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Bacteriological and Physicochemical Assessment of Abattoir Wastewater and Its Contaminated Soils in Adamawa State, Nigeria

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Abstract

Water and soil contamination by abattoir waste is a growing environmental concern worldwide. Abattoir wastewater is emerging as a significant contributor to environmental degradation, particularly in Nigeria and the developing countries. This research was aimed at assessing the Bacterial load and physicochemical properties of abattoir wastewater and its contaminated soils in Adamawa State, Nigeria. Wastewater/effluent and soil samples were collected from three (3) abattoir sites in three senatorial district of the State. Both samples were transported to the Microbiology Laboratory for analysis. The bacterial load and the physicochemical parameters were determined from both samples using standard methods of examination of wastewater and soil. All data obtained were subjected to statistical analyses using analysis of variance (ANOVA) IBM version 28. The total counts for the contaminated waste water ranged from 5.10 ± 1.2 - 7.90 ± 1.4 $\times 10^5$ cfu/mL, while the contaminated soil ranged from 5.06 ± 1- 7.90 ± 1.5 $\times 10^5$ cfu/g. Most of the physicochemical parameters were within the permissible limits except conductivity values which were above the acceptable limits of 1000 (uS/cm), biological oxygen demand (BOD) (above 50 mg/l) and total suspended solids (TSS) (1000 mg/l) of the wastewater. Physicochemical properties of soil

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contaminated with abattoir effluent showed that the soils happened to be mainly loamy and sand indicating that the effluent had no effect on the soil textural class. In terms of the chemical properties, pH values were low on the effluent contaminated soils; most of the parameters analyzed had higher values in the contaminated soils than the control. The highest values of the physicochemical parameters for pH, organic carbon, total nitrogen content, water holding capacity of contaminated soil were within the ranges of (6.06 - 6.89), (1.078 - 6.89), (1.858 – 1.943), (0.094 -0.102), (10.000 - 12. 200) and the textural class was sandy loamy. The presence of high microbial load found in wastewater and contaminated soils and the high physicochemical properties observed can be attributed to high organic waste released by these abattoirs. These affect human health by causing diarrhea, urinary tract infections and can subsequently alter the immediate environment.

Keywords: Abattoir, Wastewater/Effluent, Bacteriological, Physicochemical, Contaminated Soil

INTRODUCTION

Abattoirs, or slaughterhouses, are facilities where animals are slaughtered and processed for meat production. These establishments are meant to operate under hygienic conditions to ensure meat safety for human consumption. However, the wastewater or effluent generated during meat processing contains harmful pollutants, including animal feces, blood, fat, trimmings, and urine, which pose a substantial risk to both the environment and public health when improperly managed (Bandaw and Herago, 2019).

Research has shown that the composition of abattoir effluents varies daily depending on the type and quantity of animals processed (Ojegunle and Lateef, 2017). The effluents are characterized by high organic content, which includes nutrients such as nitrogen and phosphorus, as well as biological contaminants, including harmful bacteria and pathogens (WHO, 2010). When released into the surrounding environment, these pollutants can cause significant harm, particularly to aquatic ecosystems, by lowering oxygen levels and promoting eutrophication. Studies have indicated that abattoir effluents contribute to deoxygenation and contamination of water bodies, leading to adverse ecological and public health consequences (Okoro *et al.,* 2023, Ire *et al.*, 2017).

Furthermore, the presence of high organic matter containing high nutrients leads to the increase in bacterial load of abattoir waste water and its contaminated soils (Ja'afaru *et al.*,

2021). The wastewater from animal slaughter introduces enteric pathogens into water bodies, which further contaminates soil and the ground water (Ogunnusi and Dahunsi, 2014). In addition, there may also be the presence of pathogenic microorganisms, such as *Klebsiella* species, *Pseudomonas* species and *Escherichia coli* (including serotype O157: H7), parasite eggs and amoebic cysts (Joseph *et al*., 2021)

In Nigeria, the improper disposal of abattoir wastewater into nearby water bodies, drains, and open land is a common practice, especially in rural and semi-urban areas. This practice significantly contributes to soil and water contamination, which is particularly concerning in regions like Adamawa State. The pollution of local ecosystems not only threatens water quality but also exposes communities to various waterborne diseases, including cholera, dysentery, and salmonellosis (Okoye *et al*., 2020, Fatunsin *et al*., 2023). Despite the existence of environmental regulations, abattoir wastewater management remains inadequate, especially in underdeveloped regions where treatment facilities are either scarce or non-existent (Adeyemi-Ale, 2004).

While several studies have examined the impact of abattoir effluents on the environment, there is a notable gap in research that addresses both soil and water contamination in Adamawa State, Nigeria. Previous research in Nigeria has highlighted similar environmental concerns, yet a comprehensive study of abattoir wastewater impacts across all senatorial zones in Adamawa State remains limited (Ja'afaru *et al*., 2021). This study aims to fill this gap by assessing the bacteriological load and physicochemical properties of soil and water contaminated by abattoir wastewater in different local governments within Adamawa State. Through this research, we seek to provide crucial insights into the extent of contamination and the environmental risks posed by improper abattoir waste disposal.

MATERIALS AND METHODS

Study Area

Adamawa State is located in the North Eastern part of Nigeria. It lies between latitude 7 and 11°N and between Longitude 11 and 14° E. It shares boundary with Taraba State in the south and west, Gombe State in its North-west and Borno State to the North (Adebayo, (1999). The three main abattoirs used in the study are the ones providing wholesome meat for the populace in those areas. Yola has the highest population of over 336, 648 (NPC, 2006) which makes the Jimeta abattoir the busiest with more than 200

animals slaughtered per day including goat, sheep and cow (Adamawa State ministry of livestock, 2025). It has the highest human activities going on in terms of animal processing for meat purposes compared to Mubi and Ganye. The abattoirs are continuously monitored by the ministry of environment, while the ministry of livestock takes care of the animal health being monitored by veterinary personnels in all the selected areas. The source of water for the abattoirs is industrial bore hole in Jimeta, locally dugged bore hole in Ganye and Mubi uses water from other sources which is mostly from water vendors as at the time of this research.

Sample Collection:

Abattoir wastewater and soil contaminated with effluents were collected from the three abattoirs located in each of the three senatorial districts of Adamawa state, namely; Jimeta, Mubi and Ganye respectively in Adamawa State, North Eastern Nigeria.

Abattoir wastewater

Nine (9) wastewater/effluent samples were collected in all from the three abattoirs; three samples from each at intervals of two weeks from the months of May to June. All samples were collected at the exit points along the drainage just as it leaves the pavements of the abattoir using sterile wide mouthed bottles using the grap technique. The sample bottles were placed on ice box and were transported to the laboratory using all the aseptic guide lines (Rabah *et al.* 2011)

Soil samples

Nine (9) soil samples were collected in total from the three different abattoirs mentioned in the studies. At each of these abattoirs, top contaminated soil in the slaughter house or where the abattoir wastes are disposed were collected. The abattoir contaminated soils were collected after clearing off waste materials from the surface of the soil within the vicinity of these abattoirs. Soil samples were collected at intervals of two weeks using soil Auger to obtain soil from the depth of 0 – 20 cm using sterile sample bottles (Emmanuel *et al.* 2018).

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these abattoirs. Soil samples were collected at intervals of two weeks using soil Auger to obtain soil from the depth of 20 cm (Emmanuel *et al.* 2018). Soil samples for microbial and physicochemical analysis were placed in a sterile sample bottles and transported to the laboratory.

Control sample

Control samples were collected for all the sampling sites. Abattoir waste water and soil were collected distances of 300- 400 meters away from the main slaughter area and the abattoir premises where it appears not to be influenced or contaminated by the operating processes of the abattoir. Wastewater from a pond or river close to the abattoir that appeared not to be influenced by abattoir processes was collected as control.

Bacteriological Analysis of Abattoir Wastewater and Soil

Enumeration of bacteria from waste water

Abattoir wastewater was analyzed according to the method of Adesemoye *et al. (*2006). Zero point one (0.1) ml of serially diluted (10^{-3}, 10^{-5} and 10^{-7}) wastewater samples were plated in triplicate plates of nutrient agar (NA) and Plate count agar using surface plating method. The plates were incubated at 37^0C for 24 hours. After the incubation period, the colonies on Nutrient Agar were sub-cultured on fresh media to obtain pure isolates. The pure isolates were maintained on agar slant for further identification. However, those on Plate Count Agar were used for enumeration of bacteria. Colony counts were determined in colony forming units per milliliter of the sample as described by Chouhan, (2015).

$$\text{Cfu/ml} = \frac{\text{No.colonies counted} \times \text{Dilution factor}}{\text{Volume of the sample taken}}$$

Enumeration of bacteria from soil

Ten grams each of the soil samples were weighed and added to 90 ml of sterile distilled water to get an aliquot. One milliliter of the solutions were then serially diluted (10^{-3} 10^{-5} and 10^{-7}) as described by Osu and Okereke, 2015). Surface plating method was used, where 0.1 ml of each of the serially diluted solution (aliquot) were plated on Nutrient Agar (NA) and Plate Count Agar. The plates were incubated at 37^0C for 24 hours. After incubation, the colonies on the Nutrient Agar plates were sub-cultured repeatedly on fresh media to obtain pure isolates, the pure isolates were then maintained on agar slant for further identification. While those on the Plate Count Agar were counted and colony forming units per gram calculated using the formular:

$$\text{Cfu/g} = \frac{1}{\text{V}} \times \text{N} \times \frac{1}{\text{D}}$$

V = volume of inoculum

N = Number of colonies counted

D = dilution factor

Analysis of physicochemical properties of Abattoir wastewater or effluent

The physico-chemical quality of the abattoir effluent and its contaminated soil were determined using standard methods as described by Ezeronye and Okerentugba (1999) and Ja'afaru *et al.,* (2021). Parameters analyzed included: hydrogen ion concentration (pH), temperature, turbidity, conductivity, total suspended solid, total dissolved solid, dissolved oxygen (DO), biochemical oxygen demand (BOD) and chemical oxygen demand (COD).

Temperature was measured with a mercury in-glass thermometer in the field; pH was determined using pH meter (jenway, U.K 3505). Electrical conductivity of the wastewater sample was determined using a conductivity meter (Jenway, U.K 3505).Total dissolved solids (TDS) were determined using the formular as described by Obijiofor *et al*., (2018).

$$\text{Mg Dissolved solids/L} = \frac{(A - B) \times 1000}{\text{ml sample}}$$

Where A= weight of dried residue + dish Mg

B= weight of dish Mg

A total suspended solid (TSS) was determined using the formular cited by Akan *et al.* (2010).

Dissolved oxygen (DO) was determined using DO meter model Acorn DO using standard methods 4500-OG and recorded as D_1. Biochemical oxygen demand (BOD) was determined after incubation for 5 days at 20°C, using dissolve oxygen meter model Acorn DO using standard methods 5210B and recorded as D5. Biochemical oxygen demand (BOD) is the difference between the two determined oxygen levels (APHA, 1998, Adesina *et al*., (2018). $BOD_5 = D_1 - D_5$. Where D1= dissolved oxygen on day one, D5= dissolved oxygen on day five. Chemical oxygen demand (COD) was determined by the titrimetric method as described by Ogunlade *et al*., (2021).

Analysis of Physicochemical properties of Abattoir contaminated Soil

Soil samples from abattoir contaminated sites and controls were analyzed for the following physicochemical properties: pH, Organic carbon, Organic matter, Total nitrogen content, water holding capacity and particle sizes.

pH was determined using pH-meter Jenwey 3015 as described by Pramod *et al.* (2014). Organic carbon was determined by using the titrimetric method as described by Pramod *et al.* (2014). Organic matter was achieved by the method described by Pramod *et al.* (2014) as cited by Ja'afaru *et al.*, (2021) in which the percentage organic carbon is multiplied by a factor 1.724.

The total nitrogen was determined by Kjeldhal method as adopted my Pramod *et al.* (2014). Water holding capacity was determined using the method described by Saiki *et al.* (2015) as cited by Ja'afaru *et al.*, (2021).

$$\text{WHC} = \frac{W0 - \Delta W}{W0} \times 100\%$$

$$\text{wo} = \frac{V0}{V0+D0} \times 100\% \quad \Delta = \frac{\Delta V0}{V0+D0} \times 100\%$$

Where = V_0 = initial water content of the sample, V_0 = difference in water contents of the sample before and after configuration, D_0 = initial dry mass of the samples, W_0 = final water content (Ja'afaru *et al.*, 2021). Soil particle analysis was done using hydrometer method as described (Drummond *et al.*, 2013).

Statistical Analysis

The data generated was subjected to Analysis of Variance (ANOVA) IBM version 28

RESULTS AND DISCUSSION

Determination of bacterial load of in wastewater and soil samples.

Abattoir wastewater poses a significant threat to water and soil environment as it may harbour high levels of pathogens, organic matter and some chemicals especially those from the detergents used during the washing of the abattoir. This in turn affects the overall homeostasis of the water and soil parameters. Table 1 and 2 presents the results of the consequence of abattoir waste which present an imminent pollution leading to increase in the bacterial load of the waste water and soil environment. Bacterial counts in the abattoir

contaminated waste water were higher than that of the control with the ranges of 5.10 ± 1.2 - 7.90 ± 1.4 $\times 10^5$ cfu/mL. This is similar to the research conducted by Rabah *et al.* (2008) who reported the total viable counts s between $4.9x10^7$ cfu/ml-$7.3x10^7$ cfu/ml of Abattoir Wastewater in Sokoto, Nigeria. Adesemoye *et al.* (2006) also reported high mean bacterial counts in different abattoir contaminated waste waters as $3.32x10^7$cfu/ml and $2.7x10^7$cfu/ml in Agege and Odo respectevely. In another research reported by Ogunnusi and Dahunsi (2014) states categorically that there is high bacterial count in abattoir contaminated effluent with ranges from 4.9 $\times 10^7$ to 7.73× 10^7 cfu/mL from Abattoir Effluents from Oyo, Oyo state, Nigeria. Similar findings were reported by Ezeoha (2010) who reported a mean bacteria count of 3.32 × 10^2 cfu/ mL in waste water collected from Agege abattoir (Nigeria). High bacterial count in the wastewater was due to the rich protein content of the whole blood which serves as a medium for growth of microorganism (Rabah *et al.,* 2008).

The bacterial load of the contaminated soils as presented in Table 2 which were within the ranges of 5.06 ± 1- 7.90 ± 1.5 $\times 10^5$ cfu/g. This is in line with the works of Ja'afaru *et al.* (2021) reported a mean viable bacterial counts of soils within the abattoir as follows blood bank site (6.99 ± 0.01), dung dumping site (7.28 ±0.02) bone dumping site (6.98 ± 0.03) Herd burning site (7.19 ± 0.02) green grass site (6.19 ± 0.03) pens site (6.40 ± 0.02) SPS Selling Point Site (6.30 ± 0.01), waste water site (8.50 ± 0.02) cfu/g, in abattoir environment. This result was in conformity with that of Adesemoye *et al.* (2006) who reported similar high counts of 3.36×10^7 cfu/g of microorganisms from soil samples contaminated with wastewater at Agege and Odo in Lagos, Nigeria. The high counts of both bacteria obtained indicated that the contaminated soil had a high population density than the control soil.

Physicochemical properties of Abattoir wastewater or effluent

Results from this study (Table 3 and 4) have demonstrated that the abattoir effluents significantly affect the physicochemical parameters of both the soil and water.

The physicochemical assessment of abattoir wastewater revealed that the temperatures across all sites ranged from 27 to 30°C. Temperature being one of the most important environmental features in waste water as it controls the characteristics of organisms, solubility of gases and salts in water (Joanne *et al.,* 2011). These findings align with Adeyemo *et al.* (2019), who reported a temperature of 29°C in abattoir contaminated

effluent near the Bodija Municipal Abattoir. Similarly, these results are also consistent with Ire *et al.* (2017), who recorded temperature ranges of 27-30°C in abattoir effluents and their receiving water bodies in Port Harcourt. Furthermore, a recent study by Nfor *et al.* (2022) documented a mean temperature variation of 26-32.4°C in effluents from the Iyi-Etu Amansea Market Settlement in Anambra State. Despite these values being within the permissible limit of < 40°C set by WHO (2013), they may still pose potential environmental and health risks. The Ph values of the abattoir wastewater/ effluent, slightly acidic values were observed ranging from 6.3- 6.5. However, the mean pH level of 6.4 was within the WHO tolerance limits of 6.0-9.0 of wastewater for discharge. This is similar to the work of Elemile *et al.*, (2019a) who observed pH value of approximately 5.7 which is indicating slightly acidic value. However, the value is in concordance with earlier report of Adesina *et al.* (2018) who reported the range of 5.74- 5.93 which is also within the allowable limit of the WHO. Okoye *et al.* (2023) reported a pH range of 6.66–7.78 in a study of Ugwuoba Abattoir Activites on Ezu River, Enugu state, Nigeria. This acidic nature may be due to high waste from the abattoir which includes organic and inorganic components which has the ability of decreasing the pH of the abattoir effluent. pH plays a key part in determining both the qualitative and quantitative abundance of the microorganisms in the environment, (Elemile *et al.* 2019b). The dissolved oxygen (DO), biological oxygen demand (BOD) and chemical oxygen demand (COD) values recorded all showed higher values in both abattoir wastewater and contaminated soils. Though all the values appear to be within the permissible limits for discharge of waste water but that does not guarantee safety of human and the environment. The higher levels of DO, BOD and COD values obtained in this study is in line with the works of Adesemoye *et al.* (2006) who reported high BOD (35 mg/L), COD (142 mg/L) in Agege (Lagos) abattoir. Okoye *et al.* (2023) who reported in a study the chemical oxygen demand (COD) range of (48.0-234.7 mg/L) in Ugwuoba Abattoir Activites on Ezu River, Enugu state, Nigeria. In another research, Ire *et al.* (2017) reported (BOD) values ranging from 120 - 2500 mg/L, chemical oxygen demand (COD) levels ranged from 436- 5240 mg/L and dissolved oxygen values of 2.40 -5.28 mg/L of the Rumuokoro abattoir effluent. Nwogwugwu *et al.* (2022) reported that the effluent sample had a higher BOD, COD and TDS values as 5.10 mg/L, 58 mg/L and 1400 mg/L respectively. These could be attributed to the fact that the effluent usually contains fat, blood, bones, and other soluble and insoluble substances which are rich in nutrients and also support microbial growth Nafaranda, (2005).

Total suspended solids (TSS), total dissolved solids (TDS), and turbidity values in the study area appeared to be higher in the effluent than the control which may not be unconnected to the organic matter released during the abattoir processes. In a similar report by Abdullahi *et al.* (2020) reported high values of TDS (260 mg/L) in waste water of Kasuwan shanu abattoir, Maiduguri. Adesina *et al.* (2018) reported very high range total suspended solids values of 27 - 6,650 (mg/L) and total dissolved solids of 40 - 1,344 (mg/L) in assessing Kara abattoir effluent. In a recent research conducted by Okoye *et al.* (2023) reported total dissolved solids range of 23.90 -112.40 mg/L in a study of Ugwuoba abattoir waste water, Enugu State, Nigeria. This is also in line with the works of Ekanem *et al.* (2016) who reported higher values for TSS (mg/L) (2133.33) in effluent discharge from Karu Abattoir. These attributes effects the environment, human health and infrastructure, it also lead to increase water treatment cost, potential risk of gastrointestinal issues, habitat disruption, reduced visibility and potential toxicity to aquatic life (EPA, 2020). Turbidity, conductivity values in this study appeared to be higher in the abattoir waste water and the contaminated soil than their controls. Turbidity has values within the standard limits, but conductivity values were above the acceptable limits of 1000(uS/cm). This is related to the study conducted by Okoye *et al.* (2023) who reported in a turbidity range of (20.53- 87.33 NTU) in Ugwuoba abattoir water, Enugu state, Nigeria.In a similar report by Abdullahi *et al.* (2020) also reported high electrical conductivity of (1784 µS/cm) in effluent of Kasuwan shanu abattoir, Maiduguri. In a close but related study Ekanem *et al.* (2016) reported higher values for Conductivity of 4007.70 uS/cm in effluent discharge from Karu abattoir which is also above the standard limit of 1000(uS/cm). Nfor *et al.* (2022) reported mean electrical conductivity range of (945-3810 uS/cm) in Iyi-Etu Amansea market settlement effluent, Anambra State. Similarly, these reports disagrees with the works of Akan *et al.* (2022) who reported a lower conductivity values in ranges of 317 -325 µS/cm in the determination of physical and chemical properties of abattoir waste water. The high conductivity values may be as a result the animal tissues, organic matter (manure, urine), paunch content and inorganic compounds like salts and mineral these obviously causes eutrophication, oxygen depletion in water and soil contamination when released on the land, in humans can lead to water borne illnesses and gastrointestinal problems, skin irrigation and long term exposure can possibly risk cancer. (Okoro *et al.,* 2023).

Physicochemical properties of Abattoir contaminated Soil

The physicochemical properties of soil samples contaminated with abattoir effluent presented in Table 2 showed soils to be mainly loamy and sand indicating that the effluent have no effect on the soil textural class. To that effect, such sand can allow high rate of leaching and infiltration of the effluent through the soil fractions. In terms of the chemical properties of the soil which showed low pH values on the effluent contaminated soils and had ranged from 6.06 – 6.89 which indicates that the abattoir effluents had the ability to lower the pH of the soils in all the study sites. This is in conformity with the work of Fatunsin *et al.* (2023) who reported a pH ranges of (5.83−7.65) on the effect of abattoir activities on the quality of the surrounding soil of the Anwai River in Asaba, Nigeria. In a related study Ebong *et al.* (2019) reported a lower pH in abattoir soils which ranged from 4.80 to 5.82 in assessment of abattoir wastes in soil and leafy vegetables. In another related but different report, Ja'afaru *et al.* (2021) reported a slightely alkaline values in soil contaminated with abattoir effluent which ranged between 6.00 and 7.03 while that of the control was slightly higher at 7.18. The lower pH allows for the proliferation of higher number of microorganisms and growth of plants in the abattoir contaminated soils compared to the control soils and that results in the higher bacterial counts and species. The pH of an environment influences the growth and biochemical activities of organisms including microorganisms such as bacteria (Ja'afaru *et al.,* 2021). The study reveals higher organic matter organic matter content in the soil contaminated with effluent with ranges from 1.858- 1.943. This agrees with the study conducted by Fatunsin *et al.* (2023) who reported organic matter content ranges of 0.2494 - 4.7128 the surrounding abattoir soil in Asaba, Nigeria. The range of Organic matter obtained is lower than 6.45 - 11.76% and relatevely close to 1.87 - 2.85% reported by Neboh *et al.* (2013) and Abukabar (2014) in abattoir contaminated soils respectively. It is also in agreement with the works of Ja'afaru *et al.* (2021) who also reported organic matter content of 1.88- 13.85 in abattoir contaminated soils in Yola, Adamawa state. Okeke *et al.* (2020) reported higher values of organic matter in soil samples (6.28- 8.99 %) in Nnobi abattoir contaminated soils in Anambra State. Abattoir effluent contains high levels of organic matter because of the presence of manure, blood and fat, the nature and composition of abattoir effluents are high organic content sufficient organic nutrients, relatively high temperature (Mohammed and Musa 2012). Organic carbon (org C), total nitrogen (TN) and water holding capacity content of the contaminated soil had shown to be all higher than the control soils with ranges in

percentages of (1.078 - 1.127) , (0.094- 0.102), (12000 - 13000) in contaminated soil. This conforms with the works of Ja'afaru *et al.*, (2021) who reported higher values of organic carbon, total nitrogen and water holding capacity in abattoir contaminated sites in soils in Adamawa state, with organic matter ranging from (11.68 – 13.58%), total nitrogen (2.00-33.46%) and water holding capacity (23.11 -33.46%) . This is also agrees the work of Ebong *et al.* (2019) who reported higher organic matter content from different abattoirs soils higher than the control with ranges of (1.64 - 30.05%) and mean values of a mean value of (6.77± 1.64%) in the contaminated soils. Similarly, the nitrogen content of the effluent contaminated soil was high and ranged from (0.094 - 0.102). This is attributed to the impact of abattoir waste products on the studied soils or the fecal wastes present in the effluent including urine and other blood components (Saiki *et al.*, 2015).

Table 1. Mean Bacterial Count of Abattoir wastewater and control in the Study area.

Sites	Mean Bacterial count in waste water			
	Wastewater ($x10^5$cfu/mL)		Control ($x10^5$cfu/mL)	
Ganye	6.13±1.0		3.97±0.6	
Jimeta	7.90±1.4	F = 3.3	4.63±1.5	F = 7.1
Mubi	5.10±1.2		4.4±0.98	

Table 2. Mean bacterial Count of Abattoir contaminated soil and control in the Study area

Sites	Mean Bacterial count in soil			
	Abattoir soil ($x10^5$cfu/g)		Control ($x10^5$cfu/g)	
Ganye	5.23±1.10		3.30±1.0	
Jimeta	7.90±1.5	F = 4.3	6.63±1.5	F = 1.1
Mubi	5.06±1.0		4.40±0.9	

Table 3. Physico-chemical properties of abattoir waste water and control of the study area.

	GANYE		JIMETA		MUBI		
Parameters	Abattoir w/w	Control	Abattoir w/w	Control	Abattoir w/w	Control	Standard limit (WHO Standard)
Temperature ^{0}C	28	28	30	29	27	27	40
Color	Ox-blood	Colourless	Ox-blood	Colourless	Ox-blood	Colourless	NA
Odour	Offensive	Odourless	Offensive	Odourless	Offensive	Odourless	NA
Appearance	Turbid	Non-turbid	Turbid	Non-turbid	Turbid	Non-turbid	NA
Ph	6.4^a	6.2^a	6.5^b	6.4^b	6.3^c	6.4^c	6-9
Turbidity (NTU)	21.05^a	8.10^a	23.40^b	10.00^b	21.00^a	7.00^c	NA
Conductivity(µS/cm	1125^a	1050^a	1550^b	1001^c	1005.9^b	950^c	1000
TDS(mg/l)	834.3^a	680^b	849^b	511^c	837^a	730c	2000
TSS(mg/l)	2980^a	1600a	3112^b	1932^b	2930^b	1965^c	1000
DO(mg/l)	63.20^a	58.10^a	62.20^b	68.90^b	73.00^b	61.00^c	75
BOD(mg/l)	120.10^a	83.20^b	124^a	94^b	123.01^a	91.00^b	50
COD(mg/l)	91.60^a	58.00^a	95^b	64^c	90.30^a	73.05^c	80

KEY: DO: dissolved oxygen, BOD: biochemical oxygen demand, COD: chemical oxygen demand, µS/cm: micro Siemens per centimeter. TDS: total dissolved solids, TSS: total suspended solids, W/W: waste water, NA: not applicable

a, b, c: means with different alphabets denotes significance at p = 0.05

Table 4. Physicochemical properties Soils contaminated with abattoir wastewater in the study area

SITES	GANYE		JIMETA		MUBI	
Parameters	CTD Soil	Control	CTD Soil	Control	CTD Soil	Control
Ph	6.06^a	6.12^a	6.63^b	6.87^b	6.89^c	7.03^c
Org. C (%)	1.122^a	1.061^a	1.078^b	1.017^b	1.127^c	1.024^c
Org. M (%)	1.935^a	1.829^a	1.858^b	1.754^b	1.943^c	1.765^c
TN (%)	0.101^b	0.096^a	0.094^a	0.097^a	0.102^b	0.111^b
WHC (%)	12.200^a	11.000^a	10.000^b	13.000^b	10.200^c	12.000^c
Sand (%)	64.2^a	75.2^a	80^b	51^b	78.2^c	71.2^c
Silt (%)	30.8^a	8.8^a	6^b	15^b	5.8^b	17.8^c
Clay (%)	5^a	16^a	14^b	34^b	16^b	11^c
Textural classes	Sandy loam	Sandy loam	Sandy loam	Sandy clay loam	Sandy loam	Sandy loam

KEY: ORG.M: Organic matter, TN: total nitrogen, WHC: water holding capacity, ORG. C: organic carbon, CTD: contaminated soil

a, b, c: Means with different alphabets denotes significance at p = 0.05

CONCLUSION

The physicochemical analysis of abattoir wastewater and its contaminated soils from three abattoirs in different parts of Adamawa State showed that the quality of waste water and soil is negatively affected by the activities of the abattoir. The results indicated that most of the parameters analyzed were within the permissible limits for discharge or disposal but their effect cannot be overlooked as gradual bioaccumulation could still be dangerous as the case may be. Nevertheless, it has clearly indicated that in both the wastewater and soil contaminated with abattoir waste values were extremely high compared to the control samples which is an indication of pollution by the content of the waste from the abattoir. The high protein content in the abattoir waste which contains blood, organic and inorganic components seems to be reason behind the high content of all the parameters analyzed.

Generally, contamination of the surrounding soil and water environment by abattoir wastes significantly disrupts environmental parameters and homeostasis, potentially impacting the ecosystem of these areas. In light of these findings, we recommend that abattoir effluents/wastewater in the study area be treated before discharge or disposal into the environment. Additionally, wastewater treatment plants should be constructed for all abattoirs nationwide, supported by a legally enforceable policy framework. Finally, relevant agencies should implement aggressive public awareness to enlighten the public on the dangers associated with pollution from abattoir wastes.

Competing interests

The authors declare that no conflict of interest exists.

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