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Evaluation of the Impact of Wastewater Generated From Catfish Ponds on the Quality of Soil in Lagos, Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript

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ABSTRACT

The study was performed to examine catfish (*Clarias geriepinus*) effluents on the quality of soil in Lagos State, Nigeria. Five fish farms with highest stock density were selected for evaluation. The soil sampling was collected at 10 metres apart before the effluent discharged site; at the effluent discharged site; 10 metres after the effluent discharged site and Non-effluent discharged siite (control) denoted as S_A, S_B, S_C and S_D respectively. Analysis of the required soil physical and chemical properties were performed at 5cm depth from 0 – 20 cm. Results showed that the effluents discharged site and Non-effluents discharged site indicated that they contained Temperature (26.5±0.1, 27.5±0.1℃), pH (6.7±0.1, 6.2±0.1), Wate r Holding Capacity (WHC) (36.4±2.1, 21.4±1.2%), Organic carbon (10.8±0.1, 7.4±0.1 mg/kg), TN (26.4±2.2, 22.4±2.1 mg/kg), TP (7.3±0.1, 6.1±0.1 mg/kg), Potassium (3.4±0.1, 3.1±0 .1 mg/kg), Calcium (9.5±0.1, 5.9±0.1 mg/kg), Sodium (1.6±0.1, 0.9±0.1 mg/kg), magnesium (8.8±0.1, 7.2±0.1 mg/kg), Zinc (3.3±0.1, 3.0±0.1 mg/kg), Iron (58.7±4.2, 55.8±3.2 mg/kg) and Manganese (23.6±2.3, 21.1±2.2 mg/kg) respectively and were significant different (p≥0.05). Both soil nutrients at the immediate environment of effluents discharged site were within critical range of soil fertility for arable crop production.

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1. INTRODUCTION

The catfish industry played very important role in the Nigeria aquaculture industry as the largest segment of aquaculture in the Nigeria. Most catfish are grown in the southern part of Nigeria. Adekoya et al. [1] found the most popular species that thrived well in Nigerian environment to be: *Clarias gariepimus, Heteroclarias spp*., and *Heterobranchus spp*. Besides catfish, other species that are common cultured are Tilapias (*Oreochromis niloticus*, *Sarotherodon galilaues* and *Tilapia guinessis*), *Heteriotis niloticus, Gymnarchus niloticus, Mugil cephalus, Chrysichys Nitrodigitatus* among others. Further, the importance of *Clarias geriepinus* as source of protein cannot be overemphasized. Earlier work by Jeje [2] reported that fish is becoming the most important protein source to consumers.

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) Environmental interaction as a critical link between the atmosphere, geology, water resources and land use; it receives precipitation of various types from the atmosphere; it is a reservoir of carbon and in the water cycle on the world it has a role in regulating the flow of this precious material from rainfall to watercourses, aquifers, vegetation and the atmosphere. (2) 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. (3) Providing habitat for myriad living beings from microorganisms to bigger animals; it gives support for terrestrial ecosystems and providing water and nutrients for the entire plant kingdom. Soil generally composed of sand, silt and clay particles, organic matter (humus), water and air space.

The impact of pond effluents on soils have been investigated [3-13]. They reported that it generates offensive odour on the immediate environment and impacts negatively on the aesthetic value and also affect the texture and mineral composition of the soil in intermediate vicinity. The effluent from fish pond contains oxygen-demanding waste that competes for available oxygen in soil and water for organic matter decomposition. 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. 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. The latter method, effluent is disposed into a body of water or water course. There were divergent opinions reuses of catfish effluent for irrigation (integrated system). The report accredited to Ghate et al. [14] concluded that rice crop removed nitrogen and phosphorus concentrations from catfish effluents. However, it was not clearly stated that catfish effluents increased the production of crops. While the report of Miller, and Semmen, [15] stated that effluents from polyculture of tilapia and African catfish which contained 6.03 mg/L nitrogen and 3.89 mg/L phosphorus increased production of French beans significantly from 4,300 kg/ha in normal canal irrigation to 7,700 kg/ha. Environmental agencies of different countries have also been focusing on appropriate regulatory and abatement measures to minimize the potential adverse impact of aquaculture [16], but little success has been reported so far. With the increased interest of implementing eco-friendly and sustainable fish farming, the aquaculture industry are gearing toward effective waste management practices to combat the menace created by indiscriminate disposal of waste water from fish ponds. This study was performed to assess the impact of catfish effluent discharged on the quality of soil in Lagos, Nigeria and come up with appropriate practice to minimize the negative impact on the soil quality.

2. MATERIALS AND METHODS

Information on the existing location of fish farms in Lagos State of Nigeria was collected from the Fisheries section of the Ministry of Agriculture, in the State, along with other relevant Fishing agencies. Fifteen out of the forty fish farms were used as pre-testing base on their site proximity to water source, effluents disposal, fish stock density and access located at Ikeja, Badagry, Ikorodu, Lagos Island and Epe divisions. Only five farms were finally picked for detail study based on their unique features and closeness, fish stock density, accessibility for sampling among others.

2.1 Experimental Procedures

2.1.1 Visual characteristics of the location

Physical inspection of the catfish effluent discharged sites was conducted and the differences between the sites in terms of vegetation, soil colour, odour, moisture and animal were observed and noted.

2.1.2 Soil measurements

Soil physic-chemical properties measurements were taken on sites on the 15th and 16th march, 2013.

The soil sampling was done four times for each site at 10 metres distance apart. Before effluent discharged site (designated, S_A), the effluent discharged site denoted(S_B),the site 10 metres after effluent discharged site denoted (S_C) and non-effluent discharged site denoted (S_D) which served as control. The required physical and chemical properties of the collected soil samples were measured at various depth ranges from 5 cm to 20 cm at 5cm intervals by auger and were taken to the laboratory for the analyzed accordance with American Public Health Association (APHA, 2005). Measured physico-chemical soil quality parameters were temperature, pH, Water Holding Capacity (WHC), Organic carbon, total nitrogen (TN), total phosphorus (TP), Potassium, Sodium, magnesium, Zinc, Iron and Manganese. All measurements were replicated four times.

2.1.2.1 Soil temperature

The iron pipe was inserted into the soil at 5cm depth of soil from 0 -20cm. The thermometer was dipped into the soil and the reading was taken [17].

2.1.2.2 pH

The pH of the soil was determined with 10 g of air – dried finely powered soil sample put in a beaker and mixed well with 25 ml of distilled water and kept for about half an hour with occasional stirring. The electrode of pH meter was dipped into the solution and the reading was taken [17].

2.1.2.3 Soil texture

100 g of air-dried finely powered soil was put in a 500 ml of conical flask and 15 ml of 0.5 N sodium oxalate (Na_2SiO_3) was added. 200 ml 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 stiring and 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 of 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 [17].

2.1.2.4 Total nitrogen (mg/l)

10 g of air-dried soil was put in Kjehdahl flask. 100 ml of 0.32% potassium permanganate ($KMnO_4$) and 100 ml of 2.5% Sodium Hydroxide (NaOH) solutions were added to the mixture. The mixture was distilled after adding 2 ml of Paraffin and 10 – 15 ml of glass beads. 75 ml of 0.02 N, Sulphuric acid with a few drop of methyl red indicator were titrated with 0.02 N NaOH to a colorless end point. Nitrogen (mg/l) = (25-no. of 0.02 N NaOH required) × 2.8 [17].

2.1.2.5 Phosphate

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

Available phosphate (mg/l) = phosphate in solution × 20 [17].

2.1.2.6 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:

$$\text{Percentage} \times \text{moisture in soil} = [(Y - Z) \div (Z - X) \times 100].$$

Where:

X = weight of empty moisture box
Y = weight of moisture box + moist soil

Z = weight + moisture box + ordinary soil [17].

2.1.2.7 Organic carbon (%)

10 g of soil samples were placed into vessel and oven dried at 105℃ and dried for four days. The soil vessel from the dried oven was removed and placed t in air – dried. When cooled, placed 2 g of soil into furnace and bring temperature to 400℃ 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℃ [17].

2.1.2.8 Zinc, Iron and Manganese (mg/l)

10 g of dried and powdered soil sample was put in a glass bottle with stopper. 200 ml of Zinc sulphate ($ZnSO_4.7H_2O$), ferrous sulphate ($FeSO_4.7H_2O$) and Manganese sulphate ($MnSO_4.H_2O$) solution was added and shake for 30 minutes with a mechanical shaker. Their respectively solutions were flamed using atomic absorption at a wavelength of 213.8 nm photometer which determined the cement atom. [17].

2.1.2.9 Sodium (mg/l)

2.6 g of soil sample dissolved in water and diluted to make up to 1 litre. (1000 µg Na/ml) solution. 100 mL was taken from solution and diluted to 1 litre to make 100 µg Na. ml stock solution. 5, 10, 15 and µg Na/ml of stock solution were fed on the flame photometer one by one to obtain a standard curve on Y-axis against the concentrations of Na on X-axis.

NA (mg/l) = A

Where,

A= absorbance reading (µg/ml) from the standard curve [17].

2.1.2.10 Potassium (mg/l)

5 g of soil sample dissolved in water and diluted to make up 20 µg K/ml solution. 100 mL 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/ [17].

Calcium and Magnesium (mg/l): 5 g air dried soil sample was put in 150 ml conical flask and 25 ml of ammonium acetate was added. The mixture was shaken on mechanical shaker for 5 minutes and then filtered through Whatman filter paper No. 1. 5 crystals of carbamate and 5 ml of ammonium chloride-ammonium hydroxide buffer solution. 4 drops of Eriochrome black T indicator was added to the mixture and then titrated with 0.01N versenate (EDTA) till colour changed from orange red to purple and green to wine red respectively.

2.2 Data Analysis

Physical and chemical properties of soil samples were determined in accordance with the American Public Health Association Standards [17]. Data were analyzed using descriptive statistics. Means of each parameter was compared using Duncan`s multiple range test. The statistical inference was made at 0.05 (5%) level of significance.

3. RESULTS AND DISCUSSION

3.1 Impact of Catfish Effluent on Physical Characteristics of Soil

Physical observation of sites revealed similar characteristics of odour, presence of white egret and soil dampness. The observed characteristics of the soil environment are presented as in Table 1.

3.2 Impact of Catfish effluent on texture of the Soil

The textural class of the site after the effluent discharged at (Site C) type soil and effluent discharged at (Site B) was sandy clay loam (SCL) as can be seen in Table 2, while that before the effluent discharged at (Site A) and the non-effluent discharged at (Site D) was sandy loam (SL). The different textural classes may be explained by the higher organic matter content (Table 3). Major factors are the water holding capacity of the soils that was affected due to the impounding force and higher organic matter of the effluent discharged, when compared to the non-effluents discharged, which was probably why the effluent discharged soil retained more water. The presence of little vegetation was not surprising since the nutrient yet to be mineralised and still in the organic state and not available to the plant and also the effluent discharged soil has the ability to retain water could cause blocking of soil pores and hence water logging of the soil. Excess water in soil restricts micro-organisms and their activities by preventing oxygen movement into and through the soil in sufficient quantity to meet the oxygen demand of the organisms.

3.3 Impact of Catfish Effluent on Physico-Chemical Parameters of the Soil Samples

3.3.1 Soil pH values and Nutrients level

The means and standard deviation of the physico-chemical parameters of the soil samples was presented in Table 3.The results show that pH of effluent discharged at (Site B) were relatively higher than that of non-effluent discharged at (Site A, Site C and Site D). The effluent discharged at (Site B) is more alkaline than other sites. The pH of the effluent discharged soil was significantly different ($p \geq 0.05$) from the non-effluent discharged sites. The pH is one of the principal factors affecting nutrients availability in the soil as it was observed in Table 3. The concentrations of both micronutrients and macronutrients were higher in effluent discharged at (Site B) than that of non-effluent discharged at (Sites A, C and D). This could be attributed to the organic matter content of the catfish effluents in enrichment of the nutrient content of the soil. The contributions of catfish effluents to the nutrients content of the soil were quite appreciable. Soil pH affects the others soil's physical, chemical, and biological properties At very acid or alkaline pH levels, organic matter mineralization is slowed down or stopped because of poor microbial activity linked to bacteria. Smith and Doran, [18] Highlighted that most microorganisms have an optimum pH range for survival and function and Bacteria, and Fungi that aided decomposition performed well at pH range of 5 – 9 and 2 -7 respectively. The pH for both discharged and non-discharged sites were good for microbial activities that enhanced decomposed and mineralized.

3.3.2 Water holding capacity, organic carbon and temperature of the soil

It was observed that the water holding capacity and organic carbon for all the sites were significantly different ($p \geq 0.05$) from each other for all the samples. The concentrations of both micronutrients and macronutrients were higher in effluent discharged at (Site B) than that of non-effluent discharged at (Sites A, C and D). The nitrogen, phosphorus and potassium compounds were naturally high because they are the major macronutrient in fish food. This could be attributed to the organic matter content of the catfish effluents in enrichment of the nutrient content of the soil. The contribution of catfish effluents to the nutrients content of the soil was quite appreciable. The effluent discharged site was the most statistically significant site ($p \geq 0.05$) while the other sites followed by site C and site A the least significant. The reason for this was not far- fetched as site B was the one where effluent was discharged and was the most altered site when compared to the control (non-effluent discharged site D). The organic carbon content in the effluent discharged site was significantly higher than that of non-effluent discharged site (Site D). The mean temperature at effluent discharged soil (26.5℃) was significantly lower ($p \geq 0.05$) than the other three non- effluent

Table 1. Visual characteristics of the soil samples

Characteristics	Site A	Site B	Site C	Site D
Vegetation	Little vegetation	Very little vegetation	Little vegetation	Grow with weeds
Colour	Brown	Black with humus	Dark brown	Brown
Moisture	Dry	Damp	Little moisture	Dry
Odour	Free of odour	Odorous	Slight odour	Free of odour
Animal	Absence of Animal	Presence of white egret	Presence of white egret	Absence of Animal

Key: Site A = 10 metres before effluent discharged site, Site B = Effluent discharged site
Site C =10 metres after effluent site, Site D =10 metres after C (non-effluent discharged site)

Table 2. Particle size analysis / textural class

Sample station	% silt	% sand	% clay	Textural class
Site A	12.4±1.4	60.3±2.5	27.2±2.1	SL
Site B	22.5±1.5	50.3±2.3	26.3±2.2	SCL
Site C	23.4±1.2	51.2±2.1	25.4±2.3	SCL
Site D	10.1±1.2	65.3±2.3	24.6±2.2	SL

Key: SCL – Sandy Clay Loam; SL - Sandy Loam

Table 3. Average concentration of the physico-chemical parameters of the soil samples at various discharges sites

Parameters	Site A	Site B	Site C	Site D	Critical range
Soil temperature (℃)	27.6±0.1a	26.5±0.1b	27.2±0.1a	27.5±0.1a	18 - 23
Soil pH	6.2±0.1a	6.7±0.1b	6.4±0.1b	6.2±0.1a	5 – 6.5
Total nitrogen (mg/kg)	21.3±2.1a	26.4±2.2b	24.6±2.1b	22.4±2.1a	20 - 30
Total phosphorus (mg/kg)	6.0±0.1a	7.3 ±0.1b	6.9±0.b	6.1±0.1a	6.5 - 18
Potassium (mg/kg)	3.0±0.1a	3.4±0.1b	3.3±0.1b	3.1±0.1a	3 - 6
Calcium (mg/kg)	6.6±0.1a	9.5±0.1b	6.7±0.1a	5.9±0.1a	2 - 9
Sodium (mg/kg)	1.1±0.1a	1.6±0.1b	1.3±0.1b	0.9±0.1a	2 - 5
Magnesium (mg/kg)	6.8±0.1a	8.8±0.1b	8.7±0.1b	7.2±0.1a	6 - 15
Zinc (mg/kg)	3.0±0.1a	3.3±0.1b	3.1±0.1a	3.0±0.1a	3- 15
Iron (mg/kg)	55.7±3.1a	58.7±4.2b	56.3±3.1a	55.8±3.2a	50 - 100
Manganese (mg/kg)	20.8±2.1a	23.6±2.3b	22.3±2.1b	21.1±2.2a	26 – 36
Water holding capacity (%)	18.3±1.1a	36.4±2.1b	24.3±1.2c	21.4±1.1d	40 - 60
Organic carbon (mg/kg)	6.2±0.1a	10.8±0.1b	8.1±0.1c	7.4±0.1d	10 -12

Values are means of four replicates (n = 4) in all Treatment, Results presented are means values of each determination ± standard error means (SEM), Means indicated by the same letter did not differ (P ≥ 0.05) as assessed by Duncan`s multiple range test (horizontal comparisons only), Key: Site A = 10 metres before effluent discharged site (B) (ii) Site B = Effluent discharged site, Site C = 10 metres after effluent site (iv) Site D = 10 metres after C (non-effluent discharged site)

discharged sites. Water holding capacity is controlled primarily by the soil texture and the soil organic matter content. The amount of organic material in a soil also influences the water holding capacity. As the level of organic matter increases at the discharged site, the water holding capacity also increases, due to the affinity of organic matter for water. Soil temperature that described the internal energy of the soil and it controls many chemical and biological processes within the soil. More water a soil has, the slower it will heat up because water needs to absorb lots of energy to increase its temperature. Low soil temperature decreases microbial activity This might be possible due to the slow decomposition of organic matter in effluent discharged site under saturated water conditions, particularly when mean soil temperatures was low which contributed significantly to the higher organic carbon at the effluent discharged soil. The finding agreed with Read et al. [16], Boyd [7], Fore shell [19] and Tucker [20] that catfish effluents have negative impact on the soil where discharged is untreated.

4. CONCLUSIONS

The impact of catfish effluent on quality of soil was investigated. Results of this study indicate that:

Catfish effluent affects both physical and chemical properties of soil.

Catfish effluent contained higher concentration of macro and micro nutrients than that of soil at locations.

The quality of soils at the immediate discharged site appears to be favourable in respect of soil enhancement.

It has impact on soil quality in the immediate environment of the discharged site.

Catfish eluent should be treated before discharged into environment.

Impacts of catfish effluent on water sources should be investigated.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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