Centrepoint Journal (Science Edition)
Volume 21, No. 2, pages 53- 66
http//www.unilorin.edu.ng/centrepoint

2141-3819/2015 $5.00 + 0.00
©2015 University of Ilorin

CPJ 2015018/21204

Potential Environmental Impact of Household Solid Waste Management in Nigeria: A Case Study of Ilorin Metropolis

K. A. Adeniran, * A. A. Ajayi-Banji, and G. Ojeanelo

Agricultural and Biosystems Engineering Department, Faculty of Engineering and Technology, University of Ilorin, Ilorin, Kwara State, Nigeria

***Author for correspondence:** ajayibanjiademola@gmail.com*

Abstract

Anthropogenic activity induced emissions have led to significantly increased environmental degradation. The greenhouse gas emissions generation rates are stimulated by technological innovations including solid waste management technologies. In this study, categorized household solid wastes from Ilorin metropolis were collected, sorted and weighed vis-a-vis population densities and income groups. The classifications are high income low density area (HILDA), High Income High Density Area (HIHDA), Low Income Low Density Area (LILDA) and Low Income High Density Area (LIHDA). Data were processed for potential emission generation from solid waste management technologies. Result shows that householders generate high food composition (25%) in comparison with other household refuse categories. Occupants' lifestyle with respect to domestic waste composition is influenced by income level, as high income earners generated more disposables. Strong nexus exist between household income-population and all the technologies considered except composting. Order of emission generation rate per week from the waste management technologies is landfilling> anaerobic digestion> incineration> composting. Landfill technology produces the highest CO_2 emission (0.0015- 0.65 $KgCO_2e$/week) for all waste categories and HIHDA householders have the highest values while anaerobic digestion has the least emission equivalent (0.0 – 0.01 $KgCO_2e$/week). High contributive waste management method to global warming should be replaced with environment-friendly techniques.

Keywords: Environmental degradation, GHG, solid waste management technologies, life cycle assessment

Introduction

Environmental pollution induced by human-activities is presently a global concern due to its extant and pronounced alteration of the natural ecosystem. This phenomenon has been aggrandized by population growth, industrial development and lean waste management practices. Cramer (2013) documented the synergy among population growth, environmental degradation and human health. The author observed that population growth has resulted in health risks, enhanced deforestation and contributed immeasurably to air, soil and water pollution. Strong relationship was equally established between industrialization and climatic change (Alison *et. al.,* 2001; Zhang, 2009; WTO-UNEP, 2009). This correlation indicates that acidification and global warming potentials from industrial-based activities have significant impact on ozone layer depletion. Furthermore, poor waste management practices have been linked with harmful emission generation, building devaluation, odourous environment and ground and surface water contamination (USEPA, 2002; Abul, 2010; Karija *et. al.*, 2013). Over the years, environmental integrity maintenance and sustenance has been tailored majorly towards mitigation of emission generated directly from heavy fossil fuel related activities such as gas flaring, exhaust from automobile, incomplete combustion and other heavy-duty equipment. Recently this scope has been expanded in most developed nations. Emission generation, quantification and management from both industrial and domestic activities including waste management technology are being monitored and addressed by environmentally-inclined bodies. This is induced by observed contributive impact of other environmental pollution activities such as municipal solid waste (MSW) management methods. Although, this consideration barely applies in most underdeveloped and developing countries.

The general municipal waste management techniques are composting, anaerobic digestion, landfilling and incineration in most developed and few developing countries. Other waste management methods such as open dumping and uncoordinated burning of municipal solid waste are the common trends in Nigeria (Udoakah and Akpan, 2013). All these methods release green house gases (CO_2, CH_4 and N_2O) to the atmosphere thereby

aiding climate change. However, the extent of damage depends on municipal solid waste composition (Jha *et. al.*, 2007; EEA, 2011). Therefore, GHG emissions quantification from this waste management technique should be considered if issues of environmental degradation are to be holistically addressed. Studies have been carried out on solid waste quantification and management practices employed in Nigeria however most authors did not consider potential emission generation from waste through the management technology. These include abattoir solid waste (Sangodoyin and Ajayi-Banji, 2013), institutional solid waste (Amori *et. al.*, 2013) and municipal solid waste (Ogwueleka, 2009; Adejobi and Olorunnimbe, 2012). This research focuses on the potential impact of GHG from household waste management in Ilorin, the north central zone of Nigeria.

Study Area

Ilorin is one of the major cities in the north central zone of Nigeria. The city is located on latitude 8^{o} 20'N and longitude 4^{o} 35'E. The state occupies about $100km^2$ land area (Ajadi, 2010) with a population density of 814,192 according to 2012 GeoNames geographical database. Due to the small numerical value of its industry scale, Abdul Raheem (2006) classified Ilorin as a semi-industrialized state.

Methodology

Five hundred and fifty households were randomly surveyed and questionnaire administered in Ilorin Kwara State, Nigeria. The questionnaire was centered on municipal solid waste management data and householder's income. Solid wastes generated in the randomly selected households from two different population density (high and low) regions were collected weekly in waste-containers served to individual householders. This categorization is in line with Oyedapo and Saadu's (2008) study of Ilorin metropolis. Two income earners (low and high) were equally used for further householder classification. Earners with monthly income less than and equal to ₦50, 000:00 (≈$300) were categorized as low income earners while householders with greater remuneration were considered as high income earners. Nevertheless the categorization differs from MDG's and

World Bank's grouping, it reflects the standard of living for householders in Ilorin (Personal interview). For the purpose of this study, Life Cycle Assessment (LCA) method was employed to evaluate potential GHG emission generation for some feasible municipal waste management technologies in Nigeria. The tool has gained prominence in project impact assessment (Freed and Choate, 2000; USEPA 2006; Assamoi and Lawryshyn, 2012). LCA could revolve round the entirety of a project (cradle – grave) or cover a fraction of it (cradle – gate; gate – gate; gate – grave) with four basic steps. These steps are research objective, life cycle inventory, study scope and assessment of estimated effect of the subject. In this study, LCA assesses the potential effect of emissions from municipal solid waste treatment methods such as composting, landfilling, incineration and aerobic digestion in Nigeria. Household solid wastes from High Income Low Density (HILDA), High Income High Density (HIHDA), Low Income Low Density (LILDA) and Low Income High Density Areas (LIHDA) was adopted as the functional unit for the study. Inventory was obtained from average weekly weight of household wastes. Collected waste stream was manually sorted, weighed and recorded for a period of 6 weeks. The inventory was evaluated using material conversion factor documented by Defra/DECC (2012) to obtain the CO_2 equivalent for GHG per functional unit (Table 1).

Table 1: Conversion factors for municipal solid waste technologies

	Composting	**Landfill**	**Incineration**	**Anaerobic Digestion (Kg CO_2e/tonne)**
Glass	NSP	26	21	NSP
Metal	NSP	20-21	21-31	NSP
Rubber	NA	NA	NA	NA
Leather	NA	NA	NA	NA
Wood	21	851	21	NSP
Textile	NSP	552	21	NSP
Paper	21	553	21	NSP
Food	6	570	21	21
Yard	6	213	2	21
Plastic	NSP	34	21	NSP

Source: Defra/DECC (2012)

*NSP- Not subjected to the process. NA- Emission factor not available

Results and Discussion

Result of the randomly surveyed households indicates 30% were low income high density area, 20% were high income low density area, 15% were high income high density area and 35% were low income low density area. The disparity in householders' number was catered for by the mean values used in the study (Figures 3-5 and Tables 1-4). Householders' waste composition include glass, metal, rubber, leather, food, wood, yard, ash, dust sweeping and some hazardous waste materials like spent battery labelled as others (Figure 1). Similar composition was observed by Ogwueleka (2009) in a study on municipal solid waste management in Nigeria. Food scraps proportion of about 25% was the greatest for this study (Figure 1). Nonetheless, this result contradicts USEPA's (2004) report on municipal waste, with paper taking the lead. Justification for the high paper waste generation was attributed to lifestyle change influenced by growth and development. Decomposable portion of the waste stream (wood, paper, yard, food and ash dust sweeping) has the highest percentage (69%), while the non-putrescible (leather, plastic, glass, metal, textile, rubber, others) captures the remaining percent. This is in line with the findings of Hoornweg *et. al., (*1999) and Amori *et. al.,* (2013). The authors observed over 50% organic materials fraction in waste stream obtained from developing countries. Ogwueleka (2009) led credence to this finding as about 60% organic waste composition was found in solid wastes collected in Nigeria. Thus substantial fraction of the waste could be managed using aerobic technology. According to Defra/DECCA (2012), this technology generates less GHG emissions with high tendency of harnessing the product (compost) as soil amender and manure.

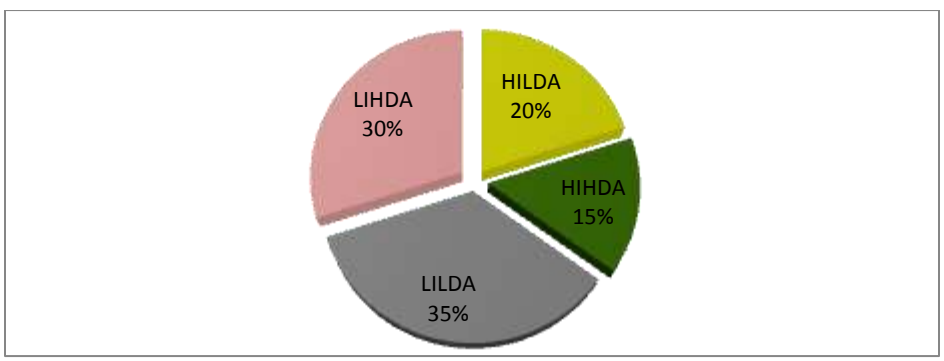


Figure 1: Household categorization

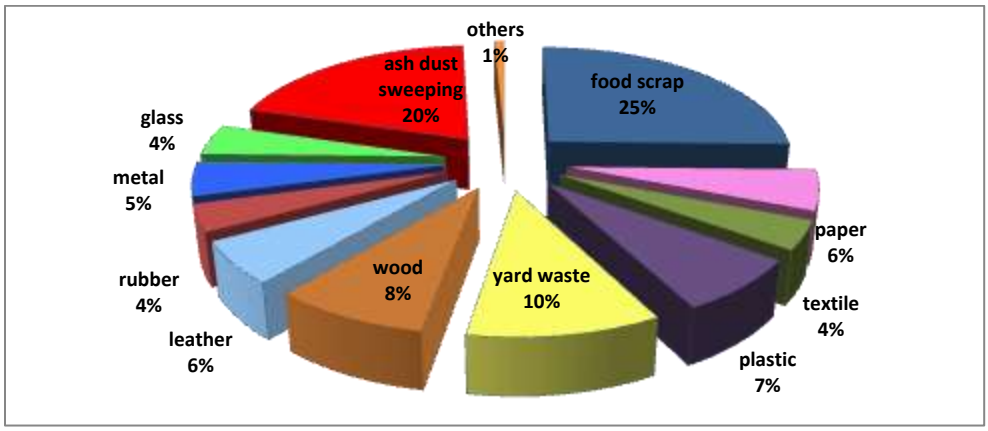


Figure 2: Household waste composition

Income level and population density affect waste generation. As a result of these combined factors, household waste generation per week was greater in high densely populated area and for high income earners (Figures 3 - 6). Mean weight of over 5000 g and 4000 g of waste was turned out per week by high income earners and high density households respectively (Figure 3). This is owing to householders' lifestyle as influenced by high income level; thus, high income earners generate high level of waste in terms of weight. Garbage (food waste) has the highest generation fraction per week for all the income-population density categories (Figure 6). This high waste volume will obviously attract rats, rodents, decomposers and detritivores in the vicinity. Another challenge from category of waste is its odour generation during decomposition.

Population density equally plays a vital role in emission generation because of the increased volume of wastes produced. Most high population densities classifications generate more GHG emissions from the waste treatment technologies than the corresponding low population densities (Figures 7 - 14). This trend is in line with the observation of Bogner *et. al.*,(2007) on regional waste generation. The researchers observed that population cum economy is a major factor influencing waste generation.

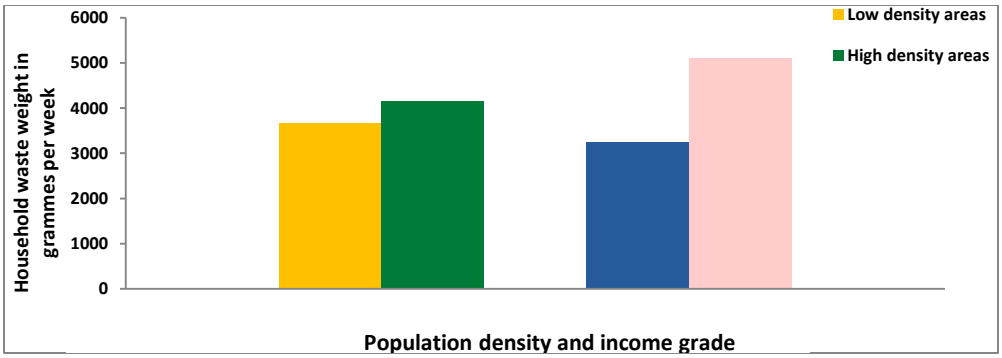


Figure 3: Mean household waste aggregate

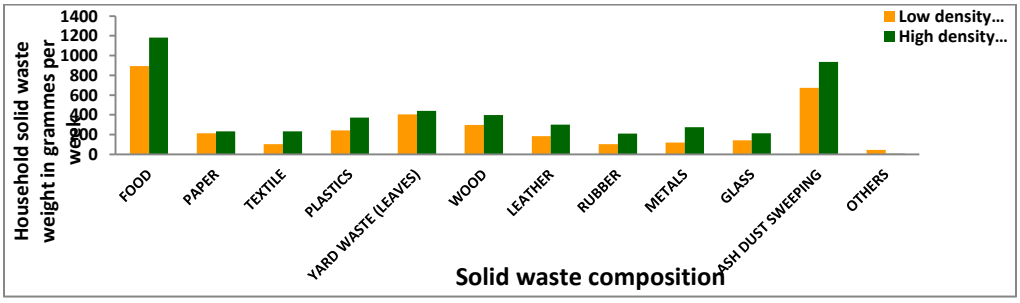


Figure 4: Mean household waste composition based on population density

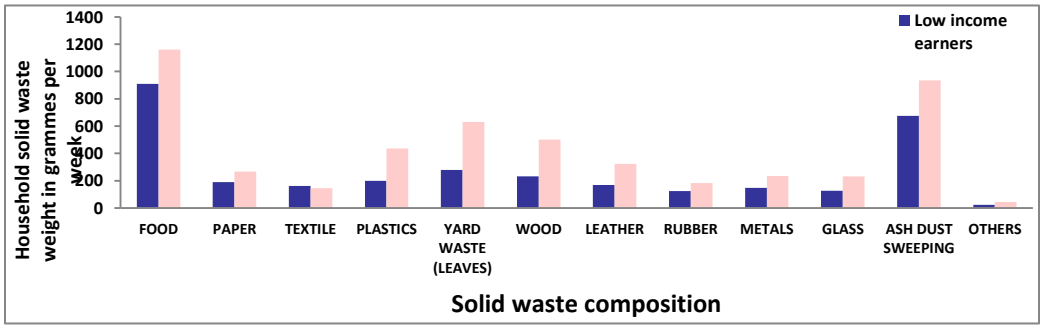


Figure 5: Mean household waste composition based on income grade

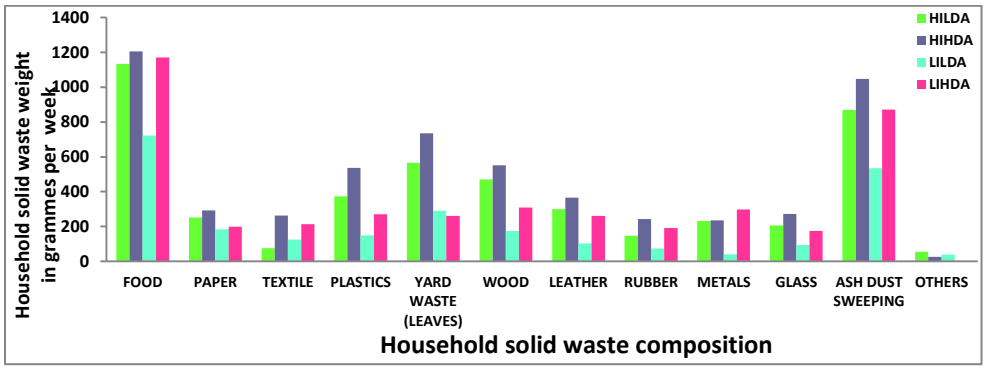


Figure 6: Mean household waste composition based on income-density grade

In line with the information in Figures 7 – 14, putrescible and recalcitrant wastes landfilled have the potential to generate about 40 – 97% more GHG emission than other solid waste management technologies. A similar trend was observed by USEPA (2000). The author considered this method as the worst waste management technology choice because of its pronounced environmental degradation effect due to elevated emission gases production. On the contrary, metal has higher GHG emission potential when incinerated than when landfilled. Therefore metal waste should be sorted, recycled or re-used in an environment-friendly way with the intention to avoid emission from its incineration. Other good management practice suggested by Asante *et. al.*, (2014) is autoclaving.

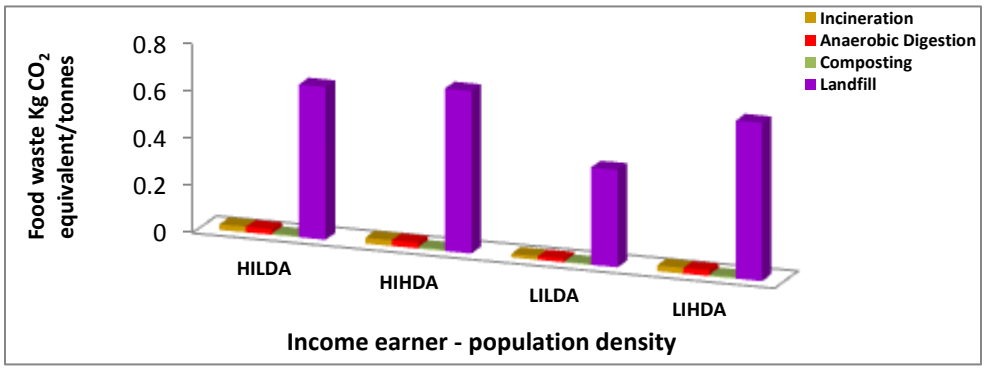


Figure 7: GHG emission from food waste management technologies

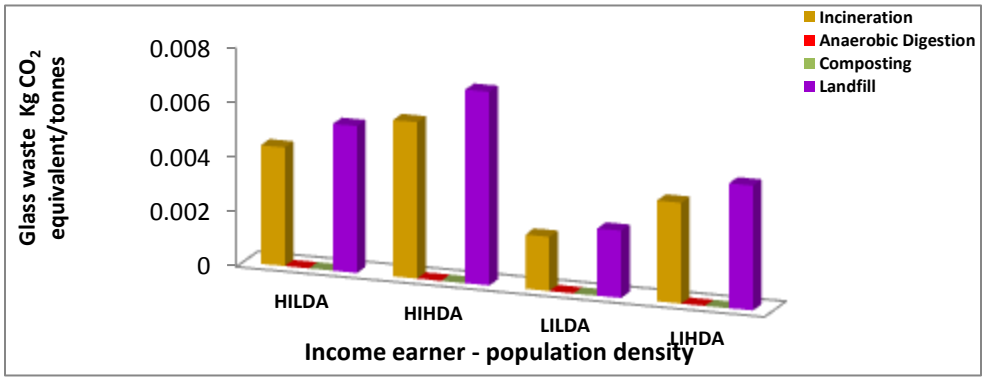


Figure 8: GHG emission from glass waste management technologies

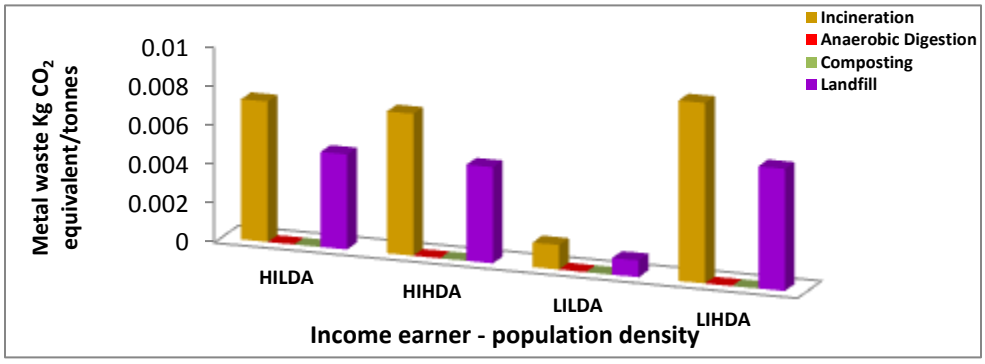


Figure 9: GHG emission from metal waste management technologies

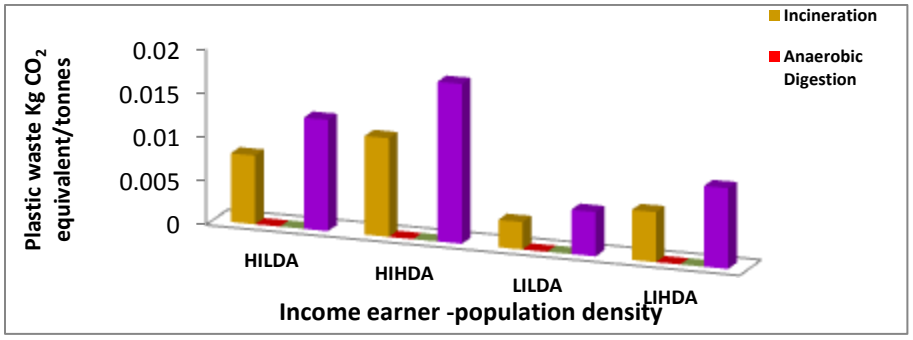


Figure 10: GHG emission from plastic waste management technologies

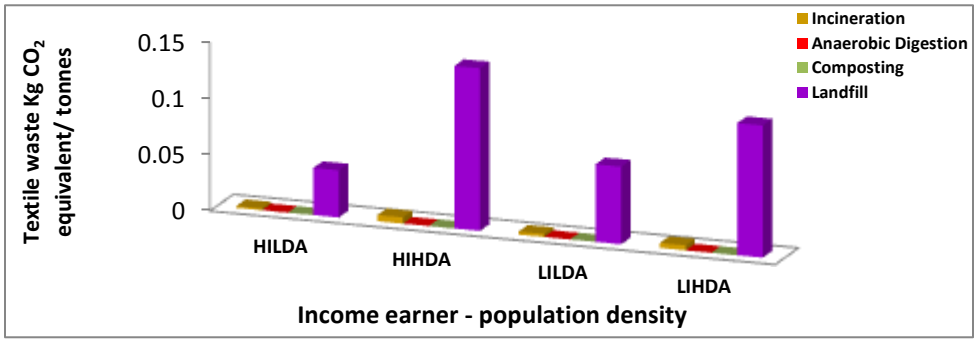


Figure 11: GHG emission from textile waste management technologies

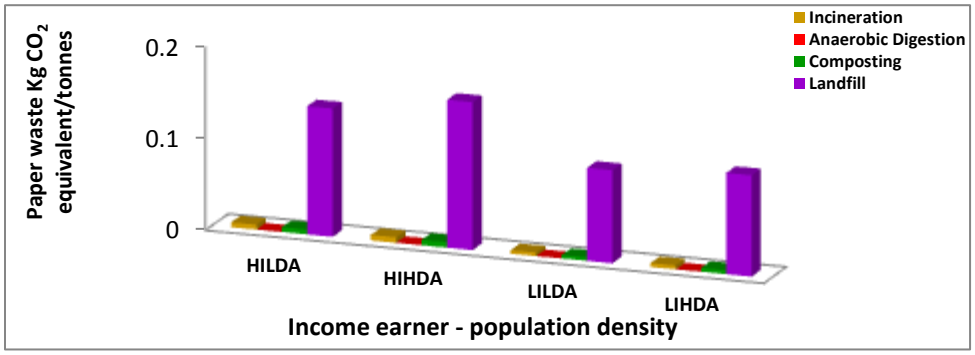


Figure 12: GHG emission from paper waste management technologies

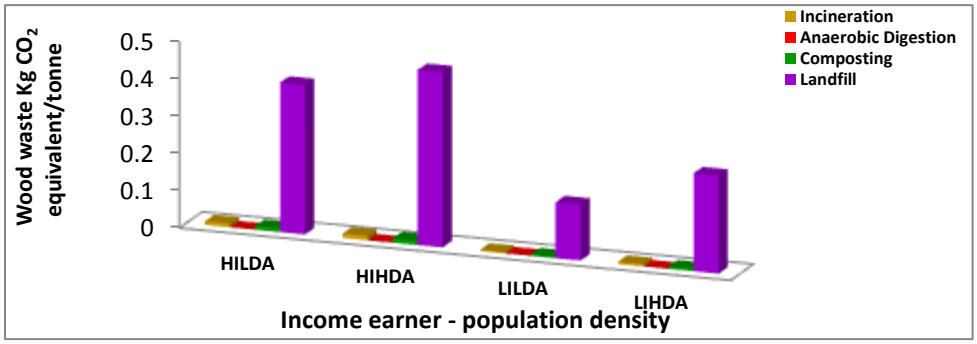


Figure 13: GHG emission from wood waste management technologies

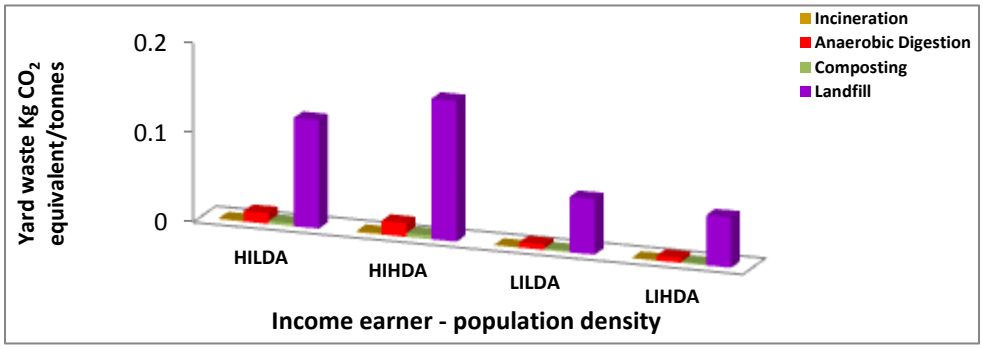


Figure 14: GHG emission from yard waste management technologies

Relationship between potential mean emissions generation from solid waste management technologies was strong for landfilling, incineration and anaerobic digestion. The correlation coefficient (R^2) values for most categories were greater than 0.70 at 99 % confidence interval (Tables 2-4). This shows that strong link exist between householders' income-population and mean emission from these management technologies. On the contrary, the correlation coefficients between householders' income-population and mean emission from composting were less than 0.40 (p=0.01). Therefore, poor nexus exists between the two factors. With respect to the strong relationships, landfilling produces the highest mean emission while incineration produces the least for all categories. A switch from landfilling of the biodegradables will reduce mean emission generated by 90 – 95%.

Table 1: Householder class and emission generation correlation from composting technology

	WASTE MEAN	EMISSION MEAN	EMISSION SD*	R	R^2	P
HILDA	605.8	0.0064	0.0027	0.08	0.01	0.01
HIHDA	695.7	0.0073	0.0029	0.08	0.01	0.01
LILDA	342.8	0.0034	0.0011	0.36	0.13	0.01
LIHDA	485.1	0.0048	0.0025	0.62	0.38	0.01

Table 2: Householder class and emission generation correlation from landfilling technology

	WASTE MEAN	EMISSION MEAN	EMISSION SD*	R	R^2	P
HILDA	414.1	0.1715	0.2325	0.91	0.83	0.01
HIHDA	511.3	0.2061	0.2461	0.85	0.72	0.01
LILDA	222.6	0.1013	0.1364	0.96	0.91	0.01
LIHDA	362.5	0.1542	0.2306	0.96	0.91	0.01

Table 3: Householder class and emission generation correlation from incineration technology

	WASTE MEAN	EMISSION MEAN	EMISSION SD*	R	R^2	P
HILDA	414.1	0.0076	0.0072	0.84	0.71	0.01
HIHDA	511.3	0.0093	0.0072	0.74	0.55	0.01
LILDA	222.6	0.0041	0.0049	0.91	0.82	0.01
LIHDA	362.5	0.0074	0.0074	0.93	0.87	0.01

Table 4: Householder class and emission generation correlation from anaerobic digestion technology

	WASTE MEAN	EMISSION MEAN	EMISSION SD*	R	R^2	P
HILDA	849.6	0.0178	0.0119	1	1	0.01
HIHDA	969.5	0.0204	0.0168	1	1	0.01
LILDA	505.8	0.0106	0.0064	1	1	0.01
LIHDA	716.1	0.0150	0.0135	1	1	0.01

*SD - Standard deviation

Conclusion

Landfilling is the major waste management technology in Nigeria and it contributes to the nation's environmental degradation. Green house gases from the waste management practice causes global warming which leads to climatic change. Consequently, waste management bodies in Nigeria should enlighten the populace on the drawbacks in landfilling household waste. Policy should also be implemented to check this practice. Alternate environment friendly measures such as waste reuse, recovery, recycling and autoclaving should be encouraged.

Recommendation

Similar study should be carried out in other major geo-political zones of Nigeria and the result compared. Government should carry out enlightenment programme on the damaging effect of some of the waste management technologies and sustainable waste management technologies should be adopted.

Reference

Abul S. (2010) Environmental and health impact of solid waste disposal at Mangwaneni dumpsite in Manzini: Swaziland. Journal of Sustainable Development in Africa, Vol. 12 (7): 64-78

Adejobi O. S. and R. O. Olorunnimbe (2012) Challenges of waste management and climate change in Nigeria: Lagos state metropolis experience. African Journal of Scientific Research Vol. 7(1): 345-362

Amori A. A., Fatile B. O., Ihuoma, S. O. and H.O. Omoregbee (2013) Waste generation and management practices in residential areas of Nigerian tertiary institutions. Journal of Educational and Social Research, Vol. 3 (4): 45-51

Asante O. B., Yanful E. and E. B. Yaokumah (2014) Healthcare waste management; its impact: a case study of the greater Accra region, Ghana. International Journal of Scientific & Technology Research, Vol. 3(3): 106-112

Assamoi B., and Y. Lawryshyn (2012) The environmental comparison of landfilling versus incineration of MSW accounting for waste diversion. Waste Management, Vol. 32, 1019–1030

Bogner J., Ahmed, M.A., Diaz, C., Faaij, A., Gao, Q., Hashimoto, S., Mareckova, K., Pipatti, R., and T. Zhang (2007) Waste Management, In Climate Change: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom and New York, USA.

Cramer J. C. (2013) Population growth and local air pollution: Methods, models, and results. population council. http://www.jstor.org/stable/3115267

EEA (2011) Waste opportunities: Past and future climate benefits from better municipal waste management in Europe, No 3. Copenhagen, Denmark.

Freed J. R., Choate A. and E. Lee (2000) Greenhouse gas emission factors for municipal waste combustion and other practices. Eastern Research group, 1-11

Hoornweg D., Thomas, L., and L. Otten (1999) Composting and its applicability in developing countries. Urban waste management working paper series 8, Washington DC, World Bank

Jha A. K., Sharma, C., Singh, N., Ramesh, R., Purvaja, R. and P. K. Gupta (2007) Greenhouse gas emissions from municipal solid waste management in Indian mega-cities: A case study of Chennai landfill sites. Chemosphere, 71: 750-758

Le-Yin Zhang (2009) Does climate change make industrialization an obsolete strategy? Fifth urban research symposium. 1-17

Karija M. K., Shihua, Q. I. and Y. S. Lukaw (2013) The impact of poor municipal solid waste Management practices and sanitation status on water quality and public health in cities of the least developed countries: the case of Juba, South Sudan. International Journal of Applied Science and Technology, Vol. 3 (4): 87-99

Ogwueleka T. C. (2009) Municipal solid waste characteristics and management in Nigeria. Iran. J. Environ. Hth. Sci. Eng., Vol. 6 (3): 173-180

Oyedepo S. O. and A. A. Saadu (2008) Changing noise climate of Ilorin metropolis. Environmental Engineering Science, Vol. 25 (6): 797-807

Sangodoyin A. Y. and A. A. Ajayi-Banji (2013) Utilization of abattoir solid wastes as biosorbents for surface water treatment. International Journal of Engineering Inventions, Vol. 2(11): 42-47

USEPA (2002) Solid waste management: A local challenge with global impact. Solid Waste and Emergency Response, www. epa.gov/ global warming

USEPA (2006) Solid waste management and greenhouse gases: a life-cycle assessment of emissions and sinks. Third edition, Washington, D.C.

Udoakah Y. O. N. and U. S. Akpan (2013) A sustainable approach to municipal solid waste management in southern Nigeria. Global Humanitarian Technology Conference, IEEE Institute of Electrical Electronics, 321 - 325

WTO-UNEP (2006) Trade and climate change. A report by the United Nations Environment Programme and the World Trade Organization, Geneva