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Evaluation of the Physico- Chemical Properties of Surface and Groundwater Resources in Umueri and Environs, Southeastern Nigeria

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Abstract
The study evaluated the Physico- chemical properties of surface and groundwater resources in Umueri and environs. Water samples were collected from "12" different sources of groundwater (boreholes and hand-dug wells) and "6" different sources of surface water from the study area. The samples were analyzed for pH, Conductivity, Hardness, Total suspended solids, Lead, Arsenic, Cadmium, Bacteria and Yeast loads. Various experimental and instrumental techniques (including photometric using the Atomic Absorption Spectrometer and Species inventory) were employed to analyze the different chemical components. The results revealed variations in quality for different groundwater and surface water samples. The result showed that the pH value ranged from 5.40-7.20 which implied that the water is slightly acidic. Magnesium and iron revealed relatively high levels concentration of 0.00 to 4.73 and 0.00 to 0.71 respectively. The groundwater and surface water samples presented with quality impairment when compared to WHO threshold limits. Hence, it is considered unsafe for consumption and other domestic uses. Treat before use and regular water quality monitoring to keep tract with the water quality trends.
Keywords: Water resources, Baseline characteristics, groundwater, surface water, Conductivity.

Introduction
The quality of any surface water body or groundwater is a function of either or both natural influences and human activities. Groundwater resources contain geogenic elements which may be important but long-term exposures to humans may result to both harmful (Arsenic) and beneficial (precipitation of iron and manganese oxides) health effects. Climate change also is not just an energy problem because the incursion of storms and the loss of coast may cause drinking water supplies to be contaminated with salt water (Anarado et al., 2019). Some heavy metals such as lead, cadmium, arsenic, mercury, cadmium and metalloid are among the hazardous toxins around us and have caused major human health problems in various parts of the world. Chronic exposure to high levels of arsenic, cadmium, and other toxic metals have also been associated with high risk of cancers of the bladder, kidney, liver, lung, and skin (Tchounwou et al., 2012). Emerging evidence from previous researches suggested that these toxic metals may have adverse effects on living organisms even at lower concentrations. Water is life and therefore determination of quality of potable water is very important because it determines the health of man. Traditionally, management of water resources has focused on surface water or groundwater as if they were separate entities. As development of water resources increases, it is apparent that development of either of these resources affects the quantity and quality of the other. Almost all surface water features (streams, lakes, estuaries etc.) interact with groundwater. These interactions take many forms. In many situations, surface water bodies gain water and solutes from groundwater systems and on the other side surface water body is a source of groundwater recharge and may cause changes in groundwater level and quality. As a result, withdrawal of water from streams can deplete groundwater or conversely, pumping of groundwater can deplete water in streams, lakes, rivers, estuaries. Pollution of surface water can cause degradation of groundwater quality and conversely pollution of groundwater can degrade surface water.
The effective evaluation of water resources potential of an area requires a clear understanding of the linkages between groundwater and surface water as it applies to any given hydrologic setting (Winter et al., 1998). More than 65% of the people living in Umueri and environs engage in agricultural activities. Agricultural processes such as uncontrolled spreading of manure, disposal of sheep dip, use of pesticides and fertilizers can cause both surface and groundwater pollution. The widespread use of petroleum products such as fuels, lubricants, and solvents have led to increase in surface and groundwater contamination. Groundwater quality is being affected in a number of ways including oil spills from petrol stations during delivery, deliberate disposal of waste oil into drainage systems from mechanic workshops and power generating plants. Landfill leachates being one of the principal pollutants of groundwater is characterized by high organic and inorganic pollutant concentrations (Bodzek et al., 2006) and is extremely toxic to the environment.

Due to its high toxicity, Landfill leachate is a major threat for groundwater and surface water health status (Bulc, 2006). Due to increase in population and economic activities, the volume of effluents (waste water from domestic and industrial processes) released into the surface water and on the environment has been on the increase over time, this is however, not different from what is witnessed in Umueri and environs. The study area is characterized by a number of surface water bodies including River Anambra (Omambala River), Nkisi, with other minor streams like Oyi stream. In recent time, assessment of water quality and water resources potential of many places has been studied, some suggestion and regulation established to protect both surface water bodies and groundwater, but little study has been done on the water resources of Umueri and its environs, thus the reason for the research

Study Area

The study area comprises, Umueri, Nando, Aguleri, Nsugbe, Umuoba Anam and Nteje. It lies between latitudes $6^0 16$'N and $6^0 21$'N and longitudes $6^0 49$'E and $6^0 55$'E. The area can be accessed through some minor roads, foot paths and river from Kogi State and other inland towns in Anambra West.The local geology of the study area is Ogwashi-Asaba and upper Ameki Formation. Onwuemesi and Egboka (2006) proposed that the Ameki Formation which outcrops in most parts of the study area is lateral equivalent of Nsugbe sandstone, embodied with grayish green sandy clay which is characteristically fossiliferous. The thickness of Ameki Formation was around 1,400m in certain section of the study area, which is typically found around Nsugbe and Umueri.

Litreature Review

Several researchers have been attracted to study the water potential characteristics of many areas, as well as the processes that lead to pollution of natural water sources example Bodzek et al., 2006 stated that landfill leachate is one of the principal pollutants of groundwater and is characterized by high organic and inorganic pollutant concentrations and is extremely toxic to the environment. Bulc, 2006 noted that Landfill leachate is a major threat for aquifer and surface water health status due to its high toxicity. Even though many studies have confirmed that the concentrations of these heavy metal and trace elements in leachates are usually very low but they tend to constitute significant threat even in low concentrations and leached into surface water or groundwater resources (Ehring, 1983; Cecen and Gursoy, 2000; Christopherson and Kjeldsen, 2001). Ibezue, 2019 revealed that heavy metal and trace elements are among the major toxic pollutants in the surface and groundwaters Moreover, in the case of coastal aquifers, the combination of groundwater level drop and sea level rise due to the direct and/or indirect effects of climate change resulting from increase in saltwater intrusion, which in turn will pose serious threats to the livelihoods that depends on the water. Adelana et al., 2003, Ocheri and Odoma, 2013 revealed that increase in the rate of urbanization in Nigeria is characterized by high population concentration, while increase in industrial and agricultural activities contributes to environmental pollution/degradation and also indiscriminate disposal of all kinds of wastes contribute to serious pollution threat to both surface water and groundwater quality. From several other literatures reviewed, little study has been done on the water resources of Umueri and environs, hence the need for the research.

Materials and Methods

Fresh samples of Groundwater and surface water from the six towns that make up the study area were collected and labeled accordingly. In each town surface water samples were collected around the bank of Anambra River and other sources of pollution in the area and each sample collected was labeled by stating their exact sample location accordingly. Groundwater samples collected from dug wells and borehole were collected using one-liter plastic containers. Thereafter, the groundwater samples were analyzed for physico-chemical parameters that includes: pH, total dissolved solids(TDS), electrical conductivity (EC), total hardness(TH), Ca^{2+}, Mg^{2+}, $NO^{-}3$, SO_4^{2-}, Cl^-, Cu^{2+}, and Fe^{2+} ions, while surface water samples were analyzed for the following parameters; pH, total suspended solids, total dissolved solids, temperature, biological oxygen demand, chloride, nitrate, phosphate, lead, zinc, cadmium, mercury and vanadium using the following methods: pH was measured by Electrometric method using laboratory pH meter Hanna model H1991300 (APHA, 1998). Total dissolved solid was determined using APHA 2510 ATDS Determination of Total Hardness (TH) using EDTA Titrimetric method. Determination of Electrical Conductivity using Electric meter. Calcium – EDTA Titrimetric Method. Magnesium – EDTA Titrimetric Method. Nitrates – Brucine Sulphate Method. Chlorides – Argentometric Method. Copper – Spectrophotometric Meth. Iron – Spectrophotometric Method. Sulphates – Gravimetric Method with Ignition of Residue.

Results and Discussion

The groundwater samples were analyzed for physico-chemical parameters: pH, total dissolved solids(TDS), electrical conductivity (EC), total hardness(TH), Ca^{2+}, Mg^{2+}, NO_3^-, SO_4^{2-}, Cl^-, Cu^{2+}, and Fe^{2+} ions, while surface water samples were analyzed for the following parameters; pH, total suspended solids, total dissolved solids, temperature, biological oxygen demand, chloride, nitrate, phosphate, lead, zinc, cadmium, mercury, vanadium. Various experimental and instrumental techniques were employed to analyze the different chemical components. Results from physico-chemical assessment of groundwater and surface water samples collected from various locations are presented in table 1 below.

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Table 1 Physicochemical Properties of Water Samples in the study area (Data Set I)

	Salinity (mg/l)	pH	EC	TDS	Hard	Ca	Mg	Na	K	Cl	HCO3	SO4	NO3	Fe2
L1	50	7.1	348	174	211	125	86	16	5	30	193	6	2	0.2
L1	69.3	7.19	376	188	159	84	75	20	3	42	138	12	2.4	0.03
L3	23	6.8	251	119	96	60	36	13	1	14	89	4	0.8	0.55
L	Nil	6.2	165.5	78.2	46	35	6	5.3	4	9	23	9.5	9	0.04
L5	Nil	6.2	64.6	32.3	34	12	22	23.8	3	12	17	5	5.7	0.02
L6	Nil	6.3	74.9	37.4	27	10	17	21	2	7	37	6	0.3	0.34
L7	Nil	7.3	402	201	144	95	49	35	1	6	170	11	3.1	0.18
Min		**6.2**	**64.6**	**32.3**	**27.0**	**10.0**	**6.0**	**5.3**	**1.0**	**6.0**	**17.0**	**4.0**	**0.3**	**0.0**
max		**7.3**	**402.0**	**201.0**	**211.0**	**125.0**	**86.0**	**35.0**	**5.0**	**42.0**	**193.0**	**12.0**	**9.0**	**0.6**
mean		**6.7**	**240.3**	**118.6**	**102.4**	**60.1**	**41.6**	**19.2**	**2.7**	**17.1**	**95.3**	**7.6**	**3.3**	**0.2**
StDv		**0.5**	**131.0**	**65.8**	**65.8**	**40.5**	**27.9**	**8.6**	**1.4**	**12.6**	**67.3**	**2.9**	**2.8**	**0.2**

Below is plot of the measured values in different communities within the study area from locations L1-L7

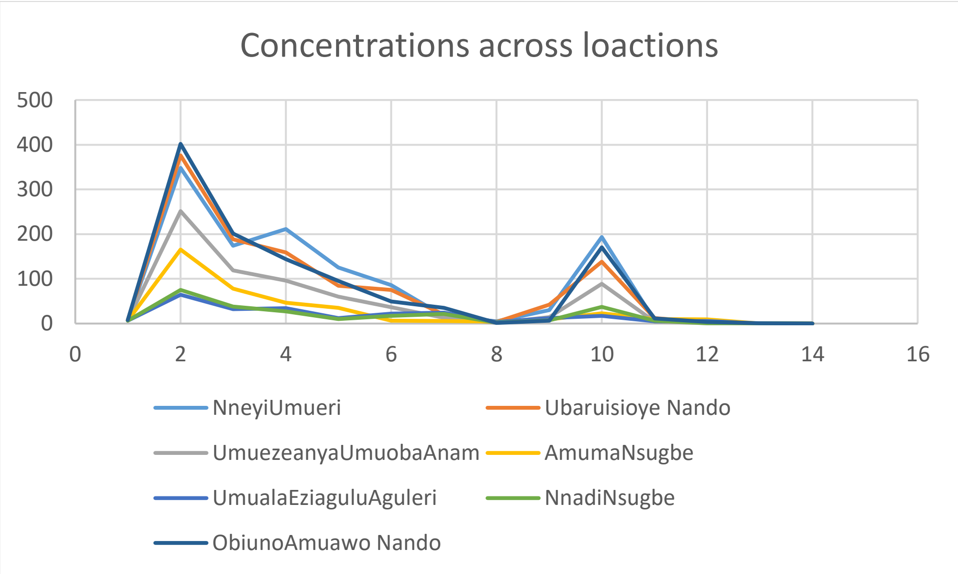

Fig. 1. Concentrations of the various parameters across Locations

The results obtained from different locations revealed variations in groundwater and surface water samples. To ascertain the level of contamination of the samples and to evaluate the water resources potential of the study area, comparisons were made using threshold values from (WHO, 2011) guideline for water resources. The table 1 below summarizes the guideline values. Statistical means from table 1 above.

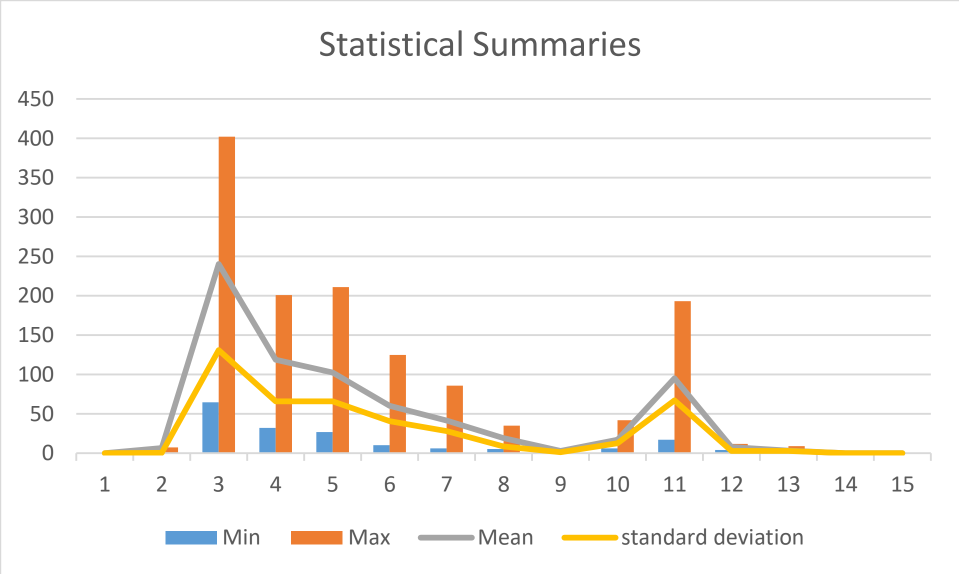

Fig. 2. Plot of the Statistical summaries

Table 2 Summary of the Physical and Chemical Compositions of Groundwater and Surface water.

S/N	Parameters	Units	Min	Max	Mean	WHO Limits
1	Temp	^{0}C	26.50	28.60	27.42	-
2	pH	-	5.40	7.20	5.90	6.50-8.50
3	Conductivity	us/cm	009	202	49.61	1000.00
4	Total dissolve Solids	-	0.01	0.03	0.01	500.00
5	Chloride	Mg/l	3.54	32.46	14.38	250.00
6	Salinity	Mg/l	5.60	12.00	8.28	-
7	Sulphate	mg/l	3.06	33.10	10.92	100.00
8	Nitrate	mg/l	0.22	4.12	1.39	50.00
9	Hardness	mg/l	0.24	1.38	0.58	150.00
10	Magnesium	mg/l	0.00	4.73	0.72	0.20
11	Calcium	mg/l	0.00	14.00	0.91	200.00
12	Iron	mg/l	0.00	0.71	0.14	0.30
13	Copper	mg/l	0.00	0.00	0.00	1.00

Following is a plot mean versus WHO threshold limits for the parameters

Fig. 3. Means versus WHO threshold limits for various parameters

From the results shown above, it is likely that leachate from improper solid waste disposal and indiscriminate dumping of waste into water bodies affected both groundwater and surfaces water resources.
Data set II presented in the table 3 is the outcome of laboratory analysis of samples collected during field work.

Table 3 Physicochemical Properties of Water Samples (Data Set II)

Source	Temp.	pH	Cond.	TDS	Salinity	Hard	Ca	mg	Na	K	HCO3	Cl	SO4	NO3	Fe
	ºC		uS/cm	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
SW	28	5.6	22	11	6	0.26	75.84	7.75	18.22	2.82	101.92	10.53	3.37	64	0.47
SW	27	5.5	54	27	10	0.76	44.20	3.33	20.55	1.90	97.07	15.45	27.40	0.69	0.54
WL	28.2	5.4	24	12	6.1	0.76	23.60	7.06	18.36	2.83	88.15	10.25	5.74	0.85	ND
SW	28.6	5.9	36	18	9	0.44	44.67	2.90	5.63	1.81	52.08	23.40	16.61	0.22	0.71
SW	28.4	6.1	36	18	12	0.44	23.60	2.30	5.97	2.86	48.36	15.32	6.16	0.36	0.06
SW	28	6.2	404	202	11.6	0.24	98.73	4.57	49.05	3.78	199.78	50.90	6.52	0.75	0.16
BH	28	5.6	238	119	8.6	0.92	254.73	7.07	37.68	3.30	207.82	13.54	8.61	0.59	ND
WL	28.2	5.9	102	51	10.1	0.38	99.12	19.96	24.05	3.02	132.60	30.22	8.54	0.71	0
BH	26.5	7.2	36	18	7	0.24	23.60	2.90	5.63	2.86	47.67	13.62	17.38	0.59	ND
BH	26.8	6.3	28	14	7.4	0.7	14.45	5.67	5.28	2.39	45.22	12.81	36.41	0.55	ND
BH	26.9	6	18	9	7	0.5	3.01	9.14	9.43	2.81	57.02	11.80	16.52	1.04	ND
BH	27	5.6	152	76	5.6	0.58	156.33	17.28	24.20	3.15	146.82	25.37	8.03	2.54	ND
WL	27	5.9	58	29	8.6	0.72	48.78	4.72	13.04	2.91	77.64	17.57	11.13	0.51	0.54
BH	27	6.3	44	22	9.1	1.38	32.76	0.13	14.93	2.88	76.49	14.43	11.28	0.71	ND
BH	27	6	84	42	8.2	0.7	78.52	13.73	18.36	2.98	106.54	18.49	8.95	3.17	ND
BH	27	5.4	144	72	8.6	0.44	147.18	2.51	24.40	3.13	136.77	24.56	4.25	3.12	ND
BH	27	5.4	170	85	7.9	0.44	176.93	5.52	22.28	3.19	140.03	23.55	8.17	4.12	ND
SW	27	5.9	136	68	6.2	0.46	138.02	11.74	14.91	3.11	110.98	27.35	11.22	3.91	0.01
Min	**26.5**	**5.4**	**18.0**	**9.0**	**5.6**	**0.2**	**3.0**	**0.1**	**5.3**	**1.8**	**45.2**	**10.3**	**3.4**	**0.2**	**0.0**
Max	**28.6**	**7.2**	**404.0**	**202.0**	**12.0**	**1.4**	**254.7**	**20.0**	**49.1**	**3.8**	**207.8**	**50.9**	**36.4**	**64.0**	**0.7**
Mean	**27.4**	**5.9**	**99.2**	**49.6**	**8.3**	**0.6**	**82.4**	**7.1**	**18.4**	**2.9**	**104.1**	**20.0**	**12.0**	**4.9**	**0.3**
StDev	**0.6**	**0.4**	**95.9**	**48.0**	**1.8**	**0.3**	**66.6**	**5.3**	**11.1**	**0.5**	**48.0**	**9.6**	**8.2**	**14.4**	**0.3**

Following is the plot of the concentration levels of the parameters from the laboratory analysis of the water samples.

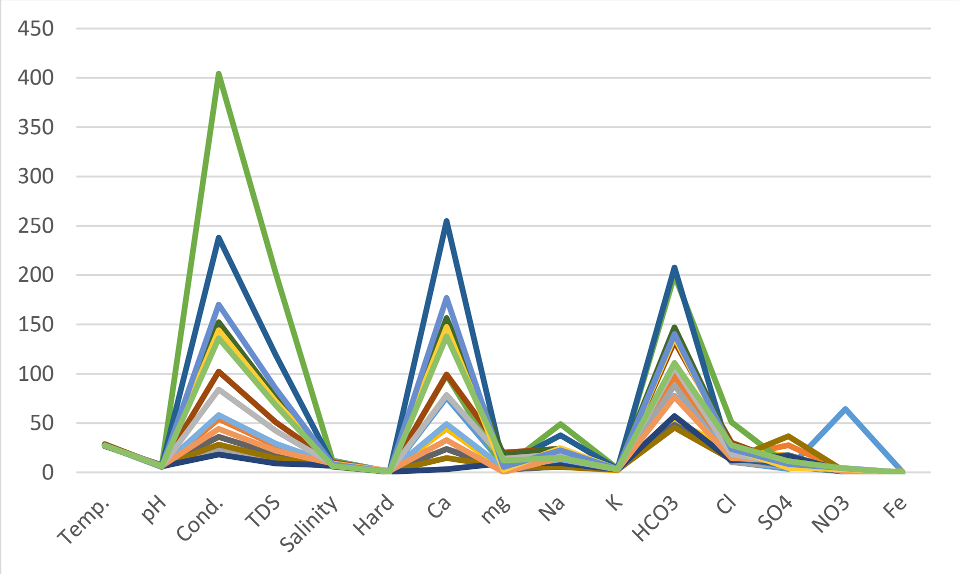

Fig. 4. Plot of the data set two from the laboratory analysis

pH

Normally, pH is not of health concern at levels found in both groundwater and surface water. The pH value of the samples in the study area is between 5.4 and 7.2 which is likely to be corrosive when compared to the WHO range for pH in water (6.5 – 8.5), Generally, acidic pH indicated the possible effect of contamination due to natural or anthropogenic sources or both.

Conductivity

Conductivity from table 1 showed that all the samples fell within the WHO acceptable limit.

Total Dissolved Solids

Total dissolved solids (TDS) are not of health concern. Samples from this investigation were observed to have noticeable very low TDS values that are almost constant. The TDS level of the water samples ranges between 0.01 and 0.03 which is considered good for drinking and other purposes.

Chloride

Chloride falls within the acceptable limit and so it is not of health concern. From the result of the analysis the chloride level is between 3.54 and 32.46 compared to WHO acceptable limit of 250mg/l.

Salinity

The salinity values for the samples range between 5.6 and 12.00 which is generally not fit for drinking, but can be used for irrigation and livestock purposes. This is in line with water salinity scale of Department of Water, Government of Western Australia 0f 2016.

Sulphate

Sulphate is not of health concern at levels found in the water samples but it may not be fit drinking water. The presence of sulphate in drinking water can result to a noticeable unpleasant taste. Very high levels of sulphate in water can cause laxative effect in unaccustomed consumers and may also contribute to corrosion of distribution channels. The sulphate level in the samples analyzed ranged between 3.06 - 33.10.

Nitrate

The nitrate levels in the samples tested is not of health concern, it ranges between 0.22 - 4.12.

Hardness

Hardness is not of health concern at levels found in the study area. The samples analyzed were below the 150mg/l standard by WHO.

Magnesium

Magnesium is high in some samples with the range 0.20- 4.73 mg/l and was absent in about half of the samples.

Calcium

Calcium is not of health concern at the levels found within the study area. Calcium when at high level is associated with water hardness. The level of calcium found in the samples range between 0.00 – 14.00.

Iron

Iron concentration was found to be present at a high level especially in surface water. Surface water can come in contact with the groundwater in the area either through leakage. Also, on exposure to the atmosphere, however, the ferrous iron oxidizes to ferric iron, producing an objectionable reddish-brown colour to the groundwater. Some samples indicated absence of iron for groundwater while some showed presence of iron for surface water and ranged between 0.01 and 0.71.

Copper

Copper was not dictated in the samples analyzed.

Field observation from water quality analysis indicated variation from location to location. This follows that some of the water samples had significant concentrations of the physico-chemical parameters analyzed revealing presence of contamination in groundwater and surface water sources, example iron was not detected in some samples, but where present showed above permissible limit. Another particular concern is the indiscriminate dumping of refuse into surface water and unapproved waste dump disposal at various locations within the study area, which stood as a major suspect for both groundwater and surface water contamination.

4.2 Statistical Summary

Existing information on boreholes within the study area were collected and analyzed. The summary of the analysis is presented in the table 4 below. The Pearson's correlation matrix of the analyzed data is presented in Table 4. All the ions showed positive correlation (R) with TDS except for K and NO_3. This revealed the different degrees of influence of the ions on the salinity of the waters.

Table 4 Correlation Matrix of Data Set I

Column1	*Temp*	*pH*	*TDS*	*Salinity*	*Hard*	*Ca*	*mg*	*Na*	*K*	*HCO3*	*Cl*	*SO4*	*NO3*
Temp	1.00												
pH	-0.27	1.00											
TDS	0.13	-0.13	**1.00**										
Salinity	0.39	0.12	**0.32**	1.00									
Hard	-0.18	-0.11	**-0.19**	0.00	1.00								
Ca	0.05	-0.48	**0.66**	-0.08	-0.02	1.00							
Mg	0.03	-0.20	**0.10**	-0.32	-0.20	0.30	1.00						
Na	0.22	-0.36	**0.89**	0.26	-0.04	0.66	0.19	1.00					
K	-0.04	0.00	**0.71**	0.03	-0.16	0.53	0.26	0.65	1.00				
HCO3	0.17	-0.43	**0.88**	0.13	-0.05	0.85	0.31	0.95	0.68	1.00			
Cl	0.18	0.00	**0.80**	0.42	-0.41	0.33	0.21	0.63	0.49	0.58	1.00		
SO4	-0.40	0.34	**-0.34**	-0.03	0.18	-0.43	-0.19	-0.43	-0.65	-0.48	-0.27	1.00	
NO3	0.18	-0.20	**-0.17**	-0.34	-0.29	0.02	0.06	0.01	0.00	0.02	-0.22	-0.28	1.00

R < 0.4 = weakly correlated; 0.4< R< 0.7 = moderately correlated; 0.7 < R < 1 = strongly correlated and -ve = negatively correlated.
The data set I, table 4 served as a precursor to the analysis from the field samples so as to help establish the water quality. While the correlation matrix table 5 is that of the measured values.

Table 5 Correlation Matrix for Data Set II

	PH	EC	TDS	HARD	CA	MG	NA	K	CL	HCO3	SO4	NO3	FE2	MN
PH	1.00													
EC	0.96	1.00												
TDS	0.97	1.00	**1.00**											
HARD	0.90	0.91	**0.91**	1.00										
CA	0.90	0.93	**0.93**	0.98	1.00									
MG	0.86	0.81	**0.82**	0.96	0.89	1.00								
NA	0.44	0.28	**0.30**	0.18	0.16	0.24	1.00							
K	-0.15	-0.03	**-0.02**	0.26	0.22	0.27	-0.50	1.00						
CL	0.53	0.53	**0.54**	0.68	0.56	0.80	-0.14	0.46	1.00					
HCO3	0.95	0.93	**0.93**	0.97	0.97	0.91	0.37	0.07	0.52	1.00				
SO4	0.45	0.57	**0.58**	0.32	0.34	0.25	0.25	0.03	0.30	0.34	1.00			
NO3	-0.47	-0.26	**-0.27**	-0.34	-0.28	-0.46	-0.34	0.42	-0.23	-0.44	0.27	1.00		
FE2	0.10	-0.01	**-0.03**	-0.02	0.02	-0.06	-0.09	-0.55	-0.27	0.08	-0.58	-0.69	1.00	
MN	-0.12	-0.01	**-0.03**	-0.29	-0.13	-0.53	0.12	-0.41	-0.77	-0.17	0.15	0.47	0.06	1.00

R < 0.4 = weakly correlated, 0.4 < R < 0.7 = moderately correlated, 0.7 < R < 1 = strongly correlated and -ve = negatively correlated

Summary and Conclusion
The pH values are acidic and are below WHO acceptable limit, hence the pH of water is not good for consumption. The concentration of salinity and magnesium in both groundwater and surface water in the study area are above WHO standard limit for safe drinking water and for other purposes. Most surface water in the area have high iron concentration compared to WHO permissible limit, while all the groundwater have minimal concentration of iron within WHO limit. In conclusion, the study revealed that the groundwater and surface water samples were polluted when compared to WHO standard, hence it is considered unsafe for consumption and other domestic uses. This is remedied by treatment of water before use.

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