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Projection of Municipal Solid Waste Generation Rates and Greenhouse Gas Emissions from Municipal Solid Waste Management in Yola, Adamawa State, Nigeria

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Abstract: Planning is an essential part of solid waste management (SWM), a city's ability to predict the quantities of solid waste is crucial to its medium and long-term solid waste management plans. In this research, a projection of the quantities of Yola's solid waste for a period of 16 years was made. A corresponding projection of the quantities of greenhouse gases that will be emitted into the atmosphere within that period envisaging three different SWM scenarios was also made using İller Bankası method. The first scenario being the existing practice of open dumping. The second open burning, the third - incineration with electricity recovery. Institute for Global Environmental Strategies simulation tool for greenhouse gas emissions from solid waste management was used for the analysis of the greenhouse gases emissions. It was found that by the end of the 16 years being forecasted, 963,276 tonnes of solid wastes would have been dumped at the dumpsite in the city. The study also found that if this waste accumulated over this 16-year period are to be managed based on the three scenarios envisaged, 337,822tCO_2eq, 444,825tCO_2eq and 250,461tCO_2eq would have been emitted into the atmosphere respectively. The study recommended that reduction in the per capita waste generation of the city should be encouraged. In addition, incineration with energy recovery should be adopted since it is the most environmentally friendly method for managing the huge quantities of solid waste disposed of in the city's dumpsites.
Keywords: Carbon Footprint, Greenhouse gases, Municipal solid waste, Solid waste management, Simulation, Waste-to-energy.

INTRODUCTION

The health and wellbeing of every community is intricately linked to its economic growth and standard of living. It has been found that poor solid waste management (SWM) has a far-reaching impact on the health and consequently economy of communities, it equally has impact on the immediate and global environment. The economic implications of poor SWM have been found to be much higher than what it would have cost to properly manage the waste in the first place [1] . Environmental problems such as flooding, air pollution, contamination of groundwater and the emission of unusually high amounts of greenhouse gases (GHGs) [2]. The waste management sector is one of the sectors which has experienced an increase in the quantities of solid waste being generated at an almost direct proportionality with global growth in population and economy [3]. As the waste generated by individuals globally grows, so also has the emission of GHGs from solid waste and its management. This increase in the emission of greenhouse gases from the management of solid waste is expected to steadily increase in the forthcoming decades especially in developing countries such as Nigeria because of their high population growth and economic growth which consequently results in increased purchasing power [4]. It is estimated that the SWM sector is responsible for 5% of global GHG emissions, this figure is said to be much higher in developing countries because of the unsustainable SWM techniques being practiced in these places [5].

It is now mainstream knowledge that anthropogenic emission of GHGs is one of the key drivers of global warming which has resulted in climate change with its attendant effects on the environment, biodiversity, lifestyle and livelihoods of humans. Like the saying goes "if it is not measurable, it is not manageable", sustainable SWM needs careful planning, a key ingredient in this planning is the ability to accurately project waste generation rates. Yola the capital of Adamawa State in Nigeria is one of the cities with a poorly organised SWM sector, the archaic practice of open dumping is still the SWM

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technique being practiced in the city [6]. The first step in making plans to have a sustainable, environmentally responsible and eco-friendly SWM sector in the state is by determining the current and future quantities of municipal solid waste (MSW) being generated in the city. In the light of the aforementioned, this research utilised secondary data obtained from literature to predict the annual quantity of MSW generation in the city from year 2014 to year 2030 and the carbon footprint associated with its management. Projection for the quantities of GHGs that will be emitted during that period was done envisaging three scenarios: Business as Usual (BAU) which is the open dumping of MSW; open burning of MSW (which is what is occasionally practiced) and incineration with electricity recovery.

It is expected that findings made in this research can be used as basis for planning of solid waste management in the city while also providing relevant data for researchers and also contributing to the body of knowledge regarding solid waste management and its inherent environmental impacts.

MATERIALS AND METHODS

Study Area and Data Sources

Yola, the study location is the capital of Adamawa state, it lies within latitudes 9°11'59''N and longitudes 12°28'59''E and at an altitude of about 192m192m [7], like most other urban centres in Nigeria and in most other developing countries, the solid waste management sector is still undeveloped. The SWM technique being practiced in the city is the age-old collection of unsegregated waste from collection points where residents dump them, the waste is then transported to dumpsites where they are dumped in unsanitary landfills and allowed to decompose, occasionally the waste in the dumpsites are burnt to reduce their mass and to give room for more waste to be disposed there. Adamawa State Environmental Protection Agency (ASEPA) is the state-owned agency under the supervision of the state's ministry of environment is responsible for the management of solid waste in the state. ASEPA has designated collection points in residential and commercial areas, these points are usually built dumpsters or the conventional large metal dumpsters, residents dispose of their waste in these dumpsters and ASEPA routinely collects and transports it to the city's dumpsite [8]. Figure 1 shows the map of Nigeria with Adamawa State highlighted.

Figure 1. Map of Nigeria with Adamawa State Highlighted

Study of literature was undertaken to obtain the required data for this study, data obtained include per capita MSW generation rate, MSW composition, population of Yola, annual population growth rate and MSW collection efficiency for Yola. Others include the SWM process practiced in the city and average moisture content of the MSW generated in the city.

Data Analysis

The daily amount of MSW disposed of at the city's dumpsite was estimated using the population of the city, waste collection efficiency in the city and its per capita waste generation. According to UNDP Nigeria [9], Yola has a waste collection efficiency of 40%, this was used for the analysis and it was assumed that this collection efficiency did not change for the period being forecasted. The daily quantity of MSW disposed of at the city's dumpsite was estimated using the formula presented in Equation 1 [10]:

$$\text{Daily Waste} = \text{PCW} \times \text{CF} \times \text{Pop} \quad \text{(Equation 1)}$$

Where
PCW = Per Capita Waste Generation (kg) = 0.65kg [11]
CF = Waste collection efficiency (%) = 40% [9]
Pop = Population of the city

The population of Yola for the year the analysis starts (2014) is 482,424 [12], the population growth of the city for the projected period was determined using İller Bankası method, a growth rate of 2.65% [13] was used. The İller Bankası method is used to forecast population of fast-growing locations, it is a geometric progression method of estimating population growth. It is based on the following equation:

$$P_n = P_O \left(1 + \frac{r}{100}\right)^n \quad \text{(Equation 2)}$$

Where
P_n = the projected population
P_o = the base population
r = Population Growth Rate (in percentage)
n = the number of years for which the population is being forecasted

The Institute for Global Environmental Strategies simulation tool for estimation of GHG emissions associated with SWM was used to estimate the emission associated with the three different scenarios being simulated. The tool is based on IPCC's 2006 guidelines for quantification of GHGs emissions associated with the waste sector [14]. The emissions for the different scenarios were simulated for Year 2014 to 2030. Composition of MSW in Yola inputted into the software for the analysis. It was also assumed that the composition of the city's MSW did not change for the period being forecasted. For open burning scenario, it is assumed that all the waste disposed of at the dumpsite is burnt in order to reduce its size and give room for more waste to be dumped at the site. The burning is done without any form of energy recovery or additional fuel to aid the combustion process. It is worthy to mention that open burning is occasionally being practiced at the city's dumpsite [15].

RESULTS AND DISCUSSIONS

Composition and Quantities of Waste in Yola

It was found that non-putrescible constituted more than half of the waste generated in Yola, while plastics and rubbers constituted up to 54% of the total waste disposed of at the city's dumpsites. This is unsurprising considering the high usage of plastic packaging in the state as it is in most parts of the country [16]. Glass and metals constituted just 6% of the waste disposed of in the city's dumpsites, this low quantity is likely because of the activities of scavengers. A large market exists for metal and glass scraps as such, households sell unwanted glass and metallic materials to scavengers who resell them for recycling, in instances where households thrash these materials, the scavengers pick them up before the materials reach dumpsites [8,17]. Like in most other cities in Northern Nigeria, food waste was found to be minimal (12%), this is mainly due to two factors: feeding of household animals with food ruminants

and the fact that there is actually not enough to eat and remain in most houses [18,19]. Table 1 shows the composition by weight of MSW disposed of at the dumpsites in Yola [15] .

Table 1. Average Weight Composition of MSW in Yola

Component	Weight (%)
Food	12
Plastics	24
Paper	18
Textiles	3
Leather/Rubber	32
Glass	3
Metal	3
Total	**100**

As at the year 2014, the daily, monthly and annual amount of MSW disposed of at the city's dumpsite was estimated to be 127 tonnes, 3,815 tonnes and 45,782 tonnes respectively [9,11,12]. If the current per capita MSW generation rate of 0.65kg/day of the city is maintained, the amount of waste disposed of at the dumpsite in the city will gradually keep rising such that by the year 2020, those values will be 148 tonnes, 4,450 tonnes and 53,405 tonnes. It was estimated that the annual MSW disposed of at the city's dumpsite would reach 69,032 tonnes by the end of the period being projected. Cumulatively, 963,276 tonnes of MSW would have been disposed of at the dumpsite by the end of year 2030. Table 2 shows the projected quantities of MSW to be disposed of at the city's dumpsite for the period being considered.

Table 2. Estimated Quantities of MSW sent to dumpsites in Yola from 2014 to 2030

Year	Daily (Tonnes/day)	Monthly (Tonnes/Month)	Yearly (Tonnes/Year)
2014	127	3,815	45,782
2015	130	3,914	46,972
2016	134	4,016	48,194
2017	137	4,121	49,447
2018	141	4,228	50,732
2019	145	4,338	52,051
2020	148	4,450	53,405
2021	152	4,566	54,793
2022	156	4,685	56,218
2023	160	4,807	57,679
2024	164	4,932	59,179
2025	169	5,060	60,718
2026	173	5,191	62,296
2027	178	5,326	63,916
2028	182	5,465	65,578
2029	187	5,607	67,283
2030	192	5,753	69,032
Total			**963,276**

Greenhouse Gas Emissions from Solid Waste Management Practices

For the BAU scenario, it was assumed that the current SWM practice of open dumping is sustained [4]. The analysis showed that in the base year, 762.79 tonnes of methane which is equivalent to 16,019tCO_2eq was emitted into the atmosphere due to the anaerobic degradation of organic components of the MSW at dumpsites in Yola. That figure is projected to rise to 18,635tCO_2eq by the year 2020 and 24,529tCO_2eq by the year 2030.

For open burning scenario, it was estimated that at the base year, 21,266tCO_2eq is emitted into the atmosphere, this figure gradually increases to 24,705tCO_2eq by the year 2020, and then 31,718tCO_2eq by the final year of the projection. For the 16-year period being projected, it is estimated that a total of 444,825tCO_2eq would have been emitted into the atmosphere if open burning is practiced as the preferred SWM scheme for the city.

For the scenario where incineration with electricity recovery is the city's choice SWM process, it was found that for the base year, this SWM has a net GHGs emission of 11,912tCO_2eq. By 2020 that figure is expected to rise to 13,885tCO_2eq and then 17948tCO_2eq by the end of year 2030. It is estimated that at the end of the 16-year period being forecasted, cumulatively, 250,461tCO_2eq would be emitted into the atmosphere. Table 3 shows the annual and total amount of GHG estimated to be emitted for the three scenarios being projected.

Table 3. GHG Emissions Projection for the 3 Scenarios from Year 2014 to Year 2030

Year	BAU (tCO_2eq)	Open Burning (tCO_2eq)	Incineration (tCO_2eq)
2014	16,019	21,266	11,912
2015	16,435	21,804	12,213
2016	16,862	22,356	12,530
2017	17,289	22,921	12,856
2018	17,726	23,501	13,190
2019	18,175	24,096	13,533
2020	18,635	24,705	13,885
2021	19,106	25,330	14,246
2022	19,590	25,971	14,617
2023	20,085	26,628	14,997
2024	20,593	27,302	15,387
2025	21,114	27,992	15,787
2026	21,648	28,701	16,197
2027	22,758	29,427	16,618
2028	23,334	30,172	17,050
2029	23,924	30,935	17,494
2030	24,529	31,718	17,948
Total	**337,822**	**444,825**	**250,461**

It can clearly be seen from Table 3 that MSW incineration with energy recovery is the most environmentally friendly SWM process. Having stated this, it is important to state that the relative lower values recorded for this SWM technique is because the emission values recorded are net values and not the gross emission values (the emission that would have been recorded if energy is not recovered during the incineration process). A total of 541,006tCO_2eq can be avoided by employing this method of SWM for Yola's dumpsite. The estimated gross emission, net emission and avoided emissions (due to substitution of grid electricity with that recovered from the waste to energy scheme) for the incineration scenario are presented in Table 4.

Table 4. Gross, Net and Avoided Emissions from Incineration with Energy Recovery

Year	Gross Emission (tCO_2eq)	Avoided Emission (tCO_2eq)	Net Emission (tCO_2eq)
2014	37,616	25,704	11,912
2015	38,594	26,382	12,213
2016	39,598	27,068	12,530
2017	40,627	27,771	12,856
2018	41,684	28,493	13,190

2019	42,767	29,234	13,533
2020	43,879	29,994	13,885
2021	45,020	30,774	14,246
2022	46,191	31,574	14,617
2023	47,392	32,395	14,997
2024	48,624	33,237	15,387
2025	49,888	34,102	15,787
2026	51,185	34,988	16,197
2027	52,516	35,898	16,618
2028	53,882	36,831	17,050
2029	55,282	37,789	17,494
2030	56,720	38,771	17,948
Total	**791,467**	**541,006**	**250,461**

CONCLUSION

A projection for the quantity of MSW reaching dumpsites in Yola and the emission of GHGs when three different waste management procedures – open dumping, open burning and incineration with energy recovery are used was made. For the projection period of 16 years (2014 – 2030), it was found that a total of 963,276 tonnes of MSW will be generated. Likewise, it was noted that there is a steady gradual increase in the quantity of MSW being generated in the city. Given this steady increase in quantities of MSW generation, proper SWM plans can be made and policies introduced which will ensure there is a reduction in the amount of MSW being generated in the city. The famous 3Rs i.e. Reduce (reduction in general quantity of waste being generated), Reuse (reuse of items instead of discarding them and purchasing new ones) and Recycle (recycling of materials instead of production of new ones from virgin materials) recommended by solid waste management experts [2,21,22] should be given attention by policy makers so that the health and environmental challenges associated with large quantities of MSW sent to unmanaged open dumpsite in the state can be reduced.

For the three different scenarios forecasted, the research found that if the current method of handling MSW in the city is not changed, by year 2030 an estimated 337,882tCO_2eq will be emitted into the atmosphere. Open burning of MSW despite being inexpensive since no investment in equipment is required, is not an alternative for the city because it generates 22% more GHGs than the current method being practiced. On the other hand, incineration with energy recovery is advised to be considered by the city authorities because it will reduce the GHGs emission from MSW dumpsites by approximately 26%.

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