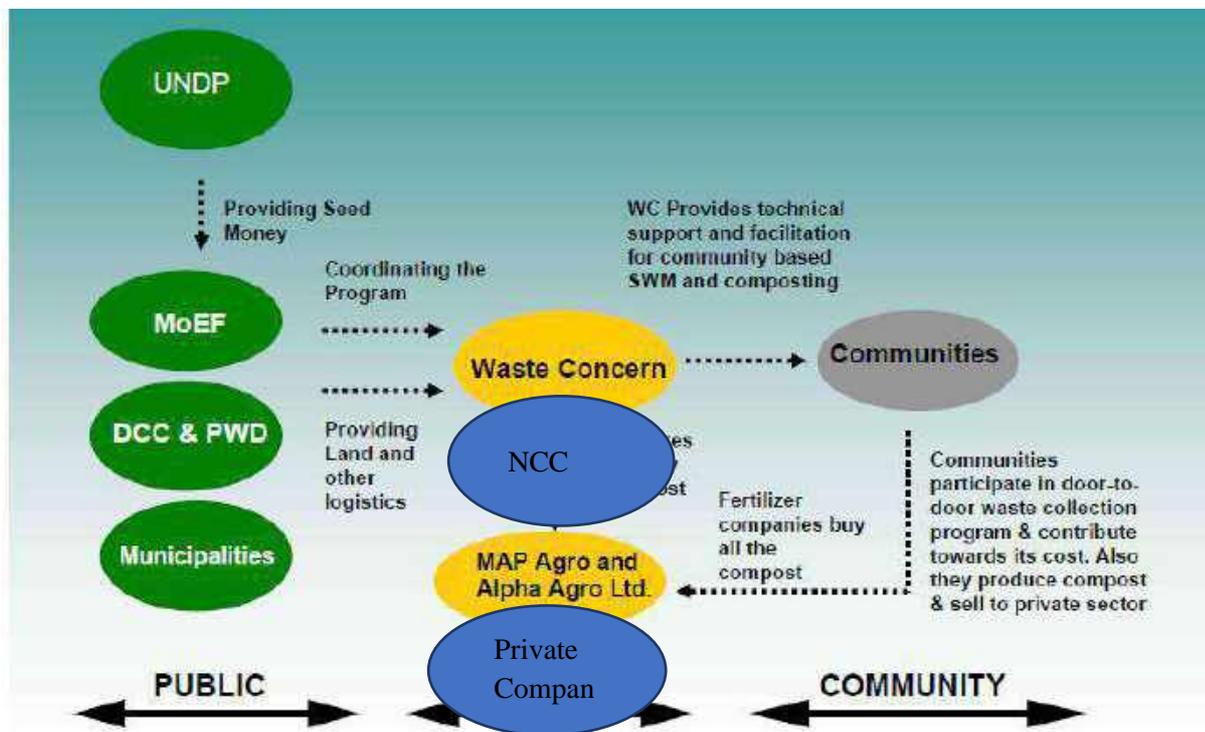


Figure 7- 39:Partnership model based of community

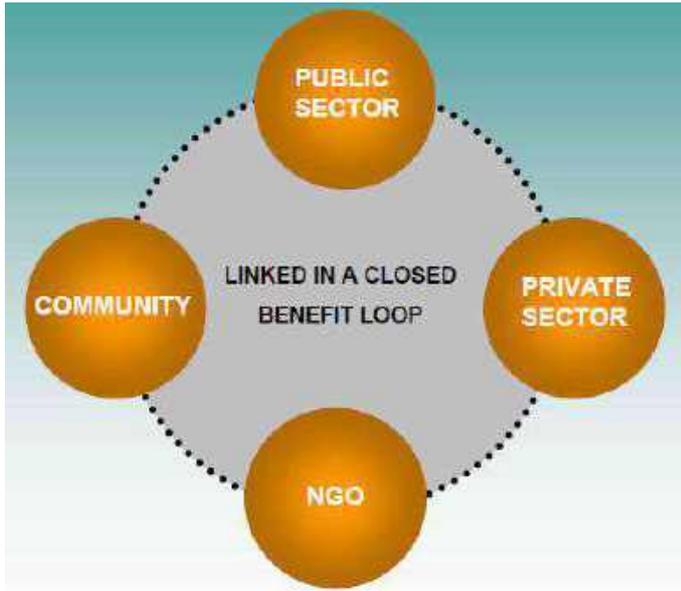


Figure 7- 40: Linked in a closed benefit loop

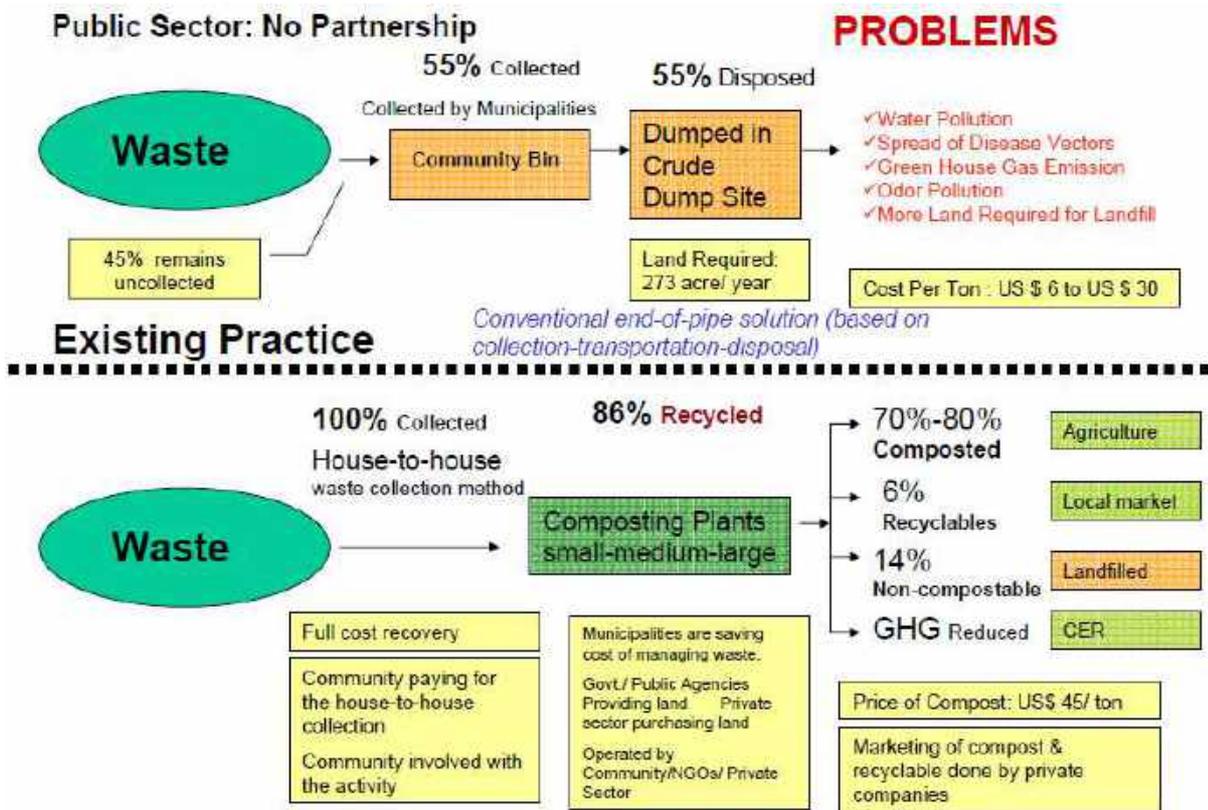


Figure 7.42: Decentralized Approach-Based Model

Figure 7- 41: Cost recovery/sustainability of community-based model

- The project is financially viable
- Fixed cost of 3 ton capacity plant is US \$ 8800
- Operational cost per year is US \$ 10200
- Per year income from the project is US \$ 14,800
- 70% is the income from sale proceeds of compost
- 30% is the income from charges for house-to-house waste collection
- Pay back period of the investment is 23 months

Step by Step Guidelines for Box Type

Composting System:

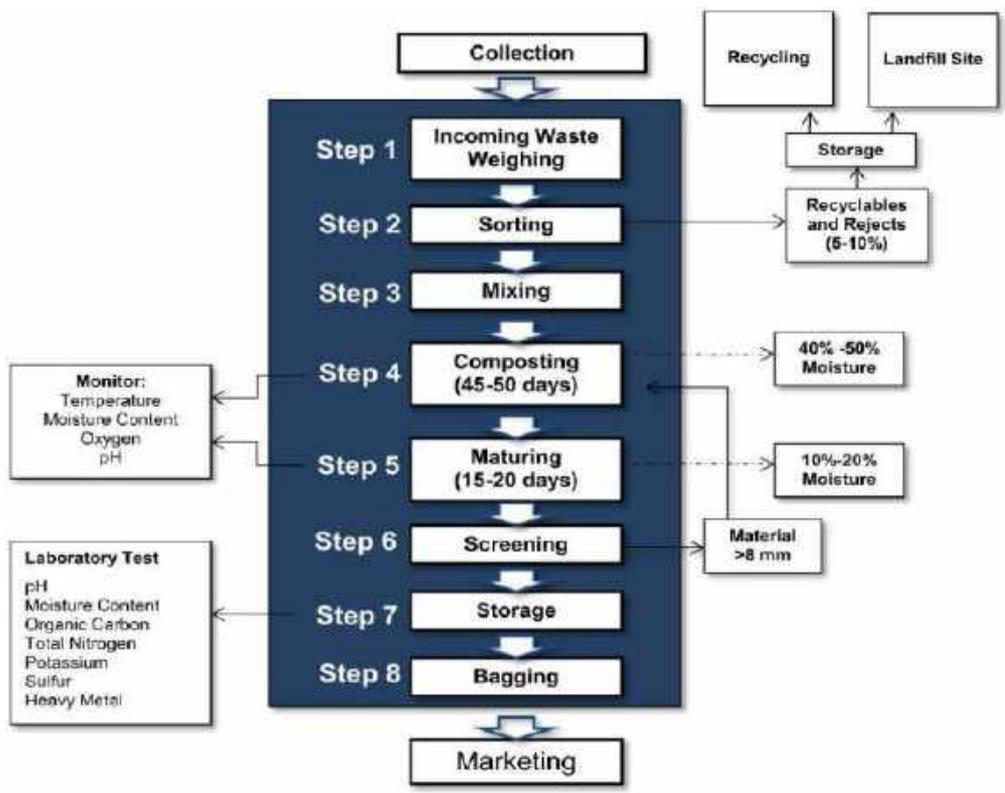


Figure 7- 42: Flow Diagram of Composting Activity(IRRC, 2012)

The three major steps are shown below.

**Stage 1: Collection of waste**

Collection of source-separated fresh organic waste is necessary for the proper composting process. Organic waste is normally collected from communities, markets and other sources of organic waste of a city/town to a compost plant by rickshaw van or trucks.

**Stage 2: Composting of organic waste**

Eight (8) major steps are shown in this stage of the composting process. During this stage, a small portion of rejects are disposed in the landfill site and sorted recyclables (plastic, tin cans, paper, cardboards, iron, glass, etc.) are stored and sold to recycling industries. During this stage, input organic matter loses a significant amount of moisture from the final produce compost. Also, during this stage, temperature, moisture, oxygen and pH need to be monitored for proper composting.

**Stage 3: Marketing**

A proper compost marketing strategy is necessary to market compost products to farmers and crop growers. Compost can be produced based on local quality standards and enriched with necessary nutrients to meet the demand of different types of soil and crops(IRRC, 2012).

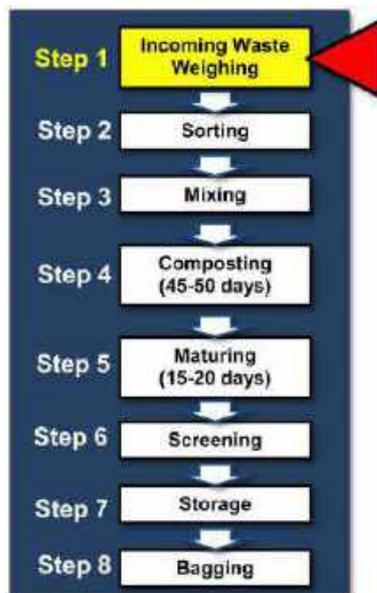


Figure 7- 43: Step incoming waste

### Weighing of Incoming Waste

Source-separated incoming waste after collection from households and markets must be weighed using manual or electronic digital weighing machines. Usually rickshaw vans or trucks loaded with waste enter the gate and unload the waste in the unloading platform of the compost plant. Depending on the size of the plant weigh bridge, capacity can be from 250-500 kg. During this step, incoming waste can be weighed using 50-100-liter buckets or baskets. Plant operators should note the numbers of the license plates and register them as incoming weight. It should be noted that keeping a record of incoming waste in a compost plant is required in order to claim in carbon trading as well as important in running the business. The important requirements are that both waste delivery and residual collection is regular and that waste is delivered in a fresh condition.

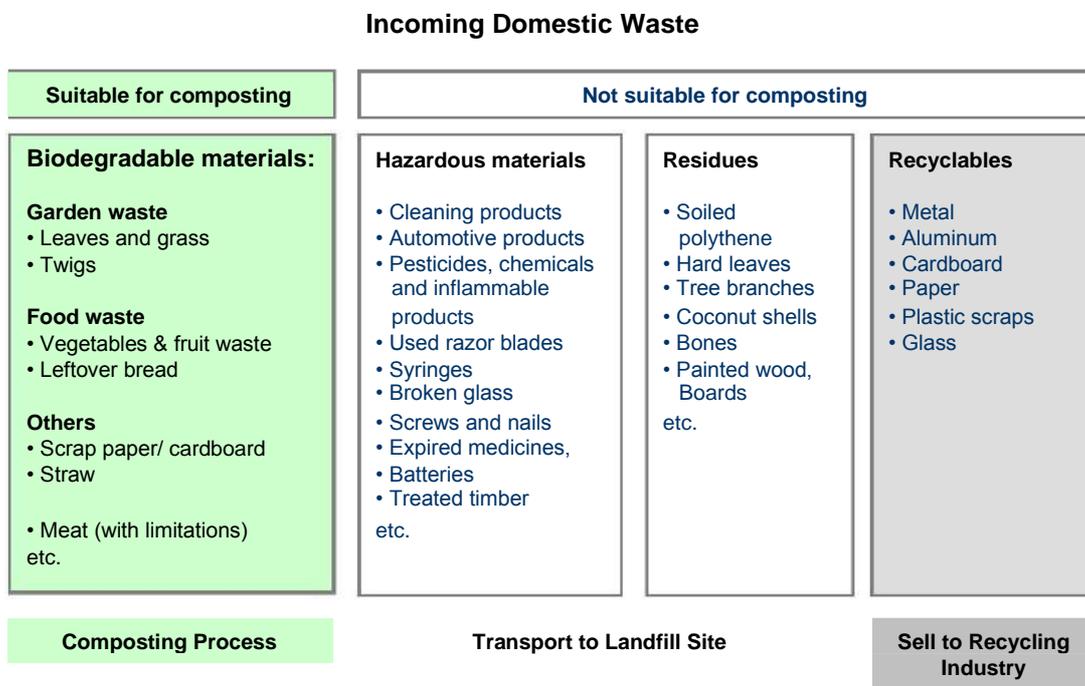


Figure 7- 44:Waste delivered by truck; Digital meter used in the digital weighing bridge and Weighing bridge platform (all pictures from compost plant at Katchpur, Dhaka).



Figure 7- 45: Step 2, Sorting

Compost quality is mainly determined by the quality of the input material. Hence, the sorting of the waste plays a vital role. Substances which are not biodegradable need to be separated from the biodegradable fraction. Sorting is especially crucial with regard to hazardous materials. These must be removed before they are loaded in the compost box, or they will contaminate the entire pile and severely compromise the final compost quality. Figure 7.47 shows the classification of typical domestic waste and gives guidance regarding which materials are suitable for composting. If households are willing to segregate their waste at source, it saves a tremendous amount of time and costs for the composting scheme. Moreover, it increases the quality of both biodegradable waste and recyclables. Hence, the long-term goal should be the introduction of source-segregation of waste in households.



**Figure 7- 46: The quality of compost strongly depends on the input material. If source segregation cannot be implemented, waste separation prior to composting is necessary.**

**Sorting of incoming waste**

- ✓ As soon as the household waste arrives at the composting site, it is separated manually into biodegradable material, recyclables, and rejects.
- ✓ Manual sorting can be done in different ways, including on the ground with a small rake. Workers must wear protective gloves, boots and masks, as they are in close contact with the waste.
- ✓ Rejects and recyclables are sorted into different buckets and/or baskets.

- ✓ Recyclables are stored for sale in a shed.
- ✓ Rejects are either disposed of in nearby municipal waste bins or temporarily stored on-site before being transported to the landfill.
- ✓ The biodegradable waste fraction is further processed inside the plant.
- ✓ After having finished the sorting process, the sorting platform is cleaned.
- ✓ No waste should remain overnight on the sorting platform as it can attract vermin and cause smells.
- ✓ Which materials can be sold as recyclables depends on the local market? In most cases, at least, a market for paper and cardboard already exists. In other cities, industries processing of glass, plastic or aluminum can be found.
- ✓ Check the local market for prices and retailer networks. Generally, industries only accept bulk delivery. If space is limited, it might be more suitable to find a reliable middleman instead of storing large amounts of recyclables at the composting site.



Figure 7- 47: Step 3, Mixing

Under the activity 'Mixing', balancing of the carbon and nitrogen ratio is necessary for the composting process. The ratio of carbon (C) to nitrogen (N) - also called the C/N ratio - is very important for the biological degradation of organic waste. Both C and N are feedstock for micro-organisms responsible for the degradation of organic matter. While carbon is important for cell proliferation, nitrogen is the nutrient. The text explains the effects of a too high or a too low C/N ratio in the composting process and how problems can be avoided.

Generally, one can classify "green" materials as being high in nitrogen and "brown" materials as high in carbon. The input material should have a carbon/nitrogen ratio of 25:1 to 40:1. This mixture allows for the most rapid and efficient degradation of the organic material. The wide range of the C/N ratio already indicates that a certain variation of waste components is possible. It is recommended to keep incoming "brown" waste (i.e., from parks) separate from "green" household waste and to add it later depending on the composition of the household waste. For a start, these "green" materials and "brown" materials are mixed in equal volumes. This ratio may need to be adjusted if the composting process is not satisfying. For instance, if the waste is very wet with little structure (e.g., kitchen or restaurant waste) the fraction of "brown" materials has to be increased (not only to correct the C:N ratio, but also to reduce the moisture content and to encourage the movement of air). Table 7.12 gives guidance on how to classify the waste materials. It also indicates that household waste is already close to the ideal C:N ratio and normally needs just a little additional "brown" material high in carbon.

In practice, the ideal combination wastes as input material for composting must be determined by trials. It takes some time to learn the specifics of your local waste. Over time, the plant manager will get a keen sense of how to mix the different incoming waste types and when to add wood chips or animal manure. Laboratory tests of your waste can assist in finding the ideal ratio but are not crucial.



Figure 7- 48: Picture of waste mixing

**The right waste mixture in a nutshell:** An efficient composting process needs a C:N ratio within the range of 25:1 to 40:1. Wood chips or sawdust (high C) or manure (high N) may be mixed with the organic waste to optimize the C:N ratio. Wood chips can also increase the pile porosity, thereby improving aeration. Organic screening residues from previous piles can be added to fresh piles as a carbon source. As the screening residues already contain micro-organisms, they also accelerate the start-up of the composting process.

**Determining the Right C/N Ratio:** As stated previously, we can classify "green" materials as being high in nitrogen and "brown" materials as high in carbon. The input material should have a carbon/ nitrogen ratio of 25:1 to 40:1, as this mixture allows for the most rapid and efficient degradation of the organic material. For example, if we want to achieve a 30:1 C/N ratio using vegetable wastes and various high carbon wastes, we can use the following algebraic equations to find the appropriate mix.

**Table 7- 12: Carbon-Nitrogen Ratio of Green and Brown Materials for Composting**

<b>GREEN: Material with High Nitrogen Values (Materials vs C: N)</b>	
Vegetable wastes	12-20:1
Coffee grounds	20:1
Grass clippings	12-25:1
Cow manure	20:1
Horse manure	25:1
Poultry Manure (fresh)	10:1
Poultry Manure (with litter)	13-18:1
Pig Manure	5-7:1
<b>BROWN: Material with High Carbon Values</b>	
foliage (leaves)	30-80:1
Corn stalks	60:1
Straw	40-100:1
Bark	100-130:1
Paper	150-200:1
Wood chips and sawdust	100-500:1

**Example: How to find the C:N ratio**

Let: A = Weight of Vegetable Wastes

1 - A = Weight of Sawdust

$$\text{Formula} = \frac{A \times [\text{manure C/N}] + (1 - A) \times [\text{wheat straw C/N ratio}]}{30} = 1 \times$$

$$20A + 500 - 500A \quad \text{ratio)} = 1 \times 30 \quad (\text{desired compost ratio})$$

$$20A - 500A = 30 - 500$$

$$-480A = -470 \quad \text{which is the same as,}$$

$$480A = 470$$

Parts by weight

$$\text{litter: } A = \frac{470}{480} = 0.98 \quad \frac{0.98}{0.98} = 1.00$$

$$\text{straw: } 1 - A = 1 - 0.98 = 0.02 \quad \frac{0.02}{0.98} = 0.02$$

---


$$1.00$$

---


$$1.02$$

Therefore, in this example, for every 98 kg of vegetable waste, 2 kg of saw dust would be required to bring the C/N ratio to 30.



Figure 7- 49: Step 4, Composting

### Box Composting System

The box is constructed with perforated walls, a perforated bottom grid and vent-pipes allowing air circulation through the waste. The construction of the box in combination with the layer technique ensures sufficient aeration and additional turning is not necessary. Air is supplied to the organic material through holes in the walls and through the perforated vertical pipes embedded in the pile. The perforated bottom of the box additionally acts as drainage for excessive water. As in the box system, the temperature within the mass increases within a few days up to 60°C, ensuring that the final compost product is free of viable pathogens or weed seeds. Typically, a box is filled within 5-7 days and the waste in the box decomposes aerobically for 45-50 days before it is removed from the box. This decomposed product needs another 15 days for maturing in the Maturing Box. All the compost boxes are placed under a covered roof to protect the composting process from rain and excessive sun.

If one box is not sufficient, the remaining waste has to be spread in a second box. Assuming an input load of 3 tons per day with a density of 800kg/m<sup>3</sup> with 15 tons capacity, one box may be filled within 5 to 6 days. The box receives one layer (3 tons/day) of waste per day. Each time a

layer is added, it is loosely mixed with the previous layer using a fork or shovel. When the box is full, the waste is left for 45-50 days to go through a thermophilic composting process. Frequently measure the temperature inside the box following the procedure shown in Chapter 5 for detail. To measure the moisture, dig several holes into the compost and check the moisture content according to the description of Moisture control (see Chapter 5) of this guideline on a weekly basis. If the material is too dry, spray water over the compost and level the material again. After 45-50 days, open one side of the box and remove the decomposed organic matter, storing it in a Maturing Box for 15 days. After the produce is matured, the fresh compost product is dried (if necessary) or screened and stored.



**Figure 7- 50: Picture of Compost Plant**

One of the important factors during the composting process is to ensure a sufficient supply of air. Within a few days, aerobic micro-organisms exponentially proliferate, consuming an enormous amount of oxygen. A lack of oxygen likely favors the growth of anaerobic organisms, which cause unpleasant odors. Furthermore, anaerobic conditions slow the degradation process, resulting in a longer composting period. Thus, attention must be given to ensuring an adequate air supply.

- Box composting requires less space than windrows. The piles can be moved closer together and piled higher (to a maximum height of 1.5m) to save space.
- Box composting requires less manpower than windrow composting. Turning is no longer necessary.
- Box composting is less labor-intensive than windrow composting. Only little watering is necessary, if the piles are too dry.
- During the rainy season, keep the compost under a roof to prevent it from getting soaked. Rain might leach valuable nutrients from the compost.
- Continue daily temperature monitoring until the compost is at the ambient temperature. If the temperature of the compost rises when water is added to it, the compost is not mature and needs additional days for final curing.
- The presence of white or grey color indicates the presence of fungi, which are important micro-organisms for the composting process. Their appearance also indicates that the pile is still in the mesophilic phase.
- Mature compost appears dark brown, has an earthy smell and a crumbly texture.
- Frequency of Water Addition: Water needs to be introduced to the compost pile to initiate microbial activity and assist in reaching temperatures in excess of 65 degrees Celsius.
- Free Air Space (FAS) is important to allow for the movement of air and moisture within the compost pile. Various products can be used, but the most logical and suitable is ground wood chips or saw dust. Too much air space increases porosity - moisture will be readily lost and excess air flow will be too drying, thereby preventing the windrows from reaching optimum temperature rates for pathogen reduction. A lack of sufficient FAS will cause the compost pile to go anaerobic (without oxygen), which can cause odor and process problems.

The plastic perforated pipes increase oxygen supply by passive aeration through the perforated side walls and bottom. The box should not be filled within a day; filling of the box with organic waste should be done incrementally in layers. If the box is filled in a day, the pile may become anaerobic. The depth of each layer should be kept within the range of 30-45 cm so that it allows additional oxygen to the pile when the waste comes into contact with fresh air. The presence of steam is a good indicator of the effectiveness of the composting process. There are several advantages of layered filling of waste, including:

- Helps in keeping the pile temperature within the optimum range of 60 – 65°C.
- Ensures that all biodegradable material comes in contact with air, thus avoiding “anaerobic zones” causing an unpleasant odor.
- Allows the outer layer of the pillow to be exposed for a day and ensures better Hibernization (killing of fly eggs and pathogenic microorganisms) of the final compost.

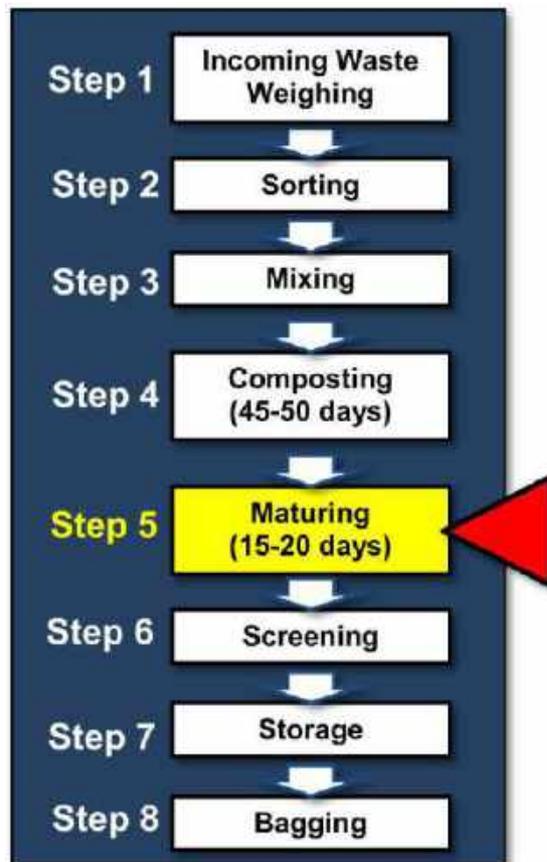


Figure 7- 51: Step 5, Maturing

After about 45-50 days, the materials in the piles change into a color similar to soil and the pile temperature falls below 50°C. This indicates that the process has entered the curing or maturing phase. After 45-50 days residence time in the compost box, the pile is unloaded and taken to the maturing box. It is a specially-designed box with a drying bed (with layers of coarse sand and brick or stone chips) to absorb extra moisture from the pile. This box has a blower to maintain the moisture content before screening. Compost with high moisture becomes difficult to comply with regulations of compost standard and also difficult to screen. If the moisture is too high during this stage, forced aeration should be provided with a mobile blower (1 horse power). The blowers will be kept running for hours with intervals, till the piles have the required amount of moisture.

If the moisture is too high during monsoon season, a blower can reduce the moisture content within a short time. During this stage, complex organic materials further break down while

producing substances somewhat like topsoil. Residence time at this stage is 14-15 days in a maturing box, which is necessary to ensure that the compost is mature and suitable for direct application to plants. During this phase, the compost needs less oxygen and less water. The temperature constantly goes down to the ambient temperature.

This process is gentler, since the easily degradable structures have already been decomposed during pre-composting. This means that less heat is generated. The temperature during this process is around 40 to 50°C. Measurements for temperature and moisture content are carried out in the same manner as in pre-composting cells.

After 14-15 days, the material, which has undergone final composting, is transferred for screening.



Figure 7- 52: Picture of compost maturing

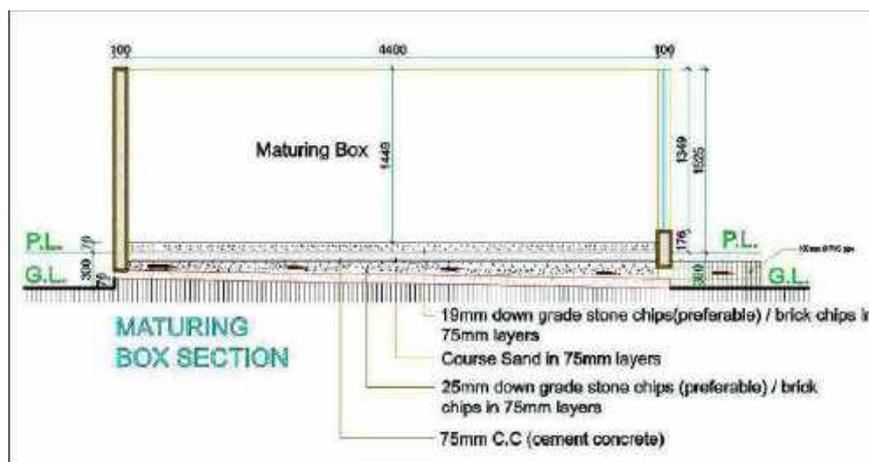
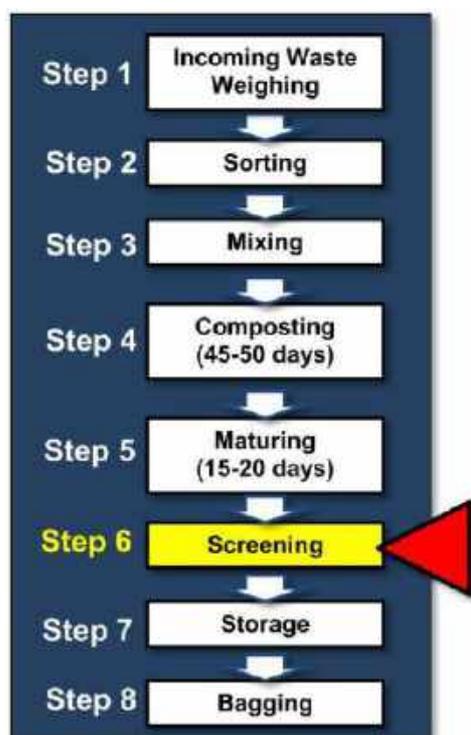


Figure 7- 53: Cross-section of the Maturing Box shows the provision of the drying bed at the bottom of the box, absorbing excess moisture from the matured compost (IRRC, 2012)



**Figure 7- 54: Step 6, Screening**

The mature compost has a rather coarse texture. The particle size of the compost strongly depends on the size of the individual pieces and the composition of the input material and the turning frequency. In many cases finer compost is required and so the compost must be screened. The screening is done either by using a flat frame sieve or a rotating drum sieve. Each size and type of sieve with its particular mesh size is suited for a particular throughput and application. In any case, they need to be adjusted to the local conditions and compost structure.

- The frame sieve (a rectangular wooden frame with a wire mesh stretched across it) is propped up in a sloping position. The raw compost is thrown onto the sieve and rubbed through the mesh.
- A manual rotating drum sieve is more expensive but can have a higher throughput. It also protects the workers from close contact with the compost.
- There are four different grades of compost, which may be referred to as coarse, medium, fine and superfine. Screens with four-centimeter square openings are used for the medium grade of compost and a one-centimeter mesh is used for fine grades of compost.
- Compost should be virtually free of all foreign matter such as pieces of plastic or broken glass. Small inorganic particles which were missed during the initial sorting should be sent to the disposal site together with other residues.

- Coarse organic material which has not been completely composted normally remains in the screening residues. This material is a valuable carbon source and should be mixed with fresh incoming waste. It already contains micro-organisms that can accelerate the decomposition of the incoming material.



Figure 7- 55: Picture of waste/compost screening (IRRC, 2012)

The screening process generates two fractions. The particle size and amount of the compost is determined by the mesh size of the sieve through which it passes. For instance, a sieve with a 10 mm mesh size produces:

- Fine compost (1 mm up to 10 mm); and
- Screening residues containing both coarse organic material and inorganic residues (> 10 mm).

If required, several screens with decreasing mesh size can be put in a row, allowing the production of several compost qualities. However, in most cases, one compost quality - fine (1-10 mm) - is sufficient.

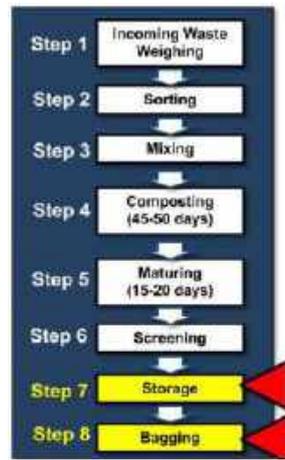


Figure 7- 56: Step 7 & 8, Storage and Bagging

Depending on your customers, you might store compost in bulk or pack it in bags of different volumes. If compost reheats above ambient temperature after the screening process, it still is not completely mature. In this case, sprinkle a little water and let the compost rest for another week. Check the temperature again before you start bagging it. The compost should be relatively dry when it is bagged to avoid transporting large amounts of water with the compost (moisture content < 40 %).



Figure 7- 57: Picture of compost storage and Bagging (IRRC, 2012)

- Store the mature and screened compost in a dry and covered place. Rainwater would leach out valuable nutrients.
- The storage of compost should not be for longer than two years, as the nutrient value of the product and the organic matter content slowly decrease over time.
- Compost is usually sold in bulk (delivered loosely) or in bags of different sizes (e.g., 5 kg, 10 kg, 40 kg). Some bulk purchasers may be content to use a coarser grade of compost if the price is attractive.
- Pack the compost into bags only just before it is to be sold.

- The bags should be waterproof but permeable to air as compost is still a “living” material requiring air. Woven polypropylene bags prove to be very suitable for compost.
- Label the bags. The label should indicate the name and origin of the product, the weight, the date of packing and the average nutrient content of the compost.

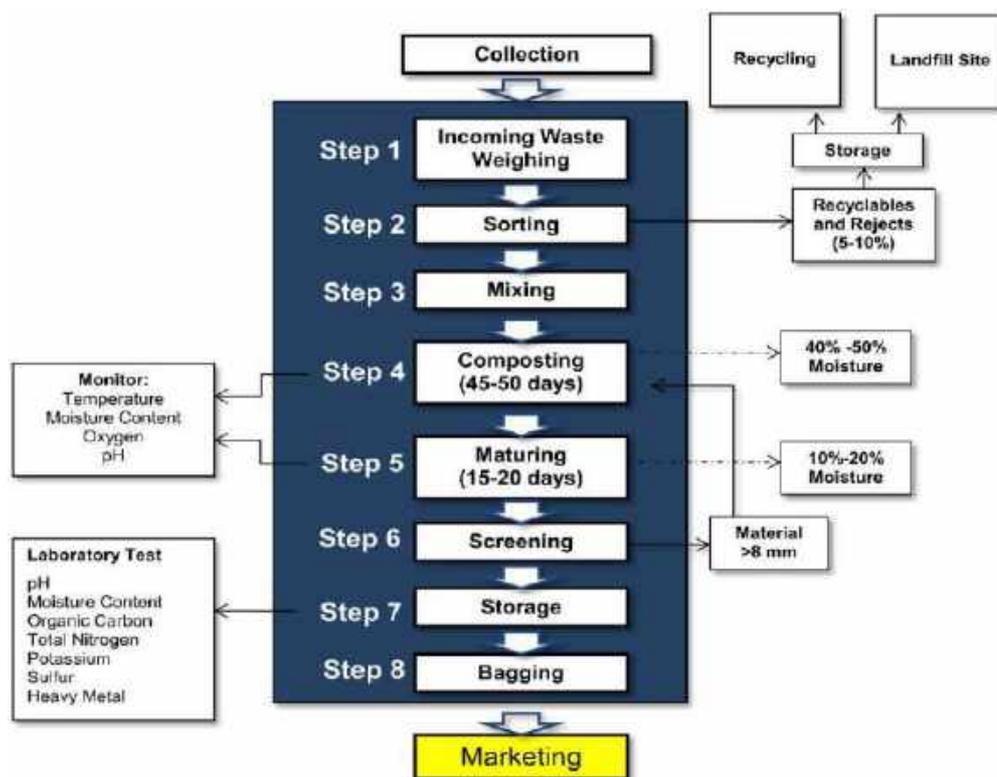


Figure 7- 58: Step, Marketing of Compost(IRRC, 2012)

If

composting activities are based on a business approach with little or no external support, assessment of potential markets and customers are key elements for launching a compost business. Yet, even if composting is accepted as a treatment option within a SWM strategy and receives additional subsidies from institutions, a demand for the product should be identified. Before starting compost production, determine for what purpose the compost will be used and decide on the target customers. When asked, "Who are your customers?" or "Who will buy your product?." many entrepreneurs or project coordinators either have no clear idea or they assume that "everyone" will. Such assumptions can lead to wrong decisions and pricing policies, incorrect marketing strategies and, finally, to business failure. A market demand study aims at identifying compost customers, usages and their demands in terms of both quality and quantity.

**Activity 1: Assess potential customers and competitors**

**Potential customers** must either show a need or a want (or both) for compost, including the ability and willingness to pay for it. A few important questions should be asked to find the market, such as:

- Where could compost potentially be used and for what purposes?
- Who are your potential customer groups and what are their different needs?
- What are the potential quantities each customer group would require (potential market demand)?
- What is the ability and willingness to pay of your potential customers?

### **Knowing your competitors**

In addition to knowing your customers, you must also be informed about your competitors and the competing products on the market. Familiarize yourself with the characteristics of the competing products (quality, price, etc.), the methods used by competitors to sell their products and reasons why customers buy their products.

It will help you understand not only the needs of your potential customers but also how to establish your marketing plan.

Typical competing products for compost are:

- Fertile soils mined and transported to the end user (peat, red soil, etc.);
- Chemical fertilisers;
- Animal waste (chicken manure, cow dung, etc.);
- Raw municipal refuse;
- Human fecal sludge (from pit latrines and septic tanks) and wastewater sludge;
- Nutrient-rich wastes from industrial processing (neem cake, brewery and distillery waste);  
and
- Mined, decomposed landfill material.

To compare products, determine the amount of compost required to replace the competing product.

1. Make a list of the competitors
2. Quantify and characterise them

3. Classify them into different categories according to their competing products or targeted customer groups
4. Collect detailed information on them and their products (e.g., products, prices, sales volume, distribution networks, other services)
5. Use direct surveys or collect information indirectly by studying the customers or secondary sources
6. Answer the following questions:
  - What advantages do competitors have over your business or project?
  - What lessons can you learn from them?
  - What advantages do you have over your competitors or competing products?

### Activity 2: Develop a marketing strategy

After having obtained a comprehensive view of the compost market demand and condition, it is far easier to develop a marketing strategy. The sale of compost faces several obstacles which threaten the development of a successful overall composting and recycling approach.

- There is an apparent lack of awareness and yet there are numerous reservations regarding compost. Compost often has a negative image due to its input material (waste) and sometimes bad quality.
- There is a great lack of knowledge on compost benefits and application.
- The nutrient value of compost is often compared with that of chemical fertilisers.
- Compost has to compete with low-cost traditional products like manure.
- The long distances between production (composting plant) and application (fields and gardens) prevents the sale of compost.
- Inadequate or unfair regulations and policies (e.g., subsidies for chemical fertilisers) hinder the composting approach.

A marketing strategy is needed to tackle these product-specific obstacles. The risks and opportunities identified in the “window of opportunity” analysis should be taken into consideration (see Introduction). Marketing professionals focus on four main parameters to attain a successful marketing strategy: **Product, Price, Place, and Promotion**. These are the so-called “**4 Ps**” of the **Marketing Mix**. The following section describes each element and aspect to be considered in detail.

- **Product:** Relates to features, benefits, quality, packaging, presentation, and service and abstract messages such as image or principles.

**Example:** *Compost is produced from organic solid waste and is hence an environmentally-friendly and high-quality product. Compost is high in organic matter and, therefore, an important soil amendment for agriculture and horticulture.*

- **Price:** Is dependent on your customers' financial circumstances, on compost demand and the prices of competing market products. However, it is also determined by your production costs and expected profit margin.

**Example:** *Compost has to compete with commercial fertilisers and other natural manures. The market price will range somewhere in-between these two products; however, production costs have to be covered.*

- **Place:** Can be regarded as a link between your product and your potential customers.

**Example:** *You have decided to market the compost via a retailer who has already established a distribution network for other agricultural products. Customers can purchase the compost locally at low transport costs.*

- **Promotion:** Supports and influences the perceptions and judgements of your potential customers to ensure the sale of your product.

**Example:** *Your compost has an official quality label. The customer opts for your product as he/she trusts the label or is aware of your company's good reputation.*

#### a. Product

**Product features** must be adapted to the needs of the targeted groups to ensure continuous - or even increasing - sales. Product features are, for example:

- Purpose and benefit of the product (e.g., fertiliser, soil conditioner)

- Quality (e.g., maturity)
- Packaging (e.g., bulk or packed products)
- Additional services (e.g., free delivery)

Customer needs have been identified in the market demand analysis. Yet, the product may also include an **extended product feature** or information for the customer. Packaging, for example, should be of appropriate size for easy use, indicate nutrient content of the compost or provide application guidance for different plants. This is an additional benefit to the customer and can promote repeated purchase of your product.

After-sales **service provided with the product** is a further benefit as it also includes an important product feature and may offer an advantage over competitors. Many fertiliser or composting companies provide compost consultancy services, thereby also allowing a detailed analysis of customers’ needs and product acceptance.

**Product quality** is another key feature in gaining satisfied and loyal customers. Compost quality criteria can be divided into visible and easily controlled quality criteria or invisible criteria difficult to assess by the customer. Table 4.3 contains selected quality criteria classified into customers’ assessments.

**Table 7- 13: Compost quality criteria and the possibility to be assessed by customers(IRRC, 2012)**

Factors possible to be assessed by customers	Factors impossible to be assessed by customers
<ul style="list-style-type: none"> <li>▪ Colour</li> <li>▪ Smell</li> <li>▪ Visible foreign matter (plastic, glass, wires)</li> <li>▪ Degree of maturity assessed by colour and smell</li> </ul>	<ul style="list-style-type: none"> <li>▪ Nutrient content (NPK)</li> <li>▪ Degree of maturity in terms of chemical constituents</li> <li>▪ Suitability for plants (pH, salt content)</li> <li>▪ Inactivation of weed seeds</li> <li>▪ Freedom from pathogens</li> <li>▪ Heavy metal content</li> </ul>

Since the customer is not in a position to assess the most important compost quality criteria (e.g., nutrient content) by its appearance, he has to trust the information provided by the producers. Ways to gain customer confidence include intensive process monitoring and quality control conducted by independent laboratories. A compost quality label can also generate customer confidence. However, it will have to be introduced and awarded by an independent regional or national organization acting as a control institution.

**What is enriched compost?**

Compost exhibits a natural nitrogen content of 1-2%, which is low compared to chemical fertilisers or even animal manure. To compete with such products and to meet customer requirements, compost can be enriched with additives (e.g., urea, potash or poultry manure) to obtain a balanced NPK ratio. However, prior to starting with compost enrichment, a detailed market demand analysis should be conducted to ensure regular sales, as investment and production costs for the enrichment may be quite high.



**Figure 7- 59: Mature compost, ground compost and amended/granulated compost(IRRC, 2012).**

**Table 7- 14: Comparison of nutrient contents in different composts(Waste Concern, 2014)**

Nutrient concentration (OM, N, P, K in %)	Compost Products of Waste Concern	
	Conventional compost	Enriched compost
Organic matter (OM)	35 – 40%	30%
Nitrogen (N)	1.0 – 2.0%	7%
Phosphorus (P)	0.4 – 4.0%	7%
Potassium (K)	0.5 – 2.6%	14%
pH	7.8	7.5

Source: Waste Concern (2001)

#### b. Price

Product pricing is a core issue facing all companies, as many aspects have to be taken into consideration. For a self-sustained business activity, cost coverage is ultimately the most important factor. Hence, product price is dependent on the specific **production costs**. However, a producer will add a profit margin to provide for further investments or technological improvements. The margin is, nevertheless, limited as the prices of **competing products** and the **willingness and ability to pay** of the customers have to be taken into account. If the price per unit fails to cover all costs and to yield a profit for future investments, the business will eventually collapse. In other words, if you realise that your production costs are much higher than the current market prices for the product, and that you are unable to reduce these costs or introduce mechanisms for cross-subsidies (from other products or other income), you should think about changing your business activity.

The **terms of payment** required to accommodate the ability and willingness to pay of a customer is a further important factor. Assuming you sell the compost directly to the end users, their income should be taken into consideration. While a household buying small quantities will be able to **pay cash directly**, a farmer ordering larger quantities to prepare his/her field will

only be able to pay after harvesting when he/she has generated a cash income from the sale of the crop. In the latter case, **credit** should be **granted** as it allows the farmer to profit from compost when he/she needs it and pay for it when funds become available.

**Table 7- 15: Terms of payment for the sale of compost(IRRC, 2012)**

Terms of Payment		
<b>Direct payment</b>	<b>Credit</b>	
Advance payment	Short-term credits	Long-term credits
Cash payment	Grace period	Profit-dependent payment
Invoice payment	Payment period	
<b>Households, dealers</b>	<b>Dealers</b>	<b>Farmers after harvesting</b>

Preliminary pricing should already have been determined when establishing the business plan of the composting project. However, these factors have to be based on the prevailing conditions and adapted accordingly.

**c. Place**

“Place” can be defined as a **link** for product transfer **between buyer and seller**. If the link to your customer is strong enough, and better than his link to rival suppliers, the customer is more likely to buy your product. There are several **sales or distribution strategies** that can link a customer to your product. The “place” in the sales strategy comprises two main aspects – **location and distribution**.

**“Location” refers to your customer’s geographic location**

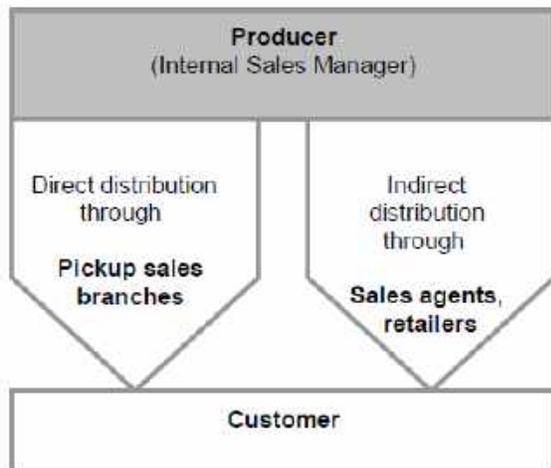
It is crucial for your business to be located in an optimal geographical position in relation to staff availability, supply of raw materials, cost of land and, certainly, location of customers. Assuming that compost is produced in urban areas, certain market segments, such as households or nurseries, may be located nearby. However, since the bulk market is located in peri-urban or even rural areas, distance is one of the main criteria for the sale of compost,

especially as it is a material that is required in large quantities. **Distribution strategies** will therefore have to be developed. The markets for compost can roughly be divided into:

- Local markets (e.g., households, nearby nurseries)
- Regional markets (e.g., nurseries, farmers, peri-urban areas)
- National markets (e.g., rural agricultural markets, landscapers, industries)
- International markets (export to countries in need of organic fertilisers)

The bulky nature of compost and its low market price generally do not allow for the serving of national or international markets. However, several examples prove that a national distribution strategy can be successful thanks to already existing distribution networks.

**Table 7- 16: Alternative Distribution Channels for Compost(IRRC, 2012)**



Development of a **distribution strategy** and selection of **distribution channels** are dependent on the available capacity of your organisation (e.g., staff, means of transport).

**Direct sales** are suitable if customers are located nearby and known to your organisation. If your customers require large compost quantities, direct delivery may be suitable if you have access to transportation. As transport costs are relatively high, you need to decide whether to include transport costs in the compost price or charge the customer additional costs for delivery.

Another strategy consists in concentrating on compost production and **handing over the sale and distribution to a specialised company**, such as a transport company, trade agent or retailer. Retailers may even change some product features or the packaging, thereby, creating a new product. You lose your direct link to the end user and the retailer becomes your direct customer. Some organisations involved in waste collection and composting combine both strategies. They sell compost directly to nearby customers but also supply retailers on the regional or even national market. They are thus able to focus on their core business of waste collection and treatment. The box below contains two examples of different sales strategies practised in India and Bangladesh.

#### d. Promotion

A product does not sell by its mere presence! The potential user has to be informed of its existence and aware of its benefits. The purpose of promotion is to inform customers and stimulate product demand. Information will raise awareness of the market and is particularly useful in turning “ability to pay” into “willingness to pay”. Promotion is a vast field that cannot be covered in the context of this handbook. However, experience reveals that demonstration nurseries or demonstration farms can often be very effective in promoting compost. Farmers can directly see the effect of compost on plants and how it is used. The following table contains an overview of possible starting points for promotion campaigns and promotion tools.

**Table 7- 17: Type of promotion campaigns and tools(IRRC, 2012)**

Tool	Description
<b>Direct contact/ customer service</b>	Face-to-face selling is the most direct contact with the customer. It allows the seller to inform a customer and to react directly to perceptions and behaviour. This method is very time-consuming and staff-intensive. It may be a suitable approach when starting up a business and penetrating a new market.
<b>Word-of-mouth advertising</b>	One customer recommends and praises a product to another on the basis of his/her own experience. This is often the most important communication method with customers and also less time-intensive than face-to-face selling. If your product is unsatisfactory, even for a short period, the word-of-mouth strategy can also be powerful in lowering the reputation of your product and business.
<b>Advertising</b>	Advertising uses mass communication media such as newspapers, television, radio, billboards, etc. It is less time-intensive, should be conducted professionally and requires considerable financial resources.

<b>Internal distribution</b>	The employees of an organisation can also act as links to potential customers. Encouraging employees or associated organisations to use and promote compost in their own environment can help to spread the information and raise awareness (e.g., among associated NGOs, community associations, schools and clubs).
<b>Training</b>	Training can also be classified as a face-to-face sales strategy; however, it goes beyond the mere sale of a product. It is also time-intensive but has a significant impact on a specific target group. This is especially true for the sale of compost. Training farmers on compost application sells an additional service along with the product. The farmers acquire a broader knowledge of compost and its effects, which will in turn be spread to other neighbouring farmers. Hence, selection of farmers to be trained is one of the most vital tasks if conducting training courses.
<b>Free samples</b>	Free compost samples allow farmers to test the product without taking great financial risks. In combination with a training course, this may be a very effective promotion strategy for compost. However, farmers should be informed that free samples are only distributed once, since compost is a valuable product that has to be purchased.
<b>Exhibition</b>	Exhibitions in trade fairs that attract specific target groups are generally cost-intensive. NGOs often have the opportunity to participate in congresses or religious festivals where they can present their activities and products.
<b>Packaging</b>	As already mentioned, packaging serves several purposes. For promotional purposes, it plays a key role as it also transfers messages beyond printed information. In addition to a trade name, colour, cleanliness, stability of the packaging or even condition of the truck for bulk delivery can also indicate quality and build confidence.

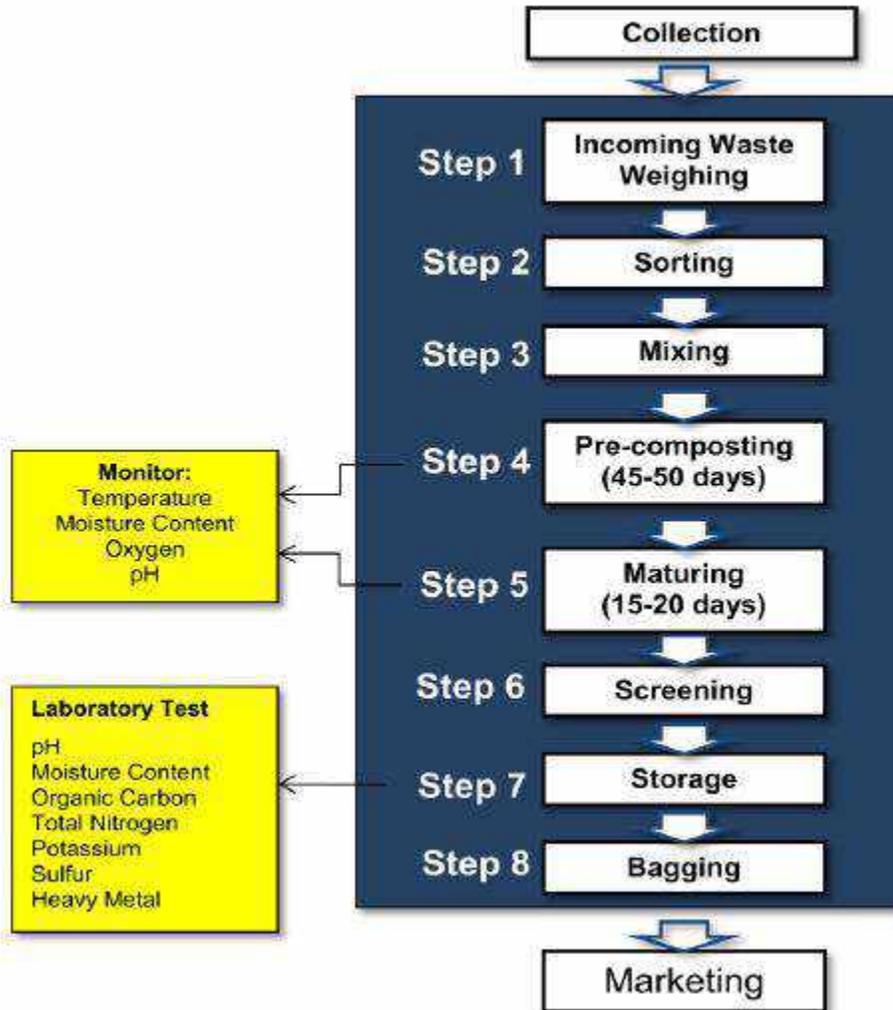


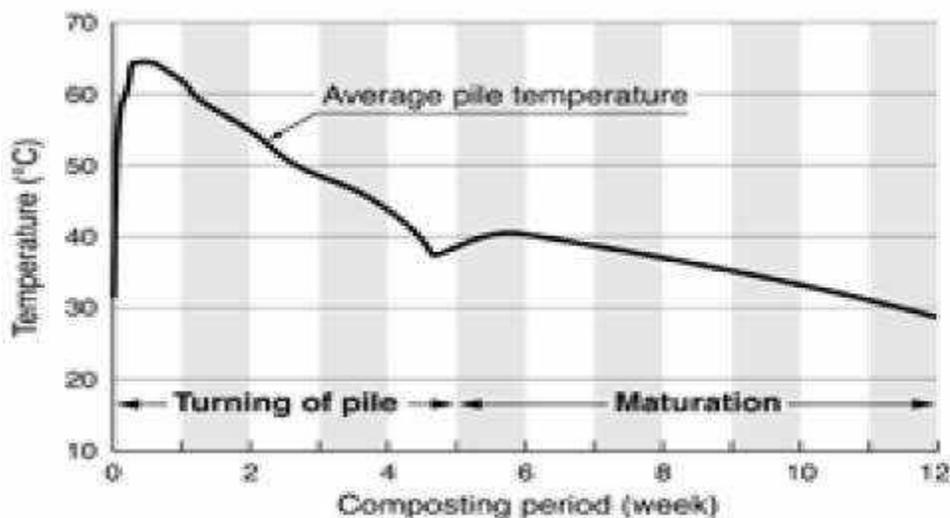
Figure 7- 60: Steps, Monitoring and Laboratory Test(IRRC, 2012)

### Develop a Protocol for Monitoring the Composting Operation

In order to maintain an efficient operation and develop a safe, attractive product, you should regularly track the volume of incoming waste, the temperature and, possibly, the oxygen content of the piles, as well as evaluation of any odor generation. Perform an initial and regular follow-up analyses of the compost produced, including tests for contaminants and the compost’s nutrient value. The data will help you evaluate the success of your operation and decide whether to alter your process. Also, it will provide information that will be requested from potential end users. While carrying out composting activities, quality control of the compost needs to be ensured by regular laboratory tests of incoming waste and final product compost.

### Temperature Control

Provided that the C:N ratio, the aeration and the moisture content are all within the optimal range, the micro-organisms multiply exponentially. This microbiological activity results in a temperature increase to 65 – 70°C within 1 to 2 days (see Figure 5.1). Temperatures above 70°C need to be avoided as they are too high for even thermophilic bacteria and so inhibit the microbiological activity. Temperatures above 80°C are lethal to most soil micro-organisms and the process comes to a halt. Although composting will occur at temperatures below 65°C, a temperature of around 65°C favours rapid composting and ensures the destruction of weed seeds, insect larvae, and potential plant or human pathogens. Therefore, it is preferable for the temperature of the composting pile to stay at around 65°C for at least three days. After the first week, the temperature gradually decreases and the decomposition process slows down. The process moves into the mesophilic phase (45-50°C) and other micro-organisms take over the transformation until the waste material is transformed into fresh compost.



**Figure 7- 61: Temperature curve showing the two composting phases: thermophilic phase with frequent turning, and maturation (mesophilic) phase with occasional turning (IRRC, 2012).**



**Figure 7- 62: Temperature measurement with an alcohol thermometer (Quy Nhon City, Vietnam); and electronic thermometer with stick probe (Dhaka, Bangladesh).**

#### How is temperature measured?

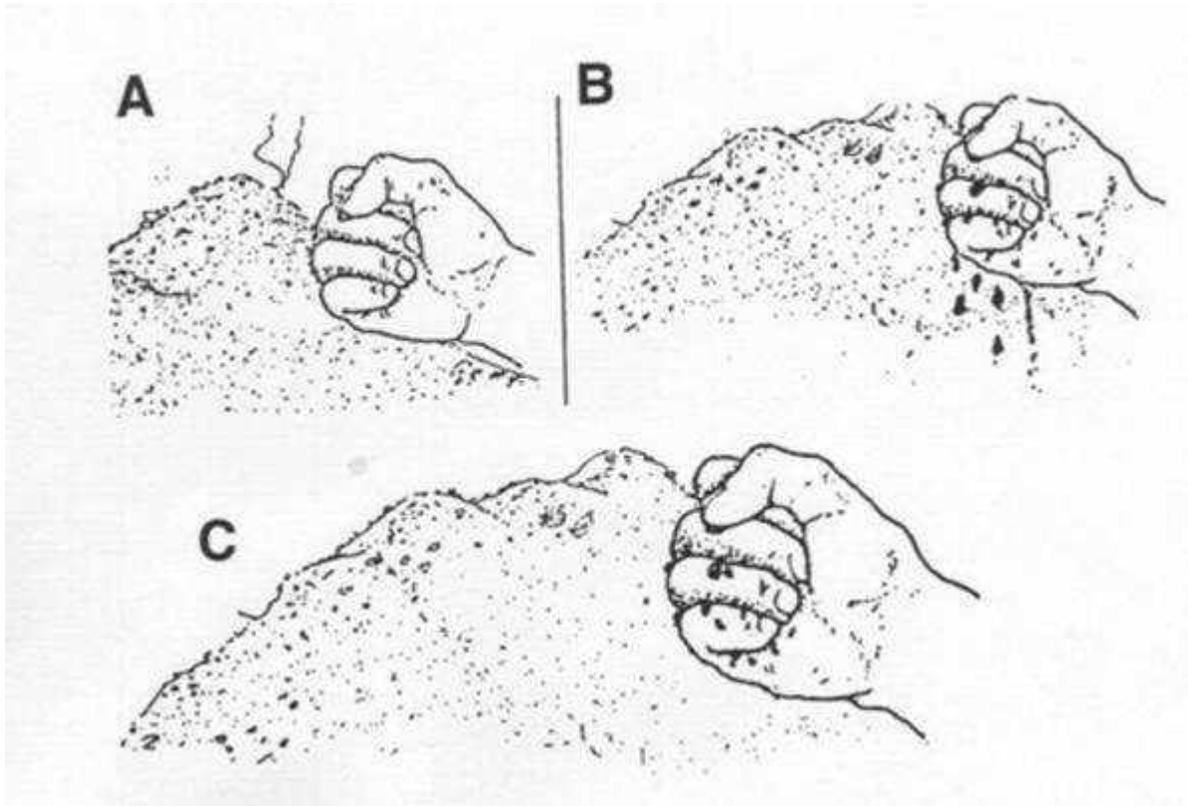
- Use an alcohol thermometer and attach a string to the top of the thermometer. (Do not use mercury thermometers, as the mercury can pollute the entire compost pile if the thermometer breaks during measurement).
- If you use an alcohol thermometer for measurement, first push a hole into the compost to the required depth within the pile using a broom handle or an appropriate stick.
- Then, carefully lower the thermometer into the hole with the string.
- Leave the thermometer in the compost for about 1 minute, then pull the thermometer out by the string and immediately record the temperature.
- Record the temperature trends twice a day at three points within the pile: the top, middle and bottom of the pile or the box.
- Record the ambient air temperature as well.

**Table 7- 18: Showing Comparative Advantage of Thermophilic Composting(IRRC, 2012)**

Types of Treatment	Bacteria	Virus	Protozoa	Helminths
Night soil, faeces at 20 <sup>o</sup> -30 <sup>o</sup> C	90 days	175 days	10 days	Many months
Composting (anaerobic) septic tank/ pit latrine	60 days	60 days	30 days	Many months
Thermophilic Composting 50-60 <sup>o</sup> C	7 days	7 days	7 days	7 days
Waste Stabilization Pond Retention time >20days	20 days	20 days	20 days	20 days

### Moisture Control

Microbes take up nutrients only as dissolved ions in a film of water. Thus, the moisture content of the waste plays an important role. To ensure rapid decomposition, maintain the moisture content in the composting piles at a level of 40 to 60%. Ideally, water is only added during turning as the material is spread out on the floor. Figure 7.64 describes a quick test for moisture measurement. Take a handful of compost and squeeze it hard. If only a few drops of water appear, the moisture content is in the optimal range. If no drops emerge, the moisture content is below 40%, indicating that the nutrient provision is hampered. Consequently, the composting process slows down. Often, the temperature of the waste pile decreases though the process is not finished, because the water content is too low. Adding water raises the temperature of the composting pile and the decomposition process continues (see Figure 7.64 below: maturity test). If the moisture content is too high, the pile tends to become anaerobic and produces unpleasant odors.



**Figure 7- 63: Testing of Moisture Content: Protect your hand with a glove. Take a handful of compost and squeeze it in your fist. A: If no water is squeezed out, the compost is too dry; B: If many drops can be squeezed out, the compost is too wet; C: If few drops can be squeezed out, the moisture content is ideal(IRRC, 2012).**

- Wear protective gloves when testing the moisture (squeeze test) for hygienic reasons and in case there are sharp materials in the material.
- Add water during turning with a sprinkler until optimal moisture content is reached.
- The box system needs less water as the material is not turned.
- In some cases, compost produces excessive water (leachate) in the beginning of the process. This leachate can be collected and reused for watering the next pile.

### **Staff and Data Management Process**

#### **Plan staffing requirements**

Generally, composting plant staff needs to be willing to work with waste. Such a commitment ensures long-term capacity building and increases know-how within the plant. Selection of staff strongly depends on local habits and values (culture, religion, gender, perceptions) and has to

be discussed in detail (e.g., if women can be involved in waste handling). Experience reveals that composting plants often provide interesting job opportunities for underprivileged and poor people. Formalised waste collection, sorting and composting ensures long-term employment and the opportunity to get trained on the job and specialised in composting. However, some of the workers should be literate, as the composting process requires reliable monitoring and recording activities (e.g., temperature, weight and moisture measurements). Furthermore, the composting business also offers jobs for dedicated engineers, which have the overall responsibility of management and operation.

A typical small to medium scale compost plant consists of a Plant Manager, Assistant Plant Manager, Supervisor, and Plant Workers who take care of the operation of the compost plant. They are also responsible for data management of the overall composting process.

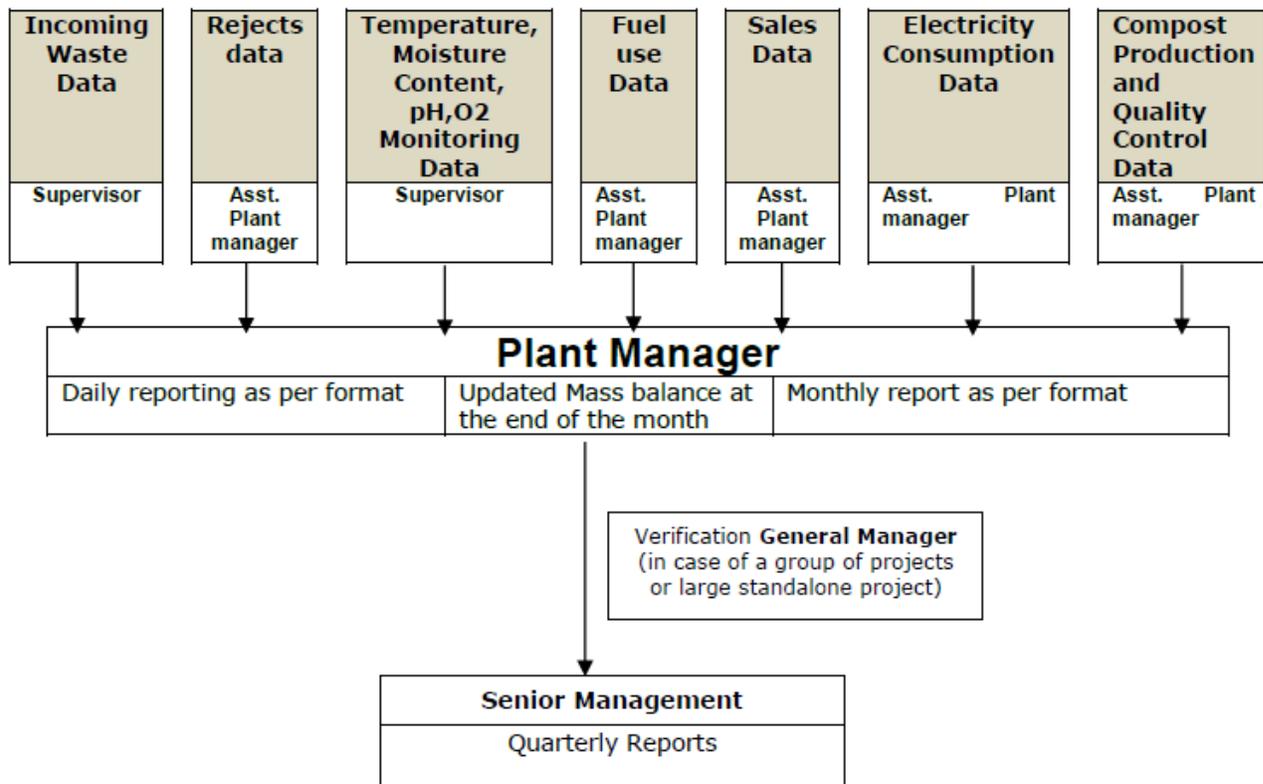


Figure 7- 64: Compost Plant Data Management Flow Chart

**Table 7- 19: Staff required for a three tons/day composting plant(IRRC, 2012)**

	<b>Box Technique</b>	<b>Requirements</b>
Plant Manager/ Engineer	1	Graduate with management skills and willing to work with waste. Responsible for monitoring mass flows, keeping records on plant performance and accounting. Strategic planning and marketing if not conducted by an external agent (e.g., NGO or company).
Asst. Plant Manager	1	Secondary School Certificate
Supervisor and worker	1	Can read and write
Workers	3	Carries out sorting, piling, screening and bagging to produce compost from waste

### **Control the quality of compost**

First and foremost, the quality of compost is controlled best by controlling the quality of the incoming waste that is to be composted. Only biodegradable waste should enter the process, to avoid visible pieces of plastic particles or sharp broken glass in the final product. Invisible pollutants, such as heavy metals, must also be avoided. An effective separation of waste before composting facilitates process steps like turning and screening. Hence, if you need to improve quality, start with a better control of the input material and improve the process control.

Secondly, as discussed above, process control is a crucial factor for good quality compost. Maintain high temperatures to inactivate pathogens and weed seeds. Optimum moisture content during composting ensures the maturity of compost and its benefit to plant growth. Complete and precise monitoring reports can improve the confidence of inspectors and customers in the quality of the final product. In European countries, quality is mainly controlled by evaluating monitoring reports once the quality has been proven to be good by a certified laboratory. In addition, quality inspectors are authorized to make unannounced spot tests.

Finally, the product needs to be frequently analysed to provide important information about nutrient content and invisible pollutants like heavy metals. Figure 5.4 below provides an overview of the most important physical, chemical and biological quality criteria, which are

briefly introduced and discussed in this handbook. Annex 8 shows examples of compost quality standards from selected countries.



Figure 7- 65: Selected quality criteria for compost.

**Visible Pollutants** can be easily detected by the end-user. Each piece of glass or plastic shows the user the origin of the material and causes a loss in confidence in the product. Especially glass or metal pieces pose a harm to users and should be strictly avoided. Pre-sorting the incoming waste and avoiding crushers before the composting process results, in most cases, in clean and good quality compost.

**Maturity** is the most important aspect for horticulture and vegetable production. Compost should be stable, which means that it does not release substances (e.g., ammonia or acidic substances) which can hamper plant growth. The application of immature compost causes root damage and nutrient loss, and therefore a reduction in yield. Unfortunately, maturity is difficult to measure; it requires more than one test to assess maturity. The four indicators below allow a rough on-the-spot check of maturity:

- Appearance: dark brown, soil-like material, no insects or larvae visible
- Earthy smell
- If you dig into the compost (storage) heap, the temperature should not exceed ambient temperature
- pH 7 plus-minus 0.5

**Non-toxicity** means the absence of substances which could harm plants and human beings. Apart from the above-mentioned visible pollutants, many toxic substances are invisible. The absence of toxic substances (e.g., organic chemicals or heavy metals) is particularly crucial for the application of compost for food production, as many plants are able to take up these substances. Heavy metals play a particular role. Once heavy metals are detected in the compost, they hardly can be eliminated again. Mixed municipal solid waste can contain heavy metals, but the organic fraction is low in heavy metals. Hence a contamination can largely be avoided by separating the organic waste from other residues prior to composting.

**Balanced nutrient content** is defined by each customer differently according to individual needs. Hence, different products are available on the market. Pure compost contains a balanced mixture of nitrogen, phosphorous, potassium, calcium and other essential micronutrients. It cannot compete with artificial fertilizers in terms of nutrient content, but is especially beneficial due to the high content of organic matter and the presence of useful micronutrients. If higher nutrient contents are required, enrichment with other fertilizers is an option.

#### **Who can assist in quality analysis?**

Apart from the on-site testing methods that have been described above, additional chemical analyses from laboratories are necessary to determine nutrient content. However, it is not justifiable to establish a laboratory purely for such analyses. Agricultural laboratories typically have the equipment for soil analyses, which are also suitable for compost analysis. National agricultural research institutes or universities could be contacted for a start. For instance, in Bangladesh, there are several possibilities:

- The Soil Resources Development Institute (SRDI);
- Bangladesh Council for Scientific and Industrial Research (BCSIR) of the Government of Bangladesh;
- Bangladesh University of Engineering and Technology (BUET); and
- The Soil Science Departments of any university.

**Table 7- 20: Problems during composting and recommends solutions**

Situation	Requirements / Possible solutions
<b>1. Raw Material Composition</b>	
Large amounts of sand and stones	<ul style="list-style-type: none"> <li>• Improve public awareness to reduce the proportion of inert materials in waste</li> <li>• Adapt collection vehicle (e.g., by fitting mesh floor) to reduce sand content</li> <li>• Remove organics from the mixed waste instead of removing the residues from the organic waste (inverse selection)</li> <li>• Pre-screening of waste at the composting site with fine mesh size</li> </ul>
Large amount of household hazardous waste	<ul style="list-style-type: none"> <li>• Improve public awareness to initiate source segregation</li> <li>• Provide separate collection for hazardous materials</li> </ul>

**Table 7- 22: Composting Parameters**

(high C/N value)	
Carbon deficiency (low C/N ratio)	<ul style="list-style-type: none"> <li>• Add wood chips, dry leaves or saw dust</li> </ul>
Too high temperature during thermophilic phase (> 70° C)	<ul style="list-style-type: none"> <li>• Turn pile</li> <li>• Water pile if necessary</li> </ul>
Too low temperature during thermophilic phase (< 30° C)	<ul style="list-style-type: none"> <li>• Check moisture content, if necessary add water</li> <li>• Check c/n ratio</li> </ul>
High moisture content (> 70%)	<ul style="list-style-type: none"> <li>• Turn pile, spread out pile before reforming and leave to dry</li> <li>• Add sawdust or wood chips for absorbing moisture</li> </ul>
Low moisture content (< 40%)	<ul style="list-style-type: none"> <li>• Spread waste and sprinkle sufficient water</li> </ul>
Odor development (anaerobic conditions)	<ul style="list-style-type: none"> <li>• Insufficient oxygen!!! Turn the pile more often</li> <li>• If waste is very sticky and compact, mix in coarse material like wood chips to increase aeration</li> <li>• If heap is too wet, turn it and let dry before re-piling</li> <li>• Avoid composting meat and fish leftovers</li> </ul>

**Table 7- 21: Climatic influences and Vectors**

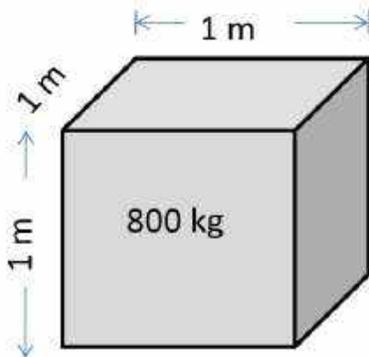
Hot and humid climate or high rainfall season	<ul style="list-style-type: none"> <li>• Protect waste from getting soaked, use roofed area for composting and maturing</li> <li>• Or, cover piles with tarpaulin or composting fleece</li> </ul>
Hot and arid climate or extended dry season	<ul style="list-style-type: none"> <li>• Use roof to protect compost from direct sunlight</li> <li>• Or, cover with tarpaulin or composting fleece to avoid excess evaporation</li> <li>• Water more frequently. Collect rainwater and store for dry season if possible</li> </ul>
Frequent strong winds	<ul style="list-style-type: none"> <li>• Check moisture more frequently as evaporation will increase</li> </ul>
<b>Vectors</b>	
Excessive flies, insects	<ul style="list-style-type: none"> <li>• Cover heap with 2 inch layer of coarse compost</li> <li>• Make sure to receive fresh organic waste (not older than 2 days)</li> </ul>

How many compost boxes and maturing boxes are required for a 3 tons per day capacity compost plant?

The daily density is calculated according to the following equation:

$$\text{Density} \left[ \frac{\text{kg}}{\text{m}^3} \right] = \frac{\text{Mass}}{\text{Volume}}$$

The density is measured in kg per m<sup>3</sup>



**Consideration of Incoming Waste Density:**

Mass = 800kg,

Volume = height x width x length = 1m x 1m x 1m

Volume = 1m<sup>3</sup>

Density = mass/volume

Density = 800 kg/ 1m<sup>3</sup>

Density = 800kg/m<sup>3</sup>

3tons/day capacity compost plant

Capacity of box

3 tons/day x 1000kg = 3000 kg/day

Box Volume Required: 3000kg/day ÷ 800kg/m<sup>3</sup> = 3.75m<sup>3</sup> per day [Considering the Density of Input Waste: 800 kg/m<sup>3</sup>]

Every day 3 tons/day waste input

For @50 days Pre-composting cycle : @ 3tons/day x 50 days = 150 tons will come to the compost box

Total Capacity of Boxes Needed=150000 tons x 800 kg/m<sup>3</sup> = 187.5m<sup>3</sup>

Considering Total Composting Process Time: 50 days

Considering Designing 15 tons/day capacity compost box

Total number of Compost Boxes required: 150 tons/day ÷ 15 tons/day = 10 nos.

One 15 tons/day capacity compost box will take 5 days to be filled up if 12" layer of waste is spread every day in the box.

**Capacity of Maturing Box**

After 50 days resident time in the compost box, 15 tons of waste in each compost box will lose moisture and its weight will become: 15 tons \* 50% = 7.5 tons

7.5 tons of decomposed comparatively dryer waste will come to the Maturing Box.

Maturing Box Requires: 7500kg ÷ 600kg/m<sup>3</sup> = 12.5m<sup>3</sup> [considering matured compost density=600kg/m<sup>3</sup>]

Considering 15 days residence time in the maturing box, total number of compost boxes required are:

3 nos. x @12.5m<sup>3</sup>/m<sup>3</sup>

The idea is that the first compost box will be emptied on the 50<sup>th</sup> day and on the 50<sup>th</sup> -65<sup>th</sup> day, matured compost will be taken.

Table 7- 23: Composting Quality Indicator

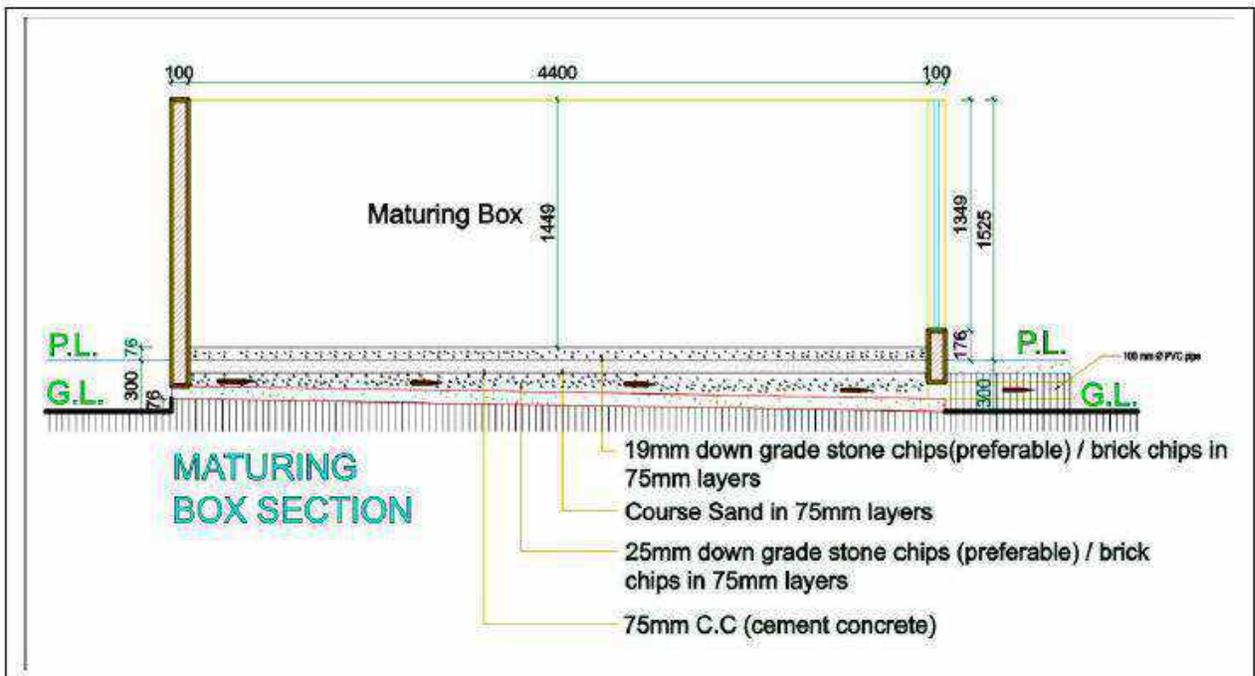
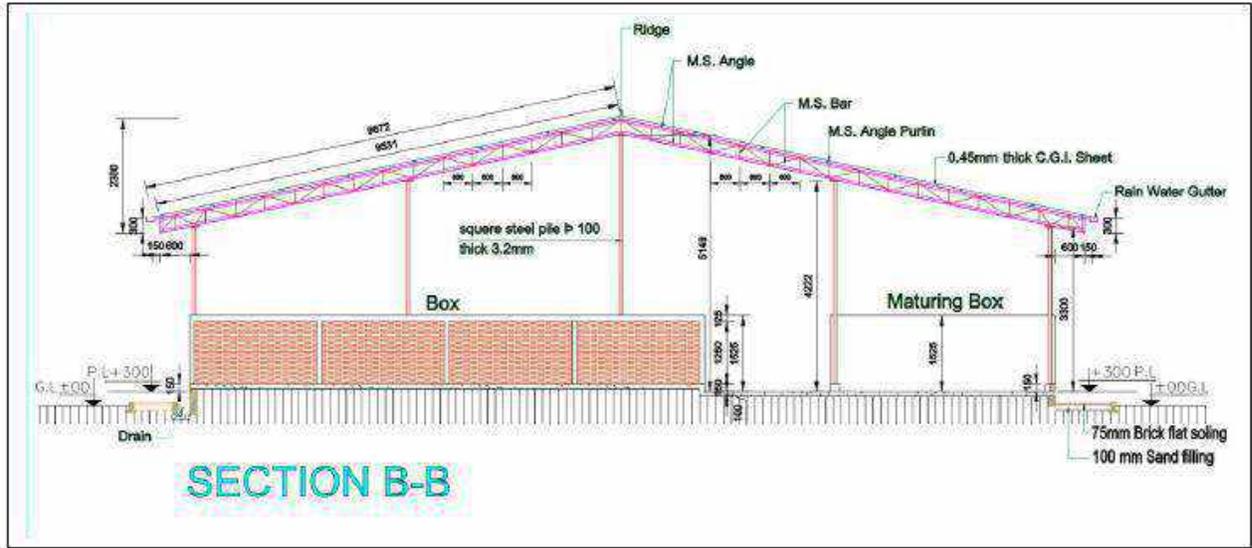
## Compost Quality Standards

Comparison of quality standards for compost used in agriculture from Switzerland, India and Great Britain.

Criteria	Switzerland Association of Swiss Compost Plants (ASCP)	India Indian Institute for Soil Science (04 Task Force)	Great Britain PAS 100 (BSI) and Apex-Standard*
<b>Indicators for Maturity/Stability</b>			
pH	< 8.2	6.5 – 7.5	7.5 - 8.5*
Organic Matter	< 50 %	> 16 % C <sub>org</sub>	30 - 40 %*
NO <sub>3</sub> -N/ NH <sub>4</sub> -N ratio	> 2	---	
C/N ratio	> 21:1	20:1	15:1 - 20:1*
Dry weight	> 50 %	75 – 85 %	65 - 55 %*
Decomposition	feedstock unrecognisable, except for wood	dark brown no odour	---
Plant compatibility	planting tests (cress, salad, beans, ...)		20 % below control
Respiratory Test	---	< 15 mg CO <sub>2</sub> -C per 100 g TOC/ day	< 16 mg CO <sub>2</sub> / g organic matter/ day
<b>Indicators for Nutrients</b>			
Phosphorous (P <sub>2</sub> O <sub>5</sub> )	> 0.7 %	0.5 – 0.8 %	25 - 40 mg/l*
Potassium (K <sub>2</sub> O)	-	1-2 %	0.5 - 0.7 %*
Total Nitrogen	> 1 % DS	> 0.8 % DS	0.7 - 1.0 %*
NO <sub>3</sub> -N	> 40 mg/ kg WS	---	15 - 120 mg/ l*
NH <sub>4</sub> -N	> 300 mg/ kg WS	---	1 - 5 mg/ l*
<b>Indicators for Pollution</b>			
Impurities	< 1 %, no visible plastic, glass or metal	< 1 % inert material and foreign matter	< 0.5 % of total air-dried sample by mass
Cadmium (mg/ kg DS)	1	5	1.5
Chromium (mg/ kg DS)	100	50	100
Copper (mg/ kg DS)	100	300	200
Lead (mg/ kg DS)	120	300	200
Nickel (mg/ kg DS)	30	50	50
Mercury (mg/ kg DS)	1	2.5	1
Zinc (mg/ kg DS)	400	500	400

\* Apex is a voluntary standard, launched by three of the UK's biggest waste management firms.

\*\* DS = dry solids





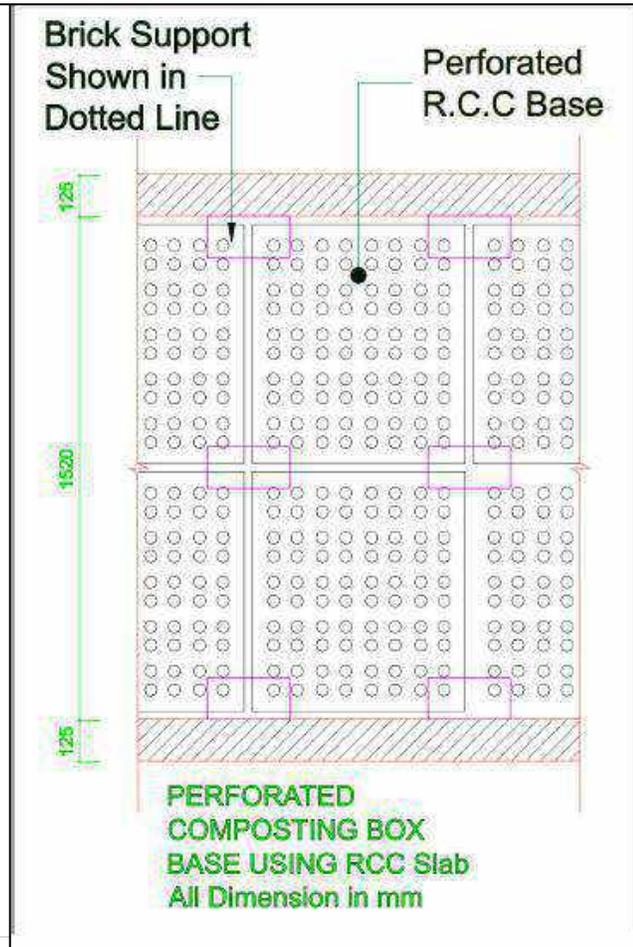
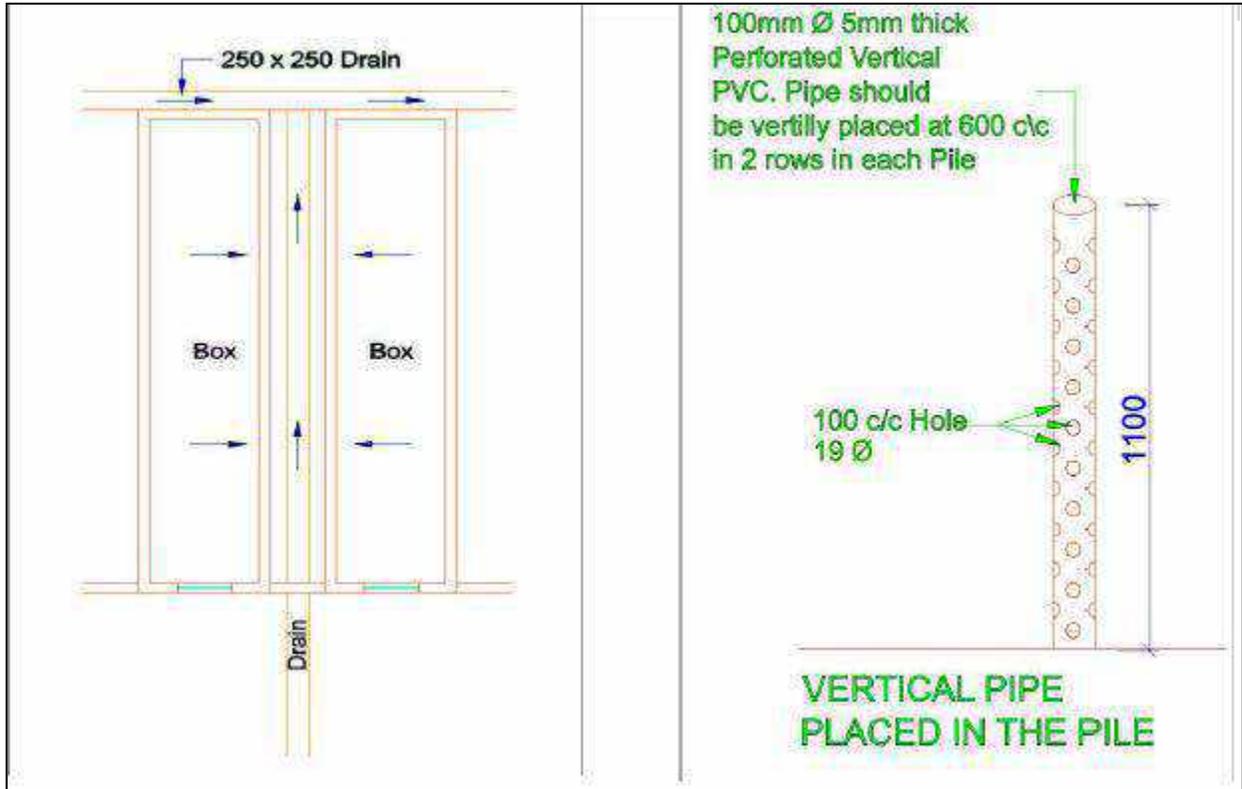


Figure 7- 68: Detail Section with dimension of composting box

**Table 7- 24: Percentage of activity area required inside a compost plant**

Sl.	Activity Area	Area Covered inside Compost Shed	
		%	
1	Reception, Sorting, Screening and Packaging Areas	12	
2	Compost Boxes	50	
3	Maturing Boxes	10	
4	Office, Toilets, Wash room, Equipment Storage	12	
5	Store for Finished Compost	10	
6	Store for Recyclables	6	

**Table 7- 25: Operational Description of Compost Plants**

Description		Name of Plant		Total
		Narayanganj (22 Tons/d)	Mymensingh (8Tons/d)	
<b>Waste Collection</b>		14 MT/ day	12 MT/day	26 MT/day
<b>Organic waste forcomposting</b>		10 MT/day	8 MT/day	18 MT/day
<b>Compost (15-18%)</b>		1.7 MT/day	1.36 MT/day	3.06 MT/day
<b>worker</b>		Male: 7	Male: 03	Male: 10
		Female: 10	Female: 13	Female: 23
<b>Employee</b>	Management	Male: 03	Male: 02	Male: 05
		Female: 00	Female: 00	Female: 00
		Total: 20	Total: 18	Total: 38

**Table 7- 26:** Cost benefit analysis of Compost Plant (per day)

Description	Name of Plant		Total Cost
	Narayanganj	Mymensingh	
<b>Waste Collection</b>	Free delivery	Free delivery	00
<b>Worker (US\$ 4/P/day)</b>	US\$ 68	US\$ 64	US\$ 132
<b>SalaryManagement (US\$ 5/P/day)</b>	US\$ 15 Total: 83	US\$ 10 Total: 74	US\$ 25 Total: 157
<b>Utility (Electricity, water supply, packaging etc.)</b>	US\$ 40	US\$ 58	US\$ 98
<b>Plant Rent</b>	US\$ 4.16	US\$ 2.08	US\$ 6.24
<b>Total Cost</b>	US\$ 127.16	US\$ 134.08	US\$ 261.24
<b>Total Income from Compost Sale (US\$ 125 per ton)</b>	US\$ 212.50	US\$ 170.00	US\$ 382.50
<b>Net income per day</b>	US\$ 85.34	US\$ 35.92	US\$ 121.26

### 7.13 BIOGASPLANT

- Biogas plant is an airtight container that facilitates fermentation of material under anaerobic condition
- Anaerobic digestion of organic matter produces a mixture of methane (CH<sub>4</sub>) and carbon dioxide (CO<sub>2</sub>) gas.
- The material which is used in biogas plant for producing Biogas called Biomass.
- Forms of biomass listed below may be used along with water.
- Animal dung, Poultry wastes, Plant wastes, Human excreta, Industrial wastes, Domestic wastes

#### 7.13.1 Biogas Composition

**Table 7- 27: Biogas composition**

Composition	Percentage (%)
<b>Methane, CH<sub>4</sub></b>	<b>55-70</b>
Carbon dioxide, CO <sub>2</sub>	25-40
Carbon dioxide, CO <sub>2</sub>	0-2
Hydrogen Sulphide, H <sub>2</sub> S	0-3
Hydrogen, H <sub>2</sub>	0-2
Oxygen, O <sub>2</sub>	0-2

#### 7.13.2 Operational Parameters of a Biogas Plant

##### Temperature

- Methane- forming bacteria works best in temp. ranges 35 -38C.
- The gas production decreases sharply below 20 C and almost stops at 10 C

##### Solid to moisture ratio in the biomass

- If water content is too high, the mean slurry temp. and gas production drops.
- If water content is too low, acids accumulate and hinder fermentation process.

#### **pH value**

- During methane forming stage, pH value 6.5 to 7.5 is maintained.

#### **Carbon to nitrogen ratio**

- The optimum C/N ratio is 30:1 for maximum microbiological activity.

#### **Another Parameter**

- Total solid content – the total solid content in the material 18 – 20 %
- Diameter to depth ratio 0.66: 1
- Uniform feeding.
- Mixing or stirring or agitation of the content of the digester
- Toxicity due end product
- Acid accumulation inside the digester.

#### **7.13.3 Selection of site for a biogas plant**

- Distance-distance b/w the plant and site of gas consumption should be less
- Open space-the sunlight falls on the plant as temp b/w 15 C to 30 c
- 15 m. distance from well
- Space requirement-10M<sup>2</sup> to 12M<sup>2</sup>area is needed per M<sup>3</sup>of the biogas
- Availability of water
- Source of cow dung /material for biogas generation

#### 7.13.4 Utilization of biogas

- ✓ Cooking
- ✓ Lighting
- ✓ Operating small engine
- ✓ For pumping water

#### 7.13.5 Proposed Method for Biogas Production:

##### Fixed-dome digester

Waste matter is fed into the digester where it collects and is broken down, producing biogas which is stored in the gas holder part of the hemispherical digester. As the pressure of the biogas increases the more the volume of slurry which is displaced into the displacement tank. Excess slurry from the displacement tank will be removed, dried or composted and used for fertiliser or will overflow into a sewage outlet or slurry/composting bed. Biogas is removed from the gas holder and can be used for cooking, lighting and heating (as detailed). When the gas is used some of the slurry moves back from the displacement tank into the digester causing mixing. The fixed-dome generator is commonly known as the 'Chinese' design and can be used in small scale (household) or larger scale (community) systems.

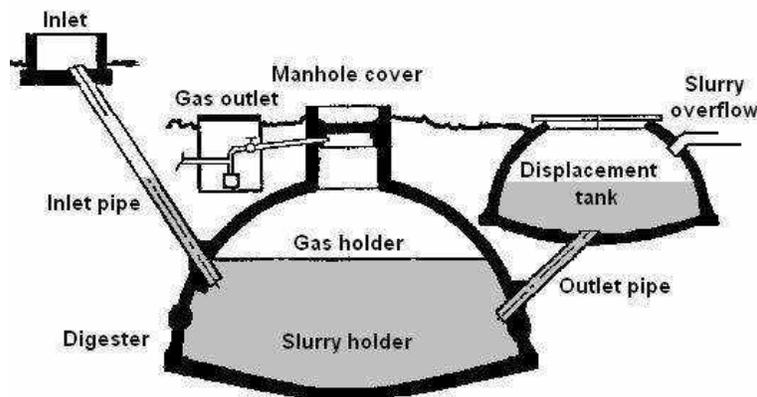


Figure 7- 69: Fixed-dome generator

Construction consists of an underground digester (usually flat/bowled base with a hemispherical top) covered with earth up to the top of the gas holder so as to counteract the

gas pressure. Plastic pipes or masonry tunnels provide the inlet/outlet for the digester. Bricks and mortar are used to create the structure, the inside of which must be rendered and coated in a waterproof and gas-proof coating.

**Benefits** of fixed-dome generators include:

- o simple design
- o simple maintenance (no moving parts, no potential of rusting, long life (20 years+))
- o lower set-up costs

**Disadvantages** of fixed-dome generators include

- o fluctuating gas pressure
- o potential for leaks in mortar if not well constructed

According to GTZ the **volume of the displacement tank should be roughly equal to that of the gas holder** however there is a lot of variance between designs since the shape of the displacement tank can vary so much (from a simple self-contained tank with an overflow to a large drying bed structure).

#### **Design check-list**

- o The slurry overflow outlet must be higher than the slurry bed/slurry distribution channel (to prevent backwash into the digester)
- o The digester inlet must be at least 0.3m higher than the slurry overflow outlet
- o The gas outlet must be situated as close to the top of the gas holder as possible and at least 0.1m higher than the slurry overflow outlet (to prevent clogging with scum)
- o The generator should be located away from trees (where roots can interfere with the structure) and 30m from water supplies (to avoid possible contamination)
- o The generator should not be built on top-of or be situated beneath a throughway for heavy machinery
- o The outlet pipe/channel of the digester is fully accessible from the manhole of the displacement tank to enable unblocking

### 7.13.6 Maintenance tasks

#### Daily activities:

- o Cleaning/unblocking of latrine(s) – water with no added detergents should be used to clean the pipes regularly (detergents can kill the methane producing bacteria). Soap water, from time to time, can be tolerated.
- o Agitate the digester contents.
  
- o Check the appearance and odour of the digested slurry – if the slurry is not fully digested and odour free (to an extent) a reduction in rate of waste addition may be required to increase the HRT or the solid: liquid ratio of the waste may require adjusting. If the pH of the slurry drops this can be remedied by the addition of lime or cow dung.

#### Weekly/Monthly activities:

- o Clean and inspect the gas system and appliances – check for leaks in piping with soapy water. Ensure appliances are working correctly (with efficient flames, etc) and thoroughly cleaned.
- o Inspect the water trap (if present) and empty excess water (if tap style trap is used).
- o Inspect the water bath in the digester neck – for gas leaks through the clay and water levels.
- o Clean the displacement tank – to prevent solids build up and thus restriction of slurry.
- o The slurry overflow pipe/channel should be kept clear and checked regularly. The overflow should direct slurry away from the outlet effectively.
- o Unblocking of inlet and outlet pipes.

#### Annual activities (should be conducted by experienced biogas engineers):

- ✓ Check for scum formation in digester – remove as necessary by opening manhole cover. Gas should be vented for a number of days or burned off before doing this.
- ✓ Remove solid sludge from digester depending on solid sludge build-up. An assessment should be made as to the level of solid sludge collected in the bottom of the generator

(test the substrate with a pole/dipstick and test consistency of the overflow slurry). If the amount of solid sludge is deemed too high (blockages are common, overflow slurry does not flow well, etc.) then the digester should be emptied. The frequency of emptying depends on size of the digester, quality of inlet waste, diet, generator design, etc. and can vary greatly between generators (some generators are designed not to be emptied before 5 years of use). Any sludge removed can be dried or composted and used as fertiliser as detailed in *Table 7*.

- ✓ Clean the displacement tank.
- ✓ Pressure test the gas valves and fittings.

### 7.13.7 Trouble shooting

A selection of common problems and possible remedies have been collected and are listed in Table 30 (sources: GTZ; Practical Action).

**Table 7- 28: Common problems and suggested solutions**

Problem	Possible cause	Solution
<b>The gas does not burn well</b>	Poor quality gas	Vent all of the gas from the gasholder, close the valves and allow it to refill
	Methane content is too low -air is mixing with the gas	Check the gas pipes for leaks with soapy water and repair as necessary
<b>The flame is orange and not clear</b>	Moisture content in gas is too high	Install a water trap and bury piping underground to increase waste condensation. Empty water trap
	Incorrect biogas: air ratio	Adjust this ratio until the flame is compact and blue in colour
	Gas jets are blocked	Remove and clean the gas jets of the appliance
<b>Infrequent biogas production</b>	Water collecting in the pipes	Install a water trap and bury piping underground to increase water condensation. Empty water trap
<b>Flame of cooker/lamp</b>	Too little gas	Increase flow of gas by increasing size of

## Master Plan of Solid Waste Collection and Disposal Management of Narayanganj City Corporation

<b>is too small</b>		gas outlet
	Gas leak in the piping	Check the gas pipes for leaks with soapy water and repair as necessary
	Gas leak from the digester lid	Check the lid (water bath) for leaks. Apply more clay to seal if leaks are found
	Gas production and consumption rates are not equal	Ensure the correct amount of waste is added each day (refer to the design parameters calculated)
	Incorrect solid: liquid ratio in added waste	Ensure a solid: liquid ratio of 1:1 is adhered to. Try adjusting this ratio and note any gas production changes
	Scum layer on top of slurry prevents gas Production and causes blockages	Scum – a thick floating layer of solid matter – forms from indigestible waste (e.g. vegetable husks, sand, feathers, etc.). Daily stirring of substrate can help to reduce scum formation but the only way to prevent it is to control the type of waste input into the digester. In serious cases remove any solid scum from the digester (gain access as detailed in the maintenance section)
	Sand/rocks/solid non-degradable waste in the digester	Remove any non-degradable waste from the digester (gain access as detailed in the maintenance section)
	<b>The amount of biogas is reducing day by day</b>	Cracks in the digester masonry leading to gas leakage
<b>Slurry from the outlet has a strong odour, has solid and liquid parts and changes in colour</b>	Slurry is not being digested Fully	Ensure the correct amount of waste is added per day. If too much waste is added this may have to be reduced in order to increase the HRT
	Waste is not mixing in the digester effectively.	Increase stirring of the waste in the Digester
<b>Slurry from the over flow has a low pH (is acidic)</b>	Incorrect balance of input Waste	Add lime (or cattle dung) to the digester to increase the pH
<b>Flow of the slurry from the over flow is sporadic</b>	Blockages in the digester or displacement tank piping	Unblock all piping (digester inlet and outlet and slurry overflow) using a rigid pole
	Waste is becoming lodged in the inlet	Ensure a solid: liquid ratio of 1:1 is adhered

<b>Blocked inlet pipe</b>	pipe	to Conduct daily checks/unblocking of all inlet pipes
---------------------------	------	---

### 7.13.8 Safety

Biogas is combustible and explosive. A number of safety measures must be taken and clear education and warning as to the dangers must be given.

Safety factors to consider include:

- o Location – the generator should not be housed underneath or within any other permanent structure
- o Biogas piping system should be protected, clear and obvious (whether underground or above ground)
- o Careful installation and regular inspection are mandatory
- o Regular inspection of gas appliances
- o Good ventilation of rooms containing gas appliances without pilot lights
- o Installation of safety stop valves (at the plant and on each appliance) and venting valves (at the plant)

**Educational factors to consider include:**

- o Users must be aware of the dangerous nature of biogas when formed in the explosive mix of Oxygen (air) and biogas
- o Always close the gas and safety valves of each appliance properly and after each use
- o Close the generators safety valves over night or when the generator is unattended
- o Quick detection of gas leaks by watching for the conspicuous odour of unburned biogas.

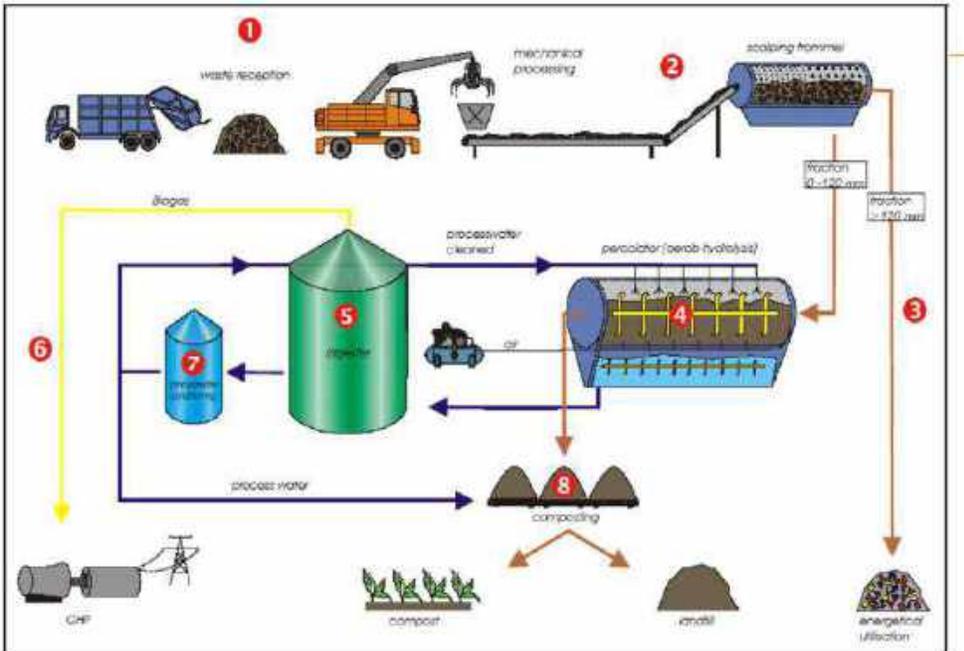


Figure 7- 70: Detail procedure of Biogas production and its uses

### 7.13.9 Staffing Levels

- ✓ Staff levels will depend on the scale and type of operation
- ✓ A small-scale batch flow plant may be operated by a single individual
- ✓ Large-scale plants typically have a site manager, operators to load waste, and maintenance staff

A range of employment and training opportunities may be available throughout the development of an AD facility.

A variety of skill levels are required, including:

- ✓ construction (short term)
- ✓ laboring
- ✓ technical
- ✓ scientific
- ✓ maintenance engineers

- ✓ administrative staff

Some of the maintenance requirements of an AD facility include:

- ✓ General engine maintenance Digesters
- ✓ Grit removal
- ✓ Electrical, fuel, and air system inspection
- ✓ Inlet and outlet pump cleaning
- ✓ Valve and pipe leakage checks
- ✓ Mixing equipment servicing

#### 7.13.10 Economic Considerations for AD Projects

- ✓ Accurately predicting costs and revenues remains challenging due to few projects operating in developing countries
- Local factors vary (e.g., tipping fees, labor costs, site conditions)

#### Costs to consider:

- Predevelopment: siting, permitting, planning and design, and environmental impact assessment
  - Construction: infrastructure, buildings/reactors, equipment, and labor
  - Operations: maintenance, manager training, labor, materials, water and energy, wastewater disposal, solids disposal, and other fees
- ✓ Costs savings possible if incorporated with existing waste management facilities (e.g., co-located at a landfill)
  - ✓ Economies of scale apply
  - ✓ Maximizing all revenues is critical (energy, tipping fees, secondary products, and incentives)

#### Capital Costs (CAPEX)

A range of capital costs (CAPEX) are reported for different facility types and scales. Some examples in different county are following,

- UK: an average cost of £4 million per MW
- USA: \$600 per (short) ton of annual waste through put capacity

### **Operational Expenses (OPEX)**

As with capital costs, operational expenses (OPEX) are varied and depend on the scale, location, system configuration and product utilization. Typical costs include:

- Utilities
- Staff costs
- Effluent disposal
- Mobile plant hire / running costs (e.g., front loaders)
- Permit / license fees
- Insurance
- Consumables
- Disposal of rejects
- Health & safety (e.g., signage)
- Facilities (office, telephone)
- Digestate transport costs
- Gas cleaning / upgrading
- Lifecycle – maintenance
- Gate fees

In some countries, waste producers such as municipalities and commercial and industrial producers may pay a gate fee to the AD facility for accepting and treating their waste.

Typical gate fees are:

1. £40 - £60/ ton in UK
2. \$50 - \$60 / tones USA (Ref: 8)

### 7.13.11 Revenues

#### Digestate

Digestate may be sold as a fertiliser and soil improver, generating a further source of income.

– Revenues

#### Electricity and Heat

- Electricity can be sold to existing network operators or used via a local distribution system (private wire)
- Electricity is easy to transport through existing networks; no 'user' has to be identified; constant market if exported to a network; no marketing is required
- Heat can be used on site and can be sold to adjacent properties for space and water heating, cooling and manufacturing processes
- Heat is not transported as efficiently as electricity; district heating networks can be hard and expensive to retrofit

#### Biomethane

- Biomethane can be used as a natural gas alternative for gas injection and as a transport fuel
- A study found that, compared to diesel vehicles, fuel costs (direct substitute) were 12.8% less; however, vehicles had higher capital costs
- Biomethane as a transport fuel can be an attractive option for fleet vehicles
- Similar to electricity and heat Feed-in-Tariffs (FiTs), other financial incentives may be available for biomethane such as the Renewable Transport Fuel Obligation Order and biomethane injection FiT.

– Financial Support

To support the growth of the AD industry and renewable energy, financial support may be available:

- Grants
- Loans
- Funding Incentives are often critical for the Incentive schemes (e.g., FiT) economic feasibility

#### 7.13.12 Environmental Issues

- To operate an AD facility, environmental legislation must be considered
- An environmental permit(s) may be required from the relevant regulatory body
- An Environmental Permit sets out rules you must follow to prevent damage to the environment and human health

#### Potential environmental impacts

- Odor – feedstocks can cause odorous emissions; these can be managed through an odor management plan and suitable control and abatement techniques (e.g., inside storage)
- Water emissions – run off from wastes stored outside, site must be bunded to prevent leaks in the event of tank failures
- Bioaerosols – can be emitted from storage areas
- Air emissions from burning biogas (compared to fossil fuels)
- Proximity to sensitive receptors
- Potential litter if waste is contaminated

#### Potential environmental benefits

- Reduces reliance on fossil fuels
- Diverts waste from landfill
- Reduces GHG emissions
- Provides a valuable fertilizer / soil improver

AD can provide many benefits if correctly designed and managed

- Reduces reliance on chemical fertilizers and associated production emissions
- Can reduce odor intensity of waste
- Reduces pathogens
- Reduces weed seeds

### 7.13.13 Partnerships and Stakeholders

Developing an AD project in partnership with relevant stakeholders can help ensure the success of the project:

- Feedstock producers – farmers, food manufacturers, local authorities/municipalities
- Landowners
- Local communities
- Energy companies
- Heat users – leisure centers, hospitals
- Investors – banks, private investors

### 7.13.14 Project Implementation

Typical timeframe for a large-scale AD plant:

- Scoping: ~2 months
  - Project development: up to 12 months
- full feasibility – 4 months
- detailed design – 3 months
- Planning and permitting – 3-6 months
- Construction: up to 12 months from mobilization
  - Commissioning (hot / cold): up to 4 months

If you think AD is for you, complete a feasibility study to help you decide whether you should proceed. Here are just a few of the questions answered by a feasibility study:

- Do you have the right feedstock?
- How much will the project cost?
- How much biogas could the feedstock produce?
- How will you use the biogas?
- Do you have an outlet for the digestate?
- What is the potential revenue from biogas and digestate?

Once you have completed a feasibility study, developing a business case will help secure investment. A business plan looks at:

- Technical description: feedstock, outline design,
- A technology options, mass & energy balance, output markets
- Technology option: proven? reference plants?
- Financial: CAPEX, OPEX, cash flow, revenues

#### 7.13.15 Project management

- Contract lengths, letters of support from locals / companies, feedstock providers

#### Things to Remember

- The feedstock creates the biogas, not the digester
- Secure your feedstock
- Feedstocks must be digestible
- Pre-treatment can help prevent damage downstream
- Monitoring is vital
- Digesters never stop operating – maintain!
- Digester performance is best compared on a volume of methane produced per gram of Biological Oxygen Demand (BOD)
- Biogas generation rates are more useful for evaluating financial viability

#### More Things to Remember!

- Maximize digestate storage (especially in wetter climates)

- Don't spread digestate in wet conditions
- Implement a digestate management plan
- Life cycle analysis (LCA) has shown that AD is the most environmentally beneficial waste management option
- Consider whether you will be able to charge a gate fee
- Can you access financial support?
- Contact the relevant regulatory body early
- Engage with stakeholders early
- Make sure it all adds up!

CHAPTER 08: Drawing and Design for Proposed Jalkuri Landfill Site

Name of Proposed Landfill Site: Jhalkuri

Area of Proposed Landfill Site: Approx. 23.19 Acre

Land for Waste to Energy: 9.77 Acre

Land for SWM Master Plan: 13.42 Acre



Figure 8- 1: Picture of Jalkuri Landfill Site

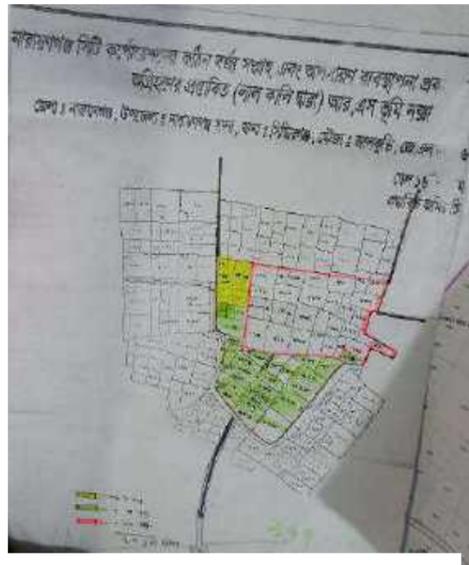


Figure 8- 2: Muza Map of Proposed



Figure 8- 3: Existing condition of Jalkuri Landfill Site



Figure 8- 5: Google Earth Map of the Site



Figure 8- 4: Picture of Consultant Site Visit

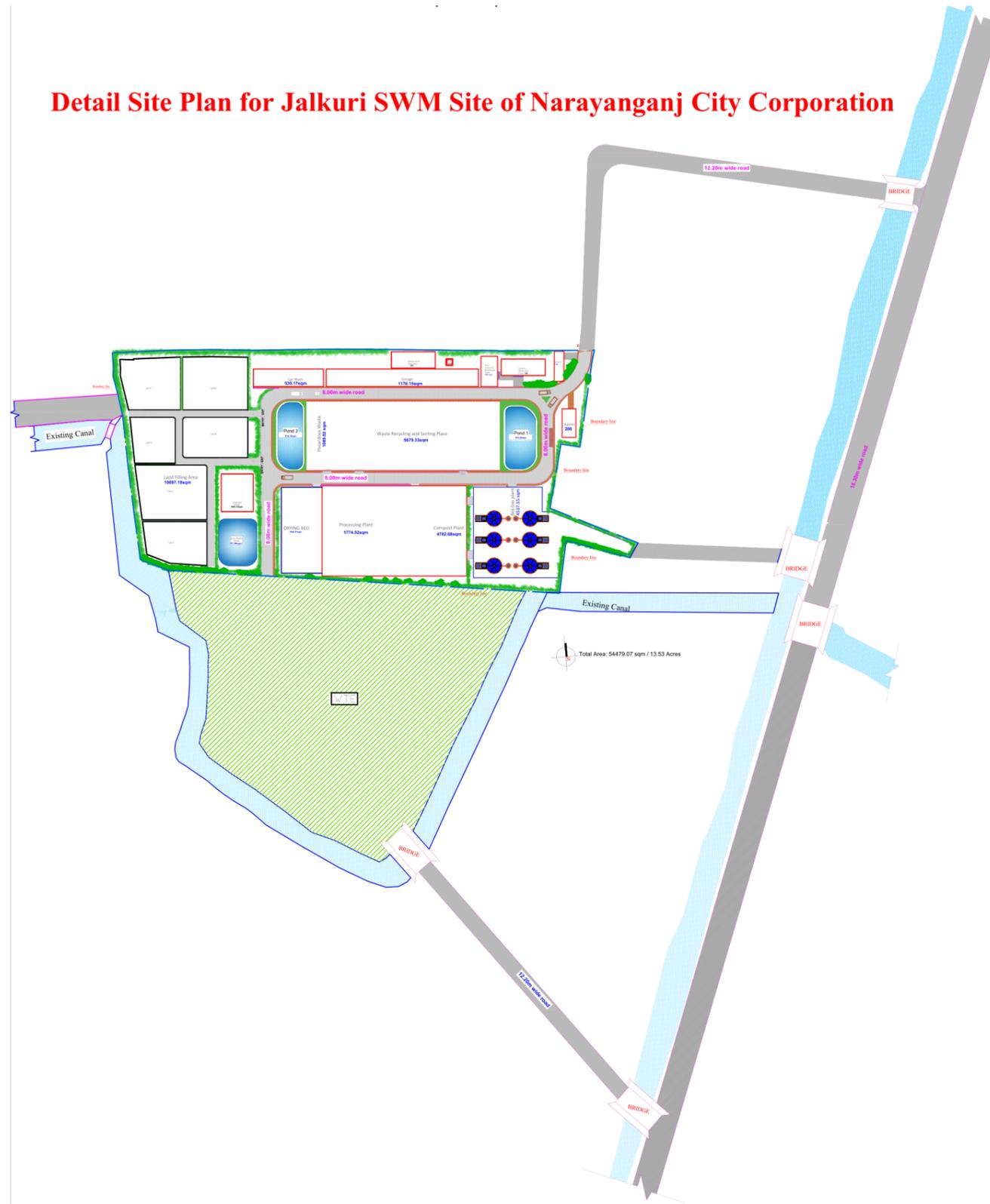


Figure 8- 6: Layout plan with connectivity



### Final Layout Plan for Jalkuri SWM Site of Narayanganj City Corporation

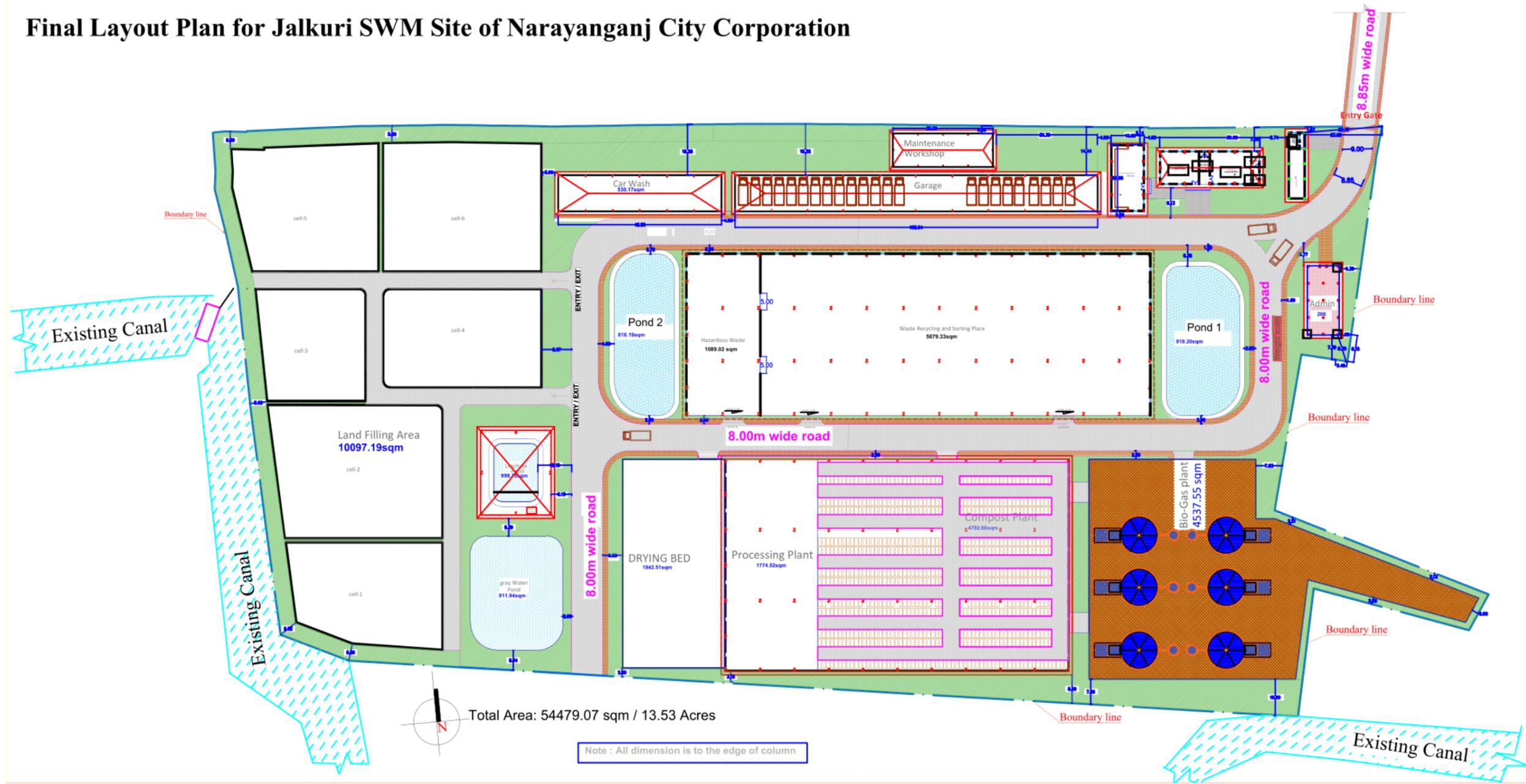


Figure 8- 8: Layout Plan of Jalkuri Landfill Site



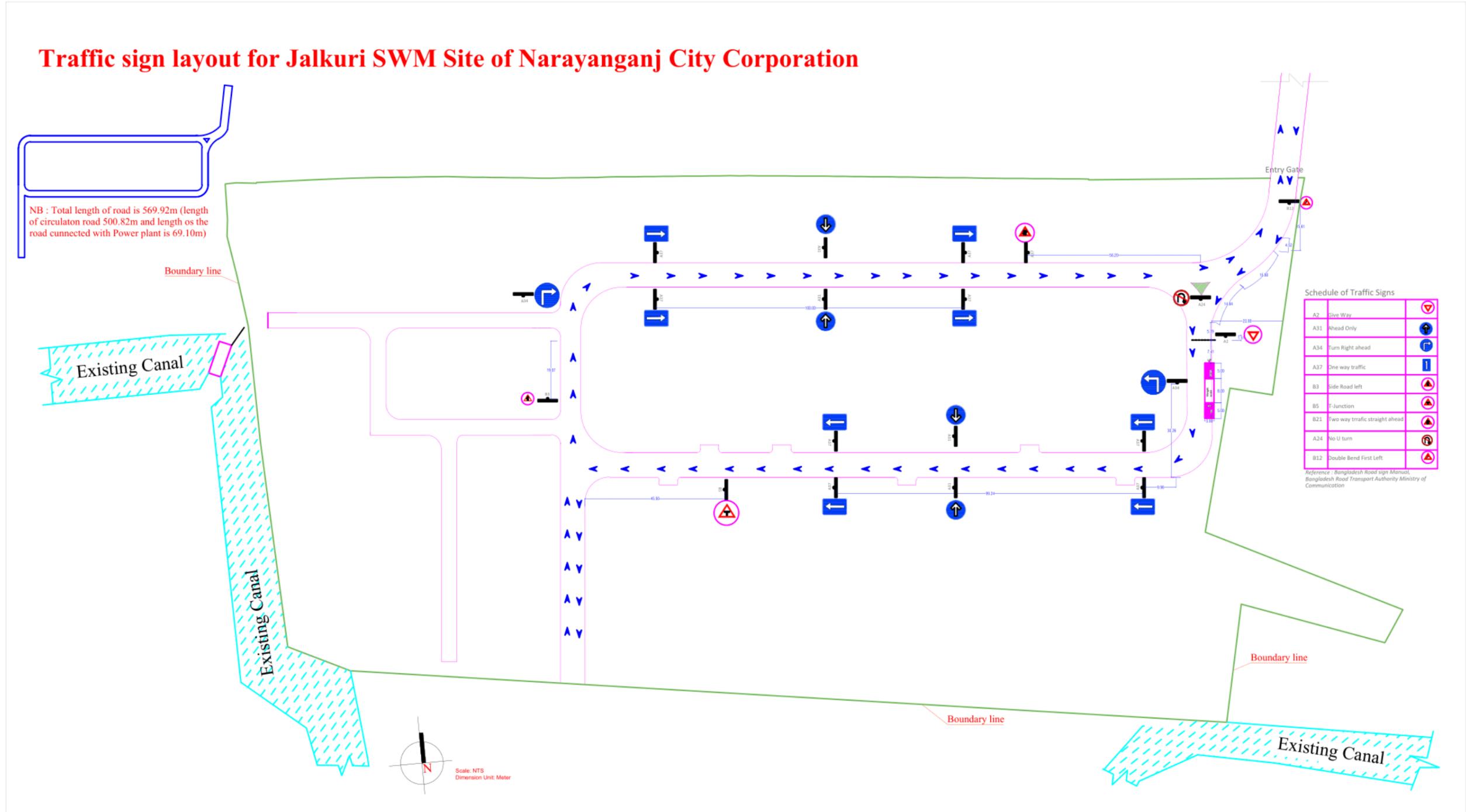


Figure 8- 10: Details of road network plan with traffic sign

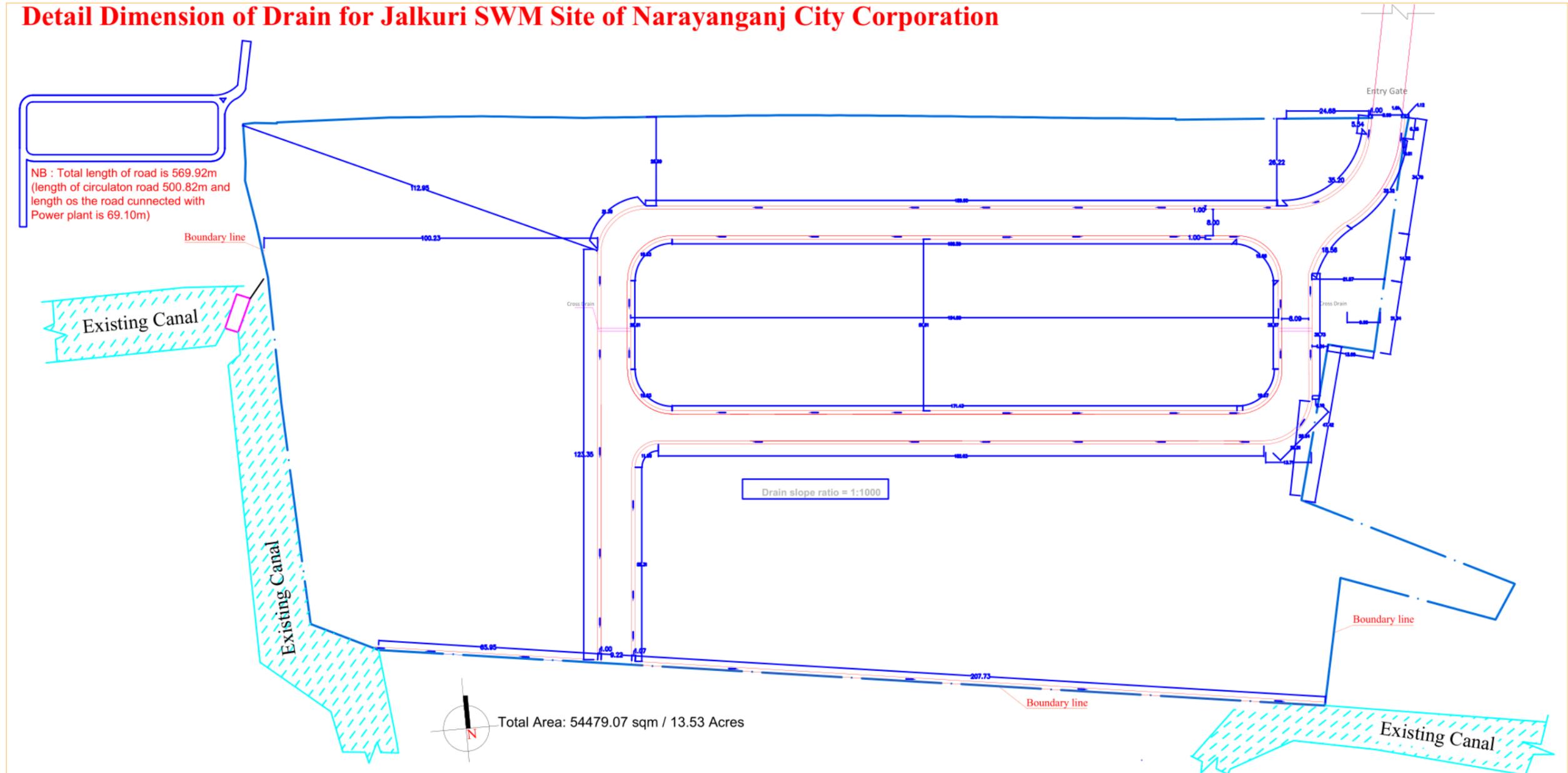
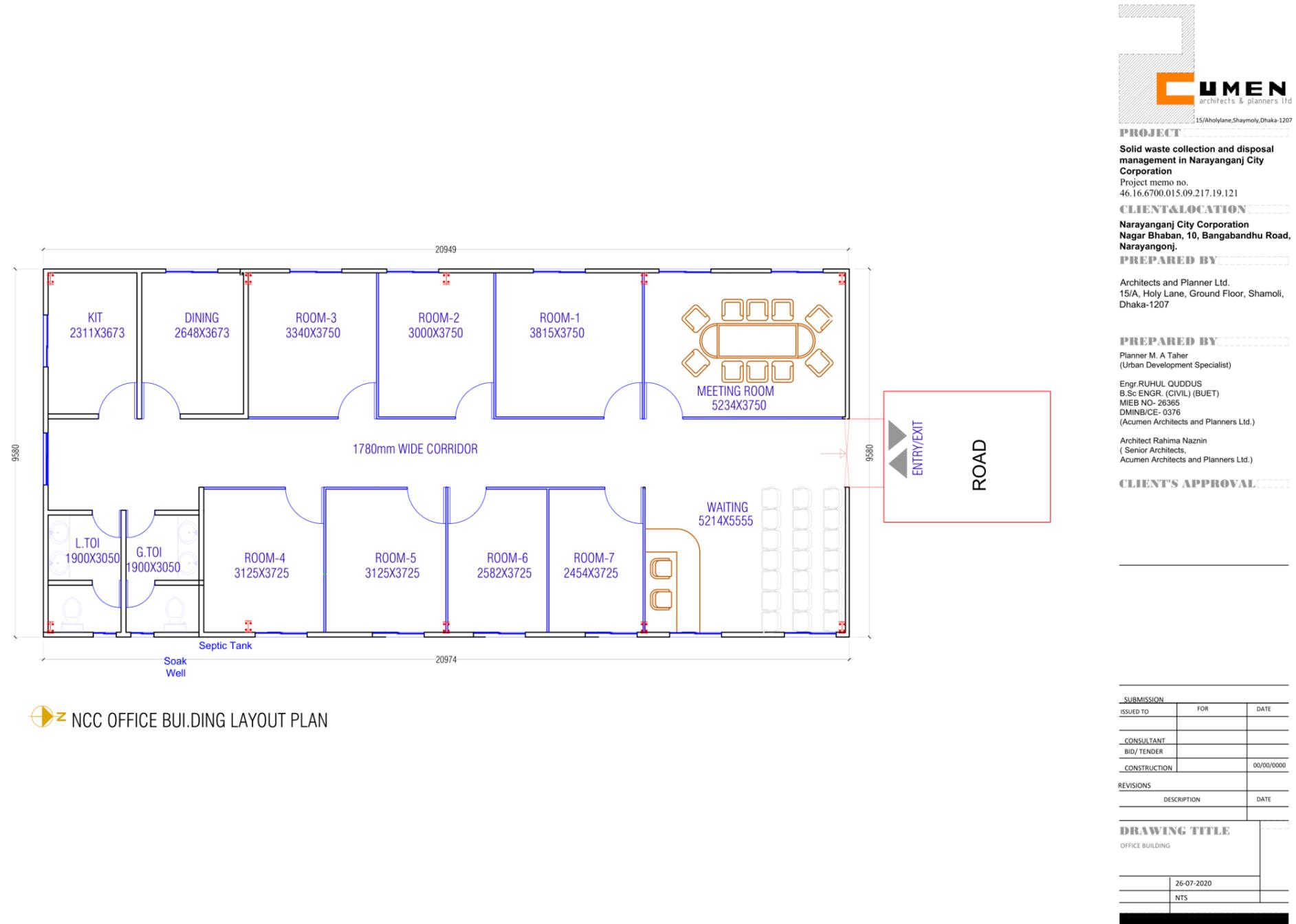


Figure 8- 11: Detail dimension of Layout plan of Jalkuri Landfill site



**PROJECT**  
 Solid waste collection and disposal management in Narayanganj City Corporation  
 Project memo no. 46.16.6700.015.09.217.19.121

**CLIENT&LOCATION**  
 Narayanganj City Corporation  
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**CLIENT'S APPROVAL**

SUBMISSION		
ISSUED TO	FOR	DATE
CONSULTANT		
BID/ TENDER		
CONSTRUCTION		00/00/0000
REVISIONS		
	DESCRIPTION	DATE
DRAWING TITLE		
OFFICE BUILDING		
	26-07-2020	
	NTS	

Figure 8- 12: Detail design and section of Office Building

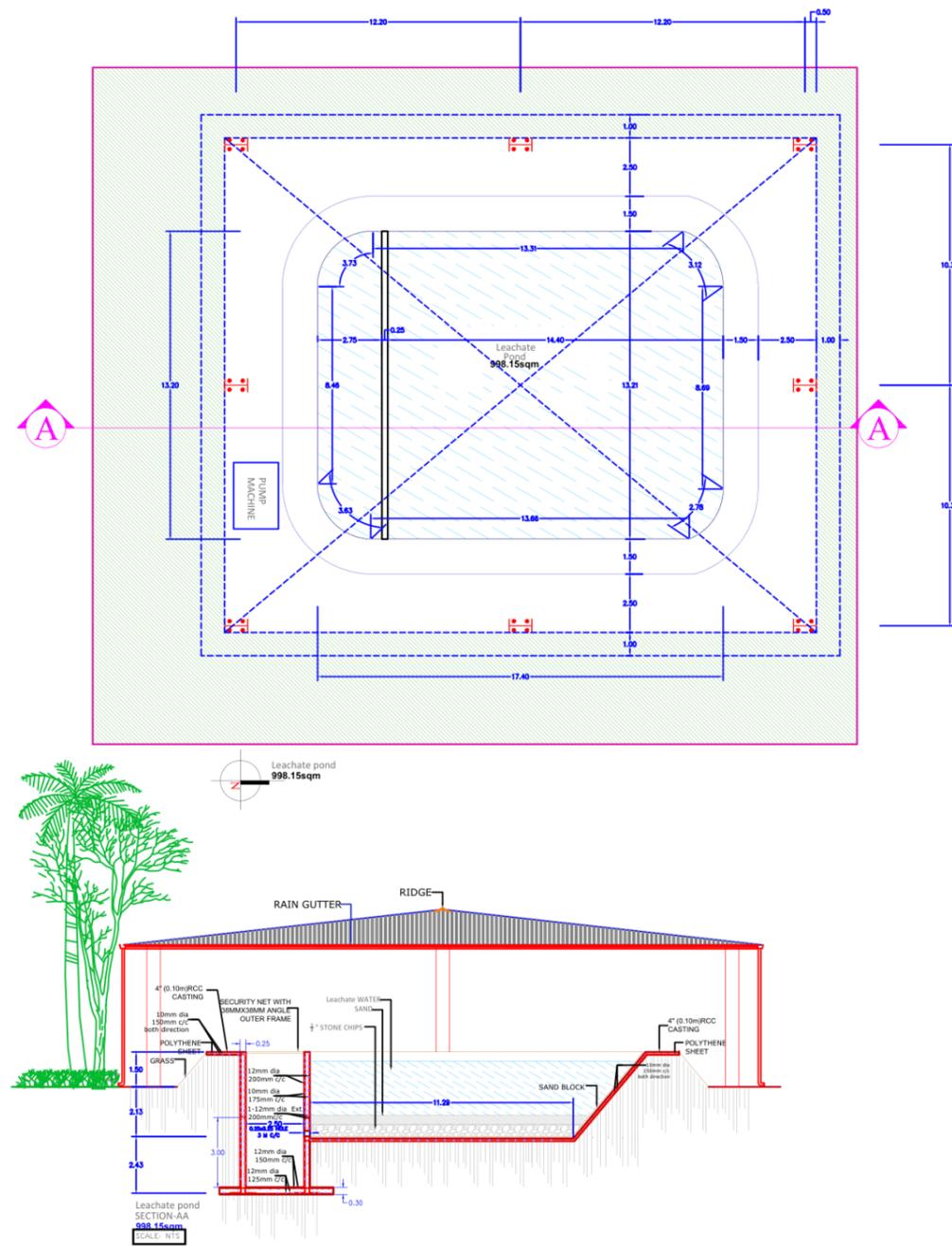


Figure 8- 13: Detail drawing, design and section of Leachate Pond

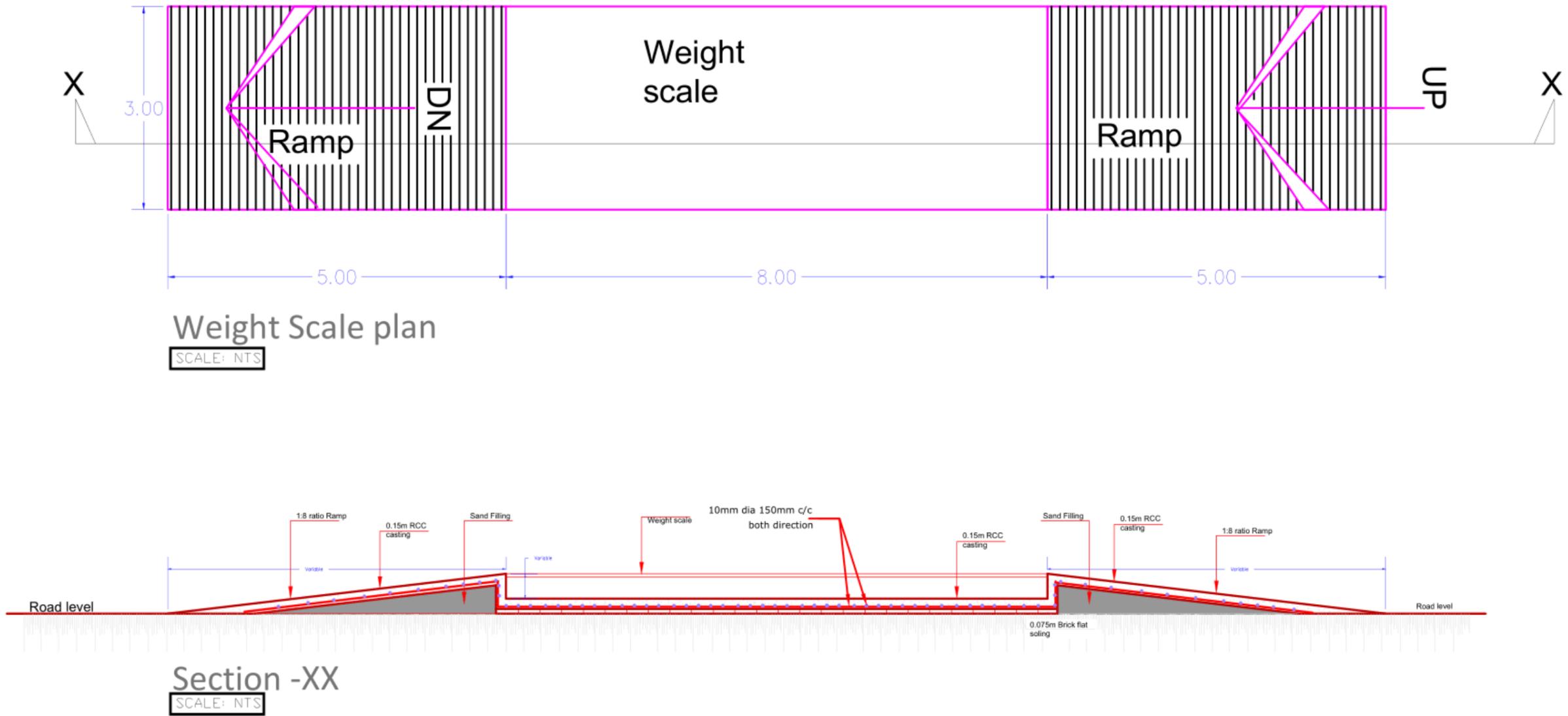


Figure 8- 14: Detail design and section of weight Scale

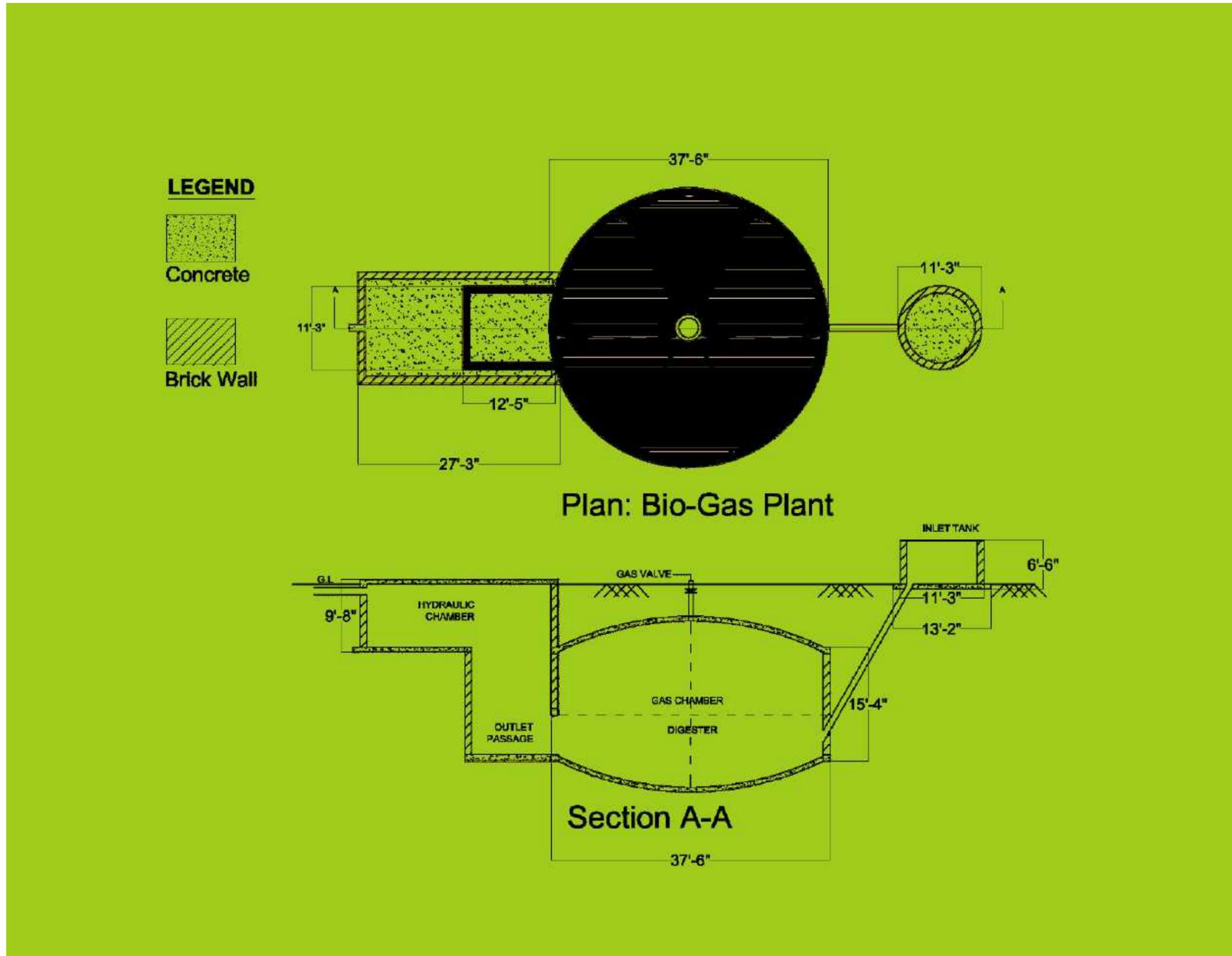


Figure 8- 15: Detail design and section of Biogas Plant

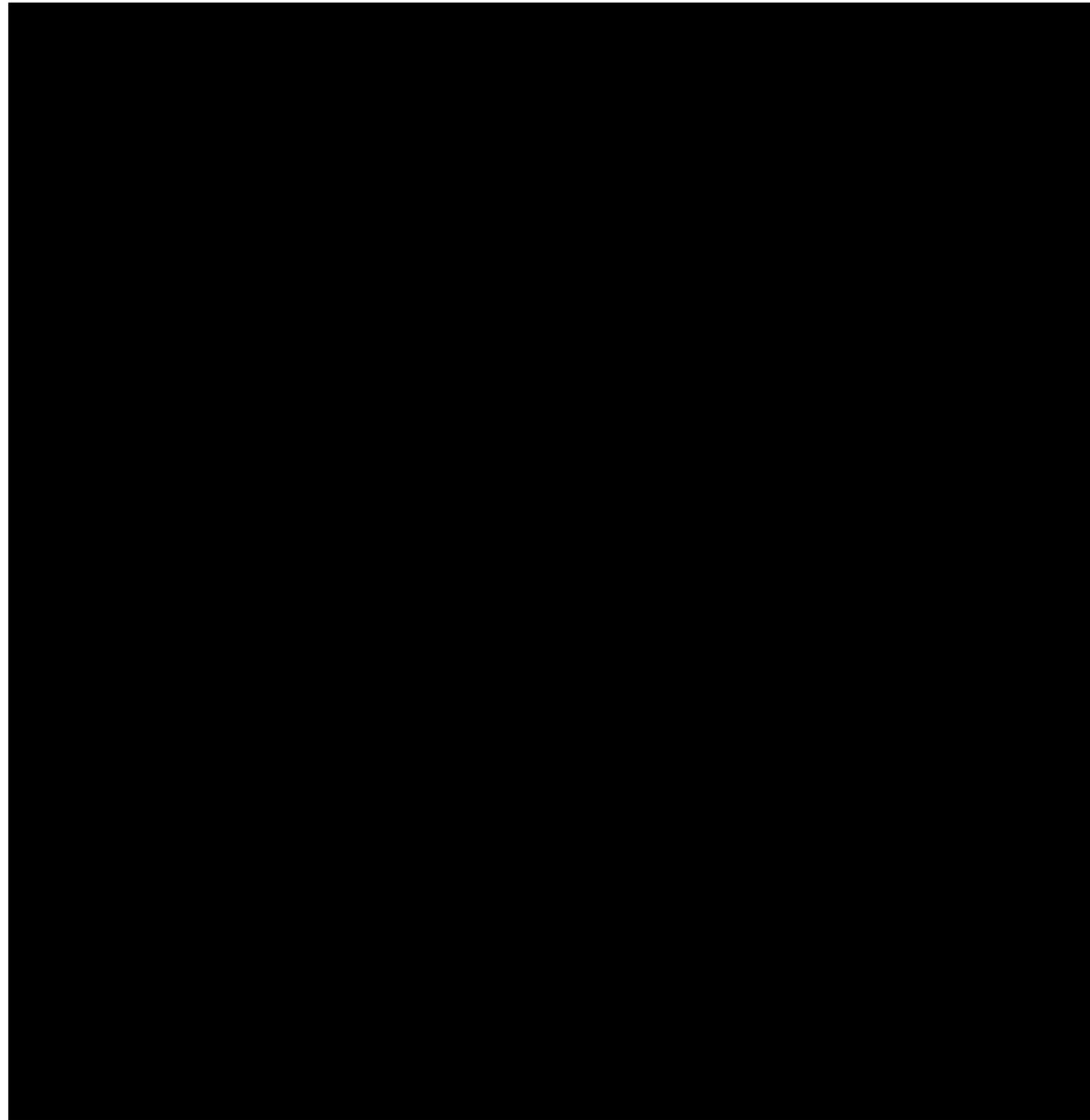


Figure 8- 16: Detail design and section of Gray water pond

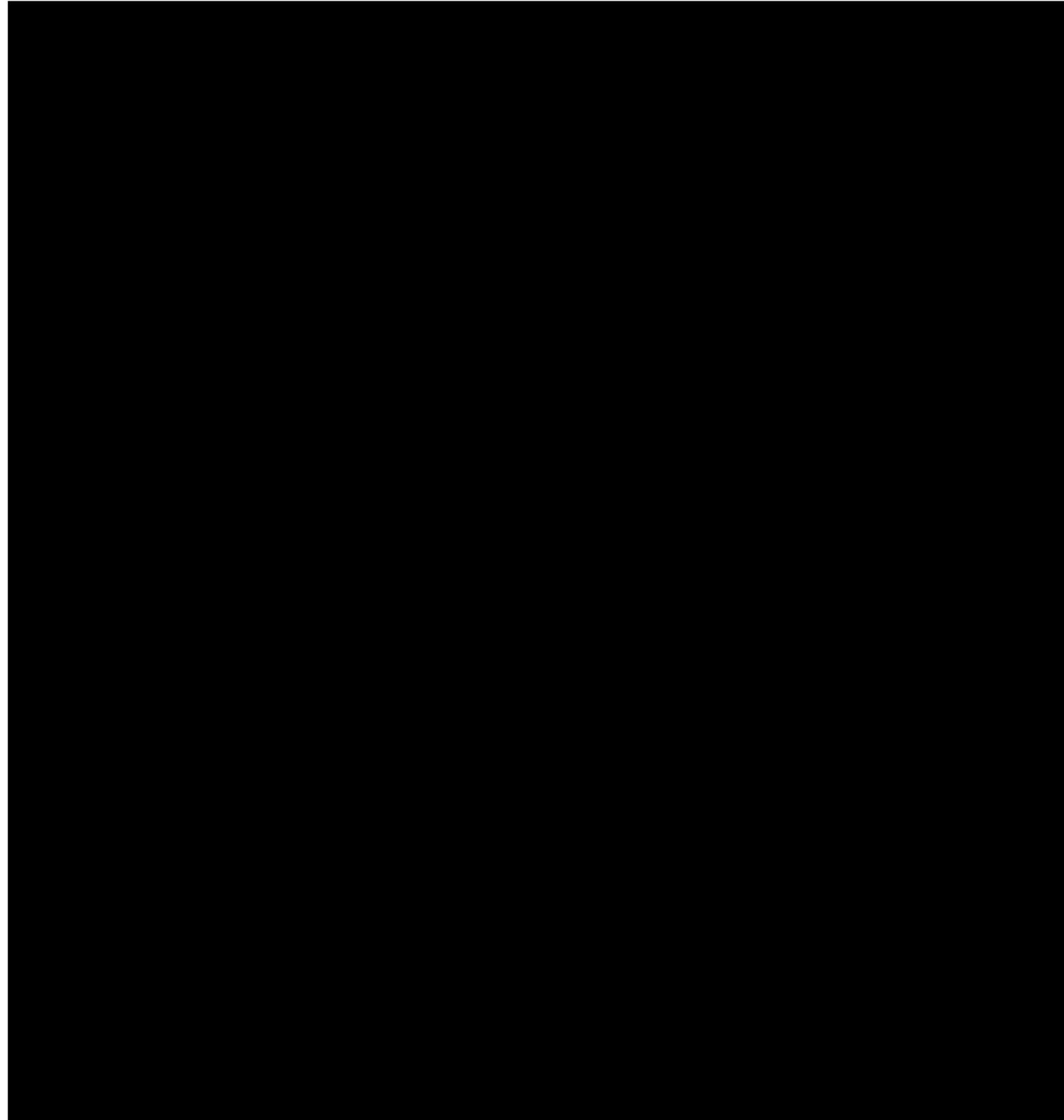


Figure 8- 17: Detail design and section of Pond-1

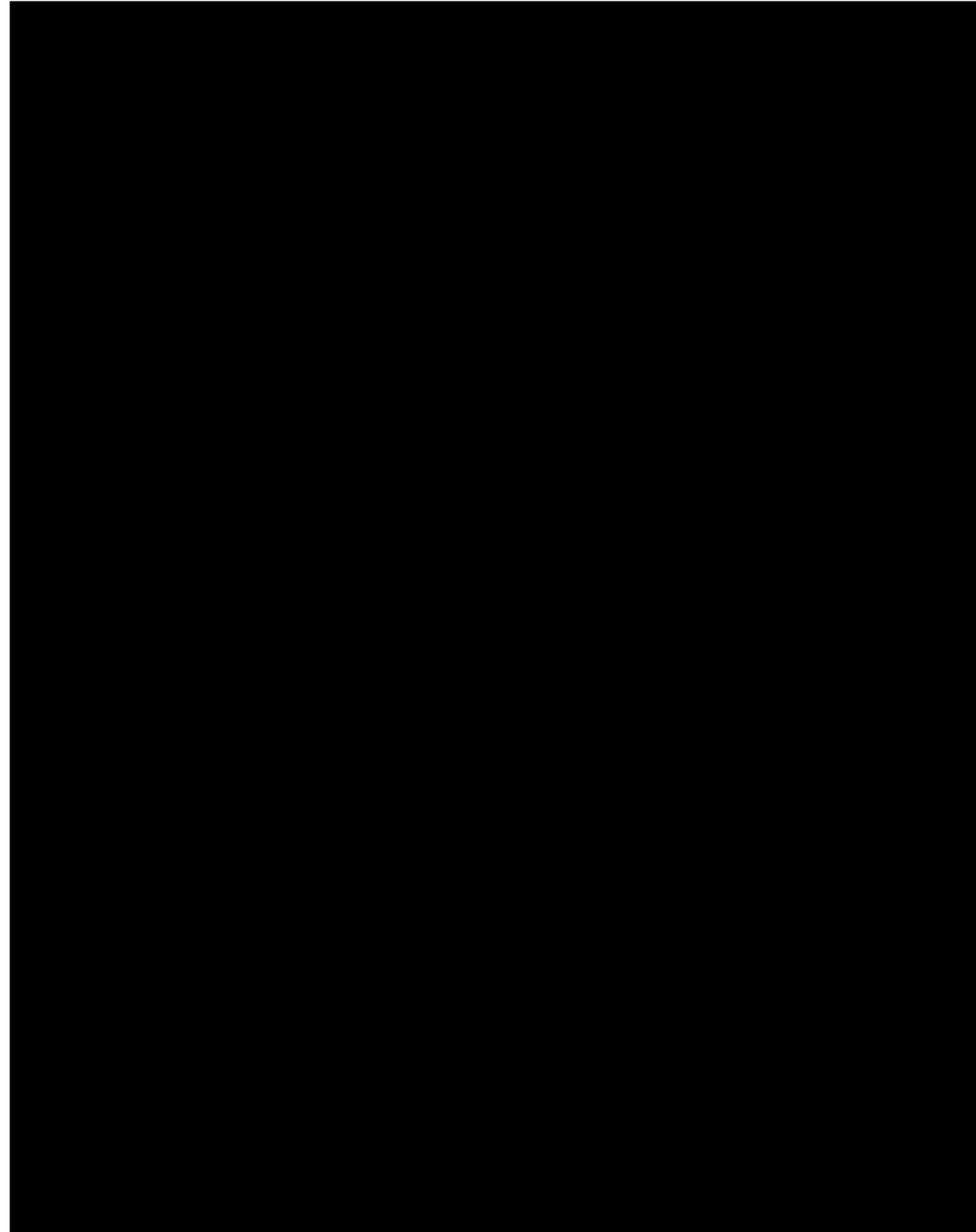


Figure 8- 18: Detail design and section of Pond-2

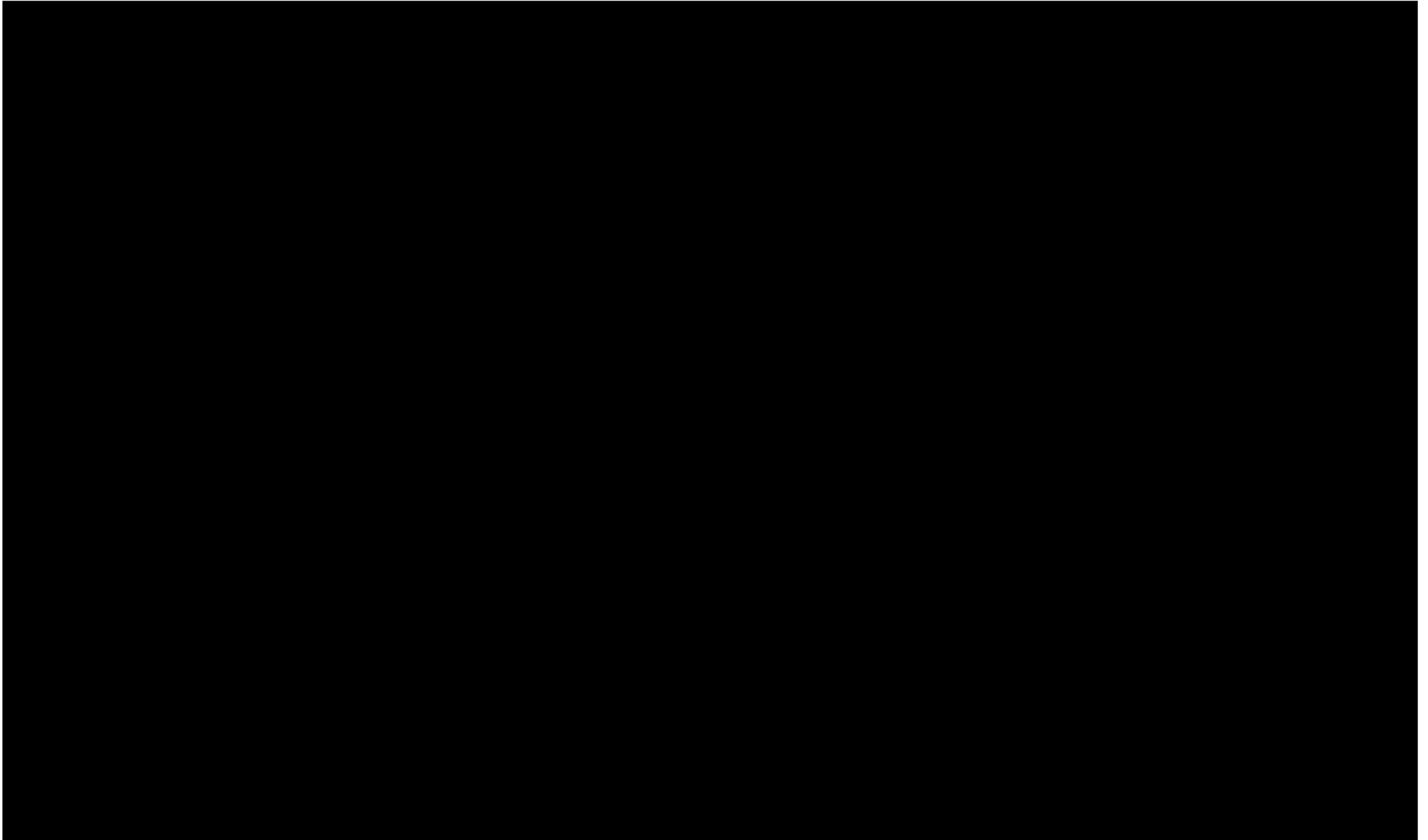


Figure 8- 19: Plantation for Jalkuri Landfill Site



Figure 8- 20: 3D Design of Entry Gate



Figure 8- 21: Internal 3D view of landfill site



Figure 8- 22: Internal 3D view of landfill site



Figure 8- 23: Internal 3D view of landfill site



Figure 8- 24: Internal 3D view of landfill site



Figure 8- 25: Internal 3D view of landfill site



Figure 8- 26: Internal 3D view of landfill site



Figure 8- 27: Internal 3D view of landfill site

# SOLID WASTE COLLECTION AND DISPOSAL MANAGEMENT IN NARAYANGANJ CITY CORPORATION



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**Client**  
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Figure 8- 28: 3D view of Layout Plant

SOLID WASTE COLLECTION AND DISPOSAL MANAGEMENT IN NARAYANGANJ CITY CORPORATION



Figure 8- 29: 3D view of Layout Plant



Prepared by



Acumen Architects and Planners Ltd.

Figure 8- 30: Alternate Road Network Plan for the Proposed site





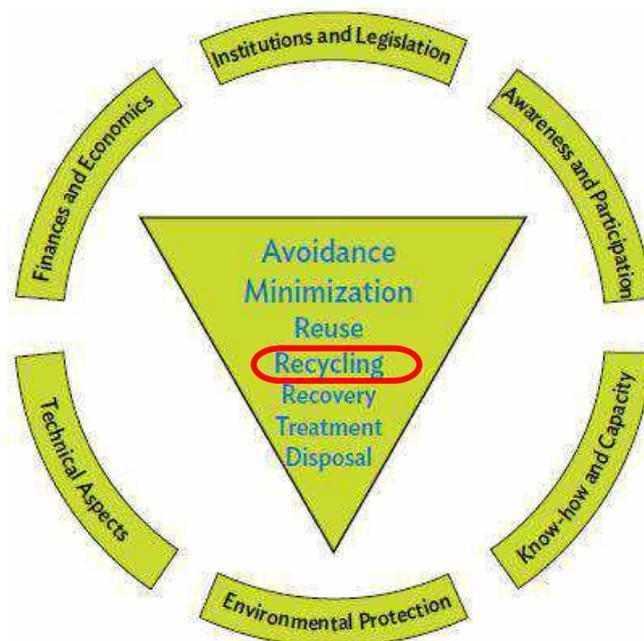
Figure 8- 32: Alternate 3D view of Landfill site

## CHAPTER 09: WASTE PROCESSING AND DIVERSION

### 9.1 Recycling

Recycling is a form of resource recovery that allows materials recovered to be used in a form similar to its original purpose, such as recycling paper for use again as paper or cardboard. Local governments should advocate recycling as it diverts a considerable amount of useful materials present in the waste stream from being disposed of in landfills while at the same time providing livelihoods. In terms of the local effort required, they must likewise ensure that they are complying with the requirements specified in legislation, such as achieving a certain percentage of recycling. Recycling, however, cannot be the global solution to waste management, since there will always be some residuals. Recyclables have to be market driven to be sustainable.

Recycling programs are always constrained by the makeup of the waste being processed. Generally, most of the higher value recyclables, such as metals, glass, and paper, are already removed to a significant degree by domestic reuse, scavengers, and agents.



**Figure 9- 1: Waste Management Hierarchy**

Recycling is a series of activities that includes:

- The collection of used, reused, or unused items that would otherwise be considered waste
- Sorting and processing the recyclable products into raw materials
- Remanufacturing the recycled raw materials into new products.

Consumers provide the last link in recycling by purchasing products made from recycled content. Recycling also can include composting of food scraps, yard trimmings, and other organic materials. Recycling prevents the emission of many greenhouse gases and water pollutants, saves energy, supplies valuable raw materials to industry, creates jobs, stimulates the development of greener technologies, conserves resources for our children's future, and reduces the need for new landfills and combustors.

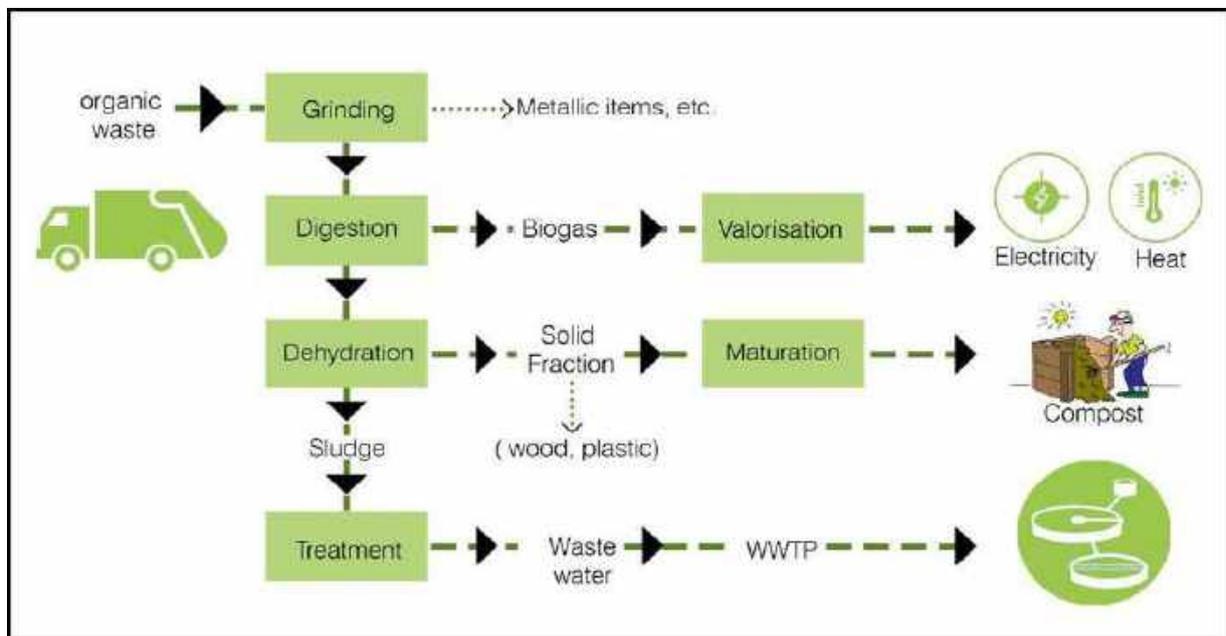


Figure 9- 2: Solid Wastes Conversion to Energy

Improper solid waste disposal poses a major threat to the environment and high risks to human health. Most of these wastes are biodegradable and can be converted into valuable resources that reduce their otherwise negative impacts. These wastes are generally in either a solid or a semi-solid form. They can be classified as biodegradable wastes that include the following: food and kitchen waste, green waste, and paper (recycled); recyclable materials (e.g., paper, glass, bottles, cans, metals, and certain plastics); inert waste (e.g., construction wastes, demolition wastes, dirt, rocks, and debris); composite wastes (e.g., clothing and tetra packs); waste plastics (e.g., toys); domestic hazardous wastes (also referred to as

household hazardous wastes); and toxic wastes (e.g., medication, e-waste, paints, chemicals, light bulbs, fluorescent tubes, spray cans, fertilizer, pesticide containers, and shoe polish).

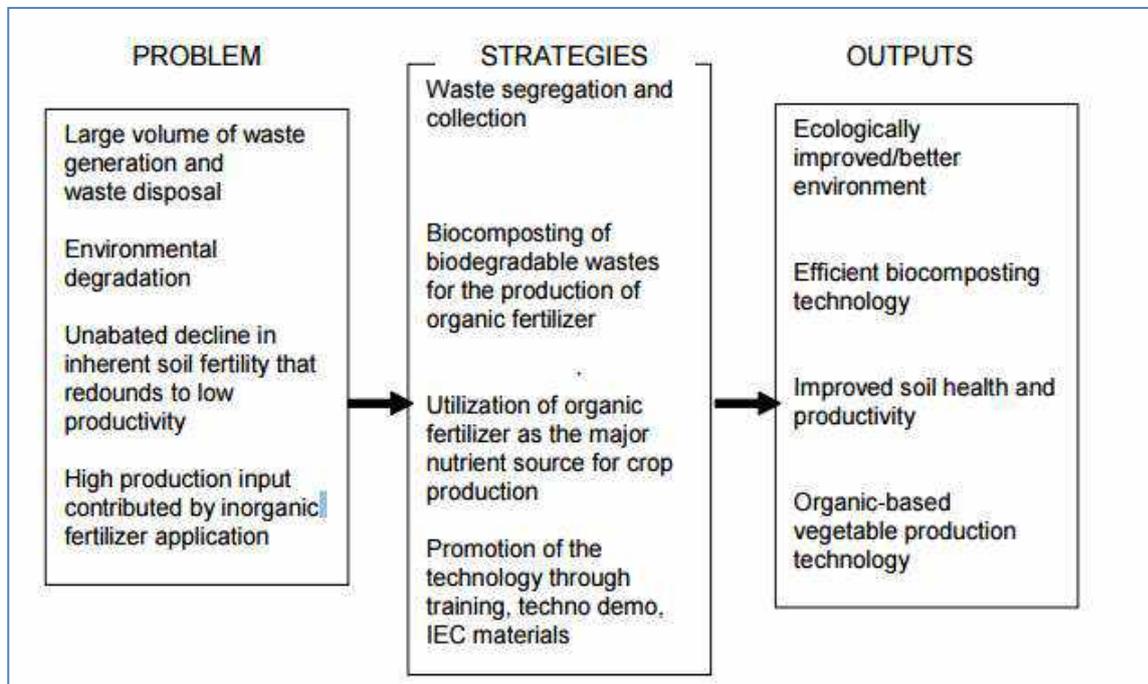


Figure 9- 3: Problems for Recovering the Solid Wastes

### 9.1.1 Collecting Recyclables

A lot of the things that people trash can be recycled. Prime examples include paper, newspaper, corrugated cardboard, high-grade paper, aluminum, steel (tin) cans, glass, plastic, motor oil, organic waste, and scrap metals.

Some notes on recycling:

- Paper with residues cannot be recycled in most cases. This is why used pizza boxes are not recyclable
- Recycling centers will not accept light bulbs, ceramic glass, dishes, or plate glass because these items consist of different materials than bottles and jars.
- Recyclable items not accepted by your city recycling programs may be accepted by local companies. For instance, glass might not be accepted by NCC’s recycling program but might be accepted by a supermarket.

Main recycling collection methods can be facilitated by NCC:

- There will be curbside collection facilities for homeowners to separate recyclables from their garbage. Clean recyclables may need to be placed in special containers, while the garbage goes in standard containers. Both are placed at the curb for collection by separate trucks.
- Drop-off centers are one of the simplest forms of collecting recyclable materials; NCC will facilitate this service where people can drop off their used glass, metal, plastic, and paper at a designated recycling drop-off site. These centers will be placed in an easily accessible location near a high-traffic area such as the entrances of supermarkets and parking lots.
- Buyback centers will be placed to purchase aluminum and other metals, glass, plastic, newsprint, and sometimes batteries and other materials.

Introducing a recycling or diversion program for green waste has the largest possible impact on the quantum of waste being recycled. Recycling programs must reflect the local environment in terms of domestic diversion or scavenging, local major recycling markets and haulage distances involved, as well as the local makeup of the waste stream. The best recycling programs are those developed to suit local conditions. Most high-value materials and useful reusable containers (domestic reuse) are usually recovered prior to the waste entering the landfill. As disposable income increases, diversion domestically decreases. In a typical waste stream, the remaining focus for recycling is typically on plastics and organics, in particular green waste.

### 9.1.2 Composting as Recycling

Composting is described in detail in a separate practice brief. However, for green waste (which accounts for up to half of the total waste stream in wet climates), the common approach to recycling is to separate it and then chip it. These green waste chips can be used for composting when mixed with high nutrient sludge, such as from a sewage treatment plant. They can also be used on parks and gardens or given to the local community. In most cases, introducing a recycling or diversion program for green waste has the largest possible impact on the quantum of waste being recycled. Aerobic composting (using abundant oxygenation) can be achieved in small- to large-scale facilities and is relatively quick to process. Nuisances and odors are also relatively reduced. Anaerobic composting (in the

absence of oxygen), on the other hand, takes far longer and produces objectionable odors, contaminating leachate and releases methane (a high strength greenhouse gas and flammable gas) into the atmosphere. Most domestic composting becomes anaerobic if the compost pile is not frequently mixed.

### 9.1.3 Lead-Acid Battery Recycling

There are also specialist roles in recycling, such as for automotive lead-acid battery recycling. Unskilled operations to recover lead usually result in gross pollution and disabling illness. The dispatch of whole batteries shrink-wrapped on pallets to recyclers in the Republic of Korea is simple and profitable. There are established agents shipping the batteries to the Republic of Korea from other countries, which might easily pick up additional loads. NCC can follow this Korean strategy to recycle lead acid battery.

### 9.1.4 Plastic Bag Recycling and Processing

There is very little opportunity for recycling plastic bags apart from burning as a fuel source or bringing in shredding equipment and melds to make plastic items such as posts, decking, chairs, and seats. However, given that most plastic bags are soiled in terms of either inorganic soil or organic material attachment, the overall environmental cost associated with having to clean and dry these bags, not to mention the higher labour content, would make such a scheme generally unattractive at the present time.

The plastic bags can be used as a fuel source in refuse-derived fuels or waste-to-energy facilities and hospital incinerators or laundries, cement kilns, and charcoal production where partial processing is sometimes required. Beverage containers can be recycled and are often chipped or crushed to increase their density, thereby making transport more efficient. Polyethylene containers and bottles and polyethylene terephthalate “rocket bottom” bottles may be reprocessed into outdoor furniture, roadside markers, and rot-proof planks for waterside uses, and they burn cleanly (as do the polyethylene shopping bags) with a fuel value equal to diesel or natural gas. In some locations, free plastic chair melds are provided by beverage manufacturers for nongovernment organization to reuse their scrap bottles to make extruded plastic products.

### 9.1.5 Recycling Mechanization

There are three stages of development for centralized recycling. The most appropriate stage typically depends on community wealth, which impacts the waste characteristics and the level of segregation.

The first stage is fully manual (scavengers). It is possible to improve conditions with personal protective equipment, weather covers, forming collectives to get better prices, and so on. Larger municipalities with significant distances to the landfill may profitably operate a transfer station, allowing segregation at the gatehouse, plus potentially scavenging in a large open concrete pit before dozer track roll compacting and pushing into transfer trailers parked below the pit chute to cart to disposal. This retains the advantages of scavenger sorting in a safer and more controlled environment.

The second stage is partially mechanical with selected mixed waste such as for refuse-derived fuels or composting.

The final stage is mechanically separating and packaging segregated waste. These fully mechanized recycling facilities or materials recovery facilities will only work sustainably on fully segregated waste.

### 9.1.6 Role of Municipalities

It is important for the municipality to take a supporting role rather than the leading role in recycling programs. There are many cases of market distortion when the municipalities establish their own facilities in direct competition with private sector recyclers. Almost always, the municipality reduces its direct involvement in running materials recovery facilities over the long term, meaning that the suppressed private sector then has to return to the recycling sector.

A suitable potential role for the municipality is to provide the equipment such as mobile chippers or the land area for stockpiling of recyclables prior to baling and sale. They should leave the primary role of recycling with the private sector (or may lease the sites). The other potential key role of the municipality is implementing an information, education, and communication campaign to encourage community awareness on the need for recycling

which would then support the private sector endeavours. The only need for intervention is if scavengers are paid an unfairly low price by agents.

## 9.2 Composting

Composting is the biological process in which organic matter is broken down into simpler compounds by the action of microorganisms. Compost is the product of decomposition of organic matter. This chapter describes the different aspects of the design of composting plants. The aesthetics of a composting plant must become an important component of the design to achieve sustainable development and to avoid repeating costly mistakes. A proper architectural approach to the design of a composting plant makes a substantial contribution to its integration with its surroundings and better acceptance by the public. The design and implementation of a composting plant involve a number of contributions from a variety of disciplines, such as architecture, civil works, and those involved in the technical facilities. A composting plant for size reduction and the stabilization of mixed organic waste will be located as close to the disposal site as possible. This typically is an interim solution because the landfill will eventually be closed. The closure plan for the landfill will aim at making the site inconspicuous in the landscape. The configuration of all the units of a composting plant has to be not only required by the necessity of the machinery, but also by the need of existing urban patterns and an aesthetical solution for the building.



Figure 9- 4: Typical compost plant

Organic waste can be composted aerobically (in the presence of oxygen and the desirable approach for most compost schemes) or anaerobically (in the absence of oxygen). Anaerobic compost can be highly odorous and is what effectively occurs in stable landfills. It is a suitable soil conditioner, as differentiated from a fertilizer. Composting is often promoted as a suitable scheme for managing organic wastes, such as food scraps and green waste, which often represent half the total waste stream. However, composting has not been consistently successful

in many developing and even developed countries, especially where food scraps are delivered to a centralized facility. There has been renewed interest in composting lately. However, the focus is more on composting chipped green waste, rather than food and vegetable scraps. Closed container fermentation for liquid fertilizer has been a recent trend for segregated food waste or commercial food processing waste in a number of developed countries.

### Interventions

Not all organics can be composted: no meat, oils, fish, dairy products, and bones should be composted as they can attract flies and vermin, can have a very high oxygen demand to decompose, and are odorous.

For a compost scheme of any size, two items must be right for successful composting:

1. Correct moisture content (40%–60%) and
2. Correct carbon (old grass clippings, leaves, paper, etc.) to nitrogen (food scraps, green grass, manure, etc.) balance.

Composting can be done at three levels:

1. Domestic or household scale;
2. Neighbourhood; and
3. Centralized scheme.

#### 9.2.1 Household composting

Domestic or household composting schemes are common throughout the world and are often done in conjunction with feeding scraps that cannot be used for domestic animals like chickens or dogs. There are many types of home composting bins such as old tires stacked up, timber slats, open weave plastic bags, and slotted plastic bins (specially made). Domestic

or home composting has an established operator and user and no legal liability issues unlike centralized systems. Obviously, this approach encourages waste segregation at source. Home composting reduces potential odor problems later in the collection, haulage, and disposal stages. It also helps municipalities minimize initial and operating costs. However, composting does have the following issues:

- ✓ It requires educating households.
- ✓ It will not work with only small land allotments.
- ✓ It may require initial investment by the municipality where households will not or cannot fund the small start-up expenses required.
- ✓ Not all organic wastes can be composted.
- ✓ Rotating suspended bins have the best chance of aerobic composting in the home. Unless carefully operated, compost will become anaerobic (lacking oxygen) and emit methane and leachate, which in aggregate (for many households) can be detrimental to the environment. Many municipalities in developed countries and elsewhere provide plastic cylindrical bins and ignore these negatives in order to avoid the disposal costs.
- ✓ Stacked tires should have the sidewalls largely removed so as to avoid insect and stagnant water being a mosquito micro breeding site and should be suspended above ground level on a frame to admit airflow for ventilation of the composting pile.

### 9.2.2 Neighbourhood Composting

If household compounds are too small, or control of associated insect or rodent pests needs a more structured processing area, neighbourhood-scale systems are the next option. This involves collecting compostable material from households and taking it to a neighbourhood scheme. The neighbourhood will have to develop and market the system, noting that the issues are much the same as centralized schemes. The municipality may ideally provide a mobile chipper upon demand several times a year, preferably for no charge. Many neighbourhood schemes have failed, however, due to odor, poor compost quality, lack of compost demand and sales, and poor levels of segregation at the household.

### 9.2.3 Central Compost Facility

The last option is a large central compost facility, but organics must first be segregated from nonbiodegradable wastes. At-source (household) segregation is preferred but very unlikely to be 100% effective. Therefore, mechanical segregation using costly equipment (costly to buy and run) is required. A basic set of equipment for a small neighbourhood scheme will cost in excess of \$100,000, excluding loaders and buildings. Even if this mechanized segregation is efficient, it often still allows contamination of the compost feed with glass, sharps, metals, meat, fish, etc. For example, a single small battery can cause a large quantity of compost to exceed the very stringent heavy metal level standards for food production. The main sustainability issue is usually the overall operating budget. A sustainable market must be found for the compost generated, and experience suggests this is often difficult as long-term demand is low. Farmers are unwilling to pay a sustainable price as they need to still apply artificial fertilizers to obtain the right nutrient content for crops. Compost alone will not achieve these nutrient levels. The best crop productivity outcome is a blend of fertilizers and compost, but this has to be economically attractive to the farmers and in most cases will require agricultural extension services and on going financial interventions. The only sustainable centralized composting schemes are those which are either fully funded by private operators in carefully selected markets with secure segregated feedstock or external donors supporting operations on an ongoing basis or large public-private partnership (PPP) schemes where product quality is not critical as the PPP partners are using the compost on trees or other less sensitive crops. An economic analysis taking into consideration the value of landfill airspace saved as a result of composting could be undertaken if considering such a composting scheme.

### 9.2.4 Green Waste Compost

Green waste is garden waste, lawn clippings, and tree trimmings. It often makes up a much larger fraction of the total organic waste stream than food scraps and is suitable for composting. Separate collection of green waste is common and it is usually chipped and used for

- compost (mixed with high-nutrient sludge) or trace elements and fertilizer;
- garden mulch;

- protection of initial placement over engineered linings, daily cover of active subcells, and establishing vegetative cover on final soil batters at landfills; or
- coarser woody material to improve road access in wet weather.

Organic wastes such as food scraps or green waste can be composted. For food scraps, generally household-based composting or in-vessel processing for liquid fertilizer are the best approaches. Both neighbourhood and central composting schemes utilizing food scraps commonly fail unless there is a local sustainable demand for compost and the market is willing to pay a sufficient price to make the compost operation economic. Numerous neighbourhoods or centralized composting schemes utilizing food scraps have failed because of the lack of a suitable compost market in the long term. Even if the economics can be made to work, there is a history of ongoing contamination from centralized composting schemes that reduces buyers' interest in the product. In many of the wetter climates, green waste is the dominant fraction of the total organic waste stream, compared with food scraps. Provided that green waste can be separated at source, it can then be chipped and composted or just mulched. Successful green waste composting schemes are usually established with a sewage treatment plant where dried sewage sludge is mixed with the green waste to provide the correct nutrient balance in the compost.

#### 9.2.5 Guidelines for organic fertilizer production from solid waste for NCC

- ✓ Collect raw materials (leaf litter, farm waste, household, and market waste, buffalo or goat manure, carbonized rice hull).
- ✓ Mix the materials at a ratio of 2:1:1 (2 solid wastes [household, farm, market]: 1 buffalo, chicken or goat manure: 1 carbonized rice hull).
- ✓ Moisten the mixed materials and shred to reduce the size and to enhance the decomposition process.
- ✓ Pile the shredded materials at the height of 100-150 cm under a shed and cover with plastic to increase the temperature, maintain moisture, and minimize the escape of gases to the atmosphere.
- ✓ Monitor the temperature of the pile weekly. Maintain 60% moisture in the pile. If the compost pile becomes dry, moisten it using compost leachate or manure tea.

- ✓ After two weeks, open and turn the pile thoroughly to facilitate uniform decomposition.
- ✓ Incubate for another two weeks or more depending on the type of compost material. If most of the compost material is composed of leaf litter and/or rice straw, decomposition is prolonged from 30 days to 60 to 75 days.
- ✓ After another two weeks, the compost is already mature. Matured compost material is compost that does not generate heat, has no smell of decomposing material, and looks like soil. Harvest the composted material and spread on a flat floor in the drying area for at least a week or to a moisture level of 30%. Avoid sun drying the harvested composted material.
- ✓ Shred and sieve using a 2-cm mesh prior to bagging.
- ✓ Pack the composted material using polyethylene plastic bags in a sack (50 kg/bag) and store it in a cool dry place.

### 9.3 Waste-to-Energy Emissions Management

The production of energy from waste is not a new concept, though it is a field that requires serious attention. Various energy conversion technologies are available. The selection, however, is based on the physicochemical properties of the waste, both the type and quantity of the available waste feedstock and the form of energy desired. The conversion of solid waste to energy will be undertaken with three main process technologies: biochemical extraction, thermochemical extraction, and mechanical extraction.

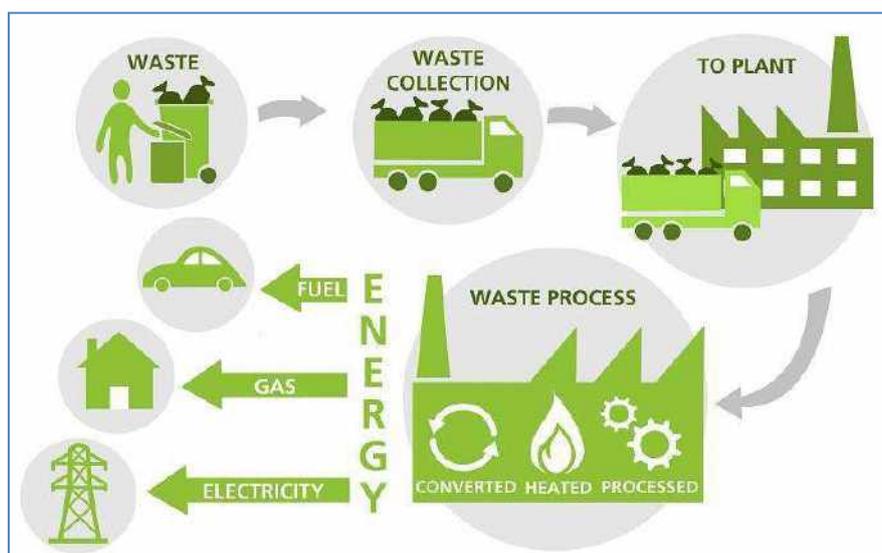


Figure 9- 5: Overall Process of Solid Wastes to Energy

### 9.3.1 Waste – Energy Models/Practices

**Waste Reduction:** Prevention, minimization, and reuse – product redesign

**Recycling and Materials Recovery:** 3Rs Generates income and employment;

eg: Construction waste

**Composting and Biogas Production:** Composting of organic matter with oxygen (aerobic) for agricultural fertilizers or fuel; anaerobic digestion – methane collected and combusted for energy;

**Landfill/Methane Capture:** Most common among all countries; must be done properly to protect the environment and public health. Landfill gas (LFG) from organic matter decomposition can be recovered and the methane (about 50% of LFG) burned with or without energy recovery to reduce GHG emissions.

**Incineration/Gasification:** Burning of waste to reduces volume of waste (up to 90%); energy recovery models with waste streams with very high amounts of packaging materials, paper, cardboard, plastics and horticultural waste. Burning without energy recovery is not recommended - results in air pollution, health problems.

### 9.3.2 Waste Pre-treatment Required for Waste to-Energy Incinerators

The primary goal of municipal solid waste (MSW) incineration is to reduce volume and mass and make the waste chemically inert in a non-polluting combustion process without the need of additional fuel. This process also enables recovery of energy, minerals, and metals from the waste stream. By using appropriate waste preparation and combustion conditions, an efficient combustion process can be reached, thus achieving the primary goals.

### 9.3.3 Waste Preparation Process

A key parameter in MSW combustion is the energy content or the lower calorific value or lower heating value in megajoules per kilogram. To ensure autothermic combustion of the waste, the lower heating value should not be below 7 megajoules per kilogram on average over a year. In developing countries, the lower heating value of unsorted MSW often is below this threshold due to a dominant organic content with high moisture. Also, a

significant level of inert waste fractions, such as ash or sand, could reduce the lower calorific value of MSW. Therefore, despite the pre-treatment process not being necessary for moving grate incinerators, sorting the waste can increase the efficiency of combustion or reduce air pollutant emissions. Fluidized bed incinerators are an example of incinerators that require pre-treatment to improve the combustion efficiency. Tables 3 and 4 show different types of waste sorting technologies and the impacts of removing certain MSW fractions to the incineration process. After being weighed by the weighbridges and throughout pre-treatment (if any) at the incineration plant, the MSW will then be unloaded to the waste storage bunker at the unloading platform. As mentioned earlier, since the MSW of most developing countries has a high organic content and high moisture content, the temperature of the combustion chamber could be lowered as a result and could degrade the combustion performance. Hence, the MSW received at the incineration plant should, in most cases, be kept in the waste bunker for about 3–7 days to drain away some of the leachate and excess moisture. As such, the bunker should be designed with sufficient capacity to at least store a few days of MSW. It should also be covered, protecting against additional moisture entering due to rain.

**Table 9- 1: Different Types of Waste Sorting Technology**

Technologies	Description
Size separation	Involves separation of mixture of materials into portions by means of one or more screening surfaces, which are used as go or no-go gauges. Typical equipment includes vibrating, trommel, and disc screens.
Density and/or mass separation	Separates materials based on their densities and aerodynamic characteristics. It has been applied to municipal solid waste on two major components: (i) the light fraction, composed primarily of paper, plastics, and organics; and (ii) the heavy fraction, which contains metals, wood, and other relatively dense inorganic materials. A typical example is light or heavy pneumatic separators.
Magnetic and electrostatic separation	Sorts out wastes based on their electrostatic charge and magnetic permeability of materials. In particular, magnetic separation is used to separate ferrous and nonferrous materials, while electrostatic separation can be utilized to separate plastics from paper, based on the differing surface charge characteristics of the two materials.
Optical sorting	Recyclables, especially plastics, are separated into the appropriate type of recyclables by using optical sensors.

Source: ADB, 2017

**Table 9- 2: Impacts of Removing Certain Municipal Solid Waste Fractions on the Incineration Process**

Glass, metals, ash, and minerals from construction and demolition waste	Increased calorific value Decreased quantity of slag and recoverable metals
Paper, cardboard and plastic	Decreased calorific value Decreased chlorine loads (e.g., from polyvinyl chloride) in emissions
Organic waste from kitchen and garden	Decreased moisture loads Increased calorific value
Bulky wastes	Reduced effort for shredding waste
Hazardous waste (e.g., batteries and electronics)	Reduced effort to remove toxic volatile heavy metals from air emissions (e.g., mercury) Reduced concentration of toxic pollutants in slag and fly ash (e.g., cadmium, lead, and zinc)

Source: ADB, 2017

The pros of WTE plants and associated electricity generation are the proven technology, electricity sale benefits (government contracted via a concession agreement that could provide regular income), little to no pre-treatment in the case of moving grate incinerators (see practice brief on Waste Pre-treatment Required for Waste-to-Energy Incinerators), able to meet high environmental performance standards if designed and operated properly, and a smaller footprint required than for landfilling. The cons of WTE plants are the long lead time to build the plant, high capital expenditure and operating costs, difficulty locating the facility due to public concerns, and a large capacity requirement (normally a minimum of 250–300 tons per day of waste throughput to be economical).

A range of technologies are available for each of the thermal treatment processes. The following are those that have been reviewed for the purpose of this comparative assessment:

- ✓ Moving grate incineration,
- ✓ Fluidized bed incineration,
- ✓ Rotary kiln incineration,
- ✓ Gasification,
- ✓ Plasma gasification, and
- ✓ Pyrolysis (conventional pyrolysis).

#### 9.3.4 Moving Grate Incineration

This is an incineration system equipped with an inclined moving grate system which keeps the waste moving through the furnace during the combustion process. It is one of the most widely used MSW incineration technologies worldwide with an extensive commercial track record. The moving grate system has a high operating efficiency regardless of the composition, calorific value, and moisture content of the MSW. Therefore, the MSW feedstock does not require extensive pre-treatment before undergoing the incineration process (if any) is not required to be extensive.

#### 9.3.5 Fluidized Bed Incineration

This is an alternative design to a conventional combustion system in which the moving grate is replaced by a floating bed of granular materials, such as sand, which can withstand high temperatures. There are two main types: bubbling and circulating beds. Pre-treatment of MSW is required for this system, usually by shredding, drying, and pelletizing. The process efficiency may also be improved by co-combusting waste with other homogeneous, high-calorific materials such as coal or woodchip.

#### 9.3.6 Rotary Kiln Incineration

This system provides good mixing and stoking of wastes, along with a high level of control of waste residence time, thereby resulting in more complete combustion. A significant advantage of a rotary kiln is that no waste pre-processing is required and that it is able to handle both liquids and solids. It is commonly used to treat hazardous wastes, including high-energy liquids. However, it has higher maintenance requirements than moving grate systems and capacity is restricted by limitations in drum size. Energy recovery efficiency is also lower as heat is lost through the metal shell of the rotating drum.

#### 9.3.7 Gasification

This refers to incomplete oxidation of organic compounds and conversion of combustible waste to syngas or producer gas at temperatures in the range of 500°C–1,800°C. Syngas comprises carbon monoxide, hydrogen, methane, carbon dioxide, water, nitrogen, argon, solid carbon, and contaminated substances such as tar, particulate, chloride, alkali metals,

and sulphide. The amount of air pollution substrates, particularly dioxins and furans, emitted from gasification is typically reported to be less than from mass burn incineration. Furthermore, although the types of air pollution control devices may be similar, they are smaller than for incineration. Gasification provides higher efficiencies and energy recovery rates along with lower investment cost than incineration. Therefore, gasification technology has a good potential to treat MSW in the future because of easy handling and burning of syngas, efficient conversion, low air pollution substrates, and the capability to scale down the technology. However, the current gasification plants in operation have a much lower unit and plant capacity than the moving grate incineration plants for mixed MSW treatment with their plant capacity generally ranging from 100 tons to 450 tons per day, respectively.

### 9.3.8 Plasma Gasification

This is a more recent advent in waste treatment technology. It entails the chemical decomposition of waste in a low-oxygen environment, utilizing a high-temperature plasma torch. The temperature of the plasma arc typically ranges from 2,700°C to 4,400°C. However, instances of temperatures up to 10,000°C have been reported. Plasma gasification plants have a comparatively low capacity range (between 20 tons and 500 tons per day), and high capital expenditure and operating costs. At present, it has not been widely adopted for MSW treatment.

### 9.3.9 Pyrolysis

This is an anaerobic indirect heat process in which organic waste is decomposed to produce oil, carbonaceous char, and combustible gases. These by-products are used as a fuel source and are burned to generate heat. Since oxygen is not required in the pyrolysis process, the volume of flue gas generated is lower than in the incineration and gasification processes. Unlike incineration and gasification systems, which are self-sustaining and use oxygen for waste combustion, an external heat source is required to drive the pyrolysis reaction. Relatively low temperatures (in the range of 400°C–800°C) are required for pyrolysis. Pre-preparation of the MSW is also required. Pyrolysis is not yet widely used as a treatment technology for MSW and information available for review is limited as many projects are still

in the pilot stage. Challenges include low energy production (due to the amount of energy required to power the process), difficulties in process optimization, and safety concerns.

### 9.3.10 Technical Feasibility

When evaluating the WTE technologies, moving grate incineration is believed overall to be the preferred option for developing countries for the following reasons:

#### I. Flexibility in Waste Composition

Moving grate incineration possesses a high level of flexibility to deal with variations in solid waste quality and composition. It also does not require extensive pre-processing of MSW (if any) in contrast to other systems (apart from rotary kiln incinerators) that require pre-treatment of MSW for higher efficiency. Moving grate incineration is also flexible in terms of treatment capacity, with

effective facility sizes ranging from 20 tons to 4,000 tons per day.

#### II. Electricity Production Efficiency

For conventional incineration systems (i.e., moving grate, fluidized bed, and rotary kiln), energy in the MSW is recovered through a near complete waste burning process and the heat energy is then diverted to waste heat boilers to generate steam for electricity generation using steam turbines. Although this process can result in greater heat loss as the energy is exchanged between the various systems, the electricity production is still considered to be acceptable to moderately efficient.

#### III. Reliability and Track Record

Broadly speaking, the greatest operational reliability at present is provided by moving grate incineration. This is by far the most widely used technology for both energy recovery from MSW as well as incineration without energy recovery. They have been proven to be robust and easy to maintain in comparison to other technologies.

#### IV. Land Requirements and System Complexity

Although moving grate incineration has a large footprint, each process unit has a large treatment capacity, requiring a smaller number of units to be installed for large throughput. In contrast, other technologies have a relatively smaller footprint, but each unit has limited treatment capacity, requiring a larger number of units to be installed for large throughput.

As such, for large volumes of MSW throughput, moving grate incineration can provide an optimal combination of land requirement and treatment capacity.

#### **V. Capital and Operating Costs**

In terms of cost efficiency, moving grate incineration is usually the go to option, as it has large treatment capacity (reducing the number of treatment units required), relative operational simplicity, widespread application, and low pre-treatment requirement (if any).

#### **VI. Air Emission**

Comparing with direct combustion technologies (i.e., rotary kiln and fluidized bed), moving grate produces the lowest volume of flue gas. Although the flue gas emissions may contain various pollutants, application of appropriate air pollution control technologies can mitigate the pollution and meet the international emission standards.

### **9.3.11 Economics**

WTE plants normally need to be designed and constructed for relatively large waste throughput. Facilities need to sell the electricity generated and, in most cases, charge a gate fee for the waste being incinerated to be economical. The facilities are usually provided through a public–private partnership or similar arrangement, and the concession is usually more than 25 years to allow capital cost recovery by the operator.

There are many options and issues to be considered for WTE facilities. Some processes are more efficient than others, others require more waste pre-treatment, others need large quantities of waste to be economic, and yet others are effectively only emerging technologies with few full-scale functioning facilities. Municipalities therefore should be very cautious of being influenced by marketing materials associated with WTE facilities and should retain experienced WTE independent consultants to guide their decisions. The consultant suggests pyrolysis WTE for NCC.

### **9.3.12 Detail of Pyrolysis**

Pyrolysis is the decomposition of organic compounds under an oxygen-free (anaerobic) atmosphere that produces gas, oil, carbon black, and steel. Efficient industrial Pyrolysis is a process to treat rubber and industrial plastic wastage as well.

### 9.3.12.1 Technical Details

- This is a batch process system.
- The waste tires are fed into the reactor vessel and heated under a controlled amount of temperature and pressure.
- The process will bring about a molecular restructuring of the rubber under the pyrolysis process as the result; furnace oil in gaseous form is produced along with other gases.
- These vaporized gases are passed through heat exchanges, wherein the furnace oil is condensed into liquid form.
- During the process, carbon black and steel are also generated.
- The heat exchanger uses coolant water, as a condensing medium and this water is Re-circulated through the process.
- These systems can be operated 24\*7/365.

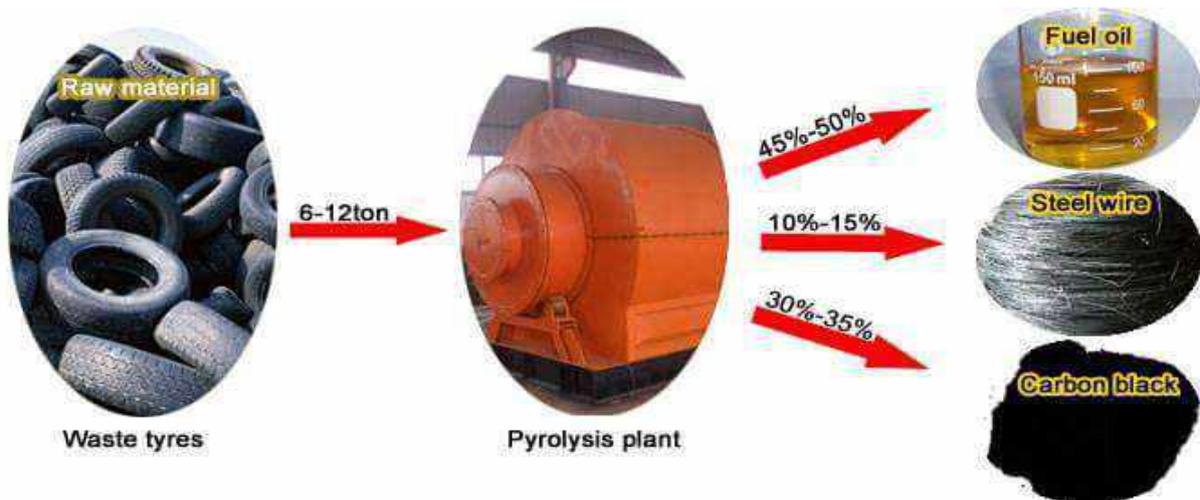


Figure 9- 6: Steps of Disposal of Waste Tiers

### 9.3.12.2 Output Products

- Pyrolysis Oil or Fuel Oil (45 to 50%)
- Uses: Fuel oil for industrial and commercial purposes
- Carbon Black (30 to 35%)
- Uses: Electric cable jacketing, Carrier Bands, Rubber additive
- Steel Wire (10 to 15%)
- Uses: Steel re-rolling, For ETP
- Gas (10 to 15%)

- Uses: Source of energy for pyrolysis, can be replaced where natural gas and propane are stored.

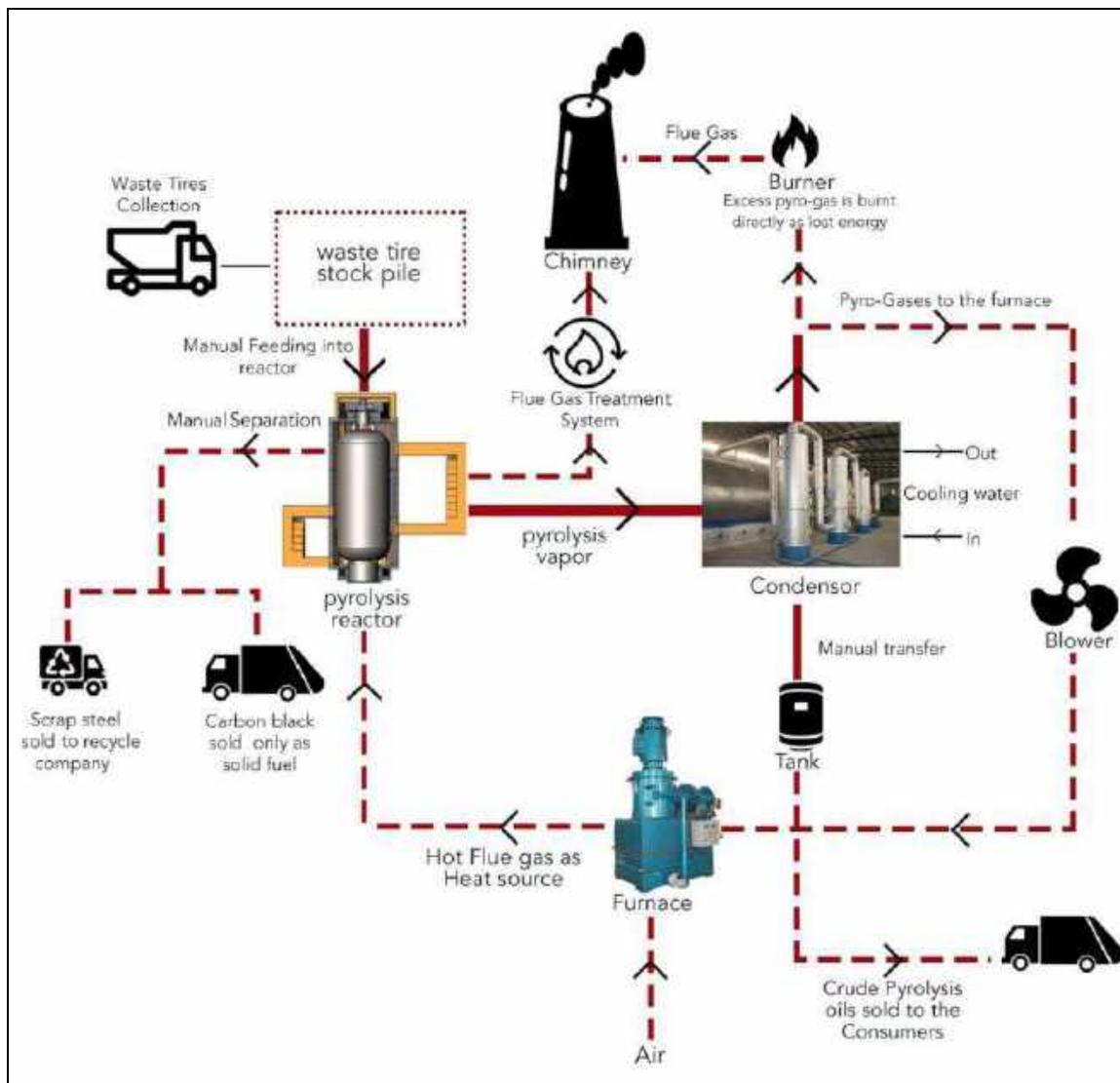


Figure 9- 7: Overall Process of Pyrolysis

### 9.3.13 Overview of Waste-to-Energy Options for NCC

This section presents the assessment of the electrical power generation potential from municipal solid waste (MSW) in Narayanganj City Corporation (RCC), Bangladesh. NCC generates a huge amount of solid waste (SW) which is left very poorly managed due to a crisis in governance. About 80% of organic food wastes are the major constituents of SW generated in NCC in the year 2019. Electrical energy can be produced from SW generated in NCC as a sustainable commercial solution. The average calculated value of the heat content of MSW of the year 2012 based on the data of MSW of 2005 (MSW: 2005) and MSW of 2012

(MSW: 2012) is 7234.5 kJ/kg, which is sufficient to produce electricity. Integrated sustainable waste management (ISWM) has to be put into operation to harness energy from MSW. A 645.543 ton/day energy recovery Mass Burn Incinerator (MBI) system of 19.71% overall efficiency is to be used. It is found that the potential of electrical energy generation from MSW in NCC is 3-5 MW (500 tons of waste). The government plans to generate electricity using 500 metric tons of solid waste in Narayanganj. Bangladesh Power Development Board (BPDB) has already signed a memorandum of understanding (MoU) with Narayanganj City Corporation (NCC). The PDB will implement the 3MW-5MW waste-based IPP power project at Jhalkuri in Narayanganj.

Subsequent systems for WTE-facilities and the underlying concepts were evaluated for their conformity with state-of-the-art-standards. The consultant takes into consideration both, biogas generation concepts as well as thermal treatment concepts, in particular incineration, but also gasification and pyrolysis. Where such systems, facilities, and concepts do not meet the formulated requirements, it will be particularly highlighted in which points and to what extent they do not conform to the given conditions.

**In accordance with international standards, the chosen technologies and concepts shall support the following waste management objectives:**

- The re-processing of waste by the way of recycling, re-use or any other process aiming at the extraction of secondary raw materials
- The production of energy from certain waste.

The concepts will include necessary pre-treatment of waste or a combination of different technologies, e.g. mechanical-biological treatment together with a thermal treatment process. Sustainable infrastructure for organic waste management will be put in place with biogas plants.

#### 9.3.14 Thermo chemical conversion

Thermal conversion is one component in a number of integrated waste management solutions proposed in various strategies. Four main conversion technologies have emerged for the treatment of both dry and solid wastes: combustion, gasification, pyrolysis, and liquefaction (to produce an intermediate liquid or gaseous energy carrier) and are as follows:

Combustion is the burning of biomass in air. It is used over a wide range of commercial and industrial combustion plant outputs to convert the chemical energy stored in the solid waste into either heat or electricity. Combustion uses various items of process equipment, such as boilers and turbines. In theory, any type of biomass can be burned in practice; however, combustion is feasible only for biomass with a moisture content <50% unless the biomass has been pre-dried.

The gasification process involves treating a carbon-based material with either oxygen or steam to produce a gaseous fuel. The gas produced can be either cleaned and burned in a gas engine or transformed chemically into methanol that can be used as a synthetic compound.

Pyrolysis is the heating of biomass in the absence of oxygen to produce liquid (termed bio-oil or bio-crude), solid, and gaseous fractions in varying yield. Pyrolysis depends on a range of parameters such as heating rate, temperature level, particle size, and retention time. Liquefaction is the low-temperature cracking of biomass molecules as a result of high pressure to produce a liquid-diluted fuel. Liquefaction employs only low temperatures of around 200 °C to 400 °C.

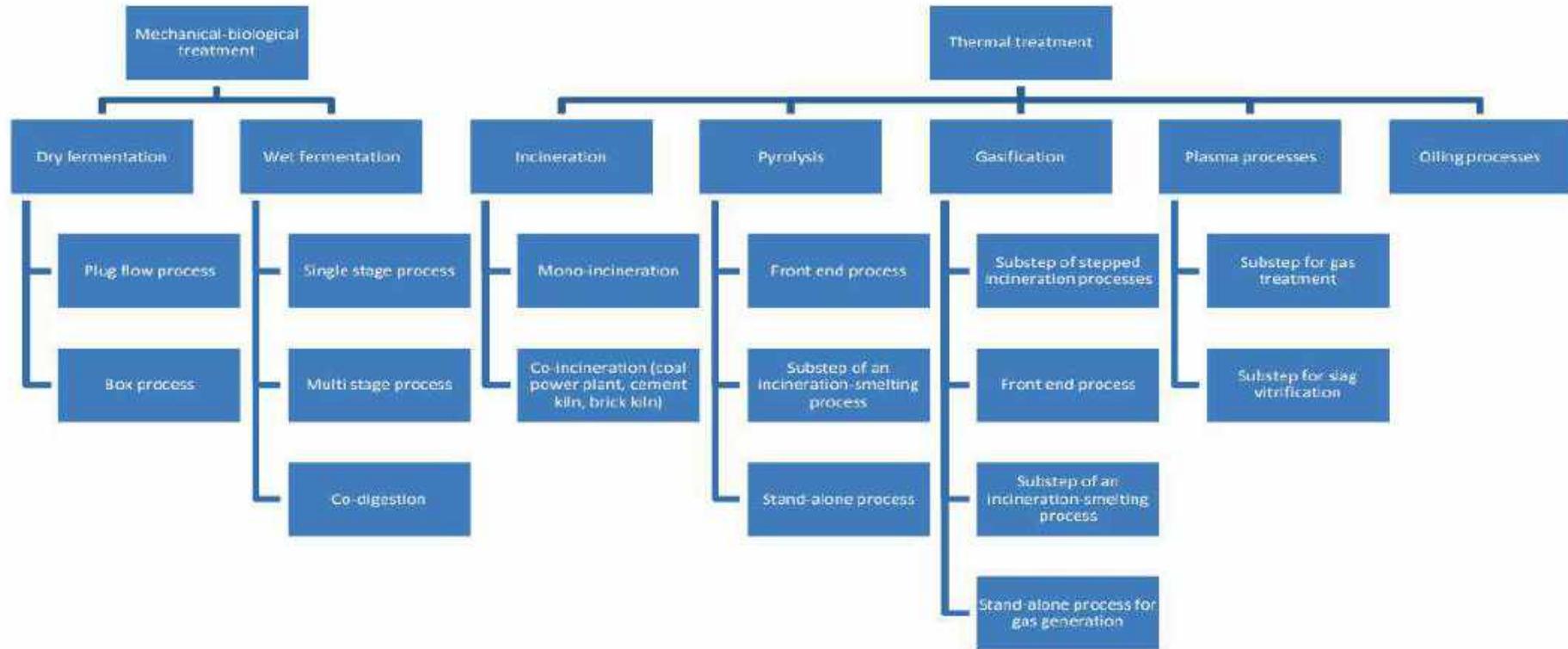


Figure 9- 8: Overview diagram a WTE-Technologies

### 9.3.15 Mechanical extraction

Mechanical extraction can be used to produce oil from the seeds of solid waste. Rapeseed oil can be processed further by reacting it with alcohol, a process known as esterification, to obtain biodiesel. The type of energy produced from biogas depends directly on the buyer's needs. These needs can be broken down into three categories: electricity generation, heat and steam generation, and transportation of fuel.

### 9.3.16 Electricity generation

The most common form of energy production today is through well-designed facilities and are as follows:

Combined heat and power (CHP) generation, also known as cogeneration, is an efficient, clean, and reliable approach to generating both power and thermal energy from solid waste. When a CHP system designed to meet the thermal and electrical base loads is installed, it can greatly increase a facility's operational efficiency while decreasing its energy costs, and CHP can also reduce greenhouse gases, which contribute to global climate change.

The conversion of biogas to electricity via fuel cell technology offers significant increases in efficiency and, hence, is highly sought-after technology. Several biogas installations utilize molten carbonate fuel cell technology. However, solid oxide fuel cell technology is thought to be the most promising technology due to its higher power density and its applicability to a wide range of scales.

Biogas can be used as motive power for the production of electricity using engines. A biogas-fueled engine generator will typically convert between 18% and 25% of biogas to electricity. The biogas engine depends on engine design and load factors. Small gas turbines that are specifically designed to use biogas are also available. An advantage of this technology is lower NO<sub>x</sub> emissions and lower maintenance costs. These turbines, however, are not as efficient as IC engines. Additionally, they cost more than IC engines.

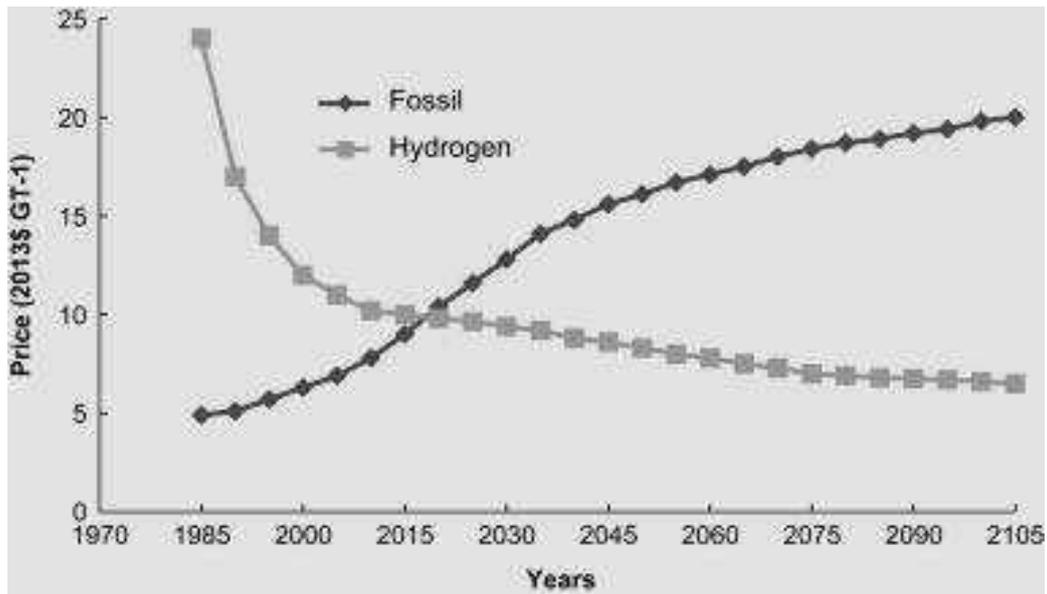


Figure 9- 9: Fossil fuel and hydrogen price predictions vs. time

**Heat and steam generation:** Producing and selling both heat and steam requires the existence of available industrial customers. They should be matching the supply with their needs. Steam can also be used at institutional domestic complexes.

**Transportation fuel:** Biogas is used as a transportation fuel in a number of countries. It can be upgraded to natural gas quality for use in normal vehicles designed to use natural gas.

Abedin, M. N. (2012). *Public Private Partnership in Service Delivery: An Evaluation of National Sanitation Program of Bangladesh*. Institute of Governance Studies, Brac University, Dhaka, Bangladesh.

Abedin, M., & Anwarul M. (2015). *Waste generation and management in Bangladesh: An Overview*. Retrieved March 15, 2020, from [file:///E:/Acumen/Jisan/To%20Shahadat%20Vai/Chapter%2004/Resource%20artical/Waste\\_generation\\_and\\_management\\_in\\_Bangladesh\\_An\\_o.pdf](file:///E:/Acumen/Jisan/To%20Shahadat%20Vai/Chapter%2004/Resource%20artical/Waste_generation_and_management_in_Bangladesh_An_o.pdf)

Abedin, M., & M. Jahiruddin, M. (2015). *Waste generation and management in Bangladesh: An Overview*. *Asian Journal of Medical and Biological Research*. 1, 1-3. Retrieved March 15, 2020, from [file:///E:/Acumen/Jisan/To%20Shahadat%20Vai/Chapter%2004/Resource%20artical/Waste\\_generation\\_and\\_management\\_in\\_Bangladesh\\_An\\_o.pdf](file:///E:/Acumen/Jisan/To%20Shahadat%20Vai/Chapter%2004/Resource%20artical/Waste_generation_and_management_in_Bangladesh_An_o.pdf)

Alam, M.M., and Rashed, M.A. 2011b. *Private Sector Participation in Infrastructure Development: A Non-Residence Infrastructure Fund in Bangladesh*, *Journal of Bangladesh Studies*, Vol. 13(1), pp. 34-38.

Ashikuzzaman, M., & Howlade, M. (2019). *Sustainable Solid Waste management in Bangladesh: Issues and Challenges*. *Research Gate*, 3-4. Retrieved March 10, 2020, from [file:///E:/Acumen/Jisan/SWM%20Master%20Plan/New%20folder/Sustainable-Solid-Waste-Management-in-Bangladesh\\_Issues-and-Challenges.pdf](file:///E:/Acumen/Jisan/SWM%20Master%20Plan/New%20folder/Sustainable-Solid-Waste-Management-in-Bangladesh_Issues-and-Challenges.pdf)

Association for the Sustainable use and Recovery of Resources in Europe (ASSURRE) profile, (October 2000) Brussels, Belgium.

Ballinger, Ann (Eunomia). *Anaerobic Digestion: Climate Change Impacts of Treatment*. Sept. 2011. <http://www.eunomia.co.uk/reports-tools/anaerobic-digestion-climate-change-impacts-of-treatment/>

Bahauddin, k., & Uddin, M. (2012). *Prospect of Solid Waste Situation and An Approach of Environmental*. *J. Environ. Sci. & Natural Resources*,5, 1-3. Retrieved April 09, 2020, from <file:///E:/Acumen/Jisan/To%20Shahadat%20Vai/Chapter%2004/Resource%20artical/11601-Article%20Text-42733-1-10-20120808.pdf>

BKH, "Solid Waste Management, Housing Development Project", UNDP/UNCHS (Habitat), Bangladesh, 1986

Bochmann, G., and Montgomery, L., (IEA Research cooperation). Pre-treatment Technologies for Anaerobic Digestion. Available from: [http://www.iea-biogas.net/files/daten/redaktion/download/publications/workshop/14\\_spring/Feedstock\\_Pre-treatment\\_Guenther\\_Bochmann\\_04-2014.pdf](http://www.iea-biogas.net/files/daten/redaktion/download/publications/workshop/14_spring/Feedstock_Pre-treatment_Guenther_Bochmann_04-2014.pdf)

BPSIG, 2004. Bangladesh Private Sector Infrastructure Guideline, Government of Bangladesh.

Center for Policy and Implementation Studies (CPIS). 1993. "Enterprises for the Recycling and Composting of Municipal Solid Waste." Volume 1: Conceptual Framework

Chowdhury, M.S.R. (2016). Problem Analysis and Overcome Strategies of Public Private Partnership in Bangladesh. University of Chittagong, Bangladesh.

Combined heat and power station brochure, (without year) Haderslev, Denmark.

"Composting Yard Trimmings and Municipal Solid Waste" (1994) by U.S Environment Protection Agency (EPA), Office of Solid Waste and Emergency Response.

Cointreau–Levine, (1994) Private sector participation in solid waste services in developing country, the World Bank.

Connet, Paul. (1998) 4th annual international management conference, waste to energy, Amsterdam.

Daily Star. (2019, October). When the garbage piles up. Dhaka. Retrieved April 05, 2020, from <https://www.thedailystar.net/opinion/environment/news/when-the-garbage-piles-1810375>

GTZ. Biogas Digest–Volume 1 (Biogas Basics). Retrieved April 21, 2020, from <http://www.gtz.de/de/dokumente/en-biogas-volume1.pdf>

GTZ. Technology Review of biogas Sanitation. Retrieved May 7, 2020, from, <http://www.gtz.de/en/dokumente/gtz2010-en-technology-review-biogas-sanitation.pdf>

IRRC. (2012). *Operational Manual on Composting for an Integrated Resource Recovery Center (IRRC)*. ESCAP. Retrieved March 13, 2020, from <https://www.unescap.org/resources/operational-manual-composting-integrated-resource-recovery-center-irrc>

Ludwig Sasse (BORDA), 1998. *DEWATS - Decentralized Wastewater Treatment in Developing countries*. Retrieved May 10, 2020, from <http://www.ted-biogas.org/assets/download/Sasse1998.pdf>

M.A. Salam. "Analysis and Design of Solid Waste Management System for a Residential area of Dhaka City", M.Sc. Thesis, Bangladesh University of Engineering and Technology, Dhaka, 2000

Menon, M.A. (2002), "Solid Waste Management in Dhaka, Bangladesh Innovation in Community Driven Composting", A master's thesis Bangladesh University of Engineering and Technology, Dhaka.

M.F Ahmed, "Municipal Waste Management in Bangladesh with Emphasis on Recycling", Regional Workshop on Urban Waste Management in Asian Cities, Dhaka, Bangladesh, April 10 -12., 1993

M.M. Rahman, M.D. Hossain, A.B.M. Badruzzaman, M.A. Ali, and M.M. Rahman. "Characterization of Municipal Solid Waste and Preliminary Environmental Impact Assessment of Collection and Disposal Works in Dhaka City", Bureau of Research, Testing and Consultation, Bangladesh University of Engineering and Technology, Dhaka, 1999

M.N. Bari. "An Integrated Approach for Ultimate Disposal of Municipal Solid Wastes", M.Sc. Thesis, Bangladesh University of Engineering and Technology, Dhaka, 2003

Moriarty, K., (NREL). *Feasibility study of Anaerobic Digestion of food waste in St. Bernard, Louisiana*. Retrieved May 3, 2020, from <http://www.nrel.gov/docs/fy13osti/57082.pdf>

"Modern Composting Technologies", (2005) Edited by the staff of BioCycle, a Journal of Composting & Organic Recycling, Emmaus, PA 18049, USA

PMO. (2004). *Bangladesh Private Sector Infrastructure Guidelines*. Prime Minister's Office, Government of the People's Republic of Bangladesh, Dhaka.

PMO. (2010). *Policy and Strategy for Public-Private Partnership (PPP)*, 2010. Prime Minister's Office, Government of the People's Republic of Bangladesh.

## Master Plan of Solid Waste Collection and Disposal Management of Narayanganj City Corporation

Waste Concern. (2014). *Bangladesh Waste Database 2014*. Dhaka. Retrieved April 07, 2020, from [http://wasteconcern.org/wp-content/uploads/2016/05/Waste-Data-Base\\_2014\\_Draft-Final.pdf](http://wasteconcern.org/wp-content/uploads/2016/05/Waste-Data-Base_2014_Draft-Final.pdf)

Waste Concern; Report on “The effect of nutrient enriched compost on plants for the Community Based Urban Solid Waste Management in Dhaka”, Component 3.3.2, Sustainable Environmental Management Program, 2001

Yasmin, s., & Rahman, M. (2017). A review of Solid Waste Management Practice in Dhaka City. *International Journal of Environmental Protection and Policy*. 1-5. Retrieved January 17, 2020, from <file:///E:/Acumen/Jisan/To%20Shahadat%20Vai/Chapter%2004/Resource%20artical/10.11648.i.ijepp.20170502.11.pdf>



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### Volume II



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