Waste Management Practices and Profile of Selected Key Green House Gases at Selected Livestock Farms in Ibadan, Nigeria

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Abstract: Livestock farm waste contributes substantially to annual worldwide emissions of GHG (Greenhouse Gases), including CH₄ (Methane) and CO₂ (Carbon Dioxide). However, despite evidence of global climate change and its adverse health effects, studies on anthropogenic contributions to the increasing levels of GHG, particularly from livestock waste management practices, have not been adequately explored, especially in less developed countries. This study determined waste management practices and outdoor levels of CH₄ and CO₂ at three selected livestock farms (A-C) in Ibadan, Oyo State, Nigeria. Each study farm consisted of poultry, cattle and pig units. A 30-point observational checklist documented adequacy of solid waste management practices. Ambient concentrations of CH₄ and CO₂ at farm buildings and at waste disposal sites were monitored every other day, twice each day of monitoring (morning and evening hours), for eight weeks during months of September-November in 2013. Average scores for the waste management practices for Farms A-C were 29.6%, 33.3% and 18.5%, respectively. Morning and evening CH₄ concentrations in parts per million (ppm) at main buildings of Farms A-C were 2,538 ± 773 and 1,916 ± 662, 2,325 ± 773 and 1,180 ± 483, and 2,389 ± 687 and 1,854 ± 571, respectively. Morning and evening CO₂ concentrations (ppm) at Farms A-C main buildings were 350 ± 130 and 330 ± 110, 470 ± 100 and 440 ± 100, and 430 ± 80 and 400 ± 70, respectively. Morning and evening CH₄ concentrations (ppm) at Farms A-C waste disposal sites were 2,452 ± 495 and 1,614 ± 372, 1,527 ± 390 and 1,736 ± 269, and 2,345 ± 615 and 1,690 ± 387, respectively. Morning and evening CO₂ concentrations (ppm) at Farms A-C waste disposal sites were 330 ± 90, 370 ± 60 and 350 ± 30, respectively. Waste management practices were inadequate; solid waste management practices like infrequent evacuation of slurry waste and open burning of waste may have contributed to the production of CH₄ and CO₂. This study suggested proper handling, removal and disposal of farm waste which can reduce production of GHGs like CH₄ and CO₂.

Key words: Livestock farms, greenhouse gases, waste management.

1. Introduction

In recent times, climate change has been a subject of global importance because of its associated environmental and health impacts. Globally, CO₂

(Carbon Dioxide) and CH₄ (Methane) contribute 60% and 15%, respectively, to anthropogenic emissions of GHGs (Greenhouse Gases) and the resulting greenhouse effect [1]. GHGs are expected to influence extreme weather changes and potentially affect crop yields and productivity, food supplies and food prices [2].

Livestock production has been noted as the largest source of methane from agriculture [3], with enteric

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fermentation and manure management accounting for 35% to 40% of the total anthropogenic CH₄ emissions and 63-80% of CH₄ released from agriculture [4]. The demand for livestock products is rising rapidly in LDCs (Less Developed Countries), mainly a consequence of increased human population size, urbanization and rapidly increasing income [5]. The world population figure is expected to increase from more than seven billion, as the number stands today, to well over nine billion by 2050 [6] with one billion of this increase expected to occur in LDCs in Africa.

Demand and consumption of animal products are growing even faster than the increase in world population. Such demand has called for development of the livestock industry. GHGs can occur at each stage of manure management, i.e., the livestock building,

manure stores, manure treatment and manure spreading to the land. The development of the livestock industry also leads to a pollution problem caused by the increasing amount of animal waste; farmyard manure is an inevitable consequence of livestock products generated from housed animals [7-9].

In Nigeria, one of the largest LDCs in West Africa, there is a dearth of information on GHGs from livestock production and waste sites. Therefore, this study determined the emission levels of CO₂ and CH₄ associated with livestock waste management practices.

2. Methodology

2.1 Study Area

This study was carried out in three LGAs (Local Government Areas), namely: Ibadan North, Egbeda and Lagelu LGAs of Oyo State, Nigeria (Fig. 1).

Fig. 1 GIS map showing the study locations.

2.2 Sampling Strategy

Three livestock farms were purposively selected for this study based on the inclusion criteria that the selected farms must have cattle, poultry and pig units. The farms chosen for this study were: The Teaching and Research farms of the University of Ibadan, TRFUI (Farm A)-Ibadan North LGA, Hope Farms HF (Farm B)-Egbeda LGA and Anu's farms AF (Farm C)-Lagelu LGA (Fig. 1).

2.2.1 On-site Observation

The waste management practices of the selected study locations were documented using a 30-point observational checklist reflecting indicators such as types of waste generated, frequency of waste removal from farm building, method of manure storage and disposal, availability of waste collection tanks etc.. On-site observational checklist also assessed the housing conditions of the farm building.

An on-site farm observational checklist was carried out once a week at each sub-unit of each farm for 8 consecutive weeks. Each good practice of a farm odor management plan was scored one (1) and bad practice was scored zero (0). Then, composite scores (30/30 as 100%) were ranked inadequate (0-39%), fairly adequate (40-59%) and adequate ($\geq 60\%$).

For each farm:

$$\text{Percentage score} = \frac{\text{Total no. of good practices}}{30} \times \frac{100}{1}$$

2.2.2 Determination of Carbon Dioxide and Methane Concentration

A carbon dioxide monitor (Telaire 7001) was used to measure the ambient concentration of CO₂ emissions at the farm buildings/waste disposal sites. A methane monitor (KT 605 model) made in China was used to measure ambient concentrations of CH₄ at the farm buildings/waste disposal sites.

According to standard good practices, measurements of these gases were carried out at three (3) different strategic points on a stable surface for about 5-10 minutes per sampling point.

Measurements of CH₄ and CO₂ were carried out every other day, i.e. three days in a week for eight consecutive weeks. This was usually done at specific periods of the day (6-11 a.m. and 4-7 p.m.).

2.3 Statistical Analysis

Gas levels measured at the different selected farms were recorded on spread sheets. These data were subsequently entered into SPSS (Statistical Package for the Social Sciences) version 15 software. Descriptive statistics (mean, standard deviation, maximum and minimum) were used to summarize levels of GHGs in study locations. Gas levels were compared with USEPA (the United States Environmental Protection Agency) guideline limits of 5% (50,000 ppm) and 600-1000 ppm for CH₄ and CO₂, respectively. ANOVA (Analysis of Variance) was used to determine potential statistical differences between the gas levels at the different farm locations and time of measurement. Correlations were also explored to establish the relationship between the different gas levels and meteorological data such as temperature and rainfall.

3. Results

Table 1 shows the on-site observation related to the solid waste management practices in the selected study locations. Open dumping and burning of waste were observed prominently at Farms B and C, respectively. Poultry straw and shavings evacuated from the buildings of these farms were disposed of often by open burning. Open dumping was also observed more at the cattle and pig units of Farm B, where animal dung was freely deposited at the vicinity. However, pit dumping of waste was a common site at Farms A and C.

Table 2 shows the average estimated percentage score as well as the pooled percentage of the on-site observation related to the waste management practices in the selected study locations.

Generally, based on observation, all farms selected for this study lacked an effective drainage system around animal waste storage facilities. Slurry from the

Table 1 Solid waste management practices observed.

Location	Pit dumping	Waste bins	Open burning	Open dumping
Farm A	+++	+	++	+++
Farm B	++	+	++++	++++
Farm C	+++	+	++++	+++

Key: ++++ = Highly present;

+++ = Moderately present;

++ = Present.

Table 2 Observed estimated average scores (%) from survey of the 30 total observed waste management practices, by type of livestock at study locations.

Average % score	Cattle	Pig	Poultry	Pooled % score*
Farm A	30.2	31.0	17.5	29.6
Farm B	30.0	38.0	32.0	33.3
Farm C	17.5	22.0	16.0	18.5

*Pooled % score represents the sum average percentage score for each sub-unit of the farms.

Table 3 Generalized mean concentration levels of methane and carbon dioxide according to the stratified farm sections.

Sections		CH ₄ (farm building)	CO ₂ (farm building)	CH ₄ (waste disposal site)	CO ₂ (waste disposal site)
Cattle	AM	2,845.6 ± 551.9	410.6 ± 120.0	2,662.5 ± 255.3	370.0 ± 90.6
	PM	1,832.7 ± 482.5	380 ± 86.1	1,462.5 ± 270.5	380.2 ± 30.5
Pig	AM	2,060.3 ± 672.8	370.4 ± 108.9	2,300.0 ± 400.0	320.0 ± 80.0
	PM	1,684.3 ± 629.0	340.0 ± 87.1	1,618.7 ± 341.0	360.0 ± 60.0
Poultry	AM	2,476.9 ± 617.3	440.0 ± 130.6	2,233.3 ± 743.1	340.4 ± 70.6
	PM	2,005.7 ± 514.8	425.0 ± 130.4	1,815.7 ± 403.0	315.7 ± 91.3

Table 4 Mean concentrations of methane (CH₄) and carbon dioxide (CO₂) at different time periods at each study location.

Farm		CH ₄ (farm building)	CO ₂ (farm building)	CH ₄ (waste disposal site)	CO ₂ (waste disposal site)
Farm A	AM	2,538.2 ± 773.3	350.2 ± 135.5	2,452.1 ± 495.9	330.0 ± 90.0
	PM	1,916.7 ± 662.6	330.4 ± 110.5	1,614.6 ± 372.4	335.0 ± 86.8
Farm B	AM	2,325.4 ± 577.5	470.5 ± 100.0	1,527.3 ± 390.1	365.0 ± 35.0
	PM	1,880.5 ± 483.9	440.4 ± 90.0	1,736.4 ± 269.3	370.5 ± 70.0
Farm C	AM	2,112.0 ± 555.7	430.5 ± 80.0	2,666.7 ± 622.7	370.4 ± 30.0
	PM	1,611.6 ± 400.7	400.7 ± 70.0	1,972.7 ± 440.7	330.5 ± 20.0

poultry units were not removed from buildings as frequently as required. However, solid/slurry manure evacuated from the farm buildings were indiscriminately dumped openly.

Waste from the cattle and pig units of Farm A were evacuated daily from the pen houses in accordance with the work plan; however, good waste management practices such as storage of waste in concrete slabs or on compacted clay soil, and provision for water diversion around the animal waste storage facility were lacking.

The generalized mean concentration of methane and carbon dioxide according to the stratified farm sections can be seen in Table 3. The summary of CH₄ and CO₂ emissions from the farm houses/pens is presented in Table 4.

The level of CH₄ measured over the eight weeks of sampling period at the three study locations showed that at the farm buildings, mean concentration values (ppm) of 2,227.4 ± 783.3, 2,102.9 ± 576.5 and 1,861.8 ± 543.7 at Farms A, B and C, respectively, were obtained. Also, at the waste disposal sites, mean

concentration values (ppm) of $2,033.3 \pm 606.2$, $1,631.8 \pm 344.2$, and $2,334.8 \pm 638.6$ at Farms A, B and C, respectively, were obtained. The levels of this gas as elucidated in the emission results obtained were far below the 5% (50,000 ppm) USEPA guide line limit.

The levels of CO_2 measured over the eight weeks of sampling period at the three study locations showed that at the farm buildings, mean concentration values (ppm) of 340.0 ± 120.0 , 455.0 ± 100.5 , and 420.0 ± 70.0 at Farms A, B and C, respectively, were obtained. Also, at the waste disposal sites, mean concentration values (ppm) of 330.0 ± 90.5 , $370.55.0$ and $350.0 \pm$

30.0 at Farms A, B and C, respectively, were obtained. Weekly variations of methane and carbon dioxide levels as monitored at the farm buildings and waste disposal sites of the selected study sites are represented in the figures below.

A one-way ANOVA test was used to compare measured carbon dioxide and methane concentrations by farm location and their waste disposal sites selected for this study. Emission monitoring of the gas levels showed some degree of significant difference across all three farm locations. At the waste disposal sites, methane showed a significant difference ($p < 0.05$) (Table 7).

Fig. 2 Weekly variation in CH_4 levels at study location Farm.

Fig. 3 Weekly variation in CO_2 levels at study location Farm A.

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Fig. 4 Weekly variation in CH₄ levels at study location Farm B.

Fig. 5 Weekly variation in CO₂ levels at study location Farm B.

Fig. 6 Weekly variation in CH₄ levels at study location Farm C.

Fig. 7 Weekly variation in CO₂ levels at study location Farm C.

Also, a bivariate correlation test was done showing the relationship between methane, carbon dioxide at the farm building, waste disposal site, temperature and rainfall. The result showed a strong positive correlation ($R^2 = 0.203$) between carbon dioxide levels at the farm house/pens to the methane levels at the farm house/pens. The result also showed a positive correlation ($R^2 = 0.328$ and 0.285) between the methane and carbon dioxide levels at the waste disposal sites and the farm houses/pens, respectively. Again a positive correlation was observed between temperature and the level of the gases measured (Table 6).

4. Discussion

The outcome of the on-site observation revealed how designs of study farm houses were similar. Farm pens/houses were mostly designed to be openly (naturally) ventilated with free inflow and outflow of air. Poultry houses had mesh wires as walls and the cattle and piggery sections only had short walls with open upper regions. The design presents a situation where the true ambient concentration of GHGs cannot be ascertained quite accurately as the totality of the gases could not have been captured within the buildings. The free inflow and outflow would have dispersed air by cross ventilation. This postulation

agrees with previous studies which indicate housing systems are often adapted to the category of housed animals such as calves, dairy cows, sows, fatteners etc., as most cattle buildings are naturally ventilated [10]. Studies have also suggested the quantification of gaseous emissions from naturally ventilated buildings is sophisticated [11-13] and may require modern modeling techniques [14]. The difficulty in quantifying gaseous emissions and arriving at adequate emission factors most especially when emissions sources are not clearly defined was attributed to PM (Particulate Matter), large numbers of sources, diverse emission pathways/mechanisms, and observed differences in individual characteristics in terms of chemical composition or size.

Slurry and farmland manure are an inevitable consequence of livestock products generated from housed animals [8]. These slurry and manure contain inorganic N (Nitrogen), microbial sources of carbon and water providing the essential substrate needed for the microbial production of methane. Methane can be produced and emitted at each stage of the manure production and management system, the livestock building, manure collection, manure stores, manure treatment and manure spreading to land.

Animals at the cattle and pig units of Farm A were housed in free-stall barns where manure was daily

Table 6 Relationships between levels of the gases at emission sources and weather parameters.

	CH ₄	CO ₂	CH ₄ {waste disp. site}	CO ₂ {waste disp. site}	Temperature (Max.)	Temperature (Min.)	Rainfall
CH ₄	1.000						
CO ₂	.203*	1.000					
	.000						
CH ₄ (WASTE)	.328*	.099	1.000				
	.000	.241					
CO ₂ (WASTE)	.087	.285*	.092	1.000			
	-.305	.001	.279				
Temperature (Maximum)	.141*	.222*	.121*	.232*	1.000		
	.000	.000	.000	.000			
Rainfall	.038	.042	-.058	-.052	-.212*	.306*	1.000
	.359	.309	-.507	.549	.000	.000	

* Correlation is significant at 0.01 level (2-tailed).

Table 7 Differences between the levels of CH₄ and CO₂ across the study locations based on ANOVA. Values in bold were statistically significant.

Dependent variable	Name of farm	Name of farm	P-value
CH ₄ (farm building)	A	B	.036
		C	.000
		A	.036
	B	C	.003
		A	.000
		B	.003
CO ₂ (farm building)	A	B	.000
		C	.000
		A	.000
	B	C	.003
		A	.000
		B	.003
CH ₄ {waste disposal site}	A	B	.004
		C	.027
		A	.004
	B	C	.000
		A	.027
		B	.000
CO ₂ {waste disposal site}	A	B	.047
		C	.274
		A	.047
	B	C	.467
		A	.274
		B	.467

scraped off, and packed and stored as slurry, usually in open dumps. Also, based on observations made at study farm locations, slurry from the poultry units were not removed from buildings as frequently as required. When there was an evacuation from the farm

buildings, they were indiscriminately dumped openly on the top soil. It is known as the age of manure affects emissions [15].

The application of poultry manure and litter to land near poultry production farms is usually the preferred

practice at the study locations. Such indiscriminate dumping and land management of poultry by-products brings the risk of surface and ground water contamination from potential pollutants contained in the manure and litter. This postulation agrees with some studies reported that in 2000, drinking water contamination by livestock waste led to several deaths in Canada town of Walkerton [16]. Small geographical areas have been shown by studies to hold waste well beyond the assimilation capacity of the local environment. This is due to inadequate waste management and excessive waste production.

Other studies agreed with these facts and also postulated that wastes exceeding the carrying capacity of local ecosystems are the potential cause of a number of pollution and health problems related to their organic matter, nutrients, pathogens, odors, dust and air borne micro-organisms [17]. Soils on which pig and poultry manures are continuously applied at high rate accumulate heavy metals [18]. These heavy metals are minerals deliberately added to concentrate feeds and other heavy metals such as Cadmium introduced involuntarily via feed phosphates. It is known that only 5-15% of metal additives are absorbed by animals, while the rest are excreted. Over time, these excreted heavy metals accumulate in the soil, jeopardizing the good functioning of the soil, contaminating crops and posing serious human health risks [18].

From observations, it was evident that poultry straw/shavings scrapped from most of the farm pens/houses were mostly disposed of by open burning. Studies have reported in the production process, poultry can yield some waste as bird excrement, bedding materials such as saw dust, wood shavings, straw and some other waste such as on-farm mortalities [19].

It was estimated burning biomass and agricultural waste produces 40% of CO₂, 32% of CO, 20% of PM and 50% of PAH (Polycyclic Aromatic Hydrocarbons) released into the environment around the globe [20]. Although agricultural waste burning is not an

environmentally acceptable agricultural practice, its frequency is worrisome from a public health viewpoint [21]. Agricultural waste burning not only creates non-specific sources of pollutants but also greenhouse gases and short-lived climate, forcing pollutants like black carbon into the atmosphere which is implicated in the climate change phenomenon.

Generally, methane and carbon dioxide levels were observed to be highest at the farm buildings than at the waste disposal sites. The observed high levels of these gases at the farm buildings may not be unconnected with the possibilities of trappings of these gases within the buildings and other husbandry factors such as high metabolic activity and animal feeding which can influence the expiration rate and high levels of these gases, most especially from ruminants.

Most times emission levels were captured in the morning when animal defecation had not been routinely packed. This may be the reason that higher emission levels of the gases were recorded within the building when compared with emission levels at the waste disposal sites where gas emissions were solely from manure and conditions of storage.

These factors can contribute to higher levels of GHGs at the farm buildings than at the waste disposal site where gas emissions are solely from manure and conditions of storage. The CH₄ and CO₂ emission levels from the farm buildings were relatively higher in the mornings than in the evenings across study locations sampled. The levels of methane gas as illustrated from the findings were grossly below the 5% (50,000 ppm) USEPA guide line limit. This can be attributable to the structure of the farm buildings, which are open and naturally ventilated. Studies estimated methane emissions from naturally ventilated dairy houses by measuring ventilation rate by tracer decay method [22]. The emissions varied from 749 to 2,946 g·CH₄·hr⁻¹ with variation in the house structure, the livestock and the manure removal system. The levels of CO₂ outdoors were within ASHRAE (the

American Society of Heating, Refrigerated and Air-conditioning Engineers Inc.) normally observed outdoor levels (350-450 ppm) and USEPA normal CO₂ exposure in the indoor (or indoor minus outdoor) environment of 1,000 ppm (or about 600 ppm).

Within the eight weeks of monitoring, a temperature range of 24.8 °C to 32.6 °C was observed. The result showed a positive correlation between temperature and the level of the gases measured.

Livestock housing system and design greatly affected the livestock's micro-climate, especially, temperature and air velocity near animals, which had a direct influence on gas emissions from livestock barns. Several studies investigated the effect of barn design on animals' micro-environment, where the barn design including floor design and accordingly, the management of the different components (including cooling or heating systems) inside the barn are known to affect the indoor micro-environment. The most crucial of these bio-environmental components are the temperature and the air velocity which when increased or decreased, directly affected emission rates [11, 12, 23-38].

A study suggested that methane emission activity increases with temperature [39]. During the wet season, air temperature decreased to approximately -10 °C. However, bacterial activity in the manure created heat and kept its surface temperature above 0 °C. In the dry season, manure temperatures rose rapidly reaching an average of 20 °C. The rapid increase was mainly due to the shallow depth of manure in the storage facilities after manure removal in the raining season. Because of the higher manure temperatures during the dry period, CH₄ emission potential was potentially higher.

5. Conclusion

This study was centered on two GHG emission sources, the animal building and the manure storage site, and assessed waste management practices and outdoor levels of CH₄ and CO₂ from three purposefully selected livestock farms in Ibadan,

Nigeria, the teaching and research farms (UI), Hope farms and Anu's farms. Methane levels at the farm buildings and at the waste disposal sites were below the U.S. EPA guideline limits for normal outdoor exposure. Carbon dioxide levels at the farm buildings and at the waste disposal sites were within the current U.S. ASHRAE 62 guideline limits.

Data suggested that cattle sections from the study locations had higher GHG emissions. Based on on-site observation, the frequency of slurry waste removal, especially from the poultry units of the selected farms, were poor. Burning of poultry waste like poultry beddings, which included wood shavings and saw dust, was the preferred waste management practices. Generally, disposal of livestock waste across study locations was poor owing largely to the immense volume of waste generated and the poor waste management system in place. In summary, this study suggested manure slurry storage as well as open burning were two current waste management practices contributing to emissions of two key GHG implicated in climate change, CO₂ and CH₄.

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