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Characterization of environmental impact indices of solid wastes in Surulere Local Government Area, Nigeria with *GaBi₅* LCA modeling technique

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Abstract: *Life Cycle Assessment (LCA) is currently being used in several countries to evaluate treatment options for specific waste fractions. The application of GaBi$_5$ (Holistic Balancing) modeling tool is currently apt for the impact assessment of environmental pollution indices arising from wastes. This study focuses on the characterization of environmental impact indices of solid wastes in Suurulere, one of the Local Government Area (LGA)s in Nigeria using GaBi$_5$.*
Waste classification was carried out in the selected houses of the LGA. Tool for the Reduction and Assessment of Chemical and other Environmental Impacts (TRACI) and the Centre of Environmental Science, University of Leiden, Netherlands (CML) methods of LCA inventory assessment were employed in the study. One kg of municipal solid waste of this area was selected as the functional unit. The Scenario considered in this study with its system boundaries is Landfilling. It consists of three main steps: Collection, Transportation and Landfilling. GaBi$_5$ modeling tool was used to obtain background data for the life cycle inventory and to analyse the wastes completely. Four (4) environmental impact indices evaluated are: Global Warming Potential (GWP), Acidification Potential (AP), Eutrophication Potential (EP) and Ozone Depletion Potential (ODP).
Result of the Scenario's Environmental Impacts shows that the GWP is characterized in the order: Biodegradable > Textile > Wood > Paper > plastic > Metal > Glass. The AP followed similar trend except for paper that is greater than wood wastes. EP has this trend; Metal > Wood > Glass > Biodegradable > Paper > Textile while for ODP it was Textile > Plastic > Paper > Metal > Wood > Biodegradable > Glass. The study also showed that when LCA is applied in conjunction with the waste hierarchy, it can be a useful tool for the planning of municipal waste management plans as it allows municipalities to directly compare the actual environmental impacts of different technologies and planning options. Furthermore, through system expansion, a consequential approach to LCA may encourage municipalities to integrate waste management with processes in other sectors. The GaBi software of LCA solves the problem of imprecision involved in solid waste decision making. The study concludes that the wastes all have detrimental impacts on the 4 measured categories but the highest pollution threat is on the Global Warming Potential. It is recommended that Environmental Protection Agencies at all levels should always analyze and contain the pollution impacts of the solid wastes on the environment.
Keywords: *Environmental Impact Indices, GaBi$_5$, Life Cycle Assessment, Life Cycle Inventory*

I. Introduction

Protecting the environmental and natural resources is increasingly becoming very important through environmental solid waste management programmes. It is necessary to follow the same part with the waste managers, a sustainable approach to waste and integrate strategies that will produce the best practicable option. This is very challenging task since it involves taking into account economic, technical, regulatory, and environmental issues. Solid waste management is a complex and multi-disciplinary problems that should be considered from basis. For a healthy environment, both municipal and industrial waste should be managed according to solid waste management hierarchy (prevention /minimization/ recovery/incineration/landfilling).

Studies on modelling of solid waste management system were started in 1970s and were increased with the development of computer models in 1980s. While models in the 80s were generally based on an economic perspective [1], models that included recycling and other waste management method were developed for planning of municipal solid waste management system in the 1990 [2]. It is accepted that LCA concepts and techniques provides solid waste planners and decision makers with an excellent framework to evaluate MSW management strategies [3].

The LCA, which is used to determined the optimum municipal solid waste management (MSW) strategy. Environmental LCA is a system analysis tools. It was developed rapidly during the 1990s and has reached a certain level of harmonization and standardization. The LCA of product commence with extracting of raw materials through the process of logging, mining etc and ends with final disposal of products. The life cycle of waste on the other hand, starts when a material is discarded into the waste stream and ends when the material has either been converted into a resource (such as recycled materials or recovered energy) or, when it is finally disposed.

The LCA is currently being used in several countries to evaluate treatment option for specific waste fractions [3-8]. Over the last few years back, some agencies like the Society of Environmental Toxicology and Chemistry (1991), Canadian Standards Association (1994), and the International Organization for Standardisation (ISO) have undertaken the development of standardization methodologies for carrying out the first two phases of life cycle assessment: Goal definition and scoping and life cycle inventories. The third phase of life cycle assessment, impact analysis, is intrinsically more problematic and there is, at this time, no widely accepted methodology for combining the diverse environmental effects into a single measure of environmental performance.

Regularity, technical and environmental constraints characterize LCA models [9]. The regulatory constraints give the minimum percentage of waste recycling; these percentages are proportional to the total waste generated. Also [9] presented a comprehension mixed integer nonlinear programming problem, whose planning horizon is a year. They gave a detailed description of environmental constraints that cover RDF constraints; the incineration and the SOM constraints.

The model of [10] minimize overall cost (taking into account energy and material recovery) through the solution of a nonlinear programming problem.

The aim of this present study is to select an optimum waste management system for Surulere LGA of Nigeria by evaluating, from an environmental point of view, alternatives to the existing system. Here, the LCA methodology has been used to conduct an environmental comparison of the alternative scenarios in the waste management system of the Study Area. This evaluation was according to TSE EN ISO 14040 that classified LCA into four major stages of goal and scope definition, life cycle inventory, life cycle impact analysis and interpretation of the results.

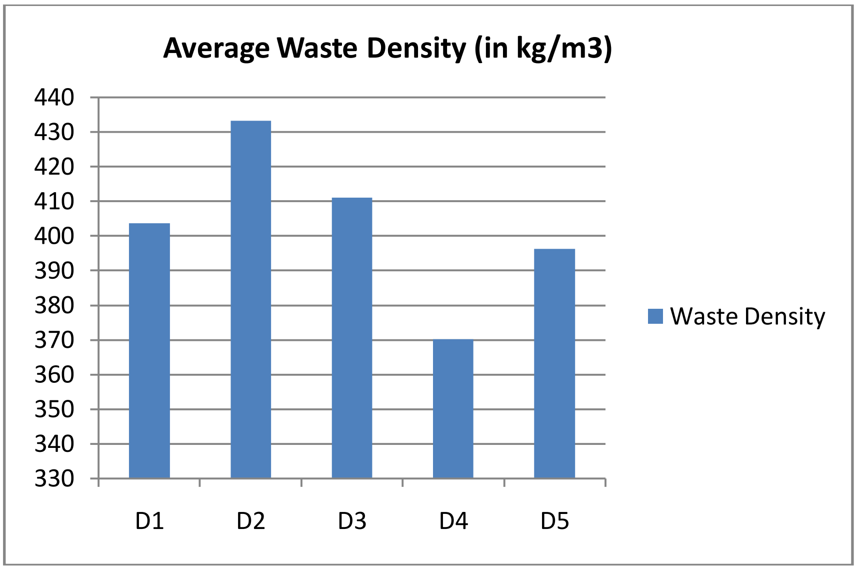
II. Methodology

(a) Study Area

The municipality of Surulere Local Government Area (LGA) in Oyo State of Nigeria is with a population of 180,000 people [11], and is increasing with an annual population rate of $0.15^{0}/_{0}$. The headquarters is situated at Iresa-Adu which is the largest of all the towns in the LGA. The study area has two different seasons; the Wet and Dry season. The wet season lasts about 6 months, April to September that is the period of maximum solid waste generation while the dry season is from October to March with scanty or no rainfall. In the study area, apart from Open – burning, there is only one waste recovery program and the program is widespread throughout the area which is uncontrolled tipping. Wastes are collected in bins or containers and compactor vehicles and are later transported by the Oyo State Environmental Protection Agency (OYSEPA) for land filling with little recovery rate.

(b) Waste Composition in the study area.

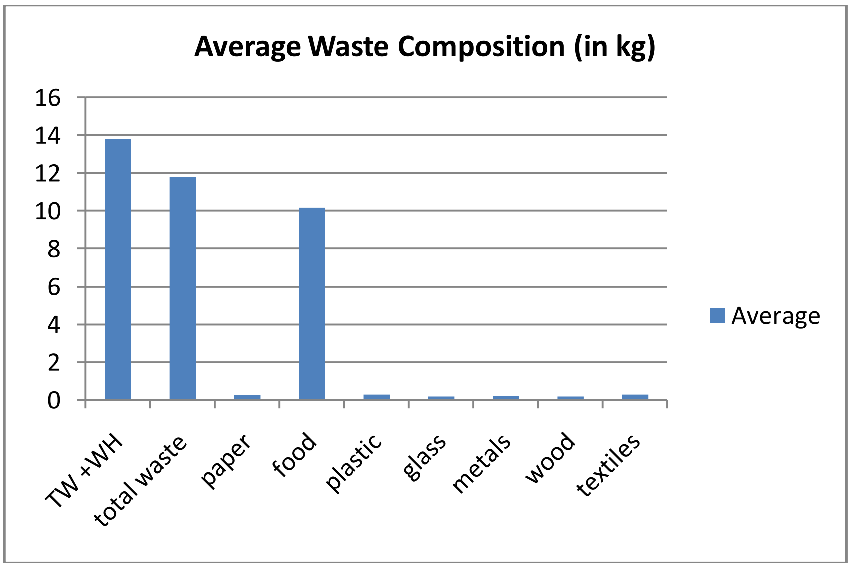
The waste density and composition in municipality of Surulere Local Government Area are given in Figures I and II respectively.



where D1, D2…D5 – Selected Dumpsites

Figure I: Waste density in selected dumpsites of the Study Area

[Source: 12]



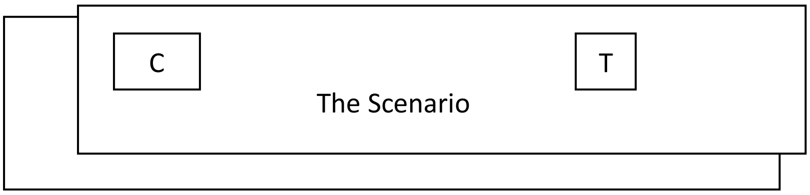
where TW – Total Waste, HW – Headpan Weight.

Figure II: Composition of waste materials by mass in the Study Area

[Source: 12]

(c) The Life Cycle Assessment (LCA)

The functional unit selected for the comparison of the alternative scenarios is the management of 1kg of municipal solid waste of this area. The scenario that was considered in this study with the system boundaries is illustrated in Figure III. The Scenario is called Landfilling Scenario consists of three main steps: Collection, Transport and Landfilling of MSW. Because of rural nature of the area, the quantities of municipal solid waste of this area are not rising rapidly; it is assumed that approximately 90 tonnes of MSW is generated daily by the 180,000 residents. Most of their wastes are being disposed when going to farm or thrown into the drains during heavy rainfall. Few private vehicles collect wastes in plastic bags that are discarded and piled up on the streets by the residents, and transport the wastes to the unregulated dumping site to dump there at all hours of the day for recycling or other use when they know they have no means of dumping waste materials. There are few unregulated open dumping site where recyclable components (about 7% of total wastes) are partially separated manually under the unhygienic conditions and piled up for recycling.



C: collection, T: transportation

Figure III: the scenario of MSW for the Study

III. Results And Discussions

The two methods employed to assess the impact of the solid waste generated in the study area are: the Tool for the Reduction and Assessment of Chemical and other Environmental Impacts (TRACI) and the Centre of Environmental Science, University of Leiden, (the Netherlands CML) Methods.

(a) Impact assessment of the Scenario with CML method of *$GaBi_5$* LCA modelling

11.60kg of waste materials were collected and transported for landfilling purposes. The flow chart of the landfill scenario and the result of Life Cycle Inventory (LCI) as produced from the *$GaBi_5$* LCA model are given in Figure IV and Table I respectively.

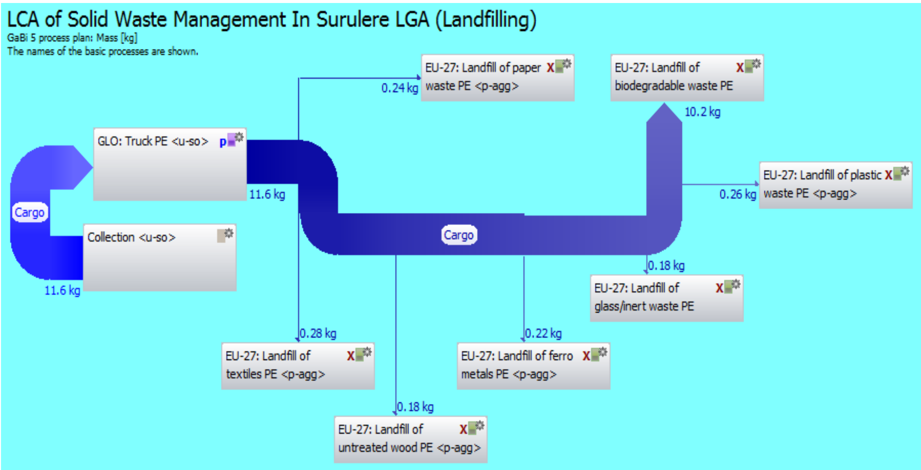


Figure IV: Plan of the LCA of Solid Waste Management in the Scenario

Table I: LCI result for the Scenario

	GWP		***AP***		***EP***		***ODP***	
	CML Kg, CO_2, eqv	**TRACI Kg, CO_2, eqv**	**CML Kg, CO_2, eqv**	**TRACI Kg, CO_2, eqv**	**CML Kg, CO_2, eqv**	**TRACI Kg, CO_2, eqv**	**CML Kg, CO_2, eqv**	**TRACI Kg, CO_2, eqv**
Biodegradable	9.74	9.17	0.00308	0.186	0.018	0.00774	2.66E-009	2.66E-009
Metal	0.00452	0.00436	1.04E-005	0.000688	8.79E-005	5E-006	6.12E-012	6.12E-012
Glass	0.00251	0.00251	1.53E-005	0.000907	2.1E-006	1.21E-006	2.48E-012	2.48E-012
Paper	0.369	0.347	8.67E-005	0.00541	0.00128	5.4E-005	6.26E-011	6.26E-011
Plastic	0.0194	0.0192	5.62E-005	0.00305	6.91E-005	3.23E-005	6.78E-011	6.78E-011
Textile	0.442	0.416	0.000102	0.0064	0.000657	0.00027	7.3E-011	7.3E-011
Wood	0.414	0.389	F89E-005	0.00507	4.31E-005	1.82E-005	4.69E-011	4.69E-011

(i) Global Warming Potential (GWP)
Using the CML Method, the global warming potential for hundred years in the LCA of solid waste management from *GaBi*$_5$ LCA model is graphically shown below:

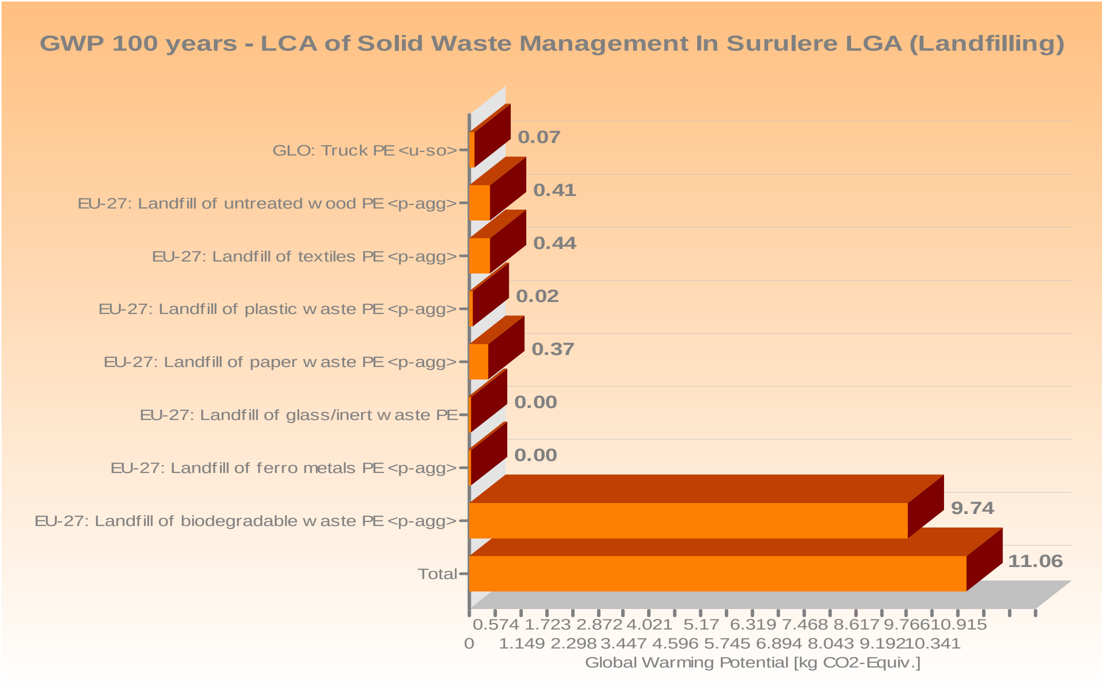


Figure V: GWP 100years - LCA of Solid Waste Management

(ii) Acidification Potential (AP)
Using the CML Method, the acidification potential in the LCA of solid waste management is graphically shown below:

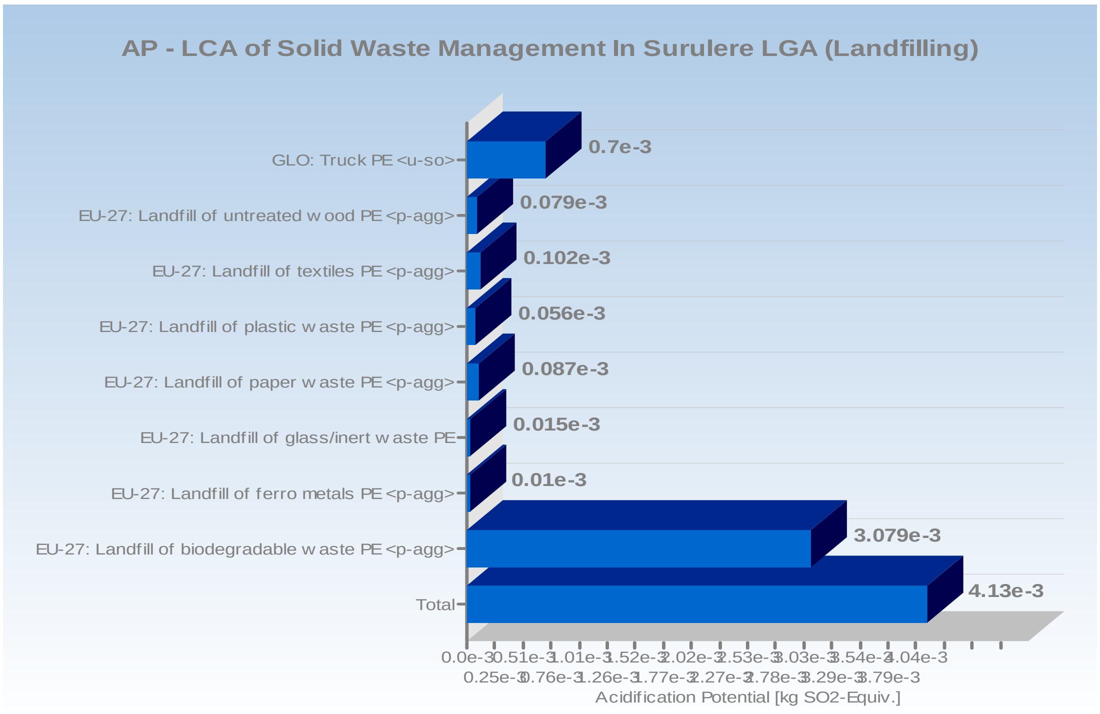


Figure VI: AP - LCA of Solid Waste Management

(iii) Eutrophication Potential (EP)
Using the CML Method, the eutrophication potential in the LCA of solid waste management is graphically shown below:

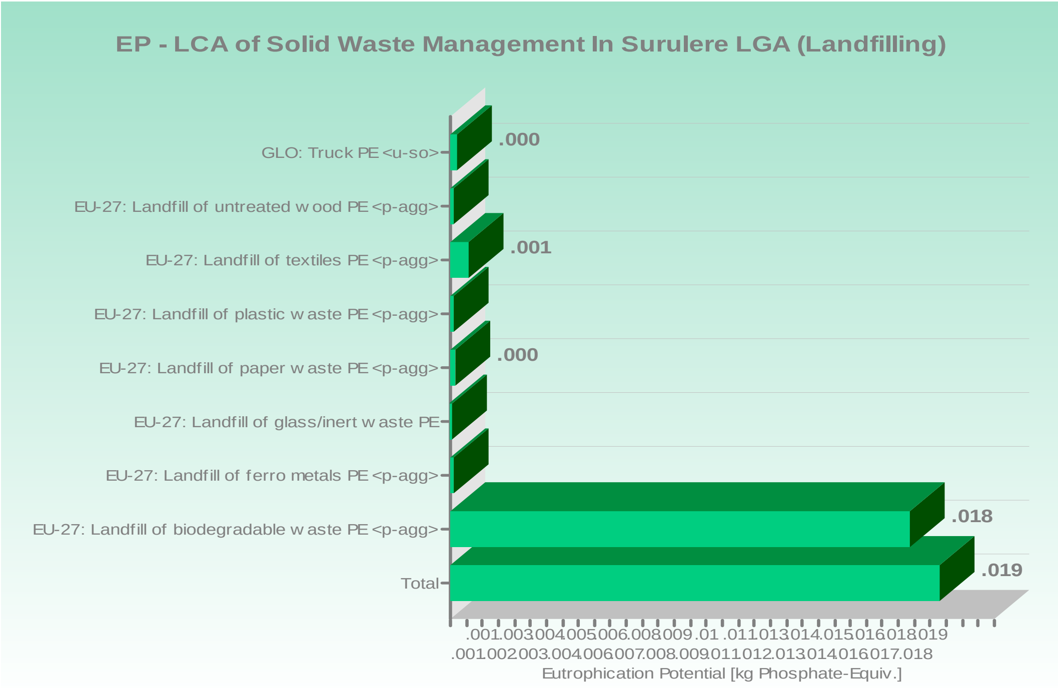


Figure VII: EP - LCA of Solid Waste Management

(iv) Ozone Depletion Potential (ODP)
Using the CML Method, the Ozone Depletion potential in the LCA of solid waste management is graphically shown below:

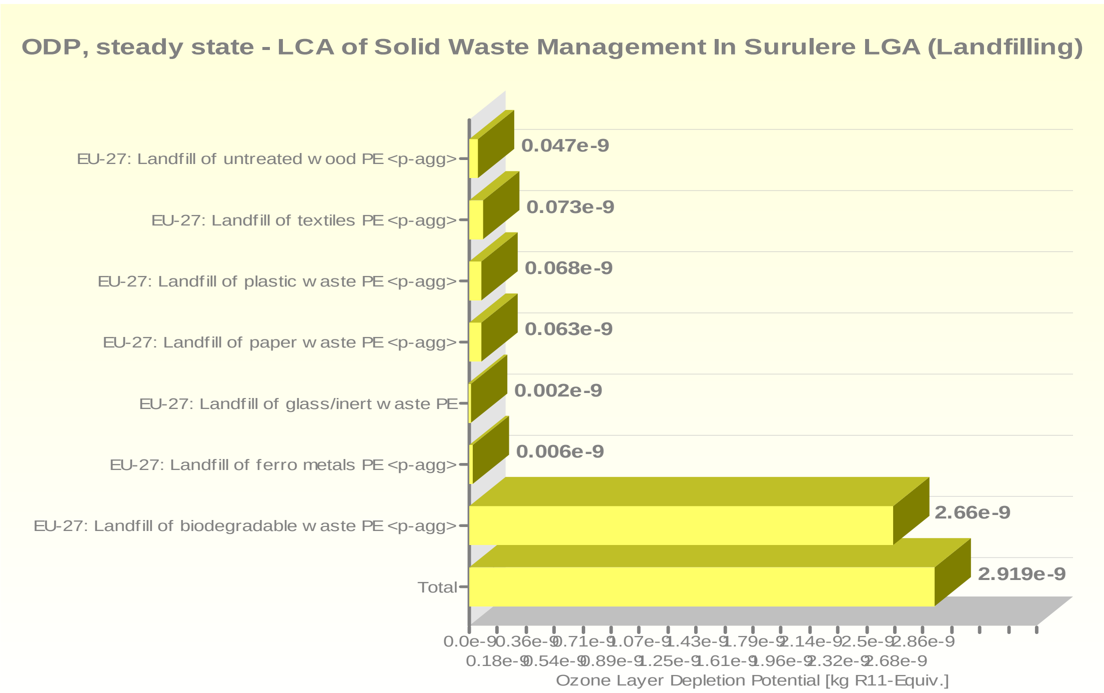


Figure VIII ODP - LCA of Solid Waste Management

(b) Impact assessment of the Scenario with TRACI method of *GaBi₅* LCA modelling

The comprehensive results of the life cycle Impact (LCI) Assessment of the scenario analyzed using the TRACI method are given below:

(i) Global Warming Potential (GWP)

Using the TRACI Method, the global warming potential for hundred years in the LCA of solid waste management of Surulere Local Government is expressed as global warming air which is graphically shown below:

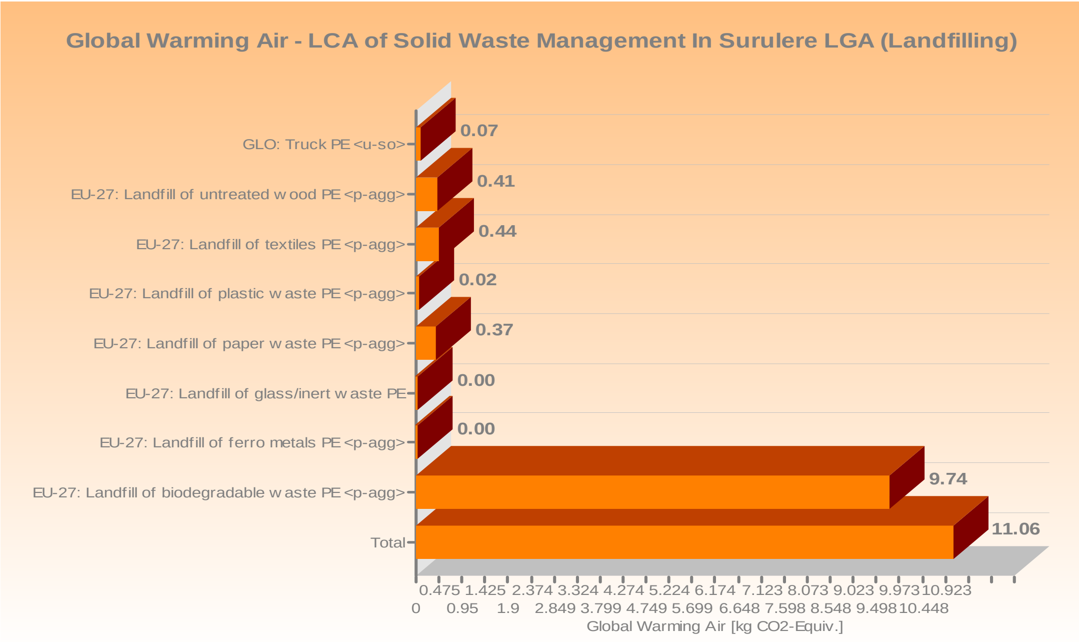


Figure IX: GWP - LCA of Solid Waste Management

(ii) Acidification Potential (AP)

Using the TRACI Method, the acidification potential in the LCA of solid waste management scenario is graphically shown below:

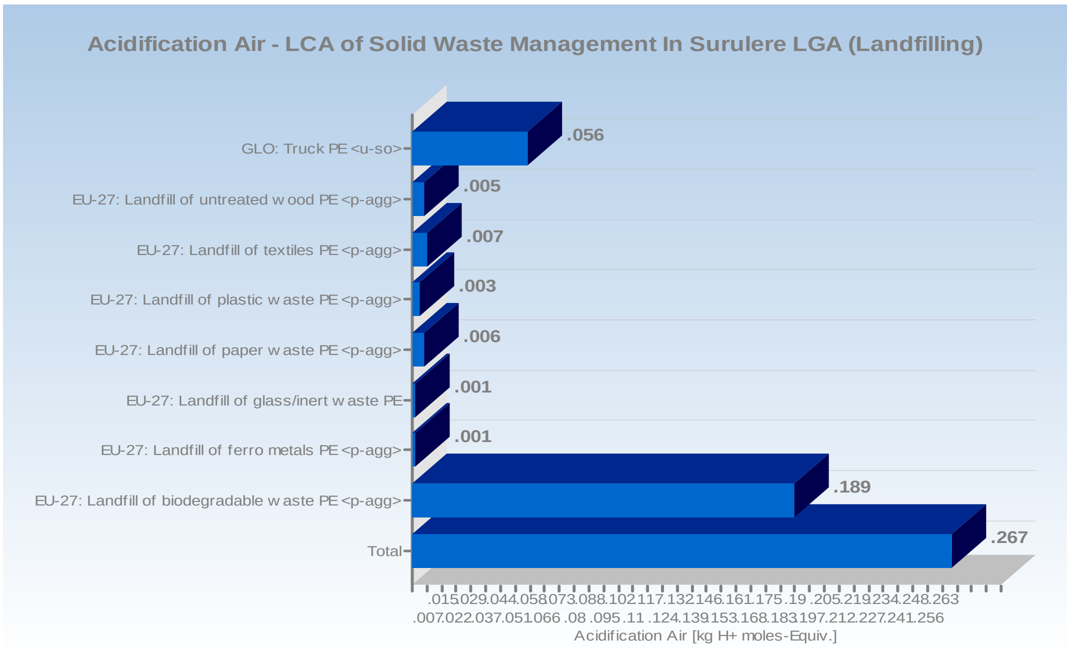


Figure X: AP - LCA of Solid Waste Management

(iii) Eutrophication Potential (EP)
Using the TRACI Method, the eutrophication potential in the LCA of solid waste management (scenario one) is graphically shown below:

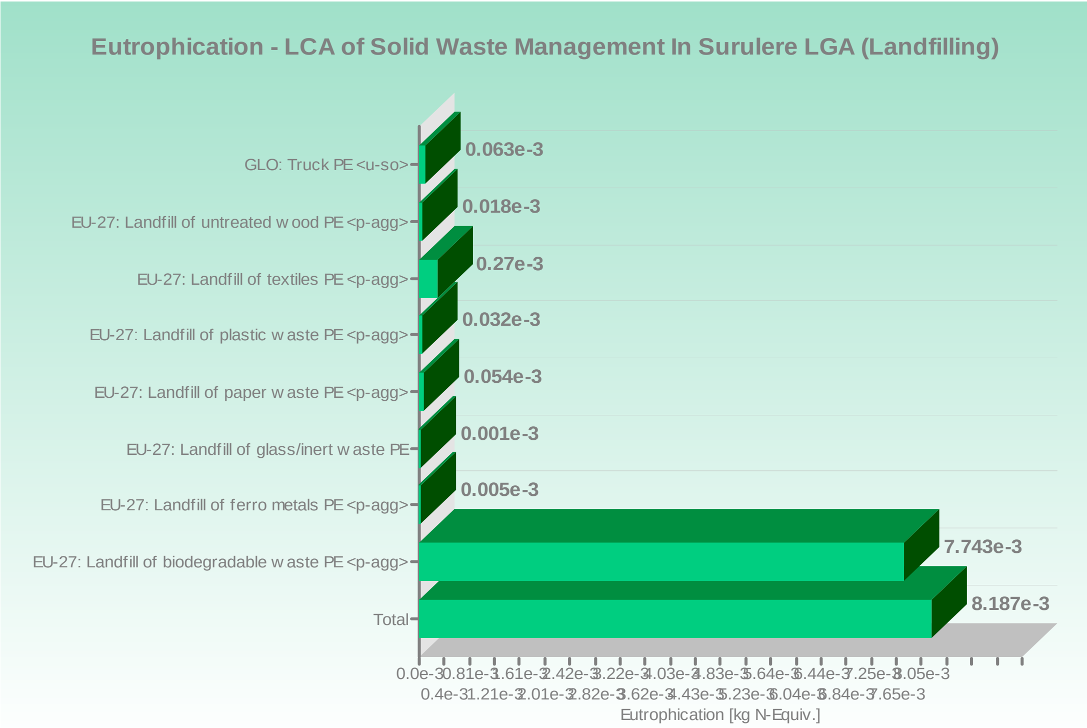


Figure XI: EP - LCA of Solid Waste Management

(iv) Ozone Depletion Potential (ODP)
Using the TRACI Method, the Ozone Depletion potential in the LCA of solid waste management scenario is graphically shown below:

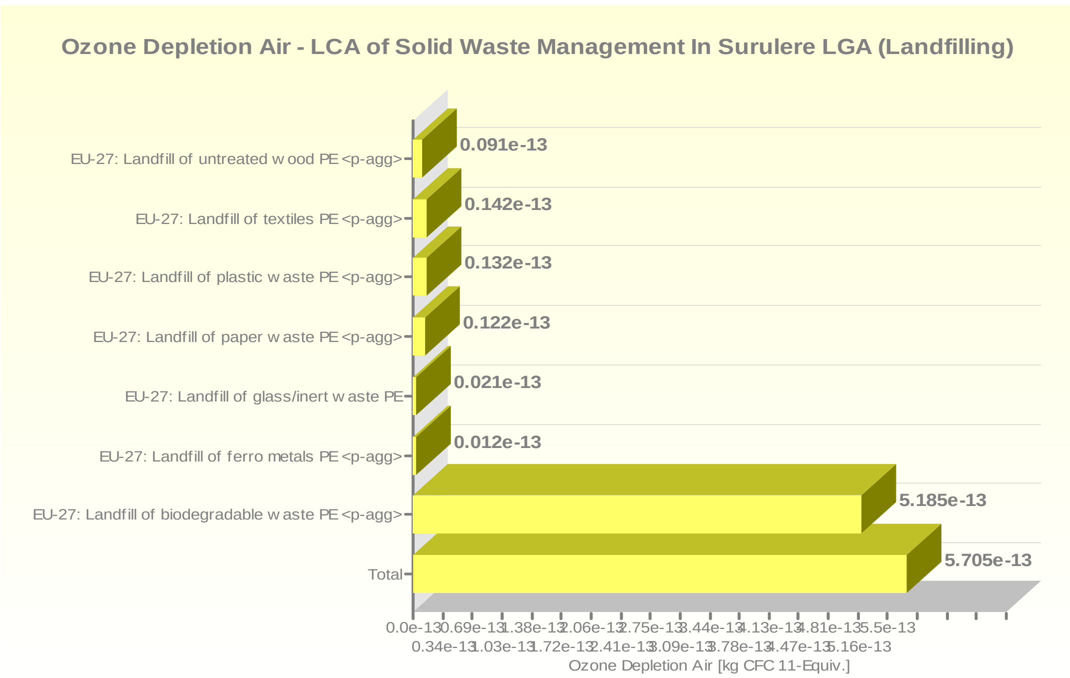


Figure XII: ODA - LCA of Solid Waste Management

(c) Comparison of Environmental impact assessment of both TRACI and CML methods

(i) Global Warming Potential(GWP)

It is generally observed that the GWP for 100years is relatively the same when the solid waste is land filled in respective of the LCI Assessment method used. From Figures V and IX, it is noted that the GWP for 100years is the same for both method of assessment.

(ii) Acidification Potential (AP)

From Figures VI and X, it is discovered that the environmental impact in terms of AP is high when TRACI method was used for the LCI assessment while it is lesser when CML method was adopted for the assessment.

(iii) Eutrophication Potential (EP)

From Figures VII and XI, it is noted that the EP as result of biodegradable waste and textile waste are high whereas the EP for other type of solid waste as indicated in the Figures are lesser when CML method was used for the LCI assessment; while when the TRACI method was used for the assessment, most of solid wastes have a high EP, with the exception of biodegradable waste and textile waste, when compared with CML method.

(iv) Ozone Depletion Potential (ODP)

The potential of ozone depletion as a result of solid waste land filled when assessed by CML method is a little higher than when TRACI method was used for LCI assessment (Figures VIII and XII refers).

IV. Conclusion

Application of $GaBi_5$ LCA modelling techniques solves the problem of imprecision involved in solid waste decision making. The study concludes that the wastes all have detrimental impacts on the 4 measured categories but the highest pollution threat is on the Global Warming Potential (GWP). The Scenario's Environmental Impacts shows that the GWP is characterized in the order: Biodegradable > Textile > Wood > Paper > plastic > Metal > Glass. The AP followed similar trend except for paper that is greater than wood wastes. EP has this trend; Metal > Wood > Glass > Biodegradable > Paper > Textile while for ODP it was Textile > Plastic > Paper > Metal > Wood > Biodegradable > Glass. The study also showed that when LCA is applied in conjunction with the waste hierarchy, it can be a useful tool for the planning of municipal waste management system as it allows municipalities to directly compare the actual environmental impacts of different technologies and planning options. Furthermore, through system expansion, a consequential approach to LCA may encourage municipalities to integrate waste management with processes in other sectors. It is therefore recommended that Environmental Protection Agencies at all levels should always analyze and contain the pollution impacts of the solid wastes on the environment.

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