

Life Cycle Assessment of Municipal Solid Waste Management in Ibadan Metropolis, South-Western Nigeria

A. A. Afolabi and S. O. Ojoawo*

Department of Civil Engineering, Ladoke Akintola University of Technology, Ogbomoso, Nigeria

Corresponding author: sojoawo@lautech.edu.ng

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ABSTRACT

Inappropriate waste management breeds negative impacts on the environment and this often results into pollution, with health implication on human beings. Control measures are more effective when the waste components are analyzed. Hence, this study focuses on the Life Cycle Assessment (LCA) of municipal solid wastes in three randomly selected Local Government Areas (LGAs) in Ibadan metropolis, South-Western Nigeria, namely Ibadan North (IBN), Ibadan North-East (IBNE) and Ibadan South-East (IBSE). Representative samples of wastes were collected from each of the LGAs on daily basis for seven days for classification purpose, and the respective quantities of waste types were estimated. Three Solid Waste Management (SWM) scenarios namely material recovery facility and landfilling (S1), recycling and landfilling (S2) and recycling, composting and landfilling (S3), were developed, evaluated and compared with the existing landfilling (S4) management practice. An Integrated Waste Management Model (IWM-1) was employed for each scenario to simulate and predict the pollution levels of the greenhouse gases (CO_2 , CH_4 , NO_x), acid gases (SO_x , HCl), smog precursors (particulate matters, VOCs), heavy metals (Pb, Hg, Cd) and organics (dioxin). The classification result showed that organic matters with a range of 60.55 and 65.71% dominate the waste types. Textile hovered between 6.94% and 8.92%, while the least was ashes with value ranges between 2.65 and 3.80%. Ibadan North-East has the highest estimated total waste quantities of 1,168 tones/week. All the scenarios have CO_2 equivalent emission as the threatening greenhouse gases. S2 generated the highest CH_4 content, while S3 poses the least global warming potential threat. The worst acidification potential threat was from S2 caused by NO_x , SO_x and HCl . Heavy metals and dioxins however have negligible values in the scenarios. The three (3) new scenarios all gave less environmental threats as compared with the existing S4. The socio-economic status of residents largely determines the composition and volume of wastes in the study area. The reusable and recyclable components of the wastes are minimal compared with the disposable ones. Carbon (IV) oxide is a noticeable environment threat in all management scenarios of the study area and could manifest in form of global warming and negative climate change, should waste management not given a priority attention. Recycling, composting and landfilling (S3) is the most environmental-friendly of the studied management scenarios. A sustainable Integrated Waste Management System (IWMS) is therefore strongly recommended for Ibadan Metropolis, South-Western Nigeria.

1. INTRODUCTION

Life Cycle Assessment is a tool used to evaluate the environmental performance of Municipal Solid Waste Management System. Waste is the matter considered discarded, worthless, and defective or of no further value and is most often derived from places of human or animals habitation or through a manufacturing process. Effective management of solid waste is an important aspect of environmental management. Waste may also be defined simply as left-over or already used items waiting for refuse or disposal (Audu, 2007). In most Nigerian cities and villages, domestic animals are usually sighted in highly populated and commercial areas; their faeces and urine pollute the environment. Solid waste consists of the highly heterogeneous mass of discarded materials from the urban community, as well as the more homogenous accumulation of agricultural, industrial and mining wastes. The principal sources of solid waste are residences, commercial establishments, and institutions, industrial and agricultural activities. At the onset, a cordial relationship existed between man and his environment. Man's relationship with his environment was that of mutual respect and dependence. However, with man's insatiable quest for technological advancement, man has breached the tacit agreement of trust reached with his environment and has conformed to lord it over the environment to his own detriment.

Moreover, solid waste generation plays an important role in solid waste management. Yet, achieving the anticipated prediction accuracy with regard to the generation trends facing many growing regions is quite challenging. The development of a reliable model for predicting the aggregate impact of economic trend, population changes, and recycling impact on solid waste generation would be a useful advice in the practice of solid waste disposal (Aboue and El-Fadel, 2004). A municipality is an administrative division composed of a defined territory and population (Al-salam and Lettieri, 2009). While there are many varieties of municipalities, most fall into one or two categories: a single settlement and a land area similar to a township that may contain multiple settlements, or even just part of one, such as a city's municipality. Municipal Solid Waste (MSW) can be defined as solid waste which includes all domestic refuse and non-hazardous wastes such as commercial and institution wastes, street sweepings and construction debris (Magutu *et al.*, 2010). The major types of MSW are food wastes, paper, plastics, rag, metal and glass, with some hazardous household wastes such as electric light bulbs, batteries, discarded medicines and automotive parts. MSW is thus seen as primarily coming from household but also includes waste from offices, hotels, shopping complexes/shops, schools, institutions, and from municipal services such as street cleaning and maintenance of recreational centers (UNEP, 2005).

Waste management is the collection, transportation, processing, recycling or disposal, and monitoring of waste materials. Operational strategy can be viewed as parts of a planning process of the larger organization. The operation capabilities of a firm can be viewed as a portfolio best suited to adapt to the changing product and service needs of a firm's customers (Hayes, 1985). The costs for SWM are high especially for collection and transportation while methods of collection of waste are either door-to-door or using containers or commercial bins. The most common municipal waste management practices include: Recycling/recovery, composting, incineration and landfilling/open dumping. The operations strategy is a very important tool in the SWM practices and processes (Peter, 1984). MSW may contain the following materials, which are considered recyclables: ferrous and non-ferrous metals, construction debris, scrap tyres, paper/cardboard, plastics, textile (including both cloth and leather), glass, wood/timber, animal bones/feathers, waste oil and grease, cinders/ashes. Waste management in all reunifications is simply a planned system aimed at effectively controlling the production, storage, collection, transportation, processing and disposal of waste. Waste management is an important element of environment protection. Its purpose is to provide hygienic, efficient and economic solid waste storage collection, transportation and treatment of disposal of waste without polluting the atmosphere, soil and water system. The path traced by solid waste in the management of solid waste from generation to the point of disposal is referred to as solid waste chain.

Solid waste is one of the fundamental environment health problems in our urban and semi-urban cities of the world, Nigeria inclusive. SWM is one aspect of urban management in which Nigeria has virtually made no significant start as observed by Okechukwu (1995). Unsightly heaps of refuse litter the streets and drains of virtually all cities in the country. Heaps of various sizes of solid waste dumps are characteristically seen on roads/street intersections, backyards, undeveloped plots and at open spaces. The main issue of interest on the subject of SWM is that all tiers of government are aware of the threat it poses, but have not confronted it adequately. Every government has some form of organized refuse collection and disposal in place. The problem has been that most cities and towns managers are still handling solid waste, as issue without potency, despite increased population, economic development and technological advancement. Most cities and towns in the country have open dump sites within or in close proximity to the city with virtually no environmental safeguards (Okechukwu, 1995).

Waste generations are inextricably linked to population. As population increases, so does the waste generated because the total amount of waste is the product of per-capital waste generation and the population. The amount of waste produced can be correlated to the output of goods and services. There has been a phenomenal increase in the volume and range of solid waste generated daily within the past few years and this is due largely to the increase rate of population growth, urbanization, industrialization, and general socio-economic growth (NEST, 1991; Botkin and Keller, 1997). Generally, the collection and disposal of solid waste is a major public health issue and a vital factor affecting the quality of the environment. This work is therefore designed to assess the life cycle of SWM in the city of Ibadan- the largest city in West Africa South of Sahara.

The aim of this research work is to assess the life cycle of municipal solid waste management system in Ibadan. The specific objectives of the study are to study how municipal solid wastes are stored and disposed of in Ibadan metropolis; identify the potentials that exist for the re-use and recycling of generated solid wastes; determine the gaseous pollutants emanating from the studied wastes; develop an Integrated Waste Management (IWM) model for the management of the MSW of Ibadan metropolis.

2. METHODOLOGY

Geographical Location of the Study Area

The study area is Ibadan metropolis. Ibadan is located in south-western Nigeria, 128 km inland northeast of Lagos and 530 km southwest of Abuja, the Federal Capital Territory, and is a prominent link between the coastal region and the areas to the north. Ibadan is located about 120 km east of the border with the Republic of Benin in the first zone close to the boundary between the first and the savanna. The city ranges in an elevation from 150 m in the valley area, to 275 m above sea level on the major north south ridge which crosses the central part of the city. Ibadan metropolis consist of five (5) Local Government areas namely:- Ibadan North, Ibadan South East, Ibadan North East, Ibadan Northwest and Ibadan South West. The three local government areas that would be concentrated on are Ibadan North Local Government, Ibadan North-East Local Government and Ibadan South-East Local Government that has its headquarters at *Agodi*, *Iwo* road and *Mapo* hall, respectively.

Ibadan North, Ibadan North-East and Ibadan South-East LGA

The Local Government areas were created on 27th August, 1991 by the administration of former Head of State - General Ibrahim Badamosi Babangida. They were carved out of the defunct Ibadan municipal Government and derived its name from the metropolitan nature of the area it covered then. The inhabitants of the local government area are predominantly Yoruba, although it is highly heterogeneous, accommodating people from various other tribes who either engage in commercial activities or work in the public service. Ibadan North Local Government has a population of 306,795. Ibadan North-East 330,399 while Ibadan South-East has 266,046 people (Afolabi, 2015).



Figure 1: Map of Nigeria showing Oyo State



Figure 2: Map of Ibadan Metropolis

Zoning of the Study Area

For proper identification of the sampling point, the study area was divided on the basis of socio-economic income.

Zone A: Ibadan North Local Government Area

Zone B: Ibadan North East Local Government Area

Zone C: Ibadan South East Local Government Area

To analyze the waste compositions within the study area, the town was examined based on their socio-economic characteristic to low, middle and high classes. These three categories, as shown in Table 1 are based on the income of the inhabitants.

Table 1: Classes of Residential Income

<i>Income</i>	<i>Zone</i>
Low	Zone C
Medium	Zone B
High	Zone A

Research Tools and Field Method

Six people were employed in carrying out the field work, two people each in the three LGAs. Each group was given a weighing scale, 168 pieces of polythene bags, two pairs of hand gloves and a paper tape. Samples of waste were collected from twenty-four selected households in each local government area on daily basis for seven days. The waste was sorted and classified into organic matter, paper, nylon, textile, glass, metal, silt and ashes.

Development of MSW Scenarios

Due to the increasing population and developing industry in Ibadan, the quantities of municipal and industrial solid waste in the town are rising rapidly. Vehicles collect waste that are discarded and piled up on the streets by the residents, and transport the waste to the unregulated dumping site to dump them at odd hours of the day in an uncontrolled manner. This unregulated dumping site is an open area where the recyclable components of the waste are partially separated manually under unhygienic conditions and piled up there to recycle. Wastes have been dumped in a natural valley within the town as controlled sustainable MSW management systems are not practiced in Ibadan at present. Therefore, in this study only three alternative scenarios to the current waste management system in Ibadan were developed, and these scenarios were evaluated by the means of LCA (Ojoawo and Babatunde, 2015).

- (i) **Scenario 1 (S1):** This scenario would be based on the current waste management system incorporating some improvements. In this scenario, a Material Recovery Facility (MRF) and a landfill would be added to the system. The percentages of recycling and land filling would be the same as for the current waste management system. The recycling fractions collected by scavengers would be separated in the MRF. These two parts would be processed separately since their qualities would be different. After separation, recyclable materials brought by scavengers and those were separated in the MRF, respectively. The residuals after the recycling process were landfilled where the recycling is undertaken. The rest wastes were landfilled as shown in Figure 3.
- (ii) **Scenario 2 (S2):** In this scenario, a source separation system with efficiency were added as an improvement to scenario 1. The recyclables obtained from source separation were sent to the MRF, and after processing they were sent to the recycling facilities. The recyclables mixed in organic waste were processed and sent to the recycling facility. After the recycling process, residuals were sent to the landfills as shown in Figure 4.
- (iii) **Scenarios 3 (S3):** The scenario emphasizes the recovery of the biologically degradable fraction. The flow of the system is similar to scenario 2 for recyclable materials while organic fractions from the MRF were transported to the composting facility. The residues from the MRF were then sent to the landfill. This is represented in the flowchart in Figure 5.

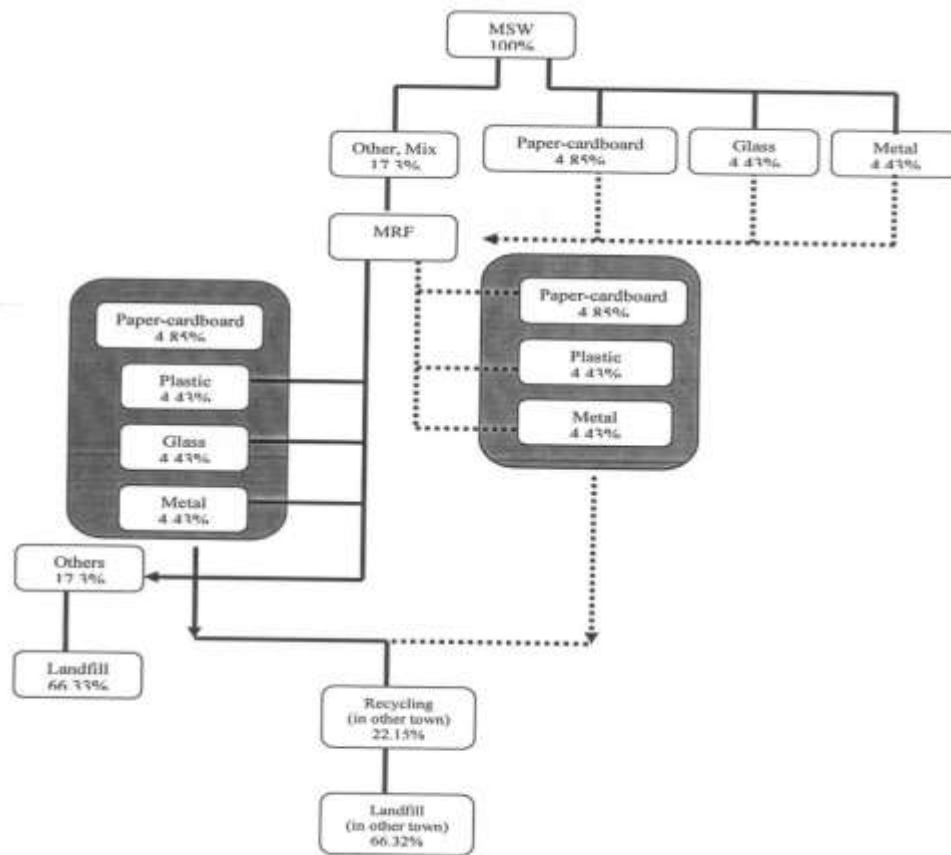


Figure 3: Flowcharts of the S1; MRF and Landfilling

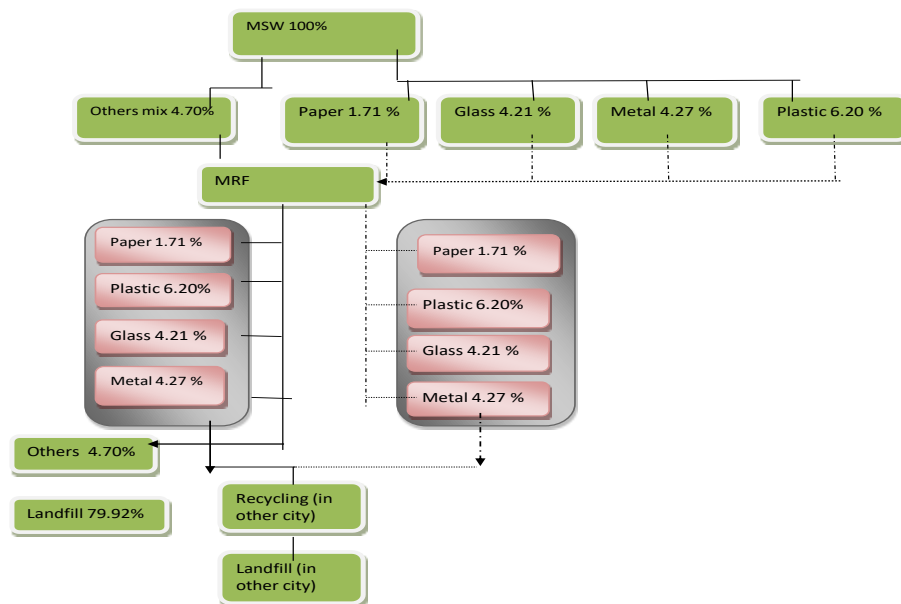


Figure 4: Flowchart of the S2; Recycling and Land filling

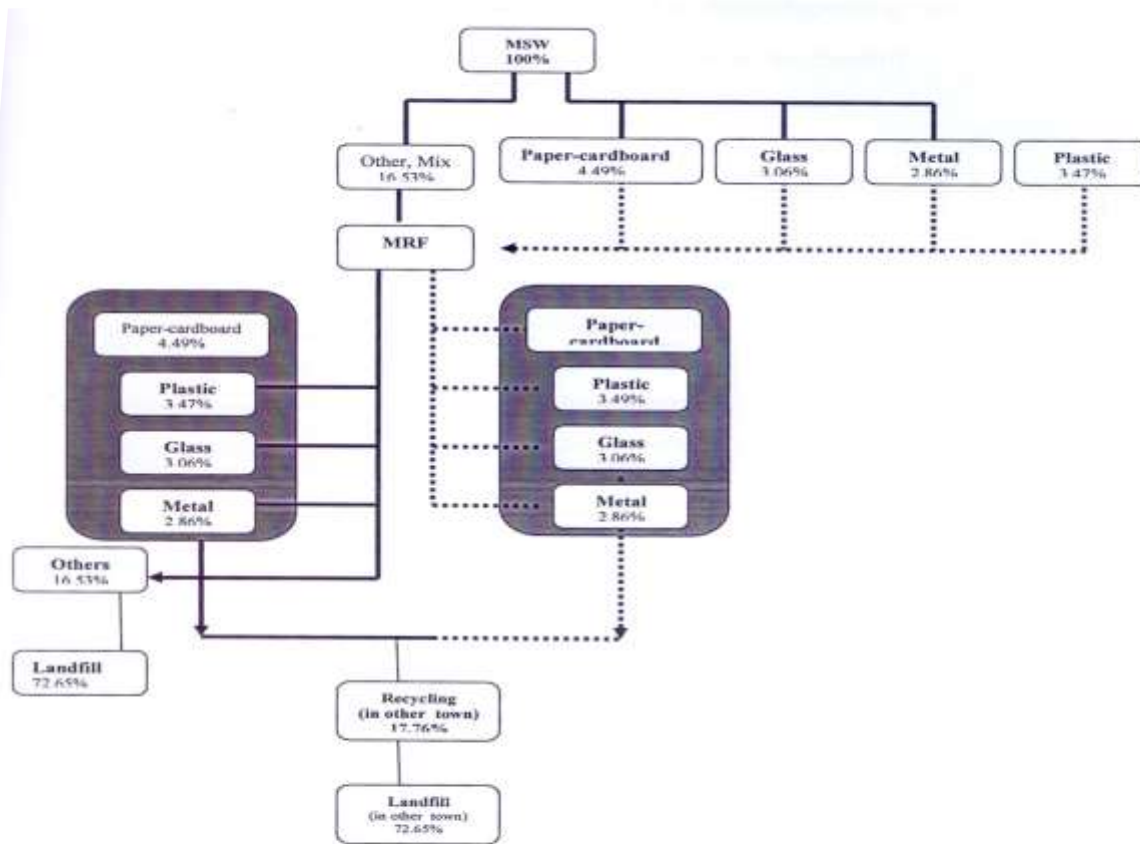


Figure 5: Flowchart of the S3; Recycling, Composting and Land filling

3. RESULTS AND DISCUSSION

3.1 Information on Local Government Areas under Investigation

Table 2 indicates the three Local Government Area (L.G.A) covered by the study. The localities were also represented. The survey revealed that the major sources of solid wastes were from residential dwelling, industrial processes, and institutional source as well as commercial and agricultural activities. Basically, solid wastes from residential dwellings come from single to multi-family households. They were mainly from housekeeping activities. Commercial waste consists of solid wastes from market places, garages, hotels/restaurants, trading shops/stores and construction/demolition processes solid waste from agricultural activities like animal husbandry and crop production constitutes agricultural solid waste. Solid waste generated from manufacturing processes, industrial activities from cottage, medium and heavy industries constitute industrial solid waste. Table 3 provides the population of each LGA considered and areas covered.

Table 2: Information in the Local Government Areas under study - Major Sources of solid waste Generated

Local Government	Res	Ind	Com	Agr	Ins
Ibadan North	+	+		+	+
Ibadan North-East	+	-		+	+
Ibadan South-East	+	-		+	+

+ = Present; - = Absent; Res = Residential; Ind = Industrial; Com = Commercial
Agr = Agricultural; and Ins = Institutional

Table 3: Population of the LGAs Covered

<i>L. G A</i>	<i>Population</i>	<i>Area</i>
Ibadan North	306,795	27km ²
Ibadan North East	330,399	18km ²
Ibadan South East	266,046	17km ²

Source: (NPC, 2006)

3.2 Wastes Composition in the Study Area

The results of the average household waste generated from each LGA are presented in Tables 4 to 6, while the mean waste composition is as shown on Table 7. The comparative percentage composition of household waste for Beere, Inalende, Yemetu, Oje Igosun, Bashorun Ashi, Saabo, Oke Itunu, Sango, Mokola, Bodija, Polytechnic Area and Agbowo in Ibadan North Local Government Area is represented in Table 3. The percentage composition of organic matter is the highest in the L.G.A. with 60.55%. The next to it is the textile 7.17%, this is followed by silt 6.33%. The next is paper 4.85%, followed by plastic, Glass and metal 4.43% each. The next is Nylon 4.01% and the least is Ashes 3.80%. These are in line with an earlier study by Ojoawo *et al.* (2011) attributing prevalence of biodegradable wastes to solid waste dumpsites in developing countries.

Table 5 comprises of the following areas, Odo Osun, Ita Baale, Kosodo, Orita Aperin, Labiran Aderigba, Oje, Aremo Alafara, Ode Aje, Oke Ibadan, Ita Akinloye, Iwo Road and Agodi Gate in Ibadan North-East LGA. Organic matter has the highest percentage composition of 65.71%, This is followed by Textile and silt with 6.94% each. Next to it is paper 4.49% followed by Nylon 3.88% plastic 3.47%, Glass 3.06%, metal 2.86% and the least is the ashes with 2.65%. The LGA represented in Table 6 comprises of the following areas in Ibadan South-East LGA; Beere, Ojaaba, Kobiowu, Kobomoje, Eleta, Elekuro, Adesola, Odinjo, Oke-Odo, Odo-Oba, Odo-Osi and Felele. The highest percentage of household waste is organic matter with 61.43%, paper 3.88%, Nylon 3.68%, Ashes 3.49% and the least is Glass 3.29%.

This mean result of the composition of the household waste in the three LGAs under study shows that Ibadan North LGA has the least value of organic matter. This indicates that higher income and economic growth have a significant impact in the composition of waste. Wealthier individuals consume more packaged products, which result in a higher percentage of inorganic matter in the solid waste of high income areas. Most residents in Ibadan North LGA depend on processed food while those in Ibadan South-East LGA depend more on unprocessed food which generate a significant amount of organic matter. The packaging materials; paper, glass, metal and Nylon from Ibadan North LGA are higher than those of Ibadan North-East and Ibadan South-East LGAs. The low value of packaging may be due to the accessibility of scavengers to waste bins that are usually placed outside the gates of buildings.

Table 4: Household Waste of Ibadan North LGA

<i>Solid waste</i>	<i>Weight (kg)</i>	<i>Ton/head</i>	<i>Composition (%)</i>
Organic matter	2.87	880.50	60.55
Paper	0.23	70.56	4.85
Nylon	0.19	58.29	4.01
Plastic	0.21	64.43	4.43
Textile	0.34	104.31	7.17
Glass	0.21	64.43	4.43
Metal	0.21	64.43	4.43
Silt	0.30	92.04	6.33
Ashes	0.18	55.22	3.80
Total	4.74	1,454.21	100

Table 5: Household Waste of Ibadan North-East LGA

<i>Solid waste</i>	<i>Weight (kg)</i>	<i>Ton/head</i>	<i>Composition (%)</i>
Organic matter	3.22	1063.88	65.71
Paper	0.22	72.69	4.49
Nylon	0.19	62.78	3.88
Plastic	0.17	56.17	3.47
Textile	0.34	112.34	6.94
Glass	0.15	49.56	3.06
Metal	0.14	46.26	2.86
Silt	0.34	112.34	6.94
Ashes	0.13	42.95	2.65
Total	4.90	1,618.97	100

Table 6: Household Waste of Ibadan South East LGA

<i>Solid waste</i>	<i>Weight (kg)</i>	<i>Ton/head</i>	<i>Composition (%)</i>
Organic matter	3.17	843.37	61.43
Paper	0.20	53.21	3.88
Nylon	0.19	50.55	3.68
Plastic	0.33	87.80	6.40
Textile	0.46	122.38	8.92
Glass	0.17	45.23	3.29
Metal	0.25	66.51	4.84
Silt	0.21	55.87	4.07
Ashes	0.18	47.89	3.49
Total	5.16	1,372.81	100

Table 7: Average Composition of Household Waste in the Three LGAs under Study

<i>Type of solid wastes</i>	<i>Weight (kg)</i>	<i>Composition (%)</i>
Organic matter	3.09	62.55
Paper	0.22	4.45
Nylon	0.19	3.85
Plastic	0.24	4.86
Textile	0.38	7.69
Glass	0.18	3.64
Metal	0.20	4.05
Silt	0.28	5.67
Ashes	0.16	3.24
Total	4.94	100

3.3 Developments of the Integrated Waste Management (IWM) Model

An IWM model based on visual Basic Computer Interface has been developed. This model would give municipalities a broad indication of the environmental effects of waste management decisions, and point to strategies that potentially can improve the environmental performance of the waste management system. The IWM model equally evaluate the environment burdens associated with waste management from the point at which a material is discarded into the waste stream to the point at which it is either converted into a useful material or, it is finally disposed. Based on this definition, the following processes were evaluated by the model: Waste collection; Waste transfer; Sorting of recyclable materials at a MRF; Reprocessing of recovered materials into recycled materials; Composting; Anaerobic digestions; Energy recovery and Land filling.

3.4 Modeling the Waste Generation and Composition

The model contains twelve main input screens (input screens A to J). A visual basic interface allows the user to insert data in an interactive manner. The designations of the respective input screens are as follows while the input parameters are presented on Table 8, while a sample of the IWM-1 interface and wastes management systems are as shown in Figures 6 and 7 respectively:

Input screen A: Quantity and composition of waste

Input screen B: Waste flow

Input screen C: Waste collection, transfer and transportation

Input screen D: Electric

Input screen E: Recycling

Input screen F: Material recovery facility

Input screen G: composting

Input screen G2: Anaerobic digestion

Input screen G3: Anaerobic digestion process

Input screen H: Land application

Input screen I: Energy from waste

Input screen J: Land filling

The results on the green house effects and acid gas distribution from the wastes of the study area are respectively presented in Tables 9 and 10, and Figures 8 and 9. It is observed that CO₂ equivalent and NO₂ dominated the wastes. These are pointer to the fact that the gaseous emissions from the waste are capable of leading to global warming over time, if neglected and uncontrolled (FEPA, 1991, 1998).

Table 8: Input Parameters into the Computer Model Interface

<i>Description</i>	<i>Ibadan North Wastes Quantities (in tons)</i>	<i>Ibadan North Wastes Quantities (in tons)</i>	<i>Ibadan North Wastes Quantities (in tons)</i>
Quantity of Waste Managed	1454.21	1618.97	1372.81
Mixed Paper	70.56	72.69	53.21
Glass	64.43	49.56	45.23
Ferrous Metals	64.43	46.26	66.51
Low Density Polyethylene (LDPE)	58.29	62.78	50.55
Poly Vinyl Chloride (PVC)	64.43	56.17	87.80
Food wastes	880.50	1063.88	843.57
Other wastes	251.57	267.63	226.14
Quantities of wastes for Recycling	322.14	287.46	303.29
Quantities of wastes for Land Application	159.53	155.29	170.27
Quantities of wastes for Land filling	972.54	1176.22	899.24

Life Cycle Model - Input Screen J

LANDFILLING

Gas recovery? ☒ Yes ☐ No

Energy recovery? ☒ Yes ☐ No

Annual Precipitation: mm

☒ Landfill lined, with leachate collection

☐ Landfill not lined, leachate collected

☐ Landfill not lined, leachate not collected

Gas recovery efficiency: 50 %

Energy recovery efficiency: 30 %

Leachate Collection efficiency: 90 %

Landfill Sequestration ☒ Yes ☐ No

Energy consumed by landfilling operation:

Diesel	<input type="text"/> 0.22	litres/tonne
Natural gas	<input type="text"/> 0.028	m3/tonne
Electricity	<input type="text"/> 0.29	kwh/tonne

Figure 6: An interface of the ISWM – 1 model

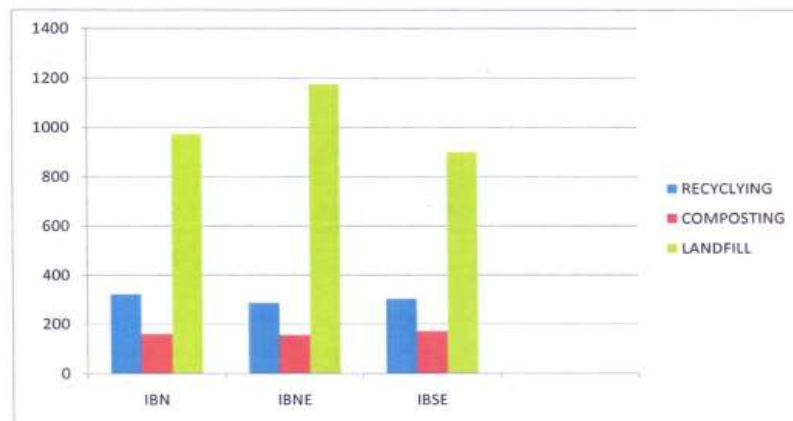


Figure 7: The studied Waste Management System in the area

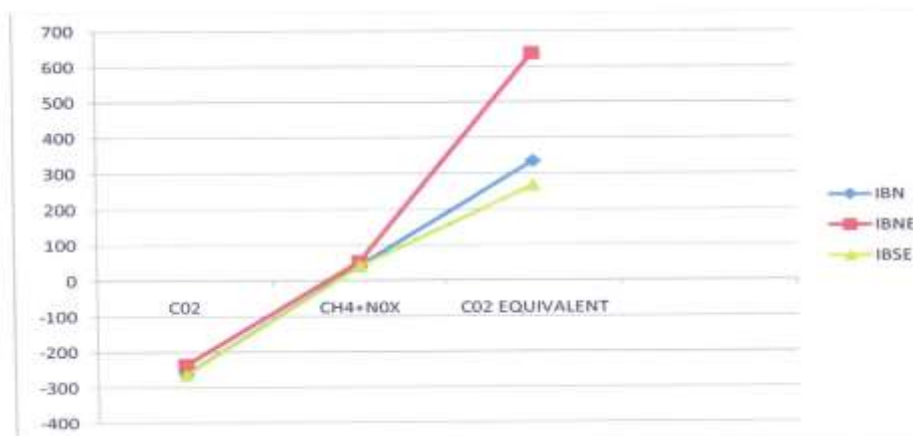


Figure 8: Greenhouse gas distribution in the Study Area

Table 9: Greenhouse Gases Distribution in the Solid Wastes of the Studied Area

Gases (in tones)	IBN LGA	IBNE LGA	IBSE LGA
CO ₂	-263	-237	-265
CH ₄ +NO _x	42	53	40
CO ₂ equi	334	637	267

Source: The IWM Model output

Table 10: Acid Gases Spread in the Solid Wastes of the Studied Area

Gases (in tones)	IBN LGA	IBNE LGA	IBSE LGA
NO ₂	-1.0	-0.8	-1.0
SO _x	-1.4	-1.1	-1.4
HCl	-9.6	-7.3	-8.9

Source: The IWM Model output

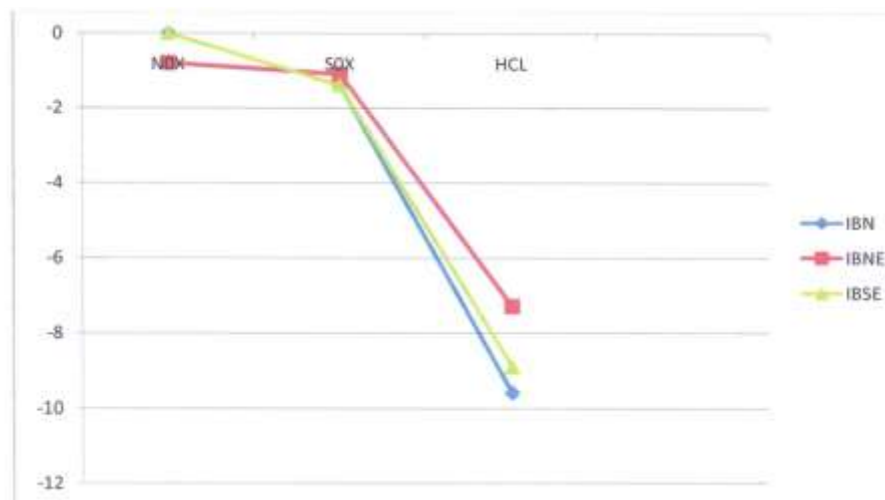


Figure 9: Acid Gases Distribution in the Solid Wastes of the Study Area

3.5 Comparison of the Modeled Waste Management Scenarios

The Life Cycle Inventory (LCI) of the markedly different Scenarios 1 and 2 (S1 and S2), depicting those of Ibadan North and Ibadan North East LGA was compared. This helps to determine the various net changes of the greenhouse Gases, acid gases, smog precursor, heavy metal and organics. The net change of residual wastes in scenarios S1 and S2 in the IBN and IBNE, IBNE and IBSE, and IBN and IBSE are as presented in Tables 11 and 13. Environmental inventory model considered the full range of waste streams being managed in the study area and viewed the available waste management practices as a menu of options from which waste managers can evaluate waste management options based on site specific environmental, economic and social considerations. The model evaluated the life cycle environmental and energy effects of waste management processes as tools to guide municipal waste managers in the evaluation of waste management systems. It utilized lifecycle methodology to quantify the energy consumed and the emissions released from a user specified waste management system and has been structured such that it uses data specific to the user municipality to ensure applicability of the results and accuracy in Ibadan Metropolis, the study area.

Table 11: The Net Life Cycle Inventory (LCI) of S1 and S2 in IBN and IBNE LGAs

	<i>S1 IBN</i>	<i>S2 IBNE</i>	<i>Net Change</i>
Greenhouse gases			
CO ₂ (tones)	-263	-237	26
CH ₄ + NO _x	42	53	11
CO ₂ EQ (Tones)	334	637	303
Acid gases			
NO _x (tones)	-1.0	-0.8	0.2
SO _x (tones)	-1.4	-1.1	0.3
HCl (Tones)	-9.6	-0.7	2.3
Smog precursors			
NO _x (Tones)	-1.0	-0.8	0.2
PM (Tones)	0.0	0.1	0.1
VOC (Tones)	-0.7	-0.7	0.0
Heavy metal and organics			
Pb (kg)	-0.29	-0.20	0.09
Hg (kg)	0.002	0.002	0
Cd (kg)	0.093	0.114	0.021
BOD (kg)	991	1134	143
DIOXINS (TEQ)(g)	0.00001	0.00001	0
Residual waste (tones)	1.007	1.207	200

Table 12: The Net Life Cycle Inventory (LCI) of S1 and S2 in IBNE and IBSE

	<i>S1 IBNE</i>	<i>S2 IBSE</i>	<i>Net Change</i>
Greenhouse gases			
CO ₂ (Tones)	-237	-265	28
CH ₄ (tones)	53	40	13
CO ₂ EQ (tones)	637	267	370
Acid gases			
NO _x (Tones)	-0.8	-1.0	0.2
SO _x (Tones)	-1.1	-1.4	0.3
HCL (Tones)	-7.3	-8.9	1.6
Smog precursors			
NO _x (Tones)	-0.8	-1.0	0.2
PM (Tones)	0.1	0.0	0.1
VOC _s (Tones)	-0.7	-8.9	1.6
Heavy metal and organics			
Pb (kg)	-0.20	-0.26	0.16
Hg (kg)	0.002	0.002	0.0
Cd (kg)	0.114	0.087	0.027
BOD (kg)	1134	956	178
DIOXIN (TEQ)(g)	0.00001	0.00001	0.0
Residual Waste (tones)	1207	932	275

Table 13: The Net Life Cycle Inventory (LCI) of S1 and S2 in IBN and IBSE

	<i>S1 IBNE</i>	<i>S2 IBSE</i>	<i>Net Change</i>
Greenhouse gases			
CO ₂ (Tones)	-263	-265	2
CH ₄ (tones)	42	40	2
CO ₂ EQ (Tones)	334	267	67
Acid gases			
NO _x (Tones)	-1.0	-1.0	0.0
SO _x (Tones)	-1.4	-1.4	0.0
HCL (Tones)	-9.6	-8.9	
Smog precursors			
NO _x (Tones)	-1.0	-1.0	0.0
PM (Tones)	0.0	0.0	0.0
VOC _s (Tones)	-0.7	-0.8	0.10
Heavy metal and organics			
Pb (kg)	-0.29	-0.36	0.67
Hg (kg)	0.002	0.002	0.07
Cd (kg)	0.093	0.087	0.006
BOD(kg)	991	956	35
DIOXIN (TEQ)(g)	0.00001	0.00001	0.0
Residual Waste (tones)	1007	932	75

4. CONCLUSION

Solid waste disposal in the study area of Ibadan metropolis is an environmental problem that becomes more complex each day. Yet, those problems need to be addressed for the survival of the people. The study established that volumes of waste and composition were not the same in each household but this depend on the lifestyle of the people. The high income group also had the highest percentage of paper waste in a print form which is linked to affordability. The amount of waste in the studied metropolis from the household can be recycled. This will significantly reduce the amount of waste being dispose into the land fill. It was established that the level of income of each household group determines the volume of waste generated by such group. Waste generation increases with increasing income of residents. In accordance with the findings from this study, CO₂ equivalent emission was the most prevalent of the greenhouse gases in all the LGAs, SO₂ was least produced among the acid gases, volatile organic compounds dominated the smog precursors, while the heavy metals (Pb, Hg and Cd) were not detected in all the studied locations. The challenges of waste disposal in Ibadan metropolis call for meaningful co-operation between individuals and government. This research work shows that carbon (iv) oxide is a potential environmental threat and could manifest in form of climate change and global warming should waste management not given a priority attention. An efficient Integrated Waste Management System (IWMS) is therefore strongly recommended for Ibadan Metropolis, South-Western Nigeria.

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