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Research Paper

Investigating The Physico-Chemical, Biological and Heavy Metal Properties of Water from Isiagu Town, AWKA South L.G.A Of Anambra State, Nigeria

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ABSTRACT
The physical, chemical, biological, and heavy metal characteristics of water from Isiagu community were evaluated. Geologically, Isiagu town is underlain by massive thicknesses of Imo Shale Formation, making it difficult to access groundwater. This makes people largely dependent on shallow wells and rainwater for survival. Seven (7) samples were taken from wells, a borehole, and rainwater for analysis. pH was tested using a pH meter. TDS and TSS were measured by filtration and evaporation, while other parameters were determined by titration. Iron, Mercury, Zinc, Chromium, and Arsenic were analyzed using a Varian AA240 Atomic Adsorption Spectrophotometer (AAS). Biological analysis was carried out using the Membrane Filtration Technique. The pH values varied from 6.19 to 7.29, whereas the other parameters complied with the Nigerian Industrial Standard for Drinking Water Quality (NISDQW) and the World Health Organization (WHO) guidelines. Arsenic and Zinc were within the permissible limit with a mean value of 0.004mg/L and 0.298mg/L, respectively. Samples W1 and W3 recorded high Chromium concentration. High Mercury concentration was recorded in all samples tested. About 71% of the water analyzed was contaminated with iron, making it unfit for drinking. Coliform count ranged between 65.00 ± 1.41 and 288.00 ± 1.41. Escherichia coli was present in all samples. Pearson's correlation showed a relationship between Sulphate and Chromium as well as pH and Chromium with significant values of (0.696) and (-0.822), respectively. The study reveals that some samples tested were below standard and could pose a health risk. Periodic monitoring is recommended for effective water resources management.

Keywords: *Physico-Chemical, Biological, Heavy Metals, Water Quality, Isiagu*

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I. INTRODUCTION

Humans, Animals, and Plants depend on water for nourishment and survival [1]; [2]; [3]. Water is useful for drinking, farming, irrigation, industrial, and recreational purposes [4]. Currently, approximately 1.1 billion people worldwide do not have access to an improved water supply, with around 450 million of them living in 29 countries across Africa.[5]. It is to this end that the United Nations Sustainable Development Goal 6, aimed at achieving access to clean water and sanitation for all by 2030, becomes imperative and timely [6].

Water is a natural resource that occupies about 75% of the Earth's surface [7]. It can be accessed from the ground, rain, or surface [4]. The quality of water, which is determined by its physical, chemical, and biological compositions, greatly influences human health, quality of life, and crop growth. According to [8], water quality is a product of several interactions between water and the surrounding environment during the water cycle. These processes include atmospheric precipitation, rock weathering, surface and groundwater transport, and evaporation, which usually control the continuous changes in the hydrochemical, physico-chemical, and biological components in natural water bodies.

In addition to the natural processes previously mentioned that affect and determine water quality, human activities also have a significant impact. Emissions from vehicles and heavy-duty industrial machines, indiscriminate dumping of domestic and industrial waste, the use of fertilizers, pesticides, herbicides, and insecticides for agricultural purposes, as well as leakages from sewage, septic, buried petroleum tanks and pipes. Not excluding ground disturbances from economic activities such as mining and construction [9]; [10]. These activities produce pollutants like oil, heavy metals, and toxic substances that enter water sources through runoff and leachates [11]. Consequently, this results in water quality degradation, public health deterioration, and environmental risk to individuals and communities that depend on these water sources for survival.

Isiagu community in Anambra State, being one of the fastest growing sub-urban cities in the State capital, is faced with challenges of accessing portable water as the depth to the groundwater aquifer is between 300m and 400m [12]; [12]; [14]. Isiagu is underlain by a thick layer of Imo Shale Formation, which is sedimentologically unfit for groundwater hydrology. This makes it economically difficult to access groundwater, which has been adjudged the best source of clean water by many researchers and professionals [1]; [15]. Consequently, the major sources of water for domestic purposes in the study area are shallow wells and rainwater. Considering the recent outbreak of Cholera in some States in Nigeria, this research becomes important as it seeks to evaluate the physical, chemical, and biological characteristics of water from three sources in Isiagu.

II. LOCATION AND GEOLOGY OF THE STUDY AREA

Isiagu is one of the nine communities in Awka South Local Government Area of Anambra State, Nigeria. These communities include Awka, Amawbia, Nibo, Nise, Ezinato, Umuawulu, Mbaukwu, Okpunu and Isiagu, which make up part of the Awka Capital Territory Development Area. Located within the Nigerian tropical rainforest zone, the Study area lies between latitudes 6°10'30" N - 6°11'10"N and longitudes 7°6'40"E - 7°7'30"E with an elevation of 61m to 79m. The terrain is generally flat to gently undulating, with several small rivers and streams contributing to its drainage. Although the exact population of people in Isiagu town is not known, [16] shows that Awka South L.G.A has a population of 148,465. However, current studies placed the entire local government area at approximately 2.5 million people [17]. The people of Isiagu are predominantly farmers. Over the years, the quest to live closer to the state capital has induced human migration and minor industrialization, making Isiagu a semi-urban settlement. There is also administrative presence such as the Nigerian Civil Defense Headquarters, Police Academy, International market, and a number of Housing Estates within the study area.

The area experiences a bimodal rainfall pattern with a mean annual rainfall of 1828mm. The first peak occurs in June-July and the second in September, with a dry spell in August. The average temperature is 27°C, and the relative humidity ranges between 85% -100% during the rainy season [18].

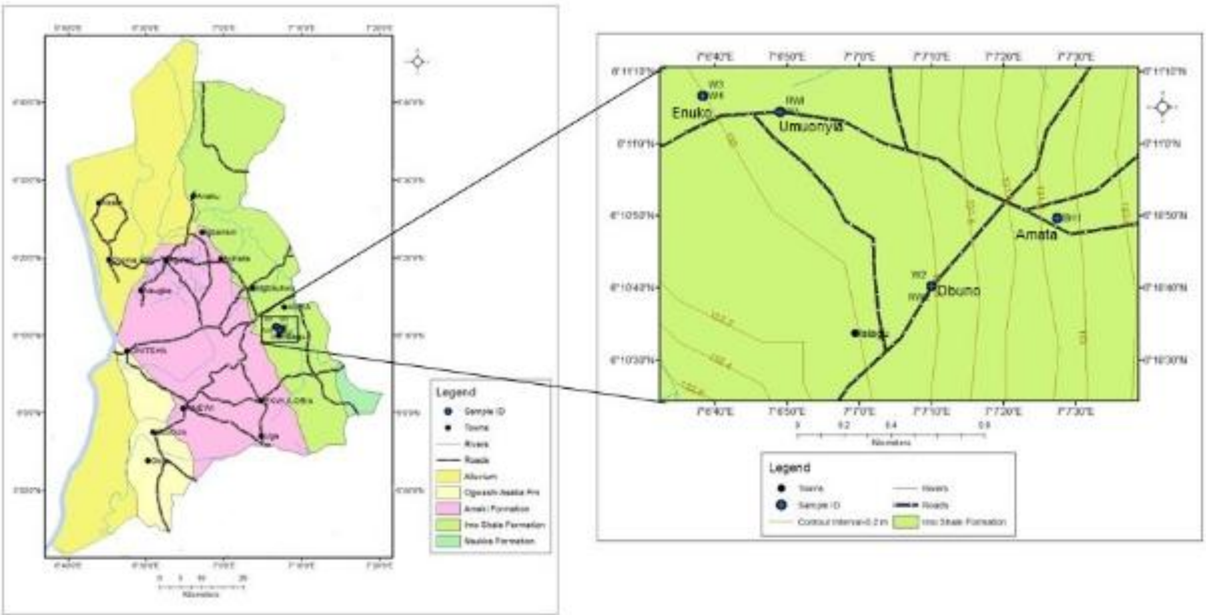


Figure 1: Geologic Map of Anambra State and Isiagu showing Sampling Points

From the geological stand point, the study area falls within the Anambra Sedimentary Basin formed during the folding of the Benue Trough in the Santonian due to the depression of the region around the southern Benue Trough [19]: [20]. Isiagu is underlain by a sedimentary sequence predominantly composed of shale, which formed part of the Imo Shale Formation of the Anambra Basin. The Imo Shale, Paleocene in age, consists of thick, fine-textured, dark to bluish grey shale with occasional admixture of clay, ironstone, and thin sandstone bands [2]; [21]. The Formation becomes sandier towards the top, where it may consist of alternation of bands of sandstone and shale. **Figure 1** shows the geologic map of Anambra State highlighting the study area, and further zoomed to indicate the Sampling points.

Hydrologically, Isiagu groundwater potential is greatly influenced by its geological formations. This is characterized by a thick sequence of grey shales with varying degrees of consolidation influencing both surface and subsurface hydrology. The sandy layers within this Imo Shale Formation serve as aquifers while the Imo Shale is an Aquiclude. These unconsolidated medium to coarse-grained sands are crucial for groundwater recharge and storage. Studies revealed depths to aquifer ranging from 10m to 310m and an estimated aquifer thickness of between 20m -180m [14].

III. METHODOLOGY

The methods adopted for this research work were in four phases: literature review, field investigation, laboratory analysis, and data interpretation.

3.1 Literature Review

Previous research works on the geology, hydrogeology, and water quality of the study area were consulted for a good understanding and to establish research gaps.

3.2 Sampling

Field operations began on the 18th of June, 2024. Three (3) water sources were sampled: Well, Borehole, and Rainwater. Well and rainwater are the most common and dependent water sources in Isiagu community. A total of seven (7) water samples were collected in clean 1 liter plastic bottles, firstly rinsed with the water before collection. The samples were properly labeled for easy identification and taken to the laboratory for analysis. Sampling point coordinates and elevation were taken using a GPS tool. **Table 1** contains details of sampling locations.

Table 1: Sample Location Points

SAMPLE ID	SAMPLE STATION	SOURCE	LATITUDE	LONGITUDE	ELEVATION (m)	DEPTH (m)	REMARKS
W1	Umuonyia Isiagu	Well	6.184561	7.113615	70.0	4.9	Not Plastered
W2	Obuno Isiagu	Well	6.177848	7.119453	66.0	3.7	plastered
W3	St. Jude Anglican Church Enuko Isiagu	Well	6.185193	7.110652	79.0	6.7	plastered
W4	Enuko Isiagu	Well	6.185193	7.110652	79.0	1.5	plastered
BH1	Amata Isiagu	Borehole	6.180469	7.124298	61.0	-	Government Sponsored (Dilapidated)
RWI	Umuonyia Isiagu	Rainwater	6.184561	7.113615	70.0	-	Rusted Zinc Roof
RW2	Obuno Isiagu	Rainwater	6.177848	7.119453	66.0	-	Aluminum Roof

3.3 Evaluations

Physical. Chemical and biological analyses were carried out on all the samples collected. The physico-chemical parameters tested were pH, Salinity, Hardness, Chloride, Sulphate, Total Dissolved Solids, and Total Suspended Solids. pH was tested using a pH Meter after being calibrated with a buffer solution 4.7. Total Dissolved Solids (TDS) and Total Suspended Solids (TSS) were measured by filtration and evaporation, while hardness and others were measured by titration. Iron, Mercury, Zinc, Chromium, and Arsenic were some of the heavy metals analyzed using a Varian AA240 Atomic Adsorption Spectrophotometer (AAS). 100ml of heavy metal samples were pre-treated with 1ml of nitric acid to arrest microbial activities, boiled at a temperature of 100°c, allowed to cool in a desiccator, and then filtered with a Whatman filter paper before evaluation. Heavy metal analysis was conducted following the American Public Health Association [22]. The biological analysis was carried out to determine the total coliform and faecal (thermotolerant) coliform in the samples collected using the Membrane Filtration Technique.

All tests were done twice, and the results were averaged to increase accuracy. The results of all tests carried out are presented in the next section. The results were further evaluated using [23] and [24] Specifications. Statistical correlation of some parameters tested was done using Excel, and the results are presented in the discussion section of this work.

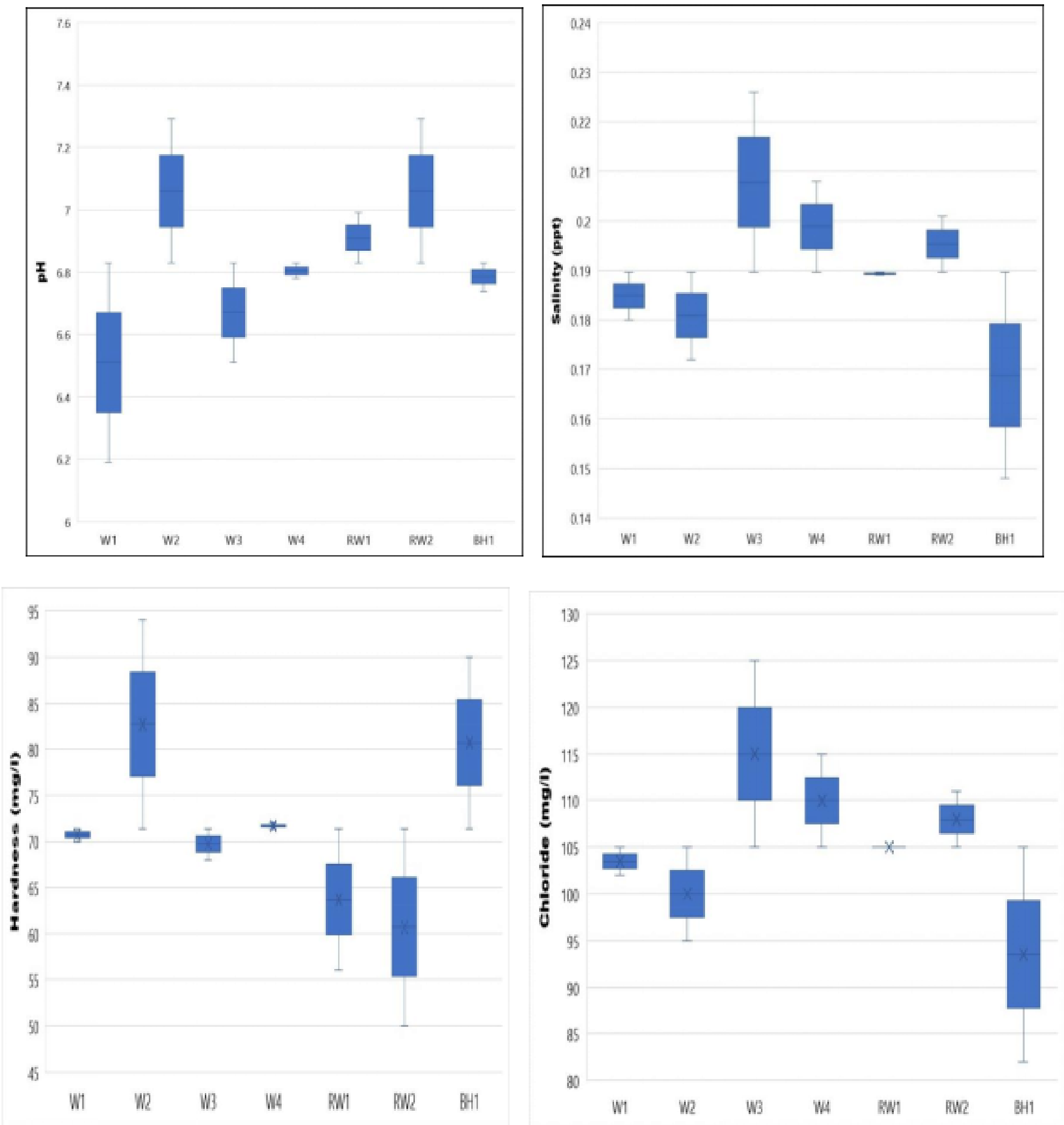
3.2 Pearson Correlation Matrix

Statistical computation was done using the Pearson Correlation Matrix to establish a linear relationship between Iron, Mercury, Zinc, Chromium, Arsenic, pH, Chloride, Sulphate, and Total Dissolved Solids. Values close to +1 and -1 indicate Positive and negative correlations, while values close to 0 indicate weak or no correlation.

IV. RESULT DISCUSSION

4.1 Physio-chemical Results

pH is greatly influenced by the origin of water, soil type, and the condition of the transporting medium. The results of some physical and chemical parameters evaluated are presented in **Figure 2**. The level of acidity and alkalinity of samples in view was determined, and the results revealed a pH range of between 6.19 and 7.29. Samples W3, W4, RW1, and BH1 were neutral, while Samples W2 and RW2 were alkaline. However, only Sample W1, which was collected from a well, is slightly acidic and below the allowable limit of 6.5-8.5 stipulated by both [23] and [24]. High acidity in drinking water connotes corrosive property and could adversely affect its taste and appearance [25]. According to [10], acidity in water can be attributed to groundwater infiltration by acid rain, industrial effluents, and agricultural chemicals. The state of the well not being plastered also aids the rate of infiltration. This was also confirmed by [26] in their reassessment of groundwater potentials and subsurface water hydrochemistry in a tropical Anambra Basin, southeastern Nigeria.



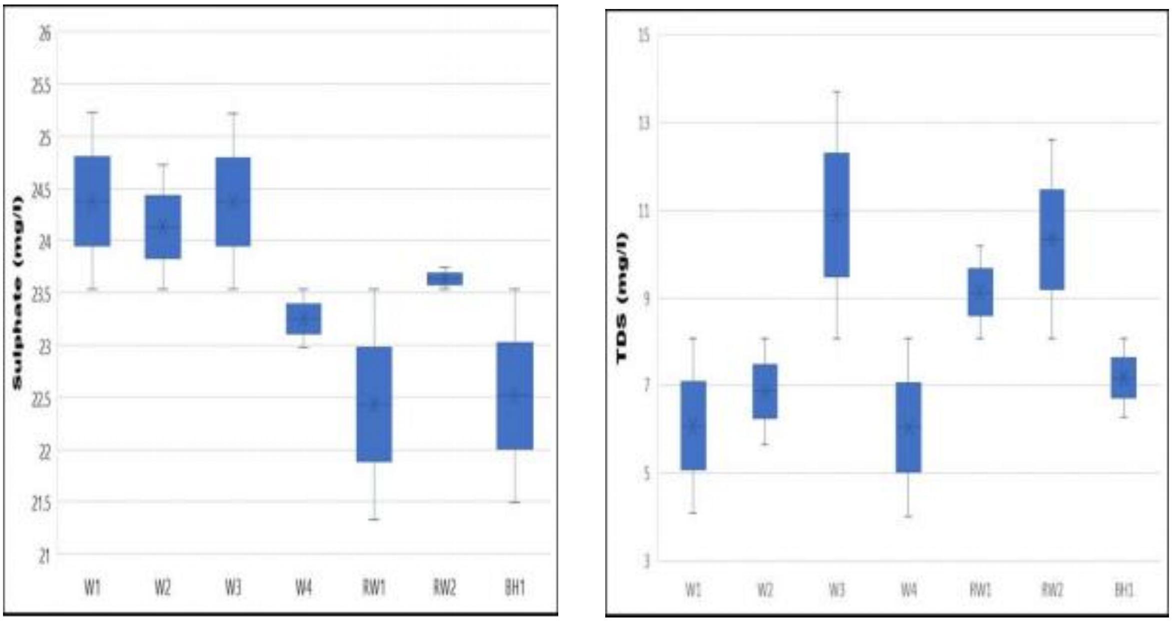


Figure 2: Box plots of Some Physical and Chemical Parameters

The measure of the dissolved salt content in water is called salinity. Water samples tested ranged from 0.148ppt to 0.226ppt. Salinity less than 600ppt is considered good for drinking, hence all samples tested are good for drinking and domestic purposes. Hardness determines the level of calcium and magnesium dissolved in water in milligrams per liter. It can be influenced by either natural geological processes or pollution from industries. The results of hardness from all the water samples tested recorded 56mg/L to 94mg/L and were all within the limits of 150mg/L and 200mg/L specified by [24] and [23], respectively. Samples W1, W3, W4, RW1, and RW2 are classified as soft water, whereas W2 and BH1 are moderately hard water [26]. Hardness can lead to scale formation on boilers, poor lather formation, and mineral build-up on equipment, as accounted by [27].

The amount and composition of solids that cannot dissolve in water and are not heavy enough to sink were tested. Total Suspended Solid (TSS) ranged from 0.210mg/L to 0.680mg/L and are not of health concerns according to Specifications **(Figure 3)**. This is contrary to the high value of 18.00mg/L recorded by [28] in Umunya. Total Dissolved Solids of all samples tested were all below 500mg/L prescribed by [23]. TDS measures the number of solid materials dissolved in both surface and groundwater. Water can dissolve inorganic and some organic minerals, including salts such as Sodium, Calcium, Potassium, Sulphate, Chlorides, and Magnesium. These dissolved minerals produce an unwanted taste and reduce potability in water. [29] opined that while high values of total dissolved solids in water may not be generally harmful to human beings, high concentrations of it may affect persons suffering from kidney and heart diseases, thus provoking paralysis of the tongue, lips, and face. Other effects include irritability, dizziness, and, on rare occasions, disturbance of the central nervous system. According to [30], TDS of less than 500mg/L is desirable for drinking, 500mg/L - 1000mg/L is permissible for drinking, less than 3000mg/L is useful for irrigation, while greater than 3000mg/L is unsuitable for drinking and irrigation. Therefore, all the water obtained from the study area can be classified as desirable for drinking based on the TDS values obtained. [10] also recorded TDS values within the same range.

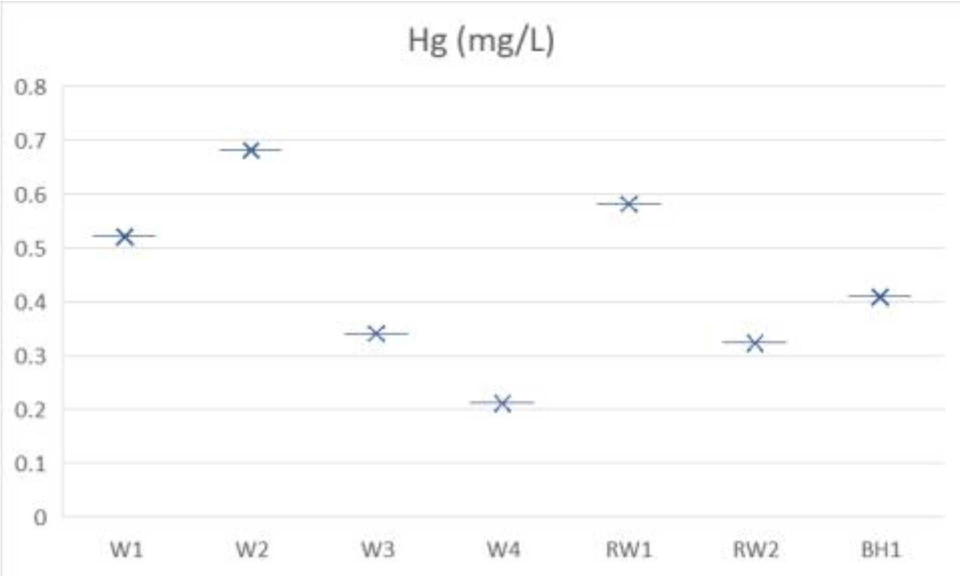


Figure 3: Box plots of Mercury Concentration

Sulphate concentration ranged from 21.33mg/L to 25.23mg/L with a mean value of 23.53mg/L. All samples tested were within the permissible limits of 250mg/L and 100mg/L according to [23] and [24], respectively. Sulphate in water can result from mineral dissolution, atmospheric deposition, and other anthropogenic sources. Chloride concentration also falls within the specification of 250mg/L as values recorded ranged between 82mg/L and 125mg/L with a mean concentration of 105mg/L.

4.2 Heavy Metal Concentration

Figures 4-8 show the distribution of Iron, Zinc, Mercury, Chromium, and Arsenic concentrations in the study area. All samples tested had Arsenic values below the permissive limits of 0.01mg/L. Contrary to Arsenic, the level of Mercury concentration recorded raises some concerns as values ranged from 0.031mg/L to 1.01mg/L with a mean of 0.277mg/L. It was observed that the highest values were recorded from samples collected from well sources. Many researchers have accounted that the primary sources of mercury could be geogenic or anthropogenic including volcanic activities, geothermal fluids, atmospheric deposition, river discharge, landfill waste, household and industrial wastewater, chemical discharge from dental preparations and laboratory activities, discharge of energy-efficient lamps and batteries, mining and fossil fuel combustion [19]; [32]; [33] and [34]. The mercury emitted into the air eventually settles into water or onto land, where it is washed into water bodies. Mercury in drinking water could cause muscle weakness, vision loss, speech and hearing impairment, and kidney diseases.

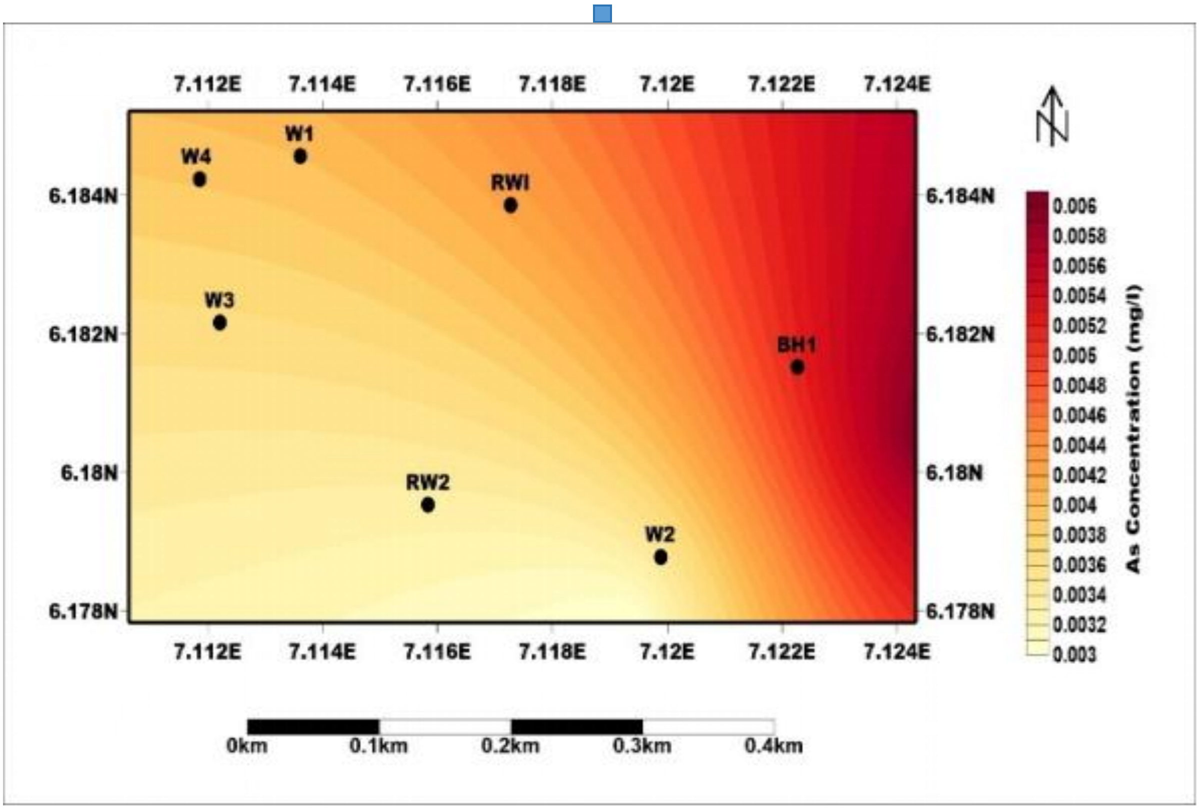


Figure 4: Distribution Map of Arsenic Concentration in the Study Area

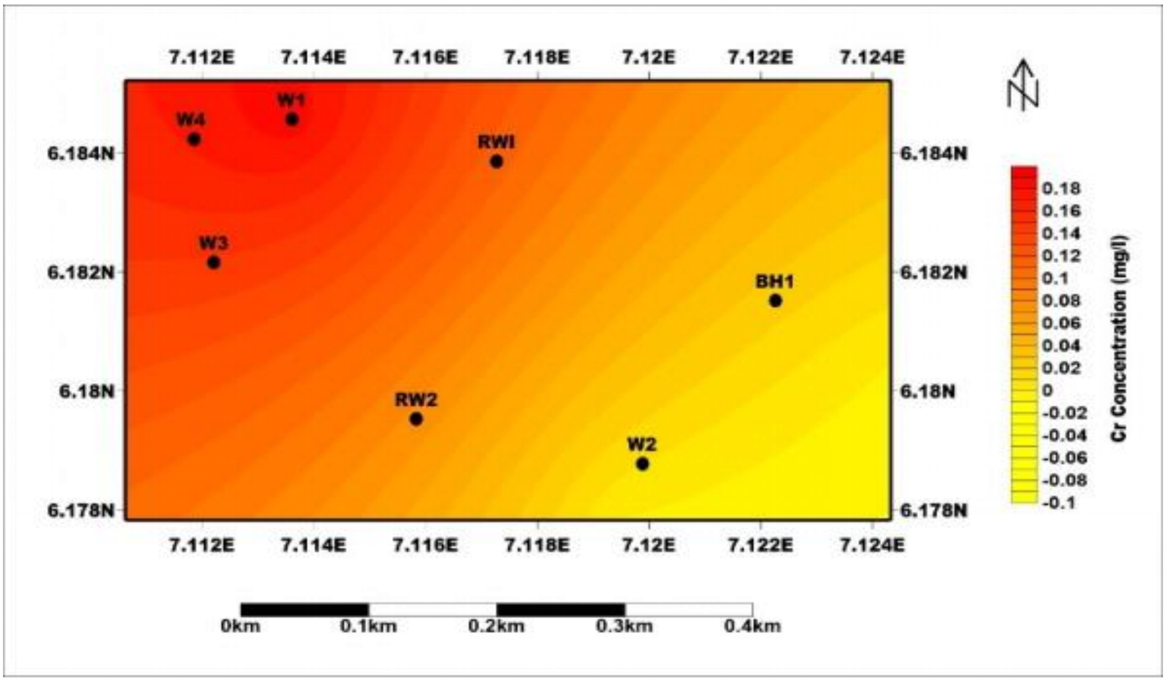


Figure 5: Distribution Map of Chromium Concentration in the Study Area

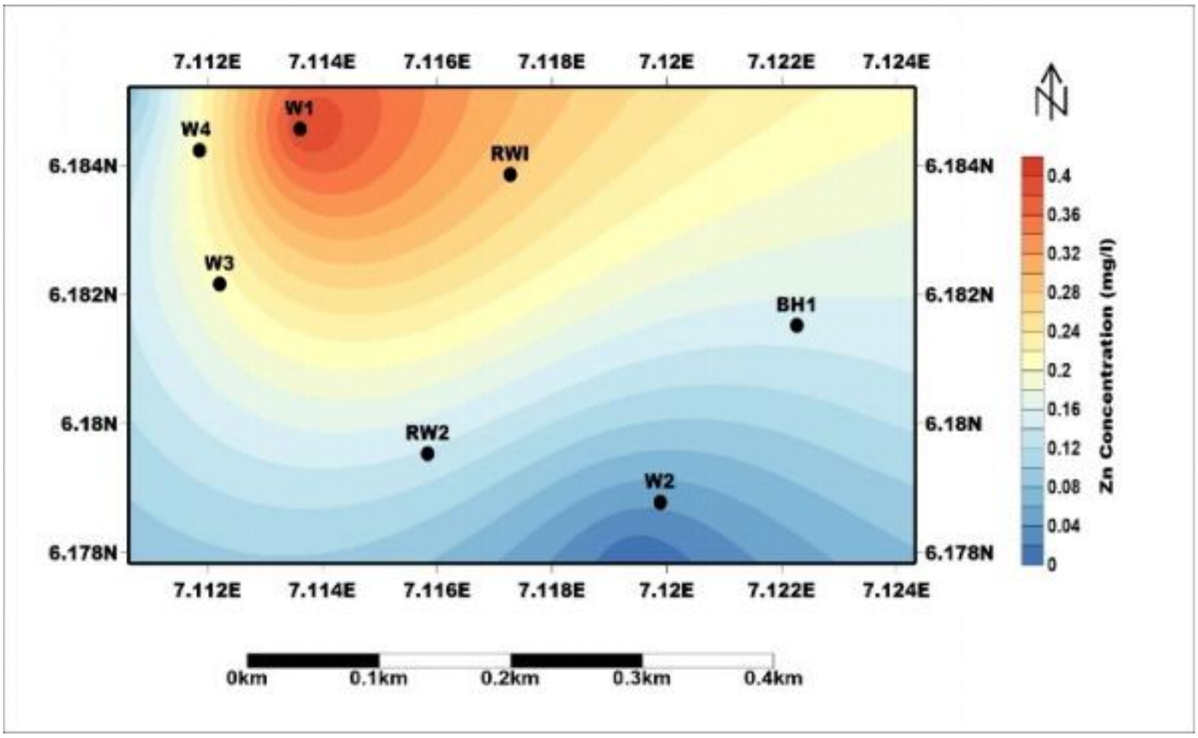


Figure 6: Distribution Map of Zinc Concentration in the Study Area

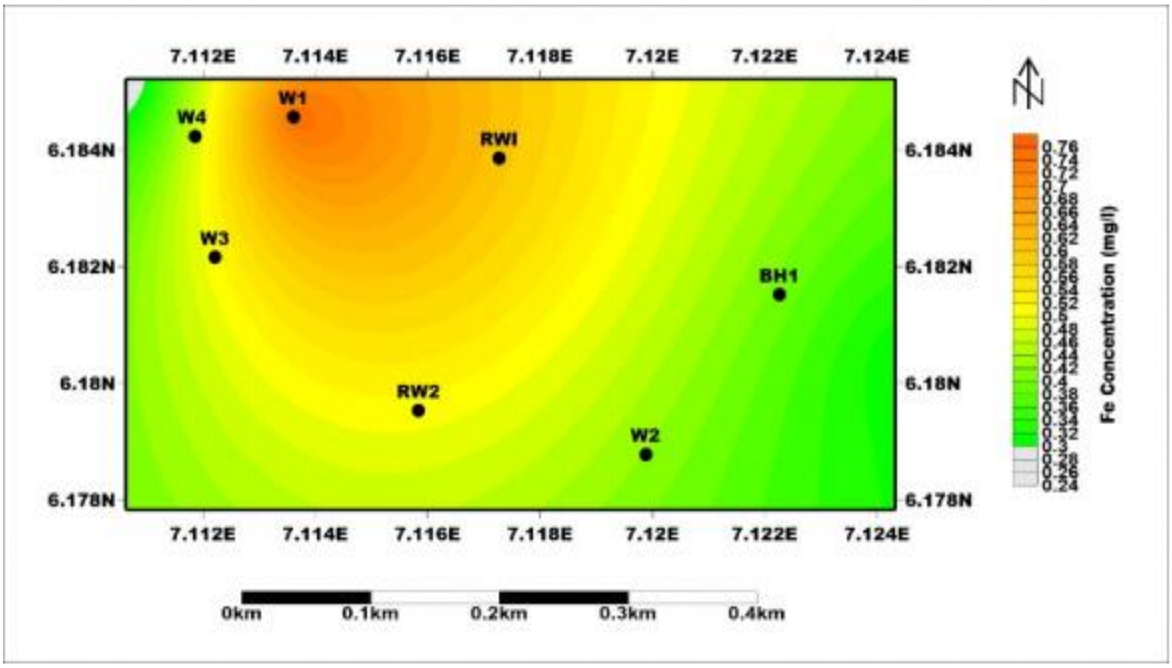


Figure 7: Distribution Map of Iron Concentration in the Study Area

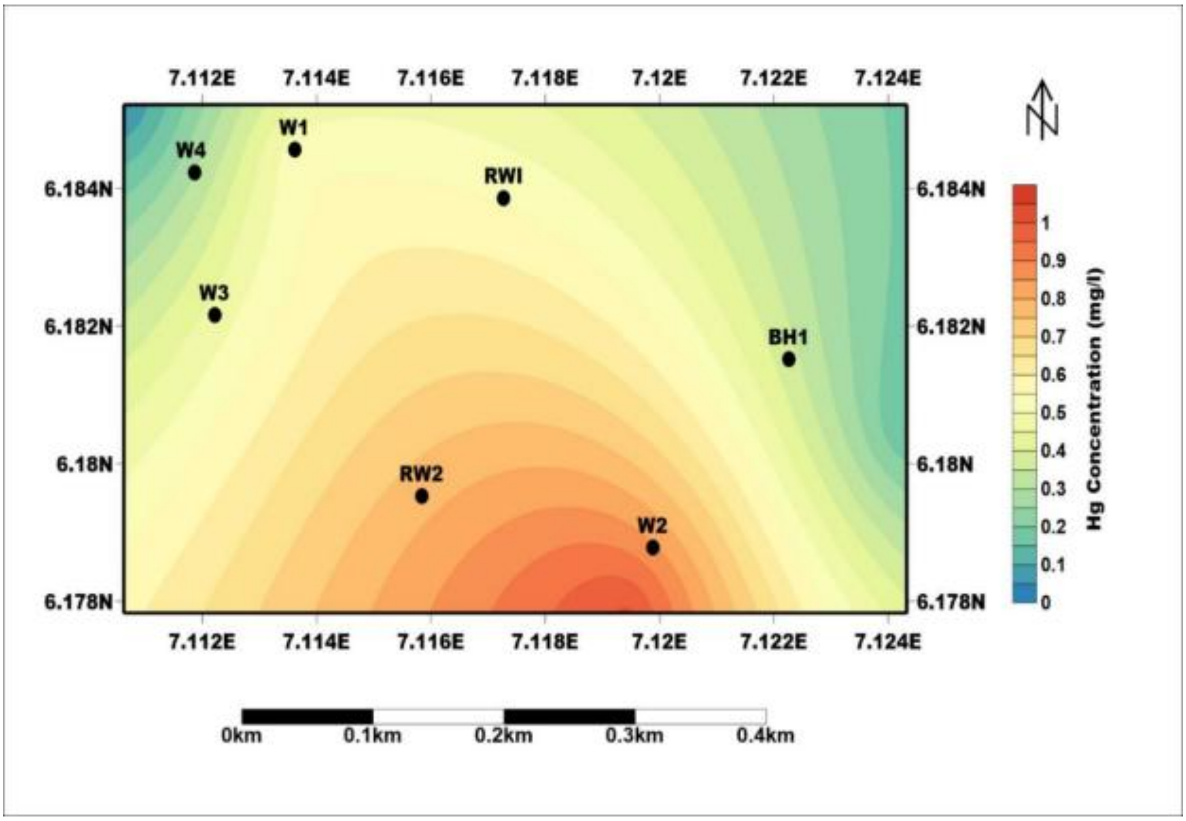


Figure 8: Distribution Map of Mercury Concentration in the Study Area

Except for samples W1 and W3, others recorded Chromium below the allowable limits as stipulated by [23]. Zinc concentration was within limits, with sample RW1 having the highest value of 1.11mg/L. Iron concentration ranged from 0.184mg/L to 0.756mg/L, with Samples W1, W2, W4, RW2, and BH1 above the recommended limit of 0.3mg/L. This implies that about 71% of the water analyzed from the study area was contaminated with iron, in line with the accounts of [4]. Iron contamination can be attributed to the presence of Clay minerals (Imo Shale Formation), which are rich in $Fe^{2+,}$ and their interaction with rainwater during infiltration [28].

4.3 Biological Evaluation

The presence of members of the coliform group in water samples collected was determined using the membrane filtration techniques, and the results are shown in **Tables 2 and 3** below. [35] considered total coliform and faecal coliforms to be the most common microorganisms indicators used for domestic water quality assessment. The mean total coliform count per 100ml of filtered sample ranged between 65.00 ± 1.41 and 288.00 ± 1.41. Samples W3 and BH1 indicated the presence of microorganisms too numerous to count (TNTC). Faecal Coliform count recorded the presence of the organism (Escherichia coli) in all samples, but was too few to count (TFTC) except for W1, W4, and RW2, which recorded no organisms at all. In general, all the samples exceeded the [23] limit of 0.0 count and [24] of 10 Counts, except for W1, which recorded no growth at all (NG). Klebsiella pneumonia, for example, which was one of the microorganisms identified, can cause Urinary tract infections and can be life-threatening for people with serious illnesses. It also accounts for about 11.8% of people who develop pneumonia in the hospital [36]. The result is in tandem with the findings of [10] and [37] in Amaenyi area of Awka and India, respectively.

Table 2: Total Microbial Count (CFU ml^{-1})

Water Samples	Total Coliform Bacteria (EMB Agar)			
	Number of Colonies counted/100ml of Sample		Mean Total Coliform Count (cfu/100ml of Sample Filtered) ±SD	Diversity
	N1	N2		
W1	NG	NG	NG	NIL
				Klebsiella pneumonia

W2	287	289	288.00 ± 1.41	Enterobacter cloacae
W3	TNTC	TNTC	TNTC	Citrobacterfreundii Klebsiella pneumonia
W4	120	124	122.00 ± 2.83	Proteus vulgaris
RW 1	64	65	65.00 ± 1.41	Proteus mirabilis Enterobacteraerogenes
RW 2	83	86	85.00 ± 2.83	Klebsiella pneumonia
BH 1	TNTC	TNTC	TNTC	Proteus mirabilis Enterobacter cloacae Proteus vulgaris

Table 3: Total Microbial Count (CFU ml^{-1})

Water Samples	Faecal (Thermotolerant) Coliform Bacteria (EMB Agar)			
	Number of Colonies counted/100ml of Sample		Mean Total Coliform Count (cfu/100ml of Sample Filtered) ±SD	Diversity
	N1	N2		
W1	**NG**	**NG**		**NIL**
W2	**TFTC**	**TFTC**	**TFTC**	**Escherichia coli**
W3	**TFTC**	**TFTC**	**TFTC**	**Escherichia coli**
W4	**TFTC**	**TFTC**	**TFTC**	**Nil**
RW 1	**TFTC**	**TFTC**	**TFTC**	**Escherichia coli**
RW 2	**TFTC**	**TFTC**	**TFTC**	**Nil**
BH 1	**TFTC**	**TFTC**	**TFTC**	**Escherichia coli**

4.4 Pearson's Correlation Matrix

The relationship between water parameters was studied under this section using Pearson's correlation. Nine (9) parameters were considered, and the outcome is presented in **Table 4**. A Correlation Coefficient greater than 0.5 was considered significant. The result showed that a positive linear correlation existed between Sulphate and Chromium, with a significant value of 0.696. Also, one negative linear correlation existed between pH and Chromium, with a significant value of -0.822. This implies that the presence of one affects the other, collaborating with the account of [38]. They opined that the presence of Sulphate in wastewater can promote the reduction of Cr (VI) to Cr (OH)3 because Sulphate triggers the release of Fe (II). The significant value of -0.822 indicates a high negative linear correlation between pH and Chromium.

Table 4: Pearson Correlation

	Fe (mg/l)	Hg (mg/l)	Zn (mg/l)	Cr (mg/l)	As (mg/l)	pH	Cl (mg/l)	S (mg/l)	TDS (mg/l)
Fe (mg/l)	1								
Hg (mg/l)	0.46434848	1							
Zn (mg/l)	-0.190194	-0.1971371	1						
Cr (mg/l)	0.5010143	0.03838149	-0.0802717	1					
As (mg/l)	-0.3688672	-0.1129719	0.51409515	-0.0393039	1				
pH	-0.4870467	0.15665617	-0.1386592	-0.8224304	0.0339034	1			
Cl (mg/l)	-0.1493363	-0.4415539	0.0265059	0.385856	-0.3653581	-0.1406609	1		
S (mg/l)	0.56215793	0.42611469	-0.534435	0.69637577	-0.4800093	-0.2801338	0.425474013	1	
TDS (mg/l)	-0.6066143	-0.4875434	-0.0511283	0.09737092	0.3899403	0.24796566	0.520979862	0.051892455	1

V. SUMMARY AND CONCLUSION

Three different sources of water in Isiagu Community were sampled and analyzed for their physical, chemical, biological, and heavy metal characteristics. The pH values ranged from 6.19 to 7.29, with only sample W1 below specification. Salinity, Hardness, Chloride, Sulphate, Total Dissolved Solids, and Total Suspended Solids values were within limits with mean values of 0.190ppt, 71.43mg/L, 105mg/L, 23.53mg/L, 8.077mg/L, and 0.40mg/L, respectively. There was a high concentration of Mercury and Iron beyond permissible limits in the study area, which can be attributed to both geogenic and anthropogenic factors. The microbial results show that total coliform and E. coli were present and were too numerous to count in some samples, while they were too few to count in others.

One positive and one negative relationship were established among the analyzed parameters: Sulphate and Chromium with a significant value of 0.696, and pH and Chromium with -0.822 value. The concentration of chemicals and pathogens in water reduces its quality and can be detrimental to human health.

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