PHYSICOCHEMICAL, HEAVY METAL AND MICROBIAL INVESTIGATION OF GROUND AND SURFACE WATER WITHIN SOUTHWESTERN PART OF NIGERIA

BY

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OCTOBER, 2025

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IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF BACHELOR OF SCIENCE (B.Sc. IN GEOLOGY & MINING TECHNIQUES OPTION) HONOURS IN SCIENCE LABORATORY TECHNOLOGY

OCTOBER, 2025

CERTIFICATION

This is to certify that this project “PHYSIOCHEMICAL, HEAVY METAL AND MICROBIAL INVESTIGATION OF GROUND AND SURFACE WATER WITHIN SOUTHWESTERN PART OF NIGERIA” was carried out by IMOUDU Glory Oshokwemhe (Miss) with Matriculation Number, LSC2009966, of the Department of Geophysical Science Laboratory Technology, Faculty of Science Laboratory Technology, University of Benin, Benin City, Edo State, Nigeria.

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External Examiner

Date

DEDICATION

To God Almighty, for His grace and faithfulness throughout this journey.

And to my parents, Mr. and Mrs. Imoudu Gali, for their foundation of love and sacrifice; and to Aghulor Oscar Ebuka, for being my unwavering pillar of strength. You reminded me I could, even when I thought I couldn't.

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I am also incredibly grateful to my wonderful siblings—Prosper, Sandra, Favour, and Praise Imoudu. Thank you for your constant encouragement, understanding, and for being my first and most cherished friends.

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To all who contributed in one way or another to the success of this work, I say thank you. This achievement is as much yours as it is mine.

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ABSTRACT

This study was carried out in the southwestern part of Nigeria in Ondo State which lies within Latitude 7° 09’ 50.1” and 7° 12’ 20.6”N, and Longitude 5° 13’ 30.5”E and 5° 14’ 30.1”, with the aim of assessing the physical, microbial and chemical parameters of the groundwater. Random sampling technique was employed in obtaining water samples from both the surface and groundwater in the study area. A sterilized one liter plastic bottle was used to collect water samples and were immediately transported to the laboratory for physico-chemical and microbial analysis. A total of ten (10) water samples were collected; seven (7) groundwater samples and three (3) river samples. The physicochemical parameters determined and values obtained are as follows: Electrical conductivity ranged 300 and 960us/cm, Temperature 25.00 to 25.01℃, pH of 6.6-9.2 with a mean value of 6.9, TDS shows a mean valve of 25.69mg/l, COD from 5-18.4 mg/liter with mean value of 10.65mg/liter, Turbidity ranged 1.5 to 6.0 NTU with mean valve of 1.03NTU, Cl^- 106.50 to 426.00mg/l, SO_4^{2-} 0.41 to 2.87 mg/l, TSS shows a mean value of 0.411mg/l, TS 1.33 to 4.33 mg/l, NO_3^- 23.73 to 41.48mg/l, Mg ranged from 0.42 to 0.67 mg/liter which is within the WHO limit with mean valve of 0.41mg/l, Ca 0.10 to 0.41 mg/l, HCO_3^- 7.00 to 22.00mg/l, Na ranged from 2.8 to 3.9 mg/liter with mean value of 1.47mg/litre, K 0.41 to 1.20 mg/l, Mn 0.01 to 0.11 mg/l, Fe 0.01 to 0.02 mg/l, Zn 0.01 to 0.65 mg/l, PO_4^- 0.07 mg/l for all locations. Pb showed a mean value of 0. 011mg/litre. Result of analysis revealed that the ground and surface water in the study area appears to be generally potable, due to concentration of heavy metals being mostly under/within the WHO standard regulation. The pH, salinity and electrical conductivity in the study area was moderate. The colour for some samples were brownish – colourless. The presence of microbial organisms in water is from sewages, septic tanks, and animal faeces. The surface water found within the study area is Ofuso River. The water quality in the study area is generally potable.

CHAPTER ONE

INTRODUCTION

1.0 GENERAL INTRODUCTION

Water makes about 65–75% of the average person's body weight (Annan, 2005 & Idiata; 2006 & Fox, 1996). It is estimated that over 25,000 people die each day from diseases spread by water, even though access to clean water is crucial for human health (Train, 1976; Davis and Cornwell, 1991). In reality, only 0.3 percent of the water on Earth is suitable for human consumption. Adekoya et al. (2003) state that atmospheric water vapor, salt, and ice are examples of useless water.

To put it simply, groundwater pollution is a departure from the typical physico-chemical and bacteriological characteristics. Nonetheless, certain practices can negatively impact water for residential, agricultural, municipal, or industrial usage while also posing health risks to the public (Akhilesh et al., 2009; Weiss, 1974 and Ogbonna et al., 2006). Natural water systems generally contain trace elements in small concentrations. Yahaya *et al*. (2009) had reported that their occurrence in groundwater and surface water can be due to natural sources such as dissolution of naturally occurring minerals that contain trace elements within the soil or the aquifer material or to anthropogenic activities such as fuels, mining, smelting of ores and illicit waste disposal. According to Yahaya *et al*. (2009), investigation of heavy metals is very essential since slight changes in their concentration above the acceptable levels, whether due to natural or anthropogenic factors, can result in serious environmental and subsequent health problems.

The importance of water to life will never be over-emphasized, as water is precious and necessary for a sustainable economic development of an area. Over the years, groundwater had served many purposes to human existence as it has been intensively exploited for private, domestic and industrial uses. Ajibade *et al*. (2011) reported that 90% of the population depend largely on hand-dug wells. They further informed that rapid growth in industrial activities, urban populations, agricultural and commercial developments result in increase in the search and uses of potable water.

It is worthy of note that trace amount of some heavy metals are required by living organisms, any excess amount of these metals can be detrimental to life (Berti and Jacobs, 1996; Akhilesh *et al*., 2009). Martinez and Motto (2000) had reported that the solubility of these metals in soils and groundwater is largely controlled by cation exchange capacity, organic carbon content and pH amount of metal (Elliot *et al*., 1986) and the redox potential of the system as well as the oxidation state of mineral components (Connell and Miller, 1984).

According to Martinez and Motto (2000), underground water has served as a useful source of water supply to man via through hand dug wells, springs and boreholes, over the years. It becomes necessary to access critically their quality and portability for human consumption, due to their increasing popularity as a veritable source of water supply. It is on this premise that this investigation was carried out to access and evaluate the amount of contamination of groundwater in the study area.

1.2 SCOPE OF STUDY

The scope of this study include water samples collection from the study area, samples analysis and interpretation of data.

1.3 LOCATION OF STUDY

This study area is within the city of Akure in Ondo State, which lies within Latitude 7° 09’ 50.1” and 7° 12’ 20.6”N, and Longitude 5° 13’ 30.5”E and 5° 14’ 30.1”.

1.4 AIM AND OBJECTIVES

AIM

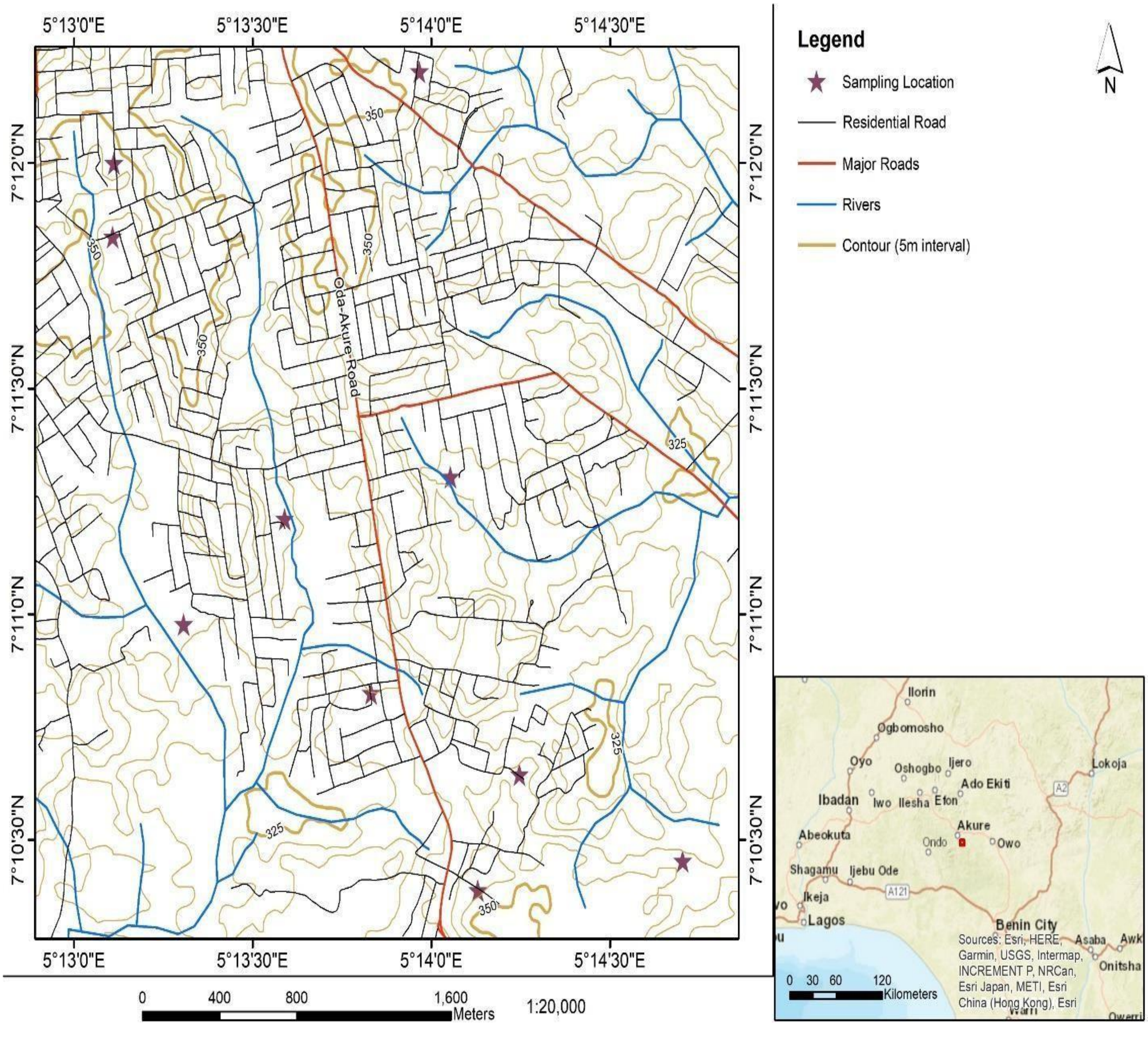
The aim of this study is to access the groundwater quality in the study area via examining the physico-chemical and bacteriological parameters.

OBJECTIVES

For the aim to be achieved, the following objectives are employed:

a) Sampling the study area
b) Examine water samples from the area

c) Examine environmental and health implications.



Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri

Fig. 1: Map showing sampled locations

CHAPTER TWO

2.0 LITERATURE REVIEW

The provision of potable and adequate water supply to the rapidly growing urban population is increasingly becoming a problem for world leaders throughout the world. The scenario has put the limited water resources in jeopardy because of the growing population's constant demand for drinkable water as well as the deteriorating quality brought on by pollution and saltwater intrusion (Idiata, 2006).

According to Idiata (2006), similar research carried in Edo South area of the state it shows that the groundwater in the area needs minimal treatment to be fit for drinking. Henley (2000) also informed that the Nigerian Government has long considered the provision of water supply and sanitation services to be the domain of the local, state and federal governments.

Wright (1992) states that the Basement Complex rocks of southwest Nigeria and the alluvial deposits inside flood plains or the weathered and/or fractured basement rocks are typically where groundwater is found. According to Mogaji et al. (2011), rocks in the Basement Complex are characterized by their low porosity and minimal permeability, unless there has been significant weathering. Therefore, a suitable hydrogeological context is typically shown by good permeability development in the form of a linked network of joints and fractures.

Toxic metals are usually present in urban, industrial and municipal runoff, which can be harmful to humans and biotic life. Increased industrialization and urbanization are to be blamed for the spike in the level of trace metals, in water system.

According to Bayode *et al*. (2006), groundwater in a typical basement complex area is contained in two major aquifer units, namely fractured basement and weathered aquifers, and the latter is derived from chemical alteration processes while the former is as a result of tectonic activities. However, in some cases, the fractured aquifer may occur singly or in combination with the weathered layer aquifer.

2.1 REGIONAL GEOLOGY

Ondo State, which is part of Nigeria's Basement Complex Rocks, is based on the Precambrian Basement Complex in Southwest Nigeria. Crucially, this Basement Complex is one of the three main litho-petrological elements that make up Nigeria's geology.

The Nigerian Basement Complex constitutes a segment of the Pan-African Mobile Belt, positioned between the Congo and West African Cratons (Black, 1980). This complex is intruded by the Mesozoic calc-alkaline ring complexes, commonly referred to as the Younger Granites of the Jos Plateau, and it lies unconformably beneath the Cretaceous and younger sedimentary formations. According to Dada (2006), the Nigerian Basement Complex was significantly influenced by the Pan-African Orogeny, approximately 600 million years ago, and occupies a reactivated tectonic zone formed through the collision of the active Pharusian continental margin with the passive margin of the West African Craton.The Basement rocks are believed to be the results of at least four major Orogenic cycles of deformation, metamorphism and remobilization, corresponding to the Liberian (2,700 Ma), the Eburrnean (2500 Ma), The Kibaran (1,100 Ma), and the Pan-African cycles (600 Ma). The first three cycles had been characterized by intense deformation that resulted in isoclinals folding accompanied by regional metamorphism, which was immediately followed by extensive and intense migmatization. A regional meta-induced syntectonic granites and homogenous gneisses accompanied the Pan-African deformation. The End stages of this last deformation was accompanied by Late tectonic emplacement of granites and granodiorites and associated contact metamorphism accompanied. According to Gandu *et al*. (1986), the end of the orogeny was marked by faulting and fracturing. Anifowose (2004) was of the opinion that the Granitic emplacement was probably controlled by fractures within the Basement, and also showed outcrop pattern indicating that the older Granite cut across all other structures with sharp and chilled contact. Rahaman (1976) had earlier informed that within the basement complex of Nigeria, four major petro-lithological Units are distinguishable namely:

I. Medium to Coarse Granite,
II. The Charnockitic rock
III. The Undifferentiated Granite,
IV. The Migmatite – Gneiss Complex.

2.2 LOCAL GEOLOGY

The study region is underlain by the Migmatite–Gneiss Complex of the Precambrian Basement Complex of southwest Nigeria. Although the Migmatite–Gneiss Complex was formed by metamorphosing pre-existing igneous rocks, migmatite, which looks to be a mixed rock with both volcanic and metamorphic traits (Dada, 2006), was discovered as outcrops in various locations around the region.

2.2.1 MIGMATITE – GNEISS COMPLEX

The migmatite–gneiss complex represents the most widespread and arguably the oldest lithological unit within the study area. Its occurrence is extensive, covering nearly the entire region without spatial restriction. Field observations reveal structural features such as joints, folds, cracks, and quartz veins, while the rock texture ranges from fine- to medium-grained. The dominant mineral constituents include mica, quartz, plagioclase, and hornblende. Well-developed foliations are evident within the migmatite–gneiss rocks, which are notably weathered and fractured across the area. Lithologically, the complex comprises grey gneiss, granite gneiss, and quartzite. Although the granite gneiss appears as slightly elevated to hilly outcrops, the general exposure of the rock units is characterized by low-lying outcrops throughout the study area.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 MATERIALS

From the research region, water samples were taken from the groundwater and surface water using a random sampling technique. Water samples were collected in a sterile 1L plastic bottle and sent straight to the lab for microbiological and physico-chemical investigation. Ten (10) water samples in all were gathered, including three (3) river samples and seven (7) groundwater samples.

3.1.1 SAMPLING

A total of 10 samples were collected from the study area, 6 well samples, 1 borehole samples and 3 rivers. Samples were taken to the laboratory for physico-chemical and microbial analysis.

Plate 3: Storage water samples collected in the study area

3.2 METHODS

3.2.1 DETERMINATION OF PHOSPHORUS

Procedure

From the samples collected, 50 ml of the water sample was pipetted into a 500 ml volumetric flask, 3 ml of ascorbic acid and 5 ml of Ammonium Molybdate solution were added with stirring. Then, the mixture was diluted to the mark with deionized water and was allowed to stand for 30 mins so as to allow for maximum color development. Thereafter, the absorbance was read at 660nm including the blank.

Calculation

$$\textbf{P (ppm)} = \frac{\text{Instr.Reading x Slop Recip.x Colour Vol.}}{\text{Aliquot Taken)}} \text{ .... Eqn. 1}$$

3.2.2 DETERMINATION OF TOTAL HYDROCARBONS

Procedure for Total Hydrocarbon Content (THC) Determination

1. Measure 50 mL of the water sample into a 150 mL separating funnel.
2. Add 10 mL of n-hexane to the sample, stopper the funnel, and shake vigorously for 2 minutes by hand.
3. Remove the stopper and allow the mixture to settle for 20 minutes to enable phase separation.
4. Carefully drain the aqueous layer, retaining the hexane (organic) layer for analysis.
5. Measure the absorbance of the hexane extract at 460 nm, using pure hexane as the blank.

Preparation of THC Standard Stock Solution (1000 ppm)

- Pipette 1.18 mL of Forcados Blend crude oil into a 1-litre volumetric flask and dilute to the mark with n-hexane to obtain a 1000 ppm stock solution.
- From this stock, prepare working standards of 0, 10, 20, 40, 60, 80, and 100 ppm by appropriate dilution with n-hexane.

Calculation

THC (mg/l) = Instr.Reading x Slope Reciprocal x 25 x 20…..Eqn.2

3.2.3 DETERMINATION OF AMMONIUM NITROGEN

2.5 ml of alkaline phenol was added after 5 ml of the filtrate from the sodium acetate extract had been pippetted. 2.5 ml of sodium hypochlorite or bleach and 1 ml of sodium potassium tartrate, making sure to shake well between additions. The standard received the same treatment and was colorimetrically read at 636 nm against the ppm as a blank.

Calculation

$$NH_4N \text{ (ppm as mg/l)} = \frac{\text{IR x SR x Colour Vol}}{\text{Aliquot taken}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

Eqn.3

3.2.4 DETERMINATION OF NITRATE (NO_3)

A 10 mL portion of the water sample was pipetted into a 50 mL volumetric flask, followed by the addition of 10 mL of 13N sulfuric acid. The mixture was stirred thoroughly and then allowed to attain thermal equilibrium in a cold-water bath maintained between 0 and 10 °C. Subsequently, 0.5 mL of bromine-sulfanilic acid reagent was added, and the solution was diluted to the mark with deionized water. The prepared solution was then placed in a hot-water bath at 100 °C for approximately 25 minutes to ensure complete color development. After heating, the flask was cooled to room temperature, and the absorbance of the solution, including that of the blank, was measured at 410 nm.

DETERMINATION OF SULPHATE $(SO_4)^{-2}$

Procedure

A 10 mL aliquot of the filtrate was transferred into a 50 mL volumetric flask, and distilled water was added to make up the volume to 20 mL. Subsequently, 1 mL of the gelatin–barium chloride ($BaCl_2$) reagent was introduced, and the mixture was allowed to stand for 30 minutes. The solution was then diluted to the calibration mark with distilled water and thoroughly agitated to ensure uniform mixing. The same procedure was applied to the standard solution. Finally, the turbidity of each solution was determined using a spectrophotometer set at a wavelength of 420 nm.

3.2.5 DETERMINATION OF CHLORIDE BY SILVER NITRATE TITRATION

Procedure

50ml aliquot, then add 2 drops of phenolphthalein indicator. 2 drops methyl orange, 3 drops of 0.025M H_2SO_4 (to bring it to methyl orange endpoint). 1ml 2% Potassium Chromate. Then titrate with the 0.05M $AgNO_3$ solution, to obtain deep brown as end point.

(0.05 x T x 35.5 x 1000/50 mg/L = 1775/50 = 35.5T)

Calculations

Cl (mg/for water) = $\frac{\text{Molarity} \times \text{Titre} \times \text{Mol.Wt} \times 1000}{\text{Aliquot taken}}$ .... Eqn. 4

3.2.6 DETERMINATION OF CHEMICAL OXYGEN DEMAND (COD)

Procedure

A 50 mL portion of the water sample was pipetted into a conical flask, followed by the addition of 10 mL of 0.00833 M potassium dichromate ($K_2Cr_2O_7$) solution. Subsequently, 1 g of mercuric sulfate ($HgSO_4$) and 80 mL of silver sulfate–sulfuric acid (Ag_2SO_4–H_2SO_4) solution, along with a few boiling beads, were added. A greaseless reflux condenser was attached, and the mixture was gently heated to boiling. The solution was then refluxed for exactly 10 minutes before being allowed to cool. The inner wall of the condenser was rinsed with 50 mL of distilled water, and the flask was further cooled under running tap water. Two drops of ferroin indicator were added, and the solution was titrated with 0.025 M ferrous ammonium sulfate [$Fe(NH_4)_2(SO_4)_2 \cdot 6H_2O$] until the color changed from blue-green to reddish-brown. A blank determination was carried out under identical conditions using 50 mL of distilled water.

Calculation

The Titre value of the sample was obtained from the difference in value between the two Titres. That is to say, if a 50 ml sample is taken, then 1 ml of difference = 0.2mgDO or 4mgDO/L.

If 25ml is used T x 8mg/l O2/l

3.2.7 DETERMINATION OF TURBIDITY

Procedure

25 ml of the water sample was introduced into the curvette and read at zero in the spectrophotometer at 450nm.

Then 25 ml of the water sample was introduced into another curvette and read in the meter

Calculation

Turbidity (FTU) = Slope Recip x Instrument Reading.. Eqn. 5

3.2.8 DETERMINATION OF COLOUR

Procedure

The filter was properly rinsed by pouring 50 ml of water through it and the water used for rinsing was discarded. Another 50 ml of water sample was introduced through the filter and a cuvette was filled with 25 ml of the filtered water and read the colour at 455nm. 50 ml of the water sample was introduced through the filter. Fill a second cuvette with 25 ml of the filtered water sample and read at 455nm.

Calculation

Colour of water in mg/l Pt.Co = Sample Colour – Water Colour……………………….. Eqn. 6

3.2.9 DETERMINATION OF SUSPENDED SOLIDS BY GRAVIMETRY

Procedure

A 15 ml Whatman Filter Paper No. 1 was dried at 50 °C to constant weight (X1g). 100ml of water sample was filtered through the weighed paper, and then dried in the same oven to constant weight at 50 °C. Thereafter, the filter paper was weighed with its content (X2g)

Calculation

Weight of Suspended solid = (X2 –X1)

Suspended solid (mg/l) = 1000x10 x (X2 – X1).

3.2.10 DETERMINATION OF CONDUCTIVITY/TOTAL DISSOLVED SOLIDS BY A METER

Procedure

The instrument was switched on by pressing power button, and allowed to stabilize for 10 minutes. The conductivity was calibrated by pressing CND and immersing the Probe in the KCl solutions above. The TDS was calibrated by pressing TDS and immersing the Probe in the KCl solution above. The probe was rinsed and immersed in the sample solution:

The Conductivity was read by pressing CND

The TDS was read by pressing TDS

Calculation

The meter is able to read the Conductivity and TDS directly in ms/cm or (s/cm and mg/l) respectively.

3.2.11 DETERMINATION OF BICARBONATE

Procedure

A 50 mL aliquot of the water sample was pipetted into a conical flask, and three drops of 0.25% phenolphthalein indicator were added. If a pink coloration appeared, the sample was titrated with 0.025 M sulfuric acid (H_2SO_4) until the color disappeared. For the resulting colorless solution—or the original sample if no pink coloration was initially observed—three drops of 0.1% methyl orange indicator were then introduced. The solution obtained after this step could subsequently be used for chloride determination. A blank determination was carried out using the same reagents and CO_2-free distilled water, with necessary corrections applied where required.

Calculation

$$(\mathrm{HCO3})^{2-} = \frac{\text{Molarity} \times \text{Titre} \times \text{Mol.Wt.} \times 18000\text{mg/litre}}{\text{Aliquot}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

Eqn. 7

3.2.12 DETERMINATION OF SALINITY

When used to describe any aqueous solution or water, the word "soluble salts" refers to the main dissolved inorganic solutes. Thus, the concentrations of soluble salts can be used to assess and characterize the salinity (in g/l) of water or solution. Electrical signals from a variety of sensors or probes, including salinity meters, can be used to determine salinity. Electrical conductivity (in us/cm or ms/cm) can likewise be used to measure salinity. Electrical conductivity increases in proportion to salinity. The table below was created using this relationship and varying NaCl concentrations in distilled water. It is simple to draw a decent conductivity versus salinity curve. Extrapolation can be used to determine the salinity of any desired sample.

3.2.13 ATOMIC ABSORPTION SPECTROPHOTOMETER (AAS)

Atomic Absorption Spectrometry (AAS) is a widely employed analytical technique for the quantification of heavy metals and various cations in environmental samples. The instrument utilizes a hollow cathode lamp as its radiation source, with the cathode composed of the same metal as the analyte of interest. Each lamp emits radiation at wavelengths characteristic of the specific metal being analyzed; therefore, a separate lamp is required for each element. The emitted light passes through a flame and is directed into a monochromator, which isolates the optimal analytical wavelength. The transmitted light is then detected by a photomultiplier tube, which converts the optical signal into an electrical output. During analysis, the sample solution is aspirated into the flame, where it undergoes evaporation, volatilization, and dissociation to produce ground-state atoms. These atoms absorb radiation from the hollow cathode lamp and become excited to higher energy levels. Although a small proportion of atoms are thermally excited in the flame, this fraction is negligible and does not affect analytical accuracy. An acetylene–air flame is typically used as the atomization source.

CHAPTER FOUR

RESULTS AND DISUCUSSION

TABLE 3: PHYSICO-CHEMICAL PARAMETERS OF WATER SAMPLES

Sample code	pH	EC	Sal.	Col.	Turb.	TSS	TDS	COD	$HC0^{3-}$	Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	PO^{3-}	NO^{2-}	NO^{3-}
		µS/cm	g/l	Pt.Co	NTU	mg/l											
LOC 1	7.2	300	0.95	ND	ND	ND	0.02	ND	33.2	3.6	0.5	0.70	0.62	78.10	ND	ND	ND
LOC 2	6.9	287	0.129	ND	ND	ND	144	18.4	61.0	0.21	0.01	0.1	0.03	90.4	ND	ND	ND
LOC 3	7.1	16.4	0.007	ND	ND	ND	8.3	12.8	24.4	0.19	0.11	0.98	0.09	39.5	ND	ND	ND
LOC 4	6.9	115.7	0.052	ND	1.5	ND	57.9	17.1	48.1	0.20	0.5	3.73	1.22	97.5	ND	ND	ND
LOC 5	6.6	32.6	0.015	ND	ND	ND	16.3	16.0	42.7	0.17	0.12	1.88	0.16	87.1	ND	ND	ND
LOC 6	7.2	31.1	0.014	ND	ND	ND	15.5	16.8	30.5	0.22	0.08	1.51	0.20	102.2	0.8	0.08	ND
LOC 7	7.2	29.3	0.013	ND	ND	ND	14.8	15.2	24.4	0.14	0.05	1.74	0.19	98.2	0.5	ND	ND
LOC 8	7.1	930	1.10	ND	ND	ND	0.04	ND	30.5	3.4	1.6	0.41	0.96	113.6	ND	ND	ND
LOC 9	6.9	710	1.05	10	5	ND	0.04	5	32.4	2.8	1.2	0.70	0.57	156.20	ND	ND	ND
LOC 10	6.8	834	2.05	10	3.8	4.1	0.03	5	30.1	3.8	2.0	0.79	0.60	130.64	0.8	ND	ND
WHO	6.6-9.2	1200	1000 mg/l	5-50	5-25	500	1000 mg/l	10	100	75	5	100	30	250	5	--	--

TABLE 4: HEAVY METALS PARAMETERS OF WATER SAMPLES

Sample code	**Fe** (mg/l)	**Mn** (mg/l)	**Zn** (mg/l)	**Cu** (mg/l)	**Cr** (mg/l)	**Cd** (mg/l)	**Ni** (mg/l)	**Pb** (mg/l)	**V** (mg/l)	**THC** (mg/l)
LOC 1	0.1	0.04	0.9	ND	ND	ND	ND	ND	ND	ND
LOC 2	0.1	0.02	0.7	ND	ND	ND	ND	ND	ND	ND
LOC 3	0.2	0.04	0.9	ND	ND	ND	ND	ND	ND	ND
LOC 4	0.1	0.06	5.0	ND	ND	ND	ND	ND	ND	ND
LOC 5	0.6	0.09	9.2	0.4	0.4	ND	ND	0.01	ND	ND
LOC 6	0.2	0.04	1.4	ND	0.1	ND	ND	ND	ND	ND
LOC 7	0.3	0.04	3.2	0.1	ND	ND	0.1	0.1	ND	ND
LOC 8	0.1	0.01	4.7	0.1	0.2	ND	ND	ND	ND	ND
LOC 9	0.1	0.02	2.1	ND	ND	ND	ND	ND	ND	ND
LOC 10	0.4	0.05	5.5	0.2	0.2	ND	ND	ND	ND	ND
WHO	0.1 - 1	0.05 –0.5	5 – 15	0.05-1.5	0.05-0.2µg/l	0.003	0.02	0.01	N/G	N/G

ND - Not Detected

TABLE 5: MICROBIAL PARAMETERS OF WATER SAMPLES

S/N	SAMPLE	TOTAL HETEROTROPHIC BACTERIAL COUNTS (CFU/ML)	TOTAL COLIFORM COUNTS (CFU/ML)	TOTAL E. coli COUNTS (CFU/ML)	TENTATIVE ISOLATES
1	LOC 1	0.1×10^4	0.1×10^5	0×10^5	*Salmonella sp.*
2	LOC 2	4.9×10^4	1.5×10^5	0×10^5	*S. aureus.*
3	LOC 3	1.5×10^4	1.4×10^5	0×10^5	*B. subtilis*
4	LOC 4	2.0×10^4	0.5×10^5	1×10^5	*B. subtilis*
5	LOC 5	1.5×10^4	1.9×10^5	1.9×10^5	*E. coli*
6	LOC 6	0×10^4	0×10^5	0×10^5	——
7	LOC 7	1×10^4	4×10^5	0.5×10^5	*S. aureus*
8	LOC 8	1×10^4	1.5×10^5	5×10^5	*E. coli*
9	LOC 9	2×10^3	1.4×10^3	0×10^5	*B. Subtilis*
10	LOC 10	1.1×10^4	1.6×10^5	1.5×10^5	*E. coli*

4.2 DISCUSSION

Seasons affect the physico-chemical characteristics of water, and human activities like agriculture, urbanization, and residential waste in catchment areas cause the quality of the water to decline. Hardness, temperature, turbidity, alkalinity, nutrients, and dissolved
The growth of organisms in water bodies is influenced by a number of factors, including the availability of certain minerals and oxygen. The relationship between all hydrogeological characteristics, such as the chemical, biological, and physical characteristics of water bodies, is revealed by water quality.

4.2.1 pH

pH is defined as a measure of the acidic or alkaline strength of a solution under specific temperature conditions. It influences the solubility and bioavailability of various chemical elements, including nutrients and heavy metals. According to WHO guidelines from 1958, a pH below 6.5 or above 9.2 can significantly reduce the drinkability of water. The International Standards from 1963 and 1971 continued to endorse the pH range of 6.5–9.2 as the acceptable limit. Notably, while pH does not typically affect consumers directly, it remains a critical factor in assessing water quality operations; furthermore, the ideal pH range is commonly set between 6.5 and 9.5. In the collected water samples, pH values varied from 6.6 to 9.2, with an average of 6.9. These results fall within the WHO-recommended standards for pH (see Table 3).

4.2.2 ELECTRICAL CONDUCTIVITY

The WHO's maximum permissible limit for conductivity is 1200 µS/cm. Conductivity readings from all ten samples, taken from ten different sites, varied between 300 and 960 µS/cm. In detail, the peak conductivity was 960 µS/cm, the lowest was 300 µS/cm, and the average stood at 334.6 µS/cm. This parameter directly mirrors the salinity levels, which in turn depend on the salt concentrations present in the samples. The electrical conductivity in every sample complied with the allowable limits outlined by NAFDAC and WHO (2003). This outcome stems from the relatively low levels of cations and anions detected in the examined water samples. Electrical conductivity acts as a key measure of a water sample's purity, indicating its lack of salts, ions, and contaminants (Aktar et al., 2010).

4.2.3 SALINITY

According to guidelines from the World Health Organization (WHO, 1979) and Nigeria's Standards Organisation (SON), acceptable salinity levels in water should remain below 1000 mg/L. As a result, the tested waters can be considered free of salinity issues. Measurements from the various sampling points showed salinity varying between 0.51 and 2.45 mg/L, averaging at 0.538 mg/L; the peak was observed at point five, whereas the minimum occurred at point two (as detailed in Table 3).

4.2.3 COLOUR

Ideally, uncontaminated water exhibits no noticeable hue. Genuine coloration arises from substances dissolved within the liquid, which may stem from natural sources or human-related activities. On the other hand, perceived coloration results from a combination of both dissolved and floating particles. For instance, water appearing brownish might originate from broken-down plant remnants in solution (genuine hue), dispersed soil fragments (perceived hue), or a mix of the two (likewise perceived). The average measurement stands at 2 Pt-Co, while the scale employs units up to 10 Pt-Co. Hue is quantified using the Platinum-Cobalt scale (Pt-Co). Additionally, pigmentation is significantly affected by elements like iron and various metals, whether occurring as inherent contaminants or residues from rusting processes (refer to Table 3).

4.2.5 TURBIDITY

Cloudiness in potable water stems from suspended particles that could originate from raw supplies due to insufficient purification processes or from stirred-up deposits in the piping network. Additionally, it might arise from mineral-based solids in certain underground sources or the shedding of microbial layers inside the conveyance infrastructure. Generally, liquid exhibiting opacity below 5 NTU is deemed satisfactory by users, though this can differ based on regional factors. Such debris can shield pathogens against sanitizing agents and promote microbial proliferation. Whenever purification involves sterilization, opacity levels need to remain minimal to ensure the treatment's success. Guidelines from the World Health Organization specify a turbidity threshold of 5 NTU, with an upper cap at 25 NTU. For the examined specimens, opacity measurements spanned from 1.5 to 6.0 NTU, averaging 1.03 NTU.

4.2.6 TOTAL SUSPENDED SOLIDS

Solids refer to the suspended and dissolved matter in water. They are very useful parameters describing the chemical constituents of water. Location five has total suspended solids of 5.8mg/l with W. H. O. standard being 500mg/l for drinking water and mean value of 0.411mg/l. (Table3).

4.2.7 TOTAL DISSOLVED SOLIDS

Water exhibiting total dissolved solids (TDS) concentrations below 600 mg per liter is typically viewed as having favorable taste qualities; however, it turns notably and progressively distasteful when TDS exceeds roughly 1000 mg per liter, featuring an average reading of 25.69 mg per liter. Elevated TDS concentrations can likewise prove undesirable for users due to the formation of heavy deposits in plumbing systems and domestic devices. In the analyzed specimens, TDS figures fall both inside and outside the World Health Organization's threshold across certain sites (as shown in Table 3).

4.2.8 DISSOLVED OXYGEN

The level of oxygen dissolved within aquatic environments is affected by elements such as its origin, the heat level of untreated supplies, purification techniques, and various biochemical reactions occurring throughout the supply channels. This factor may elevate the amount of iron in its ferrous form when dissolved. Guidelines from the World Health Organization establish a threshold of 5 milligrams per liter for dissolved oxygen.

4.2.9 CHEMICAL OXYGEN ON DEMAND

According to W.H.O. the standard for chemical oxygen on demand is 10 mg/liter. The COD for samples ranges from 5-18.4 mg/liter with mean value of 10.65mg/liter. The samples are within the WHO limit. (Table 3)

4.2.10 SODIUM, POTASSIUM, CALCIUM, MAGNESIUM, CHLORIDE AND PHOSPHOROUS

In freshwater systems, calcium stands out as the predominant ionic component, frequently accompanied by magnesium. Sources of chloride in aquatic environments include inherent geological formations, wastewater discharges from human activities, factory waste, street drainage laced with anti-freeze agents, and infiltrations from saline bodies. When maintained at appropriate levels, such elements contribute positively to human well-being. The point at which sodium imparts a noticeable flavor to liquid varies based on the paired negative ion and the fluid's warmth; under standard ambient conditions, this spans approximately 75 to 200 milligrams per liter for sodium. Recorded sodium amounts in the tested specimens fluctuate between 2.8 and 3.9 milligrams per liter, averaging 1.47 milligrams per liter, thus aligning with World Health Organization guidelines. For potassium, the flavor detection limit sits at 20 milligrams per liter. Observed potassium figures in the specimens span 0.5 to 3 milligrams per liter, with an average of 0.61 milligrams per liter, thereby conforming to World Health Organization specifications.

Magnesium's acceptable flavor range extends from 30 to 150 milligrams per liter. In the examined instances, magnesium readings vary from 0.42 to 0.67 milligrams per liter, fitting within the designated boundaries and showing an average of 0.41 milligrams per liter. Levels of chloride surpassing 600 milligrams per liter can substantially diminish the suitability of the fluid for consumption. This upper boundary was upheld in the global benchmarks from 1963 and 1971 as the highest tolerated amount. Chloride quantities exceeding around 250 milligrams per liter may produce a discernible flavor in the liquid. The chloride measurements in the specimens extend from 78.10 to 177.5 milligrams per liter, remaining compliant with World Health Organization criteria and averaging 99.34 milligrams per liter. Phosphorus concentrations in the specimens fall between 0.5 and 0.8 milligrams per liter, adhering to the World Health Organization benchmark of 5 milligrams per liter, with an average of 0.21 milligrams per liter (as indicated in Table 3).

4.2.11 NITRITE, NITRATE, AMMONIA AND SULPHATE

Nitrate and nitrite represent inherent ionic elements integral to the nitrogen circulation process. Nitrate primarily features in artificial nutrient enhancers for agriculture, while sodium nitrite acts as an additive for maintaining freshness in foodstuffs, notably in preserved animal products. Ordinarily, nitrate amounts in subterranean and aboveground aquatic resources stay modest, though they might surge considerably owing to infiltration or overflow from cultivated fields or pollution via human or faunal residues stemming from the decomposition of ammonia and comparable materials. Oxygen-deficient environments could foster the creation and endurance of nitrite. The application of chlorine might trigger nitrite development inside the conveyance infrastructure should chloramine synthesis lack adequate oversight. Nitrite generation arises from bacterial processes and could manifest sporadically. Bacterial oxidation in supply pipelines may heighten nitrite quantities to 0.08 milligrams per liter, featuring an average figure of 0.008 milligrams per liter. Benchmarks from the World Health Organization establish caps for nitrate and nitrite at 45 and 3 milligrams per liter, in that order. Within the 1993 directives, although no health-derived threshold was proposed, it was indicated that ammonia could provoke flavor and aroma concerns exceeding 35 and 1.5 milligrams per liter, correspondingly.

4.2.12 HEAVY METALS

Copper typically infiltrates consumable water supplies through the erosive effects of fluids extracting the metal from conduits crafted from it. Quantities may shift considerably based on the duration the liquid has lingered in proximity to the tubing. Excessive amounts could hinder the anticipated residential applications of the resource. The inclusion of copper in potable liquids might accelerate the breakdown of zinc-coated steel and iron elements. Discoloration of fabrics and restroom equipment emerges when copper surpasses 1 milligram per liter. Exceeding 5 milligrams per liter, it introduces shading and an offensive sharp tang to the fluid. The benchmark set by the World Health Organization for copper is 2 milligrams per liter; in the gathered specimens, figures extend from 0.1 to 0.4 milligrams per liter, remaining adherent to the guideline, alongside an average of 0.08. Subsurface waters lacking oxygen can harbor reduced iron forms at densities up to numerous milligrams per liter without any tinting or clouding immediately upon withdrawal from a shaft. Yet, when introduced to open air, this reduced iron converts to its oxidized state, conferring a repellent rusty-brown hue to the liquid. Moreover, iron encourages the expansion of certain microbes that harness power from transforming reduced iron into its oxidized counterpart, consequently layering a viscous film over the channels. The criterion from the global health authority for iron stands at 1 milligram per liter; the spectrum in acquired samples stretches from 0.1 to 0.6 milligrams per liter, all compliant, with an average value of 0.22. Flavors generally go unnoticed at iron densities beneath 0.3 milligrams per liter. Surpassing 0.1 milligrams per liter, manganese within provision networks triggers an unpleasant savor in refreshments and marks bathroom fittings along with clothing. Akin to iron, manganese in drinkable sources can prompt the buildup of residues throughout the delivery framework. Densities under 0.1 milligrams per liter typically meet user approval. At merely 0.2 milligrams per liter, manganese frequently generates layers on conduits that might flake away as inky residues. For the procured instances, manganese varies between 0.01 and 0.09 milligrams per liter, aligning with the World Health Organization's ceiling for this element, featuring a mean of 0.041.

Zinc introduces an unpleasant sharp flavor to liquids at a detection point of 4 milligrams per liter (in the form of zinc sulfate). Fluids holding zinc beyond 3 to 5 milligrams per liter might look cloudy and form an oily layer upon heating. While potable sources rarely exceed 0.1 milligrams per liter of zinc, faucet supplies can show much elevated figures due to the material in aged zinc-coated piping. The limit advised by the global health body stands at 5 milligrams per liter; in the obtained specimens, readings fluctuate from 0.9 to 5.0 milligrams per liter, staying compliant, alongside an average of 3.36.

Cadmium serves in metalworking for steel and in synthetic materials. Its derivatives play key roles in power cells. This element enters ecosystems via effluent discharges, while scattered contamination arises from nutrient enhancers and regional atmospheric fallout. Dietary intake represents the primary daily contact with cadmium, ranging from 10 to 35 micrograms. Tobacco use adds notably to such exposure. The recommended cap is 0.003 milligrams per liter.

Chromium spreads extensively throughout the planet's outer layer. It manifests in oxidation states from +2 up to +6. Overall, edibles constitute the chief avenue for absorption. A temporary threshold spans 0.05 to 0.2 micrograms per liter for overall chromium content, featuring an average reading of 0.09.

Lead finds main applications in manufacturing acid-based storage units, bonding agents, and mixtures. Organic variants like tetraethyllead and tetramethyllead once served widely as fuel enhancers and friction reducers in gasoline, though many nations are eliminating such practices. With reductions in leaded fuel components and soldering in food handling, atmospheric and dietary levels drop, making water-based ingestion a larger share of overall consumption. Lead seldom appears in household taps from geological origins; instead, it stems mostly from domestic tubing setups incorporating lead in conduits, joints, connectors, or links to residences. The quantity released from these networks hinges on aspects like acidity, warmth, mineral content, and stagnation duration, particularly in low-pH, non-mineralized conditions. The advised boundary is 0.01 milligrams per liter; specimen recordings for lead hit 0.01 milligrams per liter, averaging 0.011.

A tentative ceiling for nickel sits at 0.02 milligrams per liter. This provisional status reflects doubts regarding the impact threshold for developmental lethality, with an average of 0.01.

Vanadium lacks an interim advisory level. The examined instances appeared to show no measurable traces of vanadium (as per Table 4).

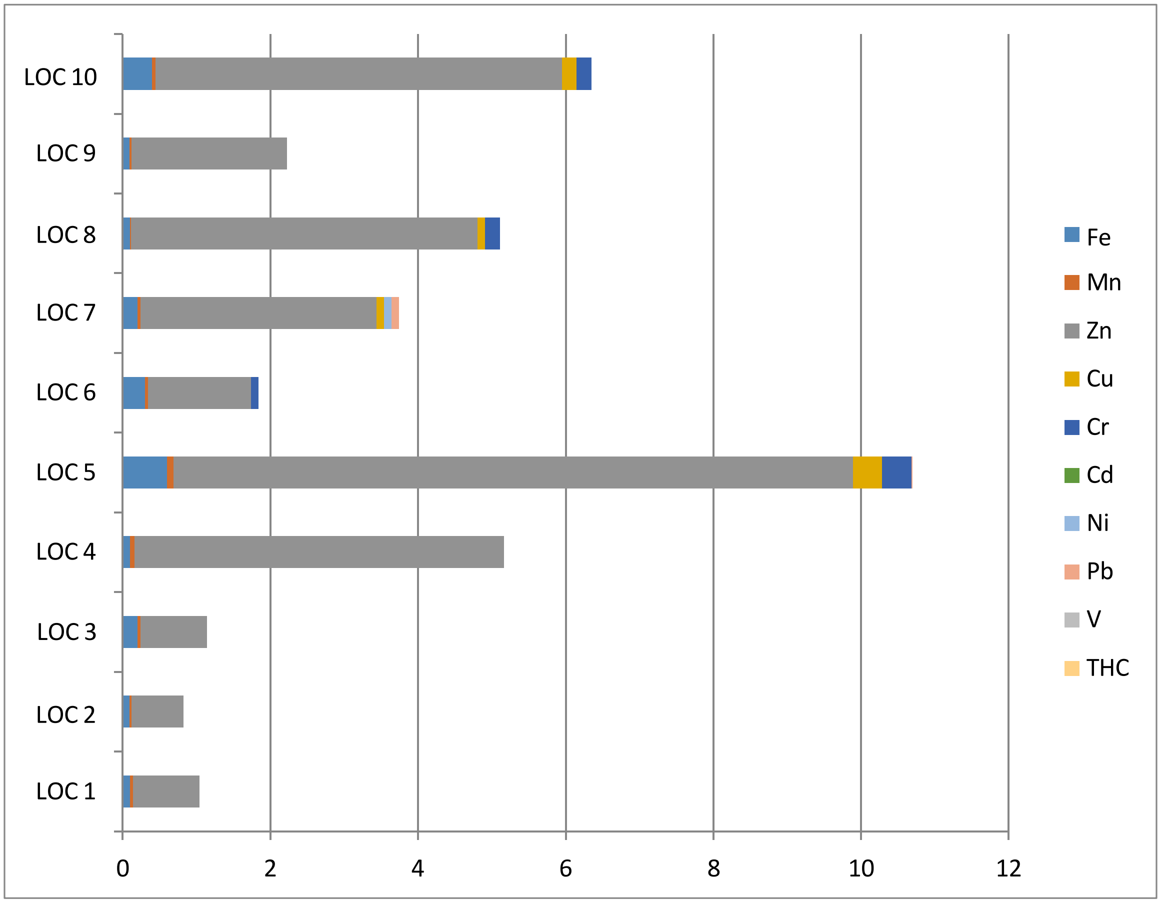


Plate 6: Chart showing the heavy metal distribution in the study area.

4.2.13 TOTAL HYDROCARBON

Gasoline and fuel oil incorporate aromatic compounds, employed in dissolving agents. Aside from mishaps or faulty containment structures, these substances rarely appear in consumable liquids. Even at amounts far under the advised safety thresholds, such compounds can often be sensed through flavor and scent.

Styrene occasionally emerges from improperly hardened conduit components (such as fiberglass-strengthened composites). Regular checks are generally not required, except when an issue is identified. These aromatic compounds may at times seep out from plastic tubing made of polyethylene. Therefore, assessments triggered by an event or concern could prove more useful at the consumer's outlet instead of at the purification facility. Multi-ring aromatic compounds (PAHs) typically manifest in potable supplies solely due to extraction from tar-based coatings on iron-based water conduits. Overall hydrocarbon presence remained absent (as per Table 4).

4.2.14 MICROBIAL ANALYSIS/RESULT

E. coli bacteria are found in the waste of people and creatures, as well as in wastewater and liquids exposed to fresh fecal contamination. The warmth and nourishment levels typical in potable water delivery networks make it extremely improbable for these microbes to proliferate.

Staphylococcus aureus has been identified for ages as a key pathogen responsible for human illnesses. It ranks as the top culprit behind dermal and subcutaneous problems like pus-filled swellings (boils), inflamed hair follicles, and tissue inflammation. While many staphylococcal issues remain mild, S. aureus may trigger severe conditions including systemic blood contaminations, lung inflammations, or skeletal and articular afflictions.

Members of the Salmonella genus act as internal invaders, with specific variants inducing sickness that spreads from beasts to individuals or between people. They generally target just the digestive pathway, leading to salmonellosis, whose manifestations often subside sans antimicrobial treatments.

Bacillus subtilis represents a widespread microbe frequently isolated from aquatic environments, earth, atmosphere, and rotting vegetation. This organism forms a resilient spore enabling survival amid harsh thermal extremes and dryness outdoors. B. subtilis secretes diverse digestive enzymes that break down multiple organic materials, aiding in elemental recirculation. Nevertheless, in typical settings, it stays dormant rather than active, persisting as spores (Alexander, 1977). Regarded as harmless, B. subtilis lacks disease-causing attributes and poses no pathogenic or poisonous risks to people, wildlife, or flora.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

This study was carried out in the southwestern part of Nigeria, and falls within longitudes 5 13′ 30″ and 5 14′ 30.7″ E and latitudes 7 9′ 50″ and 7 12′ 20″ N and shows secondary porosity due to the region underlain by the Precambraian Basement Complex as a result limiting degree of porosity and permeability.

From the results obtained, it can be concluded that the ground and surface water in the study area showed the water quality in this area to be generally potable, due to concentration of heavy metals being mostly under/within the WHO standard regulation. Zinc is released to the environment through the use of zinc galvanized pipe, the presence of Manganese in water samples is primarily from household plumbing systems. The pH, salinity and electrical conductivity in the study area was moderate. The colour for the some samples was brownish – colourless. Turbidity and TSS only occurred in river samples. The presence of microbial organisms in water is from sewages, septic tanks, and animal faeces.

5.2 RECOMMENDATIONS

1. Sanitary landfills and secured landfills should be used in this area.
2. Water from this area should be treated before use, by the application of absorptions and osmosis filter method.
3. Health surveys should be carried out to show the extent of exposure and health impact.
4. Drillers and contractors should be encouraged to drill deeper so as to obtain clean and potable water.

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