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Characterization, Classification and Aerial Pollutant Gases Concentrations in a Livestock Environment

E.U. Onweremadu
Department of Soil Science and Technology,
Federal University of Technology, P.M.B. 1526, Owerri, Nigeria

Abstract: Selected soil properties and concentrations of aerial pollutant gases of a pip pen environment were investigated at the on-set of rains in 2005. A free survey technique was used in the study. Results revealed that soils are highly weathered (very low silt-clay ratios) and differed greatly at epipedons. Carbon monoxide (CO) had a good relationship ($R^2 = 0.54$; $p<0.05$) with clay content and soil pH. Similar result was recorded when these soil properties were regressed to methane (CH_4).These results present clay content and pH as good predictors of gas emission status in a livestock environment ($R^2 = 0.51$) at $p<0.05$. Aerial pollutant gases concentrations were relatively low but there is need to study the temporal viabilities of these gases.

Key words: Air pollution, animal husbandry, environmental quality, humid tropics, pedology

INTRODUCTION

Livestock production in the tropics is gradually changing from extensive and semi-intensive to intensive husbandry systems. The relative success of commercial pig and poultry production in the tropics (FAO, 2000) has made them very attractive in the tropics, especially with the rising unemployment. Livestock farmers remove swine wastes daily (Okoli *et al*., 2006) and dispose them on soils surrounding pig pens, without consideration of the environmental impact. Soils receiving these wastes respond differently to them. Differences were found in the rate of emission of ammonia, methane and dinitrogen oxide in two soils affected by pig manure (Velthol *et al*., 2005). These differences could be due to variability in composition of swine dung as affected by dietary protein and cellulose (Karr *et al*., 2006).

Concentration of aerial pollutant gases is highly related to edaphic properties. Chantigny *et al*. (2004) reported significant relationships between ammonia (NH_3) volatilization and selected soil properties following application of anaerobically digested pig slurry. Soil pH and nitrification activity (Sommer and Sherlock, 1996) affect volatilization of gases. Soil pH and carbonate content could stimulate volatilization (Sommer and Hutchings, 2001) while presence of plants reduce NH_3 volatilization (Morvan *et al*., 1997). These dump sites scarcely permit vegetal growth. In addition, when animal manure is left in the open as most farmers do, it may lose its potassium and phosphorus but much of its nitrogen and varying amounts of other nutrients through leaching and volatilization (Matsumoto *et al*., 1997). It is reported that effects of animal wastes on soil are felt immediately after application (Gordon *et al*., 2001) but prolonged dumping of these wastes may have profound effects on the pedogenesis of affected soils.

Characterization is helpful in the appraisal of soil productivity. The dearth of pedological information on soil of most developing countries is a major constraint to agricultural production and food security. Studies on the characterization and classification of soils of the study area are scanty (Chukwu and Asawalam, 2001; Chukwu and Chinaka, 2001) and non-existent in assessment and prediction of concentrations of aerial pollutant gases. It is hypothesized that as pig dung is dumped on soils, their responses and consequent losses into the atmosphere vary. Based on the above, the study aimed at characterizing these soil while estimating concentrations of aerial pollutants in the study locations.

MATERIALS AND METHODS

Study Area

The study was conducted in Umuiahia Agricultural zone, southeastern Nigeria in 2005. The site lies between latitudes 5°30^1 and 5°39^{1}N and longitudes 7°27^1 and 7° 33^1 E and covers about 545 km^2. Coastal Plain Sands (Benin formation) is the major geological material from which soil are derived. The area is located within the humid tropics with an annual rainfall ranging from 2250 to 2500 mm and annual temperature range of 27-29°C. Rainforest vegetation predominates although it has been altered by anthropogenic activities. Both arable and livestock agriculture are practiced in the study area. Open dump waste disposal system is common in the smallholder livestock industry.

Field Sampling

A free survey guided by intensity of livestock activity aided the selection of 3 sampling locations, namely Amuzukwu, Ubani and Ossah. Field studies were conducted at the on-set of 2005 rainy season. Although livestock are allowed to roam about with little supplementation from kitchen wastes (Okoli *et al*., 2003), farmers rear pigs in pens, resulting to disposal of wastes around pig pens. Pig pens are have concrete floor and farmer practice daily removal of dung, which eventually end on soils surrounding these pens. In each sampling location, a pig pen environment was chosen for the purpose of this study based on the intensity of husbandry and flock size. On each pig pen environment, a soil profile pit was dug, described and sampled according to the procedure of FAO (1998). Munsel colour chart was used in soil colour determination (moist status) in the field. A roller tape was used to determine depth of pedons. These soil samples were air-dried, crushed and sieved using 2 mm sieve before laboratory determinations.

Laboratory Determinations

Particle Size Distribution (PSD) was determined by hydrometer method according to the procedure of Gee and Or (2002). Silt Clay Ratio (SCR) was calculated as the value of silt divided by the clay equivalent in the PSD determination. The Coefficient Of Linear Extensibility (COLE) was estimated as the difference between the moist length and dry length of a clod to its dry length. Mathematically, it is given as follows:

COLE = (Lm-Ld)/Ld...1 (SSS, 2003)
where Lm = Length of clod when moist
Ld = Length of clod when dry.

Soil pH was estimated electrometrically using 1:2.5 soil-solution ratio (Hendershot *et al*., 1993) Exchangeable cations were estimated by Inductively Couple Plasma Atomic Emission Spectrometer (ICP-AES) (Integra XMP, GBC, Arlington Heights, IL). Effective Cation Exchange Capacity (ECEC) was obtained by summation of Total Exchangeable Acidity (TEA) and Total Exchangeable Bases (TEB). Base Saturation (BS) was computed as a sum of exchangeable basic cations divided by Cation Exchange Capacity (CEC). The CEC was determined by percolating 2.5 g soil with 100 mL of 1 M ammonium chloride for about 4 h. Before percolating the soil sample, samples were soaked with extraction solution overnight. Total carbon was measured by elemental analysis (CNS 2000, Leco Ltd.

Monchengladbach, Germany) as CO_2 via infrared detection after dry combustion at 1250° in duplicate. Two detection limits, namely 0.1 and 0.09 g kg^{-1} were used for Organic Carbon (OC) and nitrogen, respectively. Carbon-nitrogen and calcium magnesium ratios were obtained by calculations.

Estimation of Pollutant Gases

Methane (CH_4), ammonia (NH_3), carbon monoxide (CO), sulphur oxide (SO_2) and nitrous oxide (NO_2) were determined in three intensively managed pig farms at Amuzukwu, Ubani and Ossah in Umuahia, Southeastern Nigeria in April 2005. Readings were taken at 10.00 am and 1.00 pm from 7-18th April, 2005 according to the procedure of Wathes *et al*. (1997), in which representative samples were taken. Concentrations of pollutant gases were estimated in milligram per kilogram (mg kg^{-1}) while Lower Emissible Limit (LEL) was used for CH_4, using the handheld personal gas detector (Crowcon Instruments Ltd, England). The gas detector employs a catalytic bead sensor for NH_3, CO, SO_2 and NO_2. Gas detectors were held about 1 m above dump litter level and readings were recorded within seconds. All analyses were calibrated for zero and spanned before and after reading. Pig environment temperatures were estimated a nd stood at 26.2-26.5°C (Amuzukwu), 26.3-26.7°C (Ubani) and 26.1-26.5 (Ossah) during samples period.

Soil Classification

Field and analytical data were used in classifying soils using the USDA. Soil Taxonomy (Soil Survey Staff, 2003). Results of soil classification were correlated with FAO/UNESCO legends (FAO, 1998).

Date Analysis

Soil data were subjected to regression analysis using SAS computer software (SAS, 2000).

RESULTS

Soil Properties

Soil are deep with crumb structure at surface horizons. Sandy textures predominate the site except in the profile pit at Ubani, where sub-surface horizons are clay. With the exception of subsurface horizons of Ubani (72-170 cm), soil are well-drained. Colour of soil ranged from dark brownish colouration at surface horizons to red colours except in Ubani soils which are characteristically grayish with mottles at deeper horizons (Table 1).

Soils are highly weathered, having Silt-Clay Ratio (SCR) less than 1.2 (SCR = 0.1-0.7) and decreased with depth (Table 2). Clay content of s oil increased with depth in all the locations while Ubani had high values of silt (10-15%) (Table 2) Results are consistent with the findings of Akamigbo (1999) in soils of Bende, Uzuakoli and Item in the same geographical area.

Soil are moderately acidic with soils of Ubani showing least acidity throughout the profile pit. Total Exchangeable Based (TEB) were higher than Total Exchangeable Acidity (TEA), leading to higher values of base saturation in the area (Table 3). Effective Cation Exchange Capacity (ECEC) was generally very low (ECEC<4.31 cmol kg^{-1}) when compared with the rankings of AIRDA (1994) which described soils having cation exchange capacity less than 6.0 cmol kg^{-1} as very low. Organic carbon distribution varied with location and decreased with depth in all the pedons. Total Nitrogen (TN) followed the same trend both spatially and vertically in soil profile pits. Higher values of carbon-nitrogen ratio were recorded in Amuzukwu, which agrees with the results of a study conducted by Nwokocha *et al*. (2003).

Exchangeable magnesium dominated exchangeable calcium in Amuzukwu and Ubani soils. Generally, low values of calcium magnesium ratio (<1.8) were obtained and this is in line with the

Table 1: Morphological characteristics of study site

Horizon	Depth (cm)	Colour (moist)	Mottles	Texture	Structure	Drainage	Roots
Amuzukwu							
A	0-9	5 YR 3/2	Nil	SL	1,2 sbk	WD	Many
AB	9-25	5 YR 3/2	Nil	SL	2,m, sbk	WD	Many
Bt_1	25-90	5 YR 4/8	Nil	SL	2,m, sbk	WD	Few
Bt_2	90-140	5 YR 4/8	Nil	SL	2,m, sbk	WD	Few
Uhani							
A	0-12	10 YR 4/4	Nil	SL	2,m, sbk	WD	Many
AB	12-72	10 YR 4/4	Nil	SL	2,m, sbk	WD	Many
Btg_1	72-90	7.5 YR 4/6	Many	SL	2,m, sbk	WD	Few
Btg_2	90-15	2.5 YR 6/3	Many	SL	2,m, sbk	WD	Few
Btg_3	115-170	2.5 YR 6/3	Many	SL	2,m, sbk	WD	Few
Ossah							
A	0-19	5 YR 2/2	Nil	SL	2,m, sbk	WD	Many
AB	19-74	5 YR 2/2	Nil	SL	1, f, sbk	WD	Many
Bt_1	74-110	5 YR 4/4	Nil	SL	1, f,sbk	WD	Few
Bt_2	110-165	2.5 YR 4/4	Nil	SL	1, f, sbk	WD	Few

SL = Sandy Loam, SCL = Sandy Clay Loam, C = Clay, Cr = Crumb, sbk = sub angular blocky, m = medium 1 = weak, 2 = modest, f = fine, YR = Yellowish Red, WD = Well Drained, PD = Poorly Drained

Table 2: Physical properties of studied soils

Horizon	Depth (cm)	Clay	Silt	Sand	SCR	COLE $(cm\ cm^{-1})$	Texture
		---- $(g\ kg^{-1})$ ----					
Amuzukwu							
A	0-9	16	5	79	0.3	0.01	SL
AB	9-25	17	5	78	0.3	0.01	SL
Bt_1	25-90	22	3	75	0.1	0.02	SL
Bt_2	90-140	23	2	74	0.1	0.04	SL
Ubani							
A	0-12	25	10	65	0.4	0.04	SCL
AB	12-72	30	10	60	0.3	0.04	SCL
Btg_1	72-90	55	15	30	0.3	6.30	C
Btg_2	90-15	56	13	32	0.2	7.00	C
Btg_3	115-170	60	10	30	0.2	7.50	C
Ossah							
A	0-19	16	11	73	0.7	0.01	SCL
AB	19-74	19	6	75	0.3	0.01	SCL
Bt_1	74-110	21	5	74	0.2	0.02	SL
Bt_2	110-165	22	8	70	0.4	0.02	SL

SCR = Silt Clay Ratio, COLE = Coefficient of Linear Extensibility

Table 3: Soil chemical properties in the study site

Horizon	Depth (cm)	pH water	TEB cmol	TEA kg^{-1}	ECEC	BS	OC	TN	C/N	Ca-Mg
						---- $g\ kg^{-1}$ ----				
Amuzukwu										
A	0-9	5.3	2.04	1.90	3.94	51.70	20.80	1.3	16	0.5
AB	9-25	5.2	2.06	1.92	3.98	51.70	11.20	0.7	16	0.4
Bt_1	25-90	5.4	1.98	1.40	3.38	58.50	5.30	0.6	9	0.9
Bt_2	90-140	5.0	0.96	1.42	1.38	69.50	2.10	0.1	21	0.9
Ubani										
A	0-12	5.5	2.12	2.10	4.22	50.20	15.60	1.1	14	0.6
AB	12-72	5.5	2.10	2.20	4.31	48.70	13.30	0.8	16	0.5
Btg_1	72-90	5.6	2.25	2.05	4.30	37.52	29.60	0.4	11	0.5
Btg_2	90-15	5.6	2.23	2.04	4.27	52.20	43.04	0.4	10	0.4
Btg_3	115-170	5.6	2.26	2.03	4.29	52.60	1.60	0.1	16	0.4
Ossah										
A	0-19	5.0	3.80	0.50	4.30	88.30	25.20	1.7	14	1.8
AB	19-74	5.1	2.00	0.52	2.52	79.30	16.60	1.2	14	1.6
Bt_1	74-110	5.5	1.95	1.38	3.33	58.20	8.10	0.7	11	1.3
Bt_2	110-165	5.6	1.52	1.40	2.92	52.00	2.40	0.3	81	1.3

TEB = Total Exchangeable Bases, TEA = Total Exchangeable Acidity, ECEC = Effective Cation Exchange Capacity BS = Bases Saturation, OC = Organic Carbon, TN = Total Nitrogen, C/N = carbon-nitrogen ratio, Ca-Mg = calcium-magnesium ratio

Table 4: Classification of studied soils

Location	Soil taxonomy (USDA)	FAO/UNESCO
Amuzukwu	Typic Haludults	Eutric Nitisols
Ubani	Vertic Hapludults	Vertic Nitisols
Ossah	Humic Hapludults	Anthropedogenic Nitisols

Table 5: Concentration of aerial pollutant gases in studied pens

	CH_4	NH_3	CO	SO_2	NO_2
Location of pen	(LEL)	----------	----------	($mg\ kg^{-1}$) ----------	----------
Amuzukwu	2.0±0.1	19.0±0.0	4.0±1.0	0.10±0.0	0.2±0.0
Ubani	1.0±0.0	0.0±0.0	3.1±0.6	0.05±0.0	0.1±0.0
Ossah	2.1±0.0	11.0±0.0	1.0±0.1	0.10±0.0	0.2±0.0
Total	5.1	3.0	8.0	0.25±0.0	0.5±0.0
Mean	1.7±0.0	1.0±0.0	2.6±0.56	0.08±0.0	0.2±0.0

Table 6: Prediction equations for concentrations of aerial pollutant gases concentrations in livestock environment (surface horizon)

Aerial pollutants	Prediction equations	R^2	Level of significant
CH_4	CH_4 = 19.23-2.36 clay + 1.16 pH	0.51	*
NH_3	NH_3 = 20.98 4.21 clay + 3.44 pH	0.18	NS
CO	CO = 13.22-4.66 clay + 2.89 pH	0.54	*
SO_2	SO_2 = 21:21-3,82 clay + 1.36 pH	0.02	NS
NO_2	NO_2 = 13.93-1.65 clay + 4.2 pH	0.21	NS

*: Significant at $p<0.05$, NS = Not Significant

findings of Oti (2002). Soils were classified as shown in Table 4, with variations resulting from mainly COLE (Table 2) and BS (Table 3) values. The represent highly weathered soils of the humid tropics.

Aerial Pollution

The aerial distribution of pollutant gases shows that CO and CH_4 had highest mean values of 2.6±0.56 $mg\ kg^{-1}$ and 1.7±0.0 LEL, respectively in the immediate environment of pig pens (Table 5). Ammonia volatilized at pig pen environments at Amuzukwu (1.9 $mg\ kg^{-1}$) and Ossah (1.1 $mg\ kg^{-1}$) while 0.0±0.0 $mg\ kg^{-1}$ was recorded at Ubani. With the exception of CO ($R^2 = 0.54$) and CH_4 ($R^2 = 0.51$), there was non-significant relationship between pollutant gas emissions and selected soil properties (clay content and pH) as indicated in Table 6.

DISCUSSION

Moderate crumb structures of the surface horizons indicate some influence of pig dung in aggregating peds. It was observed that soil away from the dump site were weak and granular and this makes them vulnerable to soil degradation. This structural modification may have influenced loss of pollutant gases from the pedosphere to the atmosphere since crumb aggregates create wider pores that allow un-impeded volatilization. This effect is surficial as Chantigny *et al*. (2004) reported that rapid NH_3 volatilization occurred at 0.5 to 2.0 cm soil layer. At deeper horizons, especially in Ubani soils, mottles occurred, indicating imperfect drainage and possible increased reduction reactions. Under this condition, nitrous oxides in the pedosphere are reduced to more environmentally benign nitrogen gas (Clough *et al*., 2004) and this increases the potential for gaseous loss, although emission depend on carbon supply (Arah and Smith, 1990) antecedent soil moisture (Dendooven *et al*., 1996) liming (Clough *et al*., 2003) and soil temperature (Holtan-Hartwig *et al*., 2002).

Eluviation and consequent illuviation in all the pedons possibly resulted to high clay values (argillation) in the deeper horizons. In addition to this, low silt-clay ratio values suggest pronounced weathering. The implication of this is that movement of pollutant aerial gases is obstructed when in contact with such argillic (Bt) horizons leading to increased evolution of gases towards the epipedal horizons to the atmosphere. Dominance of magnesium over calcium resulting to less than 1.0 Ca-Mg ratio is a further indication of the highly weathered nature of soils and implies that soil of the site are dominated by low activity clays, such as kaolinite. Dominance of soils by low activity clays portends low soil productivity potential. In terms of gaseous emission, it suggests low volatilization due o lower clay activity in Amuzukwu and Ubani soils while Ossah soil with Ca-Mg ratios higher than 1.0 have greater potential of gaseous loss.

The present results revealed that aerial pollutants gases concentration are relatively low during the month of April (on-start of rains).This could be due to reducing temperature in the month of April when the moisture-laden southwesterly winds predominate in the area. Although strong positive relationships between temperature and some gaseous elements like N have been established (Sierra,1997), factors other than temperature may have immensely contributed to low values of pollutant gases (Piatek and Allen, 1999). However, increased emissions are expected when temperatures rise (Nyborg *et al*., 1997). But, it is also possible that slope position (Izaurralde *et al*., 2004) and plant type (Lemke *et al*., 2002) influenced changes in aerial pollution of studied gases. The figures obtained 1.70.±00 Lel (CH_4), 1.0±0.0 mg kg^{-1} (NH_3), 2.6±0.56 mg kg^{-1} (CO), 0.08±0.0 mg kg^{-1} (SO_2) and 0.2±0.0 mg kg^{-1} (NO_2) are much lower than the current exposure limits recommended for animal welfare in Europe or the mean values of 12.3 (winter)-24.2 (summer) mg kg^{-1} obtained by Wathes *et al*. (1997) in poultry houses in the United Kingdom. These low values could be attributed to livestock feeding systems (Msangi and Kavana, 2001) and vegetation (Morvan *et al*., 1997; Lemke *et al*., 2002), low pH (Sommer and Hutchings, 2000) could account for the low content of pollutant gases, especially as it affects ammonia content in the study. There are abundance of secondary forests surrounding these pig pens whose oxygen output may have masked gaseous pollutants in the air. In addition to vegetation (Morvan *et al*., 1997) Again, scavengers and farm animal on extensive system feed from these pig pen dump sites containing a mixture of dung and discarded feeds. These activities enhanced air quality of studied sites. However, clay content and soil pH had good relationships with CO and CH_4 emission, suggesting that the use of these parameters a s predictors of aerial pollutant gases concentration in livestock environment having highly weathered soils.

CONCLUSION

The study revealed that soils of the study site are highly weathered but differed in characteristics, especially at the surface horizons. Activities of man through pig husbandry and consequent disposal of pig wastes around pens altered some surficial edaphic properties. There were relatively low concentrations of the aerial pollutant gases in the livestock environment. However, there is need for more studies on temporal variability of thee pollutants in the study area, involving dry, wet and transitional seasons.

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