The Environmental Impacts Assessments of landfilling with TRACI modeling technique

***#S.O Ojoawo, +O.I Odejobi and +D.J Boyejo**

*Department of Civil Engineering,
NMAM Institute of Technology, Nitte-574110, Udupi District,
Karnataka, India

+Department of Civil Engineering,
Ladoke Akintola University of Technology,
P.M.B 4000, Ogbomoso, Nigeria

#Corresponding Author; e-mail: soojoawo@lautech.edu.ng

Abstract

Assessing the environmental impacts of wastes has continued to receive concentrated attention in recent times. This research work focuses on the application of Tool for the Reduction and Assessment of Chemical and other Environmental Impacts (TRACI) modeling technique in the assessment of solid wastes in Ogo Oluwa Local Government Area (LGA), Oyo State of Nigeria.

Landfill is the main scenario considered in the study. A waste management model was developed using the GaBi$_5$ (Holistic Balancing) software approach. The indices of the impact assessment were Global Warming Potential (GWP); Acidification Potential (AP); Environmental Potential (EP) and the Ozone Depletion Potential (ODP). The LCA software presents all feasible SWM strategies for a given SWM system.

Findings showed that landfilling contributes immensely to the global warming potential and the energy consumption is much, perhaps due to its material composition. It equally posses Acidification, Eutrophication and Ozone depletion threats to the environment in the study area.

Landfill as waste management system should therefore be carried out with much carefulness. Composting of biodegradable wastes is recommended as its alternative.

Keywords: Landfill; Biodegradable; Global Warming Potential; Acidification Potential; Eutrophication Potential; Ozone Depletion Potential

1.0 Introduction

Management of solid wastes is a complex and multidisciplinary problem that requires concentrated attention for sustainability. Solid Waste Management (SWM) is a major engineering activity that has important technical, economic, social and environmental constraints. For a healthy environment, both municipal and industrial wastes should be assessed according to the SWM hierarchy. A modern technique of evaluating wastes is Life Cycle Assessment (LCA). It has been defined as an objective process to evaluate the environmental burdens associated with a product, process or activity, by identifying and quantifying energy and materials used and waste released to the environment.

In the early seventies, [1] proposed a haul optimization model. His objective was to minimize the total combined cost of solid waste transport, processing, and disposal for a given area over a certain period of time. Mathematical theory related to garbage vehicle routing was developed by [2] while [3] formed a mixed integer linear programming model applied to SWM. The model selected the size of and site for facilities and the level of their physical operation over several periods of time. Also, [4] presented a linear programming model to analyze a SWM system. The objective function was to minimize the present value of collection, recycling, treatment and disposal costs.

In the linear programming model presented by [5], the objective was to minimize a solid waste recycling system cost. The model was developed exclusively to analyze recycling strategies for some recyclable waste categories in the waste stream. Further, [6] developed a LP model for scheduling of solid waste recycling and [7] expanded [6]'s formulation by considering consecutive landfills. The tipping costs, along with the costs of implementing each recycling option, were used to determine the optimal solution for each existing and possible future landfill. Again, [8] formulated a linear programming model for analysis of material recovery facilities (MRF) with the objective of minimizing total recyclables separation and processing costs.

The environmental analysis model evaluates energy/emission from a user-specified quantity and composition of waste. This is therefore the functional unit for the model. The inventory results can be converted into burdens per tonne of MSW if, for example, the user would like to compare the environmental effects of managing one tonne of MSW by one waste management options vs. another (e.g recycling vs. landfill).

Ogo – Oluwa LGA, the study area has a population of 65,184 [9], a surface area of 385.73km^2 that increases with annual rate of $0.15^0/_0$ population-wise. It's headquarter is situated at Ajaawa. It has two seasons, the wet and the dry seasons. In the LGA, apart from open – burning, there is only one waste recovery program and the program is widespread throughout the area which is open dumping. For the sake of this research, it represents the landfilling. Wastes are collected in bins or containers which are later transported by the government environmental protection agency for landfilling with no recovery rate.

The objectives of the present study are: to explore and evaluate the applicability of TRACI models in the impact assessments of the solid wastes being generated in Ogo-Oluwa LGA; to develop and test a comprehensive mathematical model for the scenario that facilitates an integrated analysis of an SWM system using Gabi$_5$ software; and to the highest potential threat to the environment.

2.0 Methodology

Life Cycle Assessments were conducted according to the ISO 14040 and ISO 14044 standards. Figure 1 captures the plan of the landfilled LCA in the study area.

The scenario consists of three main steps: collection, transport and landfilling of MSW. A total of 11.90kg of waste materials were collected which were later transported for landfilling purposes. Because of rural nature of the LGA, the quantities of municipal solid waste of this area did not rise rapidly. Also due to the low population of the residence, approximately 35 tons of MSW is generated daily [10].

The LCI was estimated using the GaBi software. In GaBi, the LCI of the whole system is generated automatically once a system of processes is set up.

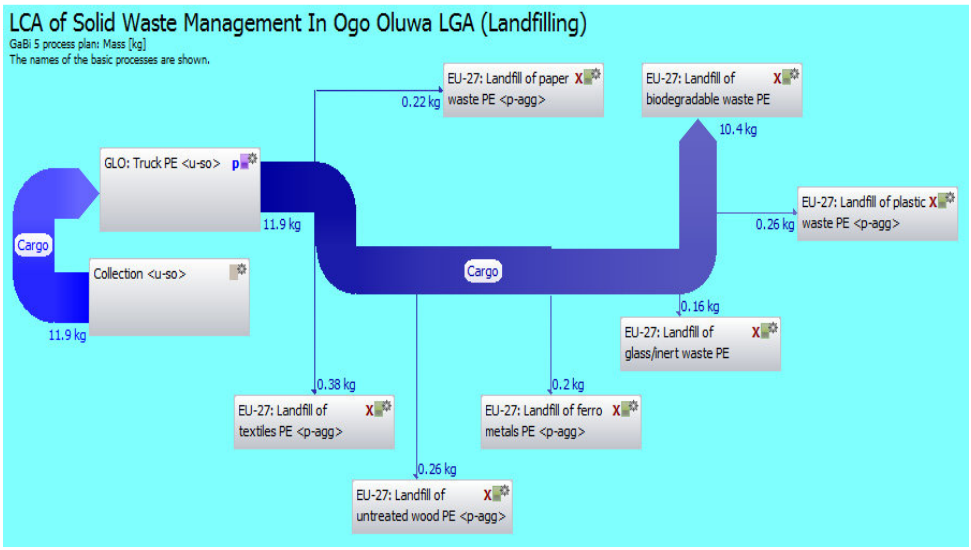

Figure 1: Plan of the LCA of landfilling Solid Waste Management in the study area

TRACI is a prominent method of impact assessment. In the life cycle impact assessment methods such as TRACI,
two main approaches are used to classify and characterize environmental impacts: the problem-oriented approach (mid -point) and the damage-oriented approach (end point).

3.0 Results and Discussion

GaBi software is designed with features refined through experience on thousands of consulting projects, GaBi supports every stage of an LCA, from data collection and organization to presentation of results and stakeholder engagement.

3.1 Average mass of waste materials

The mean mass of waste materials as measured in the study area is as presented in Figure 2. It was observed that food and putrescible products dominate. This further justifies the choice of landfilling scenario for this study.

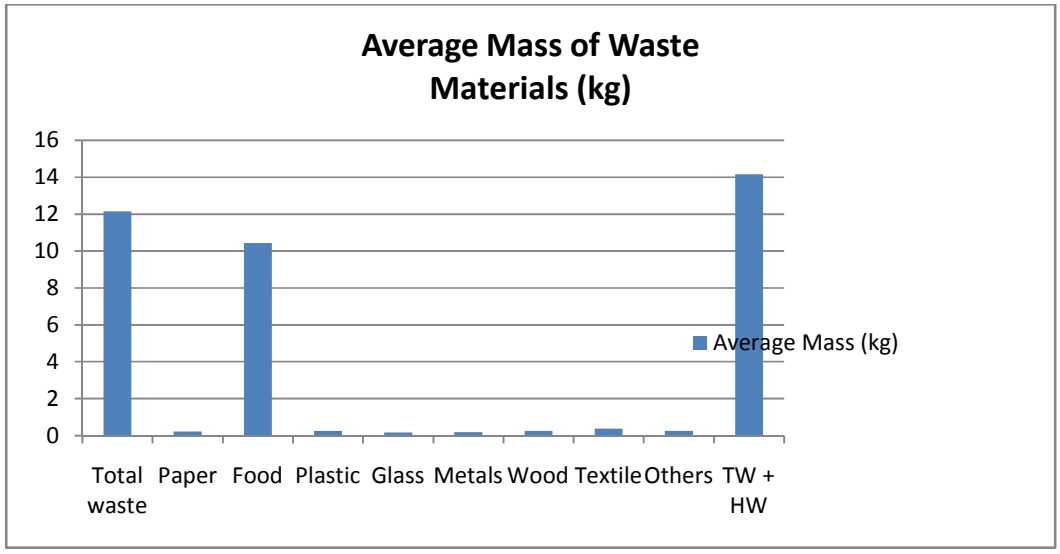

Figure 2: Composition of waste materials by mass of the study area

3.2 Life cycle inventory assessment (LCIA)

The comprehensive result of the LCIA of the scenario analyzed is as given below:

The Global Warming Potential (GWP) for a customary period of 100years was measured. The GWP was calculated in carbon dioxide equivalents (CO_2-Eq.). GWP in the LCA of solid waste management of the LGA is graphically shown in Figure 3. In the scenario, a total of 11.56 kg of CO_2 equivalent emission is released into the environment. It was observed that biodegradable wastes constitute the highest GWP threat.

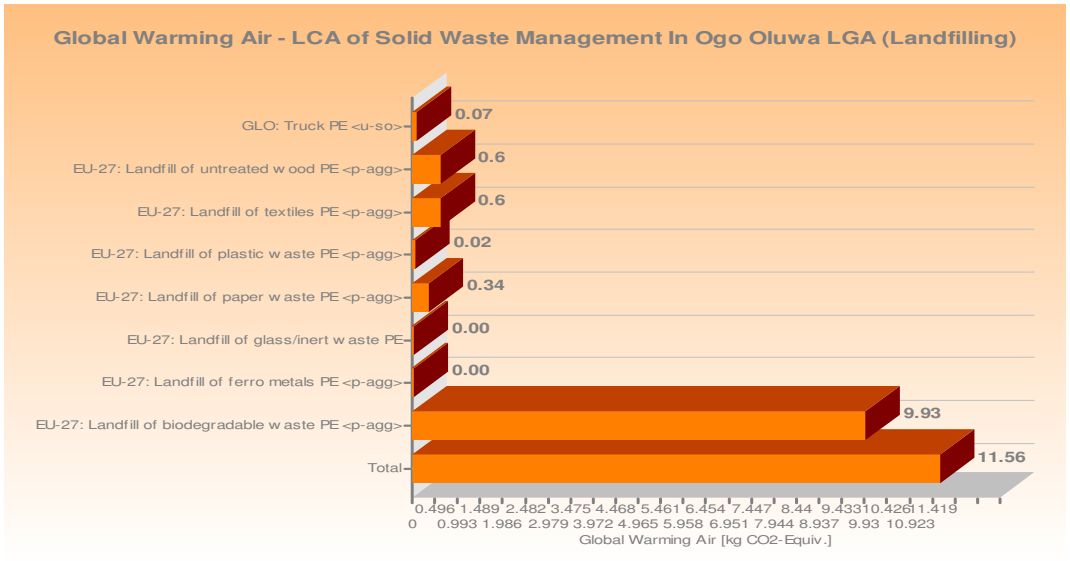

Figure 3: GWP 100years - LCA of Solid Waste Management in the study area

The AP in the LCIA of solid waste management is graphically presented in Figure 4 below. Truck emission was found to be dominant aside the biodegradable wastes. Here, the total of $4.271e^{-3}$ kg of SO_2 equivalent was released into the environment. The acidification of soils and waters occurs predominantly through the transformation of air pollutants into acids. This leads to a decrease in the pH-value of rainwater and fog from 5.6 to 4 and below. Sulphur dioxide and nitrogen oxide and their respective acids (H_2SO_4 und HNO_3) produce relevant contributions. This damages ecosystems, whereby forest dieback is the most well-known impact. Acidification has direct and indirect damaging effects (such as nutrients being washed out of soils or an increased solubility of metals into soils).

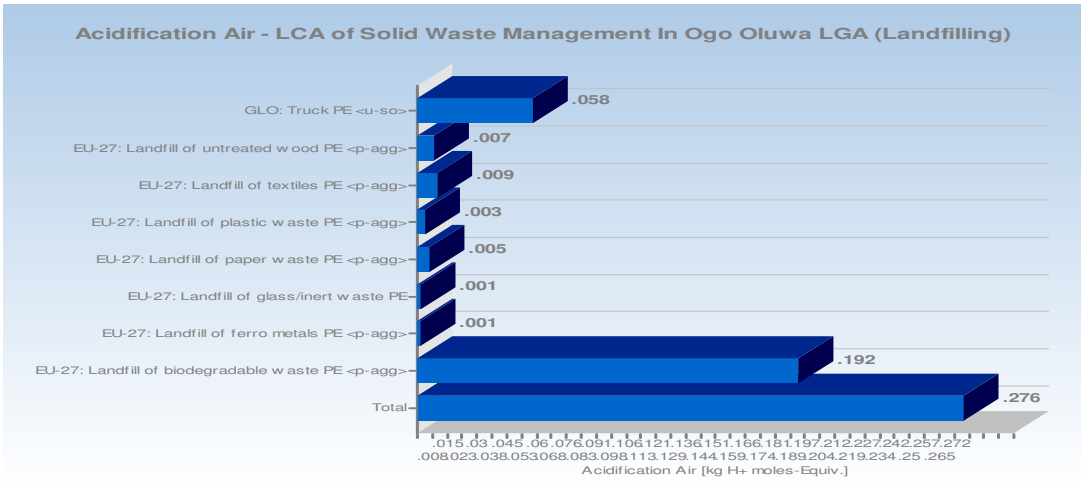

Figure 4: AP - LCA of Solid Waste Management in the study area

Figure 5 indicates that the EP was maximum for the biodegradable waste with the value of 0.018 kg phosphorus-equivalent.

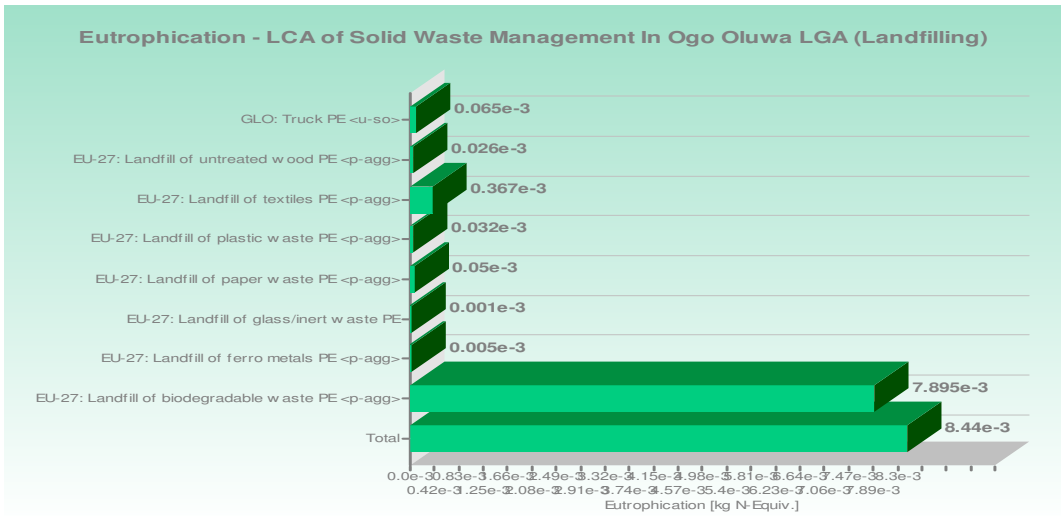

Figure 5: EP - LCA of Solid Waste Management in Ogo Oluwa LGA

The Ozone Depletion potential in the LCA of solid waste management (scenario one) is graphically shown below in Figure 6. In the scenario, a total of $5.884e^{-13}$ kg of CFC11- equivalent emissions was released into the environment. Ozone is created in the stratosphere by the disassociation of oxygen atoms that are exposed to short-wave UV-light. Anthropogenic emissions deplete ozone. One effect of ozone depletion is the warming of the earth's surface. The sensitivity of humans, animals and plants to UV-B and UV-A radiation is of particular importance. Possible effects are changes in growth or a decrease in harvest crops (disruption of photosynthesis), indications of tumors (skin cancer and eye diseases) and decrease of sea plankton, which would strongly affect the food chain.

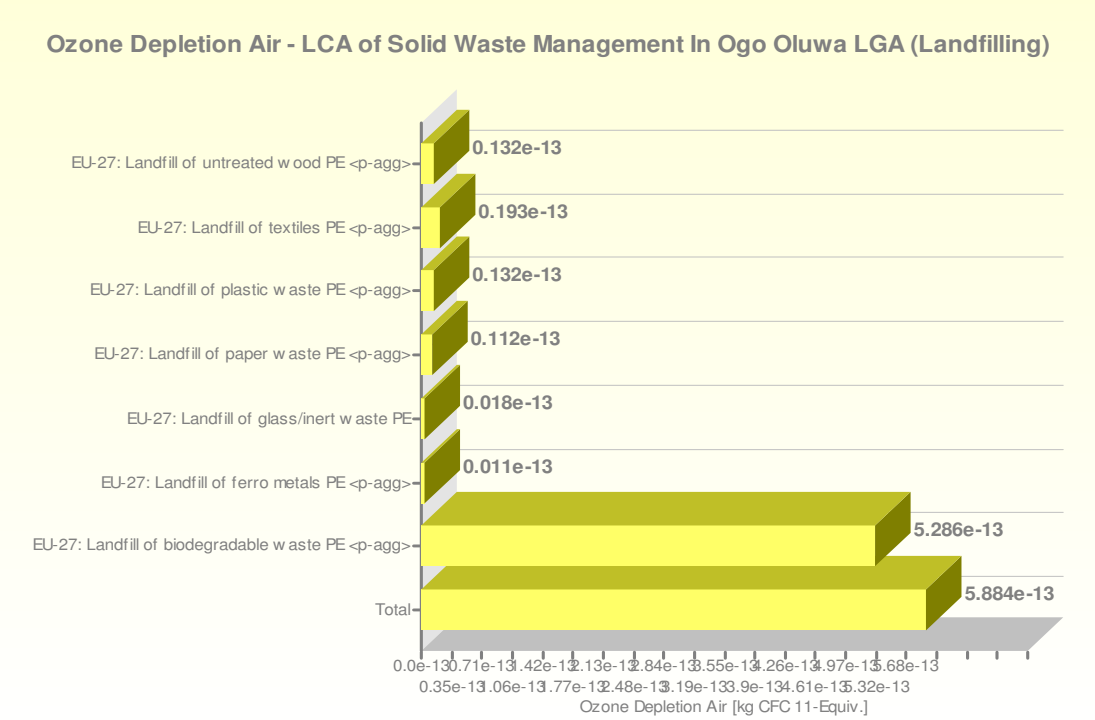

Figure 6: ODP, steadystate - LCA of Solid Waste Management in the study area

Generally speaking, the scenario offers energy savings although it is very costly to implement.

4.0 Conclusion

As much as landfilling may be publicly adjudged as the most acceptable disposal method, this study concluded that it has a number of drawbacks in its environmental impact. It contributes immensely to the global warming potential and the energy consumption is much. It equally posses Acidification, Eutrophication and Ozone depletion threats to the environment in the study area. The Biodegradable wastes in the scenario are the major waste materials/contents which are responsible for much effect or impact of both scenarios on the environment. Landfill as waste management system should therefore be carried out with much carefulness. Composting of biodegradable wastes is recommended as its alternative.

References

[1] Esmaili, H, "Facility selection and Haul optimization model." *Journal of the Sanitary Engineering Division.* Vol. 98, No.SA6., 1972. pp. 1005-1021.

[2] Liebman, Jon C. *et al.* "Minimun cost in residential refuse vehicle routes." *Journal of the Environmental Engineering Division.* Vol. 101, No. EE3, 1975. pp. 399-412.

[3] Chang, Ni-Bin. *et al.* "Environmental and economic optimization of an integrated solid waste management system." *Journal of Resource Management and Technology.* Vol. 21, No.2, 1993. pp. 87-100.

[4] Hsieh, Hsin-Neng and Ho, Kuo-Hua, "Optimization of solid waste disposal system by linear programming technique." *Journal of Resource Management and Technology*. Vol. 21, No. 4, 1993. pp. 194-201.

[5] Diamadopoulos, E, Koutsantonakis, Y., and Zaglara, V. ,"Optimal design of municipal solid waste recycling systems." *Resources, conservation and recycling.* No. 14, 1995. pp. 21-34.

[6] Lund, Jay R. "Least-Cost scheduling of solid waste recycling." *Journal of Environmental Engineering.* Vol. 116, No.1, 1990. pp. 182-197.

[7] Jacobs, T.L. and Everett, J.W, "Optimal scheduling of consecutive landfill operations with recycling."*Journal of Environmental Engineering.* Vol. 118, No. 3, 1992. pp. 420-429.

[8] Lund, Jay R *et al.,* "Linear programming for analysis of material recovery facilities."*Journal of Environmental Engineering.* Vol 120, No 5, (1994). pp 1082-1094.

[9] NPC "Official gazette for 2006 population census". National Population Commission, Nigeria, 2006, p. 8

[10] S.O Ojoawo "Management of Leachate pollution from Dumpsites in Ogbomoso-land, Nigeria". Ph.D Thesis, University of Ibadan, 2009 p. 95