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Full Length Research Paper

To determine variability of soil physical and chemical properties of a typical land disposal catfish effluent in South Western Nigeria

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Soil physical and chemical characteristics of catfish effluent disposal land at fish farm village in Ikorodu district; Lagos State, Nigeria was investigated. The physical and chemical properties investigated include: textural class, bulk density, water holding capacity, porosity, hydraulic conductivity, organic matter, total nitrogen, total phosphorus and potassium. The required physical and chemical properties were measured at various depth ranges from 00cm to 90cm at 30cm intervals and analyzed. Results showed that the soil of the study area belongs to two different textural classes: clay loam and sandy clay loam. The sandy clay loam was dominant with 67% proportion of the prevalent soil textural class in the study area. The means values across the depth 00- 90cm for Bulk density (1.43 ± 0.22) g/cm^3, Water holding capacity (25.05±0.65) %, Porosity (36.87 ± 10.55) %, Hydraulic conductivity (0.22 ±0.14) cm/hr, Organic carbon (0.66 ± 1.55) mg/kg, Nitrogen (24.30 ± 1.50) g/cm^3, Phosphorus (6.93 ± 0.20) g/cm^3 and Potassium (3.40 ± 0.10) g/cm^3 were within the recommended critical values of 1.25 – 1.45 g/cm^3, 26.25 – 35.50%, 26.25 – 50.00%, 0.20 – 0.30cm/hr, 5.0 – 7.5, 10 – 12mg/kg, 20 – 30g/cm^3, 6.6 – 18.0g/cm3 and 3 – 6g/cm^3 respectively for optimum agricultural production. Hence the soil physical and chemical properties obtainable at fish farm village land are suitable for\ micro irrigation systems (sprinkler and drip) as well as agricultural production.

Key word: Catfish, crop production, effluent, irrigation, soil nutrients, soil physical properties.

INTRODUCTION

The catfish industry play a very important role in the Nigeria aquaculture industry as the largest segment of aquaculture in Nigeria. Most catfish are grown in the southern part of Nigeria, and the industry is economically important to several other states. Adekoya *et al.,* (2006) found the most popular species that thrived well in Nigerian environment to be: *Clarias gariepimus, Heteroclarias spp*., and *Heterobranchus spp*. Soil is a thin layer that covers most of the Earth's land surface and its volume and mass are relatively small in comparison to the lithosphere. The roles the soil plays are as follows: (1) Source of food and materials as medium for growth of food and energy crops and the basis for livestock production; it is the source of minerals like peat; it is a natural reservoir for huge amounts of water and it is a natural seed bank. (2) Providing water and nutrients for the entire plant kingdom. There are two methods that have been observed in catfish effluents disposal namely: Land disposal and Dilution technique. In the case of former method, effluent is allowed to flow over cultivable land (integrated farming) or bared land which a part of effluent evaporates and some percolates into the sub-surface. The latter method, effluent is disposed into a body of water or water course. Chatterjee (2010) highlighted that the quantity (loading) of wastewater to be applied on the land depends on the following factors:

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(i) Nature of the soil: It is the most important factors; in sandy, loamy and gravel hydraulic loading may be higher than fine clay. (ii) The nature of wastewater (effluent): If effluent is primarily treated or diluted, loading can be higher. (iii) Climate condition: In dry and hot climate, loading may be higher. Effluent applying to land by above methods not only solves disposal problems, but also contributes to land its fertilizing values. The impact of pond effluents on soils have been highlighted by many researchers such as (Boyd, 1990; 2001; 2003; Stickney, 2002; Tucker, 2000; Tucker and Robinson, 1990; Tucker *et al.,* 2002, and Tomasso, 2002) that fishpond wastewater improved physical and chemical properties of soil, produces offensive odour, impacts on aesthetic value of the environment, reduces dissolved oxygen, pollutes water body and introduces diseases. There are numerous publications on the subject of catfish pond effluents. Boyd, et al, (2000) and Boyd, (2003) reported that, water in catfish ponds usually have higher concentrations of nitrogen, phosphorus, total suspended solids, organic matter, and biochemical oxygen demand than natural surface waters in the vicinity, it affects the texture and mineral composition of the soil in intermediate vicinity. There are others publications on the subject of catfish pond effluents but it is difficult to draw conclusions from these studies because the characteristics of catfish pond effluents are unique, a function of feeding, water source, location, season, farm management practice. The catfish farmers at fish farm village usually depositing their effluent on land surface as mean of disposal. Soil quality can be judged from physical, chemical, biological and aesthetic points of view. Physical and chemical parameters for soil quality are texture, temperature, water holding capacity, porosity, organic content and nutrients (nitrogen, phosphorus and potassium). These parameters affect soil productivity. Impact of catfish effluent on water quality depends on methods of drained, amounts of water drained during harvest and concentration of the effluents.

The activities of these farmers are largely without scientific knowledge of the essence and adaptability of physical and chemical properties of the prevailing soil in the area. The soil properties of fish farm village are of importance in determining the catfish effluent for re-use for irrigation as well as the type and extent of irrigation required for agricultural production. The objective of this study is to determine the variability of soil physical and chemical characteristics of the land disposal catfish effluent for sustainable agricultural production and irrigation system.

MATERIALS AND METHODS

Site Description

Geographically, Lagos State is situated in South Western Nigeria. It spans the Guinea Coast of the Atlantic Ocean for over 180km on the South, from the Republic of Benin on the West to its boundary with Ogun State in the North and East of Nigeria. It fall within longitudes 030 50`E and 030 38`E and latitudes 060 20`N and 060 18`N.The total territorial area of 3,577sq km, about 787sq km or twenty-two percent (22%) is wetland area. The altitude of the State is approximately 4.6m above the sea level. It is divided into Local Government Areas and is as shown in Figure1. The sampling station was located at Fish Farm Village in Ikorodu division in Lagos State, Nigeria.

Collection of Soil samples

Twelve locations were chosen in the study area. Soil samples at specified thickness of soil horizon were carefully collected in separated piles (to avoid mixing) and left for sometimes to dry before they were packed in polythene bag. The bags were tied and tagged included the identification number of the sampling location, the upper and lower depth of the horizon sampled and the date of collection. The collected samples were used for field and laboratory tests.

Soil Parameter measurements

Soil physic-chemical properties measurements were taken on sites on the 15^{th} and 16^{th} march, 2013. Based on visual appearances on the site and vegetation, twelve pits were dug. The soil sampling was done four times for each point. The required physical and chemical properties were measured at various depth ranges from 00cm to 90cm at 30cm intervals by auger and were taken to the laboratory for the analyzed. Measured physic-chemical soil quality parameters were Textural class, Bulk density, Porosity, Water Holding Capacity, Hydraulic conductivity, Organic matter, Total nitrogen, total phosphorus and Potassium. All measurements were replicated four times

Bulk density of the Soil: Bulk density was determined by gravimetric method. The samplers was weigh empty, and then weighed with the soil. The sample was later placed in an oven at a high temperature of about 105°C for 24 hours and cool in a desiccator.
The bulk density was then be determined by the formula.

$$\text{Bulk density of soil } (g/cm^3) = \frac{\text{Mass of oven dry soil}}{\text{Volume of core}}$$

(FAO/IIASA. 2008)

Porosity (%) = Total pore volume / Bulk soil volume. The water holding capacity was determined from the ratio of the maximum water absorbed by soil to the oven-dried weight of the soil (APHA, 2005)

Soil Hydraulic Conductivity: Soil Hydraulic Conductivity was conducted with use of mini-disc infiltrometer (version 10).

Soil Texture: 100g of air-dried finely powered soil was put in a 500ml of conical flask and 15ml of 0.5N sodium oxalate (Na_2SiO_3) was added. 200ml of distilled water was added to the mixture and shake for 20 minutes. The content was transferred to one litre capacity measuring cylinder and make it up to one litre by adding enough water. Stir the suspension thoroughly, then stop stirring and

Figure 1. Map of Lagos State showing the study area.

note the time. Hydrometer was dipped into the suspension after 5 minutes given direct reading of the percentage of Clay + Silt. Hydrometer reading after 5 hours of sedimentation gives percentage f Clay directly. Hydrometer given the reading in g/L. percentage of sand was determined by deducting the percentage of Clay + Silt from 100. Similarly percentage of Silt was determined by subtracting the hydrometer reading for Clay from Clay + Silt (APHA, 2005).

Nitrogen: 10g of air-dried soil was put in Kjehdahl flask. 100ml of 0.32% potassium permanganate ($KMnO_4$) and 100ml of 2.5% Sodium Hydroxide (NaOH) solutions were added to the mixture. The mixture was distilled after adding 2ml of Paraffin and 10 – 15ml of glass beads. 75ml of 0.02N, Sulphuric acid with a few drop of methyl red indicator were titrated with 0.02N NaOH to a colorless end point. Nitrogen (ppm) = (25-no. of 0.02N NaOH required) × 2.8 (APHA, 2005).

Phosphate: 1.0g of dried and powered soil sample was put in a glass bottle with a stopper. 200ml of 0.002N Sulphuric acid solution was added and shake for 30 minutes with a mechanical shaker. The mixture was filtered using Whatman no.42 filter paper. 25ml of the clear filtrate were used to find out the concentration of phosphate in that solution through the standard curve. Available phosphate (ppm) = phosphate in solution × 20 (APHA, 2005).

Water Holding Capacity (WHC): Uniform plots of 1m × 1m were selected. The plot were filled with sufficient water to completely saturate the soil and the plot were covered with polythene sheet to check evaporation soil samples were taken after 24 hours of saturation and determined moisture content daily till the values of successive days are nearly equal. Water holding capacity is expressed as follows:

Percentage × moisture in soil = [(Y – Z) ÷ (Z –X) ×100].

Where:
X = weight of empty moisture box
Y = weight of moisture box + moist soil
Z = weight + moisture box + ordinary soil. (APHA 2005).

Organic Carbon: 10g of soil samples were placed into vessel and oven dried at 105°C and dried for four days. The soil vessel from the dried oven was removed and placed t in air – dried. When cooled, placed 0.01g of soil into furnace and bring temperature to 400°C for four hours.

Percentage of organic Carbon (OC) = $[(W_1 – W_2) \div (W_1) \times 100]$.

Where: W_1 = weight of soil at 105°C, W_2 = weight of soil at 400°C(APHA 2005).

a) **Potassium (ppm):** .5g of soil sample dissolved in water and diluted to make up 20µg K/ml solution. 100mL of the ammonium acetate was added to the solution

Potassium (ppm): 10A

Where,

A = content of K (µg) in the sample was read from the standard curve/ (APHA, 2005)

RESULTS AND DISCUSSION

Textural Classification of Fish Farm Village

The textural class of the study area is presented in Table 1. The textural classes found within the study area are clay loam and sandy clay loam with proportionally occupied about 33 % and 67% respectively. Presence of significant qualities of sand and clay as a major soil particle element may be linked with periodic deposition of catfish effluent and also flooding during the peak of rainy season. The variations in the clay and sandy contents

Table 1. Soil textural classification of Fish Farm Village.

Sampling point	Sand	Clay	Silt	Soil textural class
1	23.8	40.4	35.8	Clay Loam
2	24.4	41.2	34.4	Clay Loam
3	22.5	43.4	39.1	Clay Loam
4	46.0	31.3	22.7	Sandy Clay Loam
5	51.2	28.4	20.4	Sandy Clay Loam
6	46.6	30.4	23.0	Sandy Clay Loam
7	45.8	31.6	22.6	Sandy Clay Loam
8	49.4	30.2	20.4	Sandy Clay Loam
9	46.3	31.6	22.1	Sandy Clay Loam
10	45.6	30.4	24.0	Sandy Clay Loam
11	42.8	31.8	25.4	Sandy Clay Loam
12	24.4	41.2	34.4	Clay Loam

have a significant effect in the physical properties of the soil. The findings agreed with (Boyd, 2001; 2003; Stickney, 2002; Tucker, 2000; Tucker and Robinson, 1990; Tucker *et al.,* 2002, and Tomasso, 2002) that catfish effluent affects the texture and mineral composition of the soil in intermediate vicinity

Bulk Density

The descriptive statistics for bulk density is presented in Table 2. The minimum and maximum bulk densities were 1.14 ± 0.12 g/cm^3 and 1.62 ± 0.12 g/cm^3 respectively for the top soil (0 -30 cm). The mean bulk density for the depth (0-30 cm) was 1.34 ± 0.22 g/cm^3. The mean bulk density was within the critical range (1.25 – 1.45 g/cm^3) for crop production, development and yield (FAO, 1979). The bulk density across the depth showed that the mean bulk density values increase as the depth increased. There was no significant difference ($p \geq 0.05$) in the mean bulk density values at the depths (30-60 and 60-90). But there was significant difference ($p \leq 0.05$) between depth 0 -30cm and others.

Water Holding Capacity

The descriptive statistics for water holding capacity is presented in Table 3. The minimum and maximum water holding capacity were 17.60 ± 0.12% and 35.60 ± 0.23 % respectively for the soil depth (60 -90 cm) while the mean value was 26.80 ± 1.45 %. This value was considered suitable for crop production and also within the critical range (Franzmeier et al., 1995; FAO, 1979). The water holding capacity across the depth showed that the mean bulk density values increase with the depth. There was no significant difference ($p \leq 0.05$) in the mean water holding capacity values at the depths (00-30 and 30-60). But there was significant difference ($p \geq 0.05$) between depth 60 -90cm and others.

Soil Total Porosity

The descriptive statistics for total porosity is presented in Tale 4. The soil total porosity showed direct proportional to organic matter and inverse relationship to bulk density. These explain the reasons for high porosity and organic matter and low bulk density. Organic matter content influence soil pores. The more the organic matter contents the lower the bulk density value and more the soil total porosity values (FAO, 1979). The mean total porosity value for the depth (0-30 cm) was 42.80± 9.40 %. The mean total porosity was within the critical range (26.25 – 50.00 %) and also most of the porosity values fell within the optimum level for crop production. The maximum value (53.20 ±6.24) exceeded the critical value due to percentages of sandy and nutrient content of catfish effluent

Soil hydraulic conductivity

The descriptive statistics for soil hydraulic conductivity is presented in Table 4. The mean soil hydraulic conductivity value for the depth (0-30 cm) was 0.23 ± 0.11cm/hr. The mean total porosity was within the critical range (0.20 – 0.30 cm/hr) and also most of the hydraulic conductivity values fell within the optimum level for crop production. The maximum value (0.38 ±0.11cm/hr) exceeded

Table 2. Descriptive Statistics for the Soil bulk density at various soil depths.

Depth (cm)	Minimum (g/cm^3)	Maximum (g/cm^3)	Mean (g/cm^3)	Critical Range for Crop Production (g/cm^3)
00 -30	1.14±0.12	1.62±0.12	1.34[a] ±0.22	
30 – 60	1.26±0.07	1.60 ±0.06	1.48[b] ±0.12	1.25 – 1.45
60 – 90	1.32±0.07	1.58 ±0.05	1.52[b] ±0.03	

The means values with different superscript are significantly different (p ≤ 0.05) while those with the same superscript are not significantly different (p ≥ 0.05) as assessed by Duncan's Multiple Range Test (vertical comparison only).

Table 3. Descriptive Statistics for the Soil water holding capacity at various soil depths.

Depth (cm)	Minimum (%)	Maximum (%)	Mean (%)	Critical Range for Crop Production
00 -30	16.60±0.36	31.20 ±0.44	23.90a ±0.45	
30 – 60	16.90±0.32	32.40 ±0.35	24.70a ±0.50	26.25 – 35.50
60 – 90	17.60 ±0.12	35.60 ±0.23	26.80b ±1.45	

The means values with different superscript are significantly different (p ≤ 0.05) while those with the same superscript are not significantly different (p ≥ 0.05) as assessed by Duncan's Multiple Range Test (vertical comparison only).

Table 4. Descriptive Statistics for the Soil total porosity at various soil depths.

Depth (cm)	Minimum (%)	Maximum (%)	Mean (%)	Critical Range for Crop Production
00 -30	25.60±3.34	53.20 ±6.24	42.80[a]± 9.40	
30 – 60	30.20 ±2.12	48.60±5.45	40.60[b]± 6.70	26.25 – 50.00
60 – 90	28.60 ±2.22	46.80 ±7.45	39.20[c]± 8.15	

The means values with different superscript are significantly different (p ≤ 0.05) while those with the same superscript are not significantly different (p ≥ 0.05) as assessed by Duncan's Multiple Range Test (vertical comparison only).

Table 5. Descriptive Statistics for the Soil hydraulic conductivity at various soil depths.

Depth (cm)	Minimum (cm/hr)	Maximum (cm/hr)	Mean (cm/hr)	Critical Range for Crop Production
00 -30	0.08±0.10	0.38±0.11	0.23 [a]± 0.11	
30 – 60	0.06±0.04	0.28±0.06	0.17 [a]± 0.08	0.20 -0.30
60 – 90	0.04 ±0.10	0.22 ±0.13	0.13 [a]± 0.16	

The means values with different superscript are significantly different (p ≤ 0.05) while those with the same superscript are not significantly different (p ≥ 0.05) as assessed by Duncan's Multiple Range Test (vertical comparison only).

the critical value due to high proportion of sand content prevalent within the high soil hydraulic conductivity locations which implies that

Soil Organic Matter (mg/kg)

The descriptive statistics for soil organic matter is presented in Table 5. The minimum and maximum soil organic matter were 8.20 ± 1.45 mg/kg and 14.80 ± 1.45 mg/kg respectively for the soil depth (00 -30 cm) while the mean value was 11.50 ± 1.50 %. This value was considered suitable for crop production and also within the critical range of 10 – 12 mg/kg (Rich and Von, 2010).

The soil organic matter across the depth showed that the mean values increase with the depth.

Table 6. Descriptive Statistics for the soil organic matter content at various soil depths.

Depth (cm)	Minimum (mg/kg)	Maximum (mg/kg)	Mean (mg/kg)	Critical Range for Crop Production
00 -30	8.20±1.45	14.80 ±1.45	11.50^{a}±1.50	
30 – 60	5.80 ±1.42	10.40±1.44	8.10^{b}± 1.40	10 - 12
60 – 90	3.40 ±1.25	7.20±1.26	5.30 ^{c}± 1.40	

The means values with different superscript are significantly different (p ≤ 0.05) while those with the same superscript are not significantly different (p ≥ 0.05) as assessed by Duncan's Multiple Range Test (vertical comparison only).

Table 7. Descriptive Statistics for the soil total Nitrogen at various soil depths.

Depth (cm)	Minimum (g/cm^3)	Maximum (g/cm^3)	Mean (g/cm^3)	Critical Range for Crop Production
00 -30	21.40 ±1.4	25.20 ±1.6	23.30^{a} ± 1.50	
30 – 60	22.60±1.6	25.80±1.6	24.60^{b} ± 1.50	20 - 30
60 – 90	23.40 ±1.4	27.40 ±1.4	25.40^{b} ± 1.40	

The means values with different superscript are significantly different (p ≤ 0.05) while those with the same superscript are not significantly different (p ≥ 0.05) as assessed by Duncan's Multiple Range Test (vertical comparison only).

Table 8. Descriptive Statistics for the soil total Phosphorus at various soil depths.

Depth (cm)	Minimum (g/cm^3)	Maximum (g/cm^3)	Mean (g/cm^3)	Critical Range for Crop Production
00 -30	5.20±0.50	7.80 ±0.60	6.50^{a}± 0.50	
30 – 60	5.80±0.60	8.20 ±0.45	7.00^{b} ± 0.50	6.6 – 8.1
60 – 90	6.00±0.50	8.60±0.40	7.30^{b}± 0.40	

The means values with different superscript are significantly different (p ≤ 0.05) while those with the same superscript are not significantly different (p ≥ 0.05) as assessed by Duncan's Multiple Range Test (vertical comparison only).

Table 9. Descriptive Statistics for the soil Potassium content at various soil depths.

Depth (cm)	Minimum (g/cm^3)	Maximum (g/cm^3)	Mean (g/cm^3)	Critical Range for Crop Production
00 -30	3.00 ±0.10	3.30±0.10	3.20^{a} ±0.10	
30 – 60	3.20 ±0.10	3.40 ±0.10	3.30^{a} ±0.10	3 - 6
60 – 90	3.30±0.10	3.50 ±0.10	3.40^{a} ±0.10	

The means values with different superscript are significantly different (p ≤ 0.05) while those with the same superscript are not significantly different (p ≥ 0.05) as assessed by Duncan's Multiple Range Test (vertical comparison only).

Total Nitrogen, Phosphorus and Potassium

The descriptive statistics for total nitrogen, total phosphorus and potassium are presented in Tables 7, 8 and 9 respectively. The minimum and maximum total nitrogen, total phosphorus and potassium were (21.40 ± 1.4; 5.20 ±0.50; 3.00 ± 0.10) g/cm^3 and (27.40 ± 1.4; 8.60± 0.40; 3.50 ± 0.10) g/cm^3 respectively for the soil depth (0 -90 cm). The mean total nitrogen, phosphorus and potassium for the depth (0-90 cm) were (24.40 ± 1.50;

6.95 ± 0.41; 3.30 ± 0.10) g/cm^3 respectively. The mean nitrogen, phosphorus and potassium were within the critical ranges (20 – 30; 6.6 – 8.8; 3 – 6) g/cm^3 for crop production, and all of their values fell within the optimum level for crop production, development and yield (FAO, 1979). The total nitrogen, total phosphorus and potassium across the depth showed that their mean values increase as the depth increased. There was no significant difference (p ≥0.05) in the mean total nitrogen, phosphorus and potassium values at the depths (30-60 and 60-90). But there was significant difference (p ≤ 0.05) between depth 0 -30cm and others. The high values of total nitrogen and total phosphorus of the soil in the study area were due to nitrogen and phosphorus contents of catfish effluent deposited while the potassium value was due to inherent property of the soil in the study area.

In summary, the findings agreed with Boyd, et-al., 2000 and Boyd, 2003 that water in catfish pond effluents usually has higher concentrations of nitrogen, phosphorus, potassium and organic matter and also affected soil physical and chemical properties in intermediate vicinity.

The means values with different superscript are significantly different (p ≤ 0.05) while those with the same superscript are not significantly different (p ≥ 0.05) as assessed by Duncan's Multiple Range Test (vertical comparison only)

CONCLUSION

An investigation of Soil properties of fish farm village land in which catfish effluent was deposited was carried out. Results from the study indicate that:

- The numerical values of the soil physical and chemical properties were within the critical range/ optimum values for soil water movement, distribution within the soil strata, root development and crop growth.
- The physical properties directly influence soil water infiltration and storability.
- Catfish effluent influence the variation of the soil physical and chemical properties
- Textural class was responsible for variation in soil water and organic matter content.
- The dominant textural class was sandy clay loam soil, hence micro-irrigation system (drip or / and sprinkler irrigation) is recommended.
- Catfish effluent must be treated before disposed into environment.
- The impacts of catfish effluent on environment should be investigated.
- The effects of catfish effluent on plant growth should be investigated

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