PHYSICOCHEMICAL ANALYSIS OF SELECTED GROUNDWATER SOURCES IN IKOT ABASI URBAN, AKWA IBOM STATE

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Abstract

This paper focused on determining the status and quality of groundwater sources in the urban region of Ikot Abasi Local Government Area of Akwa Ibom State. Physicochemical parameters of the groundwater sources were analyzed using standard methods and their spatial variations were presented and discussed. The parameters investigated included temperature, colour, odour, pH, total dissolve solids, electrical conductivity, turbidity, total alkalinity, total hardness, salinity, dissolved oxygen, chemical oxygen demand, chlorides, nitrates, phosphates, sulphates, sodium, potassium, magnesium, calcium, biological oxygen demand and heavy metals. The results of the analysis showed that temperature ranged from 28.1 - 29.6°C, TDS (13.9 - 295ppm), Turbidity (0.02 - 5.24 NTU), pH (4.18 - 7.2), EC (19.6 – 416 µS), Salinity (18.5 - 201ppt), Total hardness (12.2 – 117.25mg/l), DO (0.1 - 5.23mg/l), COD (0.12 - 8.37 mg/l), BOD (0.13 - 5.13mg/l), Alkalinity (0.07 – 1.49mg/l), Chlorides (0.02 - 0.5mg/l), Nitrates (0.02 - 72.3 mg/l), Phosphates (0.21 - 53.1mg/l), Sulphates (0.5 – 50mg/l), Sodium (1 - 83.2ppm), Potassium (1.3 - 22.3ppm), Magnesium (4.5 - 60mg/l), Calcium (5 – 200mg/l), Iron (0.130 - 1.323 mg/l) and Nickel (0.03 to 0.84 mg/l). These results were compared with water quality standards from the World Health Organization (WHO) and the Bureau of Indian Standards (BIS), and variations revealed that the water was not potable. The data obtained were also subjected to Water Quality Index to determine the quality of groundwater of the study area. The WQI value obtained was 82.95, which indicated a very poor water quality.

Keywords— Groundwater; physiochemical parameters; water quality.

1. INTRODUCTION

Water quality is a critical concern for humans because water is a universal solvent which has a wide application in basic activities that sustain human life. Globally, a greater population depends on groundwater as a reliable source of water for drinking, domestic and industrial engagements as well as agricultural purposes. Groundwater is believed to be free from contamination than any other natural water source. However, the rate of indiscriminate discharge of industrial effluents, domestic sewage, overuse of agricultural chemicals and fertilizers, oil spills, surface runoff, over-exploitation of resources and improper solid waste disposal have caused groundwater pollution and also created serious health problems across the globe (Sharma *et al*., 2014). World Health Organization (WHO) reported that about 80% of diseases in humans are usually caused by contaminated water (Kavitha and Elangovan, 2010).

The United States Geological Service defines groundwater as the water that exists underground in saturated zones beneath the earth's surface (USGS, 2015). Groundwater can also be referred to as any surface water that exists beneath the water table in the soil and other geological formations (Rail, 2000). According to William (2014), nearly all rocks in the upper part of the earth's crust have pores filled with water. Groundwater is usually naturally replenished by rain water, snowmelt or from water that leaks through the bottom of some surface water bodies. The quality of groundwater varies with location, depth of water table and season, and it is majorly affected by the composition of dissolved minerals in it (Sharma *et al*., 2014).

However, groundwater pollution has become a global discourse in the last few decades as urbanization and population explosion have threatened groundwater quality due to the impact of domestic and industrial waste disposal (Umar *et al*., 2009). These phenomena, amongst other anthropogenic exertions, have resulted in massive deterioration of groundwater quality, since some of these waste products, including sewage and cesspool may eventually seep through the soil in the unsaturated zone to pollute the groundwater (Ijeh and Onu, 2013). The quality of groundwater is sensitive and remains delicate as it cannot be easily restored polluted (Dohare *et al.,* 2014). Groundwater quality is very critical because it is one of the most important natural resources and represents about 30% of the world's freshwater, providing drinking water for more than 90% of the world's population (Clark and Briar, 2001).

The groundwater in some communities of the study area is known to be polluted due to various anthropogenic activities and this has caused shortage of potable water supply to these communities. It is essential that water distributed for use is free from toxic substances, minerals, organic substances and pathogens in order not to pose physiological risk to human health. This study assessed the physicochemical parameters of some selected wells to ascertain their fitness for human consumption.

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2.0 MATERIALS AND METHODS

2.1 Description of Study Area

Akwa Ibom State is located in the coastal southern part of Nigeria, lying between latitudes 4°32'N and 5°33'N, and longitudes 7°25'E and 8°25'E. It is falls in the South-South geopolitical zone, and is bordered on the east by Cross River State, on the west by Rivers State and Abia State, and on the south by the Atlantic Ocean.

Ikot Abasi local government area is located in the southwest corner of Akwa Ibom. It is bounded by Oruk Anam Local Government Area in the north, Mkpat Enin and Eastern Obolo Local Government Areas in the east and the Atlantic Ocean in the south. The Imo River forms the natural boundary in the west separating it from Rivers State.

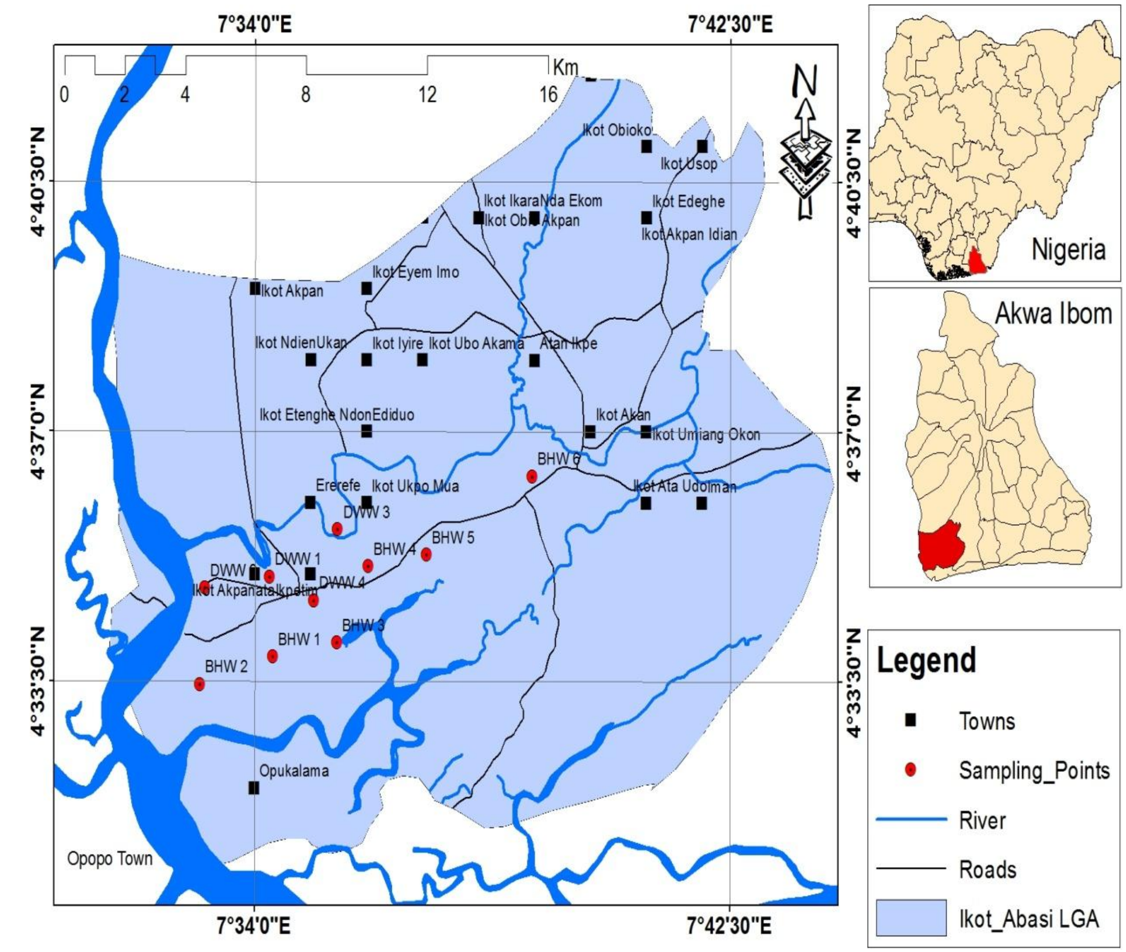

Fig. 1. Map of study area showing sampling points

2.2 Sample Collection, Storage and Preservation

Groundwater samples were randomly collected from six (6) boreholes and four (4) dug wells at varying intervals and were labeled appropriately according to their sources and locations. The samples were collected in plastic bottles, which were washed with distilled water before use. The bottles were corked and stored in an iced cooler before being transported to the laboratory where they were preserved in a refrigerator at a temperature of 4°C to prevent contamination, vaporization and biodegradation of the analytes (Gichuki and Gichumbi, 2012). Physicochemical analysis of the samples was carried out within 24 hours of sample collection. The parameters were analyzed using standard methods recommended by the American Public Health Association (APHA, 1998).

2.3 Determination of Physicochemical Parameters

2.3.1 Temperature, pH, Conductivity, Salinity and Total Dissolved Solids

The temperature, pH and electrical conductivity of the groundwater samples were measured in situ using a PCS Tester 35 Multi-Parameter. For Salinity and TDS, 50ml of each groundwater samples was measured into a 100ml beaker in the laboratory, and readings were taken with same apparatus and expressed in their appropriate units.

2.3.2 Turbidity

Turbidity was determined using the Nephelometric method. The turbidimeter (Model Hanna Instrument, LP 2000) was calibrated with the 1000, 100, 10 and 0.02 NTU standards. 50ml was measured and transferred into a cuvette which was rinsed three times with the samples to be tested. The cuvette was pushed into the optical well and indexed to the lowest reading.

2.3.3 Nitrates (No_3^-)

The nitrate (NO_3^-) content in the samples was determined by ultraviolet spectrophotometric screening method. Standard concentrations of 2 and 20 were transferred into separate beakers and 1ml of nitrate buffer $(NH_4)_2SO_4$ was added into each concentration. Absorbance of standards were read using the JENWAY-3345 instrument and recorded. 50ml of sample was poured into a beaker and 1ml of nitrate buffer was added. Nitrate readings of the sample were read at wavelength 550nm and recorded. Sample concentration was read from the graph of readings made against concentration in mg/l.

2.3.4 Phosphates (PO_4^{3-})

The concentration of phosphates in groundwater samples was determined by the colorimetric method according to the American Public Health Association (APHA, 1998). 100ml of groundwater sample was poured in a conical flask and 4ml of strong acid and 4ml of ammonium molybdate were added followed by 10 drops of $SnCl_2$. The mixture turned blue and was measured after 10 minutes at 690nm with colorimeter model Photochem 5.0.

2.3.5 Sulphates (So_4^{2-})

Sulphate in the samples was determined by the Spectrophotometric method. 100ml of groundwater sample was measured into a 250ml Erlenmeyer flask. 5ml of conditioning reagent was added and mixed by stirring and 1g of barium chloride crystals was added while stirring and timed for 60 seconds. Sulphate ions are precipitated as Barium Sulphate ($BaSO_4$) in acidic media (HCl) with Barium Chloride ($BaCl_2$). The absorption of light by the precipitated suspension is measured by spectrophotometer at 420nm. The concentration was read directly from the calibration curve on the computer screen.

2.3.6 Sodium (Na^+) and Potassium (K^+)

Potassium and Sodium ions were determined by flame photometric method. The samples to be analyzed were sprayed into a gas of the flame, where the monochromatic light of the device isolates the desired spectral line. The intensity of light emitted is usually proportional to the concentration of the element. A set of standards were run with all the samples. The standard sodium concentration at the range of 10 to 100 ppm and the standard potassium concentration were drawn in the range of 1 to 10 ppm. Traces of the ions were determined in a direct reading of a frame spectrophotometer at wavelength of 766.5nm and 589nm for potassium and sodium ions respectively.

2.3.7 Heavy Metals Analysis

5ml of each sample was measured into a 100ml beaker and digested with 10ml of a mixture of conc. HNO_3 and HCl. Mixture was heated on a hotplate to 110-120 °C for 40 minutes in a fume cupboard. Digest was allowed to cool and filtered with a Whatman filter paper. Distill water was added to make up to 50ml volume. The levels of the trace elements were determined with the Varian Spectra AA 600 Atomic Absorption Spectrometer.

2.4 Water Quality Index (WQI)

According to (Chatterjee and Raziuddin), the Water Quality Index (WQI) and status of water quality is rated as presented in the table below:

Table 1. Rating of Water Quality Index (WQI)

Water Quality Index Level	Water Quality Status
0-25	Excellent water quality
26-50	Good water quality
51-75	Poor water quality
76-100	Very Poor water quality
>100	Unsuitable for drinking

In this study, the weighted arithmetic index method was used for the calculation of WQI of the water samples. Quality rating or sub index (q_n) was calculated using the following expression:

$$q_n = 100[V_n - V_{io}] / [S_n - V_{io}] \qquad (1)$$

(Let ***n*** be water quality parameters and quality rating or subindex (q_n) corresponding to n^{th} parameter is a number reflecting the relative value of this parameter in the polluted water with respect to its standard permissible value.)

q_n = quality rating for the n^{th} Water quality parameter

V_n = estimated value of the n^{th} parameter at a given sampling station.
S_n = standard permissible value of the n^{th} parameter.
V_{io} = ideal value of n^{th} parameter in pure water (i.e., 0 for all other parameters except pH and Dissolved oxygen).

Unit weight was calculated using a value inversely proportional to the recommended standard value (***Sn)*** of the corresponding parameter following the equation:

$$W_n = K/S_n \qquad (2)$$

W_n = unit weight for the n^{th} parameters.
S_n = standard value for n^{th} parameters.
K = constant for proportionality.

The overall Water Quality Index (WQI) was calculated by aggregating the quality rating with the unit weight linearly using the expression below:

$$WQI = \sum q_n w_n / \sum w_n \qquad (3)$$

3.0 RESULTS AND DISCUSSION

3.1 Physicochemical Parameters of Groundwater Samples

The results of the laboratory investigations on the variation of physicochemical parameters of water samples taken in this study are presented in Table 2.

Table 2. Physicochemical Parameters of BHW and DWW Groundwater Samples

PARAMETERS	BWH 1	BWH 2	BWH 3	BWH 4	BWH 5	BWH 6	DWW 1	DWW 2	DWW 3	DWW 4	Mean
TEMP (^oC)	28.3	28.1	28.2	28.4	29.6	28.9	28.4	28.3	28.1	28.1	28.44
pH	7.2	5.73	5.65	4.18	5.57	6.32	5.64	6.85	6.57	5.86	5.957
EC (µS)	19.6	310	142	66.2	25.9	72.3	101.2	416	93.3	72	131.85
TDS (ppm)	13.9	220	101	46.8	18.1	56	71.9	295	66.2	51.1	94.0
Salinity (ppt)	18.5	149	71.7	37.7	21.4	73.1	53	201	49.5	40.1	71.5
Total Hardness (mg/l)	12.2	60.72	67.3	117.25	70.31	75	61.82	58.47	55.35	71.2	64.96
Turbidity (NTU)	0.02	1.2	0.09	5.24	0.13	0.1	2.1	1	2.31	0.8	1.29
DO (mg/l)	0.1	3.6	3.3	2.1	3.52	3.91	5.23	4.35	4	3.69	3.38
COD (mg/l)	0.12	1.13	1.3	8.37	1.1	2.53	8.32	5	2.95	7.21	3.80
BOD (mg/l)	0.13	1.3	1.53	5.01	2.03	1.4	4.32	4.2	5.13	2.52	2.76
Alkalinity (mg/l)	0.07	0.33	0.23	0.1	0.13	1.35	1.49	0.54	0.27	0.11	0.46
Chloride (mg/l)	0.03	0.1	0.07	0.21	0.31	0.33	0.11	0.02	0.04	0.51	0.17
Nitrates (mg/l)	0.01	10.26	63.02	38.35	25.07	40.24	72.3	27.23	51.56	63.02	39.11
Phosphates (mg/l)	0.21	30.2	32.3	50	34.4	17.3	26	36.1	45	53.1	32.46
Sulphates (ppm)	0.5	25.3	26.5	42.1	28.9	18.5	28.3	33.5	40.1	50	29.37
Sodium (ppm)	1	21.6	23.5	66	22.9	49.1	83.2	59.4	40	53.1	41.98
Potassium (ppm)	1.3	3.6	3.6	5.2	7.3	7	5.7	9.4	14.9	22.3	8.03
Magnesium (mg/l)	4.5	30	43	60	35	20	30	45	40	29	33.65
Calcium (mg/l)	5	184	180	200	145	131	184	113	193	116	145.1
Iron (Fe)	0.157	0.351	0.39	0.3	0.435	0.523	0.385	0.293	0.103	1.323	0.43
Nickel (Ni)	0.07	0.61	0.23	0.84	0.03	0.31	0.50	0.592	0.006	0.203	0.34

3.1.1Temperature

The temperature readings ranged from 29.6°C - 28.1°C with a mean value of 28.44°C. Temperature controls the behavioral characteristics of organisms, solubility of gases, pH and conductivity in water (Ramachandra and Solankin, 2007). It equally affects the DO level in water, photosynthesis of aquatic plants as well as metabolic rates of aquatic organisms. Temperature levels in this study were within the WHO acceptable range (Table 4). According to Jayaraman et al. (2007), temperature variation may be attributed to the different time of collection and seasonal influence. Water temperature is usually governed by the climatic conditions such as rainfall and solar radiation which are the major climatic conditions that influence most of the physicochemical parameters of water bodies.

3.1.2 Total Dissolved Solids

Findings of this study showed that TDS ranged from 13.9 - 295ppm with mean value of 94ppm. Maximum TDS was measured in DWW2 and minimum in BHW1. TDS usually indicates the salinity behavior of groundwater or the sum of cations and anions in water. It usually adds taste to the water (Mitharwal *et al*., 2009). In this study, the TDS level measured in the samples were within the BIS and WHO recommendation.

3.1.3 Turbidity

Turbidity measured in the samples ranged from 0.02 - 5.24 NTU with a mean value of 1.29 NTU. Maximum and minimum turbidity values were obtained in BHW4 and BHW1 respectively. Turbidity in water is caused by suspended particles or colloidal matter that obstructs light transmission through the water (WHO, 2011). As recorded in Table 2, turbidity levels measured in this study were within the BIS and WHO permissible limit, except BHW4 which exceeded the WHO permissible limit of 5 NTU. High turbidity values in groundwater could be an indication that the wells may not be properly lined (Abolude, 2007).

3.1.4 pH

The pH ranged from 4.18 - 7.2 for BHW and 5.84 - 6.85 for DWW. pH measures the acidity or alkalinity of water. All chemical and biological reactions in water are directly dependent on the pH of that water (Rao, 2006). In the study, pH ranged from 4.18 - 7.2. According to the standards prescribed by WHO, BHW1, DWW3 and DWW4 were within the pH acceptable limit while other samples were below acceptable limit, indicating acidity.

3.1.5 Electrical Conductivity

In the study, EC values ranged from 19.6 - 416µS with an average value of 131.85µS. Maximum EC level was obtained in DWW4 and minimum in BHW1. EC is an important water quality parameter for indicating salinity hazards. The differences in the EC levels may be due to the underlying geology of the study area where different chemical species interact with various anions and cations in aquifers to affect the water quality of the area. This corresponds with (Tavassoli and Khaksar, 2002), who studied the effects of geological formations on quaternary aquifers and observed that the different kinds and concentration rates of different materials in groundwater are dependent on dissolved minerals from rocks in contact with water. However, the EC values in this study were within the recommended limits in water (Table 4).

3.1.6 Alkalinity

Alkalinity of water neutralizes strong acids in water. Alkalinity values ranged from 0.07 - 1.49mg/l with mean of 0.46mg/l. Maximum and minimum alkalinity were recorded in DWW1 and BHW1 respectively. It is usually indicated by the presence of carbonates, bicarbonates and hydroxides of sodium, potassium, and calcium. High alkalinity level in drinking water imparts a bitter taste into the water. As presented in Table 4, total alkalinity levels measured in the study were within the BIS and WHO maximum permissible limit.

3.1.7 Chlorides

Chlorides occur naturally in water and usually increase as a result of increased mineral content of the ground (Dubey, 2003). Chloride levels analyzed in the study ranged from 0.02-0.5mg/l and were within the BIS and WHO maximum permissible limit. High chloride concentration in water indicates high degree of sewage and organic pollution. Singh et al. (2012) observed that no adverse health effects on humans have been reported from drinking water with high amount of chloride. However, excess chloride content above 200mg/l in drinking water imparts salty taste to water and when it combines with calcium and magnesium salts, may increase the corrosivity of water (Tatawat and Singh, 2007).

3.1.8 Nitrates

Nitrate levels in samples were within the acceptable limits except for BHW3, DWW1, DWW3 and DWW4, which exceeded the WHO maximum permissible limit of 50mg/l. The natural level of nitrates in groundwater is increased by municipal and industrial wastewater including leachates from dumpsites, sludge disposal and sanitary landfills (Foster *et al*., 2002). Nitrate toxicity comes from the body's natural breakdown of nitrate to nitrite, resulting in methemoglobinemia or blue baby disease (in infants), which decreases the ability of blood to carry oxygen around the body and could be a fatal case especially in infants (Chapman, 1996). Nitrate is an essential ingredient of plant nutrition and it is, however, regarded as an indicator of pollution in public water supply.

3.1.9 Phosphates

Phosphate levels in all the samples ranged from 0.21-53.1mg/l with a mean of 32.46mg/l. These values exceeded the WHO stipulated tolerance level, and this could be linked to seepage of sewage into the groundwater system. Abolude (2007) reported that traces of PO_4^{3-} even at 0.1 mg/l in water could have harmful effects on water quality and such traces could increase the growth of algae in the water. Phosphates are not toxic to people or animals unless they are present in very high levels.

3.1.10 Total Hardness

Total hardness ranged from 12.2 - 117.25mg$CaCO_3$/l with mean value of 64.96mg/l. Maximum and minimum values were obtained in BHW4 and BHW1 respectively, and were within the allowable limits. Hardness of water prevents lather formation and mainly depends on the amount of calcium and magnesium salts in the water (Singh *et al*., 2012). It is one of the most important parameter for determining the suitability of water usage for different purposes (Mitharwal *et al*., 2009).

3.1.11 Dissolved Oxygen

DO levels ranged from 0.1-5.23mg/l with a mean value of 3.38mg/l. Maximum and minimum DO levels were found in DWW1 and BHW1 respectively. The WHO recommends a DO of 4-6mg/l for water to be potable. Dissolved oxygen is a very important indicator of water quality. Transport and migration of untreated sewage flows, leachates and other sources of pollution could limit the amount of DO in underground water. However, elevated levels of temperature can also lead to decrease in DO (Guner, 2010).

3.1.12 Heavy Metals

Fe concentrations ranged from 0.10 mg/l -1.32mg/l with a mean value of 0.43mg/l, while Ni ranged from 0.01mg/l - 0.84mg/l with a mean value of 0.34mg/l. Heavy metals, which are natural constituents of the environment, and generally occur in low concentrations, have attracted global concerns because anthropogenic activities have inadvertently raised the levels of metals in many of the natural water systems, leaving them in polluted conditions (Essien *et al*., 2020). Heavy metals constitute a major problem because they are toxic and tend to accumulate in the body organs, causing toxicological disorders (Vilizzi and Takan, 2016). In this study, the mean concentrations of Fe and Ni exceeded the WHO recommended standards (Table 4), which suggest that groundwater sources were slightly polluted with these metals.

3.2 WATER QUALITY INDEX (WQI)

As presented in Table 3, the Water Quality Index of the means of the investigated physicochemical parameters of groundwater samples was 82.954. This water quality index value clearly shows that the status of the groundwater in the study area is very poor and hence, unsuitable for human consumption.
The WQI was calculated using the standards of drinking water quality recommended by the World Health Organization (WHO) and Bureau of Indian Standards (BIS, 2012). The weighted arithmetic index method was used for the calculation of WQI of the water body.

Table 3. Water Quality Index (WQI) of the Means of Physicochemical Parameters

Parameters	Mean	Unit Weight (Wn)	Quality Rating (Qn)	WnQn
Temp (^oC)	28.44	0.52	13.33	6.9316
pH	5.957	0.219	126.67	27.7407
EC (µS)	131.85	0.371	115	42.665
TDS (PPM)	94	0.0037	48.33	0.17882
Salinity (PPT)	71.5	0.0155	55	0.8525
Total Hardness	64.962	0.0062	76	0.4712
Turbidity (NTU)	1.299	0.0037	93.33	0.34532
DO (mg/l)	3.38	0.025	100	2.5
COD (mgO_2/l)	3.803	0.061	62.33	3.80213
BOD (mg/l)	2.757	0.0074	93.33	0.69064
Alkalinity (mg/l)	0.462	0.0412	94	3.8728
Chloride (mg/l)	0.173	0.01236	80	0.9888
Nitrates (mg/l)	39.106	0.3723	133.33	49.6388
Phosphates (mg/l)	32.461	0.893	53.33	47.6237
Sulphates (mg/l)	29.37	0.067	131.67	8.82189
Sodium (PPM)	41.98	0.3246	91.2	29.6035
Potassium (PPM)	8.03	0.419	62.5	26.1875
Magnesium (mg/l)	33.65	0.11	57	6.27
Calcium (mg/l)	145.1	0.319	79.6	25.3924
Iron (mg/l)	0.426	0.183	96	17.568
Nickel (mg/l)	0.3391	0.903	113.33	102.337
		$\sum W_n$ = 4.876	**$\sum Q_n$ = 1775.280**	**$\sum W_nQ_n$ = 404.482**

Table 4: Water Quality Parameters Standards

Parameters	WHO	Bureau of Indian Standards (BIS)
Temperature	28-31	-
pH	6.5-8.5	6.5-8.5
EC (µS)	1000	1500
TDS (mg/l)	500	500
Salinity (ppt)	-	-
Total Hardness (mg/l)	500	300-600
Turbidity (NTU)	5	5-10
DO (mg/l)	4-6	-
COD (mg/l)	10	-
BOD (mg/l)	6	30
Alkalinity (mg/l)	150	200
Chloride (mg/l)	250	250
Nitrates (mg/l)	45-50	45
Phosphates (mg/l)	5	-
Sulphates (mg/l)	250	200-400
Sodium (ppm)	200	180
Potassium (ppm)	200	-
Magnesium (ppm)	30	30
Calcium (ppm)	75	-
Iron (mg/l)	0.3	0.5
Nickel (mg/l)	0.02	-

4.0 CONCLUSION

The physicochemical parameters of the groundwater sources analyzed in the study area showed a very poor water quality. The Water Quality Index and comparison of results with standards revealed that most groundwater sources in Ikot Abasi urban area are contaminated and not suitable for drinking except for BHW1, whose parameters were within the acceptable limits recommended by BIS and WHO standards. This wide contamination could be as a result of the geology of the area coupled with increased anthropogenic activities going on in the study area. It is recommended that domestic water treatment should be carried out before water from these wells is used for drinking and other domestic purposes. Also, since most wells are usually contaminated due to poor construction and close proximity to latrines, landfills, dump sites etc, they should be properly constructed and sited at least 200m away from potential sources of contamination to ensure good water quality for domestic and perhaps, industrial application. In addition, there should be environmental intervention programs through public health awareness and sensitization campaigns by community health workers, Non-Governmental Organizations, environmental monitoring and compliance agencies, and other health professionals in the study area and its environs.

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