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The Role of Solid Waste Composting in Mitigation of Greenhouse Gas Emissions in States of North Eastern Nigeria

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Abstract: The solid waste management (SWM) sector is responsible for about 5% of all greenhouse gas (GHG) emissions globally. In countries like Nigeria with inefficient SWM systems, this figure is much higher, this reinforces the need to find suitable eco-friendlier SWM practices so as to reduce the carbon footprint from this sector. This study assessed the role composting can play in reducing GHG emissions from the SWM sector in the north-eastern states of Nigeria. Data regarding SWM practices for each of the six states in the region was obtained from literature, Upstream-operating-downstream carbon footprint assessment framework was used to ascertain the potential reduction in GHG emissions that can be obtained by composting. It was found that disposing of waste in landfills and dumpsites is the prevalent SWM technique in the region and that it is responsible for emission of 232,505.18tCO_2eq annually. However, if composting is adopted as a preferred SWM technique, a 52% net reduction of GHGs emission can be attained. The study concluded by suggesting that other SWM techniques should be studied so as to see if any of them is a better alternative to composting.
Keywords: Carbon Footprint, Composting, Greenhouse Gases, Municipal Solid Waste, Solid Waste Management.

INTRODUCTION

Population growth, urbanisation, economic and technological advancement have brought about an increase in the quantity of municipal solid waste (MSW) generated in cities [1]. Large quantities of MSW being generated in cities have created enormous strains on municipal authorities so much as that in some places about 50% of the total municipality budget is spent on SWM [2]. The problems associated with SWM are more pronounced in developing countries where inadequate funding hampers the proper evacuation and disposing off of MSW, inefficient SWM in developing countries has its hallmark which can be easily noted in most cities - filled up waste collection points, MSW littering streets and drainages, unmanaged dumpsites and landfill sites [3]. Other effects of poor SWM on the environment include the pollution of groundwater from leachates at dumpsites, air pollution from decomposition or burning of the solid waste and emission of greenhouse gases (GHGs) into the atmosphere [4–6].

According to the IPCC's 2014 report, global GHG emissions from the waste sector have grown steadily and are expected to increase in the forthcoming decades especially in developing countries such as Nigeria because of the unprecedented rise in their population and their growing economy [7]. It is estimated that globally, 20% of all methane emissions and 5% of all GHGs emissions are from solid wastes and SWM activities [8]. The need for the waste management industry to find a more sustainable option of operating has never been more urgent, this is in line with the 2015 Paris Agreement which seeks to tame global average temperature rise occasioned by the anthropogenic emission of GHGs into the atmosphere to well below 2°C above pre-industrial levels so as to save the environment from irreparable damages caused by global warming.

Composting is a controlled biological process that uses natural aerobic processes to increase the rate of biological decomposition of organic materials [1]. Simply put, composting involves putting organic materials under suitable atmospheric conditions so that these materials decompose naturally into humus. Solid waste composting is one of the SWM techniques that is fast gaining traction [9], it's advantage over traditional SWM practices of disposing of waste in landfills and dumpsites include reduction in carbon footprint, reduction in pollution of air and contamination of groundwater [10], [11].

The room for reduction of GHGs emission from the waste sector via composting is greater in developing countries because organics constitute a large portion of their waste stream [12,13]. In addition to the direct reduction in carbon footprint when compared to traditional SWM processes, substitution of

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chemical fertilizers with compost decreases the net carbon footprint of composting as a SWM technique by enhancing the soil capability to work as a carbon sink, avoiding energy consumption during the production of chemical fertilisers and the emission of nitrous oxides associated with the application of chemical fertilisers. Other benefits of composting include savings for farmers since compost are cheaper than chemical fertilizers [12], conservation of soil properties [14] and reduction in groundwater contamination from use of inorganic fertilizers [15,16].

Crop cultivation is the dominant profession of people in the northeastern states of Nigeria [17,18], this coupled with the waste stream from the region containing relatively high amounts of organics makes a perfect combination for researching the role composting can play in the reduction of emission from the solid waste sector. Results obtained from this research can serve as a compass for policy formulation and implementation geared at reducing the GHGs emission from the solid waste sector in this region and the nation at large, hence the need for this research.

MATERIALS AND METHODS

Study Area and Data Sources

This study considered the six states that form the northeast geopolitical region of Nigeria, these states are Adamawa, Bauchi, Borno, Gombe, Taraba and Yobe. The region lies within longitude 9.9992 and 13.1520 and latitude 11.8846 and 7.9867 [19–21]. As at 2016, the region had an estimated population of 26,263,865 [22]. Extensive review of literature was undertaken to determine the properties of waste generated and the SWM technique being practiced in each state. It was gathered that SWM in the region involves disposal by residents at designated collection points, evacuation by municipal authorities to designated dumpsites and unsanitary landfills. At the dumpsites, occasional open burning is practiced whenever the site is becoming filled up [23]. It should be noted that the data collected were for the MSW generated and disposed of at the state capitals alone. To achieve harmony, MSW data for the same year – year 2017 for each of the six states was used for this study.

The quantity and composition of MSW disposed of at dumpsites and landfills in each of the states being as obtained from literature are presented in Table 1 [3,24–28] and Table 2 [3,29–31].

Table 1. Annual Quantities of MSW Disposed of in The Six States

State	**MSW at Dumpsites (Tonnes)**
Adamawa	49,447
Bauchi	71,700
Borno	61,317
Gombe	135,871
Taraba	19,750
Yobe	12,736
Total	**350,821**

Table 2. Average Weight Composition of MSW in The Six States

Category	**Adamawa**	**Bauchi**	**Borno**	**Gombe**	**Taraba**	**Yobe**
Food	6.0	5.4	6.2	9.0	5.0	6.0
Garden Waste	6.0	18.8	18.8	13.9	29.0	27.7
Plastics	24.0	25.0	32.6	11.4	15.0	38.2
Paper	18.0	15.0	6.7	8.2	0.0	3.6
Textiles	3.0	1.0	0.0	9.8	3.0	0.0
Leather/Rubber	32.0	0.0	0.0	8.3	35.0	16.6
Glass	3.0	4.9	5.6	8.9	1.0	4.2
Metal	3.0	7.8	2.9	8.3	10.0	3.6
Inert Materials	5.0	22.3	27.3	22.3	2.0	0.0

Data Analysis

A framework for accounting and reporting GHG emissions associated with SWM called the upstream-operating-downstream (UOD) was adopted for this study [32]. UOD captures the upstream (indirect emissions) emanating from fuel, materials extractions and transportation; direction emission from SWM operations and downstream emissions (indirect emissions) from energy substitution, material substitution, carbon binding, fly ash transportation and decommissioning activities. However, for this study GHG emission from upstream activities were not considered since no record for them could be obtained, precedence for this was set by two other researches [33,34].

Two scenarios were simulated for the study in order to compare and ascertain the role composting can play in the reduction of GHGs emission from SWM. These scenarios are:

1. Business as usual (BAU) – disposing of unsegregated MSW in dumpsites.
2. Composting of source segregated MSW biowaste to produce organic fertiliser which is used as substitute for chemical fertilizer and then disposing of the remaining mixed MSW into existing dumpsites and landfills.

The conceptual framework for the UOD model used for this research is shown in Figure 1.

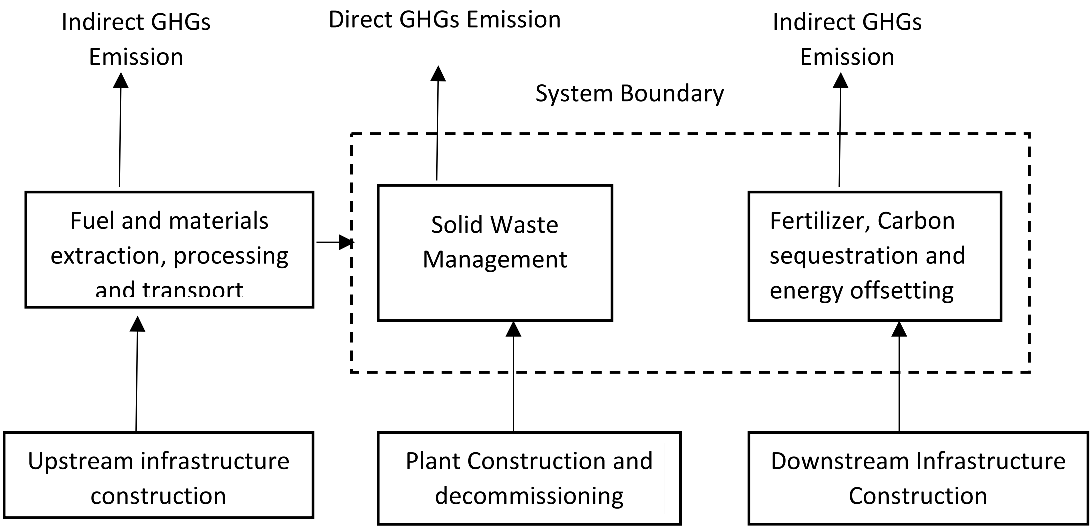

Figure 1. Conceptual Framework for UOD Model

For the BAU scenario where unsorted MSW is disposed of at dumpsites and landfills, the direct emission from such process is estimated using the first order decay kinetics model for estimation of methane generation as postulated by IPCC [35].

$$CH_4\ Emissions = MSW_X \times L_o \times (1 - f_{rec}) \times (1 - OX) \quad \text{(Equation 1)}$$

Where:

MSW_X = Mass of solid waste sent to landfill in inventory year (metric tonnes)

L_o = Methane generation potential (m^3/tonne)

f_{rec} = Fraction of methane recovered at the landfill (flared or energy recovery)

OX = Oxidation factor (0.1 for managed sites, 0 for unmanaged sites)

$$L_o = MCF \times DOC \times DOC_F \times F \times \frac{16}{12} \quad \text{(Equation 2)}$$

Where,

MCF = 0.6 for dumpsites and unmanaged landfills

DOC = Fraction of Degradable organic carbon (tonnes C/tonnes waste)

DOC_F = Fraction of DOC that ultimately degrades (0.6).

F = Fraction of methane in landfill gas (0.5)

$\frac{6}{12}$ = Stoichiometric ratio between methane and carbon

$$DOC = (0.15 \times A) + (0.2 \times B) + (0.4 \times C) + (0.43 \times D) + (0.24 \times E) \quad \text{(Equation 3)}$$

A = Fraction of solid waste that is food

B = Fraction of solid waste that is garden waste and other plant debris

C = Fraction of solid waste that is paper

D = Fraction of solid waste that is wood

E = Fraction of solid waste that is textiles

Global warming Factor of CH_4 = 28 [36]

For the second scenario, it is assumed that open windrow composting is used and that the organic waste is mixed manually. It is also assumed that only food waste and garden waste were composted [37]. Fugitive GHG emission from windrow composting obtained from literature and used in the analysis is 0.177tCO_2eq/tonne of organic waste [37], downstream emission (sequestration) from the use of humus in place of chemical fertilizers was obtained from literature: -0.059tCO_2eq/tonne of input [34]. Also, it is assumed that by the time the organic waste has fully transitioned into humus, there is a 30% reduction in its mass [38].

RESULTS AND DISCUSSIONS

Scenario 1

It was found that in the inventory year, a total of 350,821 tonnes of MSW was collected and disposed of in dumpsites and unsanitary landfills in the region. The collective emission from this SWM practice was found to be 232,505.18tCO_2eq. Gombe was found to be the state with the highest emission from the current SWM practice of open dumping/landfilling. Bauchi, Adamawa, Borno, Yobe and Taraba trailed it in descending order. Looking at the carbon footprints from SWM in these states from another perspective, a different picture emerges. If the emission is considered on basis of each tonne of MSW disposed of, Gombe's MSW appears not to be the one with the highest carbon footprint in the region, Yobe's is. However, since absolute emission is considered as a better parameter for judging emissions rather than carbon intensity (emission/unit mass) [39], it therefore means Gombe is the heaviest polluter in the region. Table 3 juxtaposes the net GHG emission from the current SWM practice in each of the states in the region with the corresponding emission per tonne of MSW disposed.

Table 3. Emissions Quantities and Emissions per Tonne of MSW Disposed for Scenario 1

State	**Emission (tCO2eq)**	**Emission/Tonne of MSW (tCO2eq/t)**
Adamawa	31,965.64	0.6465
Bauchi	52,085.17	0.7264
Borno	30,368.10	0.4953
Gombe	89,096.82	0.6557
Taraba	9,648.74	0.4885
Yobe	19,340.71	1.5186

Scenario 2

For scenario 2 where putrescible from source segregated MSW is composted, the compost used in place of chemical fertilizer and the remaining part of the MSW is disposed of in existing dumpsites and landfills, it was found that for the entire region, fugitive emission from the composting process yields 14,290.23tCO_2eq, while emission from landfilling of the remaining unsorted waste was 103,669.55tCO_2eq. For the downstream emission, it was estimated that when the humus from the composting process is used as fertilizer in place of chemical fertilizers, 3,334.39tCO_2eq will be sequestered in the entire region.

This means that for the six states in the region, adoption of composting as a replacement for the existing SWM process will lead to a net GHG emission of 114,625.40tCO_2eq. This is a reduction of 52% (120,424.78tCO_2eq) from the emission obtainable from the current SWM process. Table 4 shows the carbon footprint for each of the processes in Scenario 2 for all the six states in the region, while Table 5 shows the potential reduction in GHG emissions that can be attained by replacing open dumping with composting in the region.

Table 4. GHG Emissions from Scenario 2

State	Composting (tCO_2eq)	Landfilling (tCO_2eq)	Downstream Emission (tCO_2eq)	Net Emission (tCO_2eq)
Adamawa	1,050.25	23,158.85	-245.06	3,964.05
Bauchi	3,071.20	22,789.89	-716.61	25,144.47
Borno	2,713.28	8,282.21	-633.10	10,362.39
Gombe	5,507.26	39,647.25	-1285.03	43,869.48
Taraba	1,188.56	630.69	-277.33	1,541.91
Yobe	759.69	9,160.67	-177.26	9,743.09
Total	**14,290.23**	**103,669.55**	**-3,334.39**	**114,625.40**

Table 5. Emission Reduction Potentials

State	Potential Reduction (tCO_2eq)	Potential Reduction (%)
Adamawa	8,002	25%
Bauchi	26,941	52%
Borno	20,006	66%
Gombe	45,227	51%
Taraba	8,107	84%
Yobe	9,598	50%
Total	**117,879.78**	**52%**

For this scenario, Gombe again has the highest carbon footprint, with Bauchi, Adamawa, Borno, Yobe and Taraba trailing it in descending order as it was with the BAU scenario. Yet again, looking at the carbon footprint for the individual states from the perspective of emission per tonnage, a different picture surfaces. As it can be seen in Table 6, Yobe has the highest carbon footprint per tonne of MSW disposed of. Adamawa, Bauchi, Gombe, Borno and Taraba states follow in descending order. Gombe has persistently topped the list as the state with the highest SWM carbon footprint despite having a population about half of Bauchi and 25% lower than Adamawa. It can be speculated that this is because the parameter used for this analysis is the amount of MSW disposed of at dumpsites and not the amount of MSW generated, and because Gombe has a better MSW collection efficiency therefore more MSW is disposed of at its dumpsite.

Table 6. GHG Emissions and GHG Emissions per Tonne of MSW Disposed for Scenario 2

State	Emission (tCO_2eq)	Emission/Tonne of MSW (tCO_2eq/t)
Adamawa	23,964.05	0.4846
Bauchi	25,144.47	0.3507
Borno	10,362.39	0.1690
Gombe	43,869.48	0.3229
Taraba	1,541.91	0.0781
Yobe	9,743.09	0.7650

Comparing the results from this study to similar research done in other is a way to grade the potential GHG emissions reduction that can be attained by composting. A study carried out in Jordan found out that by composting the organic component of source segregated MSW, using the compost obtained instead of chemical fertilisers and disposing of the rest in existing landfills, a net reduction of approximately 70% (2.65 million tCO_2eq/yr) in GHG emissions from the SWM sector of the country can sector can be attained [40]. In another study, it was found that waste composting produces about 82% less GHG emissions than untreated waste disposed of in landfills [41]. In Nigeria, lifecycle inventory approach was used to evaluate the role composting can play in reduction of emission from the SWM sector in the six south-western states of the country [12]. The researchers found that in the entire region, a net reduction of 2,523,654tCO_2eq/yr could be attained by adopting composting. Comparing the results of these studies to that of this research, it can be seen that the potential for reduction of carbon footprint from SWM in northeast Nigeria is a bit lower than those from all the other studies, that notwithstanding, it is a step in the right direction.

CONCLUSION

An evaluation of the role of composting in the reduction of the carbon footprints of the SWM sector in the northeast states of Nigeria was conducted. It was found that the current SWM practice of disposing of unsorted waste in dumpsites and landfills was responsible for the emission of 232,505.18tCO_2eq. However, if composting of the organic component of the MSW is adopted, a potential net reduction in GHG emissions of 52% can be attained. This is in addition to other fringe benefits associated with composting - reduction in both air and ground water pollution and restoration of soil nutrients [10,42].

Given that composting offers a 52% potential reduction in GHGs emission, this makes it clearly a better alternative to the existing SWM practice in the region. In addition to the environmental benefits, composting has potential economic benefits such as making available cheaper fertilizer for farmers and the acquisition of foreign exchange from carbon trading.

One of the first steps by which transition to an environmentally friendlier SWM process can be achieved in the north eastern states of Nigeria and the country as a whole is by creating awareness about the need for segregation of MSW from source, this can be further encouraged by incentivising it as is done in some countries where residents whose waste are segregated pay lower sanitation dues.

Since this study has observed that a reduction in SWM carbon footprint of 52% is attainable via composting, it is recommended that other SWM techniques be studied so as to see which is the most suitable for the region in terms of its carbon footprint and economic implications.

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