

**HEAVY METAL, PHYSICAL AND CHEMICAL INVESTIGATION OF  
GROUNDWATER AT UPPER SAKPONBA COMMUNITY OF BENIN CITY,  
SOUTHERN NIGERIA**



**BY**

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BENIN CITY.**

**MAY, 2024**

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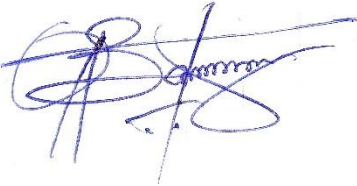
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**A PROJECT WORK SUBMITTED TO THE DEPARTMENT OF SCIENCE  
LABORATORY TECHNOLOGY, FACULTY OF LIFE SCIENCES, UNIVERSITY OF  
BENIN, BENIN CITY, IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR  
THE AWARD OF BACHELOR OF SCIENCE (B.Sc. IN GEOLOGY & MINING  
TECHNIQUES OPTION) HONOURS IN SCIENCE LABORATORY TECHNOLOGY**

**MAY, 2024**

## CERTIFICATION

This is to certify that this project work was carried out by Farwazz MUSA with matriculation number, LSC1807260 of the Department of Science Laboratory Technology (Geology and Mining Techniques), Faculty of Life Sciences, university of Benin, Benin City.



25-04-2024

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**(External Examiner)**

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**Date**

## **DEDICATION**

I dedicate this work to almighty Allah and my beloved parents Mr and Mrs. MUSA in appreciation of their inspiration and drive given towards the successful completion of this work.

## **ACKNOWLEDGEMENTS**

I am deeply grateful to almighty Allah for granting me the ability to successfully conclude this project.

To my parents (Mr. Momodu Musa and Mrs. Fatima Musa). I thank you both profoundly for your love, care, and immense support

To my siblings for always being there for me and for your great support at all times

To my supervisor, Mr. Peter Bassey for his invaluable guidance and mentorship throughout the duration of this project.

I equally appreciate the head of department Dr. E .O. Oshomoh and my Lecturers; Mr K. Ojeaga and Mrs. A. Janet for their impact in my academic journey and the entire staff of the Department of Science Laboratory Technology

To my friends; Maro, Gabriel, Eben, Favour, Blessing, Hope and Rita ,you guys are the best.

Thanks for making school easier and fun. I will always carry our memories

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## ABSTRACT

To determine the extent of physicochemical concentrations in the research area, a groundwater quality evaluation was conducted in Edo State's Ikpoba Okha LGA. Fifteen (15) boreholes were randomly selected from the study region and their physicochemical characteristics were examined. This study also used statistical and cluster analysis techniques. The most significant component of the cluster analysis is the Dendrogram, which showed the Euclidean distance level at which a combination of elements and clusters was present. Four clusters were found, and Cluster 1, which is primarily composed of heavy metals, showed correlation and similarities among the relevant parameters. Among the parameters that were looked at were the water sample's pH, turbidity, TDS, electrical conductivity, salinity, and TSS. An atomic absorption spectrometer was used to identify heavy metals and cations, such as Na, K, Ca, and Mg, whereas sulphate, phosphate, nitrate, and carbonates were detected as anions. The results of the study indicated that the water samples had a pH range of 5.28 to 5.98, indicating that they were acidic. The research region's pH ranged from 4.51 to 5.22, while TDS varied from 5.34 to 6.22 mg/l. There were 1.54 mg/l to 2.12 mg/l of nitrate in the research area. Every water sample was collected and compared to the WHO threshold of 10 mg/l. The research area's copper concentration ranged from 0.039 mg/l to 0.086 mg/l. The sample with the highest recorded value was BH9, and the sample with the lowest recorded value was BH15. The study region's manganese concentrations range from 0.05 mg/l to 0.35 mg/l, with the mean, lowest, and highest values included in these data. The WHO criterion is 0.1 mg/l, and just one sample (BH8) was higher than that. Some of the wells' water samples and those from a few boreholes are contaminated with too high amounts of certain parameters to be consumed by humans. Therefore, it has been established that human activities (refuse dumping, sewage disposal, etc.) have had an impact on the quality of the groundwater in that area.

## **CHAPTER ONE**

### **1.0**

### **INTRODUCTION**

#### **1.1 GENERAL BACKGROUND**

Water body contamination is becoming a more significant environmental hazard. After decades of waste and pollution, man has only recently started to appreciate clean water as a finite and irreplaceable resource (Plummer and McGeary, 2016). Although it is scarce in many countries, portable water is vital for both economic growth and human health (Ovrawah and Hymore, 2001). Pure, natural water contains multiple dissolved components in each drop. Water supplies have become contaminated with germs, viruses, heavy metals, nitrate, and salt as a result of improper disposal of human and animal waste, industrial discharges, and overuse of the planet's finite water resources (Singh and Mosley, 2003). Benin City, Okhuebor, and Izevbuwa have seen a notable increase in the number of boreholes as a result of the surge in housing building projects (2020). The latter also noted that practically all residential, commercial, and office buildings in Benin City have built-in boreholes, and that human activities like septic tank, soak-away pit, and pit latrine use, as well as the remediation of soil fertility and careless waste disposal, are increasing along with the city's population. They concluded that these operations might result in leachates into the groundwater formation that provides the area with water. Groundwater contamination can be avoided by placing borehole wells far away from any potential sources of pollution. Effective well design is essential to minimizing the contamination of subsurface water. During construction, chemicals, drilling fluids, and other contaminants could seep into the borehole and contaminate the water. An open hole created during construction may also offer the perfect setting for chemical and biological pollution in addition to giving pollutants a direct path from the surface to the aquifer (Piper, 1944). During the drilling process, contaminants such as

chemical casings and drilling fluids may enter the well and contaminate the water. An open hole made during construction might also provide pollutants with an easy way to go from the surface to the aquifer, which would be ideal for biological and chemical contamination.

To determine the degree of purity, it is essential to examine the water quality characteristics of borehole water, with a focus on the Evbuobogun Community in Edo State. The aim of this study is to evaluate the purity of the borehole by x-raying and estimating the amount of heavy metals, ion contents, and other factors like pH and conductivity. The results will be compared with the globally recognized standard.

### **AIM AND OBJECTIVES**

This work is aimed at investigating the physicochemical properties of groundwater in Evbuobogun Community of Edo State with the view to know the extent of concentration of the parameters in the study area.

### **OBJECTIVES**

To achieve the above aim, the following objectives will be employed:

1. Systematic collection of samples
2. Laboratory analysis to determine physical and chemical parameters as well as heavy metals presence and concentration
3. To use statistical analysis to understand the relationships that exist amongst the parameters.

## CHAPTER TWO

### 2.0

### LITERATURE REVIEW

Numerous factors that define groundwater are found by geophysical techniques including gravity, magnetic, seismic, and electrical resistivity tests, among others. However, the electrical resistivity survey approach was applied for this research project. The porosity, permeability, transmissivity, and conductivity are the most commonly used characteristics. In sedimentary environments, the electrical resistivity approach has shown to be a dependable technique for geophysical groundwater research (Emenike, 2001). Records demonstrate that variations in geo-thermal and geo-structural occurrence cause aquifer depths to vary from location to location. (Osobonye and Ekine, 1996). The research area's geology shows that sedimentary rocks cover the entire surface. These rocks range in age from Paleocene to modern. Ninety percent of the sedimentary rock is intercalated shale and sandstone. According to Abdurafiu *et al.* (2011), it is sub-angular to well rounded, coarsely grained, locally finely grained, poorly sorted, and contains fragments of wood and lignite streaks. The Benin formation is made up of the sedimentary rock in the research area. There is a sizable groundwater reserve here. In a location such as Benin City, large amounts of water are obtained. The study region is located in the Niger Delta's coastal plain, which has two distinct seasons (wet and dry). The research region receives varying amounts of rain, but it is always sufficient to support year-round agricultural growth. Every year, about 2279 mm of precipitation are reported. 26.4°C is the average annual temperature. All year long, relative humidity is high and only marginally drops during the dry season. There are brown loams and sandy loams in the area.

## LOCAL GEOLOGY

The research area is situated in the South-South geographical zone of Nigeria in Ikpoba Okha L.G.A., between 6°12'08"N and longitudes 5°38'03"E. The research region is flat, with an elevation of roughly 60 meters above sea level, and lacks a drainage infrastructure to divert surface runoff. Water stagnation following rain events is supported by this circumstance. Nonetheless, the study area has a strong residential road network.

### 2.2 GEOLOGY OF THE STUDY AREA

The region being studied is a typical Niger Delta geological setting. The research regions are designated as coastal plain sand and are located in the Benin formation (Abdurafiu *et al.*, 2011). It is made up of large, highly porous freshwater-bearing sandstones with little intercalation of clay, and it has a high permeability. Since the formation typically contains water, it serves as the municipality's primary supply of portable groundwater (Abimbola *et al.*, 2002). The research area's geology shows that sedimentary rocks cover the entire surface. The ages of these rocks range from Paleocene to modern. Ninety percent of the sedimentary rock is intercalated shale and sandstone. According to Abdurafiu *et al.* (2011), it is sub-angular to well rounded, coarsely grained, locally finely grained, poorly sorted, and contains fragments of wood and lignite streaks. The Benin formation is made up of the sedimentary rock in the research area. There is a sizable groundwater reserve here. In a location such as Benin City, large amounts of water are obtained.

## **2.2 CLIMATE AND VEGETATION**

The research region is located in the humid tropical zone, where the average yearly temperature is roughly 29°C. With an average yearly rainfall of 2500mm, the heaviest rainfall happens between July and September and decreases as the dry season approaches between December and January. There are a few trees, bushes, and grasses among the vegetation.

## **CHAPTER THREE**

### **3.0**

### **METHODOLOGY**

#### **3.1 SAMPLE COLLECTION AND PRESERVATION**

15 Boreholes in total were sampled at random with 0.75L plastic cans that had tight lids. These samples were collected from active boreholes located throughout the study area. Before the sample was introduced, the container was briefly washed with some sample water. The samples for the metal analysis were acidified with 1 ml of nitric acid (HNO<sub>3</sub>) and stored in a refrigerator before being transported to the lab for physicochemical assessment (to avoid the metals precipitating in the water). The samples underwent physical, chemical, and heavy metal analyses at the University of Benin's Chemistry Department Laboratory in Benin City.

#### **3.2 MATERIALS**

Some of the materials used include: test tubes, Petri-dish, inoculating lamp, syringe pipette, aluminum foil, test tube track, cotton-wool, slides, matches, Microscope, Incubator, Refrigerator, Autoclave, Mettler balance.

#### **3.3 METHODS**

Conductivity and temperature values of the water samples were measured with an instrument known as HANNA conductivity and temperature meter EC/TDS.

The turbidity was determined with turbidity meter wag-WT 3020, water proof with serial number 197619 and parameters such as NO<sub>3</sub>, Fe<sup>2+</sup>, Na<sup>+</sup>, Mg<sup>2+</sup> and Ca<sup>2+</sup> were analyzed using a spectrophotometer. Wagtech photometer with wavelength ranging from 410-640 and serial number 3400-008 was also used to determine parts of the chemical parameters. Physical parameters like odour, taste and colour were observed in the field, at the site of collection.

### **3.3.1 DETERMINATION OF pH**

The negative logarithm of the concentration of hydrogen ions is known as pH. It's a way to explain how acidic and basic an aqueous solution is. The pH level of water has a significant impact on the solubility of ions in it.

### **3.3.3 DETERMINATION OF CONDUCTIVITY**

Using a conductivity meter, the conductivity was immediately ascertained from the various samples. Another crucial factor to consider when calculating a solution's electrical resistance is conductivity, which provides insight into the solution's overall ionic concentration. The overall concentration of dissolved ions, their mobility, and the measurement of temperature are all related to the conductance for water. Conductivity meters are frequently used to test the purity of water.

#### **Procedure:**

The equipment makes use of a cell. It operates by detaching the measuring cell from the instrument, cleaned thoroughly with a bottle brush and rinsed with distilled water and thereafter to remove tenacious deposits. The cell was rinsed with a small quantity of the solution to be tested before filling for measurement. The button was held down while the measuring dial Pinter was slowly rotated until the balance indicator was central. The readings were measured in  $\mu\text{s}/\text{cm}$ .

### 3.3.4 TOTAL DISSOLVED SOLIDS (TDS)

#### **Procedure:**

100ml of the samples was measured and filtered into 100ml measuring cylinder using a pre weighed filter paper; it was made up to 100ml with distilled water. It was later, transferred into pre-weighed crucible and evaporated into dryness in steam water bath, dried in an oven at 180<sup>0</sup>c for 11/2hours, cooled in desiccators and weighed. The weight of the crucible was recorded as W1, with dissolved solid as W2.

#### **Total Suspended Solids (TSS):**

This is an illustration of the amount of solid that a filter retains. For thirty minutes, the pre-weighed filter paper for total dissolved solids was dried at 105<sup>0</sup>C. It was weighed after being chilled in desiccators. W1 represented the weight of the pre-weighed filter paper, and W2 represented the weight of the paper and residue upon drying.

#### **Calculation**

$$\text{TSS (ppm)} = W_2 - W_1 * 10^3 \text{ ppm}$$

### 3.3.5 DETERMINATION OF CHLORIDE

When potassium chromate was used as the end point indicator and silver nitrate as the titrate in the Mohr's method, the chloride ion in the water precipitated as white silver chloride.

#### **Procedure:**

50ml of the sample was measured into a conical flask and 10 drops of potassium chromate was then added, which turn the water samples to yellow. The water samples then titrated against

0.05ml of silver nitrate, the titration endpoint is the change in colour from yellow to reddish brown.

### **3.3.6 DETERMINATION OF NITRATE**

The chlorimetric method was used to calculate the nitrate content. This required the employment of copper sulphate ( $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ ) and hydrazine sulphate ( $\text{N}_2\text{H}_2 \cdot \text{H}_2\text{SO}_4$ ) as a catalyst to produce a crimson color, whose intensity was thereafter compared to the standard Aqua Merck nitrate color scale. The scale displayed the corresponding concentration in parts per million. The kit's unique benefit is that it makes it possible to quickly determine the ionic concentration at or near the spot. Using the Aqua Merck water analysis reagent kit, nitrite, silicate, and phosphate were measured using a methodology similar to the one described previously (Merck, 1982).

### **3.3.7 DETERMINATION OF METALS**

A model of a buck the flame emission spectrophotometer and the flame atomic absorption spectrophotometer (AAS) are comparable. The samples in (AAS) were atomized after being inhaled into the flame.

Utilizing the appropriate metal salt for each element to be determined, a standard solution was made from the solution in parts per million for each metal. The necessary lamp for each metal was fixed, and the instruments were amplified for stability for roughly fifteen minutes. Both the samples and the standard of each metal were aspirated concurrently and sequentially. Next, using the same setup as described in the Buck Scientific Operations Manual book for ASS, the absorbance series was recorded.

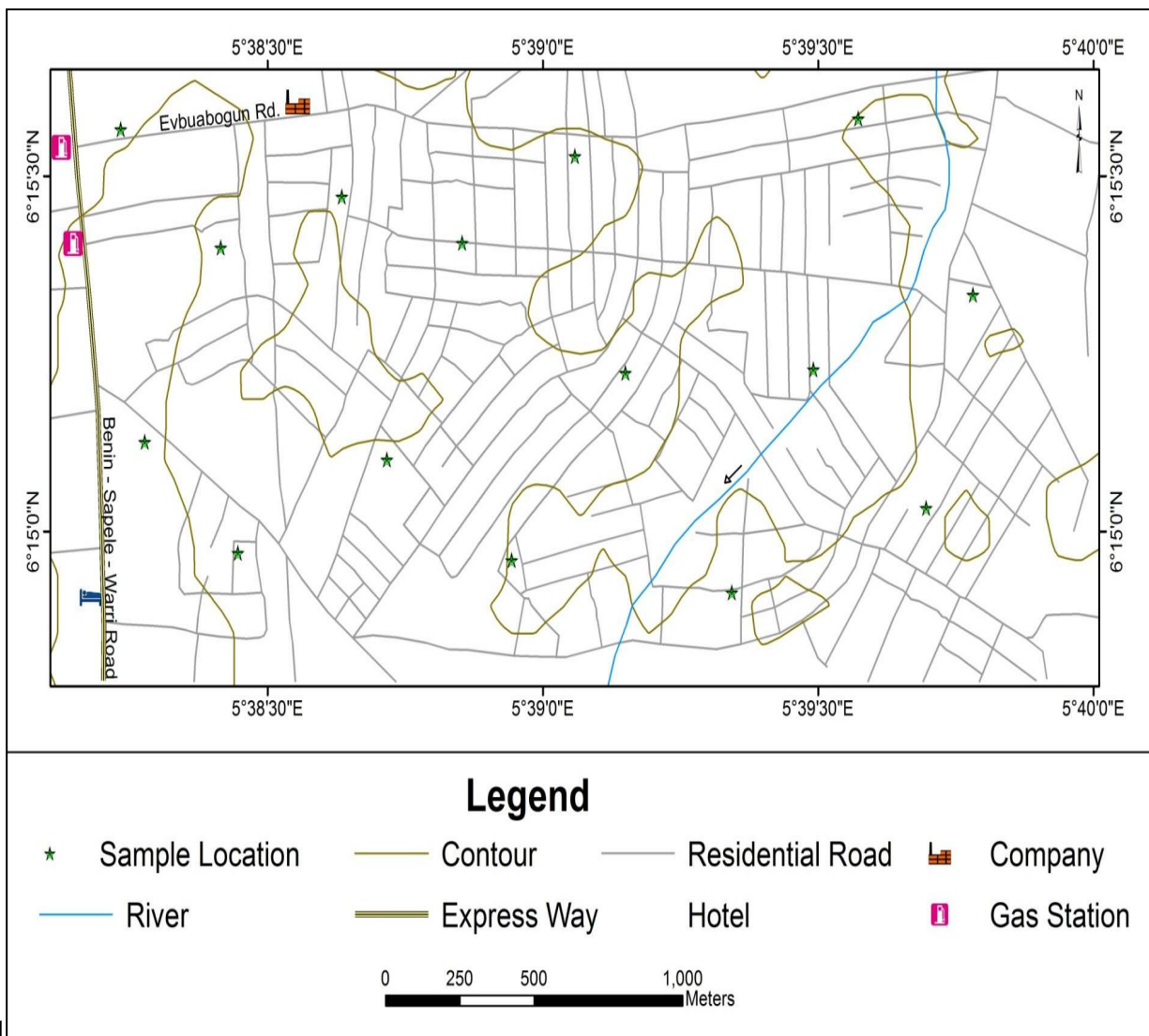


Fig. 1: Location of the Study Area.

## CHAPTER FOUR

### 4.0 RESULT AND DISCUSSION

#### 4.1 RESULT

Fifteen (15) groundwater samples from the research region underwent physicochemical examination. The following variables were analyzed: hydrogen potential, electrical conductivity, turbidity, total suspended solids, total solids, alkalinity, carbonate, sulphate, chloride, and nitrate levels, as well as calcium, magnesium, iron, zinc, lead, cadmium, copper, and manganese concentrations.

Statistical, Correlation and Cluster analysis were carried out and the outcome displayed in tables and figures below:

**Table 1:** Summary of the Physical and Chemical Analyses Of Groundwater Samples from the Study Area

Parameters	Mean	S.E.	Std. Dev.	Min	Max	WHO LIMIT
pH	4.75	0.055	0.212	4.51	5.22	6.5 - 8.5
TURBIDITY (NTU)	0.05	0.004	0.017	0.03	0.09	5
CONDUCTIVITY	12.42	0.218	0.843	11.38	13.81	1000
TDS (mg/l)	5.75	0.077	0.298	5.34	6.22	500
TSS (mg/l)	6.87	0.524	2.031	4	10	N/S
TOTAL SOLID (mg/l)	12.99	0.573	2.221	9.3	15.3	N/S
ALKALINITY (mg/l)	6.76	0.293	1.135	4	8	N/S
CARBONATE (mg/l)	5.20	0.296	1.146	4	7	N/S
SULPHATE (mg/l)	1.68	0.041	0.157	1.21	1.84	250
CHLORIDE (mg/l)	13.91	0.092	0.358	13.03	14.13	200
NITRATE (mg/l)	1.85	0.050	0.193	1.54	2.12	10
CALCIUM (mg/l)	0.92	0.107	0.416	0.39	1.73	200
MAGNESIUM (mg/l)	0.48	0.011	0.042	0.36	0.53	20

IRON (mg/l)	0.57	0.053	0.204	0.263	0.891	0.3
ZINC (mg/l)	0.17	0.013	0.050	0.116	0.269	0.01
COPPER (mg/l)	0.06	0.004	0.014	0.039	0.086	0.5
MANGANESE (mg/l)	0.05	0.021	0.083	0.021	0.35	0.1
CADMIUM (mg/l)	0	0	0	0	0	0.003
LEAD (mg/l)	0	0	0	0	0	0.05

---

**Table 2:** Correlation coefficient matrix of ground water quality parameters in the study area

	PH	Turb	EC	TDS	TSS	TS	ALK	CO <sub>3</sub> <sup>2-</sup>	SO <sub>4</sub> <sup>2-</sup>	Cl <sup>-</sup>	NO <sub>3</sub> <sup>-</sup>	Ca <sup>2+</sup>	Mg <sup>2+</sup>	Fe <sup>2+</sup>	Zn <sup>2+</sup>	Cu <sup>2+</sup>	Mn <sup>2+</sup>	
PH	1																	
Turb	.143	1																
EC	.154	<b>.855**</b>	1															
TDS	.384	<b>.770**</b>	<b>.861**</b>	1														
TSS	.052	-.312	-.182	-.080	1													
TS	.140	-.270	-.220	.016	<b>.921**</b>	1												
ALK	.364	.190	.299	.340	.010	-.031	1											
CO <sub>3</sub> <sup>2-</sup>	.045	-.332	-.300	-.241	<b>.933**</b>	<b>.846**</b>	.045	1										
SO <sub>4</sub> <sup>2-</sup>	.297	.188	.265	.315	-.136	-.126	<b>.966**</b>	-.095	1									
Cl <sup>-</sup>	.304	.262	.379	.427	.020	.125	<b>.726**</b>	-.059	<b>.773**</b>	1								
NO <sub>3</sub> <sup>-</sup>	.289	-.140	.080	.117	<b>.817**</b>	<b>.670**</b>	.261	<b>.737**</b>	.042	.128	1							
Ca <sup>2+</sup>	.058	-.084	.101	.144	<b>.678**</b>	<b>.597*</b>	.407	<b>.644**</b>	.333	.362	<b>.663**</b>	1						
Mg <sup>2+</sup>	.110	-.142	.143	.080	.510	.472	.324	.399	.229	<b>.579*</b>	<b>.673**</b>	<b>.562*</b>	1					
Fe <sup>2+</sup>	.137	.063	.080	.215	.261	.188	<b>.528*</b>	.243	.477	.181	.366	<b>.622*</b>	-.032	1				
Zn <sup>2+</sup>	.097	.176	.232	.203	.273	.183	.431	.297	.434	.330	.285	<b>.621*</b>	.341	.342	1			
Cu <sup>2+</sup>	.346	.085	.004	-.021	.099	.216	-.406	.065	-.439	-.065	.026	-.262	.066	-.506	-.434	1		
Mn <sup>2+</sup>	-.273	.065	.186	.075	.207	.119	<b>.584*</b>	.226	.484	.344	.381	.414	.435	.317	.114	-.282	1	

r (0.05)(∞2) df (13)=0.514

r (0.01)(∞2) df (13)=0.641

Bold values = Significant (P<0.05)

Bold values with underline = Highly Significant (P0.01)

## Chart Representation

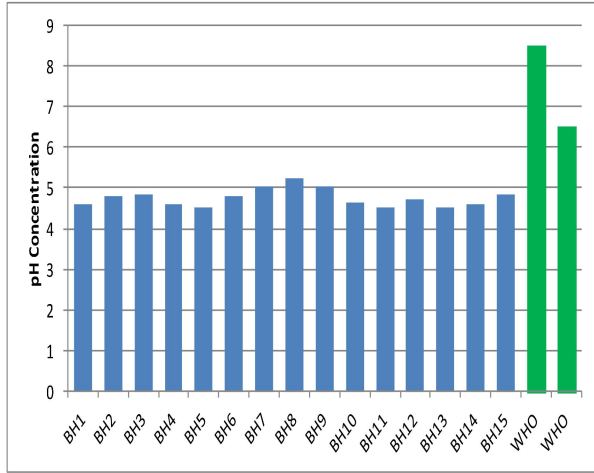


Fig. 2: Comparative pH values and WHO minimum and maximum limit

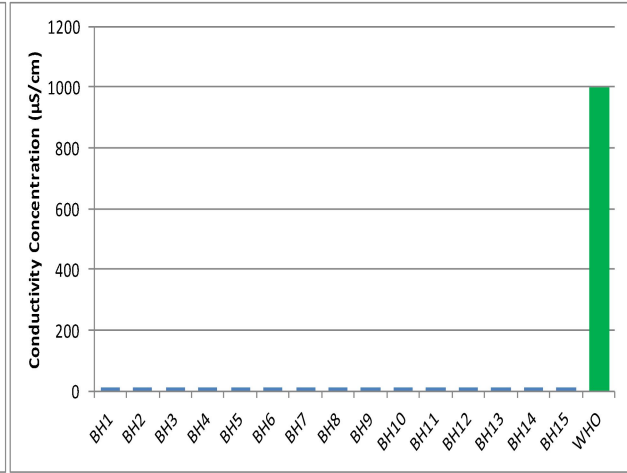


Fig. 3: Comparative EC concentration values and WHO limit

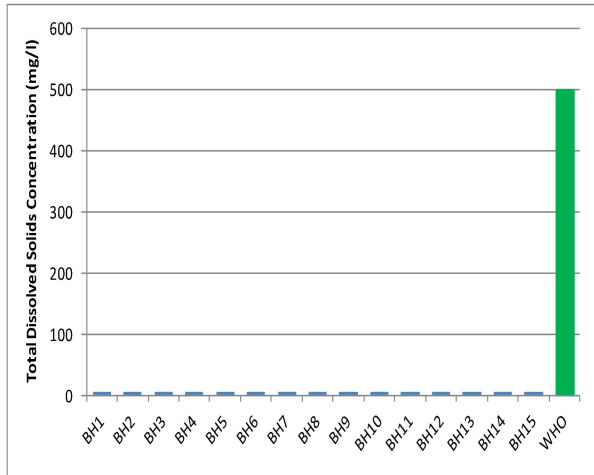


Fig. 4: Comparative TDS values and WHO standard

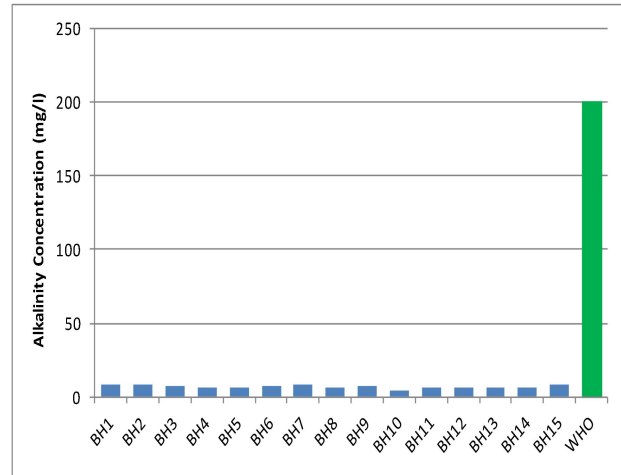


Fig. 5: Comparative Alkalinity values and WHO standard

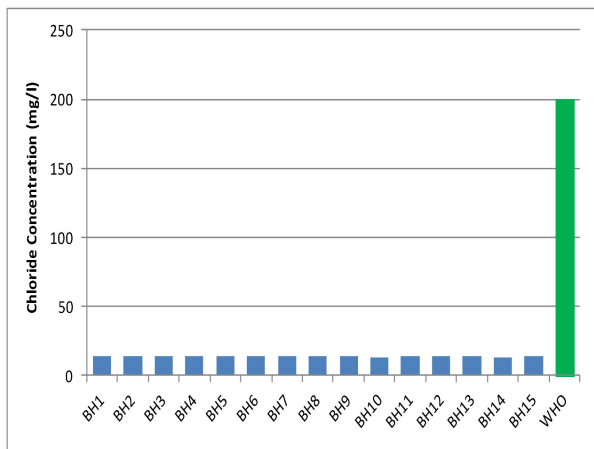


Fig. 6: Comparative Cl<sup>-</sup> values and WHO standard

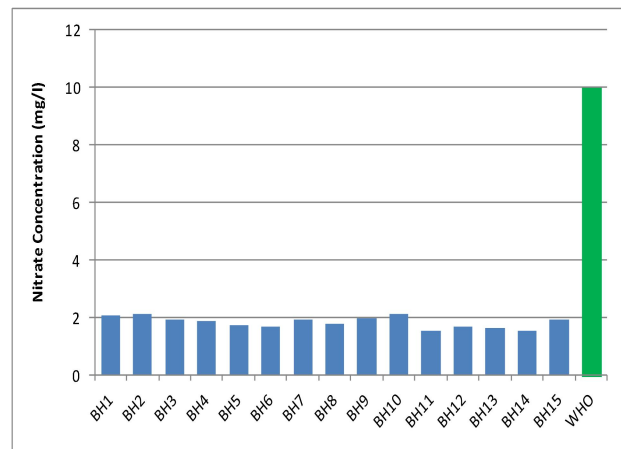


Fig. 7: Comparative NO<sub>3</sub><sup>-</sup> values and WHO standard

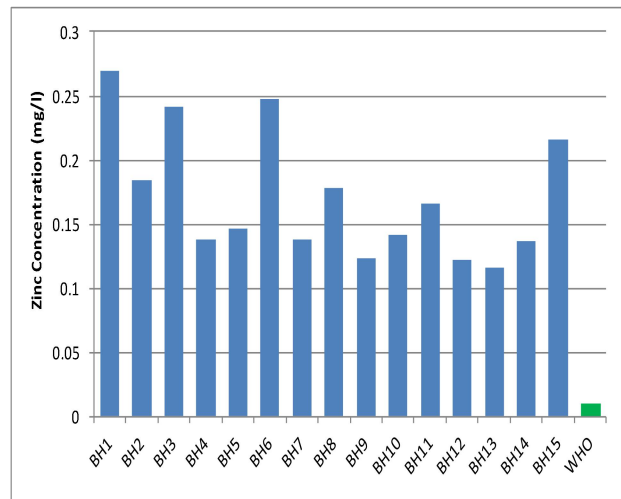
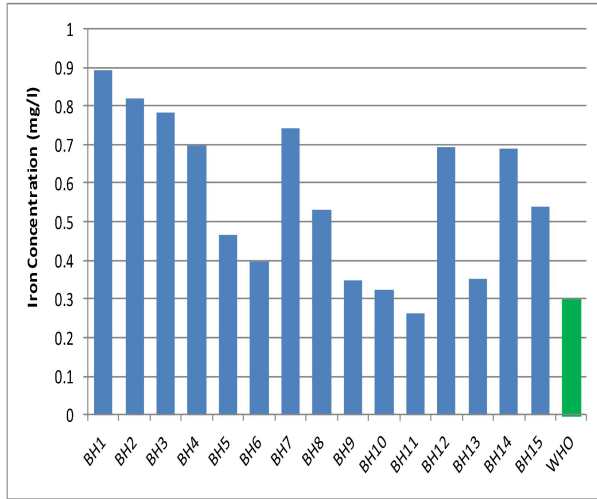


Fig. 8: Comparative Fe concentration values and WHO limit

Fig. 9: Comparative Zn concentration values and WHO limit

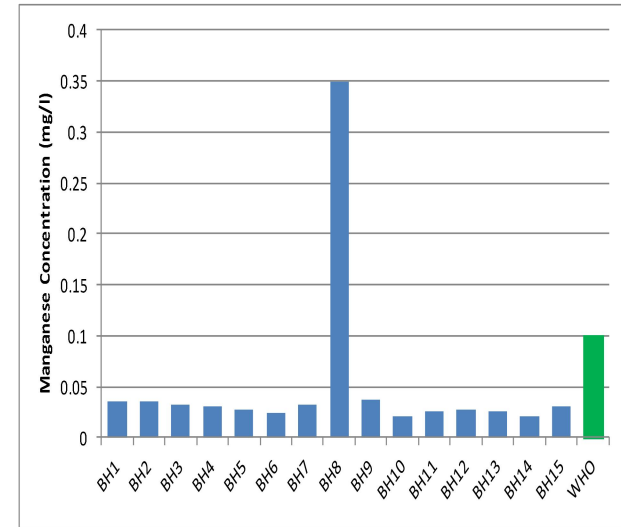
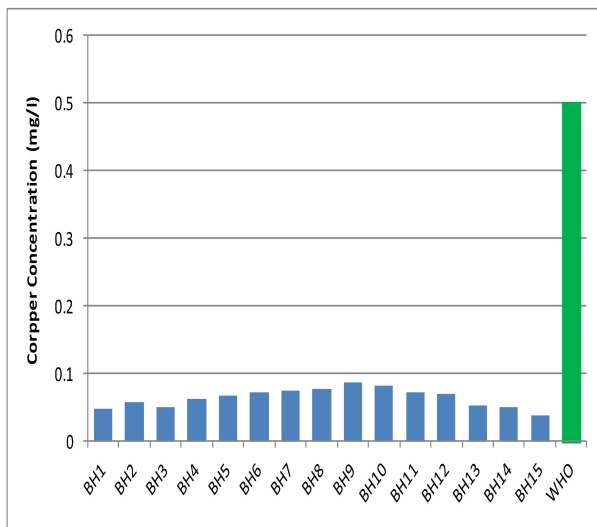


Fig. 10: Comparative Cu concentration values and WHO limit

Fig. 11: Comparative Mn concentration values and WHO limit

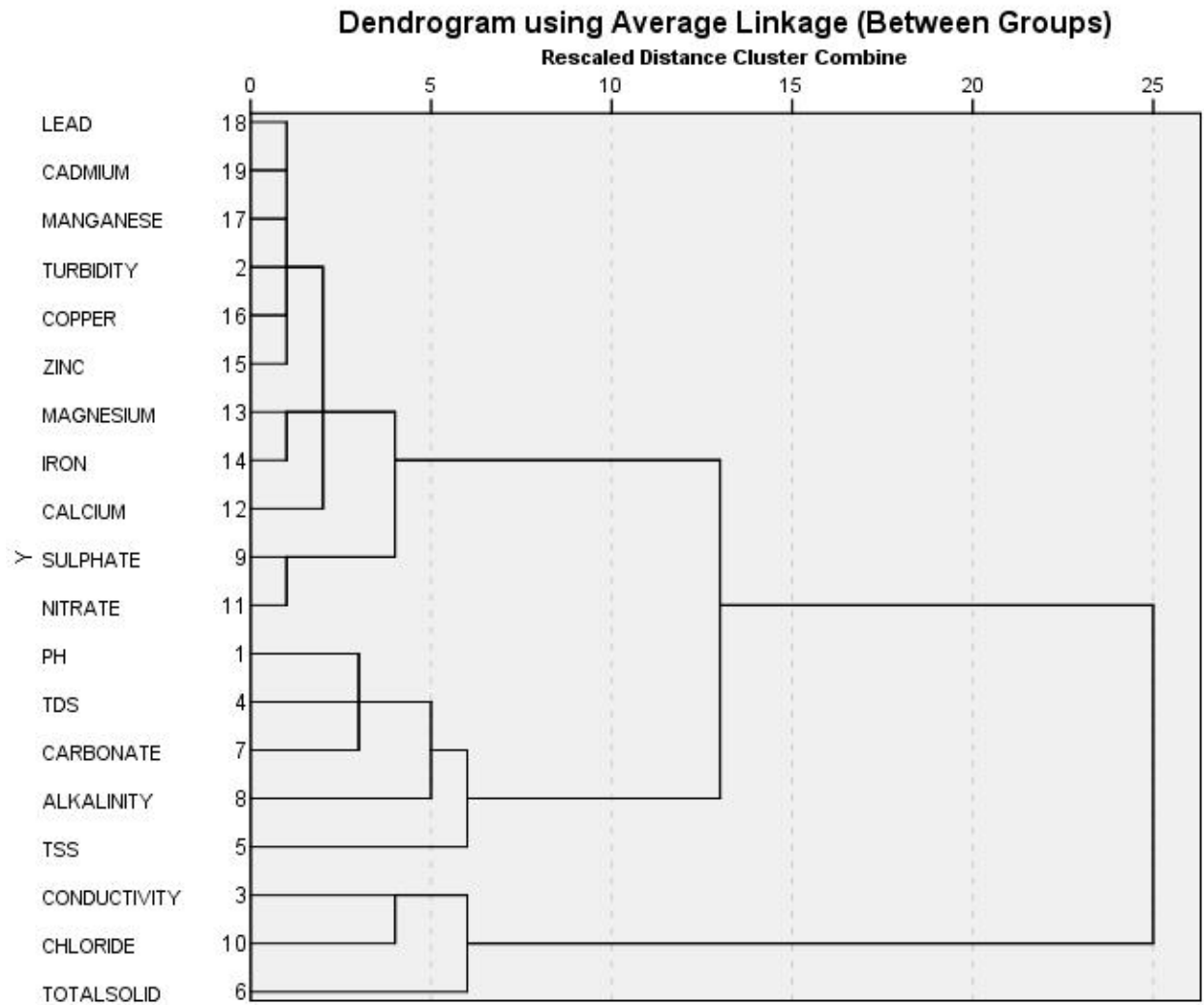


Figure 12: Dendrogram (R – mode)

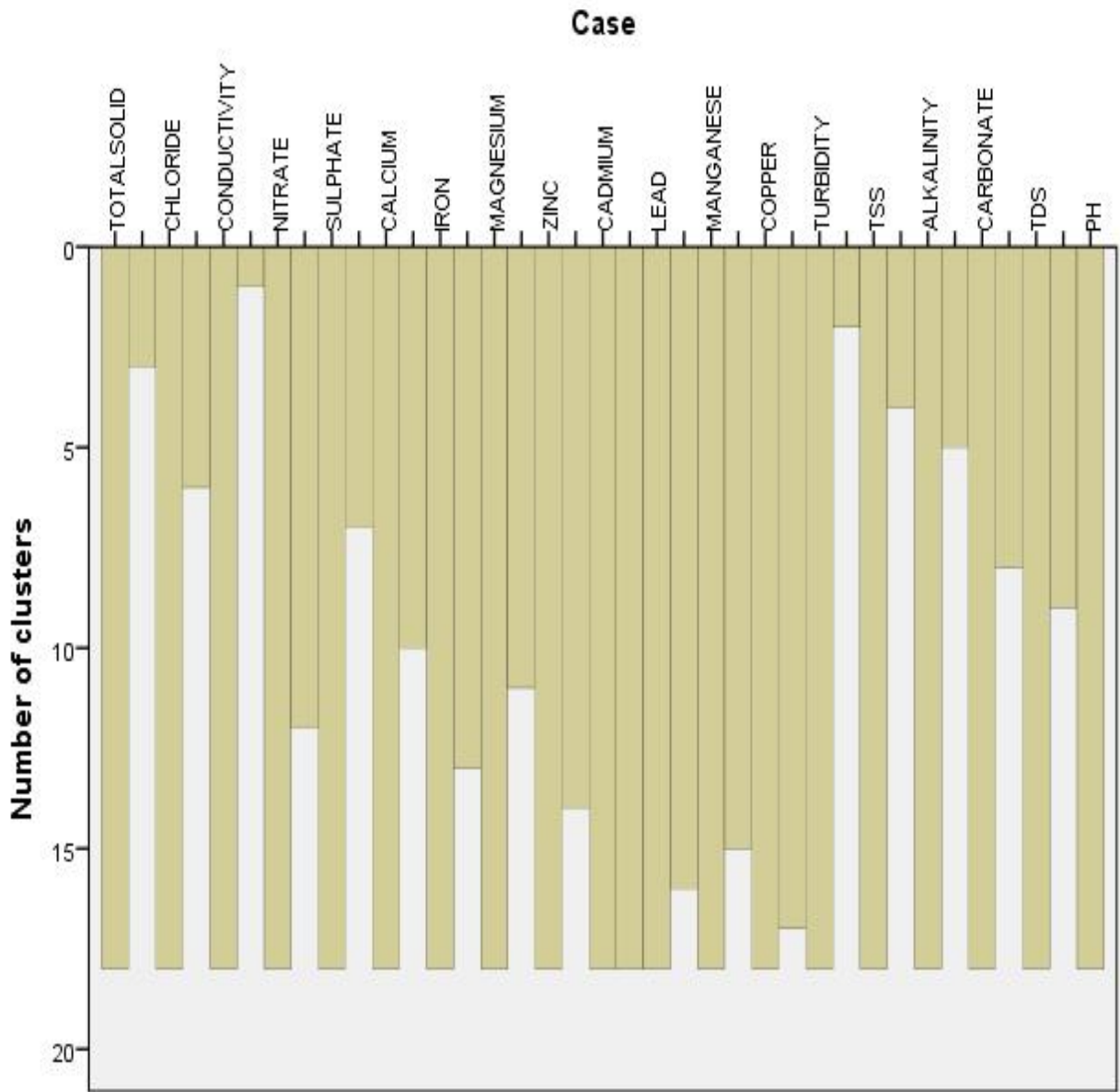


Figure 13: Icicle diagram (R-Mode)

## 4.2 DISCUSSION

### Physicochemical Parameters

Todd (1980) states that the logarithm of the hydrogen ion activity, which quantifies the activity of the hydrogen ion ( $H^+$ ), is given as the reciprocal of the pH. The research region's pH was measured, and the results showed that BH8 had the greatest pH and BH11 had the lowest pH. The pH ranged from 4.51 to 5.22. None of the results meet the suggested WHO criteria of 6.5 to 8.5 (Table 1). The research area's low pH, according to Rajappa et al. (2011), may allow metal ions from plumbing fixtures and piping, such as iron, manganese, copper, lead, and zinc. This could result in aesthetic problems such a metallic or sour taste, laundry staining, and the unusual discoloration of sinks and drains.

Total dissolved solids (TDS) are primarily composed of inorganic salts (calcium, magnesium, potassium, sodium, bicarbonates, chlorides, and sulphates), with a little amount of organic compounds. TDS values range from 5.34 to 6.22 mg/l (Table 1). At 6.22 mg/l, BH6 recorded the highest result, and at 5.34 mg/l, BH1 recorded the lowest. Every TDS measurement that was submitted in the study area fell within the WHO's 500 mg/l regulatory criterion. The average alkalinity readings in the study area are 6.76 mg/l, with low values of 1.135 mg/l, high values of 4 mg/l, and high values of 8 mg/l. There were no drilling sample locations where the 200 mg/l WHO limit was surpassed.

Water in the sample is less sensitive to acids because of its alkalinity (Olobaniyi and Owoyemi, 2004).

Both surface and groundwater contain chloride (Olobaniyi and Owoyemi, 2004). Because it is resistant to oxidation and other removal techniques, chloride has a major advantage over contaminants like ammonia when determining sewage effluent concentration (Nwankwoala *et al.*,

2009). The simplest chemical indicator of the amount of sewage effluents added is a water sample that is free of chloride concentration from all other main sources.

It also suggests that there is soft water in the water source. Table 1 shows that the chloride concentrations are, in order, 13.91 mg/l on average, 13.03 mg/l at lowest, and 14.13 mg/l at highest. According to Table 1, sample BH1 had the greatest value and sample BH10 the lowest. Every sample satisfies the 200 mg/l WHO criterion.

The range of nitrate concentration in the research area was 1.54 mg/l to 2.12 mg/l. Every water sample collected falls within the WHO's recommended threshold of 10 mg/l. All subterranean water contains nitrate because nitrifying microorganisms consume nitrogen from organic sources to make nitrate. Sewage effluents are also included in the nitrate content. For babies younger than six months old, methemoglobinemia, also referred to as "blue-baby syndrome," is a potentially fatal blood disorder (Ovrawah and Hymore, 2001; Olobaniyi and Owoyemi, 2004).

### **Heavy Metal Parameters**

The concentrations of iron (Fe) are as follows: 0.891 mg/l, 0.26 mg/l, and 0.57 mg/l, on average, lowest, and maximum, respectively. It was shown that 93% of the samples had concentrations higher than the WHO recommendation of 0.3 mg/l. Groundwater penetration may cause iron to dissolve, which would account for the high iron content. Significant iron concentrations in groundwater are not unusual, considering the high iron content of the Benin formation. Iron can precipitate out of unpalatable water and leave dark streaks behind when it is exposed to air (Lyaka and Kakulu, 2012).

The research area's zinc values varied from 0.116 mg/l to 0.269 mg/l (Table 1). Comparing the water samples to the WHO threshold of 0.01 mg/l revealed that all of them were over the limit. Landfills and chemical waste dumps could be the cause of the higher zinc level seen in the study

area. Furthermore, fungicides and insecticides may contribute to elevated zinc levels. Excessive zinc concentrations could be detrimental to animal and human health. Lyaka and Kakulu (2012) suggest that these kinds of impacts could result in vomiting, dizziness, fevers, colic, diarrhea, and nausea.

Copper levels in borehole samples from the research area ranged from 0.039 mg/l to 0.086 mg/l. The greatest recorded value was found in sample BH9, and the lowest recorded value was found in sample BH15. All of the measures of copper concentration satisfied the WHO standard of 0.5 mg/l. It is an essential trace element required to maintain optimal health. Headaches, nausea, diarrhea, and upset stomach can result from high copper levels. Additionally, a metallic or disagreeable taste lingers (Klaassen, 2001).

Throughout the research area, manganese contents range from 0.35 mg/l at the high end to 0.021 mg/l at the low end (Table 1). The chemical BH8's single sample that was above the WHO threshold of 0.1 mg/l. High manganese concentrations can cause stains and a strong metallic taste, among other cosmetic problems. Long-term exposure can have detrimental effects on the nervous system and cause symptoms similar to Parkinson's disease, especially in young children, the elderly, and expecting mothers (Nwankwoala *et al.*, 2009).

### **Cadmium and Lead**

Lead (Pb) and cadmium (Cd) are dangerous substances for human health even though they were not found in every sample (Anon, 1970). While Pb poisoning is rare, chronic exposure at relatively low levels, as is anticipated in the study's study areas, can have detrimental health effects. Nagendra and Ramkrishna (2011) state that cadmium enters aquatic systems through the weathering and erosion of soils and bedrock, atmospheric deposition, direct industrial discharge, leaking from landfills and polluted sites, and the dispersive use of fertilizers in agriculture.

Red blood cell chemistry disruption, delays in infants' and young children's typical physical and mental development, mild deficiencies in children's attention span, hearing, and learning capacities, and mild elevations in blood pressure in certain adults are some of these effects (Erah *et al.*, 2002).

### **4.3 CLUSTER ANALYSIS**

The most crucial component of the cluster analysis is the Dendrogram (figure 12), which shows the Euclidean distance level at which a combination of components and clusters existed. Four clusters were found: Cluster 1 (Pb, Cd, Mn, Cu, Zn, Iron, and NO<sub>3</sub>) at roughly a distance from Euclid; Cluster 2 (Turbidity and Ca) at a distance from Euclid; Cluster 3 (pH and CO<sub>3</sub>) at a distance from Euclid; Cluster 4 (Mg, SO<sub>4</sub>, and Chloride) at a distance from Euclid; Cluster 5 (TDS and Alkalinity) at a distance from Euclidean Euclidean Euclidean Six (TSS, Electrical Conductivity, and Total Solids).

The heavy metal-dominated Cluster 1 shows similarities and correlations between the various metrics. Figure 13 also shows the icicle diagram.

### **4.4 CORRELATION**

A correlation matrix analysis of the physicochemical data showed that there was a very strong positive correlation ( $p < 0.01$ ) between the following variables: Alkalinity and Sulphate, Chloride and Carbonate & Nitrate, Calcium; Turbidity & Electrical Conductivity, Total Dissolved Solids; Electrical Conductivity & Total Dissolved Solids; Total Suspended Solids & Total Solids, Carbonate, Nitrate, Calcium. Additionally, a positive connection at  $p < 0.05$  was found between calcium and total solids, calcium and magnesium, iron, and zinc, and calcium and alkalinity and iron, manganese.

It is significant to note that no relationship was found between pH, total dissolved solids, magnesium, iron, zinc, and manganese and copper. With a correlation coefficient of  $R^2=0.966$ , alkalinity and sulphate have the highest association.

## **CHAPTER FIVE**

### **5.0 CONCLUSION AND RECOMMENDATION**

#### **5.1 CONCLUSION**

The study assesses the heavy metal and physicochemical contents in borehole water samples taken from Benin City's Ikpoba-Okha Local Government Area. The results show that the research area's water is rather acidic.

The physicochemical characteristics showed a positive association, albeit a very significant one. There was no association found between Cu and pH, TDS, Mg, Fe, Zn, and Mn, although turbidity, electrical conductivity, total suspended solids, total solids, alkalinity, carbonate, and calcium all linked well with one or more parameters. Values for pH, Fe, Zn, and Mn were found to be higher than the WHO standard. In conclusion, it can be said generally that Zn and Fe pollution was found in the groundwater research.

#### **5.2 RECOMMENDATION**

The following recommendations are hereby given:

1. Environmental geologists should be engaged to ensure quality groundwater monitoring at specific intervals.
2. Environmental awareness should be employed in educating the citizens in the study area.
3. Boreholes should be drilled at deeper depths to get fresh water free of iron from the aquifer zone.

4. Water from the study area be treated with the addition of calcium carbonate, lime and intensive aeration/oxidation followed by filtration to neutralize the pH, remove magnesium and iron respectively.
5. Further research should be carried out in the study area to keep contamination in check, especially microbial parameters that were not investigated in this research.

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