OFFICE OF THE DEPUTY PRIME MINISTER
MINISTRY OF LOCAL GOVERNMENT
REPUBLIC OF KENYA

CITY COUNCIL OF NAIROBI

PREPARATORY SURVEY FOR INTEGRATED SOLID WASTE MANAGEMENT IN NAIROBI CITY IN THE REPUBLIC OF KENYA

FINAL REPORT
VOLUME 3 SUPPORTING REPORT

OCTOBER 2010

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

CTI ENGINEERING INTERNATIONAL CO., LTD.

NJS CONSULTANTS CO., LTD.

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PREPARATORY SURVEY
FOR
INTEGRATED SOLID WASTE MANAGEMENT
IN NAIROBI CITY
IN
THE REPUBLIC OF KENYA

FINAL REPORT

VOLUME 3

SUPPORTING REPORT

SECTION A

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1. INTRODUCTION

1.1 Background of the Waste Amount and Composition Survey

In response to the request of the Government of Kenya (GOK), the Government of Japan (GOJ), through the Japan International Cooperation Agency (JICA), decided to conduct "The Preparatory Survey for Integrated Solid Waste Management in Nairobi City in the Republic of Kenya." The survey consists of the Waste Amount and Composition Survey (WACS) and the analysis of incoming waste records of the existing truck scale in order to quantify the volume and type of waste being generated in the city.

1.2 Objectives of the Waste Amount and Composition Survey

The WACS is to be conducted as part of the study for updating the SWM Master Plan in order to identify the amount and composition of the different types of waste being generated in Nairobi City. The characteristics of representative municipal solid waste to be obtained through the WACS are those of domestic waste, commercial waste, institutional waste, market waste, street waste, etc., at the waste generation sources and the wastes to be dumped at the disposal site. The results of the WACS are to be used as basic data for the formulation of the waste collection, 3R, intermediate treatment and waste disposal plans for the review, updating and formulation of the SWM Master Plan.

1.3 Survey Area

The Survey Area covers the whole jurisdictional area of the City Council of Nairobi (CCN).

2. SURVEY METHODOLOGY

2.1 General

The Waste Amount and Composition Survey (WACS) is to be conducted by the local consultant contracted and under the supervision of the JICA Study Team, to collect quantitative data necessary for grasping the present condition and for projecting the future condition of solid waste amounts and characteristics classified according to generation source. The survey is to be conducted twice in two different seasons to minimise the difference in analysis results due to climatic conditions such as rainfall and humidity.

2.2 Solid Waste Sampling

The samplings are to be conducted in the residential areas, commercial areas, markets and roads to grasp the true and representative picture of waste amount and composition in Nairobi City. Taking into account the housing types and different socio-economic groups in the city, residential areas are to be subdivided into high income, middle income, low-middle income, low income and slum areas. Waste samples are to be taken for chemical analysis to evaluate the quality of components, namely; the moisture, ash and combustible contents. The total number of samples to be taken is as shown in **Table A.2.1**.

Table A.2.1 Number of Samples for the Waste Amount and Composition Survey

Sampling Area	Waste Amount Samples	Waste Composition Samples	
		Physical	Chemical
1. Residential area			
a. High Income	30	3	1
b. Middle Income	30	3	1
c. Low-Middle Income	30	3	1
d. Low Income	30	3	1
e. Slum	30	3	1
2. Commercial establishment			
a. Restaurants	15	3	1
b. Shops, hotels/guest houses, etc.	45	6	2
3. Public facilities (schools, institutional buildings, public and private offices in city centre, etc.)	30	3	1
4. Markets	30	3	1
5. Road waste	30	3	-
6. Sample from waste collection vehicles at landfill site	0	30	10
Total	**300**	**63**	**20**

The WACS is to be carried out from December 2009 up to March 2010 to cover the wet and dry seasons at the site.

2.3 Waste Amount Survey

The waste amount survey was carried out for eight (8) consecutive days; the first day served as the “dry run” where the surveyors were trained on how to undertake the survey.

The sampling data of the remaining seven (7) days were the valid data for the analysis of waste amount. The data of the first day were excluded from the actual analysis because the waste sample on the first

day may contain waste generated before the sampling date and may contain more quantity of waste compared to the actual condition.

The survey included the sampling of recyclable materials of self-treated waste at each generation source. The unit generation amount at each generation source was verified through the examination of existing data.

Several sampling teams consisting of 3 to 4 members each collected samples all over the city. The teams moved between the target areas and the sorting place. Six analysis teams also consisting of 3 to 4 members each waited at the sorting place for the samples, then recorded the weights upon arrival before sorting. The survey teams were briefed on the objectives of the project as well as the sampling and work methodology in advance.

2.4 Waste Composition Survey

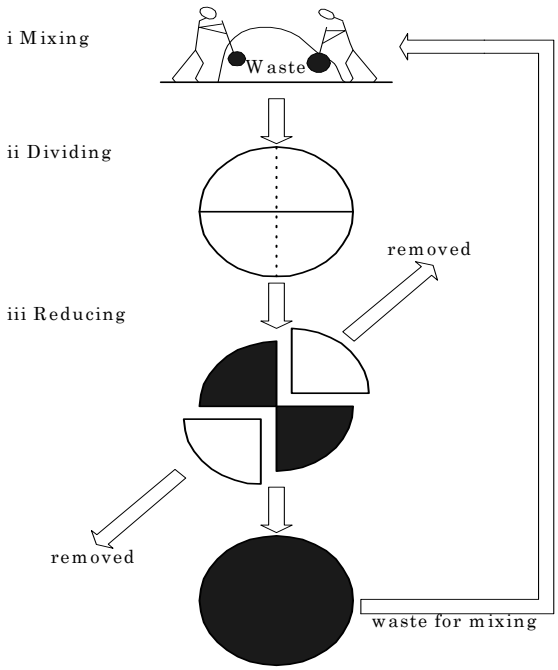
2.4.1 Survey Procedure

The waste composition survey was done in the last three (3) consecutive days of the waste amount survey. A designated waste holding area near the Dandora Dumpsite was used for sorting and analysing the collected samples.

The responsibilities of the agencies involved in the waste amount and composition survey are as shown in **Table A.2.2** and **Figure A.2.1**, respectively.

Table A.2.2 Responsibilities of Agencies involved in the Waste Amount and Composition Survey

		Residential	**Commercial**	**Market**	**Streets**	**Incoming Waste at Dandora Dumpsite**
Discharge		Owner/Tenant	Owner	CCN	CCN	
Collection		Consultant		CCN	Consultant	CCN/Private Contractors
Container		Plastic Bag		Truck	Plastic Bag	Truck
Measure	Weight	Consultant		CCN	Consultant	CCN
	Volume	Consultant				Consultant
Analysis	Physical Composition	Consultant				Consultant
	Chemical Composition	SGS Kenya Limited & University of Nairobi				



i	Mixing	:	In case that large-size waste (e.g., cardboard, textile, etc.) is contained in the collected waste, the large-size waste should be cut into smaller pieces and then mixed again. No large-size waste was however encountered in the sampling of household waste.
ii	Dividing	:	Waste should be divided into four blocks of almost the same volume.
iii	Reducing	:	The diagonal two blocks of waste divided into four should be removed.

Figure A.2.1 Procedure of Waste Reduction

2.4.2 Physical Composition

Solid wastes within a city vary considerably with respect to quantity and composition. Information and data on the physical composition of solid waste are important in the selection and operation of equipment and facilities, disposal strategy, processing and so on.

In view of the heterogeneous nature of solid waste, the determination of waste composition was not an easy task. Strict statistical procedures were found difficult to follow, even if it was not impossible to implement them. For this reason, a more generalised and commonly followed standard procedure was adopted for determining the waste composition based on common sense and random sampling techniques.

All collected samples from each generator were taken to the holding area and then sorted into the constituent waste components. The characterised wastes sorted into twenty-six (26) classifications, namely; food waste; recyclable paper; recyclable cardboard; mixed paper; diapers; plastic sheet; recyclable plastics; PET bottles; other plastics; rubber and leather; textiles; yard waste; lumber and logs; other organic wastes; returnable bottles; other live bottles; glass bins; broken glass; tin cans; Aluminum cans; copper; other metals; dirt, ash, stone and sand; unclassified residual waste; batteries-dry cells; and other domestic hazardous waste, were put inside properly labeled and pre-weighed garbage bags. The garbage bags containing the wastes were then arranged around the sorting area for weighing and recording of weights.

2.4.3 Apparent Specific Gravity

The Apparent Specific Gravity (ASG) of solid waste is an important tool to assess the total mass and volume of waste. ASG is calculated by the following formula:

ASG = weight of waste (kg) / volume of waste (litre)

Volume of waste is measured as follows:

After weighing, the waste was measured by visually inspecting the upper line of the waste inside the bucket after tapping it two or three times off the ground at the height of 30 cm. Any waste in excess of the capacity of a bucket after tapping was removed onto the sheet, then loaded into the next bucket, tapped in the same way, and the volume measured.

2.4.4 Chemical Analysis

Information on the chemical composition of solid waste is important in evaluating the alternative processing and options such as incineration, composting and energy recovery. Typically, solid waste is a combination of semi-moist, organic and inorganic materials. To assess the possible use of solid waste as fuel, the important chemical properties to be calculated are moisture, ash and combustible contents.

About 1.0 kg of composite waste samples per source were taken from the sorted waste samples and put inside sealed plastic containers properly labeled with the code of the sample, source and date when the sample was taken. All waste samples were collected and put together in a container, then sealed and shipped to the SGS Laboratories (an accredited laboratory in Kenya) for the three-content analyses.

(1) Moisture Content

The moisture content of solid waste is usually expressed in weight of moisture per unit weight of wet material. To calculate the moisture content, the solid waste sample is dried in a room for 1 day and in a drier at 105°C for more than 2 days until the weight is constant.

This temperature and time are used to dehydrate the materials completely and to limit the vaporisation of volatile materials. The moisture content is obtained by subtracting the weight of the dried mass sample from that of the wet mass sample and taking out the percentage.

Moisture Content was calculated by the following formula:

Equation 1: Equation showing how to derive moisture content

Moisture Content (%) = (B-C) / A x 100

(2) Ash Content

Each combustible sample is cut into 2 to 5 cm. The sample is reduced up to totally 500 grams in accordance with each constituent ratio. Then each combustible sample is pulverised into fractions of less than 2 mm in size by the cutting mill. After pulverisation, the samples are mixed together again and subjected to heating at 550°C for two hours in an electric furnace.

Ash Content was calculated by the following formula:

Equation 2: Equation showing how to derive ash content

$$AshContent(\%) = \frac{(l \times \frac{g}{j}) + (c - g)}{A} \times 100$$

(3) Combustible Content

Combustible content was calculated by subtracting the weight of combustion ash from the weight of combustible matters, as follows:

Equation 3: Equation showing how to derive combustible content

Combustible Content (%) =100-Moisture Content - Ash Content

2.5 Survey Team

The survey was carried out by the Environmental Cost Management Centre, Ltd. under the supervision of the JICA Survey Team and with the cooperation of the City Council of Nairobi.

The main roles and tasks of each member of the Survey Team are as given in **Table A.2.3**.

Table A.2.3 Roles and Responsibilities of Members of the Survey Team

Position of Survey Team Member	Main Role of the Survey Team Members
Team Leader	- Responsible for the overall supervision of the study - Responsible for all deliverables of the project
Technical Assistants	- To assist in the supervision of the survey - Responsible for checking and evaluating the results of the survey - Responsible for mapping the location of all respondents - Responsible for taking pictures of different activities done during the entire survey period
Field Supervisors	- Responsible for the supervision of all survey activities in each dumping site
Recorder	- Responsible for recording the weight of wastes
Working Crew	- To assist in weighing the collected wastes - To unload the wastes for the waste amount and composition survey and measurement - To mix and separate wastes for the composition survey

3. RESULTS OF THE WASTE AMOUNT AND COMPOSITION SURVEY

3.1 Waste Amount Survey Results

3.1.1 Residential Area

The total waste generated by a household was divided by the number of household members to get the average per capita generation rate. The households surveyed in the waste amount and composition survey were the same as the households surveyed in the public awareness survey. The number of household members in each income group surveyed in both seasons is the same as those shown in **Table A.3.1** and in **Table 1.1.1 of Section A of Volume 4, Data Book**.

Table A.3.1 Number of Households Surveyed in the Waste Amount and Composition Survey

Income Group	Number of Households	Total Household Members	Average Number of Household Members
High income group area	30	152	5.1
Middle income group area	30	108	3.6
Low-Middle income group area	30	113	3.8
Low income group area	30	81	2.7
Slum area	30	110	3.7

The average waste generation amounts in residential areas during the wet and dry seasons are as shown in **Table A.3.2**. The data on waste generation in residential areas are shown in **Table 1.1.2** and **Table 1.1.3 of Volume 4, Data Book**. The average weight per income group in the dry season compared to the wet season was lower except the low-middle income group, which may be attributed to the lack of rainfall in most parts of the country resulting in the reduced amount of food produced.

Table A.3.2 Average Waste Generation Amount in Residential Areas

Income Group	Average Waste Generation Amount During Wet Season (kg/day)	Average Waste Generation Amount During Dry Season (kg/day)
High income group area	3.01	2.70
Middle income group area	2.43	2.31
Low-Middle income group area	1.40	1.86
Low income group area	0.90	0.74
Slum area	1.55	1.53

The per capita waste generation rates during the wet season are as shown in **Table A.3.3** and **Figure A.3.1.**

Table A.3.3 Waste Generation Per Capita in Residential Area during Wet Season

Income Group	Survey Area	Maximum (kg/day/c)	Mean (kg/day/c)	Minimum (kg/day/c)
High Income	Kitisuru	1.262	0.614	0.245
	Karen	1.429	0.607	0.143
Middle Income	Langata	1.857	0.685	0.148
	South B	1.405	0.667	0.214
Low-Middle Income	Riruta	1.786	0.521	0.184
	Umoja	1.771	0.387	0.081
Low Income	Dandora	1.421	0.326	0.138
	Bahati	2.071	0.340	0.085
Slum	Kibera	2.871	0.438	0.130
	Mukuru	0.889	0.400	0.119

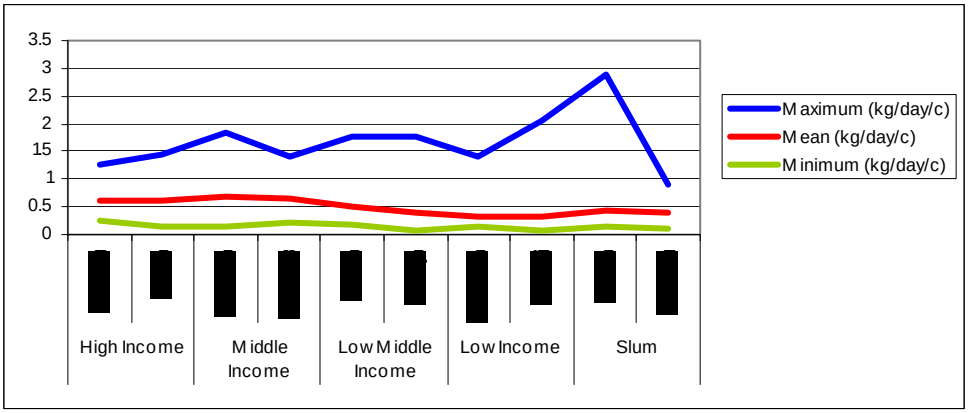


Figure A.3.1 Waste Generation Per Capita in Residential Area during Wet Season

By comparison, the dry season showed that the middle income areas and the high income areas generated more waste per capita compared to the other areas, as shown in **Table A.3.4** and **Figure A.3.2**. This could be attributed to the lack of adequate rainfall leading to the increase in cost of food and food products as well as energy, consequently reducing the amounts of waste generated in the lower income groups.

Table A.3.4 Waste Generation Per Capita in Residential Area during Dry Season

Income Group	Survey Area	Maximum (kg/day/c)	Mean (kg/day/c)	Minimum (kg/day/c)
High Income	Kitisuru	1.643	0.636	0.195
	Karen	1.029	0.412	0.186
Middle Income	Langata	3.500	0.788	0.171
	South B	2.262	0.555	0.171
Low-Middle Income	Riruta	1.179	0.445	0.179
	Umoja	3.186	0.543	0.163
Low Income	Dandora	0.689	0.233	0.087
	Bahati	1.414	0.310	0.075
Slum	Kibera	2.605	0.489	0.145
	Mukuru	1.714	0.340	0.119

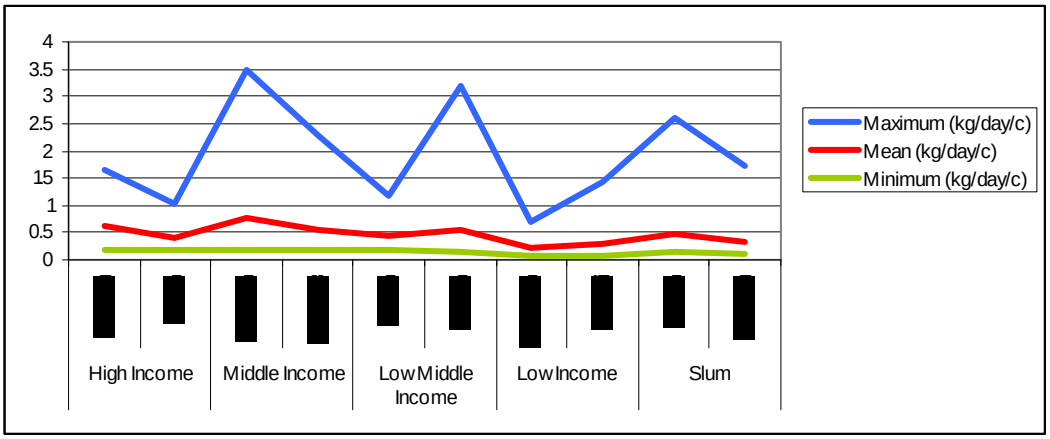


Figure A.3.2 Waste Generation Per Capita in Residential Area during Dry Season

The average waste generation rates per capita during both the wet and dry seasons showed that the slum and middle income areas generated the largest amounts of waste. However, the high income areas having a higher number of people per household were found to have less than the low income areas. **Table A.3.5** shows the average for both the wet and dry season per capita waste generation rates.

Table A.3.5 Average Waste Generation Per Capita in Residential Areas

Income Group	Survey Area	Maximum (kg/day/c)	Mean (kg/day/c)	Minimum (kg/day/c)
High Income	Kitisuru	1.107	0.625	0.329
	Karen	1.226	0.509	0.173
Middle Income	Langata	2.679	0.737	0.248
	South B	1.568	0.611	0.449
Low-Middle Income	Riruta	1.149	0.483	0.240
	Umoja	2.479	0.465	0.160
Low Income	Dandora	1.014	0.280	0.156
	Bahati	1.289	0.325	0.102
Slum	Kibera	1.535	0.464	0.190
	Mukuru	1.012	0.370	0.235

3.1.2 Commercial Establishment

Commercial establishments such as shops, restaurants and hotels, as well as public facilities like schools, private and public offices, were considered in the waste amount survey. The generation per capita should be the unit rate generation per customer or employee; however, in the process of gathering the total number required during the survey, no sufficient data was obtained. With insufficient data, the computation would be inaccurate. Therefore, the number of establishments was searched through the Department of Computer of the City Council of Nairobi so that the unit rate generation of establishments is per structure or establishment and not per person.

The average weight of each generation source of establishments is shown in **Table A.3.6** and **Figure A.3.3**. The data during the survey in both seasons are given in **Table 1.1.4 to Table 1.1.13 of Volume 4, Data Book**.

Table A.3.6 Weight of Waste Generated by Establishments

Establishments	Dry Season (kg/day)	Wet Season (kg/day	Average (kg/day)
Shops	0.57	0.43	0.50
Restaurants	30.60	45.52	38
Hotels	346.50	375.06	350
Schools	65.63	87.74	76
Public Offices	109.96	164.08	137

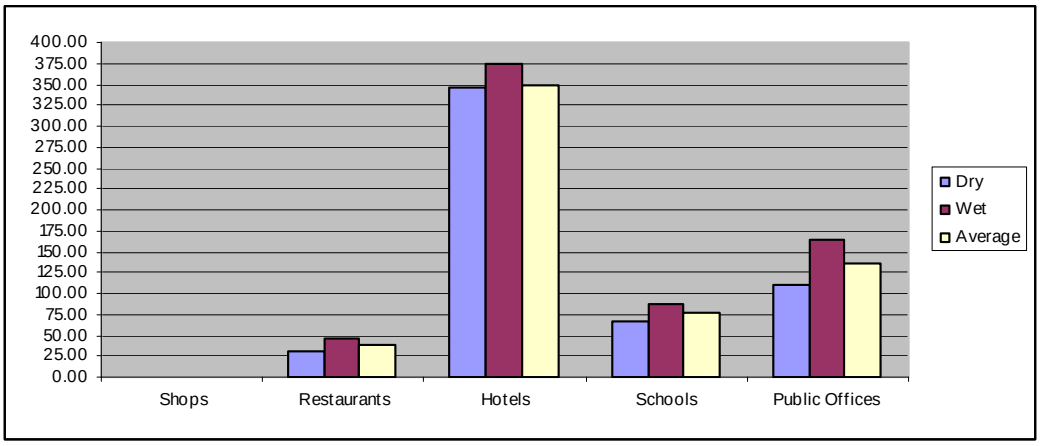


Figure A.3.3 Weight of Waste Generated by Establishments

The highest waste generators among the establishments are the hotels, about 350 kg/day, while the shops are the lowest generators, about 0.5 kg/day.

3.1.3 Market

Out of the 44 markets in Nairobi City, 30 markets were surveyed and their wastes for seven days were collected for the estimation of average waste generation per day. The data obtained during the survey of waste generation in markets are given in **Table 1.1.14 of Volume 4, Data Book**. The results of the survey show that the average daily waste generation of each market is about 2,045 kg/day.

3.1.4 Road

The average waste generation according to the waste amount survey is 50 kg/km/day. The data during the actual survey are given in **Table 1.1.15** and **Table 1.1.16 of Volume 4, Data Book** for the dry and wet seasons, respectively.

3.2 Waste Composition Survey Results

3.2.1 Residential Area

The physical composition of residential waste during the wet and dry season surveys are as shown in **Table A.3.7** and **Table A.3.8**, respectively. The data of waste composition for residential areas during each survey period is shown in **Tables 1.1.17 to 1.1.26 of Volume 4, Data Book**.

Table A.3.7 Composition of Domestic Waste in Wet Season

Waste Composition		Ratio (%)				
		High Income	**Middle Income**	**Low-Middle Income**	**Low Income**	**Slum Area**
Food Waste		57.31	61.59	68.81	67.68	50.13
Paper	Recyclable Paper	1.25	6.98	4.62	4.16	5.77
	Recyclable Cardboard	1.86	0.00	0.00	0.00	0.46
	Mixed Paper	3.70	1.21	0.00	2.69	1.41
	Diapers	4.67	5.64	7.85	4.73	0.34
	Subtotal-Paper	*11.49*	*13.83*	*12.47*	*11.58*	*7.98*
Plastics	Plastic Sheet	6.11	8.68	6.93	9.46	7.06
	Recyclable Plastics	0.61	1.76	2.68	1.45	2.96
	PET Bottles	1.70	1.09	0.00	0.71	0.34
	Other Plastics	1.04	0.00	0.51	0.00	0.00
	Subtotal - Plastics	*9.46*	*11.53*	*10.11*	*11.62*	*10.37*
Rubber & Leather		0.52	0.00	0.37	0.00	4.44
Textiles		0.64	1.82	0.83	1.60	1.82
Yard Waste		6.60	0.00	0.00	0.00	0.00
Lumber & Logs		3.58	1.21	0.00	0.00	2.96
Other Org. Waste		5.66	0.00	0.60	0.00	0.00
Organic Waste - Subtotal		95.26	89.99	93.19	92.48	77.71
Inorganic Waste		0.00	0.00	0.00	0.00	0.00
Glass	Returnable Bottles	1.46	0.00	1.25	0.00	0.00
	Other Live Bottles	0.73	1.46	0.46	4.40	0.00
	Glass bins	0.00	0.00	0.00	0.00	0.00
	Broken Glass	0.28	0.00	0.65	0.00	0.00
	Subtotal - Glass	2.48	1.46	2.36	4.40	0.00
Metals	Tin Cans (steel cans)	0.47	0.00	0.32	0.00	0.00
	Aluminum cans	0.59	0.00	0.00	0.00	0.00
	Copper	0.00	0.00	0.00	0.00	0.00
	Other Metals	0.00	2.67	1.15	0.12	0.80
	Subtotal - Metals	1.06	2.67	1.48	0.12	0.80
Dirt, Ash, Stone, Sand		0.94	5.89	1.85	2.36	21.27
Inorganic Waste - Subtotal		4.48	10.01	5.68	6.89	22.07
Unclassified Residual Waste		0.00	0.00	0.37	0.64	0.23
Domestic Hazardous Waste		0.00	0.00	0.00	0.00	0.00
Batteries - Dry Cells		0.09	0.00	0.11	0.00	0.00
Other Domestic Hazardous Wastes		0.17	0.00	0.65	0.00	0.00
Total		**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

Table A.3.8 Composition of Domestic Waste in Dry Season

Waste Composition		Ratio (%)				
		High Income	**Middle Income**	**Low-Middle Income**	**Low Income**	**Slum Area**
Food Waste		70.99	75.62	63.09	55.07	62.87
Paper	Recyclable Paper	1.10	5.37	2.87	2.18	6.07
	Recyclable Cardboard	1.90	0.00	0.72	0.00	0.00
	Mixed Paper	3.46	1.66	0.00	6.68	1.25
	Diapers	4.04	4.99	17.92	11.05	2.87
	Subtotal - Paper	*10.50*	*12.02*	*21.51*	*19.91*	*10.19*
Plastics	Plastic Sheet	4.91	5.82	1.97	13.70	6.29
	Recyclable Plastics	1.90	2.38	7.96	1.11	2.60
	PET Bottles	0.87	0.75	0.18	0.90	0.22
	Other Plastics	0.23	0.00	0.45	0.00	0.00
	Subtotal - Plastics	*7.91*	*8.95*	*10.56*	*15.72*	*9.11*
Rubber & Leather		0.29	0.00	0.79	0.00	0.00
Textiles		1.56	1.08	0.47	3.51	2.22
Yard Waste		4.10	0.00	0.00	0.00	0.00
Lumber & Logs		1.18	0.00	0.00	0.51	0.65
Other Org. Waste		0.00	0.00	0.82	0.00	0.00
Organic Waste - Subtotal		96.53	97.67	97.24	94.73	85.04
Inorganic Waste		0.00	0.00	0.00	0.00	0.00
Glass	Returnable Bottles	0.35	0.00	0.00	0.26	0.00
	Other Live Bottles	0.61	0.55	0.32	0.39	0.81
	Glass bins	0.00	0.00	0.00	0.00	0.00
	Broken Glass	0.47	0.00	0.47	0.00	0.00
	Subtotal - Glass	1.42	0.55	0.79	0.64	0.81
Metals	Tin Cans (steel cans)	0.81	0.00	0.00	0.00	0.00
	Aluminum cans	0.32	0.00	0.07	0.00	0.00
	Copper	0.00	0.00	0.00	0.00	0.00
	Other Metals	0.00	0.33	0.14	0.51	0.65
	Subtotal - Metals	1.13	0.33	0.22	0.51	0.65
Dirt, Ash, Stone, Sand		0.94	0.61	1.05	1.68	3.85
Inorganic Waste - Subtotal		4.48	3.15	1.94	2.69	5.01
Unclassified Residual Waste		0.00	0.00	0.39	0.00	0.26
Domestic Hazardous Waste		0.00	0.00	0.00	0.00	0.00
Batteries - Dry Cells		0.09	0.09	0.00	0.07	0.00
Other Domestic Hazardous Wastes		0.17	0.23	0.00	0.00	0.00
Total		**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

The following components are the highest in residential areas according to the results of the surveys in both seasons: (a) food waste (64%); (b) paper (14%); and (c) plastics (10%). See **Figure A.3.4**.

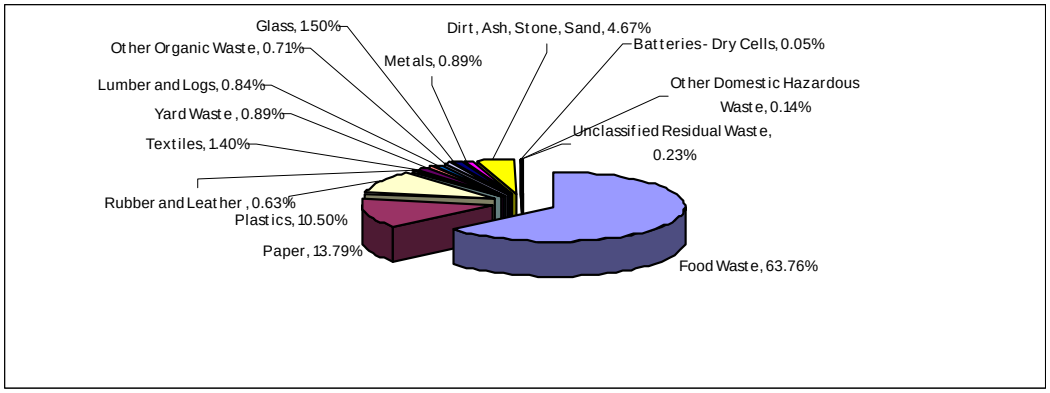


Figure A.3.4 Waste Composition in Residential Areas

3.2.2 Commercial Establishment

The physical composition of each generation source during the wet and dry season surveys and the average of the two surveys for commercial establishments such shops, restaurants and hotel and public facilities are shown in **Tables A.3.9**, **A.3.10** and **A.3.11** and **Figure A.3.6**, respectively. The data of each generation source during each survey period are shown in **Tables 1.1.27 to 1.1.34 of Section A of Volume 4, Data Book**.

Table A.3.9 Waste Composition in Establishments during the Wet Season Survey

Waste Composition		Ratio (%)			
		Shop	**Restaurant**	**Hotel**	**Public Facilities**
Food Waste		57.82	92.10	87.98	73.52
Paper	Recyclable Paper	11.94	0.00	0.56	1.91
Paper	Recyclable Cardboard	3.02	0.00	0.23	0.00
	Mixed Paper	0.60	0.00	0.00	1.74
	Diapers	0.38	0.13	0.00	0.12
	Subtotal - Paper	***15.95***	***0.13***	***0.79***	***3.78***
Plastics	Plastic Sheet	2.12	0.94	0.77	1.86
	Recyclable Plastics	5.67	2.81	2.62	1.86
	PET Bottles	2.19	1.02	1.51	5.89
	Other Plastics	2.49	0.29	0.07	0.00
	Subtotal - Plastics	***12.47***	***5.06***	***4.96***	***9.62***
Rubber & Leather		0.00	0.00	0.00	0.00
Textiles		0.00	0.00	0.00	0.00
Yard Waste		1.13	0.40	0.34	0.37
Lumber & Logs		0.00	0.00	0.00	0.00
Other Org. Waste		3.40	1.20	1.02	1.12
Organic Waste - Subtotal		**90.78**	**98.90**	**95.08**	**88.41**
Inorganic Waste					
Glass	Returnable Bottles	1.21	0.00	2.62	0.00
	Other Live Bottles	0.76	0.21	0.00	0.00
	Glass bins	0.00	0.00	0.00	0.00
	Broken Glass	2.12	0.29	0.00	4.60
	Subtotal - Glass	***4.08***	***0.51***	***2.62***	***4.60***
Metals	Tin Cans (steel cans)	1.13	0.35	0.45	5.72
	Aluminum cans	1.51	0.24	1.62	0.00
	Copper	0.00	0.00	0.00	0.00
	Other Metals	0.00	0.00	0.00	0.00
	Subtotal - Metals	***2.65***	***0.59***	***2.08***	***5.72***
Dirt, Ash, Stone, Sand		1.74	0.00	0.00	1.27
Inorganic Waste - Subtotal		**8.47**	**1.10**	**4.69**	**11.59**
Unclassified Residual Waste		**0.76**	**0.00**	**0.23**	**0.00**
Domestic Hazardous Waste		**0.00**	**0.00**	**0.00**	**0.00**
Batteries - Dry Cells		0.00	0.00	0.00	0.00
Other Domestic Hazardous Wastes		0.00	0.00	0.00	0.00
Total		**100.00**	**100.00**	**100.00**	**100.00**

Table A.3.10 Waste Composition in Establishments during the Dry Season Survey

Waste Composition		Ratio (%)			
		Shop	**Restaurant**	**Hotel**	**Public Facilities**
Food Waste		29.15	84.88	0.75	69.00
Paper	Recyclable Paper	17.05	2.10	0.81	1.35
	Recyclable Cardboard	2.75	1.30	0.00	0.75
	Mixed Paper	2.53	0.00	0.00	0.00
	Diapers	0.55	0.17	1.56	0.00
	Subtotal - Paper	***22.88***	***3.56***	***0.00***	***2.10***
Plastics	Plastic Sheet	1.43	0.97	2.77	1.35
	Recyclable Plastics	8.25	2.90	2.29	2.16
	PET Bottles	3.85	2.43	0.00	3.67
	Other Plastics	5.50	0.37	5.06	0.00
	Subtotal - Plastics	***19.03***	***6.66***	***0.00***	***7.19***
Rubber & Leather		0.00	0.00	0.00	0.00
Textiles		1.98	0.00	2.01	0.00
Yard Waste		0.00	0.00	0.00	0.00
Lumber & Logs		0.00	0.00	4.30	0.00
Other Org. Waste		1.65	0.07	94.97	7.67
Organic Waste - Subtotal		**74.70**	**95.17**		**85.96**
Inorganic Waste				2.92	
Glass	Returnable Bottles	7.26	2.20	0.00	0.00
	Other Live Bottles	1.10	0.17	0.00	0.00
	Glass bins	0.00	0.00	0.00	0.00
	Broken Glass	6.05	0.33	2.92	5.56
	Subtotal- Glass	***14.41***	***2.70***	***0.50***	***5.56***
Metals	Tin Cans (steel cans)	1.98	0.43	1.36	3.31
	Aluminum cans	2.42	1.53	0.00	3.37
	Copper	0.00	0.00	0.00	0.00
	Other Metals	0.22	0.00	1.86	1.08
	Subtotal - Metals	***4.62***	***1.97***	***0.13***	***7.76***
Dirt, Ash, Stone, Sand		3.63	0.00	4.91	0.72
Inorganic Waste - Subtotal		**22.66**	**4.66**	**0.13**	**14.04**
Unclassified Residual Waste		**2.42**	**0.17**	**0.00**	**0.00**
Domestic Hazardous Waste		**0.22**	**0.00**	**0.00**	**0.00**
Batteries - Dry Cells		0.22	0.00	0.00	0.00
Other Domestic Hazardous Wastes		0.00	0.00	0.00	0.00
Total		**100.00**	**100.00**	**0.13**	**100.00**

Table A.3.11 Average Waste Composition in Establishments

Waste Composition		Ratio (%)			
		Shop	**Restaurant**	**Hotel**	**Public Facilities**
Food Waste		46.15	88.88	85.17	71.48
Paper	Recyclable Paper	14.02	0.94	0.65	1.66
	Recyclable Cardboard	2.91	0.58	0.50	0.34
	Mixed Paper	1.39	0.00	0.00	0.95
	Diapers	0.45	0.15	0.00	0.07
	Subtotal - Paper	***18.77***	***1.66***	***1.15***	***3.02***
Plastics	Plastic Sheet	1.84	0.95	0.40	1.63
	Recyclable Plastics	6.72	2.85	2.69	2.00
	PET Bottles	2.87	1.65	1.88	4.89
	Other Plastics	3.72	0.33	0.04	0.00
	Subtotal - Plastics	***15.14***	***5.77***	***5.01***	***8.52***
Rubber & Leather		0.00	0.00	0.00	0.00
Textiles		0.81	0.00	0.00	0.00
Yard Waste		0.67	0.22	1.13	0.20
Lumber & Logs		0.00	0.00	0.00	0.00
Other Org. Waste		2.69	0.70	2.57	4.08
Organic Waste - Subtotal		**84.23**	**97.24**	**95.03**	**87.30**
Inorganic Waste					
Glass	Returnable Bottles	3.67	0.98	2.76	0.00
	Other Live Bottles	0.90	0.19	0.00	0.00
Glass	Glass bins	0.00	0.00	0.00	0.00
	Broken Glass	3.72	0.31	0.00	5.04
	Subtotal - Glass	***8.29***	***1.48***	***2.76***	***5.04***
Metals	Tin Cans (steel cans)	1.48	0.39	0.48	4.63
	Aluminum cans	1.88	0.82	1.50	1.52
	Copper	0.00	0.00	0.00	0.00
	Other Metals	0.09	0.00	0.00	0.49
	Subtotal - Metals	***3.45***	***1.20***	***1.97***	***6.64***
Dirt, Ash, Stone, Sand		2.51	0.00	0.06	1.02
Inorganic Waste – Subtotal		**14.25**	**2.69**	**4.79**	**12.70**
Unclassified Residual Waste		**1.43**	**0.07**	**0.18**	**0.00**
Domestic Hazardous Waste		**0.09**	**0.00**	**0.00**	**0.00**
Batteries - Dry Cells		0.09	0.00	0.00	0.00
Other Domestic Hazardous Wastes		0.00	0.00	0.00	0.00
Total		**100.00**	**100.00**	**100.00**	**100.00**

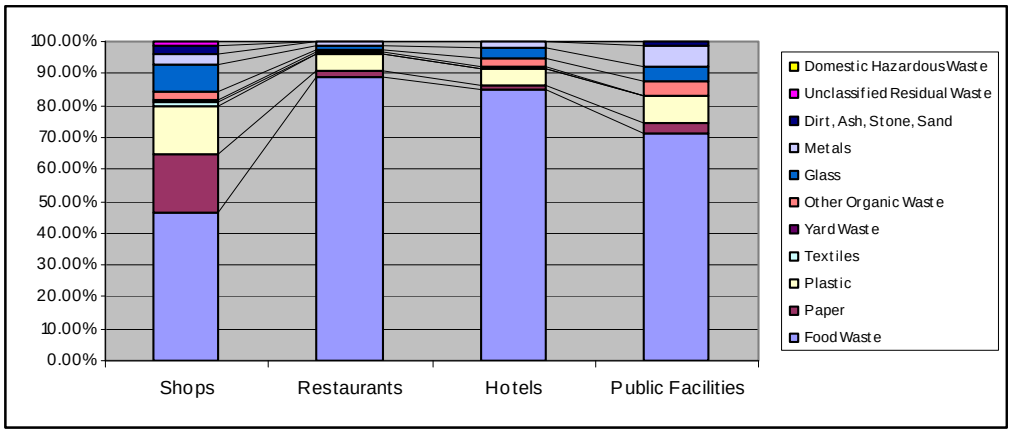


Figure A.3.5 Average Waste Composition in Establishments

The following components are the highest according to the results of the survey in establishments:

(a) Food waste: about 88.9% in restaurants

(b) Paper: about 18.8%, plastics: about 15.1%, and glass: about 8.3% in shops

(c) Metals: about 6.6% in public facilities

3.2.3 Market

The composition of market waste is shown in **Table A.3.12** and **Figure A.3.6**, while the data during the surveys are shown in **Table 1.1.35 and Table 1.1.36 of Section A of Volume 4, Data Book** during the dry season and wet season, respectively. The following are the components mostly found in market waste: 1) food waste, 89.1%; 2) paper, 4.5%; 3) textile, 3%; and plastics, 1.1%.

Table A.3.12 Waste Composition in Markets

Unit: %

Waste Composition		Dry Season	Wet Season	Average
Food Waste		90.75	87.65	89.10
Paper	Recyclable Paper	1.01	0.64	0.81
	Recyclable Cardboard	2.09	5.15	3.72
	Mixed Paper	0.00	0.00	0.00
	Diapers	0.00	0.00	0.00
	Subtotal-Paper	***3.10***	***5.79***	***4.53***
Plastics	Plastic Sheet	0.00	0.00	0.00
	Recyclable Plastics	0.72	1.40	1.08
	PET Bottles	0.58	0.00	0.27
	Other Plastics	0.13	0.12	0.12
	Subtotal-Plastics	***1.44***	***1.52***	***1.48***
Rubber & Leather		0.05	0.38	0.23
Textiles		2.50	3.37	2.96
Yard Waste		0.00	0.00	0.00
Lumber & Logs		0.00	0.00	0.00
Other Org. Waste		0.43	0.87	0.67
Organic Waste - Subtotal		**98.27**	**99.58**	**98.97**
Inorganic Waste				
Glass	Returnable Bottles	0.00	0.00	0.00

Waste Composition		Dry Season	Wet Season	Average
	Other Live Bottles	0.07	0.06	0.07
	Glass bins	0.00	0.00	0.00
	Broken Glass	0.93	0.00	0.43
	Subtotal - Glass	***1.00***	***0.06***	***0.50***
Metals	Tin Cans (steel cans)	0.08	0.00	0.04
	Aluminum cans	0.00	0.00	0.00
	Copper	0.00	0.00	0.00
	Other Metals	0.30	0.00	0.14
	Subtotal - Metals	***0.39***	***0.00***	***0.18***
Dirt, Ash, Stone, Sand		0.34	0.11	0.21
Inorganic Waste - Subtotal		**1.73**	**0.17**	**0.90**
Unclassified Residual Waste		0.00	0.25	0.14
Domestic Hazardous Waste		**0.00**	**0.00**	**0.00**
Batteries - Dry Cells		0.00	0.00	0.00
Other Domestic Hazardous Wastes		0.00	0.00	0.00
Total		**100.00**	**100.00**	**100.00**

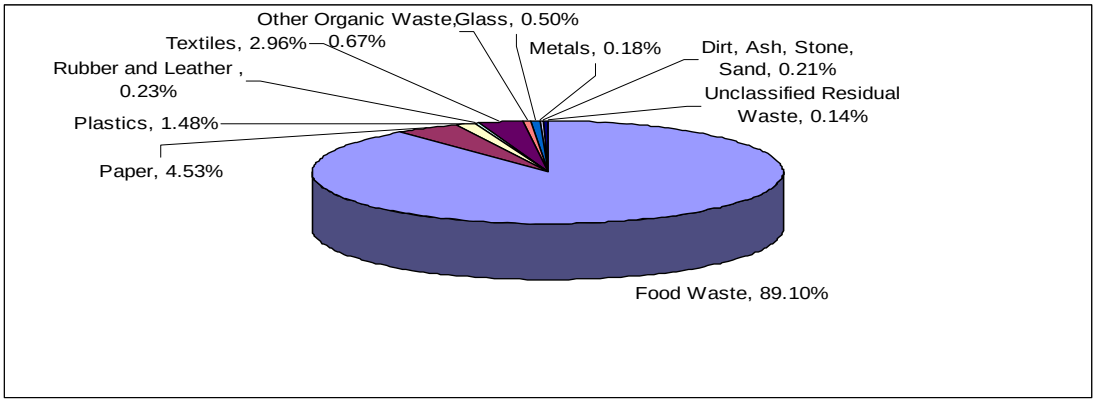


Figure A.3.6 Waste Composition in Markets

3.2.4 Road

Road wastes are composed mostly of a mixture of dirt, ash, stone and sand (about 29.6%); yard waste (about 17.2%); food waste (about 16.6%); paper (about 15.3%); and plastics (10.3%). The results of the waste composition survey in roads are shown in **Table A.3.13** and **Figure A.3.7**, while the data during the actual surveys are shown in **Table 1.1.37 and Table 1.1.38 of Section A of Volume 4, Data Book** for the dry season and wet season, respectively.

Table A.3.13 Waste Composition in Roads

Unit: %

Waste Composition		Dry Season	Wet Season	Average
Food Waste		2.74	26.23	16.61
Paper	Recyclable Paper	4.91	18.84	13.14
	Recyclable Cardboard	4.81	0.00	1.97
	Mixed Paper	0.42	0.00	0.17
	Diapers	0.00	0.00	0.00
	Subtotal - Paper	***10.14***	***18.84***	***15.28***

Waste Composition		Dry Season	Wet Season	Average
Plastics	Plastic Sheet	3.76	2.54	3.04
	Recyclable Plastics	1.67	4.78	3.51
	PET Bottles	1.67	6.09	4.28
	Other Plastics	0.21	0.00	0.09
	Subtotal - Plastics	***7.32***	***13.41***	***10.91***
Rubber & Leather		0.00	0.00	0.00
Textiles		0.00	0.58	0.34
Yard Waste		26.13	11.01	17.20
Lumber & Logs		0.00	0.51	0.30
Other Org. Waste		1.25	10.43	6.68
Organic Waste - Subtotal		**47.59**	**81.01**	**67.33**
Inorganic Waste				
Glass	Returnable Bottles	0.42	0.00	0.17
	Other Live Bottles	0.00	0.00	0.00
	Glass bins	0.73	0.00	0.30
	Broken Glass	1.15	0.00	0.47
	Subtotal - Glass	***2.30***	***0.00***	***0.94***
Metals	Tin Cans (steel cans)	0.00	0.00	0.00
	Aluminum cans	0.00	0.14	0.09
	Copper	0.00	0.00	0.00
	Other Metals	1.71	0.29	0.87
	Subtotal - Metals	***1.71***	***0.43***	***0.96***
Dirt, Ash, Stone, Sand		45.58	18.55	29.62
Inorganic Waste - Subtotal		**49.59**	**18.99**	**31.52**
Unclassified Residual Waste		2.20	0.00	0.90
Domestic Hazardous Waste		**0.63**	**0.00**	**0.26**
Batteries - Dry Cells		0.63	0.00	0.26
Other Domestic Hazardous Wastes		0.00	0.00	0.00
Total		**100.00**	**100.00**	**100.00**

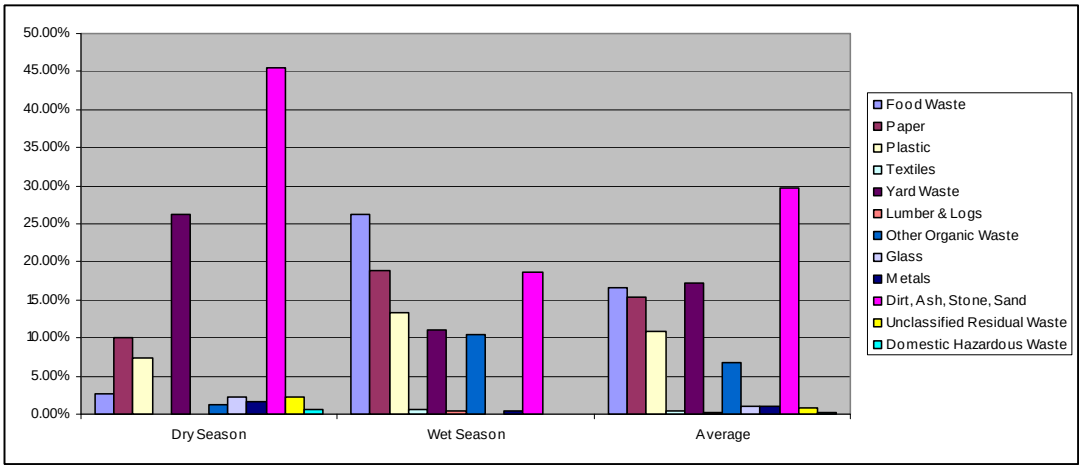


Figure A.3.7 Waste Composition in Roads

3.2.5 Incoming Waste at Dandora Dumpsite

The waste amount survey was also conducted for wastes to be dumped at the Dandora Dumpsite in order to calculate the estimated weight of biodegradable waste as well as the amount of recyclable materials. The percentages of waste composition were used as assumed ratios in computing the amount of recovery materials from the collected waste. The wastes were collected from 10 trucks and the analysis on waste composition was done for three consecutive days in both dry and wet seasons. The results of the survey are shown in **Table A.3.14** and **Figure A.3.8**, while the data during the actual surveys are shown in **Table 1.1.39 and Table 1.1.44 of Section A of Volume 4, Data Book** for the dry and wet seasons, respectively.

Table A.3.14 Waste Composition at the Dandora Dumpsite (%)

Waste Composition		Dry Season	Wet Season	Average
Food Waste		51.19	42.96	47.01
Paper	Recyclable Paper	4.79	5.93	5.37
	Recyclable Cardboard	1.83	1.33	1.57
	Mixed Paper	1.40	2.51	1.96
	Diapers	0.94	0.42	0.67
	Subtotal - Paper	***8.95***	***10.19***	***9.58***
Plastics	Plastic Sheet	2.34	4.95	3.67
	Recyclable Plastics	3.08	2.04	2.55
	PET Bottles	1.37	2.06	1.73
	Other Plastics	1.76	1.24	1.49
	Subtotal - Plastics	***8.55***	***10.30***	***9.44***
Rubber & Leather		0.38	0.38	0.38
Textiles		1.28	2.48	1.89
Yard Waste		8.38	11.79	10.11
Lumber & Logs		3.87	2.51	3.18
Other Org. Waste		3.11	4.11	3.62
Organic Waste - Subtotal		**85.71**	**84.72**	**85.21**
Inorganic Waste				
Glass	Returnable Bottles	0.39	0.30	0.34
	Other Live Bottles	0.05	0.09	0.07
	Glass bins	0.03	0.45	0.24
	Broken Glass	3.68	5.26	4.48
	Subtotal - Glass	***4.13***	***6.09***	***5.13***
Metals	Tin Cans (steel cans)	0.69	0.55	0.62
	Aluminum cans	0.12	0.17	0.15
	Copper	0.00	0.00	0.00
	Other Metals	0.33	0.70	0.52
	Subtotal - Metals	***1.14***	***1.42***	***1.28***
Dirt, Ash, Stone, Sand		7.73	7.44	7.58
Inorganic Waste - Subtotal		**13.01**	**14.95**	**13.99**
Unclassified Residual Waste		0.73	0.11	0.41
Domestic Hazardous Waste		**0.55**	**0.22**	**0.39**
Batteries - Dry Cells		0.37	0.22	0.30
Other Domestic Hazardous Wastes		0.18	0.00	0.09
Total		**100.00**	**100.00**	**100.00**

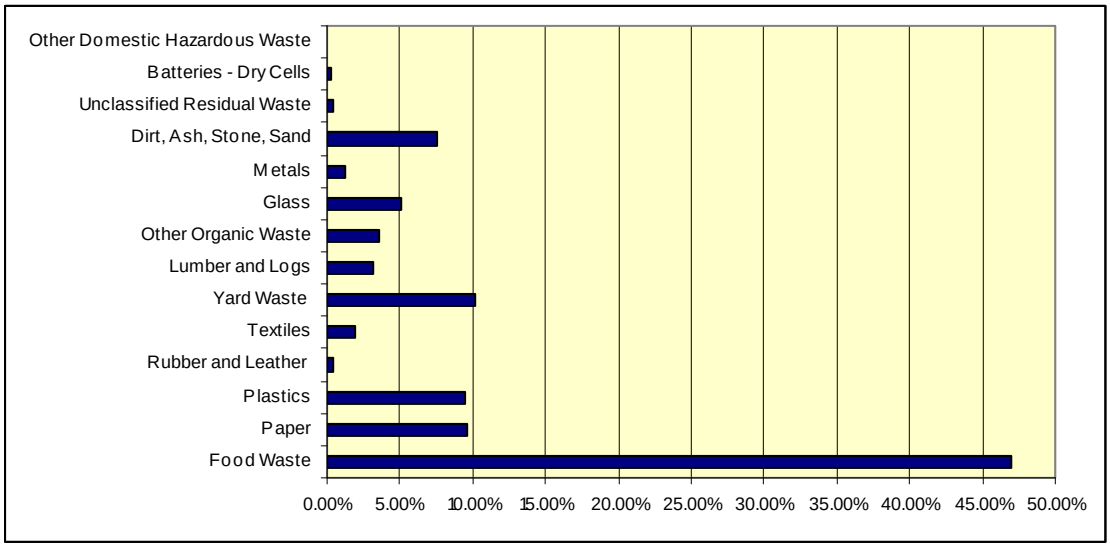


Figure A.3.8 Waste Composition of Incoming Waste at the Dandora Dumpsite

Based on the table and figure above, the amount of recyclable materials in the incoming waste at the Dandora Dumpsite are the following: paper (6.9%), plastics (4.3%), glass (0.4%) and metals (1.3%), while the amount of biodegradable waste is about 52.5% of the total waste to be dumped.

3.3 Apparent Specific Gravity

The Apparent Specific Gravity (ASG) in kg/litre of solid waste is an important tool required to assess the total mass and volume of waste. The average ASG calculated for each generation source survey in the wet and dry seasons is shown in **Figure A.3.9**.

As shown in the figure below, road waste has the highest apparent specific gravity, while shop waste has the lowest. The average ASG of waste in Nairobi City is 0.30.

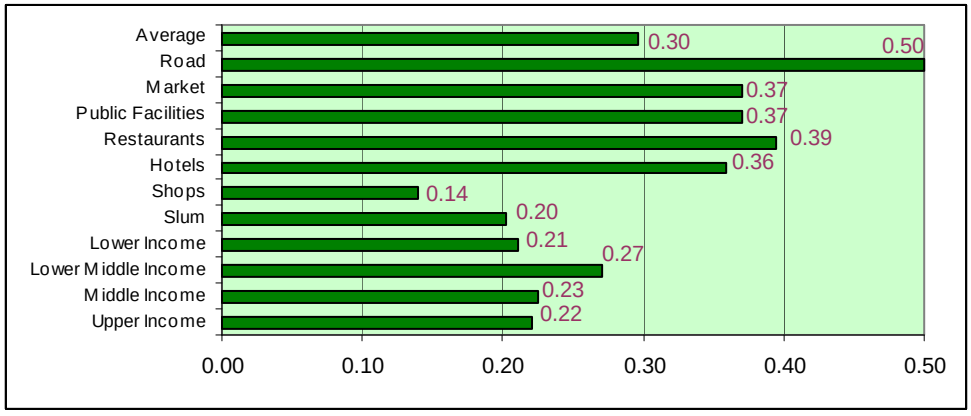


Figure A.3.9 Apparent Specific Gravity at Each Generation Source in Nairobi

3.4 Chemical Analysis Results

For this study, the chemical analysis considered was the chemical property analysis for the three-contents: moisture, ash and combustibles. The average results of the three-content analysis for each generation source during the wet and dry seasons are shown in **Table A.3.15** and **Figure A.3.10**. Since road waste was not chemically analysed, the average is considered to be the weighted value of

total waste generated in Nairobi City. Data of the three-content analysis for both seasons are shown in **Table 1.1.45 of Volume 4, Data Book**.

The waste from markets has the highest value of moisture content, while the highest percentages of ash and combustible contents were from shop waste.

Table A.3.15 Three-Content Analysis at Each Generator Source (%)

Waste Source Generators	Moisture	Ash	Combustible
High Income	79.27	7.80	12.94
Middle Income	73.41	4.63	21.97
Low-Middle Income	73.37	2.47	24.17
Low Income	67.80	4.15	28.05
Slum	59.36	2.23	38.42
Shop	7.61	33.18	59.22
Restaurant	72.63	13.64	13.74
Hotel	77.63	19.13	3.25
Public Facilities	25.57	20.30	54.44
Market	83.75	6.97	9.28

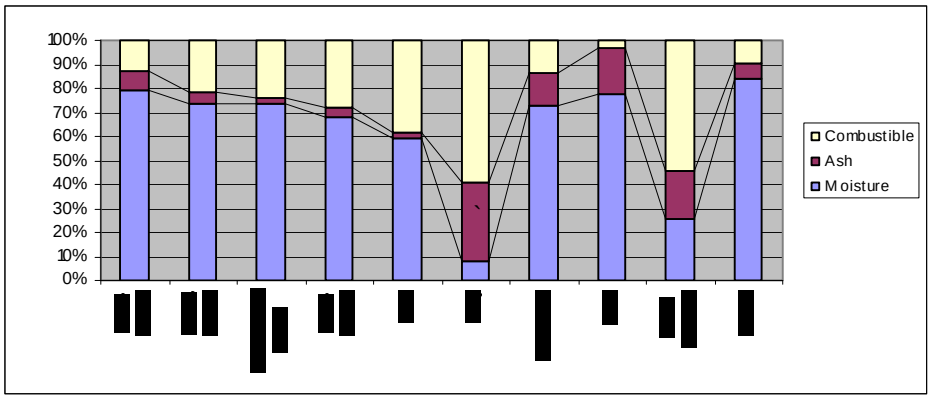


Figure A.3.10 Three-Content Analysis Results

4. ANALYSIS OF RESULTS

4.1 Waste Generation Amount

4.1.1 Estimation of Waste Generation Rate in Each Generation Source

Based on the results of the waste amount survey discussed in **Section 3.1**, the average amount of waste for each generation source are as summarised in **Table A.4.1**. The average waste generation amount per capita per day of the five income groups in the residential areas ranges from 0.302 kilogrammes per capita per day (kg/c/d) to 0.674 kg/c/d, as shown in **Figure A.4.1**.

Table A.4.1 Waste Generation Rate at Generation Sources

Generation Source	Unit	Weight Generation (kg/d)
1. Residential area		
a. High Income	person	0.567
b. Middle Income	person	0.674
c. Low Middle Income	person	0.474
d. Low Income	person	0.302
e. Slum	person	0.417
2. Commercial establishment		
a. Restaurant	establishment	38
b. Shops	establishment	0.5
c. Hotel/Guest Houses		
Standard Hotels	establishment	350
Lodging/Guest House	establishment	100*
d. Industrial Plant	establishment	150*
e. Other Establishments	establishment	0.5*
3. Public facilities		
a. Offices	establishment	137
b. Schools	establishment	76
4. Market	market	2,045
5. Roads	km	106

Note: * Not included in the waste amount survey but waste generation based on direct interview with the person-in-charge of waste management in the specific establishment.

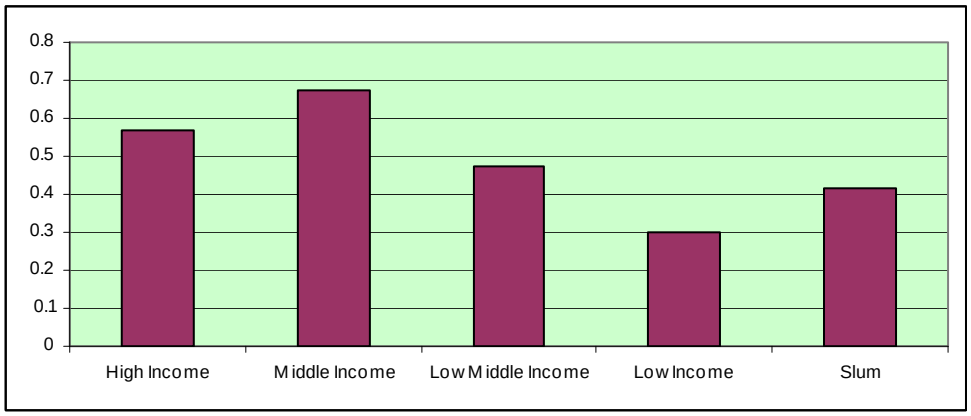


Figure A.4.1 Waste Generation Rate in Residential Areas

4.1.2 Estimation of Total Amount of Waste Generated in Nairobi City

The assumptions for the estimation of total amount of solid waste currently generated in Nairobi City were based on the results of the actual waste amount survey and the data gathered from different government agencies.

(1) Residential

The 1999 Census had placed the population of Nairobi by at 2,143,254 people. Based on this, the population of Nairobi in 2009 was estimated to be 3,040,000 (JICA Survey Team, 2010). The population ratios of high income (high and middle income groups), middle income (low-middle income group) and low income (including slum area) are 13.07%, 35.08% and 51.85%, respectively.

(2) Commercial

The estimation for establishments included the commercial waste of shops; restaurants; hotels and guest houses; public facilities and schools; industrial plants and others. Industrial plants, guest houses and other establishments were not included in the waste amount survey, but they need to be considered in the estimation in order to have a more accurate computation of commercial waste. The estimation was done through direct interview with the person-in-charge of waste management in the concerned establishment.

The number of establishments for the year 2009 was obtained from the Department of Computer of the City Council of Nairobi. Shops, restaurants, hotels and guest houses, public facilities and schools, industrial plants, and other establishments in 2009 were 47,941, 1,582, 726, 3,347, 501 and 27,077 respectively.

The unit waste amount of general waste per guest house as well as industrial plants and other establishments was estimated through the interview survey. For schools, although the waste generation amount was 76 kg/day, the computation arrived at only 32 kg/day when getting the ratio of total number of students in Nairobi City against the number obtained during the survey. This lower figure may be due to the fact that the students are not in the schools everyday.

(3) Market

At present, there are 44 markets in Nairobi City. The actual number and distribution of markets in each zone were obtained from the Department of Social Services of the City Council of Nairobi, namely; 4 in Zone 1, 3 in Zone 2, 5 in Zone 4, 2 in Zone 6, 1 in Zone 7, 8 in Zone 8, 10 in Zone 9 and 11 in CCN-Zone.

(4) Road

The length of roads being swept at present is 563.3 km. However, the amount of waste generation from roads was not added in the estimation of total waste generated considering that the waste generators are also from the residential and commercial areas. The estimation was conducted just to show the amount being swept from the roads everyday.

The waste amount survey estimated the amount of waste being generated on roads to be about 50 kg/km/day. However, during the interview with the Division Manager of each area in Nairobi City, more accurate data on the length of each road as well as the record of estimated waste being swept were obtained, and it was agreed that the average weight of waste collected from the roads is about 106 kg/km/day.

Based on the above assumptions, the total waste amount generated in Nairobi City at present (year 2009) is estimated at 1,848 t/day, as shown in **Table A.4.2**. The values in the table were the basis for the projection of future waste amounts.

Table A.4.2 Total Amount of Waste Generation

Generation Sources	Quantity	Unit	Unit Generation (kg/day)	Total (kg/day)
1. Residential Waste				
a. High Income	397,362	person	0.621	246,635.00
b. Middle Income	1,066,393	person	0.474	505,076.00
c. Low Income	1,576,245	person	0.360	566,670.00
Sub-Total for Residential Waste				1,318,381.00
2. Commercial Waste				
a. Shops	47,941	establishment	0.5	23,970.50
b. Restaurants	1,582	establishment	38	60,116.00
c. Hotels & Guest Houses				
Standard Hotels (D Class)	140	establishment	350	49,000.00
Lodging House (B & C Class)	586	establishment	100	58,600.00
d. Public Facilities/Schools				
Public Facilities	500	establishment	137	68,500.00
School	2,847	establishment	32	91,104.00
e. Industrial Plants	501	establishment	150	75,150.00
f. Other Establishments	27,077	establishment	0.5	13,538.50
Sub-Total for Commercial Waste				439,979.00
3. Market Waste	44	market	2045	90,000.00
4. Road Waste	563.3	km	106	(60,000.00)
Total				**1,848 t/day**

Note: Road waste is already included in residential and commercial wastes.

From the table above, it will be noted that the total waste generated by commercial establishments is about 25% of the total waste generated by the residential areas.

4.2 Waste Composition Amount

The average waste compositions in the wet and dry season surveys were applied in the calculation of physical composition of waste. The results are summarised in **Table A.4.3** and presented in **Figure A.4.2**.

Table A.4. 1 Waste Composition at Generation Sources

Unit: %

Waste Composition		High/ Middle Income	Low Middle Income	Low Income/ Slum	Shops	Restau-rant	Hotel	Public Facilities	Market	Road
Food Waste		66.38	65.95	58.94	46.15	88.88	85.17	71.48	89.10	16.61
Paper	Recyclable Paper	3.67	3.74	4.55	14.02	0.94	0.65	1.66	0.81	13.14
	Recyclable Cardboard	0.94	0.36	0.11	2.91	0.58	0.50	0.34	3.72	1.97
	Mixed Paper	2.51	0.00	3.01	1.39	0.00	0.00	0.95	0.00	0.17
	Diapers	4.83	12.89	4.75	0.45	0.15	0.00	0.07	0.00	0.00
	Subtotal - Paper	*11.96*	*16.99*	*12.41*	*18.77*	*1.66*	*1.15*	*3.02*	*4.53*	*15.28*
Plastics	Plastic Sheet	6.38	4.45	9.13	1.84	0.95	0.40	1.63	0.00	3.04
	Recyclable Plastics	1.66	5.32	2.03	6.72	2.85	2.69	2.00	1.08	3.51
	PET Bottles	1.10	0.09	0.54	2.87	1.65	1.88	4.89	0.27	4.28
	Other Plastics	0.32	0.48	0.00	3.72	0.33	0.04	0.00	0.12	0.09

Waste Composition		High/ Middle Income	Low Middle Income	Low Income/ Slum	Shops	Restau-rant	Hotel	Public Facilities	Market	Road
	Subtotal - Plastics	*9.46*	*10.34*	*11.70*	*15.14*	*5.77*	*5.01*	*8.52*	*1.48*	*10.91*
Rubber & Leather		0.20	0.58	1.11	0.00	0.00	0.00	0.00	0.23	0.00
Textiles		1.27	0.65	2.29	0.81	0.00	0.00	0.00	2.96	0.34
Yard Waste		2.68	0.00	0.00	0.67	0.22	1.13	0.20	0.00	17.20
Lumber & Logs		1.50	0.00	1.03	0.00	0.00	0.00	0.00	0.00	0.30
Other Org. Waste		1.42	0.71	0.00	2.69	0.70	2.57	4.08	0.67	6.68
Organic Waste - Subtotal		**94.86**	**95.22**	**87.49**	**84.23**	**97.24**	**95.03**	**87.30**	**98.97**	**67.33**
Glass	Returnable Bottles	0.45	0.62	0.06	3.67	0.98	2.76	0.00	0.00	0.17
	Other Live Bottles	0.84	0.39	1.40	0.90	0.19	0.00	0.00	0.07	0.00
	Glass bins	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30
	Broken Glass	0.19	0.56	0.00	3.72	0.31	0.00	5.04	0.43	0.47
	Glass-Subtotal	*1.48*	*1.57*	*1.46*	*8.29*	*1.48*	*2.76*	*5.04*	*0.50*	*0.94*
Metals	Tin Cans (steel cans)	0.32	0.16	0.00	1.48	0.39	0.48	4.63	0.04	0.00
	Aluminum cans	0.23	0.04	0.00	1.88	0.82	1.50	1.52	0.00	0.09
	Copper	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Other Metals	0.75	0.65	0.52	0.09	0.00	0.00	0.49	0.14	0.87
	Metal-subtotal	*1.30*	*0.85*	*0.52*	*3.45*	*1.20*	*1.97*	*6.64*	*0.18*	*0.96*
Dirt, Ash, Stone, Sand		***2.12***	***1.77***	***10.12***	2.51	0.00	0.06	1.02	0.21	29.62
Inorganic Waste - Subtotal		**4.90**	**4.18**	**12.11**	**14.25**	**2.69**	**4.79**	**12.70**	**0.90**	**31.52**
Unclassified Residual Waste		0.10	0.18	0.40	1.43	0.07	0.18	0.00	0.14	0.90
Domestic Hazardous Waste		0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.26
Batteries - Dry Cells		0.05	0.09	0.00	0.09	0.00	0.00	0.00	0.00	0.26
Other Domestic Hazardous Wastes		0.10	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

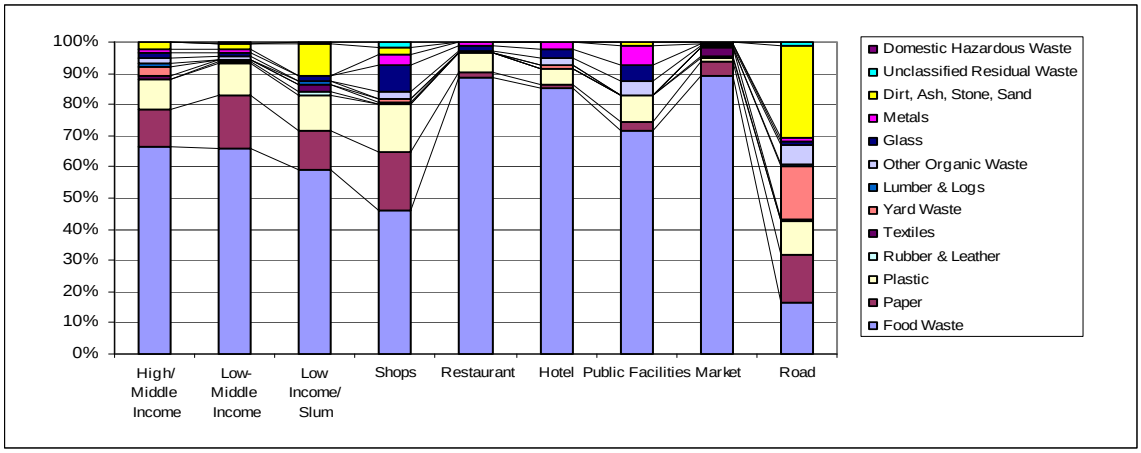


Figure A.4.2 Physical Composition of Waste at Generation Sources

From the table and figure above, the highest percentage of waste composition goes to food waste coming from market waste, followed by paper and then plastics, both of which come from shop waste. Fourth is the mixture of dirt, ash, sand and stone as expected from road waste, and fifth is glass coming from shops.

In comparison with the results of the 1998 JICA Integrated Solid Waste Management Study in Nairobi City, food waste, paper and plastics are also the topmost compositions of waste.

The weight and weighted ratio of each composition from the total waste generated in Nairobi City were calculated, as shown in **Table A.4.4**. The characteristics are as follows:

- The ratio of food waste is 69%; paper is 9.43% and almost the same with plastics, about 9.42%.
- The ratio of recyclable materials such as paper, plastics, metals and glass is 15.61%.
- The ratio of organic materials is 91.62%; non-organic materials have an extremely low ratio of 7.94%; unclassified residuals have 0.34% and domestic hazardous wastes such as battery-dry cell have the ratio of 0.1%.

Table A.4.3 Weight and Weighted Ratio of Total Waste Generated

Waste Composition		Total Weight (t/day)	Weighted Ratio (%)
Food Waste		1154	68.99
Paper	Recyclable Paper	70	4.18
	Recyclable Cardboard	14	0.82
	Mixed Paper	19	1.12
	Diapers	55	3.31
	Subtotal - Paper	*158*	*9.43*
Plastics	Plastic Sheet	59	3.54
	Recyclable Plastics	56	3.32
	PET Bottles	31	1.86
	Other Plastics	12	0.70
	Subtotal - Plastics	*158*	*9.42*
Rubber & Leather		5	0.27
Textiles		12	0.72
Yard Waste		12	0.70
Lumber & Logs		6	0.36
Other Org. Waste		29	1.74
Organic Waste - Subtotal		**1533**	**91.62**
Glass	Returnable Bottles	20	1.22
	Other Live Bottles	9	0.53
	Glass bins	0	0.00
	Broken Glass	23	1.40
	Subtotal - Glass	*53*	*3.15*
Metals	Tin Cans (steel cans)	18	1.06
	Aluminum cans	14	0.85
	Copper	0	0.00
	Other Metals	6	0.36
	Subtotal - Metals	*38*	*2.28*
Dirt, Ash, Stone, Sand		42	***2.51***
Inorganic Waste - Subtotal		**133**	**7.94**
Unclassified Residual Waste		6	0.34
Domestic Hazardous Waste		2	0.09
Batteries - Dry Cells		1	0.03
Other Domestic Hazardous Wastes		1	0.06
Total		**1,673**	**100.00**

Note: Total weight was calculated by subtracting self-disposal waste amount from the total waste generation amount, i.e., 1,884 – 175 (self-disposal amount) = 1,673 t/day

4.3 Diverted Waste Amount

The total amount of diverted waste includes the amount of waste reduced at source; the recovered recyclable materials at junkshops; the recovered materials through composting of biodegradables by residents, CBOs and pilot plant; the recovered waste by the collection crew at the Material Recovery Facility (MRF); and the recovered waste at the disposal site.

Assumptions were established to estimate the amount of currently diverted waste based on the result of the waste composition survey conducted. The assumptions are as follows:

- Target Waste Reduction at Source is 0%.
- Target Recovery Ratio for Recyclable Materials (Paper and Plastics) by Junk Shops is 30% from the 5% Ratio in Comingled Waste.
- Target Recovery Ratio for Recyclable Materials (Glass and Metals) by Junk Shops is 50% from the 1% Ratio in Comingled Waste.
- Target Recovery Ratio for Recovery through Composting is 1% from the 64% Ratio in Comingled Waste.
- Assumed Waste Recovery Ratio by Collection Crew and at MRF(s) is 1%.
- Assumed Waste Recovery Ratio at Disposal Sites is 1%.

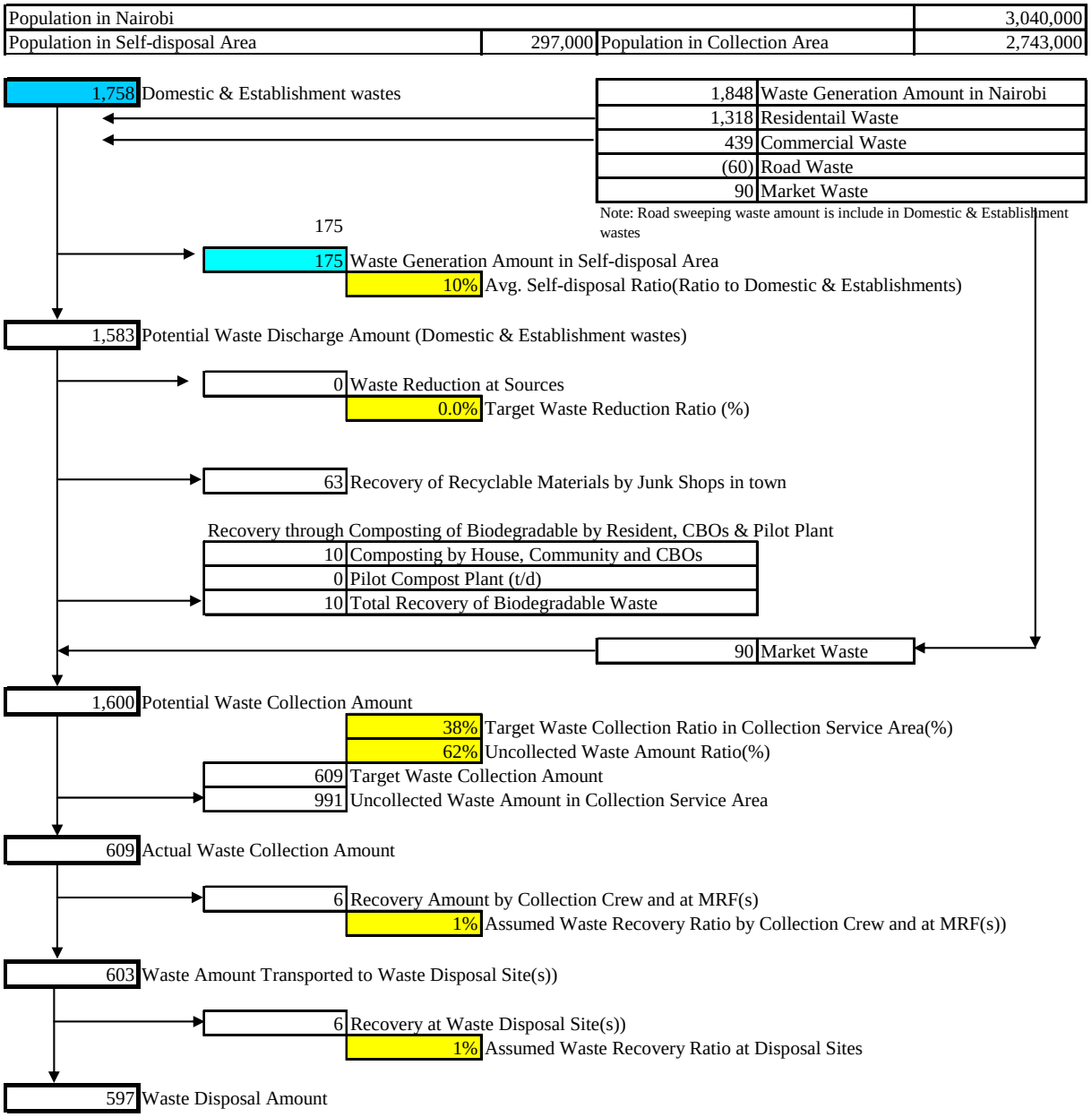
Based on the above assumptions, the amounts of currently diverted waste in Nairobi City are as shown in **Table A.4.5**.

Table A.4.4 Summary of Waste Reduction, Recovery and Diversion

Item	Amount (t/day)
Waste Reduction Amount at Sources	0
Recovery Amount of Recyclable Materials by Junk Shops	63
Recovery through Composting of Biodegradables by Residents, CBOs and Pilot Plant	10
Recovery Amount by Collection Crew and at MRF(s)	6
Recovery Amount at Waste Disposal Site(s)	6
Total Diversion Amount	**86**

4.4 Current Waste Flow

Based on the above analysis and assumptions, the current waste flow in Nairobi City as of year 2009 is as shown in **Figure A.4.3**.



Summary of Waste Reduction, Recovery and Diversion (t/day)

Material Recovery Amount	75	4.7%
Biodegradable Recovery Amount	10	0.6%
Total Waste Recovery Amount	86	5.3%
Waste Reduction Amount at Sources	0	0.0%
Waste Diversion Amount	86	5.3%

Figure A.4.3 Current Waste Flow in Nairobi City

As shown in the figure above, the current waste collection amount in Nairobi City is about 609 t/day while the present collection service area is only about 38% of the entire city.

5. PROJECTION OF FUTURE WASTE GENERATION AMOUNT

5.1 General

The projection of waste generation amount for the years 2009, 2015, 2020, 2025 and 2030 is presented in this section. The future solid waste generation amount by the year 2030 is projected based on the results obtained in the field survey.

The following considerations were used in the calculation for updating the future waste amount:

- Population
- Area
- Income Group
- Gross Domestic Product

5.2 Population Projection for Nairobi City

The most direct influence on waste generation is the change in population. As described in **Subsection 4.2.1** of the **Main Report**, the annual population of Nairobi City for the planning period is estimated, as shown in **Table A.5.1**.

Table A.5.1 Population Projection for Nairobi City (Unit: 10^3 person)

Income Class	2009	2015	2020	2025	2030
High Income	397	491	578	673	776
Middle Income	1,066	1,319	1,550	1,807	2,084
Low Income	1,576	1,950	2,292	2,670	3,080
Total	**3,040**	**3,760**	**4,420**	**5,150**	**5,940**

Source: JICA Survey Team, 2010

Based on the JICA Study on Integrated Solid Waste Management in 1998, there is a correlation between waste increase rate per capita and growth rate in GDP per capita. For updating in the present study, 0.5% is also assumed as the increase ratio per capita of waste generation.

5.3 Assumptions in the Projection of Future Waste Generation Amount

For the projection of different generators of wastes, the conditions for estimation are as set out below.

5.3.1 Residential Waste (Domestic Waste)

The data on waste generation amount per capita are as obtained in the field survey. Waste discharge amount is calculated by subtracting the self-disposal amount from the generation amount. The self-disposal amount is estimated based on the interview with the inspectors of the respective divisions who manage the waste collection system within the city. The percentage of self-disposal amount in each area is then verified with the Head of the Solid Waste Collection under the Department of Environment. The waste discharge amount per capita is estimated to increase according to the 0.5% growth rate in GDP per capita. The same assumption was used in the 1998 JICA Integrated SWM Master Plan Study in Nairobi City.

5.3.2 Commercial Wastes (Restaurant, Hotel, Shop, etc.)

Commercial waste generation is projected based on the number of establishments located in each of the eight (8) divisions of the city, namely; Starehe, Makadara, Kamkunji, Kasarani, Embakasi, Westlands, Dagoretti and Langata. The increase of waste generation is in proportion to the increase in population. The projected waste generation amount of commercial establishments is about 25% of household waste.

The projected waste generation amount of commercial and other establishments is estimated at 25% of the domestic waste amount. The projected waste generation amount of commercial and other establishments is also distributed to the nine (9) privatisation zones and the CCN-Zone in proportion to the coefficient derived from the relation between the division-based population and the zone-based population.

5.3.3 Market Waste

Market waste generation is also forecast based on the field survey. Waste generation in each market will increase based on the rate of increase of population. At present, there are forty-four (44) markets in Nairobi City.

5.3.4 Road Waste

Waste generation amount of road waste is projected based on the field survey. The generation amount will not increase and it is computed based on the length of road for sweeping service. The waste generators of road waste come from the residences and establishments. For the purpose of estimation, the road waste generation in each zone is computed, but in the computation of total waste generation in the whole city, the amount is not included considering that it is already included in domestic and commercial wastes.

5.4 Projection of Waste Amount Generation

Based on the assumptions above, the projection of waste amount for each waste generator is as discussed below.

For domestic waste, the projected amounts of waste generated in each zone are as shown in **Table A.5.2**.

Table A.5.2 Projection of Domestic Waste in Nairobi City (ton/day)

Zone	2009	2015	2020	2025	2030
Zone 1	100	127	153	183	217
Zone 2	97	124	149	178	211
Zone 3	81	104	125	149	176
Zone 4	141	179	216	258	305
Zone 5	95	121	146	174	206
Zone 6	106	135	163	194	230
Zone 7	85	109	131	157	185
Zone 8	74	94	114	136	160
Zone 9	96	122	147	176	208
CCN/SWMPC-Zone	444	588	681	814	962
Total	**1,318**	**1,747**	**2,025**	**2,419**	**2,860**

Source: JICA Survey Team, 2010

For road sweeping waste, the result of the projection of waste generation is shown in **Table A.5.3**. As mentioned above, the amount of waste generated is projected not to increase every year and it is not included in the total amount of waste generated in Nairobi City.

Table A.5.3 Projection of Road Sweeping Waste in Nairobi City (ton/day)

Zone	2009	2015	2020	2025	2030
Zone 1	10	10	10	10	10
Zone 2	1	1	1	1	1
Zone 3	3	3	3	3	3
Zone 4	2	2	2	2	2
Zone 5	2	2	2	2	2
Zone 6	2	2	2	2	2
Zone 7	9	9	9	9	9
Zone 8	4	4	4	4	4
Zone 9	8	8	8	8	8
CCN/SWMPC-Zone	18	18	18	18	18
Total	**60**	**60**	**60**	**60**	**60**

Source: JICA Survey Team, 2010

For market waste, the projected waste amounts generated is shown in **Table A.5.4**.

Table A.5.4 Projection of Market Waste in Nairobi City (ton/day)

Zone	2009	2015	2020	2025	2030
Zone 1	8	10	12	14	16
Zone 2	6	7	9	10	12
Zone 3	0	0	0	0	0
Zone 4	11	13	15	18	21
Zone 5	0	0	0	0	0
Zone 6	4	5	6	7	8
Zone 7	2	2	3	3	4
Zone 8	17	20	24	28	32
Zone 9	21	25	30	35	40
CCN/SWMPC-Zone	23	28	33	38	44
Total	**90**	**111**	**131**	**152**	**176**

Source: JICA Survey Team, 2010

To summarise the above projected results, the total amount of waste generated in Nairobi City is forecasted at 3,990 tons per day for year 2030, as shown in **Table A.5.5** and **Figure A.5.1** below.

Table A.5.5 Projection of Total Waste Amount Generated in Nairobi City (ton/day)

Zone	2009	2015	2020	2025	2030
Residential	1,318	1,747	2,025	2,419	2,860
Commercial	439	538	675	806	953
Road	(60)	60	60	60	60
Market	90	111	131	152	176
Total	**1,848**	**2,352**	**2,831**	**3,378**	**3,990**

Note: Road sweeping waste amount is included in household and commercial wastes.

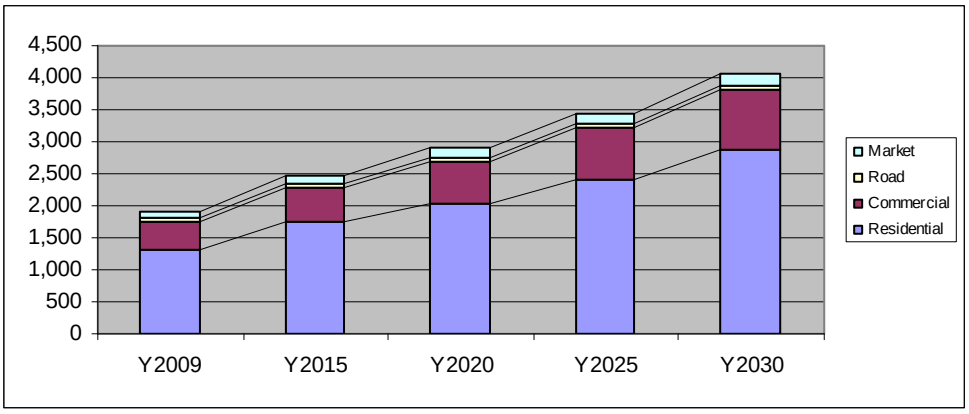
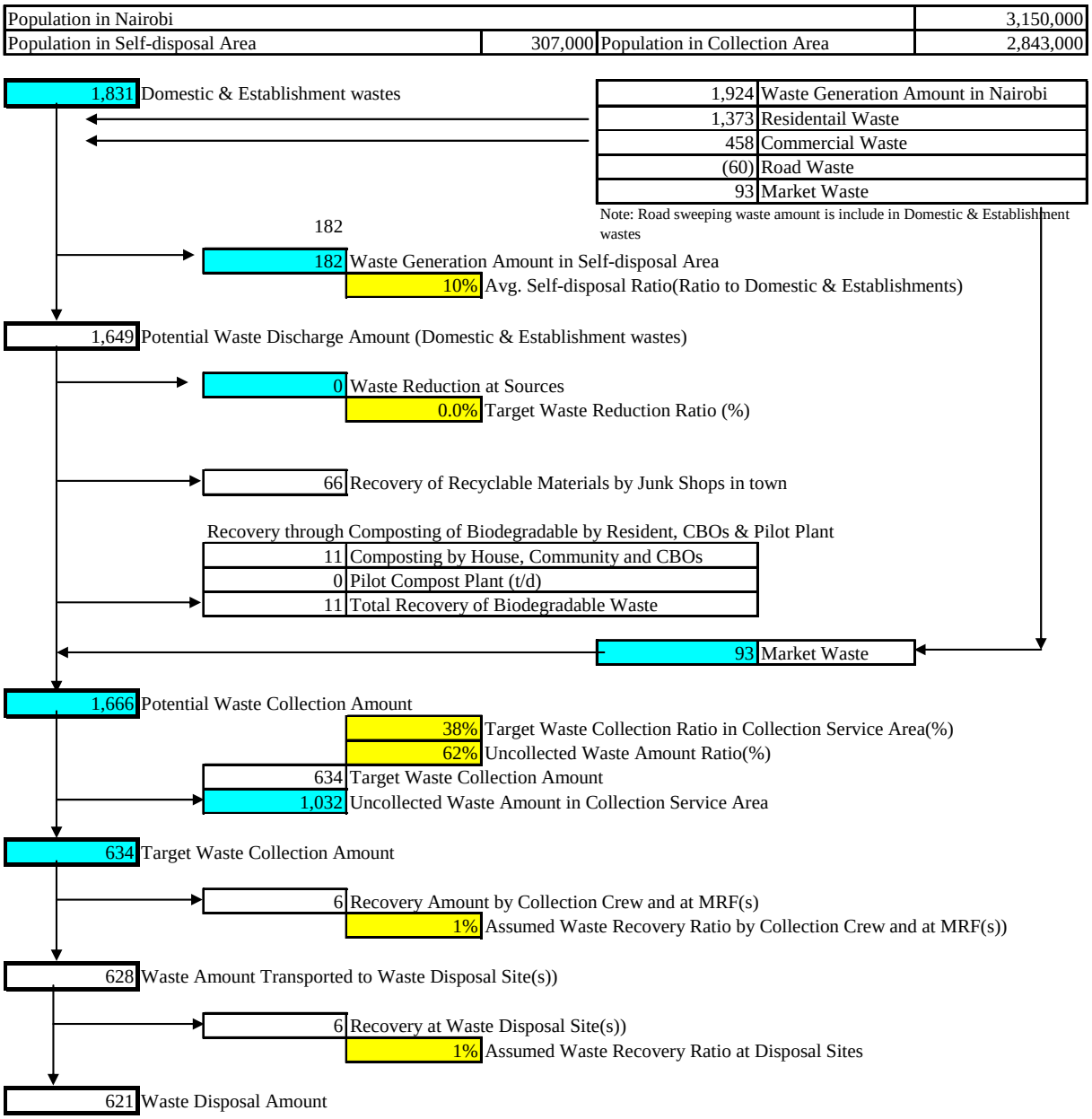


Figure A.5.1 Projection of Total Amount of Waste Generated in Nairobi City

5.5 Projection of Future Waste Flow

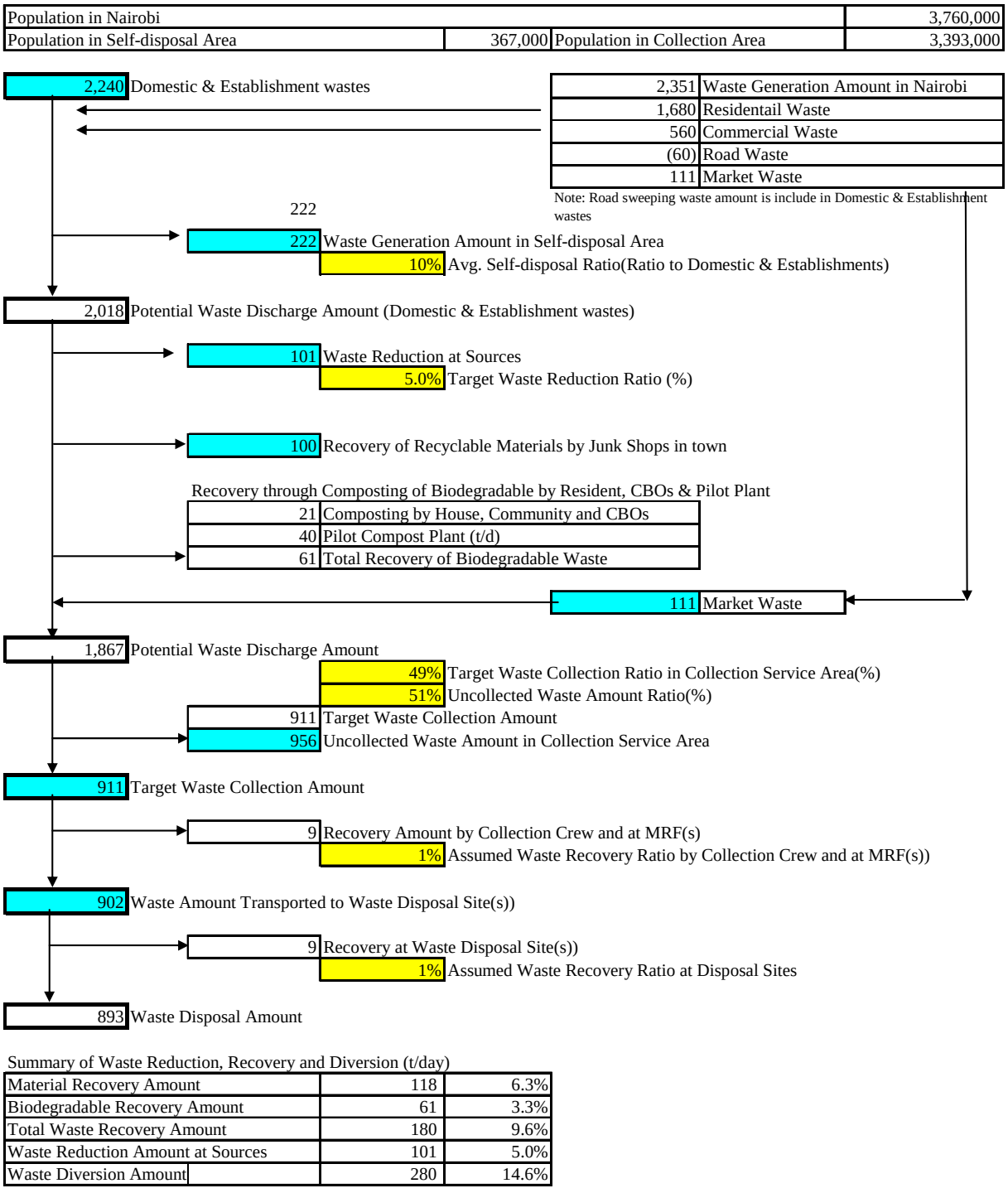
Based on the assumptions and projections above, the forecast on waste flow up to the year 2030 is as illustrated in **Figure A.5.2** to **Figure A.5.6** below.



Summary of Waste Reduction, Recovery and Diversion (t/day)

Material Recovery Amount	79	4.7%
Biodegradable Recovery Amount	11	0.6%
Total Waste Recovery Amount	89	5.3%
Waste Reduction Amount at Sources	0	0.0%
Waste Diversion Amount	89	5.3%

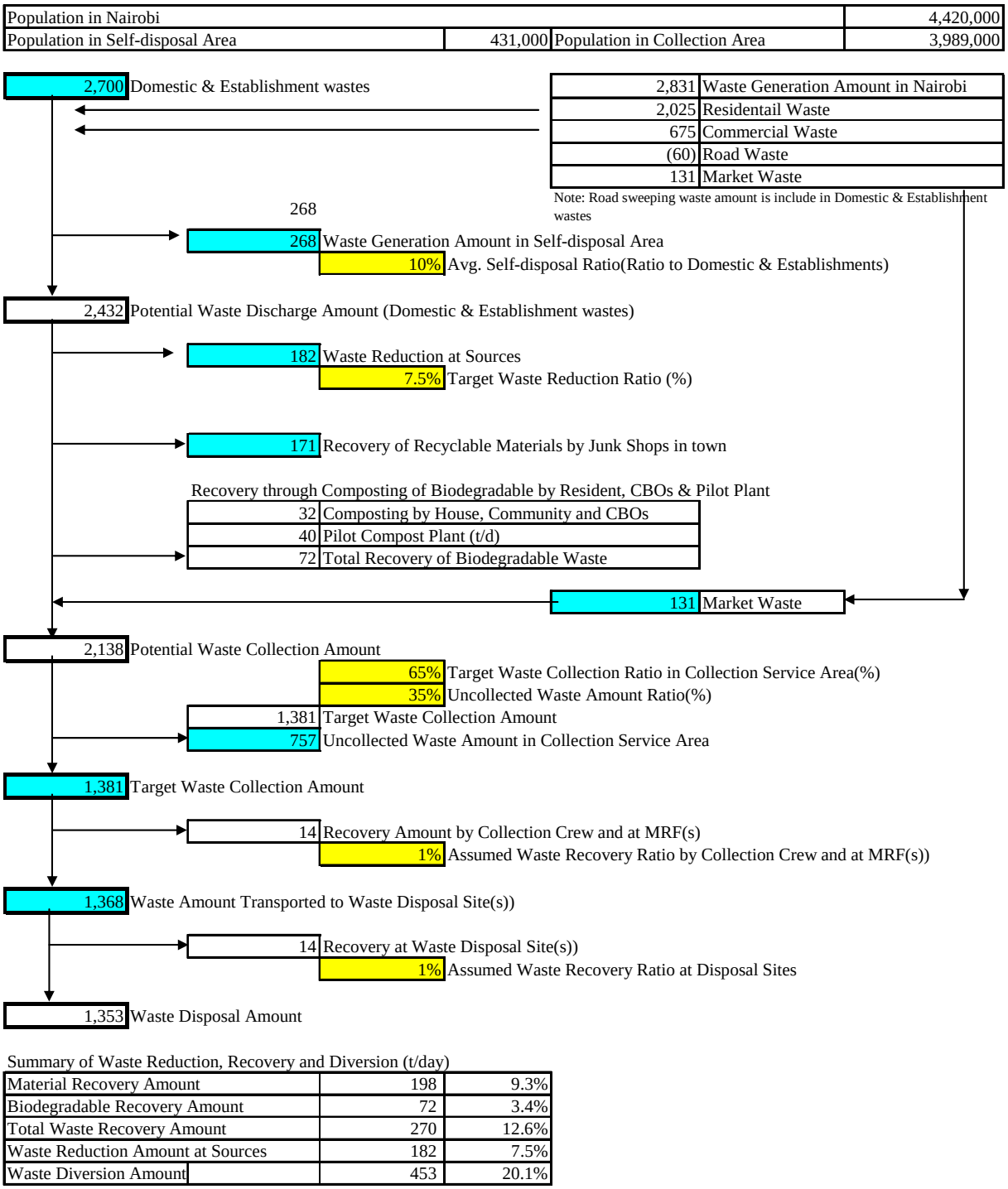
Figure A.5.2 Future Waste Flow in Nairobi City (Year 2010)



Summary of Waste Reduction, Recovery and Diversion (t/day)

Material Recovery Amount	118	6.3%
Biodegradable Recovery Amount	61	3.3%
Total Waste Recovery Amount	180	9.6%
Waste Reduction Amount at Sources	101	5.0%
Waste Diversion Amount	280	14.6%

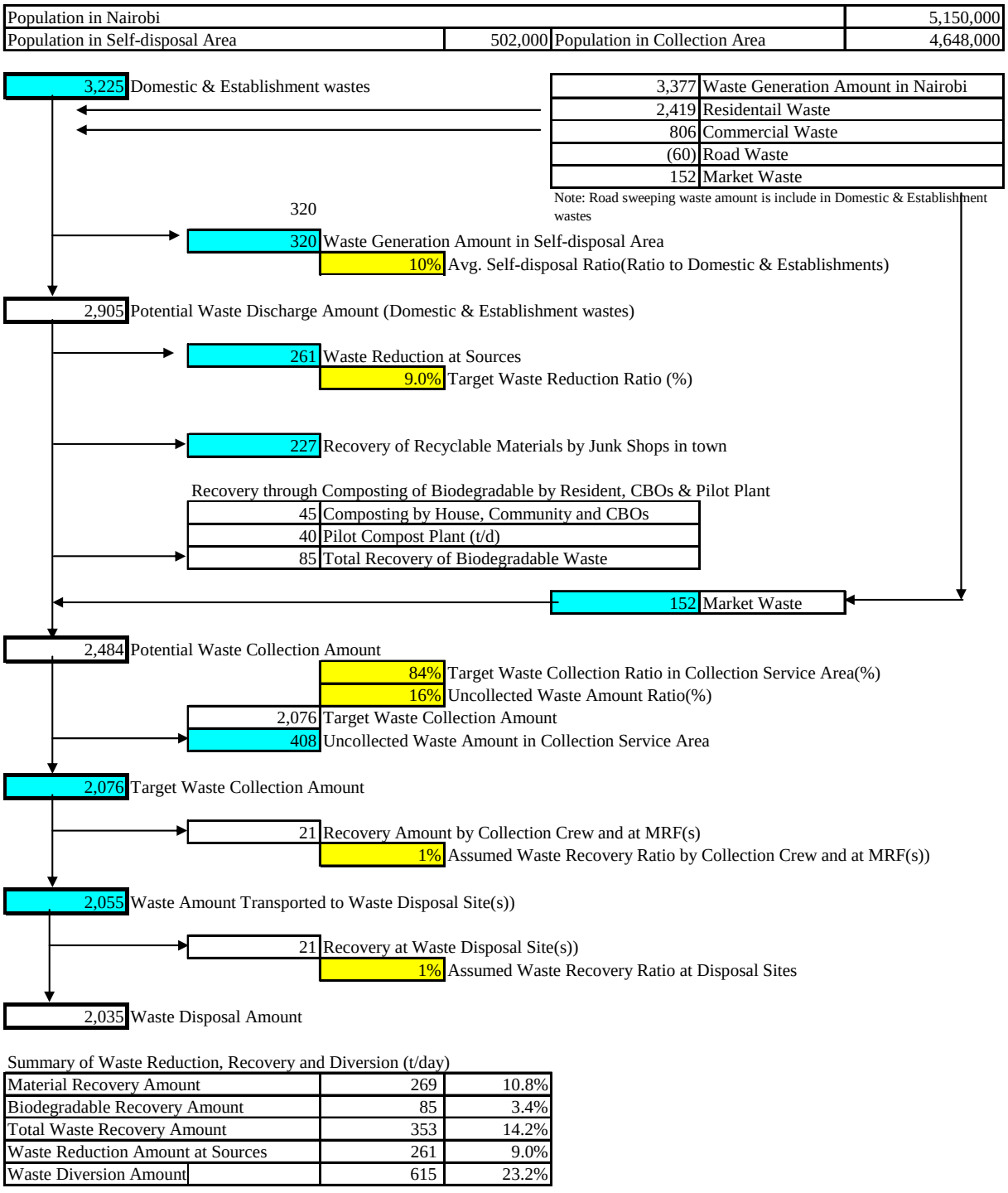
Figure A.5.3 Future Waste Flow in Nairobi City (Year 2015)



Summary of Waste Reduction, Recovery and Diversion (t/day)

Material Recovery Amount	198	9.3%
Biodegradable Recovery Amount	72	3.4%
Total Waste Recovery Amount	270	12.6%
Waste Reduction Amount at Sources	182	7.5%
Waste Diversion Amount	453	20.1%

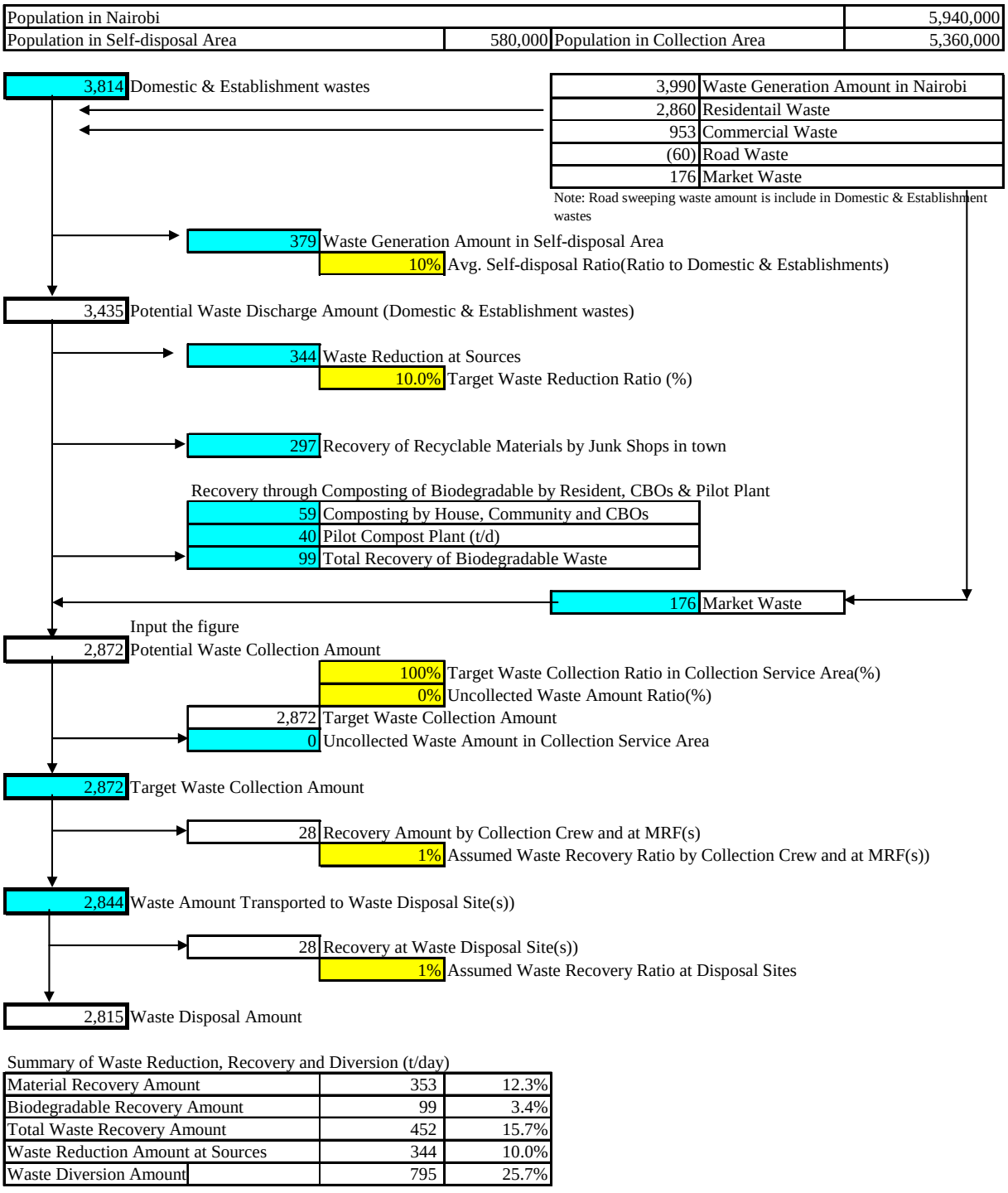
Figure A.5.4 Future Waste Flow in Nairobi City (Year 2020)



Summary of Waste Reduction, Recovery and Diversion (t/day)

Material Recovery Amount	269	10.8%
Biodegradable Recovery Amount	85	3.4%
Total Waste Recovery Amount	353	14.2%
Waste Reduction Amount at Sources	261	9.0%
Waste Diversion Amount	615	23.2%

Figure A.5.5 Future Waste Flow in Nairobi City (Year 2025)



Summary of Waste Reduction, Recovery and Diversion (t/day)

Material Recovery Amount	353	12.3%
Biodegradable Recovery Amount	99	3.4%
Total Waste Recovery Amount	452	15.7%
Waste Reduction Amount at Sources	344	10.0%
Waste Diversion Amount	795	25.7%

Figure A.5.6 Future Waste Flow in Nairobi City (Year 2030)