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Comparative Assessment of the Environmental Implication of Management Options for Municipal Solid Waste in Nigeria

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Abstract

The Municipal Solid Waste (MSW) sector contributes to global Greenhouse Gas (GHG) emission. GHG emissions from current MSW treatment options and alternative options were examined for Nigeria using the Solid Waste Management Greenhouse Gas (SWM GHG) model. Alternative scenarios considered a combination of options including collection of recyclable materials, dumping in unmanaged disposal sites, landfill without and without biogas collection, and incineration for electricity production. The results showed that the contribution of the current management strategies to global warming is 10.7 Mt CO_2 eq/yr. MSW management options featuring primary material recycling and energy recovery had reductions in GHG emissions of between 22-67% compared to the current scenario - highlighting the important contribution of recycling and energy production from MSW treatment options in reducing GHG contribution of the MSW sector.

Keywords: Municipal solid waste; Recycling; Energy recovery; Greenhouse gas emissions; Nigeria

Introduction

Nigeria with an estimated population of over 162 million [1] currently generates huge amounts of waste. 45% of the country's population reside in urban areas and generate about 41 thousand tons of Municipal Solid Waste (MSW) daily. This is approximately 0.56 kg per capita per day; and is expected to reach 0.8 kg per capita per day by 2015 driven largely by a projected increase in population [2]. The emissions from the waste sector contributes about one-fifth of global anthropogenic methane emissions, which is a key contributor to global warming [3].

An inventory of GHG emissions in Nigeria based on a gross population of 96.7 million carried out in 1994 estimated the total methane emissions as 5.9 Tg CH4. The MSW sector accounted for approximately 4% of the total amount. Although this contribution can be considered low relative to methane emissions from other sectors, given her projected population increase as well as the established correlation between population increase and MSW generation, methane emissions from the MSW sector should be given serious consideration [4]. Therefore optimal strategies for managing MSW and its potential GHG emission are needed. Studies focusing on MSW management (MSWM) in Nigeria have reported that a high percentage of MSW is: uncollected, collected and openly dumped, collected and conveyed to open dump sites, or collected and transported to landfill sites without methane capture where some informal recovery for recycling occurs and final treatment is by open incineration. However, the amount of materials recovered for recycling from the waste streams are insignificant [2,5]. Clearly, the recoverable material, energy and economic potential inherent in the MSW stream are not optimized, and there is increasing awareness that the current MSW treatment and disposal methods in Nigeria are inadequate [6].

The informal waste management system in Nigeria was examined and recommendations made for the integration of 'scavengers' into a formal and legal MSWM plan [6,7,8]. The importance of promoting source reduction to minimize the problem of MSW generation and disposal, and also the alternative energy generation potential from MSW conversion has been evaluated [5]. A case for the development of a MSWM plan and framework in Abuja, Nigeria was made by [9], and several studies [10-19] concluded that the problems of MSWM in Nigeria are: (1) insufficient budgetary allocation (2) ineffective collection of service fee (3) no active planning on establishing common disposal facility among adjacent communities, no definite regulation and guideline of MSWM hierarchy starting from source separation, recycling, collection, transportation, disposal and monitoring (4) lack of skilled personnel in operating an efficient waste collection and disposal practice (5) absence of formal waste recycling programs in most communities (6) lack of public co-operation and participation and, (7) lack of legal enforcement.

Numerous studies have called for the development, implementation, and enforcement of MSW policies but none has conducted a comparative assessment of the environmental implication of current and potential municipal solid waste management systems in Nigeria (Table 1). This study attempts to bridge this gap by carrying out a transparent comparative evaluation of current and potential MSWM systems incorporating commonly available MSW treatment technologies with the aid of the Solid Waste Management Greenhouse gas (SWM - GHG) calculator [20], a publicly available and well documented tool. In this study the SWM – GHG calculator is hereafter referred to as the 'model'.

Methodology

The model applies the Life Cycle Assessment (LCA) methodology to compare the environmental benefits of alternative SWM technologies by estimating the GHG emission avoided through reducing, reusing and recycling waste, and the application of waste to energy strategies which are supported by existing European Union waste regulations. This regulation focuses on diverting the amount of biodegradable municipal waste going to landfill through the deployment of a number

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of strategies which include waste to energy measures. Future emissions resulting from a given treated quantity of waste is also accounted for in the results presented by the model. The emissions generated by waste collection are assumed to be within the same range for each scenario in the model, and are therefore neglected. While it offers users the option of using default values or user specific values, the model has two limitations: (1) the GHG calculations for recycling chains are based on emission factors reflecting specific treatment options in Germany and Europe (2) the model is unable to quantify certified emission reductions or emission reduction units. Nevertheless, the model's ability to provide a fairly accurate approximation of the GHG impacts of alternative MSWM strategies as an incentive for decision making is not compromised.

Data inputs and sources

The composition of MSW can significantly influence the results of any MSW assessment. As such, recent estimates of the composition of MSW available from The World Bank (2012) rather than data available from the model which was published over six years ago were employed. The estimates obtained from The World Bank (2012) are shown in (Figure 1). Using data on MSW generation per day from (World Bank, 2012), the total annual waste amount was derived. Organic waste is assumed to be a composite of all food, garden and park wastes. The model requires that the water content of waste is specified either as low or high depending on the proportion of food it contains, and if it is openly stored, (with precipitation adding to its water content). Over 60% of MSW in Nigeria is organic [14]. Therefore, for the purpose of this analysis, high water content was applied in the analysis. Greenhouse gas (GHG) emission factor (EF) for direct electricity production, and data on the prevailing population for Nigeria specified in the model were applied in the study. Table 2 shows the sources and values of parameters utilized in this study. The model is capable of assessing the economic feasibility of different MSW strategies, but no economic analysis of the various MSWM strategies was carried out in this study due to lack of cost data on MSW in Nigeria.

MSW treatment practices in Nigeria, and scenarios description

A combination of MSW technologies and strategies identified to be applicable within the Nigerian context were utilized in this study. The current scenario (S0) where more than 80% of the MSW generated annually is indiscriminately dumped and insufficient MSW treatment facilities exists, and two other scenarios where advanced MSWM strategies are implemented (Table 2). The S0 scenario was compared with the competing scenarios. The collection and transfer of MSW to treatment facilities could have an impact on the GHG emissions results due to the potential difference in transportation distances [21]. Information on transport distances to treatment facilities at the macro level are not available for Nigeria, and are extremely difficult to estimate. Therefore, they were assumed to be equivalent for all scenarios evaluated, and are not extensively dwelt upon. Neither energy recovery from landfill captured gas nor incineration to produce heat and electricity is commonly practiced in Nigeria, therefore, they were not considered in the current scenario (S0). Although some recyclable materials are recovered either en-route to or at dumpsites, no information exists on the proportion of recovered materials in relation to the total annual amount of MSW generated in the country. This is largely due to the absence of formal resource recovery and recycling programs in the country [5]. To facilitate the analysis of the potential effect of recycling on the amount of GHG emitted, the recycling rates detailed in table 2 were applied for the scenarios examined. For all scenarios, it was assumed that no textile was recovered or recycled from MSW as this is not culturally acceptable in Nigeria. Scenario 1 presumes that MSW disposal patterns are changed and that increased material recycling is practiced in contrast to the current situation (S0). A significant fraction of MSW is burnt in open dumps, but because of its high water content, combustion is incomplete and atmospheric pollution often occurs [5]. S1 is assumed to reflect the adoption of MSW treatment technologies such as composting, and landfill with biogas capture, capable of dealing with these organic fractions, and also the recovery and capture of biogas which can be used in a variety of energy applications. Scenario (S2) is designed as an improvement over S1 and S0, and it includes the MSW disposal methods detailed in Table 2.

Results

Table 3 presents the breakdown of the calculated potential GHG emissions for the MSW management options considered in this study. The total net GHG emission for each scenario refers to direct emissions

Study	Location	MSW generation estimates provided?	MSW composition available?	MSW disposal strategies discussed?	Policy options examined?	Estimates of GHG emission from MSWM strategies provided?
Oke [26]	Kano (8 localities)	✓		✓	✓	×
Cheesman et al. [9]	Abuja	✓	✓	✓	✓	×
Sha Ato et al. [10]	Markurdi	✓	✓	✓	✓	×
Cooker et al. [13]	Ibadan (11 localities)	✓	✓	✓	✓	×
Ayininuola et al. [16]	Ibadan North	✓	✓	✓	✓	×
Kofoworola [5]	Lagos	✓	✓	✓	✓	×
Nzeadibe [6]	Enugu	✓	✓	✓	✓	×
Bammeke et al. [11]	Ibadan	✓	✓	✓	✓	×
Ibiebele [17]	Port Harcourt	✓	✓	✓	✓	×
Sridher et al. [11]	Ibadan	✓	✓	✓	✓	×
Ogwueleka [14]	9 States[a]		✓	✓	✓	×
Nabegu [18]	Kano	✓	✓	✓	✓	×
Nabegu [19]	15 States[b]	✓	✓	✓	✓	×

Table 1: Overview of some existing MSW literature.

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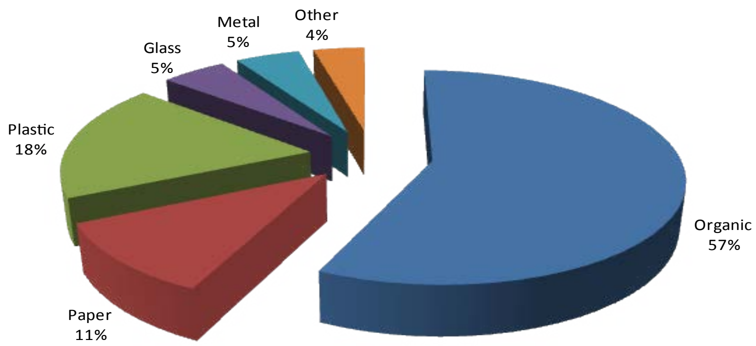

Figure 1: Composition of MSW.

Parameter	Unit	Source
Population	144 Million	Giegrich et al. [20]
MSW generated per year	14,950,035 tons/a	Calculated using population data from Giegrich et al. [20]
Water content of MSW	>60% (high)	Ogwueleka [14]
Electricity GHG EF*	358 g CO_2/kWh	Giegrich et al. [20]
Scenarios	*MSW treatment system*	*Recycling rate (when applicable)*
Current (S0)	30% scattered and not burnt, 10% scattered and burnt, 50% dumped in unmanaged disposal sites, 10% deposited in landfills without gas capture facilities. Energy recovery from landfill biogas, and incineration not considered	10% paper (including cardboard), 10% plastics, 5% glass, 10% metals (ferrous and non-ferrous)
Enhanced Scenario (S1)	20% scattered waste not burned, 4% open burning of scattered waste, 20% dumped in unmanaged disposal sites, 30% deposited in landfill without gas collection, 20% sent to sanitary landfill with biogas capture. 6% of MSW is incinerated with a plant efficiency of 10%. Sanitary landfill biogas collection efficiency of 30%, and all biogas collected used to generate electricity.	30% paper (including cardboard), 15% plastics, 10% glass, 15% metals (ferrous and non-ferrous)
Optimized Scenario (S2)	6% scattered waste not burned, 4% open burning of scattered waste, 20% dumped in unmanaged disposal sites, 30% deposited in landfill without gas collection, 30% sent to sanitary landfill with gas capture. 20% of MSW is incinerated with a plant efficiency of 10%. Biogas is captured from landfill with a collection efficiency of 50% and all of it used to generate electricity.	60% paper (including cardboard), 40% plastics, 30% glass, 30% metals (ferrous and non-ferrous). 50% of organic MSW is sent to recycling where 50% is composted and 50% digested

Notes: EF*=Emission factor, organic waste is assumed to be a composite of all food, garden and park wastes, paper encompasses all types of paper waste (including cardboard), *Metals encompasses ferrous and non-ferrous metals, CL=Controlled landfill, SL=Sanitary landfill

Table 2: Model parameters and assumptions.

	Base case scenario (S0)			Scenario 1 (S1)			Scenario 2 (S2)		
	Generated	**Avoided**	**Net**	**Generated**	**Avoided**	**Net**	**Generated**	**Avoided**	**Net**
Recycled waste									
Organic waste	0	0	0	148.3	-161.9	-13.6	306.8	-339.7	-32.9
Paper	29.6	-164.5	-134.8	88.8	-493.4	-404.5	177.6	-986.7	-809.1
Plastics	275.2	-386.6	-111.4	412.7	-579.8	-167.1	1100.6	-1 546.3	-445.6
Glass	0.8	-18.7	-17.9	1.5	-37.4	-35.9	4.5	-112.1	-107.6
Metals	1.6	-153	-151.3	2.4	-229.5	-227	4.9	-459	-454.1
Textiles	0	0	0	0	0	0	0	0	0
	307.1	-722.7	-415.6	653.7	-1 502.0	-848.2	1 594.4	-3 443.7	-1 849.4
Disposed waste									
Scattered waste not burned	0	0	0	0	0	0	0	0	0
Open burning of scattered waste	674.2	0	674.2	254.7	0	254.7	180.4	0	180.4
Wild dump	8 723	0	8 723.2	2 766.7	0	2 766.7	1 682.8	0	1 682.8
CL (No gas collection)	1744. 6	0	1744.6	4 150.0	0	4 150.0	1 682.8	0	1 682.8
SL (Gas collection)	0	0	0	1 752.6	-49.9	1 702.7	1 145.6	-75.9	1 069.7
Incineration	0	0	0	382	-60.8	321.2	901.9	-139.1	762.8
	11 142 .0	0	11 142.0	9 306.0	-110.7	9 195.3	5 593.4	-215	5 378.4
Total	11 449.2	-722.7	10 726.5	9 959.8	-1 612.7	8 347.1	7 187.8	-3 658.7	3 529.1

Table 3: GHG emissions from recycling and disposal in t CO2-eq/yr (× 10^3).

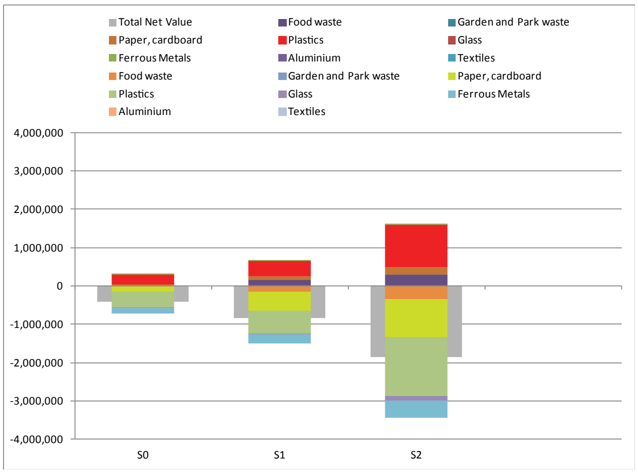

Figure 2: GHG emissions from MSWM options (tCO_2-eq/yr).

minus avoided emissions resulting from energy outputs. Energy production from waste in the form of heat and/or electricity displaces fossil fuel and hence reduces the emissions of GHGs. Electricity produced is assumed to replace grid derived electricity while biogas substitutes natural gas and can also be used to generate electricity. The net GHG emission resulting from the current scenario (S0) is estimated at about 10.7 Mt $CO_{2\ eq}$/yr, and is strongly influenced by the emissions resulting from the indiscriminate dumping of waste. This alone contributes about 81% of of the total net GHG emissions. The choice of increasing the recycling rate of materials such as paper, glass and plastics in S1 in combination with deployment of MSW disposal strategies such as composting and capture of biogas, results in a net GHG emission of 8.3 Mt CO_2 eq/yr. This represents a significant environmental benefit as it reduces net GHG emissions by 22% in comparison to the current situation. Of the MSWM strategies examined, S2 offers the best potential for reducing net GHG emissions. Its implementation avoids about 67% and 60% GHG emissions reductions in contrast to scenarios: S0 and S1 respectively. These large reductions in GHG emissions are correlated with the implementation of optimized source segregation and recycling of key materials such as metals, plastics and paper in conjunction with the deployment of sanitary landfills with gas capture, and incinerators where electricity can be produced from captured gas and incineration of MSW (Figure 2).

Discussion

Nigeria is currently ranked as a low income economy with a projected long term economic growth potential of 3,964 US$bn (GDP) by 2050. This projected growth is expected to propel the country by 2050 into the ranks of the middle income economies [22]. If the current waste composition and waste management practices continue, this study estimates that by 2050, the net GHG emission from the MSW sector would amount to 86.4 million tons.

The benefits accruable from recycling include reduction: in demand for virgin materials, lower transport and production costs, lower landfill space requirement, and employment creation [23,24]. Every 150,000 tons of waste recycled creates nine jobs. For the same amount of waste, incinerating creates two jobs and land filling only one [24]. By applying this assumption to the MSWM options evaluated in this study using the projected population of Nigeria as a middle income economy by 2050 results in the following number of jobs created simply from recycling MSW: 265 (S0), 1,354 (S1), and about 3,300 jobs (S2). In a country with a current unemployment rate of 24% [25,26], these numbers of jobs are not insignificant.

Conclusion and Recommendations

An evaluation of the potential GHG emission from different MSW treatment options in Nigeria was conducted with the aid of the SWM GHG model. The results obtained highlight the positive environmental benefit of separating and recycling primary materials such as paper, glass and plastics. The implementation of enhanced recovery and recycling in combination with MSW disposal strategies such as sanitary landfill with gas capture, and incineration can also significantly reduce GHG emissions resulting from MSW management. The social and inherent economic benefit in the form of employment creation resulting from the introduction of recycling is also clearly highlighted. A key limitation to this study was the lack of detailed and documented information relating to the proportion and components of MSW recovered and recycled, as well as volumes of MSW processed by different MSW treatment technologies in Nigeria.

This study relied on a number of assumptions such as the MSW characteristics, material recovery and recycling proportions, and employed technologies. Also, the GHG emissions resulting from different MSWM strategies calculated in this study were based on subjective modeling choices. These assumptions and limitations represent sources of uncertainty. Therefore care should be taken in interpreting the presented results, as separate assessments would be required should the underlying assumptions change. Nevertheless, the approach and methodological framework applied are consistent and useful not only for similar analysis, but can also assist decision makers in selecting management options for mitigation GHG emissions from the MSW sector. Therefore, this study could potentially stimulate the debate on the need for a detailed macro level analysis of waste management strategies for energy production and its impact on GHG emissions in Nigeria. The foundation for this will be a comprehensive database detailing the components and proportion of MSW recovered and recycled, as well as volumes of MSW which are processed by different MSW treatment technologies in Nigeria. The availability of this information within an integrated MSWM plan which promotes source separation, and enhanced material recovery and recycling would provide a solid basis for future evaluation of optimal MSW disposal strategies for Nigeria.

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