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***Journal of Scientific and Engineering Research*, 2021, 8(5):19-28**

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Geochemical Analysis of Groundwater in Ehime Mbano Southeastern Nigeria for Sustainable Groundwater Development

Magnus U. Igboekwe, Doris N. Ndubueze*, Boniface I. Ijeh

Department of Physics, College of Physical and Applied Sciences, Michael Okpara University of Agriculture Umudike, Abia State, Nigeria
*ndubuezedoris@gmail.com

Abstract Geochemical analysis of groundwater samples collected from Ehime-Mbano was conducted for fifteen water samples within the study area with the analysis cutting across physicochemical, heavy metals and microbiological characteristics: (Temperature, Color, Conductivity, Turbidity, Total Solids, Total dissolved solids (TDS), Dissolved Oxygen, Salinity, Total Hardness, Total suspended solids (TSS), pH, Nitrites, Nitrates, Alkalinity, Acidity, Phosphorus, Lead (Pb), Cyanide, Zinc, Arsenic, Iron (Fe), Faecal and Total Coliform), using standard laboratory techniques. Test for parameters such as Electrical conductivity, TDS and Temperature were conducted in-situ. The pH of 12 out of 15 water samples are below 6.5 (between 5.31 – 6.32), while 7 out of 15 water samples have turbidity values above the 0.5NTU WHO standard. Six (6) out of 15 samples have Dissolved Oxygen higher than the NSDWQ standard. Water sample UWS12GW is the only water sample with an unacceptable nitrite concentration of 335mg/l (an extremely high amount which can be attributed to the use of inorganic fertilizer by the farming community). All water samples have Iron concentration higher than the NSDWQ standard of 0.3mg/l, a situation that depicts a high deposit of iron in the soil. The result of water quality analysis raises concerns of quality and acceptability of water samples analyzed. In order for water from all sampled sources to be suitable for drinking and other domestic uses, they should be treated using WHO approved low-cost water purification substances such as Water guard, Aquatabs, etc which are affordable for rural communities.

Keywords Groundwater, Quality, Ehime-Mbano, Physicochemical, Contamination

Introduction

Groundwater is a globally relevant, cherished and renewable resource. It is described as the water found beneath the surface of the earth in underground streams and aquifers [1]. It is contained in geological formations. During the periods of no rainfall, these aquifers proffer an appreciable base flow distributing of water to rivers. Etu-efeotor [2] noted that groundwater is certainly not chemically clean as water unvaryingly melts certain of the raw materials it approaches in interaction with at any given time. These melted reserves are confined in the groundwater which impacts its hydrogeochemistry and crucial superiority [3]. They determine the quality of water. When harmful substances dissolve in in to groundwater, the water becomes potentially harmful to human health when consumed. Negative health effects and economic losses are some disadvantages of consuming contaminated groundwater.

The Study Area

Ehime Mbano is located within Anambra /Imo sedimentary basin of South-eastern Nigeria. It is bounded by latitude 5° 37N to 5 °46 N and longitude 7° 14 E to 7° 21E. It has an area of 169 square km and a population of

130,931 at the 2006 census and was projected to be 204,340 people in 2015. It is bounded at the North by Onuimo and at the South by Ahiazu Mbaise and from the East and West by Ihitte/Uboma and Isiala Mbano/Onuimo/Okigwe local government areas respectively. Its drainage pattern is dendritic, typical of sedimentary rocks with uniform resistance and homogenous geology [4]. The physiography is dominated by a segment of Northern, Southeastern trending Okigwe regional escarpment which stands at elevation of between 61mand 122m above sea level [5]. The presence of Benin Formation is a contributory factor to soil erosion especially where they are exposed and unprotected by vegetation [6].

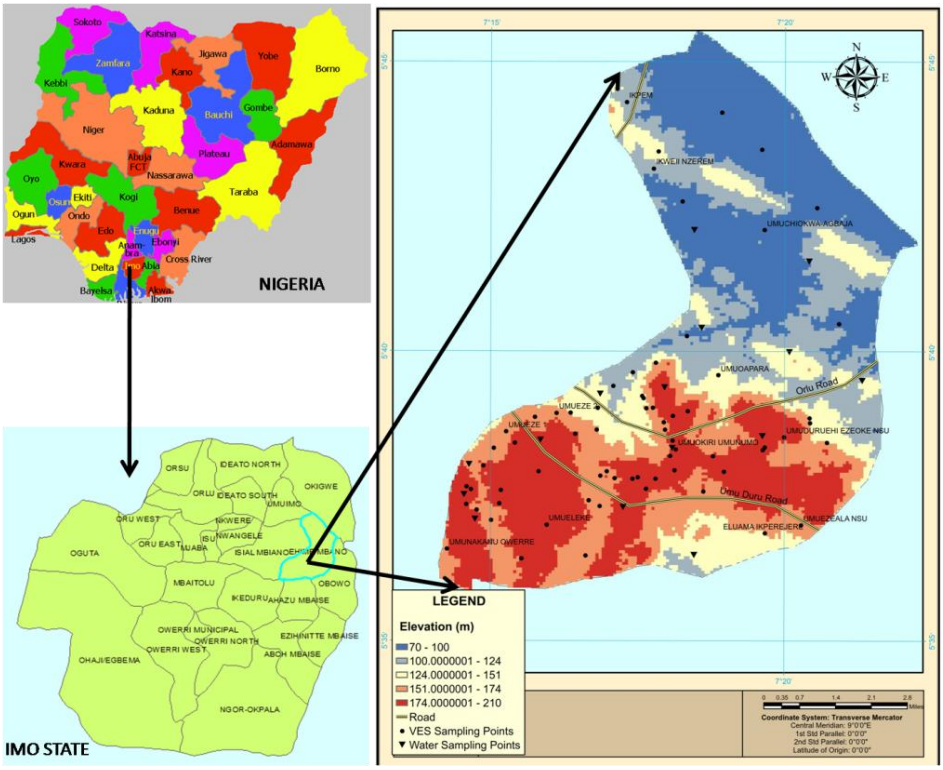

Figure 1: Location Map of the study area (Ehime Mbano)

Materials and Methods

Ehime Mbano and its environs were assessed for water quality by physiochemical analysis of samples in the laboratory. In this study, fifteen groundwater samples were carefully collected from existing boreholes and streams located within Ehime Mbano Local government and its environs. The Physicochemical parameters assessed are: Conductivity, Turbidity, Total dissolved solids (TDS), Total suspended solids (TSS), pH, Nitrites, Nitrates, Alkalinity, Acidity, Phosphorus. Also five heavy metals: Lead (Pb), Cyanide, Zinc, Arsenic and Iron (Fe) were tested. Biological parameters: Faecal and Total Coliform were also tested. Physicochemical parameters such as: Electrical conductivity, TDS, and Temperature were measured on site using HACH 44600-00 conductivity/TDS meter while the pH was determined using HACH session 3 pH meter. The Turbidity was determined using a spectrophotometer. The results are presented in the table below. Values obtained from the physiochemical parameters were correlated with the World Health Organization (WHO) values [7].

The Fifteen (15) samples consist of Twelve (12) borehole water and Three (3) Surface water in Ehime Mbano in Imo State. Twenty Three (23) water quality parameters were analyzed cutting across physicochemical, heavy metal and microbiological characteristics.

Results & Discussion

The outcome of water quality analysis conducted are as presented and discussed below

Results

Result of field activities such as mapping and sampling of study area is presented in table 1, while water quality analysis is presented in table 2.

Table 1: GPS location of sampled water sources

Location	Location Names	Location Codes	Latitude	Longitude	Elevation (m)
1	Amazi Umunakanu	Mean. UWS1 GW	5.6702	7.2561	149
2	Umuezeala Ama	Mean. UWS2 GW	5.6831	7.2557	156
3	Umualuwaku Umuezeala	Mean. UWS3 GW	5.6777	7.2612	172
4	Annunciation Convent SchUmueze 1	Mean. UWS4 GW	5.6708	7.2433	170
5	Umueze 1	Mean. UWS5 GW	5.6716	7.5008	183
6	Umuele Umunakanu	Mean. UWS6 GW	5.6542	7.2576	157
7	Tony chukwucmp - umueze 1	Mean UWS7 GW	5.5287	7.5008	135
8	Umuduruaku	Mean UWS8 GW	5.6341	7.2440	176
9	Umudiniegwelle Umueze 1	Mean UWS9 GW	5.6183	7.2456	176
10	Umueze 2	Mean UWS10 GW	5.6343	7.2338	176
11	Umuakagu Nsu	Mean UWS11 GW	5.6424	7.3271	173
12	Umunumo	Mean UWS12 GW	5.6563	7.2993	150
13	Ezeala Akpaka Stream – Umunakanu Ama	Mean SS1 SW	5.6631	7.2608	142
14	Umuanigu Umueze 1 - stream	Mean SS2 SW	5.6661	7.2355	177
15	Umuaro Umunumo	Mean SS23 SW	5.6388	7.3015	193

Elevation and Direction of Flow

A careful look at the Location Map for water samples, Elevation contour, flow direction in location map, Vector Grid and 3-D surface maps in Figures: 2, 3, 4 and 5 respectively unveils the fact that majority of the water samples are within the NE part of the study area. The study area slopes in two directions as shown in Fig. 4 and Fig. 5 (The Vector Grid Map and 3-D surface Map, the slope which also is in the flow direction is NW & SE all towards SW at Umueze 1 (sample 5); and NW & SW down to where the water ponds (converges) at location 1, 2, 3, 4, 6, 13,and 14 (around Umunakanu, Umuezeala, Umueze 1, Umuakagu, and Umunumo) beneath the NE high lands and ridgeline. Fig. 3 shows the flow directions embedded in the location map.

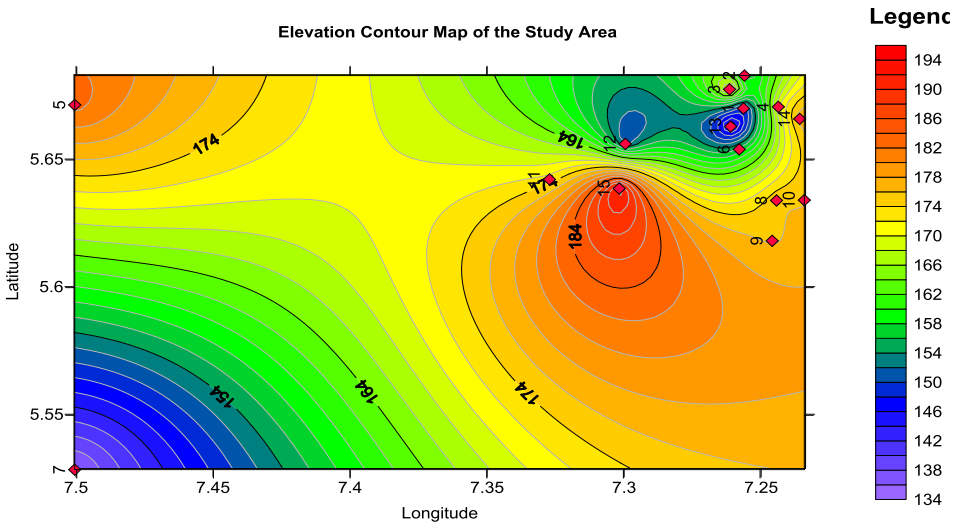

Figure 2: Elevation contour map of the study area

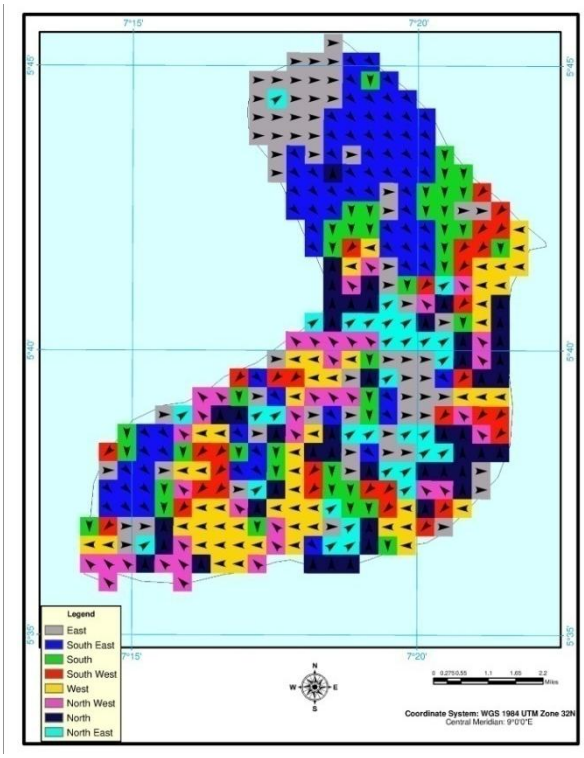

Figure 3: Groundwater flow direction embedded on the location map

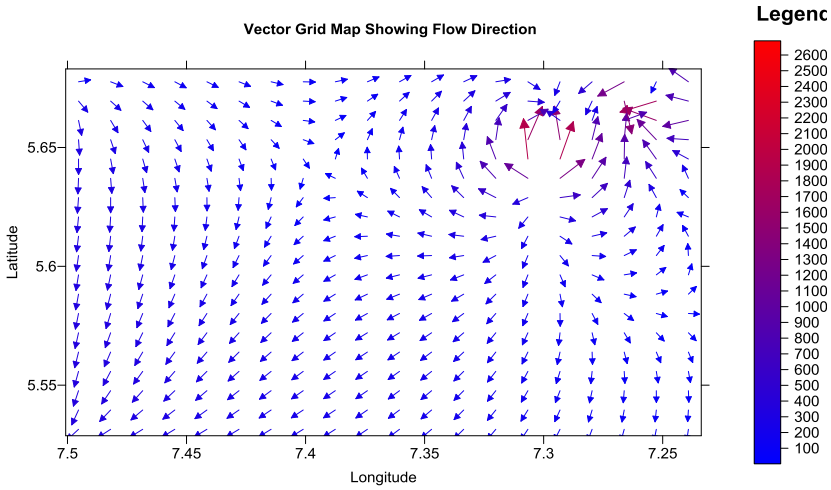

Figure 4: Vector grid map showing flow direction

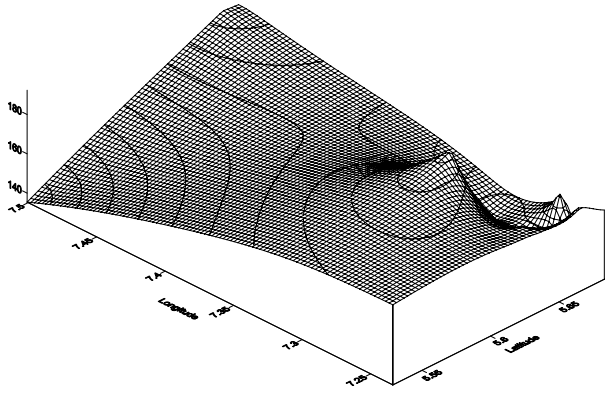

Figure 5: 3-D Surface map of study area

Table 2: Result of water quality analysis

					AmaziUmunakanu	UmuezealaAma	UmualuiwakuUmuezeala	Annunciation Convent SchUmueze 1	Umueze 1	UmueleUmunakanu	Tony chukwucmp - umueze 1	Umudurunaku	UmudiniegweleUmueze 1	Umueze 2	UmuakaguNsu	Umunumo	EzealaAkpaka Stream - UmunakanuAma	UmuanaguUmueze 1 - stream	UmuaroUmunumo
s/n	Parameters	Method	WHO 2017	NSDWQ	Mean. UWS1 GW	Mean. UWS2 GW	Mean. UWS3 GW	Mean. UWS4 GW	Mean. UWS5 GW	Mean. UWS6 GW	Mean UWS7 GW	Mean UWS8 GW	Mean UWS9 GW	Mean UWS10 GW	Mean UWS11 GW	Mean UWS12 GW	Mean SS1 SW	Mean SS2 SW	Mean SS23 SW
1	Colour,TCU	APHA 2120 B	15.00	15.00	2.00	4.00	3.67	4.67	4.67	4.67	5.00	4.67	3.67	6.00	4.33	4.67	10.67	14.33	5.00
2	Temperature, ^{o}C	Water meter	NS	Ambient	28.53	28.40	29.00	28.93	28.00	31.40	28.40	29.56	29.27	29.20	28.43	30.20	24.57	26.50	30.93
3	pH	ASTM D1293B	6.5-8.5	6.5-8.5	5.86	6.86	5.51	6.32	5.91	5.27	5.92	5.49	5.77	6.11	5.44	5.31	6.77	6.85	5.72
4	Conductivity, µS/cm	APHA 2510A	NS	1000.00	42.00	80.00	28.00	9.00	13.00	24.00	18.00	12.00	14.00	14.00	26.00	46.00	42.00	32.00	37.00
5	Total dissolved solids,mg/l	APHA 2540C	NS	500.00	21.00	40.00	13.00	4.33	6.00	12.00	8.00	5.00	7.00	7.00	13.00	22.00	21.00	15.00	18.00
6	Salinity,PSU	APHA 2520 B	NS		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
7	Turbidity ,NTU	ASTM D 1889	0.50	5.00	0.27	0.40	0.33	0.50	1.27	0.43	0.43	0.87	0.53	1.17	0.67	0.63	12.67	13.67	0.93
8	Dissolved Oxygen.mg/l	APHA 4500-O	NS	5.00	5.80	5.79	4.96	5.30	5.34	4.92	4.93	4.67	4.75	5.00	5.09	5.12	4.59	4.35	4.62
9	Total suspended solids,mg/l	APHA 2540D	NS	500.00	0.03	0.05	0.06	0.14	0.13	0.13	0.05	0.11	0.07	0.13	0.08	0.06	1.41	1.65	0.11
10	Total solids,mg/l	APHA 2540	NS		21.03	40.05	13.06	4.47	6.13	12.13	8.05	5.11	7.07	7.13	13.06	19.05	22.41	16.65	18.11
11	Nitrate,mg/l	APHA 4500-NO3	50.00	50.00	0.98	0.69	1.24	0.57	0.67	2.20	0.90	0.66	1.23	1.04	1.10	0.68	2.56	2.03	2.13
12	Nitrite,mg/l	APHA 4500-NO2	3.00	0.20	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00	335.00	0.01	0.01	0.00
13	Phosphorus, mg/l	APHA 4500-P	NS		0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.02	0.03	0.01
14	Alkalinity, mg/l	APHA 2320	NS	120.00	13.33	20.00	10.00	13.33	26.67	20.00	13.33	20.00	20.00	20.00	40.00	10.00	50.00	80.00	60.00
15	Total hardness, mg/l	APHA 2340C	NS	150.00	33.33	11.33	9.33	12.67	16.67	13.33	8.67	42.00	35.33	22.00	14.00	8.00	62.67	78.67	56.00
16	Acidity,mg/l	APHA 2310	NS		4.00	2.00	4.00	6.00	5.33	6.00	7.33	8.00	6.00	2.00	2.00	4.00	8.67	8.00	6.00
17	Cyanide,mg/l	Colori metric	NS	0.01	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
18	Lead,mg/l		0.01	0.01	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
19	Arsenic,mg/l		0.01		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
20	Zinc,mg/l	APHA 3111B	NS	3.00	0.01	0.02	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.03	0.02
21	Iron,mg/l		NS	0.30	0.65	0.56	0.94	0.84	1.03	0.93	0.73	1.01	0.54	0.83	0.93	0.53	6.03	9.04	5.10
22	Faecalcoliform,MPN/ 100ml	APHA 9221	NS	0.00	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
23	Total coliform, MPN/100ml		NS	10.00	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2

Result of physicochemical analysis of water samples revealed various degrees of contamination, with some parameters having concentration values above WHO permissible limits. Such parameters include pH, turbidity, dissolved oxygen, nitrite and iron.

pH of the water samples

Following the pH contour map (Fig. 6) shown below, it is obvious that acidity increases towards the NE flank around Umuezeala except at the point of convergence of flow around Umunakanu where acidity began to decrease, tailing into alkalinity, then increases at the high rise ridgeline. This means that southwestern part of

the study area is more alkaline while the Northeastern part is more acidic (green to white colour). Groundwater in this area needs more treatment before consumption, if acidic water is consumed, it triggers ulcer.

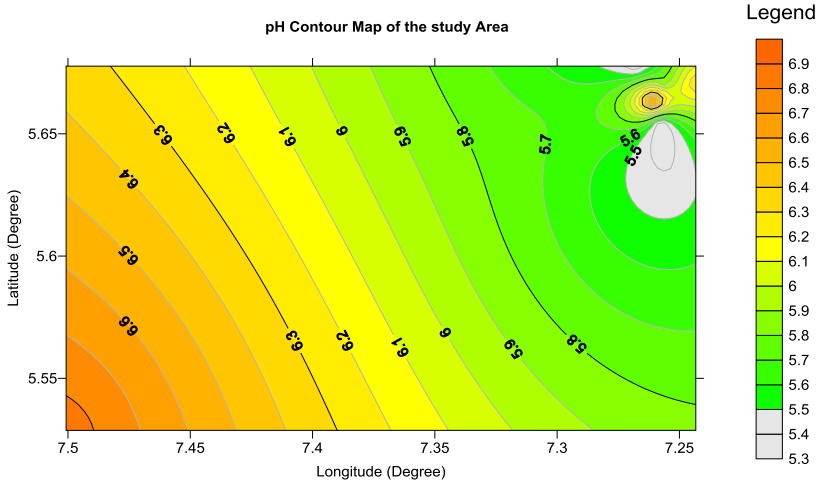

Figure 6: pH contour map

Turbidity concentration of the water samples

The above trend for pH was also observed in the spread of turbidity concentration as water in the Umunakanu area is more turbid than Umuezeala, Umueze 1 and UmuaniguUmueze 1 which are at a higher elevation. This means that areas at lower elevation are more turbid than those at higher elevation. Groundwater Water samples 5, 8, 9, and 10 (boreholes in Umueze 1, Umuduruaku, UmudiniegwelleUmueze 1 and Umueze 2 respectively), including samples 13, 14, and 15 (surface water) have turbidity values above permissible limits with samples 13 and 14 located in Ezeala Akpaka – Umunakanu Ama and Umuanigu Umueze 1 respectively having the highest values of 12.67NTU and 13.67NTU as reflected in Fig. 7 and 8 above the WHO [7] and NSDWQ of 0.5NTU and 5.0NTU respectively. Samples 5, 8, 9, 10 and 15 have values above WHO standards but below the NSDWQ permissible limit. High turbidity values above permissible limits is indicative of high total suspended solids with possible contamination by clay, silt, algae, microbial, etc [7].

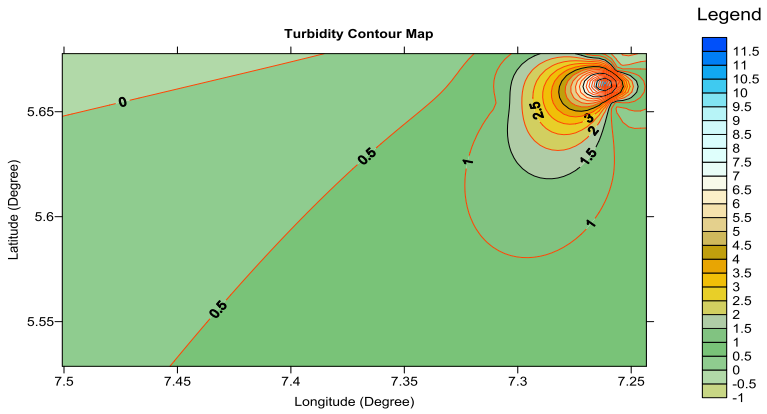

Figure 7: Turbidity contour map

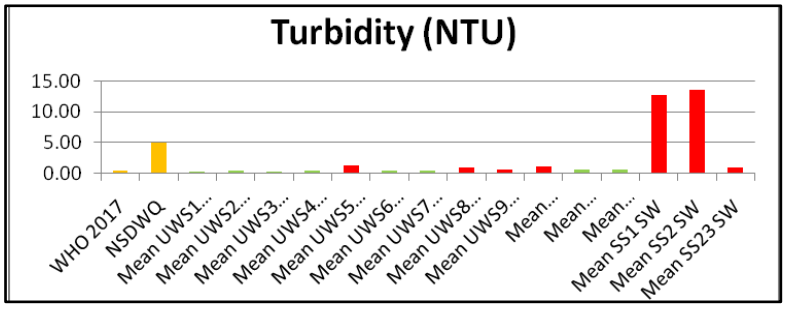

Figure 8: Turbidity concentration chart of water samples

Dissolved oxygen concentration of the water samples

Water samples 1, 2, 4, 5, 11, and 12 have values of Dissolved Oxygen (DO) above the NSDWQ standard of 5.0mg/l while samples 3, 6, 7, 8, 9, 10, 13, 14 and 15 have values below the standard. The WHO 2017 did not specify a limit for DO. The average difference from the permissible limit of 5.0mg/l for all water samples is 0.6mg/l, which shows that the average concentration of water samples are within acceptable limit. Hence, water samples are safe for use. Considering Fig. 9 and 10, the concentration of DO decreased progressively down the slope NE ward except at sample location 1 and 4 close to the ridgeline at the NE wing of the study area. Samples 1 and 2 from Amazi Umunakanu and Umuezeala Ama respectively have the highest values of DO. Having values of DO far above acceptable limit increases corrosion of water pipes which can result in further contamination. In surface water, very high DO predisposes fishes to gas bubble disease.

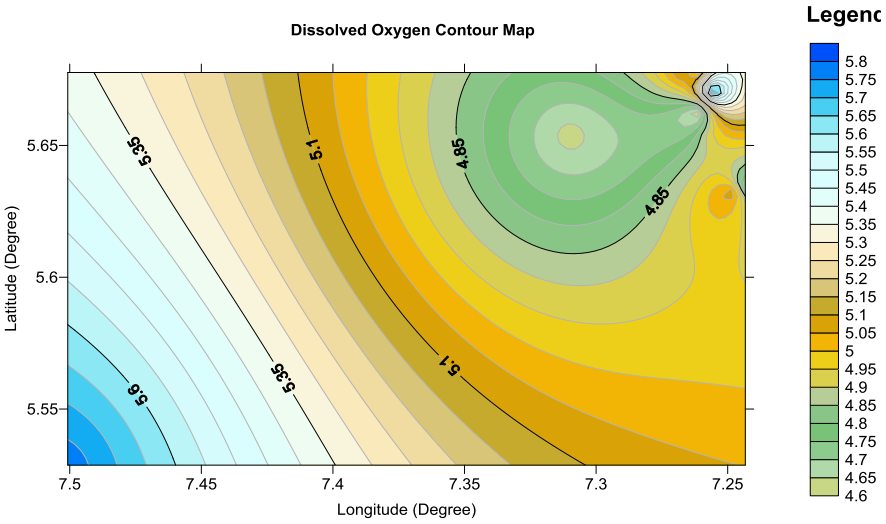

Figure 9: Dissolved oxygen contour map

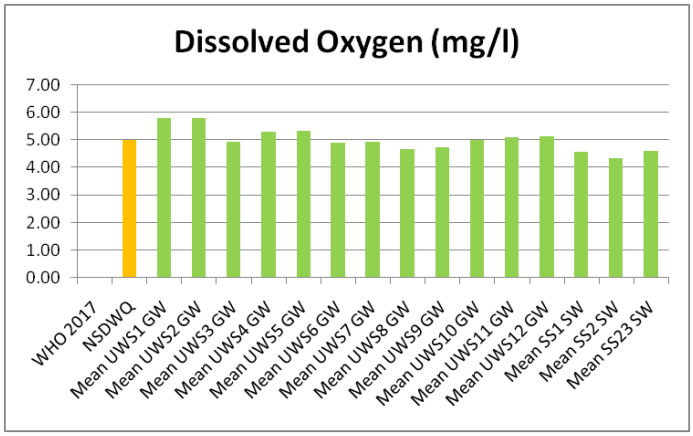

Figure 10: Dissolved oxygen concentration chart of water samples

Nitrite concentration of the water samples

Fig. 11 shows that there is barely any trace of Nitrite around the Eastern and lower SW region of the study area. Nevertheless, there is a Northward steady increase in Nitrite concentration within the study area with sample 12 located at Umunumo (see Fig. 12) having an extremely high concentration of 335mg/l. This could be attributed to human agricultural activities such as use of inorganic nitrogenous fertilizers and animal manure. Such high concentration of nitrite can cause cyanosis, asphyxia, and carcinogenic diseases [8].

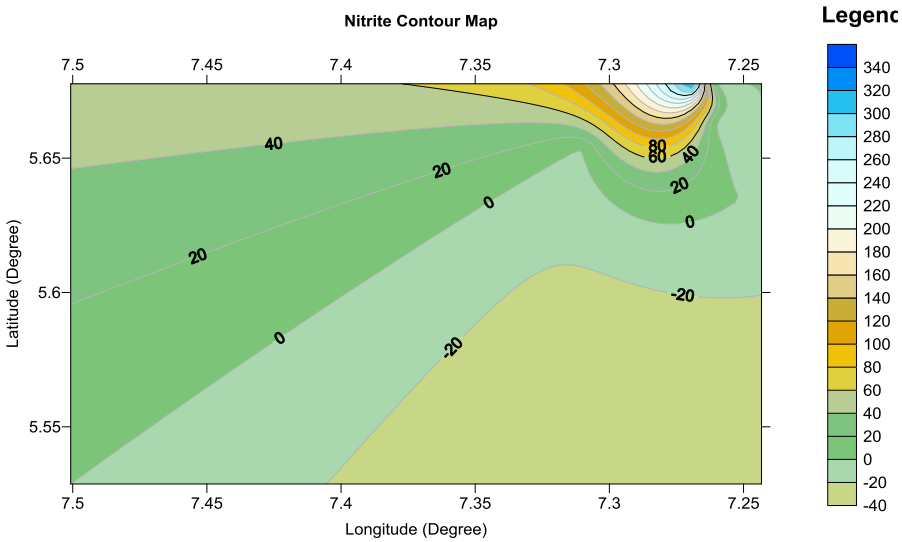

Figure 11: Nitrite contour map

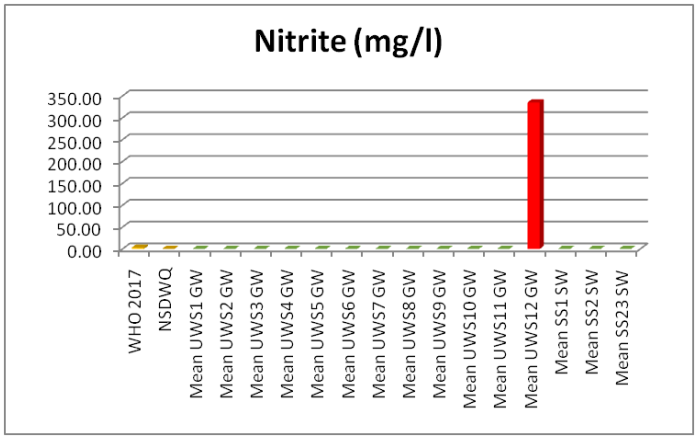

Figure 12: Nitrite concentration chart of water samples

Iron concentration of the water samples

The concentration of Iron in all water samples is above permissible limit with samples 13, 14 and 15 located in Ezeala Akpaka Stream – Umunakanu Ama, Umuanigu Umueze 1 – stream and Umuaro Umunumo having extremely high values of 6.03mg/l, 9.04mg/l and 5.10mg/l respectively as seen in Fig. 14. The high iron content in all water samples raises concern on the suitability of such waters for human consumption which can result to haemorhhagic necrosis, sloughring of areas of mucosa in stomach with extension into submucosa and even death while concentration below limits affects the aesthetics of water [9]. There is a gradual increase in concentration down the slope to location 15 (Umuaro Umunumo) from where is then decreases towards location 4 (Annunciation Convent School Umueze 1) and the ridgeline as seen in Fig. 13.

In the borehole category, groundwater sample from Umueze1 with code (UWS5GW) close to Mr. Tony Chukwu's compound has the highest iron concentration of 1.03mg/l. Then for the surface water category, Umuanigu Umueze I stream with code (SS2 SW) has the highest concentration of iron (9.04mg/l).

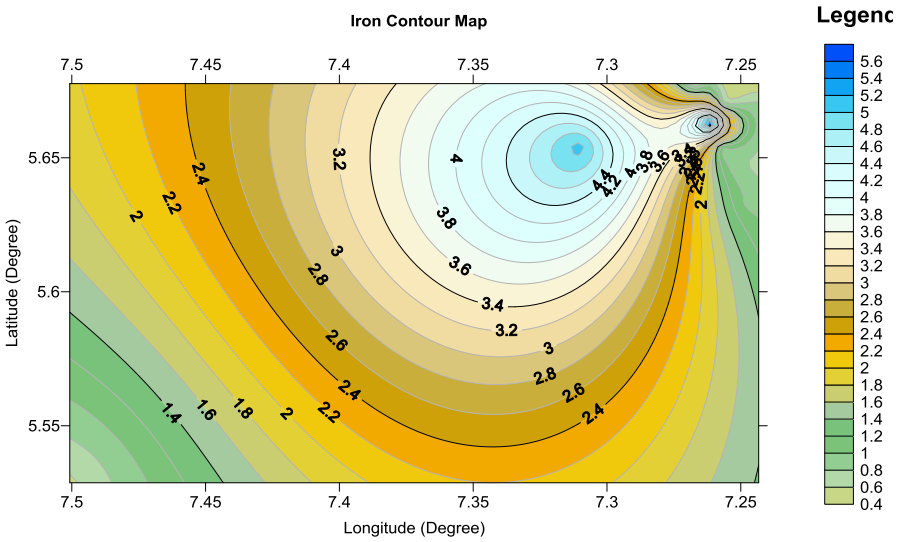

Figure 13: Iron contour map

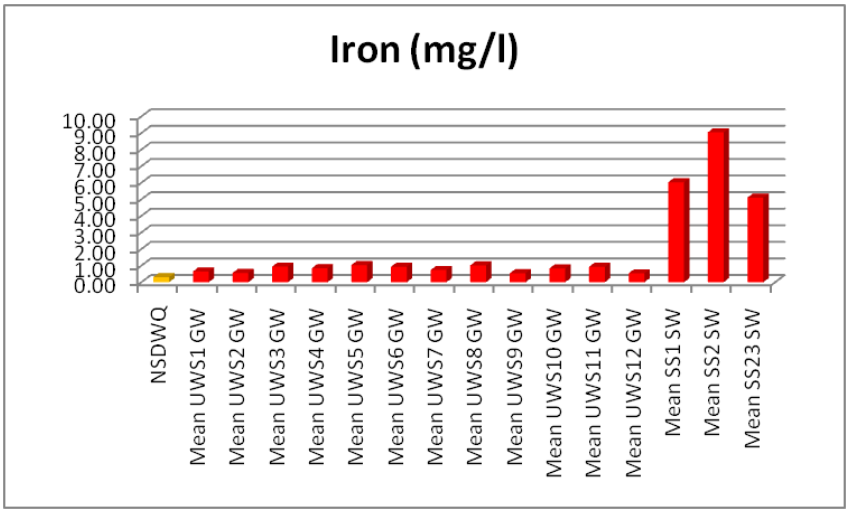

Figure 14: Iron concentration chart of water samples

Discussion

Out of the Twenty three parameters tested in the Fifteen water samples, it was discovered that some water samples had concentration of Five parameters (pH, Turbidity, Dissolved Oxygen, Nitrite and Iron) being clearly above both WHO and NSDWQ permissible limits. Whereas, the concentration of Feacal coliform is not clearly specified as it was presented to be less than 2. Nevertheless, it raises concerns of contamination and health risk as NSDWQ standard specified 0.00. Also, Cyanide concentration is below detectable limit (BDL) which hence is indicative of no contamination across water samples. Acidity, Dissolved solids, Salinity and phosphorus have no clearly defined limit by both NSDWQ and WHO 2017 which could be due to the existence of such parameters in concentrations that are not of human health concerns or other reasons.

Meanwhile, thirteen parameters have concentrations within permissible limits and hence are of no health concerns. They are Colour, Temperature, Conductivity, Total dissolved solids, and Total suspended solids, Nitrate, Alkalinity, Total hardness, Cyanide, Lead, Arsenic, Zinc and Total coliform. The presence of faecal coliform is indicative of contamination which causes diseases. According to Jamie and Richard [10], water from a source is considered non potable if at least one faecal parameter is present in it. As such all water samples are contaminated with faecal coliform and hence require treatment measures.

Conclusion

Following the water analysis outcome and discussion, physicochemical and microbial contamination of both the groundwater and surface waters is considerably low. Variation of parameters from WHO and NSDWQ is minimal particular in concentration of pH, turbidity, Dissolved Oxygen, Nitrite, Iron and Feacal coliform, except water samples in Ezeala Akpaka stream – Umunakanu Ama and Umuanigu Umueze 1 stream with high variation in Iron and turbidity values. Water sample in Umunumo also have very high variation in Nitrite value from permissible limits. Microbial contamination could be as a result of nearness to sewage tanks.

It is important to note that pH values below 7 are indicative of acidity which increases the harmful potential of heavy metals such as iron and other heavy metals which have concentration above permissible limits [9].

Generally in this work, it has been shown that the water samples tested can be said not to be hazardous since most of the results are within acceptable WHO and NSDWQ standards.

Acknowledgment

We are grateful to the Almighty God for Wisdom to carry-out this research. Many thanks to all Lecturers in Physics department of Michael Okpara University of Agriculture, Umudike. Not left out in this appreciation are our friends and well wishers.

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