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Effect of Abattoir Waste Water on Physico-chemical Characteristics of Soil and Sediment in Southern Nigeria

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Authors' contributions

This work was carried out in collaboration between both authors. Author DNO designed the study, managed the literature and wrote the first draft of the manuscript. Author TJKI managed the analysis, performed the statistical analysis and wrote the final manuscript. Both authors read and approved the final manuscript.

Original Research Article

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ABSTRACT

Aim: The study was carried out to evaluate the biophysical properties of samples contaminated by abattoir wastes. The study aims to determine the physico-chemical properties of samples contaminated by abattoir wastes in order to create public awareness about the state and health implications of abattoir activities on the environment.
Study Design: Abattoirs close to Rivers and creeks that discharge wastes into water bodies were selected in comparison with those not close to such water bodies.
Place and Duration of Study: The study was carried out in abattoirs Located at Ogbe in Ahiazu-Mbaise Local Government Area, Egbu in Owerri North Local Government Area both in Imo State, Nigeria; Trans-Amadi in Port Harcourt City Council and Ahoada in Ahoada East Local Government Area both in Rivers State, Nigeria. The study covered two seasons, rainy and dry seasons between 2010 and 2011.
Methodology: A total of thirty six sampling points were considered for the study. Soil and waste water samples were collected from four abattoirs located at Egbu and Ogbe in Imo state, Trans-Amadi and Ahoada in Rivers State. Sediment samples from Otamiri River

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and Oginigba Creek around Egbu and Trans-Amadi abattoirs respectively were collected using standard methods recommended by the American Public Health Association (APHA) and other international methods were adopted for the determination of physiochemical characteristics of the samples.

Results: The range of results obtained were 6.71 – 9.37 for pH, 20.0 – 30.4^oC for temperature, 165 – 6,080 mg/l for total suspended solids (TSS), 155 – 1,560 mg/l for total dissolved solids (TDS), 75 – 12,000 mg/l(water) and mg/kg(soil) for biochemical oxygen demand (BOD), 100 – 22,500 mg/l(water) and mg/kg(soil) for chemical oxygen demand (COD), 150.2 – 9,265 mg/l(water) and mg/kg(soil) for SO_4^{2-}, 0.45 – 90.75 mg/l(water) and mg/kg(soil) for PO_4^{3-}, 0.35 - 308.89 mg/l(water) and mg/kg(soil) for NO_3^-, 4.12 – 45.7 mg/l(water) and mg/kg(soil) for Na, 0.26 – 106 mg/l(water) and mg/kg(soil) for K and 0.00 – 2.551 mg/l(water) and mg/kg(soil) for Polycyclic Aromatic Hydrocarbon (PAH). The results generally showed significant differences, at 0.05 confidence limits, between test and control samples of soil and waste water, while the reverse was the case between rainy and dry seasons.

Conclusion: The study indicated negative impact of abattoir activities on the soil that receive wastes from abattoirs which is probably because effective waste disposal system is not practiced by abattoir operators. The study showed that abattoir wastes have high pollution strength and thus should be treated before being discharged into the environment.

Keywords: Abattoir wastes; soil; sediment; physico-chemical; test sample; Nigeria.

1. INTRODUCTION

Abattoir operations produce characteristic highly inorganic wastes such as sulphates, phosphates, etc with relatively high levels of suspended solid, liquid and fat. The solid waste includes condemned meat, undigested food materials, bones, hairs and aborted foetuses. The liquid waste is usually composed of dissolved solids, blood, gut contents, urine and water [1]. As a result of inadequate waste treatment facilities [1], wastes from abattoir are deposited on the land or channeled into water resource leading to pollution. Furthermore, [2] reported that in many countries, pollution arises from activities in meat production as a result of failure in adhering to Good Manufacturing Practices (GMP) and Good Hygiene Practices (GHP). To adhere to GMP and GHP, [2] suggested that during dressing, the oesophagus of cattle and sheep should be sealed to prevent leakage of gut content [2], further reported that the inability to observe this unhealthy condition could lead to contamination of meat from hides, hooves and content of alimentary tract during evisceration and negatively impact on the environment. In essence, slaughter activities, if not properly controlled, may pose dangers to the farmers, butchers, the environment as well as the consumers [3,4,5].

The major activities involved in the operations of an abattoir include; receiving and holding of livestock; slaughter and carcass dressing of animals; chilling of carcass products; carcass boning and packaging; freezing of finished carcass and cartooned product; rendering processes; drying of skins; treatment of wastes and transport of processed material. These meat processing activities in Nigeria are mostly carried out in unsuitable buildings and by untrained personnel or butchers who are mostly unaware of sanitary principles [6]. Abattoir activities are aimed at optimizing the recovery of edible portions of the meat processing cycle for human consumption. However, significant quantities of secondary waste materials; blood, fat, organic and inorganic solids, salts and chemicals wastes are also generated during this process [7,8].

Abattoir effluent wastewater has a complex composition and can be very harmful to the environment. For example, discharge of animal blood into streams would deplete the dissolved oxygen (DO) of the aquatic environment. Improper disposal of paunch manure may exert oxygen demand on the receiving environment or breed large population of decomposers (micro-organisms) which may be pathogenic. Furthermore, improper disposal of animal faeces may cause oxygen-depletion in the receiving environment. It could also lead to nutrient-over enrichment of the receiving system and increase rate of toxins accumulation in biological systems [9]. A specific example of what happens is logging of contaminated water in the soil. In that situation, oxygen becomes less available as an electron acceptor, prompting denitrifying bacteria to reduce available nitrate into gaseous nitrogen which enters the atmosphere with resultant negative effects. Also, anaerobic archaea (methanogens), may produce excessive methane at a higher rate than aerobic methane oxidizing bacteria (methanotrophs) could cope with, thus contributing to green house effect and global warming. Increase in methane is a concern because it is five times more effective as a green house gas than CO_2 [10,11,12,13]. Leaching into groundwater is a major part of the concern, especially due to the recalcitrant nature of some contaminants [14,15,10,16,17]. The processes of adsorption and trapping by fine sandy materials, clays and organic matter can remove pathogenic organisms and some dissolved organic matter during passage of polluted water through the soil, thus reducing the microbial load. [18] reported that abattoir effluent increased pH, available P significantly in the soil whilst exchangeable cations were reduced significantly.

Polycyclic aromatic hydrocarbons (PAHs) or polynuclear aromatic hydrocarbons are chemical compounds that are widely distributed as environmental contaminants that have detrimental biological effects, including acute and chronic toxicity, mutagenicity and carcinogenicity [19,20]. PAHs are emitted mainly from anthropogenic sources which include heat and power generation from coal and other fossil fuels, coal production, petroleum refining, cracking of crude petroleum, incineration of industrial and domestic wastes and chemical manufacturing [19]. PAHs in soil can arise from a number of sources which include hydrocarbon spillage, incomplete combustion of fossil fuels for example wood burning and burning of tyres [19].

This study aims to determine the physico-chemical properties of samples contaminated by abattoir wastes. The results will create public awareness about the state and health implications of abattoir activities on the environment.

2. MATERIALS AND METHODS

2.1 Study Areas

The study was carried out in abattoirs located at Ogbe in Ahiazu-Mbaise Local Government Area, Egbu in Owerri North Local Government Area both in Imo State, Nigeria; Trans-Amadi in Port Harcourt City Council and Ahoada in Ahoada East Local Government Area both in Rivers State, Nigeria Fig. 1. Ogbe and Egbu abattoirs are the two major abattoirs in Imo State. They are managed by Local Government authorities. Ogbe lies within longitude 05^0 $31.965^/$ - 05º $32.890^/$ N and latitude 007º $15.695^/$ - 007º $18.010^/$E, while Egbu lies within longitude 05º $28.432^/$ - 05º $29.802^/$N and latitude 007º $03.200^/$ -007º $04.215^/$E. These areas have a tropical climate. The average relative humidity is about 80%. The inhabitants of the areas are mainly farmers, civil servants, petty traders and casual workers.

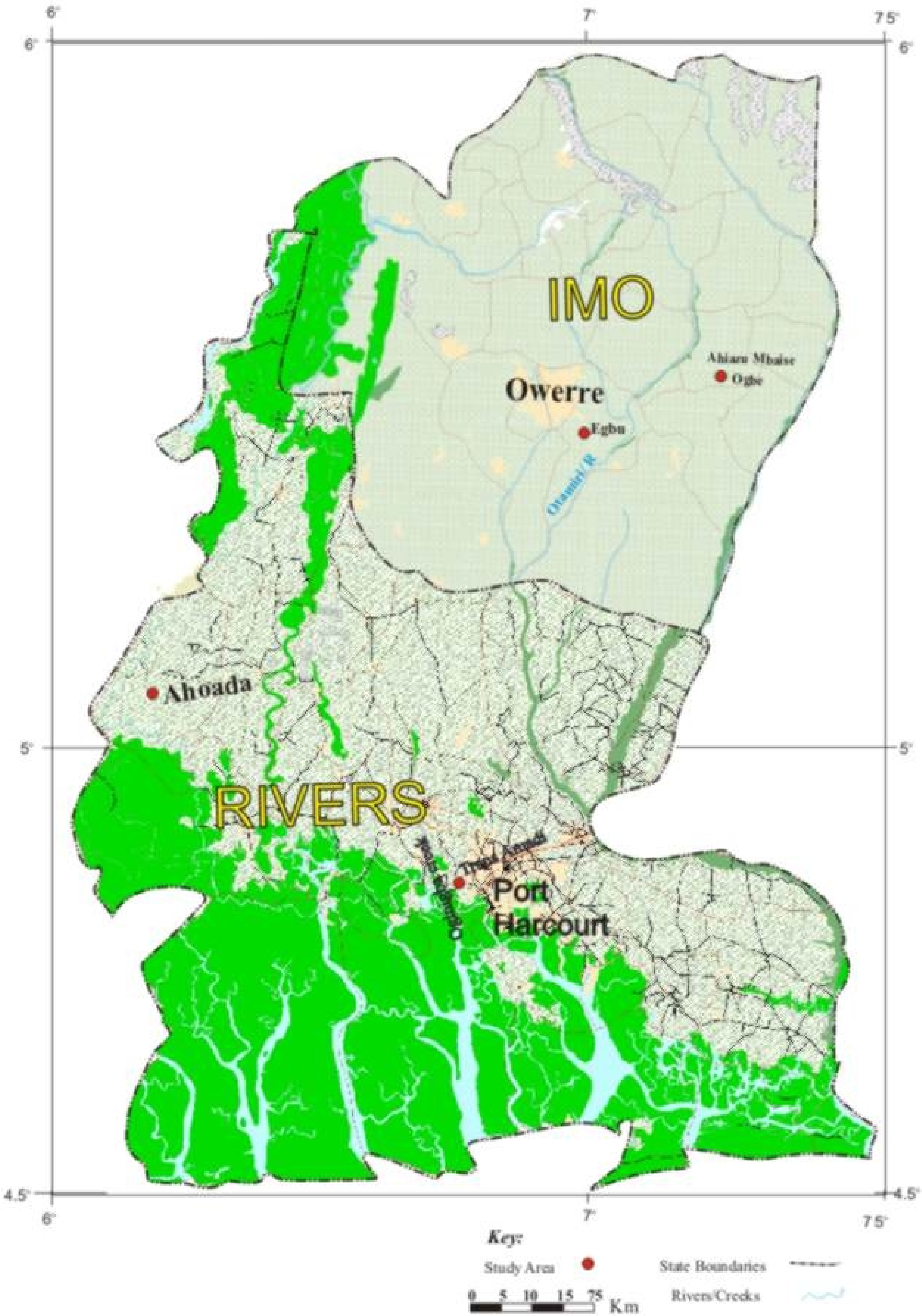

Fig. 1. Map of Imo and Rivers State showing the study area

Port Harcourt city lies within longitude 4º 48.442$^{/}$-4º 49.444$^{/}$N and latitude 007º 02.303$^{/}$ – 007º 03.545$^{/}$E. The climate of Port Harcourt falls within the sub equatorial climate belt. Temperature and humidity are high throughout the year. The area is marked by two distinct seasons, the rainy season and the dry season, with 70% of the annual rain falling between April and August, while 22% is spread in the three months of September to November. However, the driest months are from December to March. Ahoada in Ahoada East Local Government Area lies with longitude 4º 28.222$^{/}$- 4º 50.111$^{/}$ N and latitude 006º 43.122$^{/}$-007º 04.225$^{/}$ E. The inhabitants of the area are mainly civil servants, traders and farmers.

2.2 Sampling Points

A total of thirty six (36) sampling points were considered for the study. The sampling stations, sampling points' codes, sampling points' coordinates and types of samples collected are presented in Table 1 [21]. During sample collection, Global Positioning System (GPS) machine (Model GPS 76) was used for the location of the sampling points.

2.3 Sample Collection

2.3.1 Soil samples

Soil samples were collected from four different sampling points coded A, B, C and D from a depth of 0-15cm using a soil auger. About 500g of bulked composite soil samples from soil samples collected from points A, B and C was prepared using the method of [22]. Soil sample from point D, which is about 200m from Ogbe, Egbu, Ahoada abattoirs and 400m from Trans Amadi abattoir served as control sample. The samples were stored in polyethylene bags. Immediately after collection, the samples were labeled and transported to the laboratory for preparation and analysis.

2.3.2 Sediment samples

Sediment samples were collected using a grab sampler. The grab sampler was thoroughly rinsed with water sample to remove any visible sediment before and after use. At each sampling point, the sampler was lowered to the water bed and the topmost layer of the sediment heaved out. The sediment sample was scooped from the grab's cup and transferred into sterile sample bottle. The sample was labeled and then transported to the laboratory in a cooler packed with ice blocks for analysis.

2.3.3 Waste water Samples

Waste water samples were collected using the method of [2]. Sterile 2.0 litre sample bottles were used to aseptically collect part of the abattoir waste water. The samples were collected at four different points coded A, B, C and D as the waste water was running off the drainage system. About 500ml of the sample collected from each point were pooled together to get a composite sample. Control samples were collected from water stored in buckets used for washing meat and utensils in the abattoirs. After collection, the samples were placed in a cooler containing ice blocks and transported immediately to the laboratory for analysis.

Table 1. Identification of sampling stations and points

Sampling Stations	Sampling Points codes	Sampling point Co-ordinates		Types of Samples
		Northing (N)	Easting (E)	
Ogbe Abattoir I	A	05º 31.965′	007º 16.901′	Soil(Test sample)
	B	05º 32.800′	007º 15.800′	Soil (Test sample)
	C	05º 32.890′	007º 15.695′	Soil (Test sample)
	D	05º 32.065′	007º 17.001′	Soil (Control)
Ogbe Abattoir II	A	05º 31.884′	007º 6.964′	Waste water
	B	05º 31.665′	007º 16.335′	Waste water
	C	05º 31.578′	007º 16.315′	Waste water
	D	05º 33.000′	007º 18.010′	Waste water
Egbu Abattoir I	A	05º 28.432′	007º 03.200′	Soil(Test sample)
	B	05º 28.441′	007º 03.209′	Soil(Test sample)
	C	05º 28.582′	007º 03.312′	Soil(Test sample)
	D	05º 28.559′	007º 3.231′	Soil (Control)
Egbu Abattoir II	A	05º 29.651′	007º 04.205′	Waste water
	B	05º 29.668′	007º 04.215′	Waste water
	C	05º 29.705′	007º 04.285′	Waste water
	D	05º 29.802′	007º 04.918′	Waste water
Otamiri River	A	05º 28.426′	007º 03.179′	Surface water and Sediment (Test Sample)
	B	05º 27.423′	007º 04.156′	Surface water and Sediment (Control)
Trans-Amadi Abattoir I	A	04º 48.886′	007º 2.707′	Soil(Test sample)
	B	04º 48.782′	007º 2.608′	Soil(Test sample)
	C	04º 48.615′	007º 2.405′	Soil(Test sample)
	D	04º 48.442′	007º 2.303′	Soil(Control)
Trans-Amadi Abattoir II	A	04º 49.789′	007º 03.801′	Waste water
	B	04º 49.628′	007º 03.702′	Waste water
	C	04º 49.522′	007º 03.665′	Waste water
	D	04º 49.444′	007º 03.545′	Waste water
Oginigba Creek	A	04º 50.001′	007º 04.425′	Surface water and Sediment (Test Sample)
	B	04º 50.111′	007º 04.225′	Surface water and Sediment (Control)
Ahoada abattoir I	A	04º 40.126′	006º 45.278′	Soil (Test sample)
	B	04º 39′ 101″	006º 44′ 118″	Soil (Test sample)
	C	04º 28′ 222″	006º 43′ 122″	Soil (Test sample)
	D	04º 30′ 750″	006º 42′ 101″	Soil (Control)
Ahoada abattoir II	A	04º 40′ 278″	006º 44′ 216″	Waste water
	B	04º 32′ 201″	006º 44′ 003″	Waste water
	C	04º 35′ 002″	006º 43′ 100″	Waste water
	D	04º 31′ 650″	006º 41′ 222″	Waste water

2.4 Preparation of Samples

The sediment and soil samples were processed using the method of [2]. Ten grams each of the soil and sediment samples were weighed and added to 90ml of sterile distilled water to get an aliquot. One milliliter of the aliquots, waste water samples were then serially diluted using the ten-fold serial dilution method as described by [23].

2.5 Analysis of Waste Water Samples for Physicochemical Properties

Samples were analysed for the following physico-chemical parameters: hydrogen ion concentration, temperature, turbidity, total suspended solid, total dissolved solid, biochemical oxygen demand (BOD), chemical oxygen demand (COD) and conductivity according to methods used by [2]. The pH value of the samples were determined with a pH meter (Unicam 9450, Orion model No. 91-02). Temperature was measured with mercury thermometer immediately after sample collection. Turbidity was determined with Milton Roy (USA) Spectronic 20D meter. Gravimetric method involving filtration and evaporation were used to measure total suspended solids and total dissolved solids. Methods recommended by [24] were followed for the measurement of BOD and COD. Wastewater sample was drawn into a 250 ml bottle, incubated in the dark for five days at $20^{o}C$ and at the end of five days, the final dissolved oxygen (DO) content was determined. Decrease in DO between the final DO reading and the initial DO reading was corrected for sample dilution and recorded as the BOD of the sample. The COD was estimated by determining equivalent amount of oxygen required to oxidize organic matter in the samples. Conductivity was determined using a conductivity meter (Metrohm 640, Switzerland).

3. RESULTS AND DISCUSSION

3.1 Results

The results of the physico-chemical parameters monitored from samples collected at Egbu abattoir during the rainy and dry seasons are shown in Table 2. The rainy season results showed a slight variation in the pH and temperature values in the samples analyzed. There was high significant differences in the turbidity, total suspended solids and dissolved solids values obtained from the samples. Equally, there were high significant differences in the values of biological oxygen demand (BOD), chemical oxygen demand (COD), conductivity, phosphate and nitrate, while reverse was the case for sulphate that appeared highest in the abattoir soil sample. Statistical analysis using ANOVA at 0.05 confidence limit, also indicates a high significant difference in the levels of total organic carbon, potassium and polycyclic aromatic hydrocarbons (PAHs) with the highest values obtained from the abattoir soil sample. However, result also indicates slight differences statistically in the values obtained for chloride, sodium, calcium and magnesium from the samples analysed. Comparing the physicochemical values of the test and control samples using t-test at 0.05 confidence limit it was noticed that there was significant difference in the turbidity levels of the test and control samples of waste water. The same trend was applicable to total suspended solids and total dissolved solids of the abattoir waste water (test and control samples). However, while there was no difference statistically in the biological oxygen demand (BOD) levels of test and control samples of Otamiri sediment, differences existed statistically in the chemical oxygen demand (COD) from the tests and controls of all the samples analysed.

Of all the samples, test and control samples of Otamiri sediment and abattoir soil did not show significant difference in their conductivity and sulphate levels, respectively. Phosphate levels of test and control samples of Otamiri sediment and abattoir waste water showed significant difference. There was no statistical difference in the alkalinity levels of test and control of all the samples. Analysis showed statistical difference only in the nitrate and potassium levels of abattoir waste water and its control sample, while abattoir soil and its control sample did not show any significant difference in their total organic carbon content. Polycyclic aromatic hydrocarbons (PAHs) showed high level of significant difference in the test and control of all the samples analysed.

The dry season results showed that waste water sample had the highest values of pH, turbidity, total suspended solids and total dissolved solids while temperature was highest in the soil sample. Statistically, using ANOVA, there was significant difference in the values of these parameters obtained from all the samples analysed. Statistical analysis also showed significant differences in the values of biological oxygen demand (BOD), conductivity and alkalinity which recorded highest values in the waste water. The same was applicable to sulphate, phosphate, nitrate, chloride which appeared most in the soil and chemical oxygen demand (COD) that appeared most in Otamiri sediment sample. The results also revealed that although total organic carbon appeared most in the soil, the values were not highly significant in all the samples. Also high significant difference existed in the values of potassium, calcium, magnesium and polycyclic aromatic hydrocarbons (PAHs) which had highest value in the abattoir soil. Statistical difference existed in the values of sodium which appeared most in the waste water. Further analysis of data using t-test showed that there was no statistical difference in the pH values of test and control of Otamiri sediment. Turbidity values from test and control samples of abattoir waste water showed high level of significant difference. There was no significant difference in the alkaline value of all the samples, but existed in the chloride levels of the test and control samples of abattoir soil and waste water. There was significant difference at 0.05 in the magnesium, polycyclic aromatic hydrocarbons (PAHs) levels obtained from all the samples. Statistical analysis also showed difference in the manganese levels of test and control samples of abattoir soil; lead levels of test and control samples of abattoir soil.

The results in Table 3 depict the physicochemical characteristics of waste water and soil samples collected from Ogbe abattoir in the rainy and dry seasons. In the rainy season statistical analysis using ANOVA showed high significant differences in the levels of physicochemical parameters from waste water and soil samples. The results also revealed that the waste water had higher values of turbidity, total suspended solids, total dissolved solids, biological oxygen demand (BOD), chemical oxygen demand (COD) and conductivity, while the soil had higher values of pH, temperature, sulphate, phosphate, nitrate and alkalinity. Also, there were high values of chloride, total organic carbon, sodium, magnesium, calcium, potassium and polycyclic aromatic hydrocarbons (PAHs) in the soil than waste water.

Comparing the test and control results using t-test at 0.05 confidence limit, it was observed that there was significant difference in the pH values from all the soil and waste water samples similarly there was significant difference in the levels of turbidity, temperature, total suspended solids, total dissolved solids and biological oxygen demand (BOD) in the test and control samples. However, while there was no significant difference in the chemical oxygen demand (COD) and lead levels in the tests and control samples, significant difference existed in the levels of conductivity between the test and control soil samples. Levels of sulphate, phosphate, nitrate, chloride total organic carbon and calcium in the tests and control samples were highly significant at 0.05. While levels of polycyclic aromatic hydrocarbons (PAHs), potassium, sodium and alkalinity in the test and control waste water showed high significant difference.

The dry season results indicate higher levels of pH, temperature, sulphate, phosphate, nitrate, chloride, total organic carbon, sodium, potassium, calcium, magnesium and polycyclic aromatic hydrocarbons (PAHs) in the soil sample, while the reverse was the case for turbidity, total suspended solids, total dissolved solids, biological oxygen demand (BOD), chemical oxygen demand (COD), conductivity and alkalinity. Statistical analysis using ANOVA at 0.05 confidence limit, indicate high statistical differences in the level of all the parameters detected in the soil and waste water samples. At 0.05, statistical analysis using t-test did not show any significant difference in the pH, temperature, total organic carbon, calcium values from test and control samples of abattoir soil and waste water. The same statistical analysis showed high level of difference in the turbidity, total suspended solids, total dissolved solids, conductivity, phosphate, nitrate, alkalinity, chloride, sodium and polycyclic aromatic hydrocarbons (PAHs) values from test and control samples of abattoir waste water while the reverse was the case for abattoir soil. However, while there was difference statistically in the biological oxygen demand (BOD), chemical oxygen demand(COD), sulphate and manganese values from test and control samples of both abattoir soil and waste water, differences existed in the magnesium and potassium values of test and control of abattoir soil sample while the reverse was the case for abattoir waste water.

Subjecting the test and control values to statistical analysis using t-test at 0.05 confidence limit, it was observed that no statistical difference existed between the temperature values of test and control of all the samples while alkalinity and total suspended solids showed difference statistically in the test and control samples of abattoir waste water. While total organic carbon, chloride and biological oxygen demand (BOD) levels in the test and control samples of abattoir soil did not show significant difference, there was high significant difference in the level of conductivity, chemical oxygen demand (COD), sulphate, phosphate, nitrate, sodium, magnesium, calcium, and potassium obtained from tests and controls of all the samples analyzed.

The results of the physico-chemical parameters monitored from samples collected at Trans Amadi abattoir during the rainy and dry seasons are shown in Table 4. The rainy season results showed a clear significant difference (ANOVA) in the pH and turbidity level from all the samples, with soil and waste water having the highest values, respectively. While there was slight difference in the temperature values, waste water recorded higher levels of suspended and dissolved solids. The trend was the same for BOD and COD that had highest levels in the abattoir waste water.

The soil recorded higher values for sulphate, phosphate and nitrate while Alkalinity and chloride appeared most in the waste water. However, Oginigba Creek sediment had highest level of sodium, magnesium and calcium followed by Trans-Amadi abattoir soil. But while potassium appeared most in the abattoir waste water, polycyclic aromatic hydrocarbons (PAHs) appeared most in the abattoir soil. Statistical analysis using ANOVA indicated that statistical difference existed in the level of the above mentioned parameters in the abattoir waste water, soil and sediment.

Subjecting the test and control values to statistical analysis using t-test at 0.05 confidence limit,, it was observed that no statistical difference existed between the temperature values of test and control of all the samples while alkalinity and total suspended solids showed difference statistically in the test and control samples of abattoir waste water. There was equally statistical difference between the pH values obtained from test and control samples of Oginigba Creek sediment and abattoir soil; polycyclic aromatic hydrocarbons (PAHs) from test and control samples of Oginigba Creek sediment and abattoir waste water. While total organic carbon, chloride and biological oxygen demand (BOD) levels in the test and control samples of abattoir soil did not show any significant difference, there was high significant difference in the level of conductivity, chemical oxygen demand (COD), sulphate, phosphate, nitrate, sodium, magnesium, calcium and potassium obtained from tests and controls of all the samples analysed.

The dry season results showed that turbidity, total suspended and dissolved solids and biological oxygen demand (BOD) appeared most in the abattoir waste water. Abattoir soil had the highest level of pH, while temperature and chemical oxygen demand (COD) were highest in the Oginigba Creek sediment. However, there was no significant difference (ANOVA) in the conductivity values obtained from the soil and Oginigba Creek sediment. Abattoir soil sample recorded the highest level of sulphate, phosphate and nitrate, followed by sediment from Oginigba Creek. Abattoir waste water and abattoir soil had the highest values of alkalinity and chloride, respectively. But, while abattoir soil had more organic carbon (total) and polycyclic aromatic hydrocarbons (PAHs), sediment from Oginigba Creek had more sodium, magnesium, calcium and potassium.

Chemical oxygen demand (COD), phosphate and magnesium level of test and control samples of abattoir soil were not significantly different, reverse was the case for sodium and conductivity level from Oginigba Creek sediment. Likewise, among the three samples (sediment, soil, and waste water), polycyclic aromatic hydrocarbons (PAHs).. However, there was significant difference in the biological oxygen demand (BOD), sulphate, nitrate, chloride, total organic carbon, calcium and potassium levels in the test and control of all the samples analyzed.

The results of the physico-chemical parameters monitored from samples collected at Ahoada abattoir during the rainy and dry seasons are shown in Table 5. The rainy season results showed that soil recorded higher level of pH than the abattoir waste water, while the two samples had equal level of temperature. Waste water had values of 18.56 (NTU), 4120 mg/l, 6680 mg/l and 600mg/l for turbidity, total suspended solid, total dissolved solid and alkalinity, respectively. Biological oxygen demand (BOD), chemical oxygen demand (COD), conductivity and sulphate had more levels in the waste water compared to that in the abattoir soil, while reverse was the case for phosphate and nitrate. The results also showed that the soil had more chloride, total organic carbon, sodium, magnesium, calcium, potassium and polycyclic aromatic hydrocarbons (PAHs) than the waste water. Statistical analysis (ANOVA) at 0.05 confidence limit, indicates that statistical difference existed in the level of these parameters obtained from the soil and waste water.

Further statistical analysis using t-test indicates that there was no statistical difference at 0.05 confidence limit in the temperature, total suspended solid and alkalinity values obtained from tests and controls of the abattoir soil and waste water analysed. Turbidity, total dissolved solid, biological oxygen demand (BOD), chemical oxygen demand (COD) and nitrate levels were only significantly different in the test and control of soil sample. Comparing the level of conductivity, sulphate, phosphate, chloride, total organic carbon, sodium, magnesium, calcium, potassium, polycyclic aromatic hydrocarbons (PAHs), it was found that statistical difference existed in the tests and controls of both abattoir soil and waste water samples.

Table 2. Physicochemical characteristics of samples contaminated by Egbu abattoir wastes (rainy and dry seasons)

Parameters	Waste water				Soil				Otamiri Sediment			
	Test		Control		Test		Control		Test		Control	
	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry
pH	8.01	8.17	7.10	7.80	7.25	8.06	7.10	7.50	7.20	7.17	7.05	7.30
Turbidity (NTU)	18.65	18.40	11.12	11.15	ND	ND	ND	ND	ND	ND	ND	ND
Temperature (°C)	28.0	28.5	28.0	28.5	27.10	28.8	27.0	27.6	27.0	28.6	27.2	27.4
Total Suspended Solids (mg/l)	3750.0	3740.00	2001	2005	ND	ND	ND	ND	ND	ND	ND	ND
Total Dissolved Solids (mg/l)	900.0	920.00	450.0	501.2	ND	ND	ND	ND	ND	ND	ND	ND
BOD (mg/kg, mg/l)	2405.0	2400.0	980.0	995.6	750.00	800.00	600.0	680.11	1152	201.00	505.0	650.1
COD (mg/kg, mg/l)	3700.0	3504.0	1250.0	1150.0	4850.00	5000.00	4050.2	3980.9	16500.0	17000.0	15500.0	16005.0
Conductivity(μs/cm)	1130.0	1145.00	881.2	926.5	730.00	726.00	680.00	690.0	19.0	23.00	18.01	20.11
SO_4^{2-}(mg/kg, mg/l)	365.0	289.30	201.5	225.0	9000.00	9265.57	7800.0	8480.1	800.6	964.50	702.5	820.3
PO_4^{3-} (mg/kg, mg/l)	2.80	2.64	1.50	1.70	70.00	74.25	59.00	61.01	30.50	35.89	30.01	32.00
NO_3^- (mg/kg, mg/l)	41.00	35.30	29.0	28.05	24.00	251.48	205.00	215.00	160.0	150.00	140.0	138.0
Alkalinity (mg/l)	550.00	260.00	500.0	550.0	ND	ND	ND	ND	ND	ND	ND	ND
Cl^- (mg/kg, mg/l)	490.00	472.00	380.0	385.0	4400.0	4500.00	4350.0	4320.0	1405.0	1400.00	1300.0	1306.0
TOC (mg/kg, mg/l)	0.065	0.055	0.005	0.003	2.95	291.00	2.80	2.75	0.19	0.30	0.15	0.23
Na (mg/kg, mg/l)	7.96	8.52	3.59	5.64	7.90	7.82	7.80	7.58	7.00	7.14	7.00	7.02
K (mg/kg, mg/l)	1.09	0.664	1.00	1.05	8.00	7.98	8.00	7.75	6.01	5.36	6.00	5.18
Ca (mg/kg, mg/l)	0.870	0.885	0.501	0.605	140.80	136.75	130.00	135.09	100.4	120.50	98.5	110.6
Mg (mg/kg, mg/l)	0.120	0.118	0.100	0.105	74.00	70.80	71.00	68.03	45.6	50.40	40.1	38.04
PAH (mg/kg, mg/l)	0.058	0.069	0.000	0.001	2.440	2.442	1.400	0.000	0.095	0.090	0.065	0.060

KEY: BOD = Biological Oxygen Demand. COD = Chemical Oxygen Demand. PAHs =Polycyclic Aromatic Hydrocarbons. TOC = Total Organic Carbon. ND = Not Done

Table 3. Physicochemical characteristics of samples contaminated by Ogbe abattoir wastes (rainy and dry season)

Parameters	Waste water				Soil			
	Test		Control		Test		Control	
	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry
pH	8.58	8.20	8.05	8.5	9.21	9.20	8.7	9.00
Turbidity (NTU)	20.80	19.10	10.5	11.5	ND	ND	ND	ND
Temperature (°C)	28.50	27.10	27.5	27.5	29.10	28.00	28	28.7
Total Suspended Solids (mg/l)	5980.00	5650.00	190.5	301.0	ND	ND	ND	ND
Total Dissolved Solids (mg/l)	5020.00	5000.00	301.0	295.0	ND	ND	ND	ND
BOD (mg/kg, mg/l)	1600.00	1405.00	1000.0	1005.0	400.00	501.10	488.1	405.0
COD (mg/kg, mg/l)	15810.00	10900.00	7250.0	7100.0	2500.00	3600.00	3250.0	2600.4
Conductivity(μs/cm)	5646.00	5600.00	5000.0	4905.0	907.00	801.00	702.0	805.0
SO_4^{2-}(mg/kg, mg/l)	365.11	301.10	150.2	155.3	3788.89	3700.01	2400.0	2601.0
PO_4^{3-} (mg/kg, mg/l)	2.48	2.25	1.86	1.81	86.63	70.01	70.60	80.00
NO_3^- (mg/kg, mg/l)	43.24	50.36	35.00	34.0	216.19	200.10	198.05	211.0
Alkalinity (mg/l)	2300.00	1900.00	1450.0	1400.0	ND	ND	ND	ND
Cl^- (mg/kg, mg/l)	1625.00	1500.00	1200.0	1105.0	2500.00	2100.00	1800.1	2205.0
TOC (mg/kg, mg/l)	0.048	0.0200	0.000	0.01	1.74	1.50	1.45	1.55
Na (mg/kg, mg/l)	7.64	6.20	4.84	4.80	9.60	8.05	10.10	9.60
K (mg/kg, mg/l)	0.106	0.425	0.350	0.40	59.30	8.99	6.62	7.50
Ca (mg/kg, mg/l)	0.836	1.100	0.56	1.13	128.25	140.00	110.50	120.0
Mg (mg/kg, mg/l)	0.538	0.100	0.05	0.101	8.06	70.01	60.00	64.20
PAH (mg/kg, mg/l)	0.070	0.060	0.001	0.000	0.223	2.120	1.050	2.551

KEY: BOD = Biological Oxygen Demand. COD = Chemical Oxygen Demand. PAHs =Polycyclic Aromatic Hydrocarbons. TOC = Total Organic Carbon. ND = Not Done

Table 4. Physicochemical characteristics of samples contaminated by Trans-Amadi abattoir wastes (rainy and dry seasons)

Parameters	Waste water				Soil				Oginigba Sediment			
	Test		Control		Test		Control		Test		Control	
	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry
pH	8.25	8.08	8.00	8.10	8.37	9.37	8.20	7.9	7.31	9.02	7.22	8.0
Turbidity (NTU)	18.01	18.48	14.00	15.01	ND	ND	ND	ND	ND	ND	ND	ND
Temperature (°C)	27.00	26.30	28.0	28.2	27.20	30.40	27.3	29.1	26.10	30.50	27.0	28.5
Total Suspended Solids (mg/l)	6000.10	6080.00	5002.3	4900.5	ND	ND	ND	ND	ND	ND	ND	ND
Total Dissolved Solids (mg/l)	14500.00	15600.00	900.1	8500.0	ND	ND	ND	ND	ND	ND	ND	ND
BOD (mg/kg, mg/l)	5925.00	6400.00	2500.0	2502.2	2101.50	2680.00	2000.0	2290.2	5760.00	4668.00	3120.1	3020.1
COD (mg/kg, mg/l)	8005.00	9002.00	5009.2	5000.1	4120.00	2375.00	4000.0	15280.1	1320.00	22850.00	1010.2	1641.6
Conductivity(μs/cm)	5465.00	4940.00	2320.0	2300.0	998.00	1223.00	900.2	1140.4	7400.00	2670.00	5240.2	2860.5
SO_4^{2-}(mg/kg, mg/l)	320.60	337.56	270.5	29.01	1033.34	6268.90	956.3	2340.2	1584.45	1171.11	1240.0	1120.5
PO_4^{3-} (mg/kg, mg/l)	3.56	2.46	1.85	1.67	49.50	12.38	36.09	30.11	61.875	10.73	40.47	10.11
NO_3^- (mg/kg, mg/l)	20.15	19.41	15.06	14.01	52.94	308.89	40.65	236.5	88.24	79.42	65.91	60.15
Alkalinity (mg/l)	120.00	100.00	100.01	150.00	ND	ND	ND	ND	ND	ND	ND	ND
Cl^- (mg/kg, mg/l)	50600.00	44500.00	252600	21100	120.00	12500.00	160.2	8000.3	1000.00	120000.00	795.7	9800.0
TOC (mg/kg, mg/l)	0.085	0.097	0.025	0.015	0.01	0.96	0.01	0.52	0.18	0.38	0.11	0.15
Na (mg/kg, mg/l)	10.345	8.268	5.55	5.00	45.70	37.50	39.45	28.67	52.80	40.80	38.45	45.65
K (mg/kg, mg/l)	0.760	0.803	0.350	0.40	18.00	237.00	17.01	300.6	24.00	378.00	20.16	201.5
Ca (mg/kg, mg/l)	1.95	1.60	1.00	1.05	32.50	612.00	20.29	510.6	38.60	881.00	24.29	51.33
Mg (mg/kg, mg/l)	1.550	1.243	1.230	1.210	0.260	95.00	0.143	75.3	0.284	106.00	0.152	101.5
PAH (mg/kg, mg/l)	0.019	0.013	0.010	0.010	1.313	1.271	1.200	1.120	0.442	1.247	0.315	0.850

KEY: BOD = Biological Oxygen Demand. COD = Chemical Oxygen Demand. PAHs =Polycyclic Aromatic Hydrocarbons. TOC = Total Organic Carbon. ND = Not Done

Table 5. Physicochemical characteristics of samples contaminated by Ahoada abattoir wastes (rainy and dry season)

Parameters	Waste water				Soil			
	Test		Control		Test		Control	
	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry
pH	7.59	8.18	8.0	8.0	8.47	8.25	8.10	8.20
Turbidity (NTU)	18.56	20.84	12.01	13.02	ND	ND	ND	ND
Temperature (°C)	25.80	20.00	26.8	27.5	25.80	30.20	26.7	29.0
Total Suspended Solids (mg/l)	4120.00	7540.00	5601.0	5502.1	ND	ND	ND	ND
Total Dissolved Solids (mg/l)	6680.00	2676.00	780.0	750.0	ND	ND	ND	ND
BOD (mg/kg, mg/l)	2560.00	12000.00	500.2	480.0	ND	2480.00	1900.1	1120.0
COD (mg/kg, mg/l)	4600.00	21054.00	4100.6	4000.1	2800.00	22500.00	2650.0	18600.0
Conductivity(µs/cm)	13360.00	1130.00	9100.0	1090.0	347.00	1468.00	306.2	1396.5
SO_4^{2-}(mg/kg, mg/l)	328.60	351.33	138.9	130.1	244.45	1412.22	240.06	1103.5
PO_4^{3-} (mg/kg, mg/l)	2.805	1.65	2.01	2.06	90.75	24.75	79.38	50.56
NO_3^- (mg/kg, mg/l)	15.88	35.29	10.25	10.00	25.80	423.55	230.10	328.5
Alkalinity (mg/l)	600.00	600.00	601.0	615.0	ND	ND	ND	ND
Cl^- (mg/kg, mg/l)	20200.00	45000.00	100.1	12000.0	25200.00	30000.00	16250.0	20105.0
TOC (mg/kg, mg/l)	0.36	0.129	0.001	0.000	0.96	1.74	0.83	1.22
Na (mg/kg, mg/l)	20.33	21.01	15.60	14.01	37.20	31.80	30.22	30.05
K (mg/kg, mg/l)	0.028	4.01	0.013	0.02	4.02	294.00	3.01	252.2
Ca (mg/kg, mg/l)	14.56	2.402	9.56	10.10	53.60	549.00	48.88	501.2
Mg (mg/kg, mg/l)	12.68	1.389	11.02	11.00	18.30	83.00	15.03	71.5
PAH (mg/kg, mg/l)	0.009	0.023	0.001	0.000	0.155	-	0.101	-

KEY: BOD = Biological Oxygen Demand. COD = Chemical Oxygen Demand. PAHs =Polycyclic Aromatic Hydrocarbons. TOC = Total Organic Carbon. ND = Not Done

The dry season results indicate high level of pH and temperature in the soil sample. Turbidity, total suspended and dissolved solids and alkalinity though not analysed in the soil had values of 20.84 (NTU), 7540 mg/l, 2676 mg/l and 600 mg/l, respectively in the waste water sample while biological oxygen demand (BOD) and chemical oxygen demand (COD) levels were higher in the waste water. Conductivity, sulphate, phosphate, nitrate, total organic carbon, sodium, magnesium, calcium, potassium and polycyclic aromatic hydrocarbon (PAHs) levels were more in the soil sample. Statistical difference using (ANOVA) existed in the level of these parameters obtained from soil and waste water except chloride that did not show difference statistically in the value obtained from the waste water and soil.

From the t-test carried out, chemical oxygen demand (COD), conductivity, sulphate, nitrate, total organic carbon, sodium, magnesium, PAHs had values which differ significantly in the test and control of abattoir soil and waste water samples. On the contrary, significant difference did not exist in the pH, turbidity, temperature, phosphate and alkalinity levels obtained from the tests and controls of both abattoir soil and waste water. However, while there was significant difference in the biological oxygen demand (BOD), calcium, potassium, levels obtained from test and control of abattoir soil, the reverse was the case for chloride, total dissolved solid, total suspended solid which showed significant difference in the test and control of abattoir waste water. Analysis of Variance (ANOVA) revealed that there was no significant difference in the physicochemical parameters of the soil samples collected in the rainy and dry seasons from the four abattoirs.

3.2 Discussion

The biophysical properties of samples contaminated by abattoir wastes were investigated. The pH of all the samples collected both in the rainy and dry seasons from the various abattoirs are indicative of alkaline environment. The pH range of this study is comparable to pH ranges of 6.9-8.8 of previous studies on effluent from similar abattoirs in Nigeria [25], [26]. It also falls within the Federal Ministry of Environment (FMENV) effluent limit of 6-9. pH is important to microorganisms because it affects the functioning of virtually all enzymes, hormones and proteins which control metabolism, growth and development. pH is also a major factor in all chemical reactions associated with formation, alteration and dissolution of minerals [27]. The high pH observed may be attributed to the dilution effect caused by the waste water produced in the abattoir, and increased water volume resulting from rainfall and possibly due to the influx of carbonate. The waste water samples before collection was used severally for washing roasted and unroasted meat, tables, floors, utensils, etc. This action causes the agitation and re-suspension of particulate organic matter contained in the waste water which may result in increased turbidity.

Temperature values of 26.0ºC to 30.2ºC were recorded for all the samples collected from the abattoirs in the rainy and dry seasons except waste water sample collected in the dry season from Ahoada abattoir that had temperature of 20ºC. The observed temperature range of 26.0ºC to 30.2ºC is consistent with that of [28]. Total suspended solids (TSS) are the filterable particles in water. It may be of organic origin (algae, zooplankton and bacteria) or inorganic origin (clay, silt, calcium, bicarbonates, chloride etc). Total suspended solids (TSS) reduce light penetration, hence reducing the ability of algae to photosynthesize. Like the turbidity, TSS levels in the waste water samples from the abattoirs were noticed to be high. The observed high TSS recorded in the waste water samples was as a result of organic particles from roasted skin of animals and other particulate materials from abattoir tables and floors. This could also be due to lack of sedimentation facility to separate the solid wastes from the liquid wastes before discharge [25].

Total dissolved solids (TDS) usually affect the refractive capacity of the water body and the light dispersion pattern apart from having a significant effect on the heat capacity of the system. Total dissolved solids (TDS) values obtained from the waste water samples during the study followed the same trend with TSS values obtained from the samples. Organic effluents from such activities also frequently contain large quantities of suspended solids which reduce the light available to photosynthetic organisms and on settling down, alter the characteristics of river bed, rendering it an unsuitable habitat for many organisms [28], [26].

Biochemical oxygen demand (BOD_5) is a measure of the oxygen requirement for the biochemical degradation of organic materials and the oxygen used to oxidize inorganic materials such as sulfides, ferrous ions and reduced forms of nitrogen. It depicts the amount of putrescible organic matter degradable by microbial metabolism on the assumption that the water has no bactericidal or bacteriostatic effects [24]. The higher BOD_5 values obtained from test samples compared with controls from the various abattoirs could be attributed to the organic and inorganic wastes generated in the abattoirs including cow dung especially from surface run-offs and soil erosion during the rainy season months. The excessive production of organic matter leads to the build up of sludge and the mineralization process consumes all dissolved oxygen from the water column [28].

Chemical oxygen demand (COD) measures the organic portion susceptible to oxidation by a strong chemical oxidant. However, it is sometimes used to indicate the total organic matter present. COD is a determinant used to assess organic pollution in aqueous systems and is one of the most important parameters in water monitoring [24]. The chemical oxygen demand values from all the samples were observed to be high and almost followed the same trend as BOD_5 values. The COD values in all the samples were observed to be greater than 200mg/l O_2 or 200mg/kg O_2 indicating pollution. [29], stated that the concentration of COD observed in surface waters range from 20mg/l O_2 or less in unpolluted waters to greater than 200mg/l O_2 in waters receiving wastes or effluents. From every indication, the observed high chemical oxygen demand in this study can be attributed to wastes from abattoirs alongside other domestic activities like bathing and washing that take place in the adjoining water bodies. Thus the organic pollutants will create high competition for oxygen within the ecosystem.

The conductivity of a medium is an indication of its ability to conduct an electric current. It is usually determined by the presence of total concentration of ions, temperature of all the systems etc. Higher conductivity values were obtained from waste water samples from Ogbe, Ahoada abattoirs and almost all the samples from Trans-Amadi abattoir. These higher conductivity values may be due to increased decomposition and mineralization of allochthonous organic matters or due to evaporation resulting in the concentration of nutrients. The converse of the above results was the case with that obtained for samples collected from Egbu abattoir and Otamiri River which are in agreement with the results obtained by [2]. The European Economic Community (EEC) maximum conductivity for domestic water is 1250µs/cm [30]. Thus, the conductivity of Otamiri River fell within acceptable limits while that of Oginigba creek did not.

Alkalinity is basically a reflection of the carbonate content of the rocks and soils of the basin and water shed. It is a measure of weak acid and their salts present in water. Alkalinity can be better expressed as the acid neutralizing capacity of a water body. It is a measure of the buffering capacity of a system which indicates that water with high alkalinity is considered to be well buffered against acid input. Total alkalinity values obtained from waste water samples from Egbu, Ogbe and Ahoada abattoirs were above 500mg $CaCO_3$ /l. The wastes from the slaughtering and dressing grounds in these abattoirs are washed into the water body untreated and the leachates from the series of decomposition processes of these wastes percolate into the underlying aquifers to contaminate the water source [31,1,32]. High values of alkalinity may also be attributed to underground sources of pollution which might result from high concentration of mineral salts due to geological nature of the bedrock in which the aquifer is situated. Otamiri River fell below 30mg $CaCO_3$ /l. However, waste water from Trans-Amadi abattoir and surface water from Oginigba creek recorded alkalinity values that fell between 30mg $CaCO_3$ /l to 50mg $CaCO_3$ /l. The WHO permissible standard for alkalinity of domestic, waste water and water for industrial purpose is 30-500mg $CaCO_3$ /litre [30]. Thus the alkalinity values from both waste water and surface water from Oginigba creek were within the acceptable limits.

Nutrients, including phosphate, nitrate and sulphate are chemical substances required by organisms for growth. Generally, nutrients enter the aquatic environment through urban water run-off, irrigation drainage, agricultural run-off, etc. It is interesting to note that a wide variety of minerals and trace elements can be classified as nutrients, but nitrogen as nitrate (NO_3^-) and phosphorous as phosphate (PO_3^-) are required in macro quantities for growth [33]. In this study, abattoir soil and sediment samples had higher sulphate values. This could be as a result of the accumulation of this element over time. However, the values obtained from waste water and surface water samples fell between 200mg/l and 400mg/l as recommended by WHO [30]. This then indicates that the level of sulphate in the waste water and surface water samples were within the acceptable limit.

Analysis of the samples for phosphate level indicate that the abattoir soil and sediment samples from Otamiri River and Oginigba Creek showed higher phosphate levels than abattoir waste water and surface water samples from Oginigba Creek and Otamiri River. This observed result may be attributed to rapid and constant discharge of wastes from abattoir on the surrounding soil environment and the possible settlement of this element at the sediment portion of the two water bodies. The World Health Organization (WHO) permissible standard for this parameter in domestic and industrial waters is 0.4mg/l or 0.4mg/kg [30]. This means that all the samples had phosphate values far higher than this recommended limit.

In nature, nitrogen occurs as nitrate, ammonia and nitrite. All these forms are interconvertible. Nitrate occurs in trace quantities in surface water and is usually contributed by nitrifying activities of microbes. The nitrate values observed during the study showed that abattoir soil and sediment from Otamiri River and Oginigba Creek had higher values than abattoir waste water and surface water from the above mentioned water bodies. The higher nitrate values observed in the soil and sediment samples could be attributed to the natural process of organic mineralization and nitrate washed into the water bodies by surface run-off which eventually settled at the bottom of the rivers. The nitrate level of the surface water samples was observed to be lower than the 25mg/l reported by [34] from a similar environment.

Total organic carbon is an index to measure the number of carbon containing compounds in a medium. It serves as a means of determining the level of organic contamination in a given environment [35] reported that high organic carbon content consequently increases the growth of microorganisms which then leads to the depletion of oxygen supplies.

Heterotrophic microorganisms are known to be responsible for the utilization of organic carbon, thus making it available to the different food webs [36]. Results obtained in this study showed that abattoir soil and sediment samples in comparison with the organic carbon content of the abattoir waste water and surface water samples could be attributed to the rapid decay and mineralization of animal wastes and other organic materials on the soil and sediment leading to the liberation of the mineral constituents of the animal wastes.

Chlorine which results from the dissociation of salts, such as sodium chloride or calcium chloride in water is one of the major inorganic ions [37]. Chlorine is known as a toxic element but when combined with a metal such as sodium, it becomes essential to life forms. All natural environments contain chloride in varying degrees with content increasing as mineral content increases. The chloride level of the abattoir soil and sediment was noticed to be higher in the various abattoirs except Tran-Amadi abattoir where the waste water and Oginigba Creek sediment recorded higher level of chloride. However, while Otamiri surface water had chloride level lower than 250mg/l recommended by WHO [30], Oginigba Creek had values higher than this recommended level.

Sodium, potassium, calcium and magnesium are very important element required for the optimal growth and productivity in plants and animals. Sodium is usually found in the ionic form Na^+. Due to its solubility, it is usually detected in most natural waters. Potassium is also found in the ionic form as K^+. The salts are highly soluble. Potassium is found in low concentration in natural waters. It usually enters natural waters with industrial discharges and run-off from agricultural land.

Calcium is present in the soil and aquatic environments as Ca^{2+}. It is readily dissolved from rocks rich in calcium minerals, particularly as carbonates. Its salts are responsible for the hardness of water [29]. Calcium is an essential element for all organisms and is incorporated into the shells of many aquatic invertebrates as well as the bones of vertebrates. Magnesium exists in the ionic form as Mg^{2+}. It equally contributes to the hardness of water [29]. It is one of the essential elements for microorganisms.

The results in this study showed that abattoir soil, sediment samples from Otamiri River and Oginigba Creek recorded higher sodium, potassium, calcium and magnesium levels than the abattoir waste water Higher level of these elements in the soil could be as a result of the constant and incessant release of these elements through abattoir activities followed by concomitant accumulation of these elements over time [26]. Likewise, sediment samples recorded higher levels of these elements as a result of surface run-off and settlement of the elements in the sediment.

The abattoir soil samples had higher levels of PAHs. This can be as a result of constant emission of this chemical through burning of tyres and woods during roasting of meat in the abattoir. The appreciable presence of this chemical in the sediment samples could be as a result of run-off that carry along with it PAHs deposited on the soil into the rivers and subsequent settlement of the PAHs at the bottom of the rivers. The waste water had PAH values that closely followed that found in the sediment. The PAHs detected in the waste water could possibly be those left on the meat after roasting with tyre and wood and washing off.

One way analysis of variance revealed that there was no significant difference at $p<0.05$ in the physicochemical parameters of the soil and waste water samples from the four abattoirs collected in the rainy and dry seasons. This could be attributed to the release into the environment abattoir wastes that possibly have equal levels of organic and inorganic constituents. Further analysis of the result showed that there was no significant difference in the physicochemical properties of the sediment samples collected from Otamiri River and Oginigba Creek. This lack of significance can be attributed to the settlement at the sediment region of the two water bodies' equal concentration of organic and inorganic elements.

4. CONCLUSION

The study was carried out to evaluate the biophysical properties of samples contaminated by abattoir wastes. In order to accomplish the objectives of this study, soil, waste water, surface water and sediment samples contaminated by abattoir wastes were analysed for their biophysical properties vis-à-vis the pollution strength of the wastes.

Although abattoir operation could be very beneficial to man in that it provides meat for human consumption and other useful by-products, still it can be very hazardous to public health with respect to the wastes that is generated. The high pollution strength of the abattoir wastes as revealed in this study further confirmed the danger associated with discharging untreated wastes to the environment, thus the need for adequate treatment to ensure decontamination.

There is no doubt that the pollution caused by abattoir wastes is a clear evidence that the meat processing industry mostly in developing countries like Nigeria has a potential for generating large quantities of waste with high chemical and biological oxygen demands which would worsen pollution problems in the environment.

The study indicated negative impact of abattoir activities on the soil that receive wastes from abattoirs which is probably because effective waste disposal system is not practiced by abattoir operators.

5. RECOMMENDATIONS

Based on the foregoing, the abattoir management system should include a waste management plan designed for abattoir operations. Legislative measures are also necessary, laws and rules on land use and waste regulation to control the location and management of abattoirs should be made.

Rules requiring odour abatement plans and provision of Environmental Impact Assessment (EIA) for abattoirs should be enforced. Licensing of abattoir, certification of all operators as well as training of employees involved in abattoir activities should be made. In addition, public awareness and enlightenment on the possible impact of pollution from abattoir wastes should be embarked upon by relevant agencies. There should be public participation in the development of policies for abattoir management.
Swift intervention by the government and other stakeholders by putting in place waste treatment facilities to treat wastes from abattoirs mostly in Nigeria as well as adoption of better technologies which will go a long way to curb the environmental health risks posed by these hazardous wastes from abattoirs.

Disinfection of the final effluent would be required since the abattoir wastes in Nigeria have high bacterial load [38].

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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