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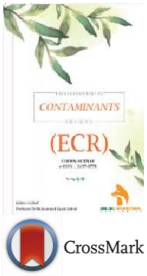

RESEARCH ARTICLE

EFFECT OF ABATTOIR WASTE ON THE PHYSICO-CHEMICAL AND FAECAL COLIFORM LOAD OF SURFACE AND UNDERGROUND WATER BODIES IN UGHELLI, DELTA STATE

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ABSTRACT

This study aimed to evaluate the effects of effluent from the Ogheneweta abattoir on the physico-chemical and faecal coliform load of surface and underground water surrounding the abattoir. The study compared the water quality parameters with the guidelines provided by the Federal Ministry of Environment (FMENV) and the World Health Organization (WHO). The research involved the determination of various factors, including physico-chemical characteristics, microbial activity, and spatial and seasonal variations of water. Four sampling stations were selected for the study, with two focusing on groundwater impact and the other two on surface water impact. Differences between the two types of stations were also analyzed. Field sampling was conducted over a nine-month period, and water quality parameters such as temperature, pH, dissolved oxygen, turbidity, biochemical oxygen demand, and faecal coliform load were measured. Standard methods and instruments were utilized for sample collection and analysis, following established water analysis procedures. Statistical analysis was performed using a paired sample T-test ($P<0.05$). The results indicated that water temperature ranged from 25.56oC to 27.78oC, pH from 6.52 to 7.11, total dissolved solids (TDS) from 10.67mg/l to 210.78mg/l, electrical conductivity (EC) from 20.95mg/l to 426.05mg/l, dissolved oxygen (DO) from 4.17mg/l to 4.72mg/l, turbidity from 1.95mg/l to 9.67mg/l, and biochemical oxygen demand (BOD) from 1.33mg/l to 1.74mg/l. Faecal coliform counts in underground and surface water samples ranged from 2.00 to 2.22MPN/100L and 2.67 to 7.33MPN/100L, respectively. The study findings revealed that the abattoir activities had a negative impact on the quality of both surface and underground water within the Ogheneweta abattoir area. While most physico-chemical and microbial parameters adhered to FMENV and WHO guidelines, the concentrations of turbidity in surface water and faecal coliform in both surface and underground water exceeded the acceptable limits. Moreover, the study showed distinct seasonal variations in physico-chemical parameters, with higher values recorded for pH, TDS, and turbidity during the rainy season, and lower values observed for conductivity. Based on the results, it is recommended that a groundwater monitoring program be implemented to assess the water quality status of wells near abattoirs, ensuring the protection of local residents' health. Prompt intervention measures, including the establishment of effluent treatment facilities, are essential for effective waste management at abattoirs in Ughelli.

KEYWORDS

Abattoir Effluent; Water Quality; Physico-chemical Characteristics; Faecal Coliform Load; Surface Water; Groundwater; Groundwater Monitoring Programme; Environmental Health Risks.

1. INTRODUCTION

Abattoir activities, including slaughtering, washing, and waste disposal, significantly contribute to environmental pollution when not properly managed (Mozhiarasi & Natarajan, 2022; Ogbonna & Ideriah, 2014). In developing countries such as Nigeria, abattoirs are known sources of environmental contamination due to inadequate waste management (Adeyemi & Adeyemo, 2007). The waste generated from these facilities often finds its way into surface and underground water bodies, thus leading to significant alterations in the physico-chemical and microbiological properties of these water sources (Ejaz, Akhtar, Hashmi, & Naeem, 2010). This study focuses on the impact of abattoir waste on the physico-chemical and faecal coliform load of surface and underground water bodies in Ughelli, Delta State. Abattoir waste comprises solids (like bones, horns, hooves, and hair), liquids (including blood, urine, and other body fluids), and sometimes, rejected carcasses (Nauman, Nauman, & Arshad, 2023). The disposal of these wastes, especially blood, into the surface and underground water bodies leads to increased organic load, biochemical oxygen demand (BOD), and chemical oxygen demand (COD), which can significantly alter the water quality (Elemile et al., 2019).

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Moreover, the faecal matter associated with abattoir waste introduces a range of pathogenic micro-organisms, including faecal coliforms, into the water bodies, posing a potential public health risk (Benka-Coker & Ojior, 1995). Abattoir waste has been identified as a significant source of pollution for water bodies worldwide (Adamu & Dahiru, 2020). According to Bello and Oyedemi (2009), the indiscriminate disposal of abattoir waste into water bodies alters their physico-chemical parameters such as temperature, pH, dissolved oxygen (DO), BOD, COD, total dissolved solids (TDS), and total suspended solids (TSS), thereby reducing the water quality. For instance, high BOD and COD values observed in water bodies around abattoirs indicate the potential for rapid oxygen depletion, which can result in a decline in aquatic biodiversity (Maizatul, Radin Mohamed, Al-Gheethi, & Hashim, 2017). Studies by Akpor and Muchie (2011) also found that the excessive nutrients from abattoir waste contribute to eutrophication, leading to algal blooms and subsequent oxygen depletion. Hence, such alterations could disrupt the aquatic ecosystem and potentially make the water unsafe for human consumption (Muchie, 2011).

The microbiological pollution of water bodies by abattoir waste, particularly faecal coliform load, is a significant public health concern (Kinge, Ateba, & Kawadza, 2010). Faecal coliforms, a subset of total coliforms, are often used as indicators of faecal contamination and the potential presence of pathogenic organisms (Niyoyitungiye, Giri, & Ndayisenga, 2020). Abattoir waste, being rich in faecal matter, increases the faecal coliform load in water bodies (Omoni et al., 2023). High concentrations of faecal coliforms in water bodies can lead to the outbreak of waterborne diseases such as diarrhea, typhoid, and cholera, among others (Control & Prevention, 2014; Nabeela et al., 2014). For example, a study by Osunla and Okoh (2017) in Nigeria found a strong correlation between the faecal coliform load in water bodies around abattoirs and the prevalence of waterborne diseases in the surrounding communities. Furthermore, Escherichia coli (E. coli), a type of faecal coliform, has been identified in numerous studies as an important indicator of water quality due to its abundance in faecal matter and its potential to cause serious health issues (Odonkor & Ampofo, 2013). Ughelli is a town located in Delta State, Nigeria, with a populace heavily relying on the surface and underground water bodies for domestic and agricultural needs (Mogborukor, 2012). Unfortunately, these water sources are under threat from various anthropogenic activities, including abattoir operations. The impact of abattoir waste on the physico-chemical and faecal coliform load of these water bodies is a subject that warrants in-depth investigation in this region. Several abattoirs within Ughelli dispose of their waste directly into nearby rivers and streams, thereby increasing the organic and faecal load in these water bodies (Aghoghovwia, 2011). However, there is a paucity of data on the comprehensive assessment of the impact of these activities on the physico-chemical properties and faecal coliform load of surface and underground water bodies in the area. This gap in knowledge forms the premise of the current study.

Abattoir waste significantly contributes to the pollution of water bodies, particularly in developing countries like Nigeria, where proper waste management practices are often lacking (Ulakpaa & Eyankwareb, 2021). The resultant alterations in the physico-chemical properties of these water bodies, coupled with the increased faecal coliform load, pose significant environmental and public health challenges. As such, comprehensive studies assessing the impact of abattoir waste on the water quality, as well as the associated health risks, are of paramount importance. This study aims to provide such an assessment for the surface and underground water bodies in Ughelli, Delta State, thereby contributing to the broader understanding of the environmental and public health implications of abattoir waste disposal. Further, it will provide the groundwork for developing sustainable waste management strategies for abattoirs in the region, mitigating the adverse effects on water bodies.

2. METHODOLOGY

2.1 Description of Study Area

2.1.1 Location

Ogheneweta abattoir lies on latitude 05° 30′N and longitude 05° 59′E and is located beside the Affisere River, Ughelli, Delta state. It is constructed in such a way as to accommodate 3-4 slaughtering at a time. The slaughterhouse is divided into three sections: the slaughtering section, the processing section (skin and bone removal/skin burning), and the waste dumping site. An average of 15 cows is slaughtered per day. Normal abattoir operations are carried out from Monday to Saturday. The blood wash and the process water from the slaughterhouse are channeled through a drain down to the Affisere River, shown in Figure 1.

2.1.2 Relief

Ughelli is a low-lying plain consisting mainly of recent unconsolidated sediments of Quaternary age. These sediments are partly of marine and partly of fluvial origin. Land elevation is generally under 50 meters above mean sea level, and there is a marked absence of imposing hills that rise above the general land surface. The area is traversed by numerous flat-floored rivers that drain into the Atlantic Ocean. The major river is the Afiesiere River. This river is prone to flooding, especially during the wet season, mainly because of the heavy rainfall, high ground water table and the flat-floored valleys.

Figure 1: Manure mixed with blood flowing into open drainage from the main slaughterhouse

2.1.3 Climate

Ughelli, like the rest of the Niger Delta, experiences a humid subequatorial climate, characterized by a lengthy wet season from March to October and a shorter dry spell from November to February. This climate is governed by two main air masses: the South West (S.W.) monsoon wind and the North East (N.E.) trade wind. The S.W. monsoon wind, hailing from the Atlantic Ocean, is warm and moisture-laden, ruling the wet season. Conversely, the N.E. trade winds, stemming from the Sahara desert, dominate the dry season.

The effects of the dry N.E. trade winds become particularly prominent in Ughelli from December to February, ushering in the dry, dusty period known as harmattan. Ughelli receives an average annual rainfall of up to 2800 mm. The onset and conclusion of the wet season are typically signified by intense, brief thunderstorms, often with strong winds that can cause significant property damage, including blowing off roofs of buildings.

Mid-season rainfall, in contrast, is typically slow and steady, lasting for several hours to a few days. The rainfall pattern has a double peak, with the highest rainfalls in June/July and September, separated by a relatively dry spell in August. The mean yearly temperature in Ughelli hovers around 27 °C, and there's little seasonal deviation as the annual temperature fluctuation is slight, rarely exceeding 3 °C.

2.1.4 Vegetation

The natural vegetation of Ughelli is a rainforest with swamp forests occurring in flat-floored valleys and adjoining low-lying areas that are seasonally or permanently waterlogged. The rainforest is floristically diverse and structurally complex, with several layers of trees. It was a major source of timber, and the notable timber-producing species include Antiaristoxicaria, Milicia (Chlorophora) excelsa, Ceibapentandra and Piptadeniastrumafricanum. Other trees in the rainforest include Pentaclethramacrophylla, Chrysophyllumalbidum and Irvingiagabonenesis. The two last mentioned tree species are fruit trees which are important as sources of income and dietary supplements for rural people. Virtually all the rainforest in Ughelli has been destroyed due to farming, especially shifting cultivation and the establishment of small-scale holdings of rubber trees, coupled with commercial lumbering. Today, much of the countryside is dominated by secondary regrowth vegetation with oil palms (Elaeisguineesis) and Chromolaenaodorata, farmland, rubber "plantations," and patches of swamp forest along rivers.

2.1.5 Soils

The soils in Ughelli are significantly weathered and deficient in nutrients, primarily originating from unconsolidated sandstone sediments (Mogborukor, 2012). They are predominantly sandy, with the top 10 cm of the soil possibly containing up to 90% sand. As a result, the soils are

loosely packed and poorly aggregated, owing to their minimal clay and organic matter content. Given the heavy rainfall in Ughelli, it's not surprising that the soils are highly leached, lacking in base elements and displaying an acidic reaction. The pH of the top 20 cm of the soil profile typically falls below 5.0, sometimes dropping to as low as 4.0. The total exchangeable base may dip to 3 cmol/kg or even lower. Nevertheless, there are sporadic patches of clayey soil derived from shale. These soil patches, usually restricted in area, are waterlogged due to poor drainage. They offer valuable resources for the local pottery industry, which focuses on crafting clay pots for cooking and water storage. Despite their higher base status, the soils derived from shale are challenging to manage, tending to be wet, sticky, and slippery during the wet season, which also happens to be the growing season.

2.2 Sampling Stations

Figure 2 displays the study area map, highlighting the specific sampling stations used in this research. The field sampling was carried out for a period of nine months. Four sampling stations were chosen because of their proximity and significance to the abattoir - two stations to check the impact of abattoir activity on groundwater and two stations to check the impact of abattoir activities on surface water.

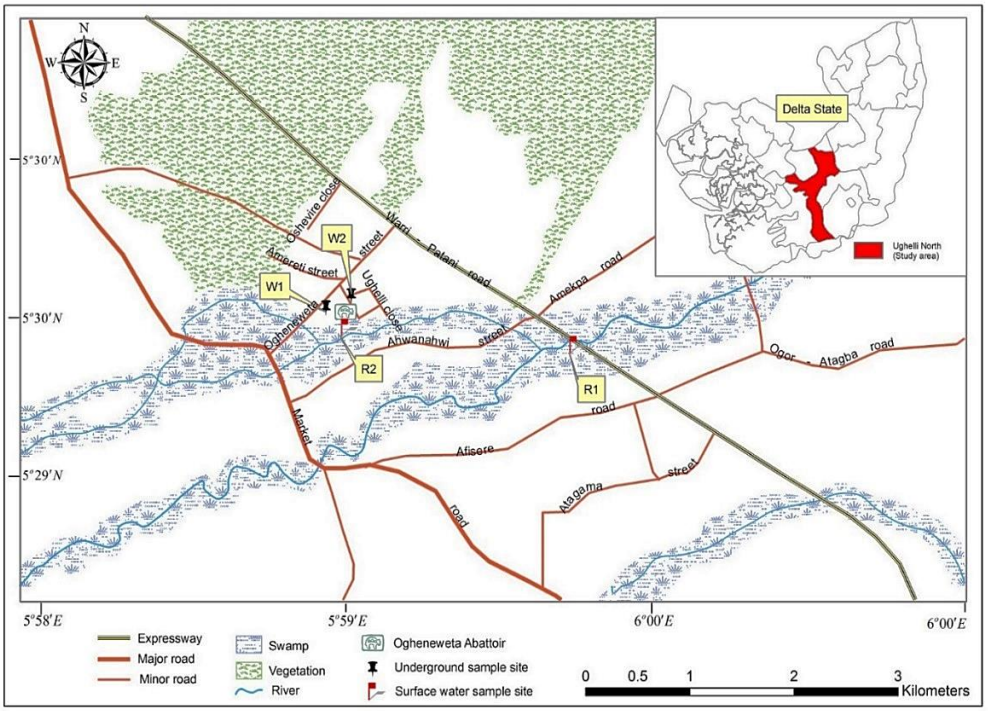

Figure 2: Map of the study area showing the sampling stations

For groundwater analysis, samples were taken from two wells around the slaughterhouse designated as W1 (5° 30'N, 5° 59'E) and W2 (5° 30'N, 5° 59'E). Sample W1 was collected at a distance of 61 meters away from the dumpsite, and sample W2 was collected from a distance of 200 meters away from the dump site. For surface water analysis, samples were taken from two points along the Affisere River that flows behind the slaughterhouse, designated as R1 (5° 30'N, 6° 00'E) and R2 (5° 30'N, 5° 59'E). Sample R2 was collected at a distance of 150 meters from the dumpsite, and sample R1 was collected along the river away from the slaughterhouse at about 800 m. Well 1, shown in Figure 3, is approximately 61 meters from the abattoir and its dumpsite. Occasionally, this well serves as a water source for abattoir activities. Well 2, as displayed in Figure 4, located around 200 meters away from the abattoir and its dumpsite, serves as a water source for drinking and domestic purposes for residents residing near it.

Figure 3: Well 1 by the Abattoir

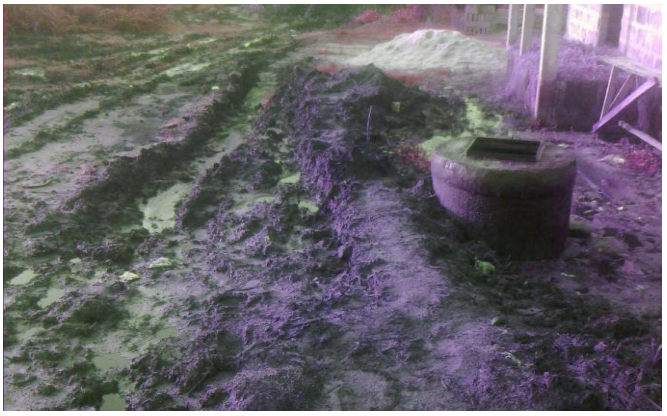

Figure 4: Well 2 (200 meters from the dumpsite)

Figure 5: Station 1(800m from Abattoir)

Station 1, as shown in Figure 5, represents the Affisere River's upstream section, characterized by a water depth of 1.68 meters and a fast flow velocity. Human activities in this area primarily involve bathing and washing clothes. Station 2 (see Figure 6) is positioned downstream from the river, approximately 150 meters away from the abattoir. The water depth at this station measures 0.5 meters, and the flow velocity is relatively fast compared to Station 1. This is the point where the abattoir's effluent is discharged.

Figure 6: Station 2 (150m from Abattoir)

2.3 Sample Collection

Water sampling was carried out around the Ogheneweta abattoir on a monthly basis, with sampling occurring between 0900 and 1200 hours. The sampling procedure followed a specific order, beginning with well 1, followed by well 2, station 2, and station 1. Surface water temperature was measured on-site at each sampling point using a mercury-in-glass thermometer. Transparent 1-litre plastic bottles were used to collect surface water samples for physico-chemical and microbial analysis. Prior to the final sample collection, the bottles were rinsed with the corresponding water sample to ensure proper preservation. During surface water sample collection, the plastic bottle was immersed in the river water at a depth of 5cm below the water surface. This process was repeated during each sampling event throughout the study period. For underground water sampling, a well bucket was used to collect samples from the wells. A 1-litre plastic bottle, rinsed with the water sample, was then employed to collect the sample. This procedure was repeated for each sampling event. To determine the dissolved oxygen content, separate samples were collected in 250 ml plain glass bottles. These samples were treated with Winkler's solution by adding 2 ml of MnSO4.5H2O below the sample surface and 2 ml of alkaline-iodide solution at the sample surface using a syringe for precise measurements. The bottles were carefully stoppered to prevent the entry of air bubbles and thoroughly mixed by rotating and inverting them multiple times. For the determination of biochemical oxygen demand, clean dark 250 ml glass bottles were used for sample collection, incubation, and subsequent dissolved oxygen determination. The glass bottle was rinsed with the water sample before being completely filled with the sample. After collection, the filled bottles were labeled with the sample name, date, and time. Subsequently, the samples were packed into a cooler box and immediately transported to the Tundaka laboratory for further analysis. These standardized sampling and analysis procedures ensured the systematic collection, preservation, and transportation of water samples, enabling accurate assessment in the laboratory.

2.4 Laboratory Analysis

The laboratory conducted analyses on the water samples to determine various parameters, including total dissolved solids, turbidity, pH, electrical conductivity, dissolved oxygen, and biochemical oxygen demand (BOD). These analyses were performed following the standard operating procedures outlined in the Standard Methods for the Examination of Water and Wastewater (APHA, 1998).

2.4.1 Turbidity Determination

In the laboratory, the determination of turbidity involved the use of a turbidity meter, specifically the model 800. To ensure accurate measurements, a calibration process was followed. After switching on the meter and allowing it to warm up for 30 minutes, a 0 NTU polymer standard was inserted into the chamber and covered. The range switch on the meter was set to "20" NTU, and the zero control potentiometer was adjusted to read 0 on the meter. Subsequently, a 10 NTU standard solution was added to the chamber and covered, and the range switch was set to "20". While the 10 NTU standard solution remained in the chamber and covered, the range switch was further adjusted to "200". Once the calibration was complete, the standard solution was replaced with the actual water sample, and the meter was set to the appropriate range based on the expected turbidity level of the sample. The turbidity value was allowed to stabilize, and the final measurement was recorded. These careful calibration and measurement procedures ensured accurate determination of turbidity using the turbidity meter (model 800) in the laboratory setting.

2.4.2 Dissolve Oxygen (DO) Determination Using Winkler's method.

The determination of dissolved oxygen (DO) in the laboratory involved the following steps. Firstly, samples for DO analysis were collected into 250ml plain bottles, ensuring that no bubbles were trapped. Below the surface of the sample, 2ml of $MnSO_4.5H_2O$ was added, followed by the addition of 2ml of alkaline-iodide solution at the sample's surface. The bottle was carefully stoppered to prevent air bubble inclusion and mixed thoroughly by rotating and inverting it several times. Afterward, the precipitate was allowed to settle completely. Next, 4ml of diluted sulphuric acid or 85-90% orthophosphoric acid was added using a pipette, and the contents were mixed by rotating with the stopper replaced. Then, 100ml of the solution was measured in a conical flask. Immediate titration using 0.00125N $NaS_2S_2.5H_2O$ as an indicator was performed, and 2ml of the starch solution was added towards the end of the titration. The color changed from straw yellow to blue at the end-point.

The DO was calculated using Equation 1:

$$DO = \frac{V_1 N(8)1000}{V_2} \quad (1)$$

Where V_1 is the volume of 0.0125N $Na_2O3.5H_2O$, V_2 is the volume of the sample taken, and N is the normality of $Na_2S_2O_3.5H_2O$.

2.4.3 Determination of pH (ALPHA 460)

Measurement of pH is one of the most important and frequently used tests in water chemistry. At a given temperature, the intensity of the acidic or basic character of a solution is indicated by hydrogen ion activity. pH was electrometrically measured using a pH meter with a glass electrode. The apparatus used was a pH meter (Model Testr-1) and beaker (100ml capacity), while the reagents used were buffer solutions of pH 4.01 and 10.01.

The procedure followed for pH measurement involved the calibration of the pH meter and the measurement of the water sample's pH level. For pH meter calibration, 100ml of pH 4.01 buffer solution was poured into a 100ml beaker, and the pH electrode was rinsed with distilled water. The pH meter was then inserted into the buffer solution, and the CAL button was pressed. After allowing the value to stabilize, the reading was recorded. To measure the pH level of the water sample, the pH meter was rinsed with distilled water and then with the sample. Approximately 100 ml of the water sample was poured into a clean 100 ml beaker. The electrode end of the pH meter was inserted into the sample, and the READ button was pressed, waiting for a stable pH reading. Finally, the pH value was recorded.

2.4.4 Determination of Electrical Conductivity and Total Dissolve Solids in Water (ALPHA 154)

The electrical conductivity of water is a numerical expression of the ability of an aqueous solution to carry an electric current. This ability is a function of the presence of ions, their total concentration, mobility, valence and relative concentration and the temperature of measurement. The equipment used was an electrical conductivity meter (Win lab), while the reagent used was 0.01M KCL solution. The calibration process involved rinsing the EC electrode of the meter with distilled water. A 100ml capacity beaker was filled with 0.01MKCL solution, and the electrode was immersed in the solution. The CAL button was pressed, and the recorded value after initialization was 1413.00uS/cm, with an allowed range of ±2.0. For the measurement of electrical conductivity in the water sample, the EC meter electrode was rinsed with distilled water, followed by the sample itself. A clean 100 ml beaker was used to hold approximately 100ml of the water sample. The electrode end of the pH meter was inserted into the sample, the READ button was pressed, and the pH readings were observed until stability was achieved. The EC value was then recorded.

2.4.5 Determination of Biochemical Oxygen Demand (Alpha 507)

The BOD measures the amount of oxygen microorganisms require to decompose organic matter in a water sample under specific conditions. Usually, samples for BOD are enriched with inorganic nutrients, buffered, seeded with bacteria and incubated in the dark for 5 days at 20ºC. The principle of this method is to measure the change over 5 days of dissolved-oxygen concentration in a stoppered bottle completely filled with the wastewater or a sample dilution of it. Dilution is necessary if the BOD is more than the solubility of oxygen in the waste (appropriately 8.9mg/l at 20ºC). Special dilution water buffered to pH 7.2, which contains essential nutrients, was used.

The apparatus and reagents used in the experiment included BOD bottles, concentrated sulphuric acid (H_2SO_4), alkali-iodide solution, standard 0.025N sodium thiosulphate, manganese (II) sulphate reagent, sodium azide solution, starch solution, and dilution water. The alkali-iodide solution was prepared by dissolving 15g of potassium iodide (KI) in approximately 25 ml of water, then by adding 66 ml of 50% NaOH and making up the volume to 100 ml. The standard 0.025N sodium thiosulphate was prepared by dissolving approximately 6.250g of $Na_2S_2O_3.5H_2O$ in freshly boiled and cooled distilled water, with preservation using 0.3-0.5g/l NaOH. The manganese (II) sulphate reagent was prepared by dissolving 48g of $MnSO_4.4H_2O$ in sufficient water and making up the volume to 100 ml. The sodium azide solution was prepared by dissolving 37.5g of sodium azide in distilled water and making up the volume to 100 ml. The starch solution was prepared by dissolving 5g of soluble starch in 100 ml of boiling distilled water, boiling for 2-3 minutes, and preserving with a few drops of toluene. Dilution water was prepared by bubbling air through distilled water until it became saturated. The BOD dilution water was made by adding the following components to each liter of air-saturated distilled water: 2ml ferric chloride solution (0.25g/l $FeCL_3.6H_20$), 2ml calcium chloride solution (36.4g/l $CaCL_2.2H_2O$), 2ml magnesium sulphate solution (22.5g/l $MnSO_4.4H_2O$), and 2ml phosphate buffer (8.5g KH_2PO_4,21.75g K_2HPO_4, 33.4g $Na_2PO_4.7H_20$ and 1.7g NH_4CL in 1000ml distilled water).

The analytical procedure for water samples involved the following steps. The diluted water samples were brought to 20ºC and aerated until saturated. The BOD of the sample was estimated, and three dilutions were selected. Each dilution was pipetted into a 250ml glass stopper reagent vessel. Dilution water was added to each bottle, filling it up to 1cm below the neck, and then stoppered. Three bottles filled with dilution water only served as blanks. All twelve bottles, including the blanks, were incubated at 20ºC for 5 days. After incubation, the dissolved concentration of oxygen in each bottle was measured using the Winkler method. A 2-liter water sample was collected and aerated until saturated with air for undiluted water samples. One clear and one opaque BOD bottle were filled with the sample. The dissolved oxygen (DO) was immediately fixed in the initial bottle using the Winkler procedure, and the bottle was incubated. The DO concentration was determined in the initial bottle, and after 5 days, the BOD bottles were removed for DO analysis. The BOD in mg/l of DO was then calculated by subtracting the DO concentration in the BOD bottle from the DO concentration in the initial bottle. In terms of calculations, the BOD was calculated using Equation 2:

$$BOD = (DO_b - DO_d) \times d \quad (2)$$

Where DO_b represents the mean *DO* concentration in the blanks in mg/l, DO_d represents the mean *DO* concentration in the bottles containing the samples at dilution in mg/l, and *d* represents the dilution factor, which is the volume of the bottle divided by the volume of the sample in milliliters. These procedures and calculations were employed to determine the *BOD* values in the water samples.

2.4.6 Total Coliform Bacteria Determination Using Multiple Tube Test (APHA 9222A)

The determination of coliform bacteria in water samples involves presumptive, confirmatory, and completed tests. The presumptive test was carried out by preparing 15 multiple fermentation tubes for both double and single-strength media (Lauryl tryptose broth). The tubes were inoculated with an aliquot of the water sample and incubated at 37^0C for 48h, after which colour changes and gas production were recorded. (Change in colour from purple to yellow and gas production indicates a positive result). Then, the confirmatory test was carried out specifically for the determination of E. coli, by mixing the contents of the coliform presumptive–positive tube through gentle shaking. Two sets A and B of the tubes containing the media (Brilliant green lactose bile broth) were prepared as in the presumptive test. Set A tubes were then incubated at 37^0C for 48h, at which the presence of coliform organisms was confirmed. Set B tubes were incubated at 44^0C for 24h, at which the presence of E. coli was confirmed. The Most Probable Number (MPN) of E.coli in 100 ml of the sample was determined using McCrady's Statistical Table. Further test (completed test) was carried out by plating 1.0ml from presumptive positive tubes on MacConkey agar and incubating at 37^0C for 24h. The distinct colony formed was gram stained and viewed under the microscope. The presence of a gram-negative rod reveals and confirms E. coli.

2.5 Statistical Analysis

Basic statistical tests of significant differences were done using the computer SPSS 16.0 Windows application. Data obtained were subjected to statistical analysis using paired sample T-test and the results obtained were compared with WHO (2006) water quality guidelines and Federal Ministry of Environment (1991) effluent limit for domestic use.

3. RESULTS

The summary of the result of physico-chemical and microbial parameters of water bodies around the Ogheneweta abattoir is presented in Tables 1-2.

Table 1: Results of physico-chemical and microbial parameters of underground water around Ogheneweta abattoir

Parameter	N	Sampling stations		FMENV limit	WHO limit	P-Value
		Well 1	Well 2			
		Mean ± SE (Min – Max)	Mean ± SE (Min – Max)			
Air temperature (^{o}C)	9	28.11±0.61 (24.00-29.00)	28.22±0.57 (24.00-29.00)	-	-	P<0.05
Water temperature (^{o}C)	9	27.67±0.17 (27.00-28.00)	27.78±0.15 (27.00-28.00)	-	-	P<0.01
pH	9	6.52±0.07 (6.16-6.82)	6.70±0.11 (6.00-7.13)	6-9	<8.0	P<0.01
TDS (mg/l)	9	210.78±10.87 (158.00-240.00)	70.23±7.78 (39.00-103.00)	2000	1000	P<0.01
Conductivity (mg/l)	9	426.05±22.46 (316.20-480.00)	139.67±14.02 (74.00-206.00)	-	500	P<0.01
DO (mg/l)	9	4.30±0.21 (3.40-5.10)	4.17±0.15 (3.20-4.65)	4-6	5	P>0.05
Turbidity (NTU)	9	2.18±0.48 (0.90-5.00)	1.95±0.42 (0.80-4.70)	200	5	P<0.01
BOD (mg/l)	9	1.56±0.32 (0.60-1.90)	1.36±0.47 (1.00-2.90)	5	-	P>0.05
Faecal coliform (MPN/100L)	9	2.22±0.67* (2.00-4.00)	2.00±0.00*(2.00-2.00)	0	0	P<0.01

Federal Ministry of Environment (1991), WHO (2006)

P>0.05 – No significant difference

P<0.05 – Significant difference

P<0.01 –Highly Significant difference

3.1 Water Temperature (°C)

Water temperature fluctuated between 27.67 °C and 27.78 °C for the underground water and between 26.56°C and 25.56°C for the surface water during the entire period of study. Temperature values in well 2 and station 2 were higher than the value obtained for well 1 and station 1. There was no temporal variation in the mean water temperature for underground and surface water. Comparing underground water temperature with surface water temperature shows that the value of underground water was higher than that of surface water. Figures 7 and 8 show the temporal variation of temperature for underground and surface water around Ogheneweta abattoir from May to January.

Table 2: Results of physico-chemical and microbial parameters of surface water around Ogheneweta abattoir

Parameter	N	Sampling stations		FMENV limit	WHO limit	P-Value
		Station 1	Station 2			
		Mean ± SE (Min – Max)	Mean ± SE (Min – Max)			
Air temperature (°C)	9	26.11±0.20 (25.00-27.00)	27.56±0.71 (24.00-30.00)	-	-	P<0.05
Water temperature (°C)	9	25.56±0.34 (25.00-28.00)	26.56±0.24 (25.00-27.00)	-	-	P<0.01
pH	9	7.11±0.11 (6.32-7.30)	7.02±0.08 (6.61-7.42)	6-9	<8.0	P<0.01
TDS (mg/l)	9	10.67±1.72 (7.00-20.00)	29.00±8.94 (10.00-88.00)	2000	1000	P<0.01
Conductivity (mg/l)	9	20.95±2.87 (14.48-40.01)	61.58±19.76 (21.00-168.90)	-	500	P<0.01
DO (mg/l)	9	4.20±0.06 (3.90-4.50)	4.72±0.47 (3.00-6.80)	4-6	5	P>0.05
Turbidity (NTU)	9	9.67±3.54* (3.28-31.80)	8.63±1.65* (3.17-16.30)	200	5	P<0.01
BOD (mg/l)	9	1.33±0.13 (0.60-2.90)	1.74±0.74 (1.10-1.50)	5	-	P>0.05
Faecal coliform (MPN/100L)	9	2.67±1.00* (2.00-4.00)	7.33±4.36* (2.00-14.00)	0	0	P<0.01

Federal Ministry of Environment (1991), WHO (2006)

P>0.05 – No significant difference

P<0.05 – Significant difference

P<0.01 –Highly Significant difference

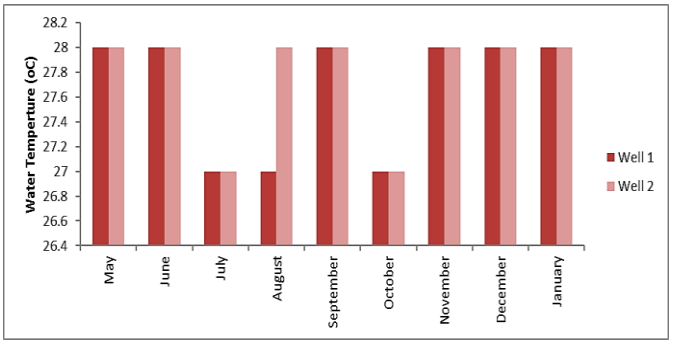

Figure 7: Temporal variation of temperature for underground water around ogheneweta abattoir from May to January

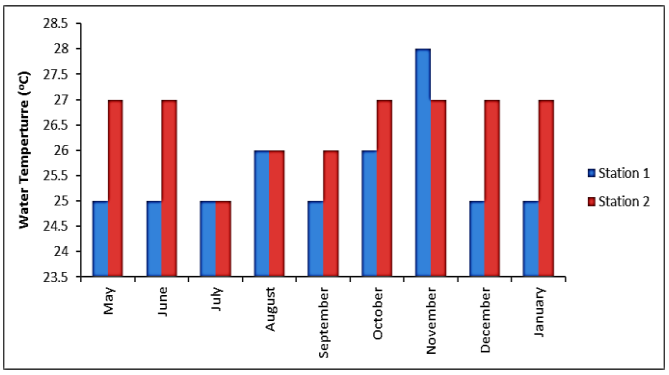

Figure 8: Temporal variation of water temperature for surface water around Ogheneweta abattoir from May to January

3.2 pH

The pH ranged from 6.52 – 6.70 for underground water and 7.02 – 7.11 for surface water. The value obtained for well 2 and station 1 was higher than the value for well 1 and station 2. From Figures 9 – 10, temporal variation indicates that the highest value was recorded at well 2 (7.13) for the month of September and the lowest at well 2 for the month of October for underground water, while the highest value was recorded at station 2 (7.42) for the month of January and lowest at station 1 (6.32) for the month of July for surface water. The pH value for surface water was higher than the values for underground water around the Ogheneweta abattoir.

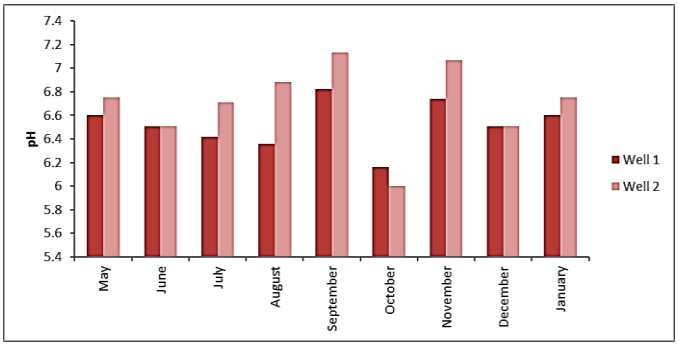

Figure 9: Temporal variation of pH for underground water around Ogheneweta abattoir from May to January

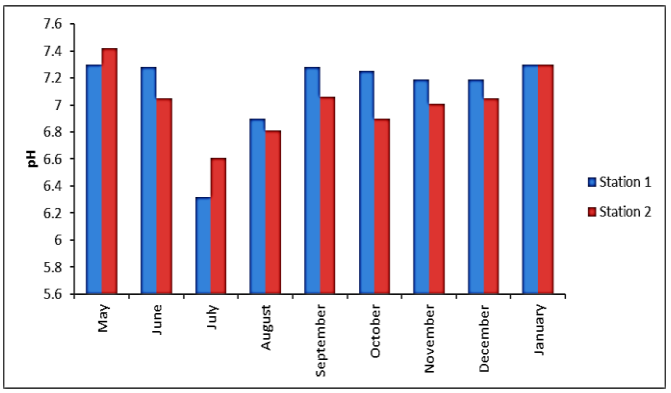

Figure 10: Temporal variation of pH for surface water around Ogheneweta abattoir from May to January

3.3 Total Dissolved Solid (mg/l)

Total dissolved solid fluctuated between 210.78 mg/l in well 1 and 70.23 mg/l in well 2 for the underground water, and between 29.00 mg/l in station 1 and 10.67 mg/l for the surface water during the entire study period. However, according to Figures 11- 12, the temporal variation shows that total suspended solid has its highest value in the month of November at well 2 and lowest in well 1 for underground, however for surface water, total suspended solid has its highest value in the month of May at station 2 and lowest in June, July and September at station 1.

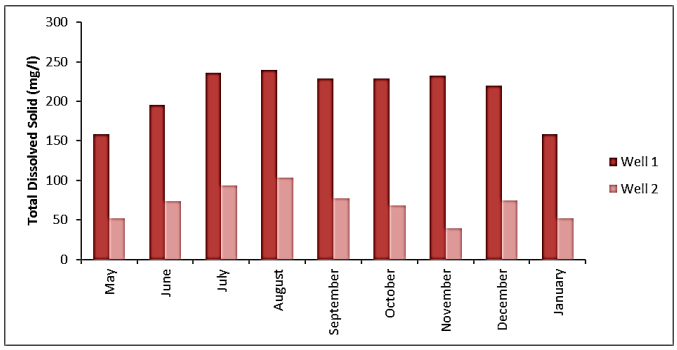

Figure 11: Temporal variation of Total Dissolved Solid for underground water around Ogheneweta abattoir from May to January

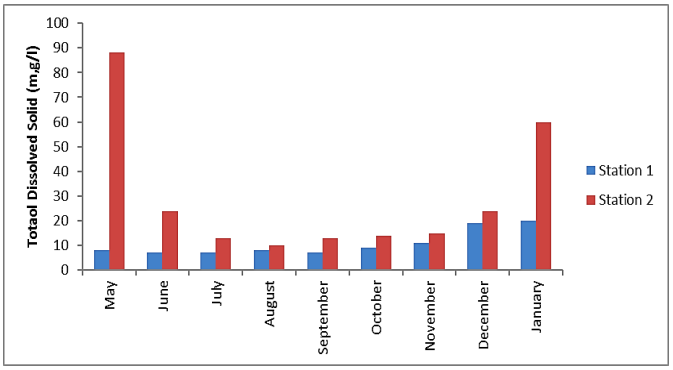

Figure 12: Temporal variation of Total Dissolved Solid for surface water around Ogheneweta abattoir from May to January

3.4 Electric Conductivity (mg/l)

The electric conductivity around Ogheneweta abattoir ranged from 426.05 mg/l – 139.67 mg/l for underground water and 61.58 mg/l – 20.95 mg/l for surface water. The value obtained for well 2 and station 1 was lower than the value for well 1 and station 2. From Figures 13- 14, the temporal variation indicates that the highest value was recorded at well 1 (480.00 mg/l) for the month of August and the lowest at well 1 for the month of November for underground water, while the highest value was recorded at station 2 (168.90 mg/l) for the month of May and lowest at station 1 (14.48 mg/l) for the month of September for surface water. The electric conductivity for surface water was lower than the values for underground water.

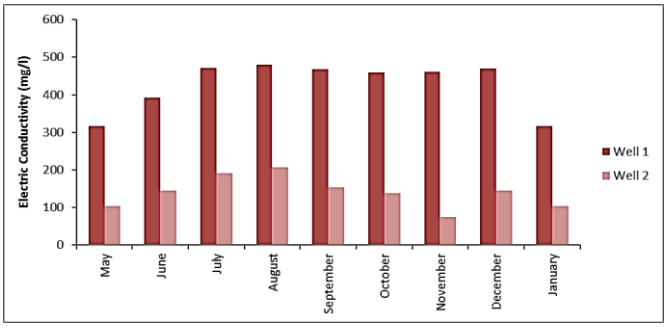

Figure 13: Temporal variation of Electric Conductivity for underground water around Ogheneweta abattoir from May to January

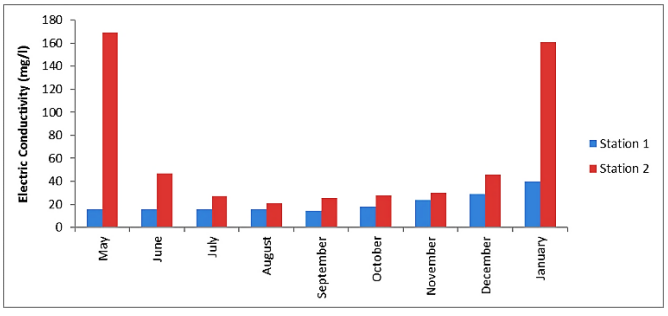

Figure 14: Temporal variation of Electric Conductivity for surface water around Ogheneweta abattoir from May to January

3.5 Dissolved oxygen (mg/l)

The mean DO was generally within the recommended range for effluent discharge; it, however, fluctuated between 4.30 mg/l in well 1 and 4.17 mg/l in well 2 for the underground water; and between 4.72 mg/l in station 2 and 4.20 mg/l for the surface water. However, temporal variation from Tables 15-16 shows that dissolved oxygen was highest in the month of August and January (5.1mg/l) at well 1 and lowest in well 2 (3.2mg/l) for the underground .

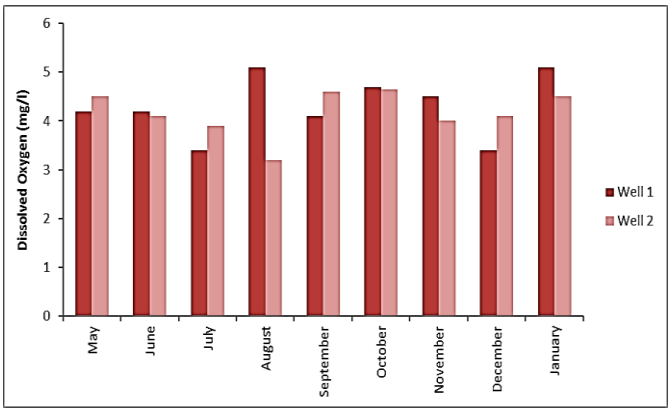

Figure 15: Temporal variation of Dissolved Oxygen for underground water around Ogheneweta abattoir from May to January

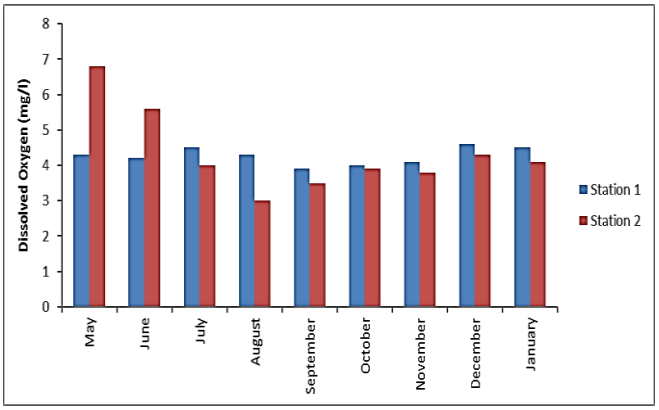

Figure 16: Temporal variation of Dissolved Oxygen for surface water around Ogheneweta abattoir from May to January

3.6 Turbidity (NTU)

Mean values recorded in stations 1 and 2 were beyond WHO standard (5NTU). However, turbidity fluctuated between 2.18 mg/l in well 1 and 1.95 mg/l in well 2 for the underground water; and between 8.63 mg/l in station 2 and 9.67 mg/l for the surface water during the entire period of study, according to Figures 17 - 18. Monthly variations observed among the various sampling stations show that the lowest value was recorded in May and January at well 2 and lowest in well 1 for September for underground water, while the highest was reported at station 1 in November and lowest at station 1 in July.

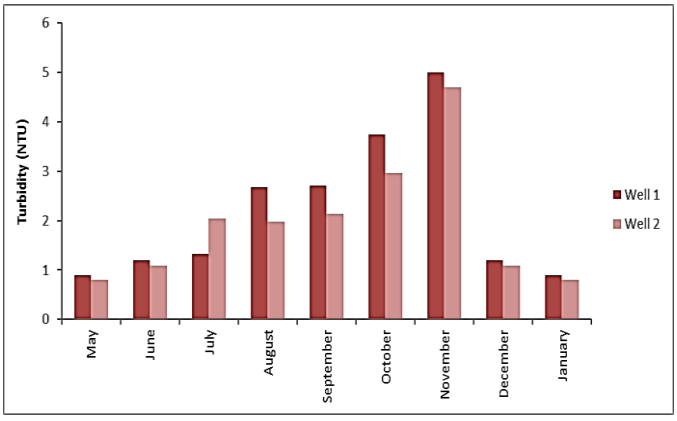

Figure 17: Temporal variation of turbidity for underground water around Ogheneweta abattoir from May to January

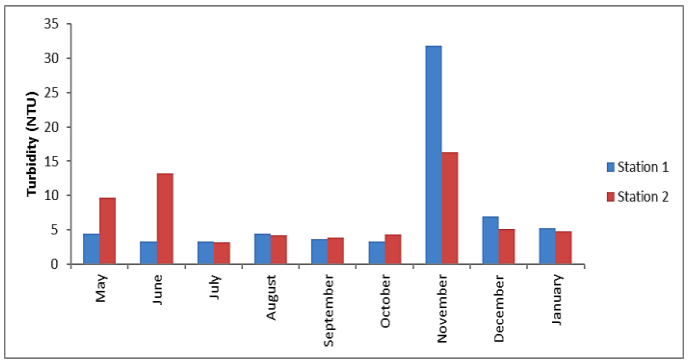

Figure 18: Temporal variation of turbidity for surface water around Ogheneweta abattoir from May to January

3.7 Biochemical Oxygen Demand (mg/l)

Biochemical Oxygen Demand ranged between 1.56 mg/l in well 1 and 1.36 mg/l in well 2 for the underground water; and between 1.74 mg/l in station 2 and 1.33 mg/l for the surface water during the entire period of study (see Figures 19 -20). However, there was no temporal variation.

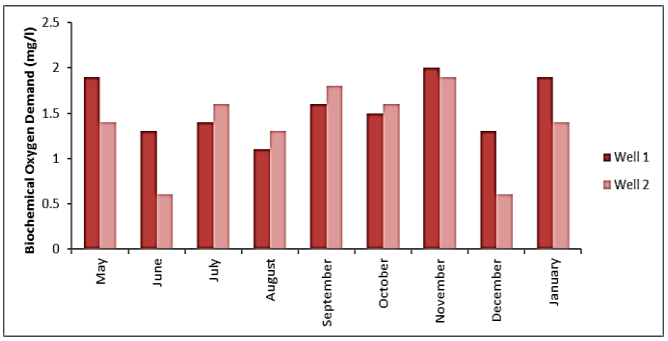

Figure 19: Temporal variation of Biochemical Oxygen Demand for underground water around Ogheneweta abattoir from May to January

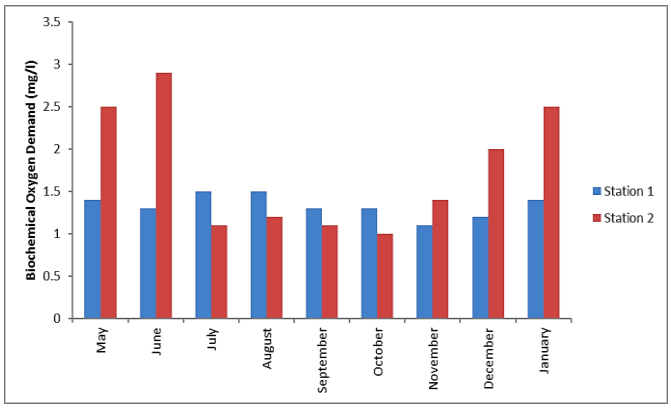

Figure 20: Temporal variation of Biochemical Oxygen Demand for surface water around Ogheneweta abattoir from May to January

3.8 Feacal Coliform (MPN/100L)

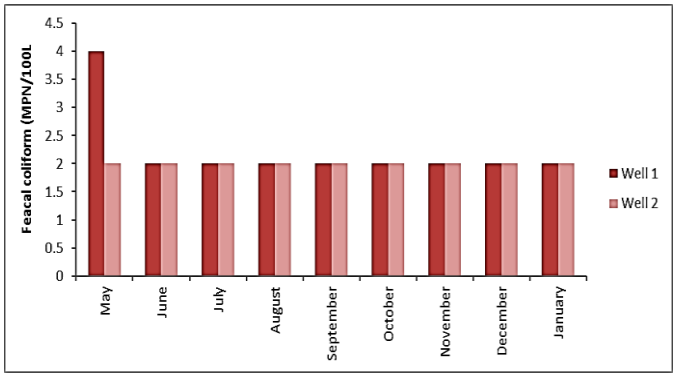

Figure 21: Temporal variation of Faecal coliform for underground water around Ogheneweta abattoir from May to January

Faecal coliform count fluctuated between 2.00 MPN/100L in well 2 and 2.22 MPN/100L in well 1 for the underground water; and between 7.33 MPN/100L in station 2 and 2.67 MPN/100L in station 1 for the surface water during the entire period of study according to Figures 21-22. However, this value is higher than the FEMEV and WHO standards of 1993. The values reported for surface water are higher than those reported for underground water.

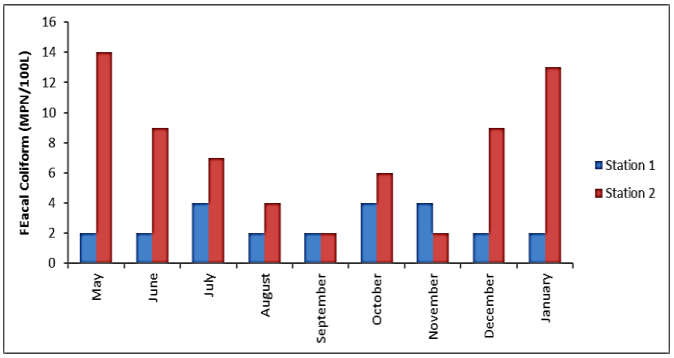

Figure 22: Temporal variation of faecal coliform for surface water around Ogheneweta abattoir from May to January

4. Discussion

The examination of water quality showed noticeable spatial discrepancies in certain parameters. Total Dissolved Solid, Electric conductivity, dissolved oxygen, turbidity, and faecal coliform were higher in well 1 (near the abattoir) than in well 2. In contrast, parameters such as water temperature, total dissolved solid, electric conductivity, dissolved oxygen, biochemical oxygen demand, and faecal coliform were elevated at the discharge point (station 2) compared to upstream stations 1. In comparison to the Federal Ministry of Environment limit for discharge into Nigeria's surface waters and WHO guideline values, both wells and stations exceeded the minimum acceptable limit for faecal coliform and turbidity (Awachie, 1981; Kusemiju, 1981; Umeham, 1989; Alabaster & Lloyd, 2013; Ekhaise & Anyasi, 2005; Odokuma & Okpokwasili, 1997; T. Imoobe & Koye, 2011; Millero, 1986; WHO, 2006; Wurts, 2003; Alabaster & Lloyd, 2013; Ogbeibu & Anagboso, 2003; Bruvold & Ongerth, 1969; Walk, Biosurvey, & Assessment, 1997; Ogbonnaya Chukwu, 2008; T. Imoobe & Koye, 2011; T. O. T. Imoobe & Ohiozebau, 2010; Chapman, 1996; Kulkarni, 2011; APHA, 1926; Packman, Comings, & Booth, 1999; Francy & Darner, 1998; United State Environmental Protection Agency, 1997; Boyd & Lichikoppler, 1979; Chapman, 1996; WHO, 2006; O Chukwu, Mustapha, & Abdul-Gafar, 2008; Ewa et al., 2011).

The pH scale (ranging from 1 to 14) indicates the water's acid/base balance. The acceptable pH range for most natural waters lies between 6.0 and 8.5, coinciding with the WHO recommendation for domestic water use (Millero, 1986; WHO, 2006). However, the pH of surface water was higher than the underground water around the Ogheneweta abattoir. This might have adverse effects on aquatic life and its suitability for domestic use (Wurts, 2003). Total dissolved solids fluctuated between 210.78 mg/l in well 1 and 70.23 mg/l in well 2 for the underground water, and between 29.00 mg/l in station 1 and 10.67 mg/l for the surface water. This higher mean value of total dissolved solids recorded in station 2 and well 1 suggests elevated levels of dissolved ions in the effluent. Excessive concentrations of suspended and dissolved solids can harm aquatic life by decreasing water quality, inhibiting photosynthesis, increasing bottom sediments, and reducing water depth (Alabaster & Lloyd, 2013; Ogbeibu & Anagboso, 2003; Bruvold & Ongerth, 1969). Electric conductivity is a measure of water's ability to conduct an electric current, which can indicate a potential problem from various dissolved substances. This study found elevated levels of electric conductivity in well 1 and station 2, likely due to the decomposition of organic matter from the abattoir. This could disrupt the ecosystem, reduce organism populations, and result in biodiversity loss (Walk, Bios.Edlund & Håkanson, 2000). Furthermore, it was reported that an increase in temperature affects the solubility of oxygen and influences the metabolic rate of aquatic organisms (Boyd, 1990). As such, the water temperature differences observed in this study between the various wells and stations could potentially have significant implications for the aquatic ecosystem. Regarding pH, it is known to be an important water quality parameter that can affect both the aquatic life and usability of water (Wurts, 2003). Our findings suggest that the pH of the water around the Ogheneweta abattoir fluctuates between neutral to slightly basic. Although these values are within the recommended ranges for drinking water, the higher pH values could potentially harm certain aquatic organisms and affect water suitability for domestic use (Wurts,

2003). The amount of total dissolved solids (TDS) can impact the palatability of drinking water (Bruvold & Ongerth, 1969). Our analysis shows that TDS varies significantly between the various wells and stations. Despite the values falling within the acceptable levels for drinking water, the higher TDS content in certain locations signifies elevated levels of dissolved ions, potentially affecting the taste of water.

Conductivity is a measure that can indicate potential problems from certain organic and inorganic substances dissolved in the water (Walk, Biosurvey, & Assessment, 1997). We observed a range of conductivity values across the wells and stations. Despite falling within the WHO limits for drinking water, the elevated conductivity values closer to the abattoir and at the discharge point could be linked to higher organic matter decomposition from the abattoir, potentially disrupting the ecosystem balance and reducing biodiversity (T. O. T. Imoobe & Ohiozebau, 2010).

Dissolved oxygen (DO) is a vital parameter, signifying the self-purification capacity of the water body and its degree of pollution by organic matter (Chapman, 1996). The DO levels observed in this study were mostly within the acceptable range, but the values were lower at locations with higher organic load. Such locations may have reduced DO levels due to increased organic matter oxidation and breakdown, leading to detrimental effects on aquatic life (Chapman, 1996).

Turbidity refers to the cloudiness or haziness of a fluid caused by suspended solids (Kulkarni, 2011). High turbidity levels can raise water temperatures, reduce dissolved oxygen, and inhibit photosynthesis, all of which can negatively impact aquatic life (United State Environmental Protection Agency, 1997). Our results show elevated turbidity levels in wells closer to the abattoir and the discharge point, which could impact the aquatic ecosystem.

Biochemical Oxygen Demand (BOD) is used to determine the level of organic pollution in water (Chapman, 1996). The BOD values obtained from the surface water in this study were lower than the ideal level to sustain aquatic life and below the WHO's minimum level for wastewater discharge. This could be due to the large quantities of effluents from the abattoir being discharged into the river, suggesting low organic pollution at the discharge point.

The presence of faecal coliform bacteria in water indicates faecal contamination, possibly from animal or human waste (O Chukwu, Mustapha, & Abdul-Gafar, 2008). Our findings revealed that the faecal coliform count in both underground and surface water exceeded the FEMEV and WHO standards, indicating potential health risks. The higher values in surface water could be due to direct waste discharge into the water body.

The detection of faecal coliform in both underground and surface water can be attributed to the presence of animal faeces, with animal intestinal matter often flushed into open drains. This aligns with the findings of Ewa et al. (2011), which state that total or faecal coliform bacteria can inhabit water polluted by human and animal waste. If total coliforms are not present in water, it suggests a minimal likelihood of disease-causing organisms existing in the water.

The study's findings showed a varying faecal coliform count, ranging from 2.00 MPN/100L in the second well to 2.22 MPN/100L in the first well for underground water, and from 7.33 MPN/100L at the second station to 2.67 MPN/100L at the first station for surface water over the study's duration. Notably, these figures surpass the FEMEV and WHO standards established in 1993.

Surface water reported higher values than underground water, likely due to the direct waste disposal into the water body. Moreover, the point of waste discharge and the underground water source near the abattoir demonstrated higher contamination levels than other locations. The World Health Organization (2004) cites the primary health risk associated with microbial contamination as consuming water tainted by human or animal faeces. This observation aligns with the findings reported by Ekhaise and Anyasi (2005).

5. Conclusion and Recommendations

Over the last few years, considerable population growth has occurred in many African countries, accompanied by a steep increase in urbanization and industrial and agricultural land use. This has entailed a tremendous increase in the discharge of a wide diversity of pollutants to receiving water bodies and has caused undesirable effects on the different components of the aquatic environment and fisheries. As a result, there is a growing appreciation that nationally, regionally, and globally, the management and utilization of natural resources need to be improved and that the amount of waste and pollution generated by human activity needs to be reduced on a large scale.

The findings of this study showed that the quality of the surface and underground water within the Ogheneweta abattoir has been impacted negatively by the abattoir activities. All physico-chemical and microbial parameters were within the Federal Ministry of Environment (1991) and WHO (2006) guidelines except for the concentrations of turbidity in surface water and faecal coliform in both surface and underground water, whose mean values for both stations exceeded the limit. The mean values of stations studied showed that temperature, TDS, and conductivity were higher for groundwater and pH, turbidity, and faecal coliform were lower. At the same time, the reverse is the case for surface water. Also, the physico-chemical parameter showed a distinct seasonal variation, as high values were recorded in pH, TDS and Turbidity. In contrast, conductivity was lower in the rainy season and vice versa. In order to reduce the rate of pollution, the following recommendations are made so as to enhance the quality of surface and underground water bodies around Ogheneweta abattoir as well as protect the public health of the people who depend on it as a source:

- A groundwater monitoring program to determine the groundwater quality status of wells in the neighborhood of abattoirs be implemented by stakeholders to safeguard the health of innocent residents.
- The use of a retention pond could carry out simple physical treatment of effluent from the abattoir. Using retention ponds to pre-treatment abattoir effluent is an effective physical treatment method in reducing BOD levels.
- Waste management practices by waste reduction, reuse and recycling should be encouraged when and where appropriate and essential. Entrepreneurs dealing in animal wastes such as bones, manures and blood should be encouraged by enabling government policies to convert abattoir waste to useful products.
- Abattoir operators should be enlightened by both the state Environmental Protection Agency and NGOs on the impacts of wash down from abattoirs on public health, the environment and the ecosystem's fragility.
- Regular monitoring of abattoir activities by the state Environmental Protection Agency and municipal government representatives is recommended to enhance compliance with hygienic requirements and sanitary regulations governing abattoir operations in the state.
- An adequate solid waste disposal method should be adopted, phasing out open dumpsites to safeguard public health from waterborne diseases.
- Wells located within 50 meters of the pollution source should be abandoned, and future wells should be constructed beyond 250 meters from the pollution source.
- Research efforts should be aimed at by-product recovery and dry clean-up so as to reduce the amount of wastewater and the actual volume of wastes released from the abattoir. This research could be expanded to include the treatability of abattoir effluents by biological treatment.

In conclusion, it is imperative for the government and other stakeholders to swiftly intervene by establishing effluent treatment facilities to effectively manage the waste generated by abattoirs in Ughelli. Additionally, adopting cleaner technologies is crucial in mitigating the environmental health risks associated with discharging hazardous effluents from abattoirs. These measures will significantly contribute to safeguarding the environment and promoting public health.

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