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LIFE CYCLE ASSESSMENT OF MUNICIPAL WASTE USING GABI$_6$ SOFTWARE

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ABSTRACT

The management of municipal solid waste (MSW) appears as a challenge for many countries in the world. The rapidly increasing amounts of waste and the consequent potential impacts necessitate proper planning and management This paper assesses the management of the MSW in Oyo Township with the main objective of evaluating the physical and chemical constituents of the wastes and determine their best disposal method using GaBi$_6$ Software. In this study, wastes were collected and their composition determined over a period of two months for each of Oyo west and east LGA. The waste data acquired was simulated using GaBi$_6$ software for Landfilling and Incineration scenarios. The scenarios were compared through the CML and the Tool for the Reduction and Assessment of Chemical and other Environmental Impacts (TRACI) methods and these comparisons were carried out from impact measurement of: Global Warming Potential (GWP), Acidification Potential (AP), Eutrophication Potential (EP) and Ozone layer Depletion Potential (ODP). The results of the analysis showed that the per capita waste generation in Oyo west LGA and Oyo East LGA is 1.25 and 1.67 kg/capita/day respectively. Portable gas detectors were used to detect and measure the gases present at selected dumpsite. The detection of 700 ppm and 1100 ppm of CO2 before and after burning portrayed the effect of open dumpsite and open burning respectively. According to the comparisons and leachate analysis, landfilling scenario is the more environmentally preferable and is the best option to achieve sustainable solid waste management; it is therefore recommended for use in Oyo Township. Suffice to note, in this study waste management alternatives were investigated only on an environmental point of view. For that reason, it might be supported with other decision-making tools that consider the economic and social effects of solid waste management.

KEYWORDS: $GaBi_6$ software; Landfill; Incineration; Simulation; Waste generation.

1.0 INTRODUCTION

Wastes, unwanted and unusable materials, have different methods of disposal management. They must be managed properly to ensure environmental best practice. Solid waste management is a critical aspect of environmental hygiene, and thus, must be incorporated into environmental planning. Mathew *et al.*, asserts that waste management is one of the main problems faced by our nation (Nigeria). Improper disposal of wastes which includes open waste dump, open burning, dumping inside rivers, and dropping indiscriminately on the streets are some major causes of environmental pollution, which gives rise to public health concerns in many developing countries including Nigeria (Mathew et.al. 2019).

In order to prevent the detrimental of improper solid waste disposal, appropriate and effective waste management planning and control has to be established and implemented to ensure the handling and disposal of these wastes. Standard methods for assessing the environmental impact of waste management systems are needed to monitor the development and implementation of sustainable waste management practices. The selection of approaches that suits a specific condition at a particular location in a certain time differs, and thus requires special consideration such as considering the Life Cycle Assessments.

Life Cycle Assessment (LCA) is a systematic and critical framework introduced to assess all the environmental consequences related to products or activities by characterizing, quantifying and evaluating the overall resources consumed and all the carbon emissions and wastes released into the atmosphere. However, LCA can be useful and conveniently applied to the life cycle related to the collection, treatment and disposal of solid waste. The LCA procedure applied to the Municipal Solid Waste (MSW) management can be seen as a useful analysis, instrument aimed at the evaluation of possible actions (Konecky et.al. 2007).

There are numerous software's effective in carrying out LCA which includes $GaBi_6$, SimaPro, Umberto, and Integrated Waste Management 2 (IWM-2) among others. $GaBi_6$

being one of the leading LCA modelling software for product sustainability is used in this research.

$GaBi_6$ is product-related software based on LCA-methodology (Ojoawo and Gbadamosi, 2013). The extensive and well documented database offered through $GaBi_6$ enables LCA practicioners get a clear and detailed understanding of the environmental aspects and life cycle environmental impacts of a system.

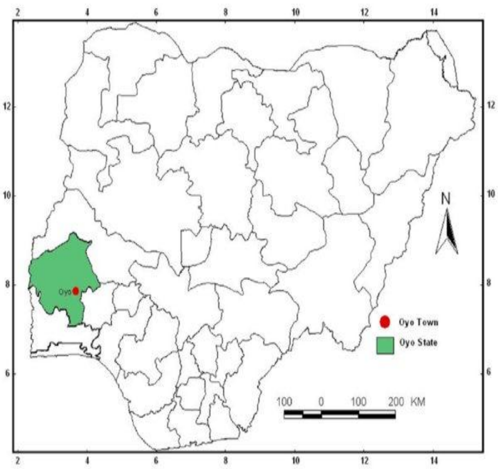
This research tends to provide solution to the selection of the best disposal approach according to environmental impacts between Landfilling and Incineration for the waste generated within Oyo township local government area (which doesn't have an established waste disposal scheme) by carrying out Life Cycle Assessment (LCA).

2.0 MATERIALS AND METHODS

These includes Selection and Sampling of Study Area, Characterization of the Waste Sample, Gas Measurement at Dumpsite with Portable Gas Detector, Modeling of Parameters with $GaBi_6$ Software, Landfill Model and Incineration Model.

2.1 Selection and Sampling of Study Area

Oyo West and East local government areas were selected as shown in **Fig 1 and 2**. The Oyo west LGA was divided into three zones based on different socio-economic population groups (low, middle and upper income groups), for assessment of daily solid waste generation, separation and waste classification and their characteristics. Also, some residential buildings and shops were randomly selected in Oyo East LGA for waste sampling. The major occupation of about 70% of the population is farming while about 20% of others engage in other trading activities.



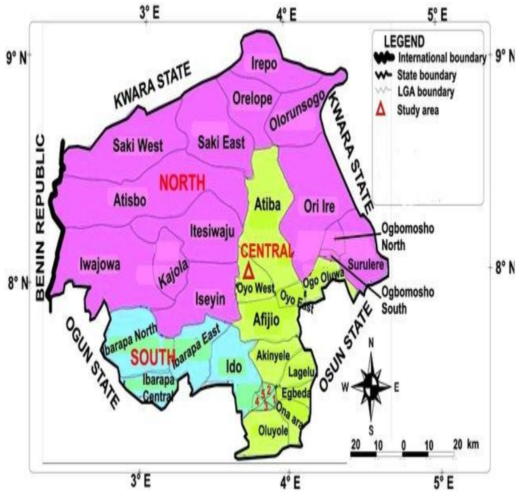


Fig. 1: Map of Nigeria showing Oyo town. Fig. 2: Map of Oyo State showing the study areas.

Source: (Adagunodo *et al*., 2018).

Reconnaissance Survey was carried out, information on how the waste is being managed, location of dumpsites and the noticeable deficiencies in the management system was observed. Personal interview with the residents (by administering 200 stratified questionnaire for each of the LGA) was conducted on how their waste is being stored, collected, transported, managed and the various agencies involved in its management. Oral interview was also granted to health department of the LCDA in both LGA as regards waste management in the areas.

2.2 Characterization of the Waste Sample

Waste nylons were provided every week for each selected residential buildings and shops for the storage of waste. The waste generated were collected, sorted and analysed. The analysed waste were weighed to obtain the weight-based characterizations for the waste components and the total waste generated was determined.

The Sub-sample waste taken from the study area was spread on a plastic tarp, such that the thickness was below 10 cm. It was ensured that there was no coverage between the wastes and they were evenly spread over the plastic tarp. The waste sample was air-dried for more than twenty-four hours, weighed and recorded as dried waste. The dried waste was then taken to laboratory for leachate analysis. Laboratory leachate analysis was carried out on the dried wastes. The tests carried out includes pH, Calorific Value (Cv), Total Carbon (TC), Total Organic Carbon (TOC), and Nitrogen Content.

2.3 Gas Measurement at Dumpsite with Portable Gas Detector

Three (3) gases: CO_2, CH_4 and SO_2 were monitored at the selected dumpsite within the study area using ToxiRAE portable gas detector. The temperature of each sampling station was measured and noted at the time of gas monitoring. Replica measurements were made before and after burning of wastes. The RKI GX-6000 with 2 smart Sensor slots was used for air quality measurements. It is a 6 Gas sample draw with PID, IR and Super Toxics sensors.

2.4 Modeling of Parameters with $GaBi_6$ Software

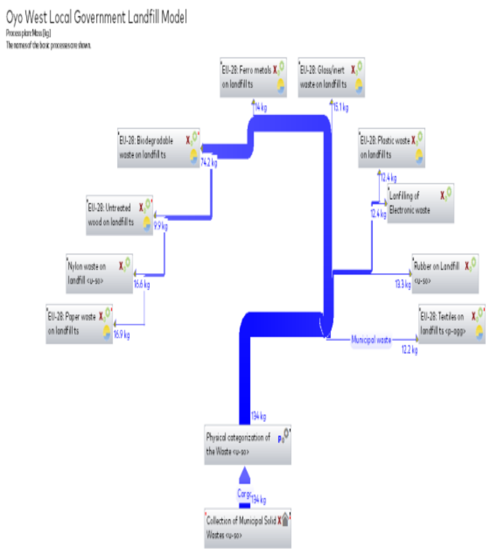
Landfill and Incineration scenarios were formulated using $GaBi_6$ as modeling tool. The environmental impact indices include Acidification Potential (AP), Ozone Depletion Potential (ODP), Global Warming Potential (GWP) and Eutrophication Potential (EP). Modeling of parameters of the study includes data compilation, quantification and analysis based on International Reference Life Cycle Data System (ILCD) recommendations. The scenarios were compared through the Methodology of the Centre for Environmental Studies (CML) of the University of Leiden and The Tool for the Reduction and Assessment of Chemical and other Environmental Impacts (TRACI) of the United States Environmental Protection Agency methods.

2.5 Landfill Model

This includes Collection, Sorting, Transportation and Landfilling. Life Cycle Assessment (LCA) modeling was achieved using plan, process and flow. The plan represents the system boundary of the LCA, process represent real life activities in the life cycle of the product being analyzed (e.g. transportation), while flow represent the materials and energy in the system. A typical Landfill Model for Oyo west LGA is as shown in **Figure 3**.

2.6 Incineration Model

In the incineration model, Collection; Sorting; Transportation; and Incineration were considered. The flow within the system was in the direction of the arrow. Incineration model of waste management was developed using $GaBi_6$ software. A typical Incineration Model for Oyo west LGA is as shown in **Figure 4**.



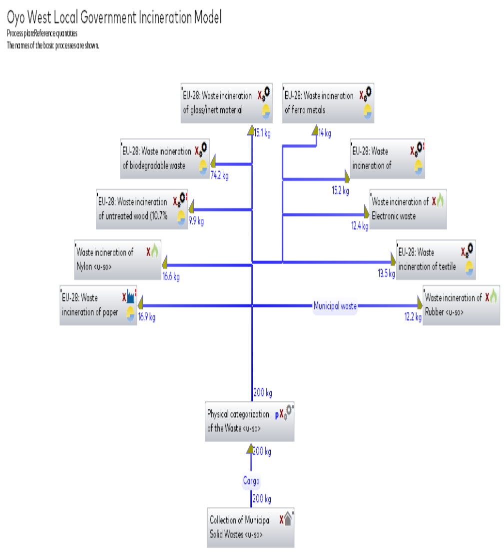


Fig. 3: Flow Charts for the Landfill model. Fig. 4: Flow Charts for the Incineration model.

3.0 RESULTS AND DISCUSSION

3.1 Composition of the waste by mass from selected residential buildings and shops

The average percent composition of waste generated per day in the selected residential buildings and shops which represents the low, middle and high income zone within the study areas are shown in **Table 1** and **2**. The population of people that generated the waste in Oyo East Local Government Area is 103. The results also showed a high percentage composition of biodegradables (37.1%), followed by paper (8.4%) then nylon (8.3%). This correlation of result can be justified as the occupation of the people within the study areas are farming and trading majorly.

The waste generated per capita per day was calculated as follows

Per Capital waste generation in Oyo West LGA =

$$\frac{Total\ average\ waste\ generated\left(\frac{kg}{day}\right)}{Population\ that\ generated\ it}$$

= 199.9/ 160

= 1.25 kg/capita/day

Per Capital waste generation in Oyo East LGA =

$$\frac{Total\ average\ waste\ generated\left(\frac{kg}{day}\right)}{Population\ that\ generated\ it}$$

= 173.5/ 104

= 1.67 kg/capita/day

Table 1: Average percent composition of waste generated by mass in Oyo West LGA.

Week	Paper (kg)	Nylon (kg)	Wood (kg)	Biodegradable (kg)	Metal (kg)	Glass (kg)	Plastic (kg)	E -Waste (kg)	Textile (kg)	Rubber (kg)
1	89.9	83.0	10.1	423.2	124.8	114.9	125.7	60.4	71.6	68.5
2	114.3	113.7	49.5	488.6	63.9	72.5	88.0	54.9	59.4	50.6
3	97.9	104.5	54.9	477.2	67.4	97.6	100.4	60.1	83.0	70.5
4	86.8	92.8	82.1	451.5	113.1	107.6	104.0	107.4	107.7	97.3
5	118.9	110.3	73.6	435.6	80.1	92.6	86.4	87.0	90.0	79.0
6	106.9	87.6	75.9	458.8	77.9	85.9	75.7	85.2	76.3	70.0
7	107.5	107.3	80.3	438.7	83.1	86.8	87.4	75.9	88.4	86.7
8	104.7	115.5	60.9	463.9	76.1	82.9	78.9	75.6	77.2	73.6
Total	826.9	814.8	487.3	3637.6	686.4	740.7	746.6	606.5	653.6	596.3
Average (kg/week)	118.1	116.4	69.6	519.7	98.1	105.8	106.7	86.6	93.4	85.2
Average (kg/day)	16.9	16.6	9.9	74.2	14.0	15.1	15.2	12.4	13.3	12.2
Percentage Composition	8.4	8.3	5.0	37.1	7.0	7.6	7.6	6.2	6.7	6.1

Table 2: Average percent composition of waste generated by mass in Oyo East LGA.

Week	Paper (kg)	Nylon (kg)	Wood (kg)	Biodegradable (kg)	Metal (kg)	Glass (kg)	Plastic (kg)	E -Waste (kg)	Textile (kg)	Rubber (kg)
1	178.3	167.9	138.6	249.6	89.9	76.0	102.8	58.5	60.1	70.8
2	147.5	124.3	97.2	253.8	67.4	63.5	148.3	69.1	55.5	58.7
3	129.7	117.5	86.7	230.0	75.8	77.1	140.7	60.2	64.1	54.9
4	136.2	125.8	98.4	215.0	66.6	56.0	151.4	57.7	55.7	53.6
5	138.1	157.9	119.5	214.6	70.3	69.3	164.1	66.3	56.0	64.5
6	116.0	135.1	93.7	197.4	67.9	61.3	146.4	57.6	65.2	62.2
7	133.3	125.8	101.8	204.4	50.3	66.2	163.5	38.6	68.0	63.7
8	121.7	139.6	106.1	209.5	55.9	59.4	169.6	53.5	49.3	69.2
Total	1100.8	1093.9	842.0	1774.3	544.1	528.8	1186.8	461.5	473.9	497.6
Average (kg/week)	157.3	156.3	120.3	253.5	77.7	75.5	169.5	65.9	67.7	71.1
Average (kg/day)	22.5	22.3	17.2	36.2	11.1	10.8	24.2	9.4	9.7	10.2
Percentage Composition	12.9	12.9	9.9	20.9	6.4	6.2	14.0	5.4	5.6	5.9

Gas measurement from the selected dumpsite in the study area

The concentration of gases emitted from the selected dumpsite (situated on latitude 07°50' 46" and Longitude 003°55'24") before and after burning of the disposed wastes were shown in **Table 3**. The temperature before burning the waste was 38.4°C and rose to 46.3°C after burning. The gases detected include Carbon (iv) oxide, Methane, Sulphur (iv) oxide and they were measured in part per million aside Sulphur (iv) oxide which was measured in mg/m^3. The detection of 700 ppm and 1100 ppm of CO2 before and after burning portrayed the effect of open dumpsite and burning respectively. CO_2 levels in outdoor air normally range between 300 – 400 ppm but they can be as high as 600 – 900 ppm in metropolitan areas. The values obtained before and after burning are higher than the usual values for normal and metropolitan areas respectively. Apart from the contribution of CO_2 to global warming, it can be responsible for the following health effects; headaches, asphyxiation, tingling sensation, sweating, dizziness, restlessness, loss of energy and concentration, increased heart rate, irritation to the mouth, throat, eyes and skin (Daffi *et al.*, 2020).

Table 3: Result of Gas emission from the selected waste dumpsite.

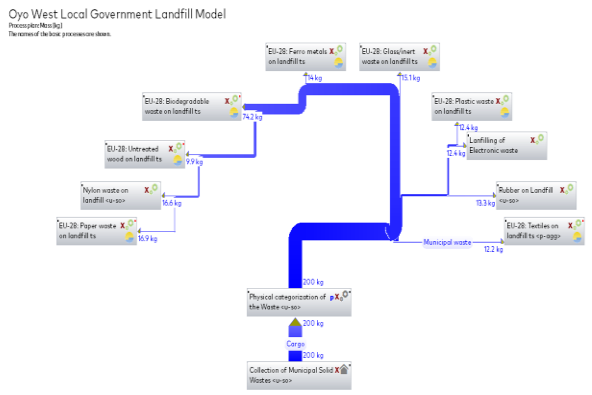
Gases	Temperature (˚C)		Concentration of Gas (ppm)	
	Before burning	**After burning**	**before burning**	**After burning**
CO2	38.4	46.3	700	1100
CH4	38.4	46.3	14	42
SO2	38.4	46.3	0. 7	2.5

3.3 Life Cycle Assessment for Oyo Life Cycle Assessment for Oyo West LGA from GaBi$_6$ software

The outputs from each of the landfill and incineration option modelled were analyzed under two environmental effect categories i.e. Methodology of the Centre for Environmental studies, University of Leiden (CML) and Tool for the Reduction and Assessment of Chemical and other Environmental Impacts (TRACI) with the aim of carrying out a synthetic study of the data. The impact assessment categories suggested are as follows: Global Warming Potential (GWP), Acidification Potential (AP), Eutrophication Potential (EP), Ozone depletion Potential (ODP).

From **(Fig.5–10)**, scenario one (which involves collection, sorting, transportation and landfilling) with TRACI method gives the total values for GWP, AP, EP, ODP as 102.276, 0.111, 0.053, 3.063×10^{-1} respectively while the CML method, the values are 111.1, 0.035, 0.125, 3.063×10^{-1} respectively. In the Incineration scenario (which involves collection, sorting, transportation and Incineration), with the TRACI method, the total values for GWP, AP, EP, ODP are 112.381, -106.74×10^{-3}, 3.365×10^{-3}, -12.455×10^{-7} respectively. While for the CML method, the values are 112.447, -82.07×10^{-3}, 1.273×10^{-3}, -13.55×10^{-7} respectively.

Life cycle Assessment of the Landfill model



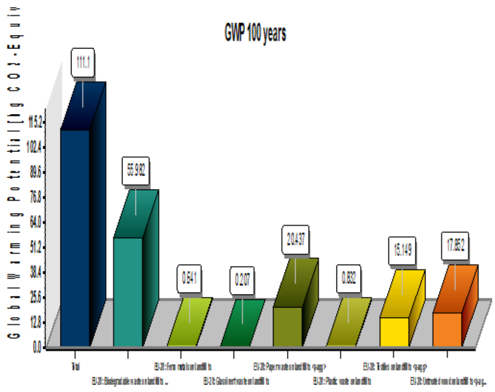


Fig. 5: Life Cycle Assessment Flow for Landfill Scenario. Fig. 6: Chart showing the Global warming Potential of CML method

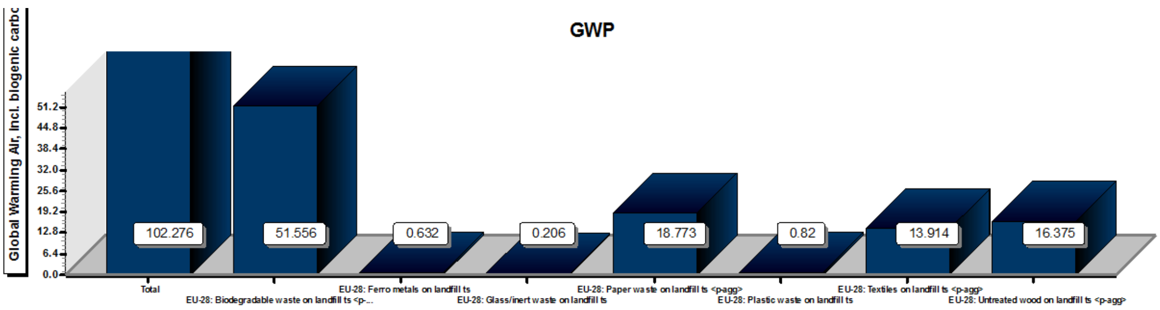


Fig. 7: Chart showing the Global warming Potential of TRACI method.

Life cycle Assessment of Incineration Model

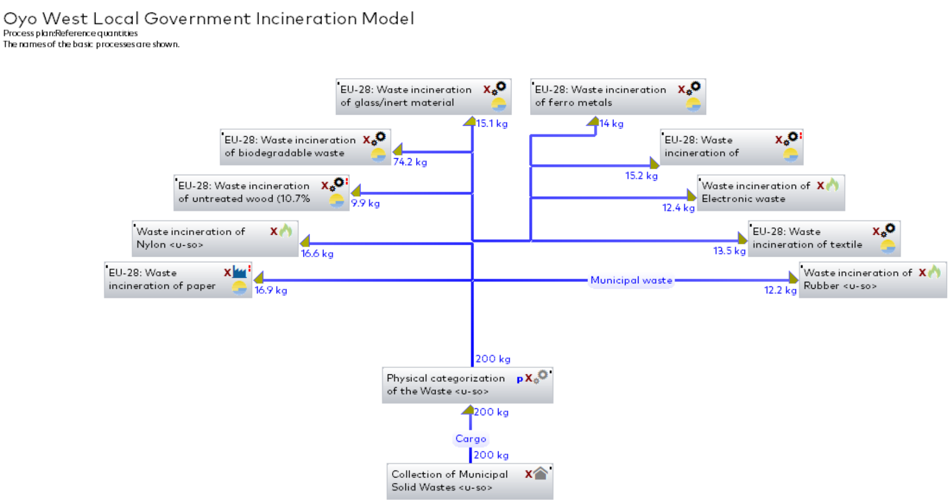


Fig. 8: Life Cycle Assessment Flow for Incineration Scenario.

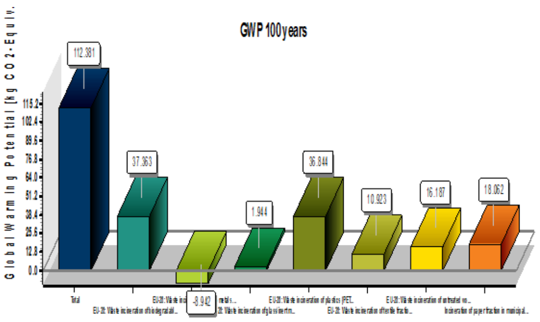


Fig. 9: Chart showing the Global warming Potential of TRACI method.

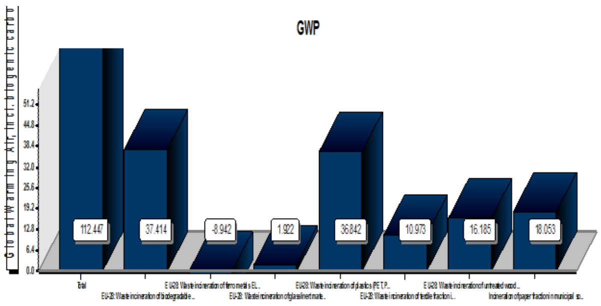


Fig. 10: Chart showing the Global warming Potential of CML method.

Table 4: Contributions to impact categories and absolute values according to each LCIA method.

Impact category	Unit	Landfilling Scenario		Incineration Scenario	
		TRACI	CML	TRACI	CML
Global Warming Potential (GWP)	kg CO2 equivalent	102.276	111.1	112.381	112.447
Acidification Potential (AP)	kg SO2 equivalent	0.111	0.035	-1.07×10^{-1}	-8.21×10^{-2}
Eutrophication Potential (EP)	kg N equivalent	0.053	0.125	3.37×10^{-3}	1.27×10^{-3}
Ozone Layer Depletion Potential (ODP)	kg CFC-11 equivalent	3.063×10^{-1}	3.063×10^{-1}	-1.25×10^{-7}	-1.36×10^{-6}

From the results, Global Warming Potential (GWP) showed the most significant values (i.e. in the range of hundreds) while the other potential e.g. AP, EP, ODP have values that are small scale compared to the GWP. It is evident to compare the scenarios based on the GWP. In Lieu of this, the GWP of Incineration in both the TRACI and CML methods are more than that of the landfill counterpart i.e. the incineration of the waste have high potential to result into global warming than the landfill method of disposal. This is an indication that landfill possess lesser environmental burdens compared to incineration. The top ranking percentage of the biodegradable component of the waste also justified the suitability of landfill as an effective means of disposal.

Also, the emission to air, fresh water, sea water, agricultural soil, industrial soil for each scenario was analyzed and the life cycle inventory results are as shown in Table 5 and 6 Comparative study of both tables showed that landfilling scenario had total emission to air (230 kg) and incineration scenario (928.4 kg). Though the total emissions to fresh water, sea water, agricultural soil and industrial soil are more in landfilling scenario, this is so because the analysis considered the worst case of landfilling i.e. a case of an un-engineered landfill that seepage of leachate to the soil is not prevented. The emissions to fresh water, sea water, agricultural soil and industrial soil can be eliminated or minimized by using leachate engineered landfill i.e. preventing the percolation of leachate formed.

Table 5: Life Cycle Inventory of the Landfilling Scenario.

Materials (kg)	Paper	Nylon	Wood	Biodegradable	Metal	Glass	E-waste	Plastics	Textile	Rubber
Flows	1.20×10^{3}	770	709	5.24×10^{3}	660	334	681	868	868	607
Resources	585	420	346	2.55×10^{3}	319	158	204	423	423	302
Deposited Goods	13.7	7.2	6.74	67.7	14.7	15.6	14	13.3	9.75	15.6
Emissions to air	25.7	15.6	18.8	91.6	7.68	4.43	17.3	9.89	18.8	20.1
Emissions to fresh water	574	325	337	2.52×103	317	156	446	421	415	267
Emissions to sea water	2.35	2.2	1.38	1.03×101	1.3	0.145	0.182	1.72	1.7	2.4
Emissions to Agricultural soil	5.72×10^{-7}	2.61×10^{-7}	3.35×10^{-7}	2.51×10^{-6}	3.37×10^{-7}	3.08×10^{-7}	3.0×10^{-7}	4.20×10^{-7}	4.13×10^{-7}	2.44×10^{-7}
Emissions to Industrial soil	0.0351	0.045	0.00298	2.04×10^{-1}	1.72×10^{-4}	1.16×10^{-6}	4.0×10^{-3}	2.09×10^{-2}	5.12×10^{-2}	1.13×10^{-2}

Table 6: Life Cycle Inventory of the Incineration Scenario.

Materials (kg)	Paper	Nylon	Wood	Biodegradable	Metal	Glass	E-waste	Plastics	Textile	Rubber
Flows	299	447	269	-845	839	239	540	592	-998	631
Resources	156	102	126	408	-1.31	54.7	62.3	283	74.9	412
Deposited Goods	1.57	7.2	0.57	-25.17	-74.8	11.17	14.3	1.006	-22.7	15.6
Emissions to air	125.5	12.6	110	279.7	24.2	15.3	17.3	257.8	73.3	12.7
Emissions to fresh water	16.2	325	32.8	-1507.77	891	158	446	50.3	-1123.6	187
Emissions to sea water	0.000744	0.00023	0.001041	0.000715721	-0.01	0.0028	0.182	0.00161	-0.004	3.6
Emissions to Agricultural soil	-7.3×10^{-13}	2.61×10^{-14}	-7.9×10^{-14}	-9.21×10^{-13}	5.3×10^{-11}	-1.7×10^{-12}	1.8×10^{-9}	0	1.3×10^{-12}	4.4×10^{-10}
Emissions to Industrial soil	0.000993	2.3×10^{-5}	7.72×10^{-5}	0.003494032	0.0024	0.004196	4.2×10^{-4}	0.0001	0.00021	3.1×10^{-4}

Life Cycle Assessment for Oyo East LGA from GaBi software

The outputs from each of the landfill and incineration option modelled were analyzed under Methodology of the Centre for Environmental studies, University of Leiden (CML) environmental effect categories. The impact assessment categories suggested are as follows: Global Warming Potential (GWP), Acidification Potential (AP), Eutrophication Potential (EP), Ozone depletion Potential (ODP).

From **Fig. (11–17)**, scenario one (which involves collection, sorting, transportation and landfilling) gives the total values for GWP, AP, EP, ODP as 99.861, 0.031, 0.078, 2.64×10^{-14} respectively. In the Incineration scenario (which involves collection, sorting, transportation and Incineration), the total values for GWP, AP, EP, ODP are 214.668, 0.108, 0.031, 8.174×10^{-7} respectively.

Life cycle Assessment of the Landfill model

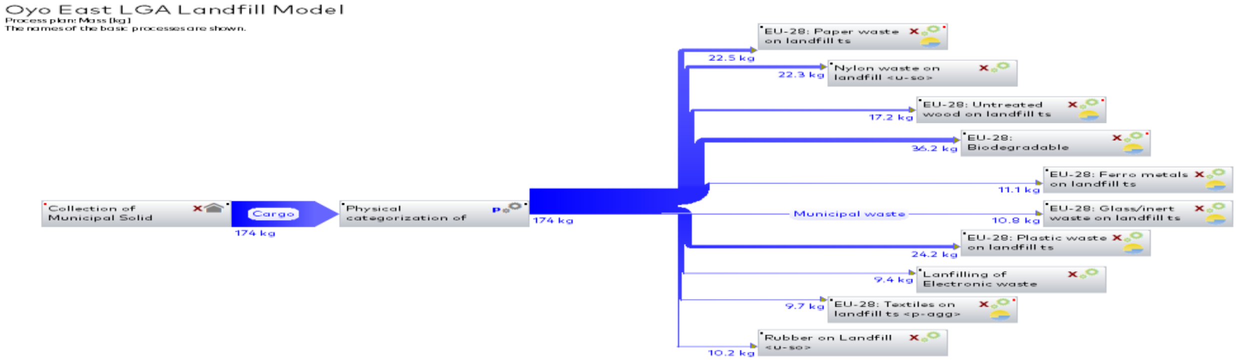
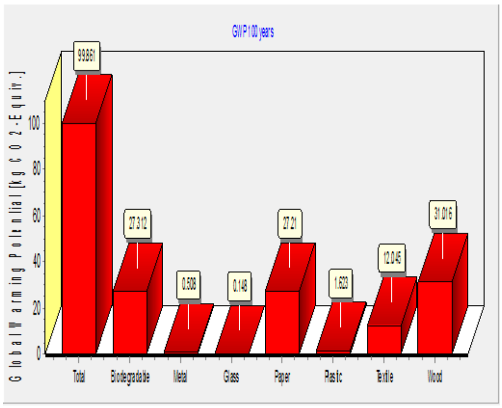


Fig. 11: Life Cycle Assessment Flow for Landfill Scenario.



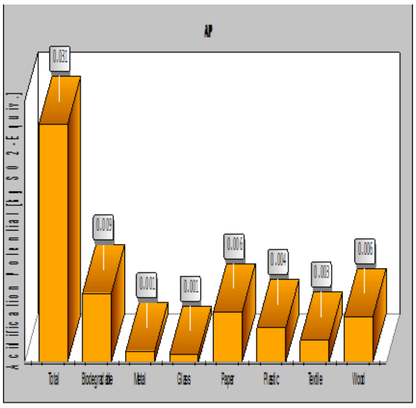


Fig. 12: Chart showing the Global warming Potential of CML method.

Fig. 13: Chart showing the Acidification Potential of CML method.

Life cycle Assessment of the Landfill model

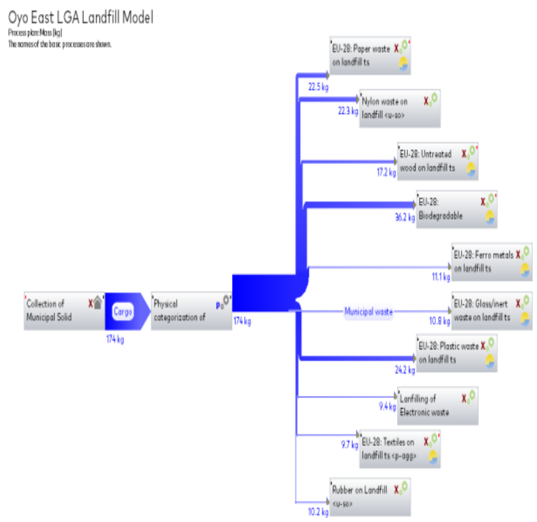


Fig. 14: Life Cycle Assessment Flow for Landfill Scenario.

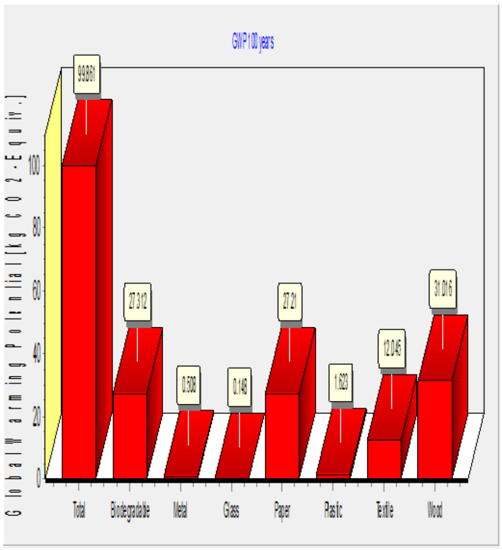
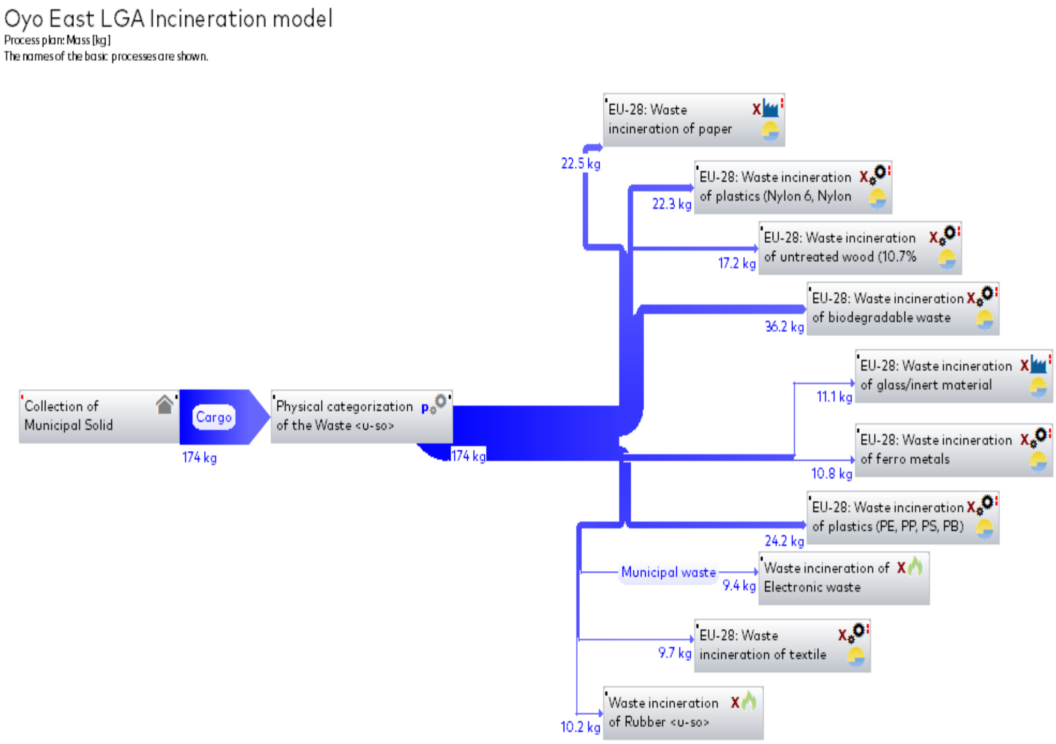


Fig. 15: Chart showing the Global warming Potential of CML method.

Life cycle Assessment of the Incineration model



Life cycle Assessment of the Incineration model

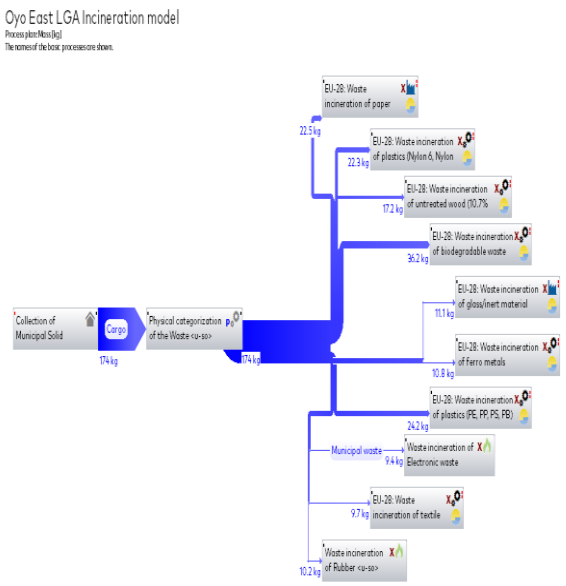


Fig. 16: Life Cycle Assessment Flow for Incineration Scenario.

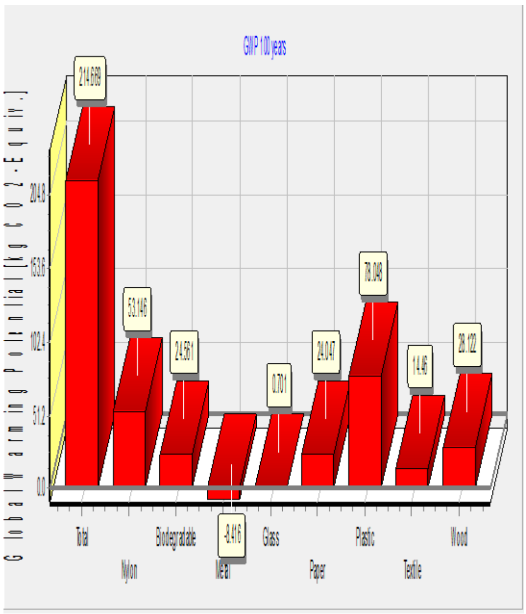


Fig. 17: Chart showing the Global warming Potential of CML method.

From the results, Global Warming Potential (GWP) showed the most significant values (i.e. in the range of hundreds) while the other potential e.g. AP, EP, ODP have values that are small scale compared to the GWP. It is evident to compare the scenarios based on the GWP.

In Lieu of this, the GWP of Incineration is more than that of the landfill counterpart i.e. the incineration of the waste have high potential to result into global warming than the landfill method of disposal. This is an indication that landfill possess lesser environmental burdens compared to incineration.

Also, the emission to air, fresh water, sea water, agricultural soil, industrial soil for each scenario was analyzed and the life cycle inventory results are as shown in Table 7 and 8 respectively. Comparative study of both tables showed that landfilling scenario had total emission to air (197.815 kg) and incineration scenario (1951.788 kg). Though the total emissions to fresh water, sea water, agricultural soil and industrial soil are more in landfilling scenario, this is so because the analysis considered the worst case of landfilling i.e. a case of an un-engineered landfill that seepage of leachate to the soil is not prevented. The emissions to fresh water, sea water, agricultural soil and industrial soil can be eliminated or minimized by using leachate engineered landfill i.e. preventing the percolation of leachate formed.

Table 7: Contributions to impact categories.

Impact category	**Unit**	**Landfilling**	**Incineration**
Global Warming Potential (GWP)	kg CO2 equivalent	99.861	214.668
Acidification Potential (AP)	kg SO2 equivalent	0.031	0.108
Eutrophication Potential (EP)	kg N equivalent	0.078	0.031
Ozone Layer Depletion Potential (ODP)	kg CFC-11 equivalent	2.64×10^{-14}	8.174×10^{-7}

Table 8: Life Cycle Inventory of the Landfilling Scenario.

Materials (kg)	**Paper**	**Nylon**	**Wood**	**Biodegradable**	**Metal**	**Glass**	**E-waste**	**Plastic**	**Textile**	**Rubber**
Flows	1600	447	1232	2559	523	239	540	1695	690	631
Resources	779	102	600	1246	254	113	62.3	825	336.1	412
Deposited Goods	18.25	7.2	11.7	33.03	11.7	11.17	14.3	25.1	7.75	15.6
Emissions to air	34.255	12.6	32.7	44.7	6.09	3.17	17.3	19.3	15	12.7
Emissions to fresh water	784.8	325	585	1230	252	111.3	446	821.4	330	187
Emissions to sea water	3.13	0.00023	2.39	5.04	1.03	0.103	0.182	3.37	1.35	3.6
Emissions to Agricultural soil	7.61×10^{-7}	2.6×10^{-14}	5.82×10^{-7}	1.225×10^{-6}	2.67×10^{-7}	2.2×10^{-7}	1.80×10^{-9}	8.19×10^{-7}	3.3×10^{-7}	4.4×10^{-10}
Emissions to Industrial soil	0.0468	2.3×10^{-5}	0.00518	0.09929	0.000136	8.285×10^{7}	4.20×10^{-4}	0.041	0.0407	3.11×10^{-4}

Table 8: Life Cycle Inventory of the Incineration Scenario.

Materials (kg)	Paper	Nylon	Wood	Biodegradable	Metal	Glass	E-waste	Plastic	Textile	Rubber
Flows	398.3	1078	467.0	596.3	447.5	82.18	2824	1444	262.27	4.41
Resources	207.45	503.5	218.6	267.4	-16.75	32.68	1393	709.27	123.17	0
Deposited Goods	2.09	2.922	0.997	4.423	-61.33	6.41	11.06	2.008	0.766	0
Emissions to air	167.09	447.38	190.4	188.11	6.66	5.45	185.9	651.3	105.08	4.41
Emissions to fresh water	21.62	124	56.96	136.4	519	37.63	1232	81.3	33.25	0
Emissions to sea water	0.00099	0.0028	0.0018	0.0041	0.0087	0.0017	2.28	0.0026	0.00094	0
Emissions to Agricultural soil	9.7×10^{-13}	0	-1.4×10^{-13}	-4.493×10^{-13}	4.1×10^{-11}	1.3×10^{-12}	1.66×10^{-6}	0	-9.6×10^{-13}	0
Emissions to Industrial soil	0.0013	0.00028	0.000134	0.0019	0.00181	0.0031	0.0215	0.00026	0.00033	0

Analysis of administered Questionnaires

The data obtained from the administered questionnaires revealed that there was no regular collection, transportation and proper disposal system for wastes being generated in the areas. The currently practice waste disposal method i.e. open waste dumps which are occasionally burned to reduce the volume of waste, disposing along river banks and indiscriminately dropping of the waste along walk paths and roadways are inadequate and results in human and environmental hazards. The problems associated with this improper waste disposal means are breeding of rats and flies, wind shift brings an odorous smell to residents living close to the dump, burning the waste results in thick black smokes and deposit of ashes in surrounding environment, ozone layer depletion, global warming, etc.

3.6 Laboratory Leachate Analysis result

The results of the leachate analysis of the waste sample for various physico-chemical parameters such as pH, Total Nitrogen, TOC, Calorific value to estimate the disposability of the waste through landfilling is shown in **Table (9 – 12)**. It was revealed that all the parameters are within ranges of acceptable values. It therefore indicates that the waste generated in the study area can be easily disposed through landfilling means.

Table 9: Total Input Weight.

	Unit	Input Sample Weight	Dried Sample Weight
Weight of Filled Container	(kg)	21.3	19.0
Tare	(kg)	5.0	5.0
Net Weight of Waste	(kg)	16.3	14.0

Table 10: pH and Temperature measurements of the waste.

Duration of Measurement(min)	15	30	45	60	75	90
Temperature (˚C)	21.4	21.2	21.1	20.9	20.9	20.7
pH (mol/L)	5.100	5.085	5.080	5.084	5.085	5.086

Table 11: pH values during Titration.

V_T	ml	0.25	0.5	0.75	1.0	1.25	1.50	1.75	2.0
pH	-	7.50	7.40	7.33	7.21	7.06	6.84	6.41	5.50

Table 12: Physico-chemical properties of the waste sample.

Property of waste sample	Value
pH	5.5 - 7.5
Total Nitrogen	60- 650 mg/L
Total Carbon	0.52-0.83 mg/L
Total Organic Carbon (TOC)	50-200 mg/L
Calorific value	800-1010 Kcal/Kg

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

The following conclusions were reached based on results from this study. The currently practiced waste disposal scheme is inadequate and leads to human and environmental hazards. Open burning had significant effect on the quality of air in the area and it constitutes to environmental and human hazard as revealed by the gas measured around the dumpsite. The open dump and burning of wastes leads to the contamination of water bodies as flying wastes and ashes got deposited on the stream course as witnessed during the survey. Therefore, landfilling is the most suitable means of disposing the waste in Oyo Township.

4.2 Recommendations

This research recommends that dumpsite be relocated to another safe location to contain its human and environmental burdens; open burning in Oyo Township should be regularize or totally abolish; landfill should be constructed as a leachate engineered landfill and should be provided with impermeable liner and drainage system at its base; and that a Life Cycle Costing (LCC) should be carried out in line with the environmental impact assessment to aid the unbiased selection of the best waste disposal method.

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