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Impact of Pig Farming on the Physico-Chemical Properties of Soils in Makurdi Metropolis, Benue State, Nigeria

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Abstract
This study evaluates the environmental impact of pig farms on the health of the soil using bacteriological and physicochemical parameters in Makurdi metropolis, Benue State, Nigeria. Twenty (20) pig farms and pen houses were randomly but evenly selected from the four cardinal points of the study area: north (5 locations), south (5 locations), west (5 locations) and east (5 locations). Samples were collected in duplicates from sample points using a soil auger and placed into well-labeled/tagged polythene bags and taken for analysis. Result revealed the presence of eight (8) pathogens dominated in equal proportion by *E. coli* (16.7%), *Proteus* spp. (16.7%) and *Klebsiella* spp (16.7%). Mean Total Variable Cost (TVC) and Total Coliform Count (TCC) in soil samples were 223.25±8.13 cfu/ml and 143.18±8.37 cfu/ml respectively with significant-variations observed at all locations ($H= 35.22$, $P<0.05$) whereas the control samples had the least counts in terms of temperature, conductivity, pH and nitrate. Two locations (F18 and F16) had the highest values of soil OM (13.1% and 13.08% respectively) while the control location had the lowest (4.7%). Soil TVC and TCC had very high positive and significant correlation ($r= +0.944$, $P<0.05$). Also, a very high positive and significant r- value was established between TVC ($r= +0.923$, $P<0.05$) or TCC ($r= +0.869$, $P<0.05$) while organic matter had high temperature indicating positive significant correlation coefficients ($r= +0.872$, $P<0.05$).
Key words: Pig farming, Soil condition, Soil properties, Impact assessment, Control

Introduction

Livestock production involves rearing domesticated animals ranging from cattle, goats and sheep, pigs and poultry birds (chicken, turkey, guinea fowl, ducks and geese) for food and commercial purposes for meats, eggs, milk, leather production [1-2]. In Africa, Livestock has historically constituted one of the major economic resources in terms of the livelihoods of its populations. According to the National Animal Production Research Institute (NAPRI), it accounts for one third of Nigeria's agricultural GDP, providing income, employment, food, manure and transportation. It is also one of the major sources of revenue through taxation and the export of hides and skins. Livestock, especially ruminants, are the most efficient users of uncultivated land and contribute substantially to crop production [2].

In most cases, pig farmers do not consider the likely environmental impacts of their proposed farming business when setting up pig farms in Nigeria [3]. The main target has been the profitability and sustainability of the business regardless of the environmental and social impacts. Compliance to all relevant laws and regulations is not usually considered due to weak policy, weak enforcement of the existing environmental laws at the State and Federal levels, bribery and corruption and nepotism. The environmental impact of pig farming refers to the threats posed to the natural environment by large-scale intensive pig farming. Farms are powerful sources of environmental pollution. [4 - 5] In many parts of Nigeria, handling pig waste is recognized as a major challenge to sustaining the growth of the industry [6]. [7] Reported rampant cases of indiscriminate open dumping of pig waste in the environment, resulting in environmental pollution, and public complaints. The environmental, and human health challenges associated with pig production are therefore, linked to poor waste management practices on farms; [8, 7]. Operations of pig farm have been linked to the deterioration of the environment in many places [9, 10]. It is one of the causes of different types of pollution and environmental stresses including land, water, air, and noise pollution. It has been linked to loss of biodiversity including the disappearance of endemic plant and animal species. It is possible that the soils around the study area are deteriorated or contaminated with pathogens. There is not sufficient data that capture the environmental impacts of existing pig pens in Makurdi, Benue State, Nigeria. The

aim of the present study was to evaluate the environmental impact of pig farms on the health of soil in the vicinity of these establishments using bacteriological and physicochemical parameters in Makurdi metropolis, Benue State, Nigeria.

Materials and Methods

Study Area

The study was carried out in Makurdi Local Government Area of Benue State, the State capital. Its coordinates are 7° 43′ 50″ North and 8° 32′ 10″ East and defined by a 26 km radius with the Benue River and its tributaries covering a substantial area of the town. Makurdi has a temperature range between a minimum of 27.8 °C to 28.2 °C and a maximum of 30.1 °C to 34.1 °C. Though a metropolitan part of the State, a reasonable size of the population is involved in agricultural production; pig production inclusive [3]

Selection of Pig Farms

Twenty (20) pig farms and pen houses (FI- F20) were randomly but evenly selected from the four cardinal points of the study area: north (5 locations), south (5 locations), west (5 locations) and east (5 locations). The inclusion criteria were farms known by the neighborhood or consented farm owners to rear a minimum of 20 pigs regardless of the sizes of the pigs. A new layout around the Genabe Phase III extension was chosen as the control location. It had no trace of pig rearing around the area.

Collection and Preparation of Soil samples

Composite soil (0-30cm) samples were collected from 4 sample points using the soil auger and placed into well-labeled/tagged polythene bags. Soil samples were collected in duplicates and transported to the Biology Research Laboratory of Joseph Sarwuan Tarka University for preparation and analysis. Soil preparation followed a standard protocol as contained in Five grams (5 g) of sample which were taken from the sieved soil and put into the beaker that contains 10 mol of nitric acid (2:1) for digestion. HCl and distilled water ratio 1:1 were added to the digestate. The mixture was transferred to the digester again for 30 minutes. The digestate was then removed from the digester and allowed to cool to room temperature. The cool digestate was added to a standard volumetric flask made up to the mark with distilled water (11, 13).

Bacteriological Analysis of Soil Samples

Sample inoculation

Exactly 1ml of sample suspension was inoculated on nutrient agar, MacConkey agar and *Salmonella-Shigella* agar (SSA). Incubation was done at 37^{0}C for 24hours [14].

Cultural characterization and identification of isolates

Morphological observations were recorded in the cultural media. These include the colour, shape and outline of the colony as well as the shape of each bacterium. Motility testing was done by adding a drop of peptone water to a glass slide containing a bacterial colony covered with a slip and viewing it under a microscope with a high power objective lens [15].

Bacterial count

Serial dilution, pour plates techniques and incubation (37^{o}C for 24 hours) methods were employed [15] Visible colonies on the plates were counted using a Colony Counter. Total Viable Counts (TVC) and Total Coliform Count (TCC) were recorded in cfu/ml x 10^3 (colony forming unit per mililitre [15]. Discreet colonies were subcultured on a Nutrient agar plate for biochemical test [16].

Biochemical characterization of isolates

Identification of bacterial species was done using standard microbiological procedures for each of the following biochemical tests: gram staining, catalase, citrate, urease, indole, hydrogen sulphide and oxidase tests [15]. All identified isolates were recorded per water and soil sample.

Analysis of Physico-Chemical Parameters of Soil Samples

Soil temperature and Electrical conductivity

The mercury in a glass thermometer calibrated in degrees Celsius was used in the measurement of soil temperature. Prior to the collection of each soil sample, soil temperature was determined *in situ* by inserting the thermometer to about 5cm depth in the soil for 5 minutes of stabilization of the instrument before temperature readings were taken in degrees Celsius (^{o}C) in duplicates [11]. Electrical conductivity was measured in situ using the conductivity meter in µs/cm.

Soil pH and Cation exchange capacity (CEC)

Twenty (20 g) of soil were weighed and transferred into a 100 mL beaker containing 40 mL of distilled water. The mixture was stirred with a glass rod and allowed to stand for half an hour (30 minutes). The electrode was immersed and the pH value was determined from the automatic display of the pH meter (Model 3510). [11].Ten grams (10 g) of soil sampled in a folded filter paper was inserted in a funnel fixed on the leaching rack. Leached soil of 10 g was poured into a 250 mL volumetric flask containing 1 N NH40AC (pH 7.0) and fixed on the rack. The residue in the filter paper/filter funnel was allowed to dry into air for 24 hours. The residue treated with 75 to 150 mL of methanol was allowed to dry again in the air. Leaching was repeated in a 0.1 N KCl solution in a 250 mL capacity. Thereafter, 1 N $NH_4$0AC leachate was used to determine K content while 0.1 N KCl was also used to determine the CEC and expressed in Cmol/kg [11].

Phosphorus (P) and Potassium (K)

The Bray-1 procedure [12] was adopted to check the available phosphorus content. Two grams (2 g) of soil in a test-tube and 20 mL of extracting solution were added to distilled water. It was corked and allowed to settle, followed by filtration. Five milliliters (5 mL) of filtrates in a 50 mL of volumetric flask was pipetted. Forty milliliters (40 mL) of distilled water plus 1 mL of calcium chlorides of

2.5% ammonium solutions was added. They were shaken and allowed to stand for 15 minutes. Phosphorus content was quantified in mg/g using the colorimetric approach at a 608 nm filter. The amount of Potassium was determined using the flame photometer and recorded in mg/g.

Nitrate content (N)

A soil sample (10 g) was poured into a 500 mL Kjeldahl flask containing 20 mL of conc.H_2SO4 and 1 g of catalyst added to the sample [12]. Kjeldahl digestion was heated until all the traces of carbon changed to blue fume. Fifty milliliters (50 mL) of distilled water were added and allowed to cool. Ten (10) glass beads and 100 mL of 45% sodium hydroxide were connected to the Kjeldahl distillation assembly. A total of 20 mL of 2.5% boric acid with three drops of mixed indicator was added. The set up was connected to an electric supply for distillation. The distillate with N/20 of HCl was titrated and the result was calculated and expressed as mg/L.

Organic matter (% OM)

It was measured by-wet acid digestion. One gram (1 g) of soil sample was weighed in a 500 mL conical flask containing 10 mL of 1 N K2Cr207. Twenty milliliters (20 mL) of concentrated sulphuric acid were added to the same flask, swirled and allowed to cool for 30 minutes. Distilled water (200 mL) was added along with 10 mL of orthophoric acid and 1 g of Na and NH4F. The mixture was allowed to cool. Diphenylamine (1 mL of 1%) was used as an indicator. A blank was prepared containing numbers 2 to 5 in the different 500 mL conical flasks. Blank and soil samples with 1 N ferrous sulfate solution were titrated. Calculations of total organic matter were done and expressed as percentages

Particles size analysis

Particles size analysis was determined by the hydrometer method using sodium hexametaphosphate and sodium carbonates (calgon) as the dispensant. Textural class determination was done using the USDA textural triangle [17]. Percentages of clay, silt, and sand were obtained.

Data Analysis

Data were analyzed using the Minitab software (17.0) for descriptive and inferential statistics. A one way ANOVA tool was applied while mean separation was done using the Fisher LSD method with a 95% confidence limit ($P \leq 0.05$). All parameters were compared with the control value and regulatory permissible limits as given by the WHO. The Kruskal-Wallice non-parametric test was applied at $P \leq 0.05$. Correlation analysis was achieved using Pearson's method which determined the relationships among all parameters measured.

Results and Discussion

Bacteriological assessment of soil samples

Table 1 presents the list of bacterial species present in soil samples collected around the pig pen. Eight (8) species were identified culturally and biochemically from 118 isolates. They were: *Escherichia coli*, *Streptococcus* spp., *Bacillus* spp., *Enterobacter* spp., *Proteus* spp., *Klebsiella* spp., *Shigella* spp. and staphylococcus spp. Among them, *E. coli* (16.7%), *Proteus* spp. (16.7%) and *Klebsiella* spp. (16.7%) were the most frequently occurring species. Out of the 20 locations, the prevalence of the bacterial species thus ranged from 40% in *Salmonella* spp to 100% in *E. coli*, *Proteus* spp. and *Klebsiella* spp. Table 2 gives the mean bacterial counts in soil samples collected around the pig pen. Soil samples in each location contained an average of 5.9 species of bacteria ranging from 4 to 10 species whereas the control water sample contained 3 species of bacteria. The mean TVC (Total Viable Counts) in soil samples collected from 20 locations was 223.25±8.13 cfu/ml. It ranged from 162.00±4.00 cfu/ml at F1 to 294.0±10.0 cfu/ml at F18. Soil samples at all sampling points in the Northbank area contained higher TVCs than other locations while the control soil had the lowest TVCs recorded (90.50±2.50 cfu/ml). The differences in TVCs in all soil samples were significant ($H=36.12$, $P<0.05$). Coliforms were heavily present in soil samples but lower than the viable counts. Total Coliform Counts (TCC) in soil samples in the vicinity of the pig pen ranged from 60.00±6.00 cfu/ml at the F2 location to 220.00±4.00 at F19. The mean TCC was 143.18±8.37 cfu/ml while the control soil had the lowest TCC value (32.00±1.00 cfu/ml) with statistically significant differences observed at all locations ($H= 35.22$, $P<0.05$).

The dominant species of pathogens found in soil samples were *Proteus* spp, *Escherichia coli*, *Enterobacter* spp and *Klebsiella* spp, an indication of soil contamination by disease causing bacteria.[18] The loads of bacteria counted in the soil were far higher than the permissible limits for healthy soils. Pig farms require a large amount of water for their production process. The resulting waste waters contain high concentrations of organic matter, dissolved and suspended solids, and pathogenic microorganisms. [4] The assessed bacteriological parameters are indicators of pollutants in soils around the pig farms possibly due to fecal contamination and waste disposals emanating from the pig farms [19, 20], [7] reported rampant cases of indiscriminate open dumping of pig waste in the environment, resulting in environmental pollution, and public complaints. The dominant species of bacteria (*Proteus* spp, *Escherichia coli*, *Enterobacter* spp and *Klebsiella* spp) identified in this work are clinically important from the public health point of view. They have been implicated in causing gastroenteritis, diarrhoea and food poisoning among other diseases with cases of multi drug resistance [21, 14, 23, 24,].

Table 1: Prevalence of Species of Bacteria Identified in Soil Samples around the vicinity of pig farms in Makurdi, Benue State

Identified bacterial species	Frequency/20	Proportion %	% Prevalence
Escherichia coli	20	16.67	100.0
Streptococcus spp	12	10.00	60.0
Salmonella spp	8	6.67	40.0
Enterobacter spp	13	10.83	65.0
Proteus spp	20	16.67	100.0
Klebsiella spp	20	16.67	100.0
Shigella spp	12	10.00	60.0
Staphylococcus spp	13	10.83	65.0

Table 2: Bacteriological Load of Soil samples around the vicinity of pig farms in Makurdi, Benue State

Farm code	TVC (cfu/ml)	TCC (cfu/ml)	No of microbial species
F1	162.00±4.00	75.00±3.00	8
F2	120.00±4.00	60.00±6.00	6
F3	210.00±6.00	124.00±8.00	5
F4	164.0±12.0	94.00±2.00	7
F5	185.00±7.00	128.0±24.0	4
F6	228.00±4.00	160.00±8.00	6
F7	246.0±10.0	150.0±26.0	5
F8	178.0±14.0	112.0±16.0	5
F9	190.0±26.0	110.00±6.00	5
F10	234.0±30.0	154.0±38.0	6
F11	240.0±32.0	156.0±48.0	6
F12	206.0±10.0	108.00±0.0	8
F13	216.0±12.0	102.0±10.0	5
F14	199.0±25.0	104.50±7.50	5
F15	258.0±34.0	170.0±54.0	6
F16	276.0±12.0	205.00±7.00	4
F17	276.0±20.0	210.0±14.0	10
F18	294.0±10.0	211.0±13.0	6
F19	291.00±3.00	220.00±4.00	5
F20	292.00±8.00	210.00±2.00	6
Mean	223.25±8.13	143.18±8.37	5.9±0.32
CONTROL	90.50±2.50	32.00±1.00	3

Key: TVC and Locations: Kruskal-Wallis H @ 20 df=36.12. P=0.015, P<0.05
TCC and Locations: Kruskal-Wallis H @ 20 df =35.22. P=0.019, P<0.05
F1= Railway market-1; **F2**= Railway market-2; **F3**= Railway market-3, **F4**= Behind J.S Tarka Foundation; **F5**= Down Inikpi street; **F6**= Rice mill area; **F7**= Behind NKST HQ; **F8**= Around Community Sec Sch; **F9**= Agbo village; **F10**= Demekpe; **F11**= Behind First Bank; **F12**= Off Awe street; **F13**= Behind Symbal; **F14**= Akpehe road-1; **F15**= Akpehe road-2; **F16**= UAM Animal Farm; **F17**= Fed Housing Ext; **F18**= Road 11 Fed. Housing; **F19**= Ucha village; **F20**= Asase

Physicochemical assessment of soil samples

Table 3 gives the results of the physicochemical assessment of soil samples in the vicinity of the pig pen. Soil temperature varied significantly (F=15.18, P<0.05) ranging between 28.4±0.25 °C at F2 (High Level) and 31.4±0.15 °C at F7 (Wadata), while the control soil had the lowest temperature recorded (28.4±0.20 °C) though inferentially of the same value with the soil temperature at F2 location. However, the control soil temperature was significantly different from the values obtained in soils collected in the vicinity of other pig pen locations. Soil EC had its lowest value in the control sample (0.2±0.01 µs/cm) and F1 sample (0.3±0.01 µs/cm) while the highest EC of 2.2±0.01 µs/cm was recorded in F3 and F7 soil samples collected from High Level and Wadata areas respectively. The observed variation in soil EC values was significant (F=27.01, P<0.05). The soil pH was almost neutral at the control site (7.3±0.05) and it was the lowest pH value recorded while other locations had significantly higher soil pH than the control location (F=14.3, P<0.05). The highest pH value of 8.2 (alkaline) was obtained in soils collected at F7, F13 and F14 locations.

Soil CEC was between 2.8±0.10 Cmol/kg in F11 (Wurukum) and 4.7±0.05 Cmol/kg at F17 (Northbank) with significant differences (F=36.04, P<0.05) while the control soil had a higher CEC value (4.5±0.15 Cmol/kg) than values recorded in samples collected from other locations except F7 and F17 samples. The minimum and

maximum Phosphorus levels recorded in soil samples were 14.3±0.30 mg/ml in F11and 22.5±0.05 mg/ml in F1 respectively with significant differences (F=565.09, P<0.05). Only 5 of the 20 locations recorded higher Phosphorus content in their soil samples than the control sample whose value was 20.0±0.10 mg/ml. Soil Potassium level varied significantly from 0.8±0.01 mg/L in F7 (Wadata) sample to 1.2±0.00 mg/L in the F15 (Wurukum) samples (F=58.46, P<0.05) while the control sample had 1.1±0.01 mg/L level. All soil samples collected from the vicinity of pig sites contained a higher nitrate content (4.9 to 7.4 mg/L) than the control soil sample (3.9 mg/L) with significant differences in nitrate level (F=13.54, P<0.05)

Figures 1-3 describe the soil composition around the vicinity of the pig pen in the study locations. Sand composition was lower at F17 (88.7%) and control locations (88.8%) than other locations. Sample F10 had the highest percentage of sand (92.3%) as shown in figure 4. The control soil had higher clay content (4.7%) than other soil samples collected, the lowest being 3.0% recorded in the F8 sample (Figure 5). Silt level varied from 4.4% (F14 and F10) to 6.6% (control soil) and 7.3% (F17) as shown in figure 6. Based on the organic matter content of the soil samples, F18 and F16 Locations had the highest values (13.1% and 13.08% respectively while the control location had the lowest (4.7%). There were 10 locations (50%) at the pig sites whose soils contained >10% OM contents (Figure 4). Table 4 shows the correlation coefficients of relationships among soil parameters where TVC and TCC had a very high positive and significant correlation (r= +0.944, P<0.05). Also, a very high positive and significant r- value was established between TVC and organic matter (r= +0.923, P<0.05) as well as TCC and organic matter (r= +0.869, P<0.05). TVC and TCC were positively influenced by soil temperature in a significant relationship (P<0.05) having recorded high positive coefficient values. Soil organic matter and temperature had high positive and significant correlation coefficients (r= +0.872, P<0.05).

Soil physicochemical parameters recorded higher values at experimental sites than the control in terms of temperature, conductivity, pH, nitrate, texture, and organic matter. The highest OM found was 13.1% while the highest pH value of 8.2 (alkaline) was obtained in some soils. All soil samples collected from the vicinity of pig sites contained a higher nitrate content. [25] Reported indiscriminate dumping of pig dung as organic manure over large areas of land that polluted the land, and resulted in eutrophication owing to excess accumulation of nitrogen, and phosphorus. The increased soil temperature observed ~~in~~ at the study sites could be attributed to the heat generated from animal manure as it decomposes. A similar finding was reported by [26].

Table 3: Physico-chemical Properties of Soil Samples around the vicinity of pig farms in Makurdi, Benue State.

Farm code	Soil temp (°C)	EC (µs/cm)	pH	CEC cmol/kg	P (mg/ml)	K (mg/L)	NO_3 (mg/L)
F1	29.8±0.10^{ef}	0.3±0.01^{l}	7.8±0.05^{defg}	4.2±0.05^{de}	22.5±0.05^{a}	1.1±0.00^{b}	6.3±0.01^{cd}
F2	28.4±0.25^{i}	1.8±0.01^{c}	7.6±0.05^{ghi}	4.0±0.10^{ef}	20.9±0.10^{c}	1.0±0.01^{cd}	5.3±0.01^{fg}
F3	30.3±0.55^{de}	2.2±0.01^{a}	7.7±0.00^{defg}	4.3±0.05^{bcd}	22.4±0.10^{a}	1.0±0.01^{cd}	5.8±0.01^{e}
F4	28.5±0.10^{ghi}	1.5±0.47^{defg}	7.6±0.10^{fghi}	3.9±0.05^{fg}	21.8±0.10^{b}	1.1±0.01^{b}	6.2±0.01^{cd}
F5	29.0±0.10^{ghi}	1.7±0.02^{cdef}	7.9±0.02^{cde}	4.2±0.10^{cde}	20.3±0.05^{d}	0.9±0.05^{d}	5.9±0.01^{e}
F6	31.1±0.25^{abc}	2.2±0.01^{ab}	7.8±0.10^{cdef}	4.3±0.05^{bcd}	18.8±0.10^{h}	0.9±0.05^{d}	5.7±0.01^{e}
F7	31.4±0.15^{a}	2.2±0.01^{a}	8.2±0.05^{a}	4.5±0.05^{ab}	18.8±0.10^{k}	0.8±0.01^{e}	6.8±0.02^{bc}
F8	28.7±0.05^{ghi}	1.1±0.01^{h}	8.0±0.01^{abc}	3.7±0.05^{ghi}	21.2±0.15^{c}	1.0±0.01^{cd}	5.3±0.01^{fgh}
F9	28.8±0.00^{ghi}	1.4±0.05^{fg}	7.5±0.05^{hij}	3.2±0.00^{k}	19.7±0.10^{efg}	0.9±0.02^{d}	5.7±0.01^{e}
F10	29.3±0.55^{fg}	1.3±0.01^{gh}	7.5±0.05^{hij}	3.6±0.05^{hij}	17.4±0.10^{i}	0.9±0.01^{d}	5.0±0.01^{h}
F11	29.2±0.45^{fgh}	1.2±0.01^{gh}	7.5±0.05^{hij}	2.8±0.10^{l}	14.3±0.30^{m}	0.9±0.01^{e}	5.2±0.02^{fg}
F12	28.9±0.35^{ghi}	1.7±0.02^{cdef}	7.8±0.10^{cdef}	3.4±0.10^{ijk}	15.0±0.10^{l}	1.1±0.01^{b}	6.7±0.01^{b}
F13	29.8±0.25^{ef}	1.7±0.01^{cdef}	8.2±0.10^{a}	3.6±0.05^{hij}	14.6±0.05^{m}	1.1±0.01^{b}	6.7±0.02^{b}
F14	28.6±0.05^{ghi}	1.8±0.01^{c}	8.2±0.05^{a}	3.8±0.10^{fg}	16.4±0.10^{k}	1.2±0.00^{a}	7.4±0.05^{a}
F15	30.4±0.25^{cde}	1.8±0.01^{c}	7.9±0.00^{bcd}	3.5±0.00^{ij}	16.8±0.10^{j}	1.1±0.00^{b}	4.9±0.01^{h}
F16	31.2±0.15^{ab}	1.7±0.01^{cdef}	8.1±0.10^{ab}	4.4±0.10^{bc}	19.8±0.05^{ef}	0.9±0.01^{e}	5.7±0.01^{e}
F17	30.6±0.20^{abcd}	1.9±0.00^{bc}	7.7±0.05^{efgh}	4.7±0.05^{a}	20.2±0.05^{d}	0.9±0.01^{e}	5.8±0.02^{e}
F18	31.1±0.35^{abc}	1.5±0.01^{defg}	7.4±0.10^{ij}	3.8±0.05^{gh}	18.8±0.10^{h}	1.0±0.01^{cd}	6.7±0.01^{b}
F19	30.3±0.10^{cde}	1.9±0.01^{bc}	7.8±0.05^{defg}	4.2±0.10^{cde}	19.4±0.10^{g}	1.1±0.01^{b}	6.3±0.01^{cd}
F20	30.5±0.20^{bcde}	1.3±0.01^{gh}	7.7±0.10^{defg}	4.0±0.10^{ef}	19.7±0.05^{fg}	1.1±0.02^{b}	6.8±0.02^{bc}
FC	28.4±0.20^{i}	0.2±0.01^{i}	7.3±0.05^{j}	4.5±0.15^{ab}	20.0±0.10^{de}	1.1±0.01^{b}	3.9±0.99^{i}
LSD	0.77	0.30	0.27	0.23	0.31	0.04	0.63

*Means that do not share a letter are significantly different
F (Temperature) = 15.18, P= 0.000 (P<0.05
F (EC) = 27.01, P= 0.000 (P<0.05)
F (pH) = 14.3, P= 0.000 (P<0.05)
F (CEC) = 36.04, P= 0.000 (P<0.05)
F (P) = 565.09, P= 0.000 (P<0.05)
F (K) = 58.46, P= 0.000 (P<0.05)
F (NO_3) = 13.54, P= 0.000 (P<0.05)

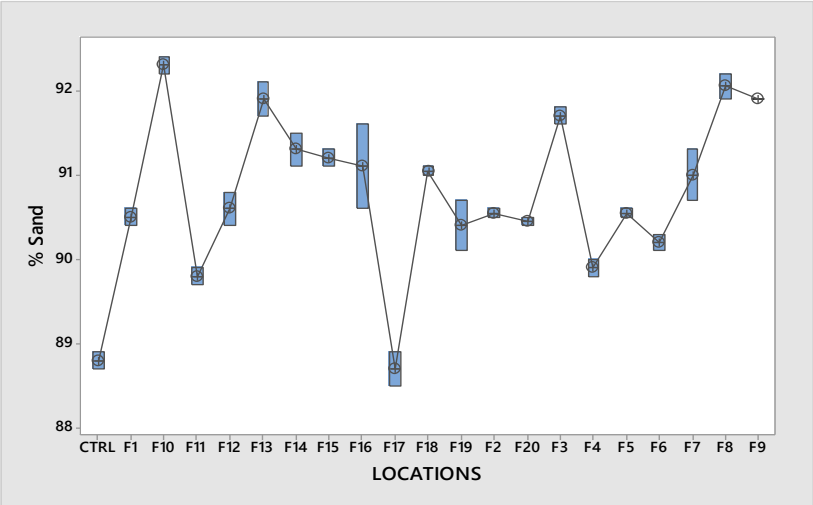

Figure 1: Sand composition in soils around the vicinity of pig farms in Makurdi, Benue State

Key: F1= Railway market-1; **F2**= Railway market-2; **F3**= Railway market-3, **F4**= Behind J.S Tarka Foundation; **F5**= Down Inikpi street; **F6**= Rice mill area; **F7**= Behind NKST HQ; **F8**= Around Community Sec Sch; **F9**= Agbo village; **F10**= Demekpe; **F11**= Behind First Bank; **F12**= Off Awe street; **F13**= Behind Symbal; **F14**= Akpehe road-1; **F15**= Akpehe road-2; **F16**= UAM Animal Farm; **F17**= Fed Housing Ext; **F18**= Road 11 Fed. Housing; **F19**= Ucha village; **F20**= Asase

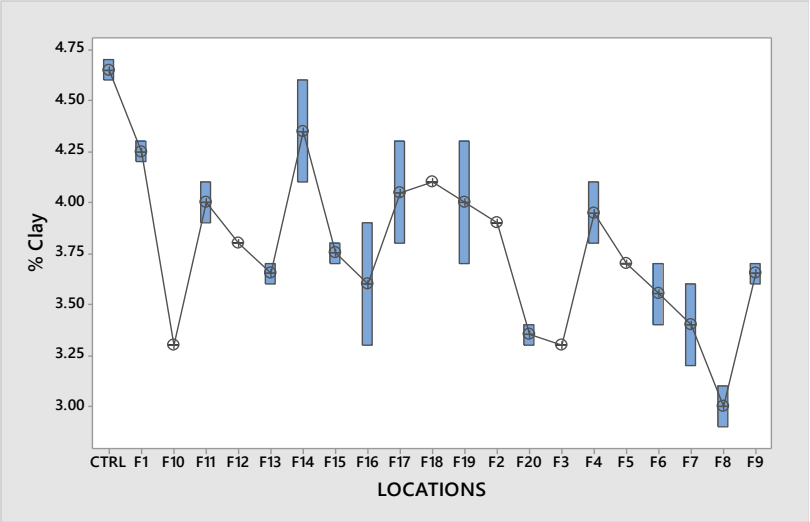

Figure 2: Clay composition in soils around the vicinity of pig farms in Makurdi, Benue State.

Key: F1= Railway market-1; **F2**= Railway market-2; **F3**= Railway market-3, **F4**= Behind J.S Tarka Foundation; **F5**= Down Inikpi street; **F6**= Rice mill area; **F7**= Behind NKST HQ; **F8**= Around Community Sec Sch; **F9**= Agbo village; **F10**= Demekpe; **F11**= Behind First Bank; **F12**= Off Awe street; **F13**= Behind Symbal; **F14**= Akpehe road-1; **F15**= Akpehe road-2; **F16**= UAM Animal Farm; **F17**= Fed Housing Ext; **F18**= Road 11 Fed. Housing; **F19**= Ucha village; **F20**= Asase

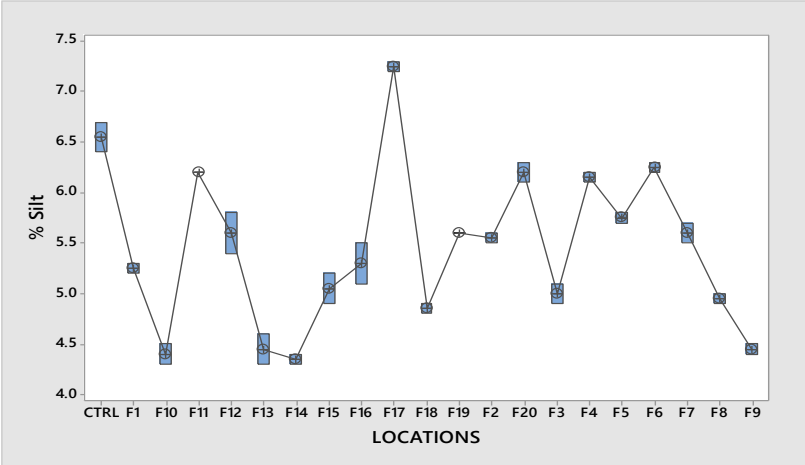

Figure 3: Silt composition in soils around the vicinity of pig farms in Makurdi, Benue State.

Key: F1= Railway market-1; **F2**= Railway market-2; **F3**= Railway market-3, **F4**= Behind J.S Tarka Foundation; **F5**= Down Inikpi Street; **F6**= Rice mill area; **F7**= Behind NKST HQ; **F8**= Around Community Sec Sch; **F9**= Agbo village; **F10**= Demekpe; **F11**= Behind First Bank; **F12**= Off Awe street; **F13**= Behind Symbal; **F14**= Akpehe road-1; **F15**= Akpehe road-2; **F16**= UAM Animal Farm; **F17**= Fed Housing Ext; **F18**= Road 11 Fed. Housing; **F19**= Ucha village; **F20**= Asase

Figure 4: Organic Matter Content of Soil Samples around the vicinity of pig farms in Makurdi, Benue State.

Key: F1= Railway market-1; **F2**= Railway market-2; **F3**= Railway market-3, **F4**= Behind J.S Tarka Foundation; **F5**= Down Inikpi street; **F6**= Rice mill area; **F7**= Behind NKST HQ; **F8**= Around Community Sec Sch; **F9**= Agbo village; **F10**= Demekpe; **F11**= Behind First Bank; **F12**= Off Awe street; **F13**= Behind Symbal; **F14**= Akpehe road-1; **F15**= Akpehe road-2; **F16**= UAM Animal Farm; **F17**= Fed Housing Ext; **F18**= Road 11 Fed. Housing; **F19**= Ucha village; **F20**= Asase

Table 4: Correlation Matrix of Soil Properties from where?

	TVC	TCC	% Sand	% Clay	% Silt	Temp	EC	OM	pH	CEC	P	K
TCC	0.944*											
Sand	0.112	-0.015										
Clay	-0.275	-0.232	-0.635									
Silt	0.007	0.143	-0.910	0.258								
Temp	0.753*	0.729*	0.010	-0.235	0.113							
EC	0.455	0.406	0.216	-0.395	-0.058	0.421						
OM	0.923*	0.869*	0.184	-0.375	-0.029	0.872*	0.571*					
pH	0.218	0.116	0.351	-0.299	-0.279	0.257	0.394	0.285				
CEC	0.003	0.112	-0.390	0.099	0.434	0.397	0.119	0.126	0.146			
P	-0.288	-0.128	-0.141	-0.029	0.191	-0.056	-0.217	-0.201	-0.261	0.526		
K	-0.153	-0.217	-0.053	0.352	-0.123	-0.288	-0.180	-0.204	0.151	-0.091	-0.012	
NO_3	-0.165	-0.227	-0.268	0.470	0.084	-0.041	-0.222	-0.187	-0.187	0.282	-0.086	0.442

* significant correlation at P<0.05

Conclusion

Bacterial loads were higher in soil samples at the experimental sitesproperties as compared with the control samples. Thus, the than at the control location. Soil physicochemical parametersdeteriorating soil condition influenced the high bacterial load. It is recorded higher values at experimental sites than the control inrecommended that wastes from pig farms be properly managed terms of temperature, conductivity, pH, nitrate, texture, and organicfollowing standard environmental guidelines. There is a need for matter. Some physicochemical and bacteriological parameters have acontinued control and monitoring by regulatory agencies on the high positive relationship. It could be deduced that pig farmimpact assessment of pig pen establishments on soil ecosystems in establishments might have had negative impacts on the quality andMakurdi metropolis and other places to prevent environmental health of soils due to the unacceptable bacterial loads, the numberhazards due to the loss of healthy soil.
of disease causing pathogens and the weak physicochemical

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