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IMPACT OF ABATTOIR WASTE ON WATER QUALITY (A CASE STUDY ON IWOFE RIVER, PORT-HARCOURT, RIVERS STATE, NIGERIA)

Chukwu Emmanuel Ogwu[1], Esievo Lawrence[2], Stephen Okanezi[3], Zainab Mika'il Zakari[4], Okoro Amaka Desire[5], Okokpa Chidiebube Patrick[6], Okoro Blessing Ogbonne[7]

[1]Ecotoxicology Dept, Helmholtz Centre for Environmental Research, Leipzig, Germany, [2] Quality Control Dept, Evomec Global Services Limited, Port Harcourt, Rivers State, Nigeria, [3]Environmental Dept, Saipem Contracting Nigeria Limited, [4]Chemistry Dept, Nasarawa State University, Keffi, Nigeria; [5]Chemistry Dept, Federal University of Technology, Owerri, Imo State, Nigeria, [6]Electrical/Electronics Engineering Dept, KAAF University College, Accra, Ghana, [7]Chemistry Dept, Akanu Ibiam Federal Polytechnic, Unwana, Ebonyi State, Nigeria.

KeyWords
Abattoir waste, Environmental Impact, Health Impact, Iwofe River, Wastewater, Water Pollution, Water Quality, Slaughter house.

ABSTRACT

The discharge of abattoir wastes has been a major cause of concern of surface water pollution globally due to it impact on public and environmental health. This study, assessed the impact of abattoir waste on water quality (A case study on Iwofe River, Port-Harcourt, Rivers State, Nigeria) using standard methods. Surface water samples were collected at three points (upstream, midstream and downstream) and the results presented. The insitu results ranged as follows; temperature 28.50 – 29.70 °C, pH 7.19 – 7.36, salinity 3.00-6.35 PSU, conductivity 5059 – 11208 µS/cm, oxidation-reduction potential 91.70 – 164.80 mV and turbidity 59.60 – 78.10 NTU, Total Dissolved Solids, Dissolved Oxygen 5.90 – 12.90mg/L. The chemical results ranged as follows: Total Suspended Solids 2542 - 5604, Biochemical Oxygen Demand 0.42 – 3.08, and Chemical oxygen Demand 2.90 – 7.75mg/L respectively. Alkalinity 25 – 113 mg/L, total hardness, 990.00 – 1256.00 mg/L, Cl^- 3669.08 – 7887.63 mg/L, CO_3^{2-} 12.50 to 66.00 mg/L, and NO_3^- 0.85 – 1.08 mg/L, SO_4^{2-} 133.56 – 283.17 mg/L, PO_4^{2-} , 90.00 – 100.00 mg/L, oil and grease 0.10 – 0.15 mg/L, and total coliform 13800 - 29800 cfu/mL. Metals results ranged as follow; As (<0.001 – 0.009 mg/L), Pb (<0.001 – 0.002 mg/L), Zn (<0.001), Fe (0.019 – 0.285 mg/L), K (8.245 – 8.540 mg/L), Mn (<0.001 – 0.005 mg/L), Mg (3.345 – 4.076 mg/L), Ca (2.452 – 4.085 mg/L), Ni (0.002 – 0.010 mg/L), Cu (<0.001 – 0.006 mg/L), Cr (0.001 – 0.003 mg/L), Cd (0.006 – 0.013 mg/L). The findings reviewed that most of the analyzed parameters did not meet the WHO regulatory limits for drinking water quality which is an indication abattoir wastes have a potential to worsen scarcity clean water availability, thereby adversely affecting the range of uses of such water bodies. It is therefore recommended that the activities of the abattoir should be monitored closely by relevant agencies in order to prevent environmental and health hazards challenges within the host communities.

1.0 INTRODUCTION

Butchering houses are known universally to pollute the surroundings either directly or laterally from their several procedures. The situation is worsened when abattoirs are positioned near domestic areas and as such the abattoir wastes are disposed in gullies where runoff washes them upwardly, thereby polluting groundwater and near watercourses*, lemile, et al, (2019*). This miracle arising from mortal conditioning is now of global concern as illustrated by *Hillel etal. (2015).* This is due to the scientific analysis that the discharge of undressed high- strength wastewater into water bodies results in water quality deterioration of the beneficiary water bodies according to *(Terrumun and Oliver 2015).*

The Abattoir is a place where creatures are butchered for the purpose of product of meat/ protein which are supplied to the public. As much as the exertion and its individual operations are to give the demanded source of protein, the way and manner it's handled and its derivations or wastes sorely could constitute hazard when the proper way aren't taken into cognizance *Mamhobu- Amadi etal., (2019).*

As worse as it could get, there are pointers which scientifically unfold the below by showing that elevated situations of nutrients (nitrogen and phosphorus) in face water due to this type pollution expiring from mortal affiliated conditioning at original slaughter-houses and slaughters accelerate the growth of oxygen- depleting microorganisms whose inordinate growth destroy the submarine ecosystems and affect in eutrophication of these water bodies forenamed, *Zhang etal., (2014).*
The impact of these damages is simple ecologically as well as biologically, chemically and physically, *(Terrumun & Oliver, 2015).* Ecologically, dangerous algal blooms(robotic and unbridled growth of algae), dead zones(areas in water bodies where submarine life cannot survive because of low oxygen situations these are generally caused by significant nutrient pollution), and fish kills(unanticipated mass mortality of wild fish over a short period of time generally attributable to pollution or impurity of waters or a combination of natural and mortal- convinced stresses in the terrain.) are the results of a process which occurs when the terrain becomes largely and suddenly amended with nutrients — eutrophication *Badruzzaman etal., (2012).*
Wastes from beast intestine (feaces and urine from ruminants and others), their feed, decayed body corridor and blood during slaughtering can be a source of pollution when it isn't managed *Osibanjo etal., (2011)*. former studies have shown that waste from abattoirs pose a great threat to beneficiary water bodies due to its implicit high content of pathogens *(Arimoro, 2009).* Also, if the creatures aren't housed, there may also be issues of corrosion and deposition transport into face waters due to their grazing conditioning *(Terrumun & Oliver, 2015).*
Still, pollution of face water from abattoir wastewater and run- offs constitutes substantial ecological and health pitfalls due to the advanced situations of biodegradable organic matter, inordinate alkalinity, phosphorous, nitrogen and micronutrient attention as described by *Del- Nery etal. (2007).*

In Iwofe area of Obio/ Akpor Local Government area of Rivers state, the wastewater from the killed creatures and the washed arbor where the creatures are butchered have a channel the water flows from to the New Calabar River veritably near to it (roughly a many measure down). Interestingly, some organic waste may be suitable to be adulterated in the swash at veritably minimum attention with the tidal characteristics of the swash; it can tone- cleanse by natural natural processes according to *Mutamim etal. (2013).*
In the light of the below, the exploration aims to decrypt the impact of the slaughterhouse waste (discharged directly and in run- offs) on the physico-chemical parameters, microbiological pointers, and heavy essence content of the face water (Iwofe River) since it's of use to humans in numerous ways and the submarine community.

2.0 LITERATURE REVIEW

Wastewaters with high attention of adulterants are discharged from slaughterhouses, food processing shops, dairies, breweries, medicinal, and tanning diligence. Slaughterhouse wastewater, in particular, contains high content of organic matter, suspended solids, oil painting and grease, and nutrients *Rajpal etal., (2022); (Magaji & Chup, 2012).* Different artificial processes, videlicet, slaughtering, refining, and washing, contribute different kinds of waste aqueducts which combine to induce colorful factors of slaughterhouse wastewater pollution, *Rajpal etal., (2022).*
One of the most critical problems of developing countries is indecorous operation of vast number of wastes generated by colorful mortal conditioning. Open and indiscriminate jilting of solid wastes in drainage channels and strands is among the problems of indecorous operation of waste in the developing countries of the world *Eze etal., (2019)*. In Nigeria, the development and growth of beast product has been on the increase and has guaranteed steady force of food creatures meant for bloodbath and processing for mortal consumption *Nwanta etal., (2008).*
Abattoir conditioning is responsible for the pollution of surface and groundwater as well as air quality which laterally affects the health of hearthstone living within the vicinity of the abattoirs. Report also shows that abattoir wastes piled up within the terrain can beget pollution and latterly produce methane gas that intensifies hothouse effect *(Tamenech & Tamirat, 2017)*.

2.1 Surface water

Surface water is water on the face of the earth similar as in a sluice, swash, lake, swamp, or ocean. It can be varied with groundwater and atmospheric water *(Ezugwu & Apeh, 2017*).

2.1.1 Importance of Fresh Surface Waters

As reported by *Chukwu etal (2022)* aqueducts, Lakes, ponds, gutters, and courses hold lower than one thousandth of a percent of the water on the earth, but they serve multitudinous critical functions for the terrain and for mortal life. These fresh face waters sustain ecological systems and give niche for multitudinous plant and beast species. They also support a myriad of mortal uses, including drinking, irrigation, wastewater treatment, beast, artificial uses, hydropower, and recreation. Fresh face waters also impact the extent

and condition of other water resources, including ground water, wetlands, and coastal systems downstream (*EPA, 2020).*

2.2.2 Sources of Surface Water Pollution

According to *Chukwu etal (2022)* face water pollution is nearly entirely the result of mortal activity. Agriculture, mining, factory effluent, tips, mortal/ beast waste and localized pollution are just some of the most common sources of face water pollution. Topography and geological conformations produce natural face water runoff, but mortal manipulation of the land increases flux rates and overall contamination *(Hydroviv, 2020).*

i. Point source pollution comes from a easily identifiable source, like a factory or sewage treatment plant. Point source pollution is discharged through a channel, gutter, or any "separate vehicle" that directly or indirectly enters a body of water. Point sources are generally regulated by National Pollutant Discharge Elimination System (NPDES) permits *(Hydroviv, 2020)*.
ii. Non-point source pollution is much harder to regulate because the source is not easily identifiable. Agricultural and storm water runoff are the two most common types of nonpoint source pollution. Heavy rain events beget contaminants to runoff from roads and fields, collecting debris and pollution as it travels into a body of water *(Hydroviv, 2020)*.
iii. Air deposit: Acidic aerosols, heavy substance, and other airborne contaminants may be deposited directly in water or may wash into water bodies after deposit on land. For illustration, mercury emitted to the air from combustion at power shops can be transported and deposited in lakes and budgets *(EPA, 2020)*. iv. Invasive species Invasive arenon-indigenous plant and beast species that can harm the terrain, mortal health, or the economy. Invasive species can crowd out native species and alter the physical and chemical condition of water bodies *(EPA, 2020).*
iv. Invasive species: Invasive arenon-indigenous factory and beast species that can harm the terrain, mortal health, or the frugality. Invasive species can crowd out native species and alter the physical and chemical condition of water bodies *(EPA, 2020)*.
v. Natural factors: rush determines the timing and amount of runoff and erosion, while other aspects of downfall and climate influence heating, cooling, and mixing in lakes — which affect the movement of adulterants and the cycling of nutrients. The mineral composition of bedrock and deposit helps determine whether a water body may be susceptible to acidification *(EPA, 2020).*
vi. Extent: The condition of fresh face waters also may be told by extent. Stream flux patterns impact contaminant and deposit loads, while changes in the shape of water bodies —e.g., barring deep pools or creating shallow imprisonments- can change water temperature *(EPA, 2020).*

2.2 Waste Management in Abattoirs

Waste management involves managing conditioning associated with generation, collection, transport, and disposal of waste in a terrain *(Anjaneyulu, 2008)*.

Waste accoutrements are always produced as a result of natural processed and domestic conditioning. Waste can also be produced by natural causes, at the same time there has been an increase in product marketing to promote consumption *(Digby, 1996)*. The conditioning in the abattoir which correspond of holding, examination, slaughtering, and meat processing in the municipality has influenced in magpie breaking off and disposal of the waste generated from these creatures in both solid and liquid forms come a major concern on how to manage them *Adeyemo etal., (2007). Alonge etal. (2008)* states that magpie deposit of waste from abattoir both from the creatures holding pens and that from the massacred beast has come a hazard to food safety of the living around the area, magpie disposal of the liquid wastes from abattoir into gutter and drainages have a negative impact on the terrain as some place come affected by the reeking smell from the abattoir, the drainage system becomes affected during the stormy season as a result of waste deposit in the gutters. In some part of the megalopolis, because of ignorance and hygienic habit, faecal matter frequently finds its way into solid wastes and contaminates the accoutrements. At times some complaint vectors like canvases and rats are being at dump spots of abattoir wastes, which create circular threat to the community. *Odeyemi (2000)* states that the environmental impacts of the abattoir waste in the megalopolis should be handled in similar way that their goods are considerable reduced, elided or excluded. The topmost impact arises from the release of waste in the abattoir are naturally set up in all cases. The adverse goods can be minimized or excluded through the perpetration of proper wastes operation.

2.3 Methods of Abattoir Wastes Disposal

Each of the being disposal styles has merit and dereliction, the styles include burial, composition, picture, and incineration.

- **Burial:** The only restriction on burial is the demand for simply two bases of earth cover. This system is used for dead creatures and other meat product waste by directors and abattoir. The effect on water and soil and the threat of pathogen transmission haven't been completely starched *(Adesemoye etal., 2006)*.
- **Composition:** The composition process for full bones or significant rates of waste takes several times; it's labour ferocious and may be in effectives in disposing of hides and bones. Bones – indeed funk bones are notoriously delicate to compost, the admissible uses of the final produced (compost) in developing countries are still uncertain and may depend on the quality of the compost. Results from so numerous studies reveal that the compost process is effective to break down the waste to Kill some pathogens and produce final compost, which is fairly safe *(Adesemoye etal., 2006)*.

- **Incineration:** This is generally used when dealing with lower amounts of waste, original result from tests of small incineration units shows significant destruction of pathogens and emigration within the admissible requires substantial capital and operation cost *(Digby, 1996)*.
- **Rendering:** Rendering is a process applied to tackle gathered from butchery packaging, processing, food medication, and dead creatures; it includes cuisine, removing humidity and separating the accoutrements into sterile beast protein refection and fat products similar as tallow, meat and bone mess (MBM), meat mess, blood mess and father mess. The muscle, fat, bones and other beast towel are change into protein rich substances which look like beach or soil. This is important safer, more fluently stored in loss reprehensible form. Unlike raw wastes accoutrements, the products deduced from rendering can be stored for long period of time. The temperature and length of the picture process kill or inactivates traditional conditions-causing organisms. picture has long been regarded as a stage at which the conditions transmission cycles could be disintegrated. In the history, protein and fat products were seen as sterile, although subject to new impurity if not duly stored or handled. Traditionally, picture has produced precious and marketable protein and fat products from meat product waste *(Digby, 1996)*
- **Land Spreading:** Another option for disposal of abattoir liquid waste is to apply it to cropland as it can be precious as an agrarian toxin. But there should be scientific substantiation that land spreading exertion will be of benefit to husbandry, and won't give rise to damaging of the terrain and won't jeopardize mortal health *(Digby, 1996)*.

2.6 Effect of Abattoir on Water Quality

Abattoirs are important in Nigeria and they play a major part in domestic meat force assiduity as well as handed employment openings to numerous members of communities where they're located *(Makwe and Chup, 2013)*.

3.0 MATERIALS AND METHOD

3.1 Equipment:

Table 3.1: List of Equipment and Model

S/N	Name	Manufacturer	Model
1	Atomic Absorption Spectrophotometer (AAS)	Perkins Elmer	AAnalyst 400
2	UV-Vis Spectrophotometer	Axiom Medical UK	721D
3	Multi-parameter (Water quality meter)	Hanna meter	HI 9829
4	Oven	Biobase	BOV-D30
5	Desiccator	UL	210mm
6	Water bath	HH-6	
7	Refrigerator	Haier Thermocool	HTF 2591W
8	Analytical balance	Dranell	DT5003A
9	Fume cupboard	Local fabrication	
10	Colony counter	Wincom Company Limited	J-2
11	Pure water distiller	UL	SZ-96
12	Magnetic stirrer	XMTD-702	85-2
13	Autoclave	Ocean MED	YX-18LD
14	Incubator	Biobase	BJPX-H30

- **The Iwofe Abattoir**

The iwofe abattoir area is surrounded by a small market directly facing a lodge accommodation for students (Plate I). There is a concreted floor area with an open housing graze pen for the cows tied to logs (Plate II). Functional boreholes are attached to the entry and exit routes around the concreted floor, some with fitted water-bearing hose for washing of hands and feet of the butchers before and after work. Also, the water is sued to wash off the blood and stains and cow dung dropped off during the slaughtering of the animals.

Plate I: Signage showing the Iwofe slaughter on the highway and the market.

The end of the concreted floor oversees an area where the washed off materials flow to meet the river flowing towards it whenever there is high ebb.

Plate II: The concreted floor and channels of waste flow

However, by the eastern part of the divide there is a small plantation with different plants like cocoa yam, water leaf, and other herbs. This plantation is furnished with fertilizers and animal dung. Same arena harbor the skin burning hearth for the slaughter where cow skins are roasted and treated to give the edible local 'kanda' or 'kpomo' as it is called. Bones from killed animals are discarded close to this point and burned after a period of time (Plate III).

At the far western part is a toilet for the butchers' use. The condition of the small building had no proper maintenance (Plate III).

Plate III: Iwofe Slaughter heart (Left), bone dump (center) and toilet facility (Right)

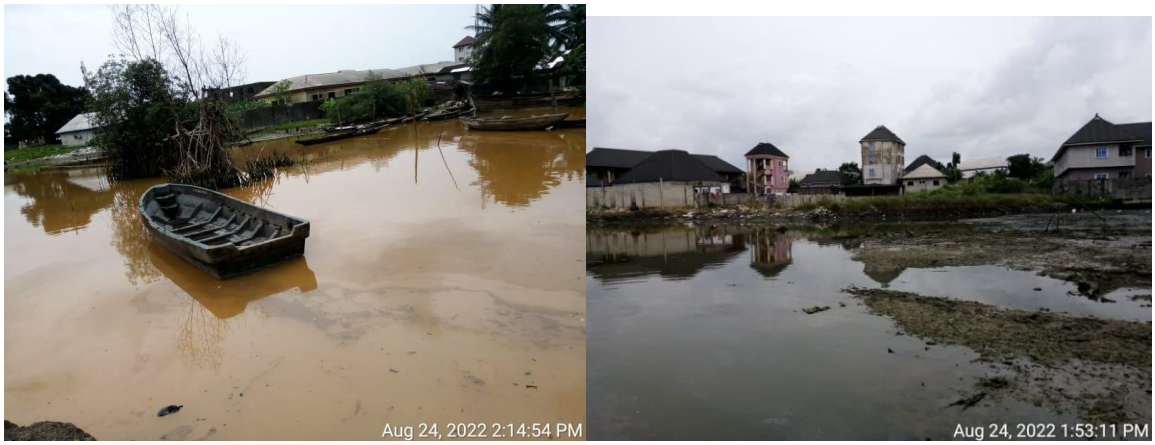


Plate IV: Locations in the Iwofe River showing low ebb

- **Sample Location**

Iwofe, the community facing the New Calabar River (Iwofe River) houses the Ignatius Ajuru University and student lodges all-round the area (first and second Erico, Azumini police station and eagle cement area). It is located in Obio-Akpor local government area in the metropolis of Port Harcourt. Iwofe Abattoir area is bordered by a small market directly facing a lodge accommodation for students. Also, the water is sued to wash off the blood and stains and cow dung dropped off during the slaughtering of the animals. Coordinates taken of the area showed the locations where samples were got for upstream, midstream and downstream on a google earth map (Fig. 3.1)

Figure 3.1: Location map showing sampling points on the Iwofe River (Adopted from Wikipedia)

- **Sample Collection**

Surface water was sampled from the New Calabar River which rendezvous the Iwofe slaughter axis in Rivers State using standard sampling methods. The surface water collection will involve rinsing each labelled container with the water at the exact geo-referenced point (Upstream, Midstream and Downstream) recording the time and coordinates. Samples collected for the analysis for heavy metals will be preserved using nitric acid while other samples will be placed in ice-packed ice chests.

3.2 METHODS

3.2.1 Water Quality Parameters Analysis

Temperature, pH, Electrical conductivity (EC), Total Dissolved Solids (TDS), Salinity, Turbidity, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD_5) and Oxidation Reduction Potential (ORP) were analysed using HANNA Multi-parameter Meter (APHA, 1998).

The main operating modes for HI 9829 are measurement, logging and setup. The measurement screen can be configured to display a single measurement or up to 12 simultaneous measurements by using the numbers 1-7 on the keypad. Use the arrow keys to scroll through the measurements not being displayed.

Procedure: the probe was inserted to the Hanna meter and screwed up. Then the equipment was turned on by pressing the power key. The parameter button was selected by pressing the displayed key. Then parameters of interest were enabled by pressing the enable key, and then exited by pressing the ESC key.

The probe/Electrode and sample beaker were rinsed with distilled water and then the sample. Exactly 2/3 of the sample was poured into the sample beaker. Then the measure key was pressed, using the up and down arrow keys to navigate to selected parameters and the reading was recorded. After recording, the meter was turned off by pressing on the power key and then the probe was unplugged. The meter was packaged and the sample beaker rinsed with distilled water.

Total suspended solid (TSS) was determined by gravimetric method using APHA 2540 D method (APHA, 1998).
A clean evaporating dish containing prepared glass fibre filter was heated at 103 ^{0}C – 105 ^{0}C for 1 hour in an oven. It was thereafter cooled in a desiccator to balance temperature and weighed. This was repeated until a constant weight was obtained. Then the glass fibre filter was stored in a desiccator until when needed. The water sample was stirred with a magnetic stirrer to obtain a more uniform (homogenous) particle size. Then 50 mL portion of the homogenized sample was measured into the seated glass fibre and filtered with applied vacuum. Then three successive volumes of distilled water were used to wash the filter paper while suction continued for about 3 minutes after filtration. The filter paper was carefully removed from the filtration apparatus and transferred back to the evaporating dish and left for 1 hour at 103 ^{0}C – 105 ^{0}C in an oven. Thereafter, it is cooled in a desiccator to balance temperature and weighed. The cycle of drying, cooling, desiccating and weighing was repeated until a constant weight was obtained.
Calculation:

$$\text{mg Total Suspended Solids/L} = \frac{(A-B)\ X\ 1000}{\text{Sample volume (ml)}}$$

Where;
A = weight of evaporating dish and filter + weight of residue (grams) and;
B = weight of evaporating dish and filter (grams)

Chemical Oxygen Demand (COD): COD was determined by Closed Reflux – Colorimetric Method using APHA 5220 D standard method (APHA, 1998).
When a sample is digested, the dichromate ion oxidizes COD material in the sample. This results in the change of chromium from the hexavalent (VI) state to the trivalent (III) state. Both of these chromium species are colored and absorb in the visible region of the spectrum. The dichromate ion ($Cr_2O_7^{2-}$) absorbs strongly in the 400 nm region, where the chromic ion (Cr^{3+}) absorption is much less. The chromic ion absorbs strongly in the 600 nm region, where the dichromate has nearly zero absorption.
a**.** Digestion solution, high range: exactly 500 mL distilled water 10.216 g potassium dichromate ($K_2Cr_2O_7$), primary standard grade, previously dried at 150 °C for 2 h, 167 mL conc. H_2SO_4, and 33.3 g $HgSO_4$. Dissolve, cool to room temperature, and dilute to 1000 mL.
b. Digestion solution, low range: exactly 500 mL distilled water was added to 1.022 g potassium dichromate ($K_2Cr_2O_7$), primary standard grade, previously dried at 150 °C for 2 h, 167 mL conc H_2SO_4, and 33.3 g $HgSO_4$. The mixture was dissolve, cooled to room temperature, and diluted to 1000 mL.
c. Sulphuric acid reagent: exactly 5.5 g silver Sulphate (Ag_2SO_4) reagent was added to 546.45 mL conc. H_2SO_4 and allowed to stand for 1 – 2 hours to dissolve.
d. Potassium hydrogen phthalate (KHP) standard, $HOOCC_6H_4COOK$: KHP was lightly crushed and dried to constant weight at 110 °C. Then 425 mg was dissolved in distilled water and diluted to 1000 mL. KHP has a theoretical COD of 1.176 mg O_2/mg and this solution has a theoretical COD of 500 μg O_2/ mL.

Table 3.2: Sample and Reagent Quantities for various Digestion Vessels

S/N	Digestion Vessel	Sample (mL)	Digestion Solution (mL)	Sulfuric Acid Reagent (mL)	Total Final Volume (mL)
1	16 X 100 mm	2.50	1.50	3.50	7.50
2	20 X 150 mm	5.00	3.00	7.00	15.00
3	25 X 150 mm	10.00	6.00	14.00	30.00
4	Standard 10-mL ampules	2.50	1.50	3.50	7.50

Procedure:

a. Treatment of samples:

Suitable volume of sample and reagents were measured into a tube as indicated in Table 3.1. Then a digest, cool samples, blank, and a standard were prepared.

b. Measurement of dichromate reduction:

The absorption of each sample blank and standard were measured at selected wavelength (420 nm or 600 nm).
At 600 nm, an undigested blank was used as reference solution. A digested blank was measured to confirm good analytical reagents and to determine the blank COD; then the blank COD was subtracted from sample COD.
At 420 nm, reagent water was used as a reference solution. All samples, blanks, and standards were measured against this solution. The absorption measurement of an undigested blank containing dichromate, with reagent water replacing sample, gave initial dichromate absorption. Any digested sample, blank, or standard that had a COD value gave lower absorbance because of the decrease in

dichromate ion.

i. Digested blank was analysed using distilled water to replace the sample. The difference between the absorbance of a given digested sample and the digested blank is a measure of the sample COD.
ii. Standard(s) were analysed and the differences of digested blank absorbance and digested standard absorbance versus COD values for each standard plotted.
iii. The sample was analysed and the differences of digested blank absorbance and sample absorbance calculated.

c. Preparation of calibration curve:

i. Exactly five standards of 100 ml from potassium hydrogen phthalate solution with COD equivalents to cover each concentration range were prepared. The volume was made up with reagent water.
ii. The same reagent volume and digestion procedure were used as for samples, then calibration curve was prepared for each new lot of tubes

Calculation: for samples, standards, and blanks ran under same conditions of volume and optical path length, COD is calculated as follows:

COD as mg O_2/L = $\frac{\text{mg } O_2 \text{ in final volume X 1000}}{\text{Volume of sample (ml)}}$

***Alkalinity**: alkalinity was determined through titrimetric method using the standard method of APHA 2320 B (APHA, 1998).*

The pH of the water sample was first measured to ascertain level of alkalinity bearing in sample pH > 7.30, it will be treated as having high alkalinity and if the sample pH ≤ 7.30, it will be treated as having low alkalinity.

For High Alkalinity (carbonate or phenolphthalein): exactly 50 mL of the sample was measured into a 250 mL Erlenmeyer flask. Then 5 drops of phenolphthalein indicator solution was added to the flask. The pH of indicator was confirmed with pH meter (phenolphthalein solution pH=8.3). Then 0.1 N sulfuric acid or hydrochloric acid was used to titrate very slowly against the sample while gently swirling it until the end-point was reached (pink to colorless) and the burette reading was taken

For Low Alkalinity: exactly 100 mL of the sample was measured into an Erlenmeyer flask and 5 drops of methyl orange or mixed indicator solution (bromocresol green) was added to the flask. Then 0.02 N sulfuric acid was used as titrant and was titrated slowly against the sample until the end-point was reached (blue to yellow), and the burette reading was taken.

Calculation:

Alkalinity, mg $CaCO_3$/L = $\frac{\text{A} \times \text{N} \times 50{,}000}{\text{mL of sample}}$

Where: A = mL standard acid used
N = normality of standard acid

***Chloride (Cl^-):** chloride was determined by Argentometric method using APHA 4500-CL^- B (APHA, 1998).*

- Potassium Chromate Indicator Solution: Exactly 50 g K_2CrO_4 was dissolved in a little distilled water. Then $AgNO_3$ solution was added until a definite red precipitate is formed. It was allowed to stand for 12 hours, filtered, diluted to 1 L with distilled water.
- Standard Silver Nitrate ($AgNO_3$) titrant; 0.0141 N: Exactly 2.395 g $AgNO_3$ was added in distilled water and diluted to 1 L. The solution was standardized against 10 mL NaCl by the procedure described below, and store in amber colored bottle
- Standard Sodium Chloride; 0.0141 N: Exactly 824 mg NaCl (dried at 140 ^oC for 1 hr) was dissolved in distilled water and diluted to 1 L.

  mL = 500 ug Cl-
- Sodium Hydroxide; NaOH (1 N): this was prepared by weighing 40 g analar grade NaOH, dissolved in little water and transferred to 1 L volumetric flask.
- Standard Sodium Chloride Solution (NaCl); 1000 mg/L: Exactly 1.648 g NaCl analar grade dried at 140^oC for 1 hr was dissolved in distilled water, and diluted to 1 L with distilled water.

  1 mL = 1.0 mg Cl-
- Aluminum Hydroxide Suspension: Exactly 12.5 g Aluminum Potassium Sulfate ($AlK(SO_4)_2.12H_2O$ or $AlNH_4(SO_4)_2.12H_2O$,) was dissolved in 1 L of distilled water. The solution was warmed to 60 ^oC and 55 mL Conc. Ammonium Hydroxide (NH_4OH) was added slowly with stirring. It was allowed to stand for 1 hr, and then transferred to a large bottle, and the precipitate washed by successive additions, with thorough mixing and decanting with distilled water, until free from chloride and the volume 1 L.

Procedure: A calibration standard was prepared to cover the range 100 ppm to 1000 ppm, by taking the appropriate volume of the stock chloride standard and diluting to volume in a 100 mL flask. Exactly 100 mL of the sample or a suitable portion diluted to 100 mL was measured, and 1 mL of H_2O_2 was added and stirred for one minute to check sulfide, sulfite or thiosulfate interference. The pH of the solution was adjusted between 7 to 10 with 1 N NaOH or 1 N H_2SO_4. Then 1 mL K_2CrO_4 indicator was added to the solution and titrated against standard $AgNO_3$ titrant to a pinkish-yellow end-point. A reagent blank value ws established by titrating distilled water as above.

Calculation:

mg Cl^-/L = (A-B) x N x 35450 / mL of Sample

Where: A = volume of 0.0141 N $AgNO_3$ used for titration
B = Volume of $AgNO_3$ used for Blank titration (Should not exceed 0.3 mL)
N = Normality of $AgNO_3$.
mg NaCl = (mg Cl^-/L) × 1.65

***Total Hardness**: Total hardness was determined by titrimetric method using APHA 2340 C*

This was done by the titration of water sample against EDTA with relevant indicator until an end-point is reached (APHA, 1998).

a) Standard EDTA titrant 0.01M:
(i) Exactly 3.723g disodium ethylenediamine tetra acetate dehydrate ($Na_2H_2C_{10}H_{12}O_8N_2.2HO$) was dissolved in distilled water and diluted to 1000 mL.
(ii) The actual concentration determined by standardizing against standard calcium carbonate solution.
b) Buffer solution (Required to adjust pH to 10.0 ± 0.1)
(i) Exactly 16.9 g of NH_4Cl was dissolved in 143 mL conc. NH_4OH.
(ii) Then 1.179 g disodium salt of ethylenediamine tetraaceticacid dihydrate (analytical reagent grade) and 780 mg magnesium sulphate ($MgSO_4.7H_2O$) or 644 mg magnesium chloride ($MgCl_2.6H_2O$) were weighed and dissolved in 50 mL of distilled water.
(iii) The resulting solution was added to the NH_4Cl – NH_4OH mixture and made up to 250 mL with distilled water.
c) Eriochrome Black T indicator solution: Exactly 0.5 g of Eriochrome Black T indicator was dissolved in 100 g of triethanolamine.
d) Sodium hydroxide, NaOH, 0.1N: Exactly 4 g NaOH pellets was dissolved in distilled water and diluted to 1000 mL distilled water.
e) Standard Calcium Solution
Exactly 1.0 g anhydrous calcium carbonate ($CaCO_3$) powder was weighed into a 500 mL Erlenmeyer flask. Then 1:1 HCl was added a little at a time until all the $CaCO_3$ was dissolved. Thereafter 200 mL of distilled water was added and boiled for few minutes to expel CO_2. The solution was cooled and transferred quantitatively to a 1000 mL volumetric flask and filled to mark with distilled water.

1.00 mL of this standard solution = 1.00 mg $CaCO_3$

Procedure for high hardness:

- Exactly 50 mL of the sample was measured and 2 mL buffer added to give a pH of 10.0 to 10.1. Then 2 drops of indicator solution was added and titrated with EDTA titrant until a change in color from reddish tinge to blue occurred.
- In standardizing EDTA titrant against standard calcium solution, 5 mL of $CaCO_3$ solution was measured out and diluted to 50 mL. Then 1 ml of buffer solution was added with 2 drops of indicator. The titrant (EDTA) was slowly added from a burette, with continuous stirring, until end point was reached. (mL standard $CaCO_3$ solution taken for titration divided by ml EDTA titrant = B.)

Procedure for low hardness:

- The sample was increased to 100 mL, and 2 mL to 3 mL of buffer and 2 to 4 drops of indicator were added for every 100 mL increment in sample size. Then EDTA titrant was added much slowly from a burette, with continuous stirring, until the last reddish tinge disappeared

Calculation:

Hardness (EDTA) as mg $CaCO_3$/L = $\frac{A \times B \times 1000}{mL\ of\ sample}$

Where; A = mL titration for sample
B = mg $CaCO_3$ equivalent used to 1.0ml EDTA titrant

Carbonate (CO_3^{2-}): CO_3^{2-} was determined using the same standard method for alkalinity determination (APHA 2320 B) illustrated above.

***Nitrate (NO_3^-):** nitrate was determined using EPA 352.1-NO_3 Colorimetric, Brucine method (APHA, 1998).*

a) Brucine-sulphanilic acid solution: Exactly 1 g brucine sulphate or brucine and 0.1 g sulphanilic acid was dissolved in approximately 70 mL hot distilled water. Then 3 mL conc. HCl was added, cooled and made up to 100 mL with distilled water.
Sulphuric acid (H_2SO_4) solution: exactly 250 mL conc. H_2SO_4 was carefully added to 62.5 mL distilled water. The solution was cooled to room temperature before use and kept tightly stoppered to prevent absorbance of atmospheric moisture.
b) Sodium chloride solution (NaCl); 30%: Exactly 30 g NaCl was weighed and dissolved. The solution was quantitatively transferred into 100 mL volumetric flask and made up to mark with distilled water

c) Potassium nitrate stock solution: 1.0 mL = 0.1 mg $NO^{3-}N$. Exactly 0.7218 g anhydrous potassium nitrate (KNO_3) was dissolved in distilled water and diluted to 1 liter in a volumetric flask. It was preserved with 2 mL chloroform per liter.

d) Potassium nitrate standard solution: 1.0 mL = 0.001 mg $NO^{3-}N$. Exactly 10.0 mL of the stock solution (6.5) was diluted to 1 liter in a volumetric flask.

e) Acetic acid (1 + 3): A 1 volume glacial acetic acid (CH_3COOH) was diluted with 3 volumes of distilled water.

f) Sodium hydroxide (l N): Exactly 40 g of NaOH was dissolved in distilled water. It was cooled and diluted to 1 liter.

g) Nitrate standard: a dilution of 1.00, 2.00, 4.00, 7.00 and 10.00ml with distilled water was made and 0.1, 0.2, 0.4, 0.7, and 1.0mg/L N prepared respectively.

Nitrate (NO_3^-) determination: the pH of the samples was adjusted to approximately 7 with acetic acid or sodium hydroxide, and filtered to remove turbidity if present. The sample tubes were set up in the rack to handle reagent blank, standards and samples and set properly in a water bath. A set of duplicate samples were analyzed by adding all reagents except brucine-sulfanilic acid to correct for color or dissolved organic matter which cause color on heating if it is necessary. Then 10 mL of standards and samples or an aliquot of the samples diluted to 10 mL were added into the sample tubes using pipette. Thereafter, 2 mL of 30% sodium chloride solution was added to the reagent blank, standard and samples omitting the fresh water samples. The content of the tubes was mixed thoroughly by swirling and the rack placed in cold water bath (0-10 °C). Using a pipette, 10.0 mL of sulfuric acid solution was added into each tube and mix by swirling. The tubes were allowed to come to thermal equilibrium in the cold bath. Then 0.5 mL brucine-sulfanilic acid reagent was added to each tube (except the interference control tubes) and carefully mixed by swirling. The rack of tubes was placed in 100 °C water bath for exactly 25 minutes. The rack of tubes was then be removed from the hot water bath and immerse in the cold-water bath and allowed to reach thermal equilibrium. Then the absorbance was read against the reagent blank at 410 nm.

Calculation:

i. A standard curve was obtained by plotting the absorbance of standards ran by the above procedure against mg NO_3-N/L.

ii. The absorbance of the sample without the brucine-sulfanilic reagent was subtracted from the absorbance of the sample containing brucine-sulfanilic acid and mg NO_3-N/L was determined.

iii.

Phosphate-Phosphorus (PO_4^{3-}): *phosphate-phosphorus was determined by Vanadomolybdophosphoric Acid Colorimetric method using APHA 4500-P C standard method (APHA, 1998).*

a) Vanadate-molybdate reagent:
Solution A: Exactly 12.5 g ammonium molybdate $\{(NH_4)_6MoO_{24}.4H_2O\}$ was dissolved in 150 mL distilled water.
Solution B: Exactly 0.625 g ammonium molybdate (NH_4VO_3) was dissolved by heating to boiling in 150 mL distilled water. The solution was cooled and 165 mL of conc. HCl added. Then solution A was poured into B, mixed and diluted to 500 mL.

b) Standard phosphate solution: Exactly 219.5 mg or 0.2195g anhydrous potassium dihydrogen orthophosphate (KH_2PO_4) was dissolved in distilled water and diluted to 1000 mL;
1:00ml = 50.0µg PO_4^{3-} - P

Procedure: Exactly 35 mL of aliquot was placed in a 50 mL volumetric flask. Excessive color in sample was removed by shaking about 50 mL with 200 mg activated carbon in an Erlenmeyer flask for 5 minutes and filtered to remove carbon. Then each batch of carbon was checked for phosphate. Exactly 10 mL vanadate-molybdate reagent will be added and diluted to the mark with distilled water. A blank was prepared in which 35 mL distilled water was substituted for the sample and treated in the manner as sample. After 10 minutes, the absorbance of the sample was measured against the blank at a wavelength of 470 nm. Then a set of serially diluted standard solutions containing 2.0, 4.0, 6.0, 8.0, 10.0, 12.0 and 16.0 mL in 50 mL final volume, corresponding to 0.10, 0.20, 0.30, 0.40, 0.50, 0.60 and 0.80 mg PO_4^{3-} - P respectively was prepared. The standards were treated in the same manner as the samples and the absorbance was measured against the blank. Then a curve of absorbance against concentration will be prepared.

Calculation:

$$\text{Mg P/L} = \text{mg P} \frac{\text{(extrapolated from the standard curve)} \times 1000}{\text{Volume of sample (mL)}}$$

Sulphate (SO_4^{2-}): sulphate was determined by Turbidimetric method using APHA 4500-SO_4^{2-} E standard method (APHA, 1998).

a) Buffer solution A: Exactly 30 g magnesium Chloride ($MgCl_2.6H_2O$), 5 g sodium acetate ($CH_3COONa.3H_2O$), 1 g potassium nitrate (KNO_3) and 20 mL 99% acetic, (CH_3COOH) were dissolved in 500 mL distilled water and made up to 1000 mL.

b) Buffer solution B (required when the sample sulphate concentration is less than 10mg/L): Exactly 30 g $MgCl_2.6H_2O$, 5g $CH_3COONa.3H_2O$, 1 g KNO_3, 0.111 g sodium sulphate (Na_2SO_4) and 20 mL acetic acid (99%) were dissolved in 500 mL distilled water and made up to 1000 mL.

c) Standard (stock) sulphate solution: Exactly 0.1479 g anhydrous Na_2SO_4 was dissolved in distilled water and diluted to 1000 mL.
1.00 mL = 100 µg SO_4^{2-}

Sulphate determination: Exactly 100 mL of the sample was measured into a 250 mL conical flask, and place on a magnetic stirrer. While stirring, 20 mL of NaCl-HCl solution and 20 mL glycerol-alcohol solution were added. Then 0.3 g $BaCl_2$ was added and stirred for 2

minutes. Some solution was poured immediately into an absorption cell and the absorbance was measured at 420 nm after exactly 10 minutes. Series of calibration standard were prepared by pipetting aliquots of the standard sulphate solution corresponding to between 0.5 and 5 $MgSO_4^{2-}$, and analyzed in the same way as samples. Sample blank was prepared by adding all the reagents except Barium Chloride $BaCl_2$ to 100 mL of sample and the absorbance was measured. Then the blank reading obtained was subtracted from each sample reading, using the same sample to compensate for sample color and turbidity. Calibration graph of absorbance against $MgSO_4^{2-}$ was prepared. The amount of sulfate in the sample was read off using the correct absorbance reading and the concentration of the sample was calculated.

Calculation:

As $MgSO_4^{2-}\ L^{-1} = 1000 \times MgSO_4^{2-}/V$

Where V = volume of the sample (mL)

Metals: Metals were determined using APHA 3030 G (Nitric acid – Sulphuric Acid Digestion) and APHA 3030 F (Nitric acid – Hydrochloric Acid Digestion) standard methods. The samples after undergoing pretreatments were analysed for heavy metals and trace metals using Atomic Absorption Spectrophotometer (AAS) (APHA, 1998).

Method: APHA 3030 F (Nitric acid – Hydrochloric Acid Digestion): protective equipment was used as appropriate and 100 mL of well-mixed, acid preserved sample was transferred to a beaker. Then 3 mL conc. HNO_3 was added in a hood and covered with a ribbed watch glass. The beaker was placed on a hot plate and cautiously evaporated to less than 5mL, making certain that sample does not boil and that no area of the bottom of the container was allowed to go dry. The sample was then cooled and rinsed down walls of beaker and watch glass with a minimum of distilled water and 5 mL HNO_3 was then added to the sample. The container was covered with a non-ribbed watch glass and returned to hot plate. The temperature of the hot plate was increased so that a gentle reflux action occurred. The heating continued, and additional acid was added as necessary, until digestion was completed. The sample solution was cooled and 10 mL 1 + 1 HCl added and 15 mL water per 100 mL anticipated final volume. The solution was heated for an additional 15 minutes to dissolve any precipitate or residue. Thereafter it was cooled and the beaker walls and watch glass washed down with water, filtered to remove insoluble material that could clog the nebulizer, and then the filtrate was transferred to a 100-mL volumetric flask with rinsing. The sample was ready for metal determination using AAS.

Trace/heavy metals analysed include the following arsenic (As), lead (Pb), zinc (Zn), potassium (K), manganese (Mn), magnesium (Mg) calcium (Ca), nickel (Ni), copper (Cu), chromium (Cr) and cadmium (Cd)

Calculation: the metal concentration in water sample is determined by using the formula;

Metal concentration, mg/L = $\frac{(A-B)\times C}{D}$

Where;

A = Concentration of metal (instrument reading) in the digested sample solution (mg/L)

B = Concentration of metal (instrument reading) in the digested blank solution (mg/L)

C = Final volume of digested solution after making up to mark (50 mL)

D = Volume of water sample (mg/L)

Microbiological Analysis: fecal and Total Coliform counts will be performed using standard membrane filtration technique. The 100 mL water sample will be filtered using 0.45 mm pore size, 47 mm diameter filter membrane as described by APHA (1998).

4.0 RESULTS

The results of the analysis of water quality on Iwofe River are shown in table 4.1 and table 4.2 below.

Table 4.1: Results of physicochemical and microbial analysis of water samples from Iwofe River

S/N	PARAMETER	UNIT	SAMPLE ID		
			Upstream	Midstream	Downstream
	Coordinates		04°48'34.0" N 006°56'07.5" E	04°48'28.9" N 006°56'09.2" E	04°48'29.2" N 006°56'11.2" E
INSITU/PHYSICAL PARAMETER					
1	Temperature	^0C	28.50	29.70	29.30
2	Ph	-	7.19	7.32	7.36
3	Salinity	PSU	6.35	3.00	3.30
4	Total Dissolved Solids (TDS)	mg/L	5604.00	2542	3088
5	Electrical Conductivity (EC)	µS/cm	11208.00	5059	6151

6	**Turbidity**	NTU	67.10	78.10	59.60
7	**Dissolved Oxygen (DO)**	mg/L	12.90	9.26	5.90
8	**Oxidation Reduction Potential (ORP)**	mg/L	164.80	91.70	109.50
9	**Total Suspended Solids (TSS)**	mg/L	7.75	3.05	2.90
10	**Total Solids (TS)**	mg/L	5611.75	2545.05	3090.9
CHEMICAL PARAMETER					
11	**Chloride (Cl^-)**	mg/L	7887.63	3669.08	4112.20
12	**Alkalinity**	mg/L	25.00	113.00	57.00
13	**Total Hardness**	mg/$CaCO_3$L	1123.00	990.00	1256.00
14	**Carbonate (CO_3^{2-})**	mg/L	12.50	66.00	28.50
15	**Nitrate (NO_3^-)**	mg/L	0.85	0.99	1.08
16	**Sulphate (SO_4^{2-})**	mg/L	283.17	133.56	144.67
17	**Phosphate (PO_4^{2-})**	mg/L	90.00	100.00	99.30
18	**Biochemical Oxygen Demand (BOD_5)**	mg/L	0.42	0.60	3.08
19	**Chemical Oxygen Demand (COD)**	mg/L	5.90	6.25	18.50
ORGANIC PARAMETER					
20	**Oil and Grease**	mg/L	0.15	0.10	0.11
MICROBIOLOGICAL PARAMETER					
21	**Total Coliform**	cfu/mL	13800	213000	298000

Table 4.2: Results of Trace/Heavy Metal analysis of water samples from Iwofe River in relation to WHO 2004 regulatory limit for drinking water quality.

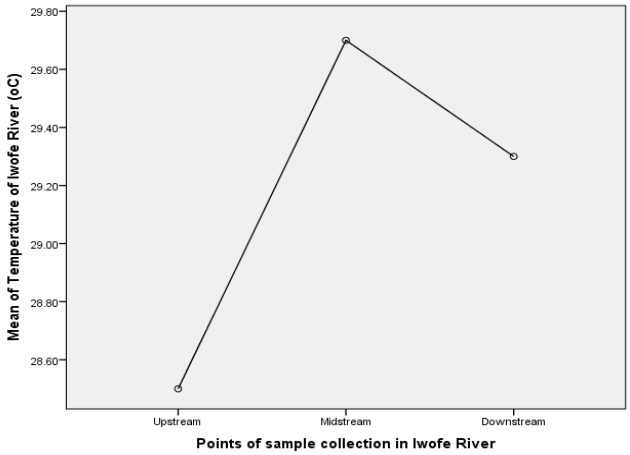
PARAMETER	**WATER SAMPLE**			
	Upstream	**Midstream**	**Downstream**	***WHO Limit**
As (mg/L)	0.009	0.005	<0.001	0.01
Pb (mg/L)	0.002	0.001	<0.001	0.01
Zn (mg/L)	<0.001	<0.001	<0.001	3.000
Fe (mg/L)	0.285	0.019	0.082	0.300
K (mg/L)	8.540	8.245	8.270	12.000
Mn (mg/L)	0.003	<0.001	0.005	0.200
Mg (mg/L)	4.076	3.345	3.479	0.200
Ca (mg/L)	4.085	2.452	2.584	75.000
Ni (mg/L)	0.006	0.002	0.010	0.020
Cu (mg/L)	0.006	<0.001	0.003	2.000
Cr (mg/L)	0.003	0.001	0.002	0.050
Cd (mg/L)	0.006	0.006	0.013	0.003

* = WHO 2004 guideline.

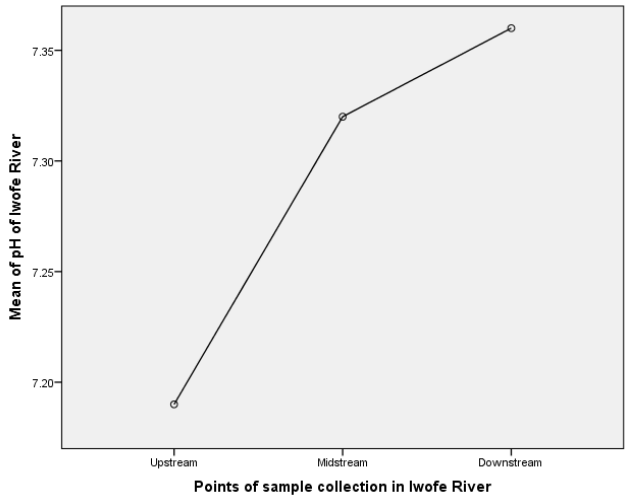
5.0 DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1 DISCUSSION

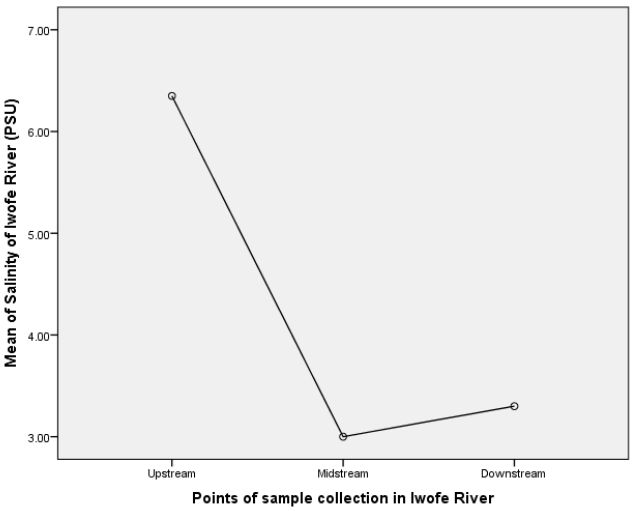
Temperature: high water temperature enhances the growth of microorganisms and may increase taste, odour, colour and corrosion problems (WHO, 2004). The temperature of the water samples within the study area was in the range of 28.50 – 29.70 ^oC with mid-stream being the highest. This was in agreement with the 28 – 29 ^oC range of temperature reported by Meride and Ayenew (2016). Adeyemo *et al*. (2002) on the other hand reported a lower range of temperature (25 – 27.8 ^oC) for Abattoir (Bodija) in Ibandan, Nigeria. Ogwu *et al*. (2022) reported similar value for upstream analysis of drinking water in Mbagule-Ipav, Gboko LGA, Benue state.



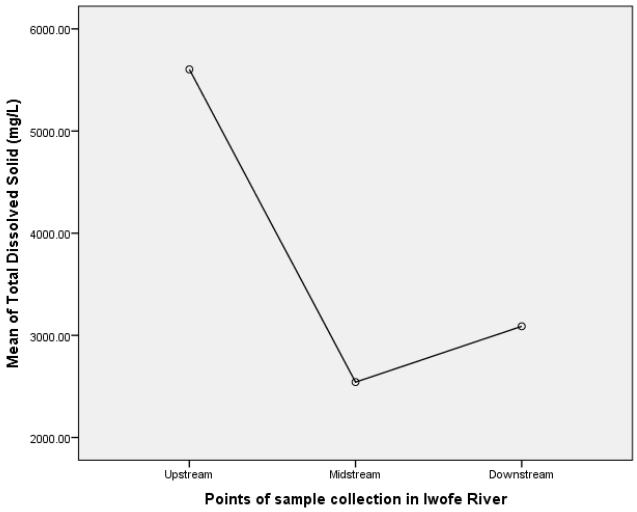
pH: pH is an important parameter in evaluating the acid-base balance of water *(Meride and Ayenew, 2016).* The pH of the water samples were in the range of 7.19 – 7.36 which was within WHO permissible limit. Adeyemo *et al*. (2002) reported lower pH in the range of 6.41 – 6.75 for Ibadan abattoir. When compared with the results of *Tekenah et al. (2014)* in the same study area (Iwofe River), lower pH values were reported for midstream and downstream; that is 7.14 and 7.00 respectively, while the upstream was higher (7.42). *Ojekunle and Lateef (2017)* having similar range of pH opined that such water is unlikely to cause health problems such as acidosis.



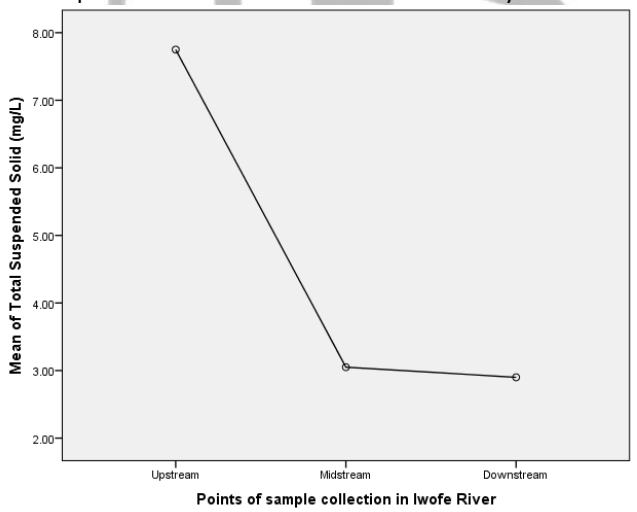
Salinity: it was in the range of 3.00 – 6.35 PSU; upstream being higher. This was below what was reported in the same study area by Tekenah *et al*. (2014) which was in the range of 50.4 – 101 PSU; downstream being higher.



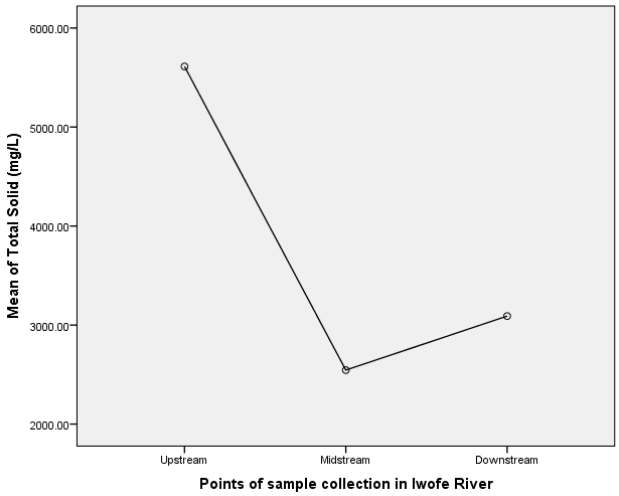
Total Dissolved Solids (TDS): the TDS of the samples were quite high compared to the 500 mg/L recommended limit of WHO (2004). Upstream recorded the highest value (5604 mg/L) followed by downstream (3088 mg/L). *Magaji and Chup (2012)* reported lower range of TDS values of 48.00 – 223.00 mg/L for abattoir in Gwagwalada – Abuja, Nigeria. *Njoku-Tony et al. (2018)* reported an even lower range of TDS (20 – 53 mg/L) for abattoir waste impact on Amilocha River Asaba, Delta state. These show that the study area in this work is highly contaminated as a result of the abattoir waste disposal in the Iwofe River (New Calabar River*). Eze et al. (2019)* and *Meride and Ayenew (2016)* also reported lower TDS values.



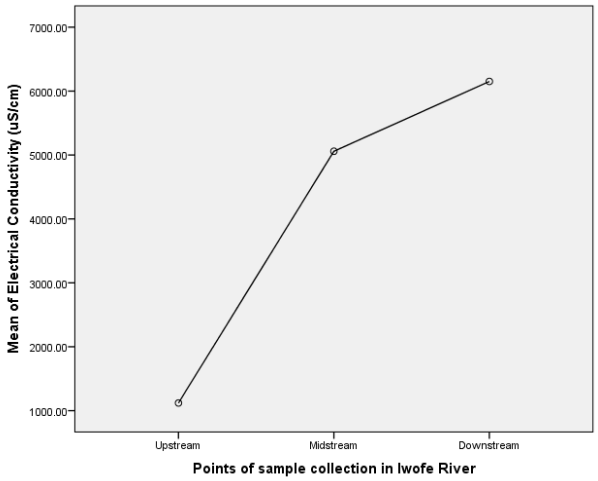
Total Suspended Solids (TSS): this was in the range of 2.90 – 7.75 mg/L, upstream being the highest and downstream recording the lowest. This was expected as waste from the abattoir is discharged directly into the river, upstream being high due to its proximity to the slaughterhouse, although the TSS value was below WHO permissible limit. *Ogwo and Ogu (2014)* reported higher range (12 – 660 mg/L) of TSS in their study on impact of effluents discharged in Nwiyi River Enugu, Nigeria. The study carried out by Tekenah *et al*. (2014) on the same river showed an increasing trend (from upstream to downstream) of 120 mg/L to 240 mg/L, midstream being 160 mg/L. These values are quite high when compared with that obtained from this study.



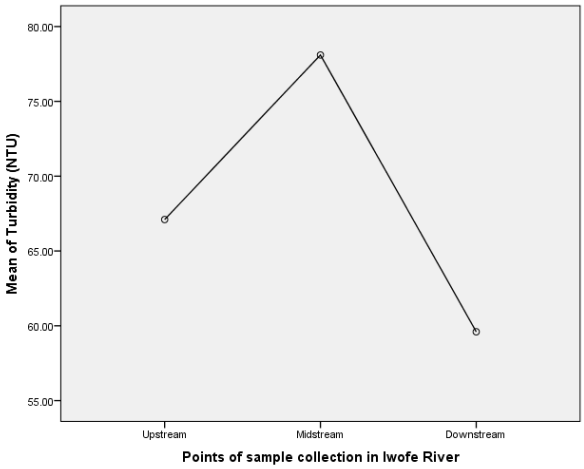
Total Solids (TS): this was in the range of 2545.05 5611.75 mg/L, upstream being the highest. The result was well above the 1000 mg/L threshold limit of WHO. This is an indication of pollution by abattoir wastes and other anthropogenic activities within the study area. TS reported by *Tekenah et al. (2014)* was in the range of 140 – 320 mg/L on the same river. This great difference shows a remarkable increase in pollution over the years as a result of abattoir wastes.



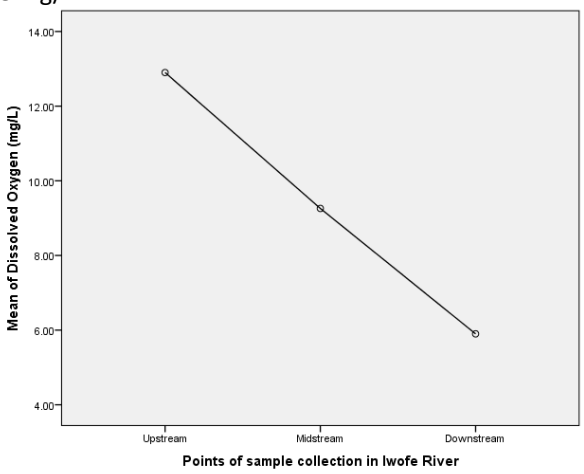
Electrical Conductivity (EC): electrical conductivity was in the range of 5059 – 11208 µS/cm, upstream recording the highest. This was in agreement with the fact that upstream had the highest TDS since the amount of dissolved solid in water determines EC *(Meride & Ayenew, 2016)*. The values were all above WHO limit. Eze *et al*. (2019) reported lower values (133 – 172 µS/cm) in Usuma River, Phase IV Kubwa-Abuja. *Magaji and Chup (2012)* also reported lower values of (46.70 – 403.00 µS/cm) in their study on the effects of Abattoir waste on water quality in Gwagwalada – Abuja, Nigeria. In the same vein *Meride and Ayenew (2016)* reported lower range of EC (179.3 – 201 µS/cm). The results clearly indicate that water in the study area is considerably ionized and has high level of ionic activity as a result of high dissolved solids.



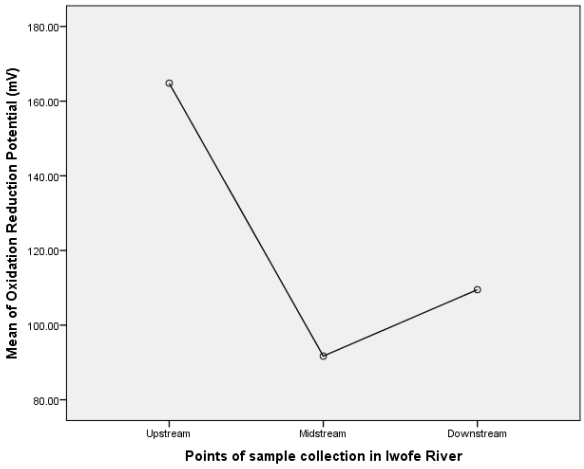
Turbidity: turbidity was in the range of 59.60 – 78.10 NTU and exceeded WHO limit with midstream being the highest. The high turbidity was expected judging by the high concentration of TDS in the water samples. Lower range of values (1.00 – 6.20 NTU and 23.00 – 41.50 NTU) were reported by *Eze et al. (2019)* and *Njoku-Tony et al. (2018)* in Usuma River, Phase IV Kubwa-Abuja and Amilimocha River Asaba, Delta state respectively. However, higher range of turbidity (590 – 900 NTU) was reported by Ogwo and Ogu (2014) in Nwiyi River Enugu.



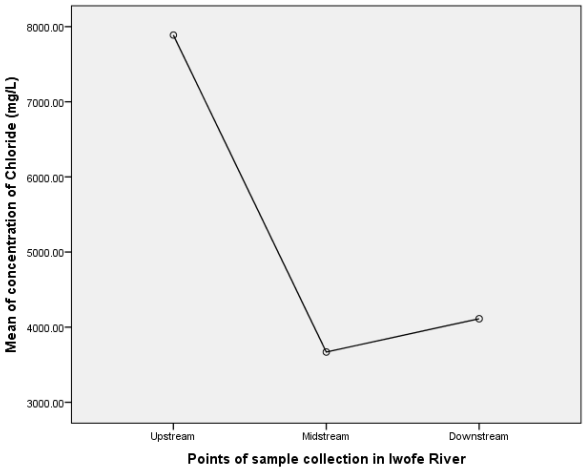
Dissolve oxygen (DO): this is a measure of the degree of pollution by organic matter, the destruction of organic substances as well as self-purification capacity of water body. Concentration below 5 mg/L adversely affects aquatic biological life while concentration below 2 mg/L may lead to death of most fishes. The higher the DO the better the water quality (Ojekunle & Lateef, 2017). In this study, the lowest DO was recorded in downstream (5.90 mg/L), while upstream recorded the highest DO (12.90 mg/L). Midstream on the other hand recorded a DO of 9.26 mg/L. Tekenah *et al*. (2014) reported lower range of DO (4.00 – 4.80 mg/L) in the same study area; downstream being the least. The same trend of result was recorded in the present study. This may be as a result of deposition of most wastes at the downstream of Iwofe River. A DO range of 2.00 – 9.00 was reported by *Ubwa et al. (2013)* on the assessment of surface water pollution status around Gboko abattoir. *Ogwo and Ogu (2014)* reported how adversely industrial effluents impacted on Nwiyi River Enugu with a DO in the range of 2.4 – 3.8 mg/L.



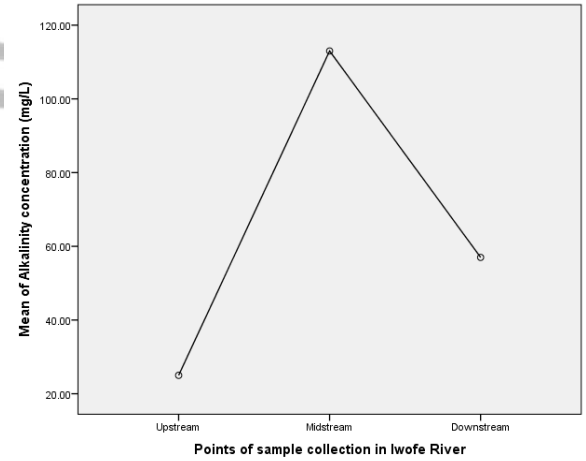
ORP: oxidation reduction potential was in the range of 91.70 – 164.80 mV, upstream being the highest. Midstream was the least with 9.70 mV, while downstream was 109.50 mV. This result was in agreement with the fact that upstream recorded the highest electrical conductivity and TDS.



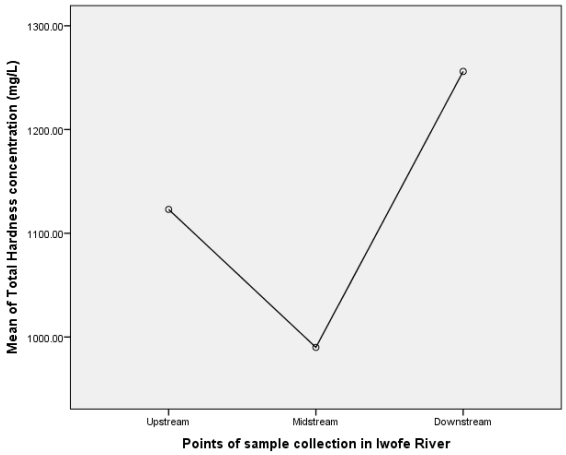
Chloride (Cl^-): Chloride in drinking-water originates from natural sources, sewage and industrial effluents, urban runoff containing de-icing salt and saline intrusion. The main source of human exposure to chloride is the addition of salt to food, and the intake from this source is usually greatly in excess of that from drinking-water (WHO, 2004). In this study, Cl^- was in the range of 3669.08 – 7887.63 mg/L, upstream being the highest. *Tekenah et al. (2014)* reported lower range (28.0 – 36.0 mg/L) of chloride in the same study area. Excessive chloride concentrations increase rates of corrosion of metals in the distribution system, depending on the alkalinity of the water. This can lead to increased concentrations of metals in the supply (WHO, 2004). Lower ranges of Cl^- value were also reported by Ogwo and Ogu (2014) and *Eze et al. (2019)* as 16.4 – 80.1 mg/L and 35 – 62 mg/L respectively. According to WHO (2004), no health-based guideline value is proposed for chloride in drinking-water, however, chloride concentrations in excess of about 250 mg/L can give rise to detectable taste in water.



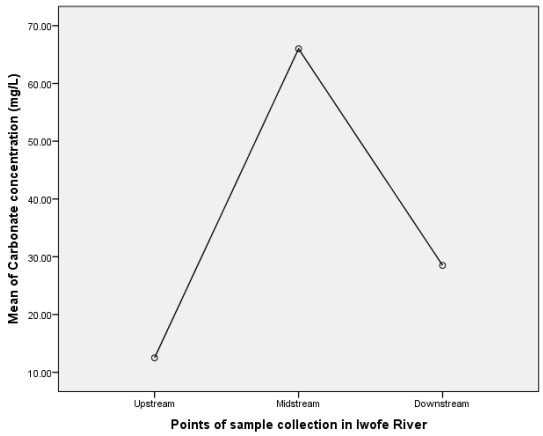
Total Alkalinity: total alkalinity represents the quantity of base present in water. The presence of bicarbonates, carbonates, phosphates, hydroxides, *etc.* causes an increase in alkalinity level *Parveen et al., (2017).* Alkalinity in this study was in the range of 25 – 113 mg/L, midstream being the highest while upstream was the least. Upstream was within WHO specification while downstream was slightly above it. Midstream was however greater than the 50 mg/L permissible limit of WHO (2004). The midstream was in agreement with the 49.00 – 58.50 mg/L range of values reported by *Eze et al. (2019)* on Usuma River Abuja.



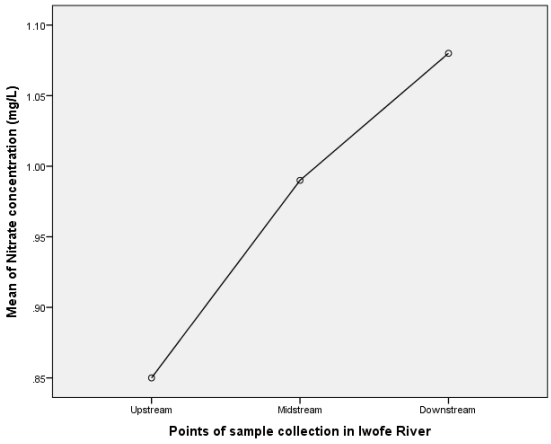
Total Hardness: hardness is a chemical parameter of water that represents the total concentration of calcium, magnesium, carbonates, bicarbonates, sulphates, chlorides, nitrates, toxic metals and organic matter (Parveen *et al*., 2017). Total hardness for upstream, mid-stream and downstream were 1123.00, 990.00 and 1256.00 mg/L respectively. They were all above the 150 mg/L specification of WHO (2004). Eze *et al*. (2019) reported lower range of values (40.0 – 150.0 mg/L). The high concentration of hardness in this study is an indication of pollution as a result of abattoir wastes and human activities on the river. Elemile *et al*. (2019) reported lower range (12.05 – 13.50 mg/L) of hardness on abattoir effluent impact on the quality of ground water in Omu-Aran, Nigeria. Similarly, Ogwu *et al*. (2022) reported hardness values of 70.00 and 90.00 mg/L for Mbagule – Ipav upstream and Mbagule – Ipav downstream respectively.



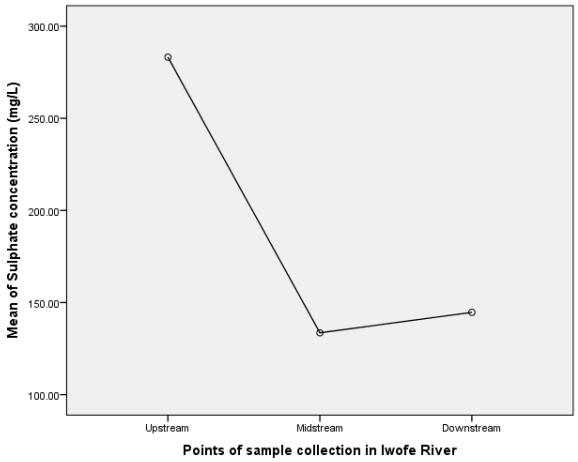
Carbonate (CO_3^{2-}): carbonate was in the range of 12.50 to 66.00 mg/L. Upstream was the least and midstream the highest. Carbonate is one of the measures of hardness of water. It refers to the buffering ability of water, which is how water maintains stable environment for aquatic life (WHO, 2004). This is also related to alkalinity and the trend of results of alkalinity and carbonate are similar with midstream high in each case.



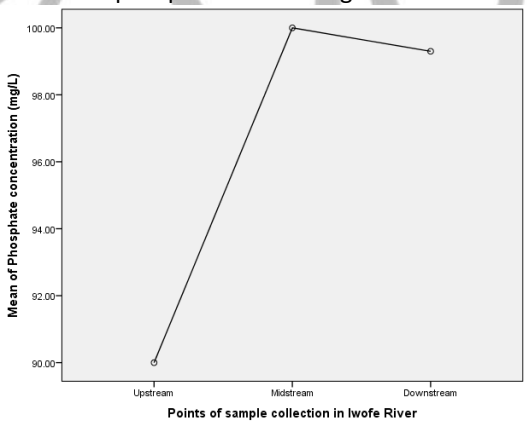
Nitrate (NO_3^-): the nitrate concentration in groundwater and surface water is normally low but can reach high levels as a result of leaching or runoff from agricultural land or contamination from human or animal wastes as a consequence of the oxidation of ammonia and similar sources (WHO, 2004). Nitrate was in the range of 0.85 – 1.08 mg/L, downstream being the highest. Nitrate in the water sample was nelow WHO limit of 50 mg/L. *Tekenah et al. (2014)* also reported low amounts of nitrates as 2.60, 3.50 and 1.80 mg/L for upstream, midstream and downstream respectively in the same study area. High concentration of nitrate in the range of 9.30 – 68.00 mg/L was however reported by *Ubwa et al. (2013)* in surface water around Gboko abattoir. The primary health concern regarding nitrate and nitrite is the formation of methaemoglobinaemia, so-called "blue-baby syndrome." Nitrate is reduced to nitrite in the stomach of infants, and nitrite is able to oxidize haemoglobin (Hb) to methaemoglobin (metHb), which is unable to transport oxygen around the body. The reduced oxygen transport becomes clinically manifest when metHb concentrations reach 10% or more of normal Hb concentrations; the condition, called methaemoglobinaemia, causes cyanosis and, at higher concentrations, asphyxia. The normal metHb level in infants under 3 months of age is less than 3% (WHO, 2004).



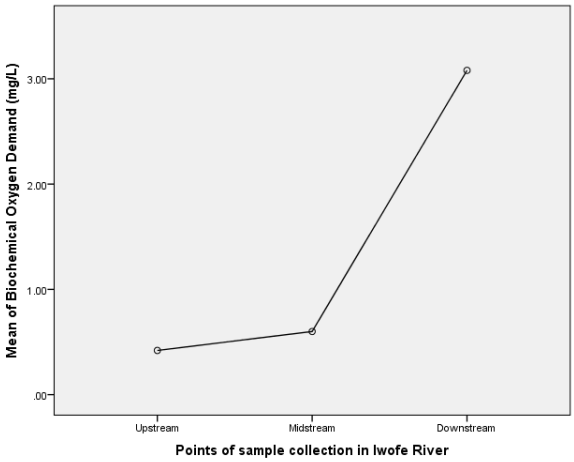
Sulphates (SO_4^{2-}): sulphates occur naturally in numerous minerals and are used commercially, principally in the chemical industry. They are discharged into water in industrial wastes and through atmospheric deposition; however, the highest levels usually occur in ground-water and are from natural sources (WHO, 2004).
Sulphate was in the range of 133.56 – 283.17 mg/L, upstream being the highest. Midstream and downstream were below WHO permissible limit of 250 mg/L while upstream was above it. *Tekenah et al. (2014)* reported lower concentrations of sulphate in the same study area. The amount of sulphate reported by *Ubwa et al. (2013)* from surface water around Gboko abattoir was in the range of 38.46 – 170.00 mg/L. *Elemile et al. (2019)* also reported lower range (12.53 – 15.00 mg/L). The existing data do not identify a level of sulfate in drinking-water that is likely to cause adverse human health effects. The presence of sulphate in drinking-water may also cause noticeable taste and may contribute to the corrosion of distribution systems (WHO, 2004).



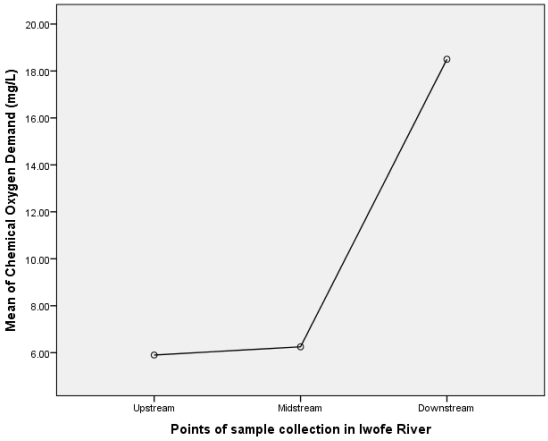
Phosphate (PO_4^{2-}): phosphate enter water ways from human, animal waste and other sources like phosphorus rich bedrock, industrial effluents, fertilizer run-off, laundry and cleaning. Phosphates in water increase the tendency of troublesome algae to grow in the water. This causes eutrophication or over fertilization as it chokes up the water ways and uses up large amounts of oxygen (Ubwa *et al*., 2013). Phosphate was in the range of 90.00 – 100.00 mg/L, midstream being higher. This implies that the activities in the abattoir are contributing to the pollution load of the river. However, lower phosphate range of 1.06 – 2.10 mg/L and 0.02 – 0.59 mg/L were reported by *Ogwu and Ogu (2014)* in Nwiyi River Enugu and *Njoku-Tony et al. (2018)* in Amilimocha River Asaba, Delta state respectively. *Ojekunle and Lateef (2017)* also report lower concentration of phosphate in the range of 0.212 – 0.850 mg/L.



BOD_5: BOD_5 it was in range of 0.42 – 3.08 mg/L, downstream being the highest. This was expected as downstream recorded the lowest DO and also higher in total coliform (2.98×10^5 cfu/ml). The high count of microorganism places great demand on the DO thereby reducing the amount of dissolved oxygen. Although the BOD_5 was below the WHO limit of 5 mg/L. Similar range of BOD_5 values in a range of 3.006 – 3.21 mg/L was reported by *Njoku-Tony et al. (2018)* in abattoir waste impact on Amilimocha River Asaba, Delta state. *Magaji and Chup (2012)* and *Ogwu et al. (2022)* also reported higher range of BOD_5 values as 1.30 – 5.09 mg/L and 19.00 23.00 mg/L respectively.

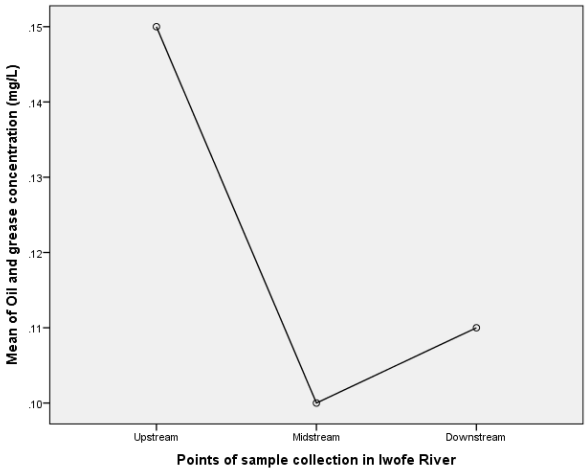


COD: chemical oxygen demand was in the range of 5.90 – 18.50 mg/L, downstream being the highest. This also followed the same trend as the BOD_5. The study conducted by *Tekenah et al. (2014)* in the same study area showed higher COD concentration of 52.0 – 76.0 mg/L in a reversed trend (upstream being the highest). Similarly, *Magaji and Chup (2012)* and *Ogwu et al. (2022)* reported higher range of COD in their respective studies as 54 – 316 mg/L and 36 – 60 mg/L respectively. According to Ogwo and Ogu (2014), high BOD_5 and COD of river depict pollution of organic origin.



Oil and Grease: oil and grease were in the range of 0.10 – 0.15 mg/L, upstream being the highest. The study *Ogwo and Ogu (2014)* on impact of industrial effluent discharge on the quality of Nwiyi River Enugu showed no detectable oil and grease, although they opined that it might not necessarily reflect that the river is pollution free. The detectable oil and grease in the study area shows that the abattoir waste actually pollutes the river mostly the upstream.

Total Coliform: the total coliform in the study area was in the range of 1.34×10^4 to 2.98×10^5 cfu/mL; midstream recording the highest. This is an indication of fecal contamination which may have arisen from the abattoirs and human waste disposals into the river. *Magaji and Chup (2012)* reported the presence of *E. coli* and other coliforms within the acceptable limit of FEPA which they attributed to people defecating in the river bank and the abattoir borehole not functioning leading to the slaughtered animals being taken to the river for washing. Lower range of coliform was also reported by Njoku-Tony *et al*. (2018) as 10.00 – 50. 00 cfu/100ml which they posited that it led to the depletion of oxygen content of the Amilimocha River as a result of microbial activities. Hence the higher the microbial loads, the lower the oxygen content of water bodies. Total coliform bacteria (excluding *E. coli*) occur in both sewage and natural waters. Some of these bacteria are excreted in the faeces of humans and animals, but many coliforms are heterotrophic and able to multiply in water and soil environments. Total coliforms can also survive and grow in water distribution systems, particularly in the presence of biofilms (WHO, 2004). *Ojekunle and Lateef (2017)* cited the zero-value recommendation of WHO for total coliform in drinking water, although their water sample did not meet the requirement.



Heavy/Trace Metals: the results of heavy/trace metals are shown in table 4.2 above.

Arsenic (As): arsenic has not been demonstrated to be essential in humans. It is an important drinking-water contaminant, as it is one of the few substances shown to cause cancer in humans through consumption of drinking-water (WHO, 2004). Arsenic in the present study was in the range of <0.001 – 0.009 mg/L, upstream being the highest. *Eze et al. (2019)* reported similar range of values (0.003 – 0.004 mg/L); *Ogwo and Ogu (2014)* however reported detectable arsenic. There is overwhelming evidence from epidemiological studies that consumption of elevated levels of arsenic through drinking-water is causally related to the development of cancer at several sites, particularly skin, bladder and lung. In several parts of the world, arsenic-induced disease, including cancer, is a significant public health problem (WHO, 2004).

Lead (Pb): Pb is a general toxicant that accumulates in the skeleton. Infants, children up to 6 years of age and pregnant women are most susceptible to its adverse health effects (WHO, 2004). Lead was in the range of <0.001 – 0.002 mg/L, upstream being the highest. *Ogwo and Ogu (2014)* reported detectable Pb, Ogwu *et al*. (2022) reported <0.001 mg/L, while *Eze et al. (2019), Olubanjo (2017)* and *Magaji and Chup (2012)* reported higher ranges of values as 0.001 – 0.008 mg/L, 0.01 – 0.02 mg/L and 0.47 – 0.79 mg/L respectively. The results from this study show that lead contamination was below WHO permissible limit of 0.01 mg/L.

Zinc (Zn): Zn is an essential trace element found in virtually all food and potable water in the form of salts or organic complexes. The diet is normally the principal source of zinc. Although levels of zinc in surface water and groundwater normally do not exceed 0.01 and 0.05 mg/litre, respectively, concentrations in tap water can be much higher as a result of dissolution of zinc from pipes (WHO, 2004). In this study, Zn was <0.001 for all three-water sample. *Ubwa et al. (2013)* and *Ogwu et al. (2022)* reported higher Zn values in the ranges of 0.1124 – 3.7445 mg/L and 6.5 – 8.60 mg/L respectively. *Tekenah et al. (2014)* also reported higher zinc values in the same study area.

Iron (Fe): Fe is one of the most abundant metals in the Earth's crust. It is found in natural fresh waters at levels ranging from 0.5 to 50 mg/litre. Iron may also be present in drinking-water as a result of the use of iron coagulants or the corrosion of steel and cast-iron pipes during water distribution (WHO, 2004). The range of iron concentration in this study is 0.019 – 0.285 mg/L, upstream being the highest. Iron stains laundry and plumbing fixtures at levels above 0.3mg/litre; there is usually no noticeable taste at iron concentrations below 0.3 mg/litre, and concentrations of 1–3 mg/litre can be acceptable for people drinking anaerobic well water (WHO, 2004). *Magaji and Chup (2012), Tekenah et al. (2014)* and *Ogwu et al. (2022)* reported higher Fe concentrations in the ranges of 0.36 – 0.76 mg/L, 0.31 – 0.33 mg/L and 3.50 – 4.40 mg/L respectively. Eze *et al*. (2019) on the other hand reported lower Fe concentration in the range of 0.02 – 0.07 mg/L.

Potassium (K): potassium was in the range of 8.245 – 8.540 mg/L, upstream being the highest. These values were below WHO permissible limit of 12 mg/L. *Meride and Ayenew (2016)* reported higher range of K values (20.83 – 27.51 mg/L), whereas lower range of values (0.11 – 0.14 mg/L) were reported by Ogwu *et al*. (2022).

Manganese (Mn): Mn is naturally occurring in many surface water and groundwater sources, particularly in anaerobic or low oxidation conditions, and this is the most important source for drinking-water (WHO, 2004). Mn was in the range of <0.001 – 0.005 mg/L, downstream being the highest. These values were below WHO permissible limit of 0.20 mg/L. Higher range of values were reported by *Ogwu et al. (2022), Eze et al. (2019), Ogwo and Ogu (2014)* and *Tekenah et al. (2014)* as 0.02 – 0.05 mg/L, 0.12 – 0.32 mg/L, 0.03 – 0.05 mg/L and 0.026 – 0.034 mg/L respectively. Manganese is known to cause neurological effects following inhalation exposure, particularly in occupational settings, and there have been epidemiological studies that report adverse neurological effects following extended exposure to very high levels in drinking-water (WHO, 2004).

Magnesium (Mg): Mg was in the range of 3.345 – 4.076 mg/L, upstream being the highest. It was above the 0.2 mg/L WHO permissible limit. Similar range of value (2.26 – 3.14 mg/L) was reported by Tekenah *et al*. (2014) in the same study area. *Ogwu et al. (2022)* and Eze *et al*. (2019) reported lower range of values as 0.19 – 0.20 mg/L and 0.16 – 0.27 mg/L respectively. Conversely, higher range of values were reported by Meride and Ayenew (2016) and Ogwo and Ogu (2014) as 10.42 – 17.05 mg/L and 1.90 – 40 mg/L respectively.

Calcium (Ca): Ca was in the range of 2.452 – 4.085 mg/L, upstream being the highest. It was below the WHO permissible limit of 75 mg/L. *Tekenah et al. (2014)* reported lower range (0.32 – 0.49 mg/L) of Ca in the same study area whereas Meride and Ayenew (2016) and Ogwo and Ogu (2014) reported higher range of values as 6.52 – 6.83 mg/L and 5.7 – 2000 mg/L respectively.
Nickel (Ni): Ni was in the range of 0.002 – 0.010 mg/L, downstream being the highest. Food is the dominant source of nickel exposure in the non-smoking, non-occupationally exposed population; water is generally a minor contributor to the total daily oral intake. However, where there is heavy pollution or use of certain types of kettles, of nonresistant material in wells or of water that has come into contact with nickel- or chromium-plated taps, the nickel contribution from water may be significant (WHO, 2004). Ogwo and Ogu (2014) reported no detectable nickel in their study area. *Ogwu et al. (2022), Ubwa et al. (2013)* and *Magaji and Chup (2012)* however reported higher range of Ni concentrations in the various study areas as 0.942 – 1.543 mg/L, 0.0569 – 0.1827 mg/L and 0.22 – 0.61 mg/L respectively.
Copper (Cu): Cu was in the range of <0.001 – 0.006 mg/L, upstream being the highest. Copper is both an essential nutrient and a drinking-water contaminant. It has many commercial uses. Food and water are the primary sources of copper exposure in developed countries (WHO, 2004). *Olubanja (2017)* reported no detectable amount of copper. *Ogwu et al. (2022), Eze et al. (2019)* and *Ogwo and Ogu (2014)* reported higher range of values of Cu as 0.11 – 0.20 mg/L, 0.10 – 0.14 mg/L and 0.05 – 0.08 mg/L respectively.
Chromium (Cr): Cr was in the range of 0.001 – 0.003 mg/L, upstream being the highest. The values were below WHO specification of 0.05 mg/L. Chromium is widely distributed in the Earth's crust. It can exist in valences of +2 to +6 (WHO, 2004). *Ogwo and Ogu (2014)* reported no detectable nickel in their study area. *Ogwu et al. (2022), Olubanja (2017)* and *Ubwa et al. (2013)* reported higher range of Cr concentrations in the various study areas as 0.358 – 1.098 mg/L, 0.16 – 0.24 mg/L and 0.0365 – 0.0868 mg/L respectively. According to WHO (2004) in a long-term carcinogenicity study in rats given chromium (III) by the oral route, no increase in tumour incidence was observed. In rats, chromium (VI) is a carcinogen via the inhalation route, although the limited data available do not show evidence for carcinogenicity via the oral route.
Cadmium (Cd): Cd is released to the environment in wastewater, and diffuse pollution is caused by contamination from fertilizers and local air pollution. Contamination in drinking-water may also be caused by impurities in the zinc of galvanized pipes and solders and some metal fittings. Food is the main source of daily exposure to cadmium. Smoking is a significant additional source of cadmium exposure (WHO, 2004). In this study, Cd was in the range of 0.006 – 0.013 mg/L, downstream being the highest. It was above the 0.003 mg/L WHO permissible limit. The daily oral intake is 10 – 35 µg (WHO, 2004). *Ogwo and Ogu (2014)* and *Olubanja (2017)* reported no detectable Cd in their study areas. *Ogwu et al. (2022), Ubwa et al. (2013) and Magaji* and *Chup (2012)* reported higher range of Cd concentrations in the various study areas as 0.075 – 0.187 mg/L, 0.0056 – 0.0135 mg/L and 0.07 – 0.16 mg/L respectively. Eze *et al*. (2019) on the other hand reported lower range of Cd values (0.001 – 0.003 mg/L) in their study area. Cadmium accumulates primarily in the kidneys and has a long biological half-life in humans of 10 – 35 years. There is evidence that cadmium is carcinogenic by the inhalation route.

5.2 RECOMMENDATIONS

In view of the findings of this work, and due to the fact that the abattoir is located at Ignatius Ajuru University, with lodges round the area, and also in view of the fact that the discharge of polluted abattoir wastes may continue unabated, the ensuing recommendations are made:

- In line with public and transnational sweats being made to guard the water terrain, give clean water as well as cover mortal health, the sanitation in our original meat processing diligence should be adequately supervised.
- The enforcement of being health and hygiene regulations as well as the provision of standard outfit and functional units within abattoirs should be encouraged.
- sweats should be made to commence conditioning towards the relocation of the abattoir to an area down from domestic areas. Immediate way should be taken to put in place ministry that will enable treatment of the abattoir wastes before they're inclined.
- Aggressive public mindfulness and enlightenment on possible impacts of pollution from abattoir wastes should be embarked upon by applicable agencies.

5.3 CONCLUSION

The results of water analysis carried out in the study area indicate that the position of impurity of Iwofe River significantly affect its water quality, with utmost of the results exceeding WHO admissible limits. The upstream was largely affected in the trend of impurities due to its propinquity to the abattoir point. It can be inferred that the direct discharge of colorful aqueducts of polluted abattoir waste is a major contributor to the poor quality of the water body. Although some heavy/ trace metals were still within recommended norms, it's still under trouble if the present habit of discharging polluted abattoir wastes continues. Inhabitants of abattoir

vicinity may in no distant time begin to witness severe consequences of adulterants from abattoir conditioning located in their neighborhood. Hence there's need for proper waste management and disposal.

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