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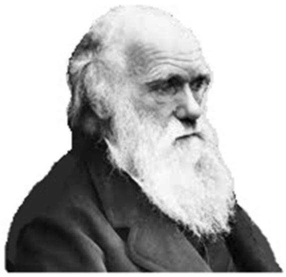

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Evaluation of Some Groundwater Sources in Ota, Ogun State, Southwestern Nigeria

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ABSTRACT

In a three year study (2018, 2019 and 2020), some groundwater sources in Ota, Ogun State, Nigeria were evaluated for quality. A total of one hundred and eighty composite borehole water samples were collected from 10 locations/sites in the study area. The sampling sites in the study were A (Iju), B (Onipannu), C (Ilogbo), D (Arobieye), E (Igbooloye, F (Osi), G (Ijoko), H (Akeja), I (Oju-ore) and J (Iyesi). Samples collected were analyzed using standard procedure for pH, electrical conductivity (EC), total dissolved solids (TDS), chloride and iron (Fe). Results over three years showed that the water was acidic with pH < 6.5, EC ranged from 39.52±0.79 to 134.99±0.03 μS/cm, TDS ranged from 19.43±0.42 to 81.00±0.02 mg/L, chloride was consistent at 0.02±0.00 mg/L while Fe ranged from 0.00±0.00 to 0.11±0.08 mg/L. There was no definite yearly trend except for Fe which dropped from 0.036 mg/L in 2018 to 0.011 mg/L in 2020. Modelling the data for consumption using water quality index (WQI) showed that the groundwater is of excellent quality with WQI < 50 while for health risks using the average daily dose (ADD) and hazard quotient showed that the groundwater would pose no non-carcinogenic risks. Periodic monitoring covering more parameter is recommended to reflect the proper status of groundwater sources in Ota.

***Keywords*:** Contamination, Groundwater, Health risks, Industrialization, Modelling

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1. INTRODUCTION

One of the basic necessities for maintaining of life and great wellbeing is water. Inside the most recent twenty years, the world has recorded a few accomplishments in the area of progress of admittance to improved drinking water (IDW) and cleanliness in accordance with the Sustainable Development Goals (SDGs) (WHO/UNICEF JMP Report, 2015; Onyeneke et. al., 2020). IDW source could be depicted as a source very much shielded from outside pollution, specifically, fecal issue (Ibe et. al., 2020). Report has demonstrated that all around the world, more than 2.6 billion individuals accessed IDW sources since the 1990s (Mkwate et al., 2017; Owamah, 2019). This accomplishment regardless, admittance to IDW is as yet an issue as around 663 million individuals on the planet are yet to approach IDW sources (Owamah, 2020). This has caused numerous individuals to rely intensely upon untreated water from private boreholes, unprotected shallow wells, streams, waterways and so on (Enyoh et. al., 2018; Ibe et. al., 2020). Drinking of contaminated water has been fingered as culprits for deaths of over 1,000,000 people yearly worldwide (WHO, 2012; Isiuku and Enyoh, 2019).

With the increasing in population, the desire for IDW is also on the rise. There are challenges in achieving this due to the lack or near absence of treated public water supply scheme, especially in the rural areas and small towns. So, people resort to groundwater which is accessed through digging of boreholes or wells and afterward put away in tanks for prompt or later use. In Sango-Ota metropolis and several other areas in Southwest Nigeria, people rely on groundwater for various domestic purposes without any prior analysis of quality. It is believed that because environmental and other geological considerations may not have been followed before most of the boreholes were drilled as proper groundwater exploration strategies were hardly applied. Thus, it is necessary and sustainable to establish frequent monitoring process for water quality parameters (Daniel, 2020). Some studies have been conducted on groundwater qualities around Ota and environs. Omole et. al., (2017) assessed groundwater quality in a faith-based campus in Ota and reported that pH, sulphate, nitrate, chloride and Total Dissolved Solids (TDS) were of acceptable limit while hardness was high. More recently, Ojekunle et. al., (2020) investigated the effects of industrialization on groundwater quality in Shagamu and Ota industrial areas of Ogun state, Nigeria in dry and rainy period of 2018. They reported that the levels of pH, calcium (Ca), lead (Pb), nickel (Ni), manganese (Mn), iron (Fe), cadmium (Cd), and chromium (Cr) were higher than the prescribed values set by World Health Organization. Irrespective of these studies, there is still a dearth of documented account or data of the groundwater quality of the area. In line, the aim of the current study is evaluate the quality of groundwater in Sango-Ota metropolis over three years using the water quality index and health risks models. The report of this study would, therefore, create the necessary awareness and consciousness amongst the inhabitants, town planners, and other relevant government agencies that will lead to the planning for the supply and development of future sustainable water schemes in the area (Harrison, 2020; Francis, 2020).

2. MATERIALS AND METHOD

2. 1. Study area

Ota is located at Ado-odo/Ota Local Government Area in Ogun State and lies between latitude 6°38′N and longitude 3°06′E with an elevation of about 53 m above the sea level. It has a territory of 878 km² and a populace of 526,565 at the 2006 registration. Being part for Ogun state, Ota has similar geologic attributes with numerous different parts of the state having the cellar complex stone and the pre-Cambrian age which are comprised of the more established and more younger rocks in the northern part of the state, and the more youthful and more seasoned sedimentary stone in the tertiary and optional ages in the southern parts (Iloeje, 1981; Ufoegbune et. al., 2016). The district has possesses climate of tropical rain-forest with two primary climatic conditions; the rainy season which keep going for somewhere in the range of seven and eight months among April and October with a break in August, and the dry season going through November till February. The precipitation experienced is generally over 90 days. The atmosphere is moist on account of all the precipitation which add up to about 250 cm in a year. Because of its closeness to the equator, the district is hot and wet with a normal temperature of at least 18 ºC for all the months consistently (Ufoegbune et. al., 2016). Being principally agrarian in nature, the Local Government Area produces money and food crops particularly cocoa, kola nut, palm oil, coffee, cassava, timber, maize, and vegetables. Mineral assets incorporate kaolin, silica sand, gypsum, and glass sand.

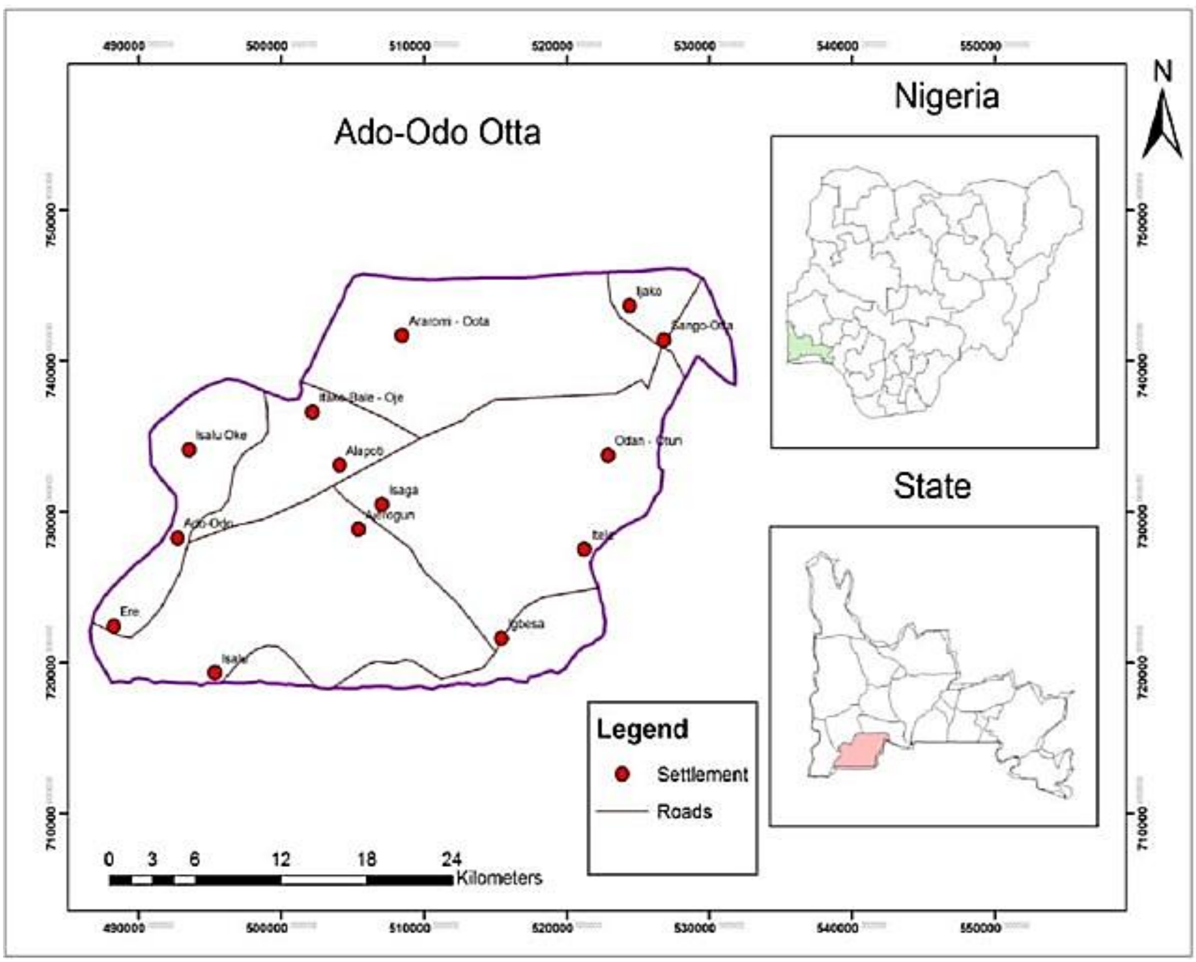

Figure 1. Map of Ado-Ota Local Government Area showing Sango-Ota (Ogunyemi et. al., 2017).

2. 2. Sampling and sample collection

In the three year study, a total of one hundred and eighty (180) composite borehole water samples were collected from 10 locations/sites (30 samples per year) in the study area. Yearly, samples were collected in dry season viz October (1), November (1) and December (1). The sampling sites in the study were A (IJU), B (ONIPANNU), C (ILOGBO), D (AROBIEYE), E (IGBOOLOYE, F (OSI), G (IJOKO), H (AKEJA), I (OJU-ORE) and J (IYESI). Sample points were spread objectively within a particular site. The water samples were collected using cleaned plastic bottles from taps connected to the boreholes at interval of two hours and mixed together to make a composite sample (Enyoh et. al., 2018). The plastic bottles used were properly labeled and cleaned prior to sample collection by soaking it in 10% HCl for 48 hours, washed and rinsed with deionized water and dried.

2. 3. Physicochemical analysis

Borehole water samples were analyzed as described by Duru et al., (2017 and 2019) for the following: pH (Checker plus pH meter), electrical conductivity (EC) and total dissolved solids (TDS) was determined using Groline TDS/EC meter; iron (Fe) and Chloride (Cl^-) were determined using Multiparameter bench photometer (using LR-Iron tablet) and Lovibond colorimeter (by dissolving DPD-4 tablet) respectively.

2. 4. Quality control

To ensure the quality of analytical results, standard procedures were followed with laboratory quality assurance. High quality analytical grade reagents with 99.9% certified purity level was used throughout the analysis. Pyrex glassware and sample bottles were properly washed with detergents and deionized water. The glassware and containers were also soaked with a solution of 10% HNO_3 in 1% HCl solution overnight, and were again rinsed with deionized water, and dried in an oven using DHG – 9023A (B. Brans Scientific and Instrument Company, England). All the reagents used for determination of concentration of anions were sourced from the manufacturer.

2.5. Data analysis

IBM SPSS 23 version was used to analyze the data for mean and standard deviation. Pollution and quantitative health risk analyses were also carried out to ascertain the possibility of water contamination and the risk due to intake of groundwater from the study locations.

3. RESULTS AND DISCUSSION

The results for the physicochemical analysis of the groundwater samples from the different sites are presented in Table 1. The results for the studied parameters are presented in the table and compared to World Health Organization (WHO) standard for drinking water. The pH range of 6.5-8.5 was set by WHO for drinking water, mean pH of all sites (100 %) fell outside this range i.e < 6.5. Some previous study on ground water in the area reported similar lower pH < 6.5 (Omole et. al., 2017; Ojekunle et. al., 2020). The groundwater from the areas can be said to be acidic. Consuming water of high acid contents is not recommended as it might lead to condition of acidiosis, which can cause arrhythmia or irregular heartbeats, imbalanced electrolyte levels and coma (Enyoh et. al., 2018; Duru et. al., 2017a; 2017b; Ibe et. al. 2020). The mean pH trend in three years is presented in Figure 2. The highest pH was recorded in 2019 while the least in 2018.

Conductivity indicates the presence of dissolved solids, which could render ground water drinkable or undrinkable. High conductivity values are indication of excess ionic concentrations in groundwater samples. The recorded mean EC was generally lower than the permissible limit of 100 μS/cm set by WHO except for groundwater sample collected from I (2018 and 2020) and J (2018 only). Oju-ore and Iyesi areas in Ota are highly populated with high anthropogenic activities and so might be receiving waste leachates from the soil as the boreholes are low in depth. Low depth of borehole was reported to be responsible for high EC in some samples collected from Owerri metropolis (Ibe et. al., 2020). The obtained results are in agreement with the study of Ojekunle et. al., (2020). Overall results for Ota areas, generally suggests that the dissolved ions in the groundwater were low. Similarly, the trend for TDS followed the EC due to strong correlation between the two parameters. The yearly trend for EC and TDS were 2020 > 2018 > 2019 (Figures 3 and 4).

The concentrations of chloride were constant in the groundwater in the three year studies (Table 1 and Figure 5). Higher concentrations of chloride which ranged from 1.5 mg/L to 25 mg/L were reported for groundwater within the vicinity of Covenant University in Ota by Omole et. al., (2017). This is not in agreement with our study and could be due to the analytical method applied in the current investigation. The concentrations of Fe were generally lower than the limit set WHO (0.3 mg/L) except for samples collected from Onipannu (B) in 2018. Drinking water that contains iron can be beneficial to your health. However, excessive iron in drinking water may have negative effects including diabetes, hemochromatosis, stomach problems, nausea, and vomiting.

It can also damage the liver, pancreas, and heart. Over three years, the concentrations of Fe dropped from 0.036 mg/L in 2018 to 0.011 mg/L in 2020 (Figure 6)

Table 1. Physicochemical characteristics of groundwater.

SITES	pH	EC (μS/cm)	TDS (mg/L)	Cl^- (mg/L)	Fe (mg/L)
WHO	6.5-8.5	100	500	250	0.3
2018					
A	5.37±0.07	45.11±0.08	27.06±0.04	0.2±0.00	0.00±0.00
B	5.25±0.04	57.63±0.70	34.58±0.42	0.2±0.00	0.11±0.08
C	5.38±0.005	55.30±2.14	33.18±1.29	0.2±0.00	0.03±0.00
D	5.58±0.01	32.38±0.70	19.43±0.42	0.2±0.00	0.04±0.02
E	4.78±0.009	41.46±0.15	24.88±0.09	0.2±0.00	0.02±0.00
F	5.83±0.008	54.41±3.12	32.65±1.87	0.2±0.00	0.03±0.005

G	5.11±0.005	55.66±0.72	33.39±0.43	0.2±0.00	0.02±0.00
H	5.17±0.02	53.35±0.02	32.01±0.01	0.2±0.00	0.00±0.00
I	5.09±0.009	134.99±0.03	81.00±0.02	0.2±0.00	0.04±0.01
J	6.04±0.005	107.24±0.77	64.34±0.46	0.2±0.00	0.03±0.005
2019					
A	5.25±0.009	43.41±0.16	26.05±0.10	0.2±0.00	0.00±0.00
B	5.31±0.02	59.58±0.61	35.75±0.37	0.2±0.00	0.00±0.00
C	5.26±0.04	46.18±2.14	27.98±1.60	0.2±0.00	0.02±0.005
D	5.42±0.02	42.36±0.76	25.42±0.45	0.2±0.00	0.04±0.00
E	4.93±0.01	39.06±0.67	23.44±0.40	0.2±0.00	0.02±0.00
F	5.94±0.008	63.28±1.83	37.97±1.10	0.2±0.00	0.00±0.00
G	5.19±0.01	50.53±0.84	30.32±0.50	0.2±0.00	0.00±0.00
H	5.29±0.02	59.97±0.06	35.98±0.04	0.2±0.00	0.02±0.00
I	5.15±0.03	79.20±2.95	47.52±1.77	0.2±0.00	0.04±0.009
J	6.35±0.01	87.22±1.57	52.33±0.94	0.2±0.00	0.03±0.00
2020					
A	5.18±0.009	32.85±1.56	19.71±0.94	0.2±0.00	0.00±0.00
B	5.41±0.07	59.77±2.74	35.86±1.64	0.2±0.00	0.02±0.00
C	5.37±0.005	71.37±2.66	42.82±1.60	0.2±0.00	0.00±0.00
D	5.41±0.008	39.52±0.79	23.71±0.48	0.2±0.00	0.00±0.00
E	4.85±0.03	48.90±0.42	29.34±0.25	0.2±0.00	0.00±0.00
F	5.62±0.005	68.97±2.01	41.38±1.21	0.2±0.00	0.00±0.00
G	5.16±0.02	37.24±0.80	22.34±0.48	0.2±0.00	0.00±0.00
H	5.21±0.009	57.80±0.79	34.68±0.47	0.2±0.00	0.03±0.005
I	5.28±0.005	90.68±0.71	54.41±0.43	0.2±0.00	0.02±0.005
J	6.31±0.02	123.06±0.19	73.84±0.12	0.2±0.00	0.03±0.00

*A (IJU), B (ONIPANNU), C (ILOGBO), D (AROBIEYE), E (IGBOOLOYE, F (OSI), G (IJOKO), H (AKEJA), I (OJU-ORE) and J (IYESI)

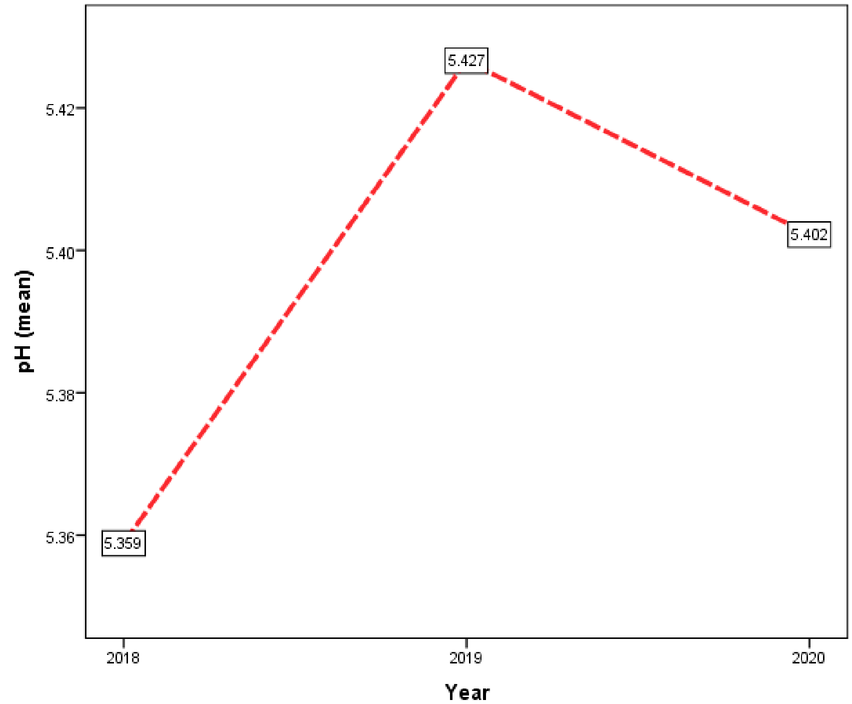

Figure 2. Yearly trend of groundwater pH.

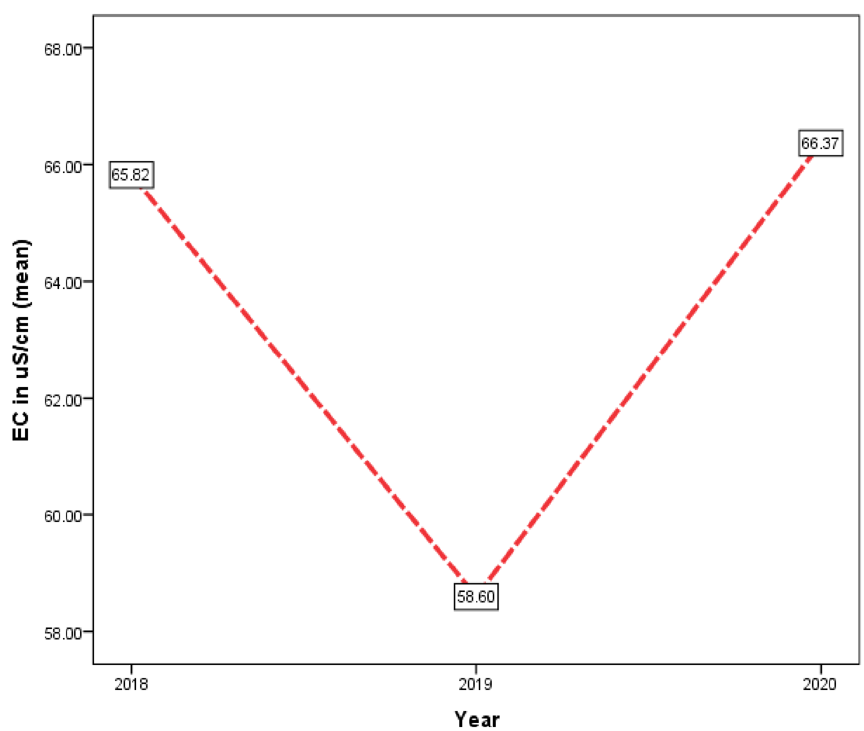

Figure 3. Yearly trend of groundwater electrical conductivity.

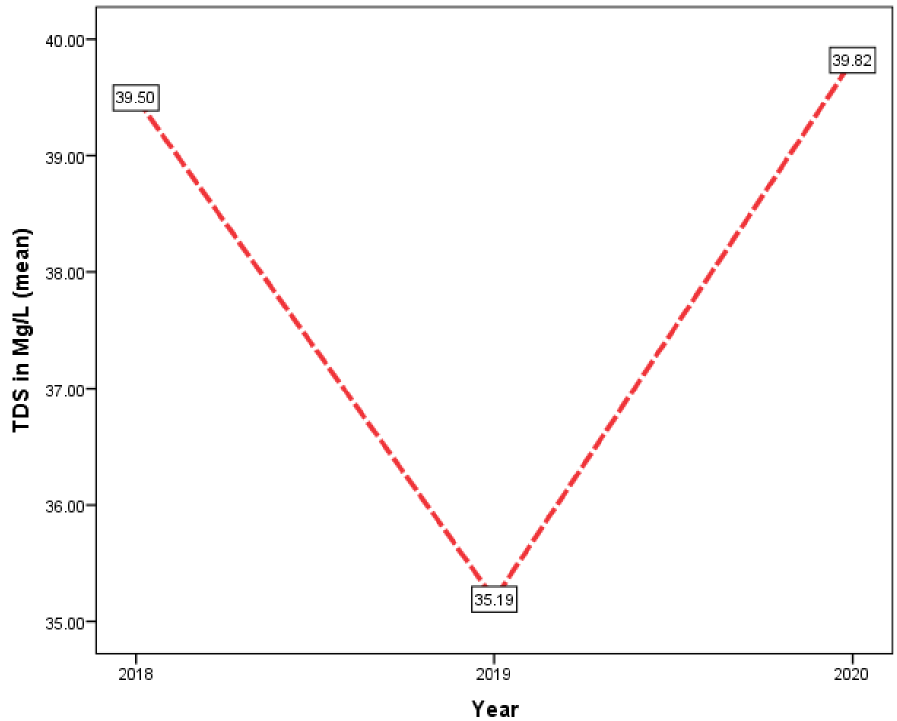

Figure 4. Yearly trend of total dissolved solis in groundwater.

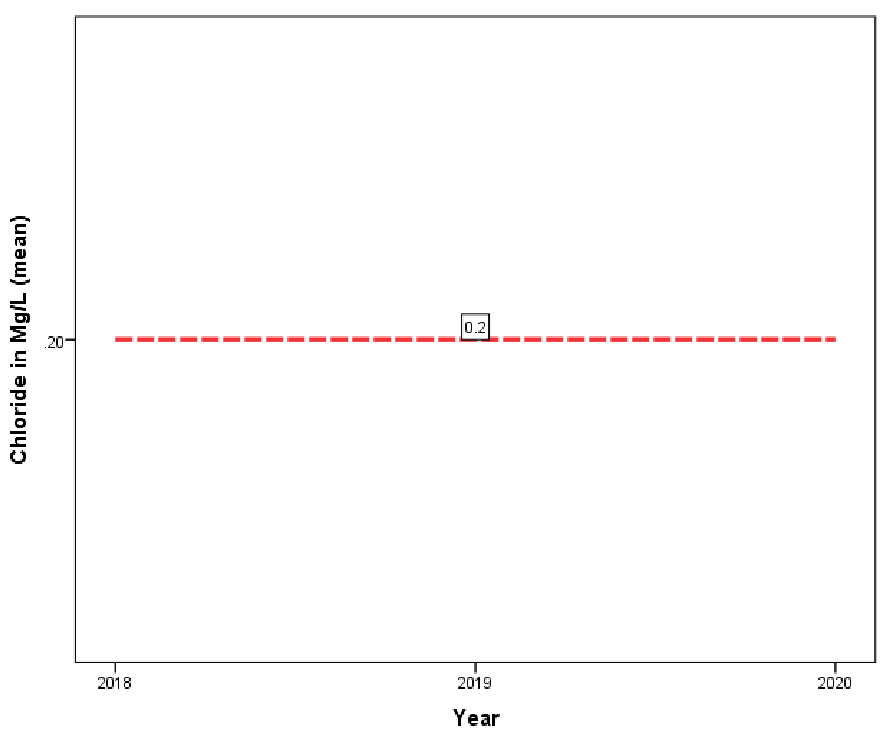

Figure 5. Yearly trend of chloride in groundwater

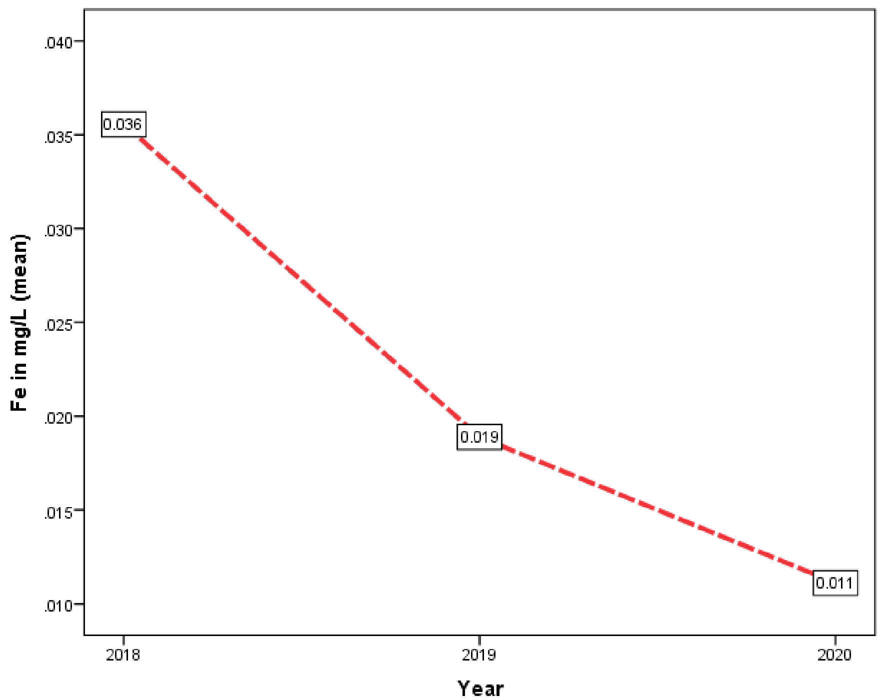

Figure 6. Yearly trend of iron content in groundwater.

3. 2. Hierarchical cluster analysis (HCA)

Hierarchical cluster analysis (HCA) was performed to evaluate the similarities and dissimilarities between the water quality parameter based on the rescaled distance between them and pearson correlation. The results obtained from this analysis are presented as dendrograms as shown in Figure 7. The level of association btween the different parameters are shown on the dendogram in the form of a tree diagram (Ibe et. al., 2019a; Verla et. al., 2020). The computed dendrogram showed a moderate similarity amongst most of the pollutants. According to Figure 7, EC and TDS showed very high association with smallest distance between them in the cluster. Other parameters showed farther distance from one another indicating weak association. Overall, the association indicates that the parameter influences one another in the matrix (Verla et. al., 2020).

3. 3. Water quality index

The water quality index (WQI) has been extensively used by many researchers for assessing the suitability of groundwater for consumption (Duru et. al., 2017; Charity et. al., 2018; Verla et. al., 2019; Ibe et. al., 2020). The index is an algorithm that gives a single number as final result from measured variables (physical, chemical, or biological parameters) computation, thereby expressing a measure of the qualitative state of the groundwater (Enyoh et. al., 2018). In this study, WQI was used as described by Ibe et al., (2020). The WQI was calculated according to Eq. 1, using assigned weight and percent values depending on the concentration of the parameter under investigation.

$$\text{WQI} = k(\textstyle\sum_{i=1}^{n} q_i P_i)/\sum_{i=1}^{n} P_i \qquad (1)$$

where: q_i = quality rating for the nth parameter, calculated for all sites as the ratio of mean value of a particular parameter to reference value of that particular parameter multiplied by 100 (Duru et. al., 2017; Enyoh et. al., 2018). P_i = weight assigned for nth parameter, taken from previous report for groundwater by Duru et. al., (2017) and k = constant taken from the values in Table 2, (all samples were assigned k value of 1), due to the appearance of the groundwater at the time of sampling (Table 2).

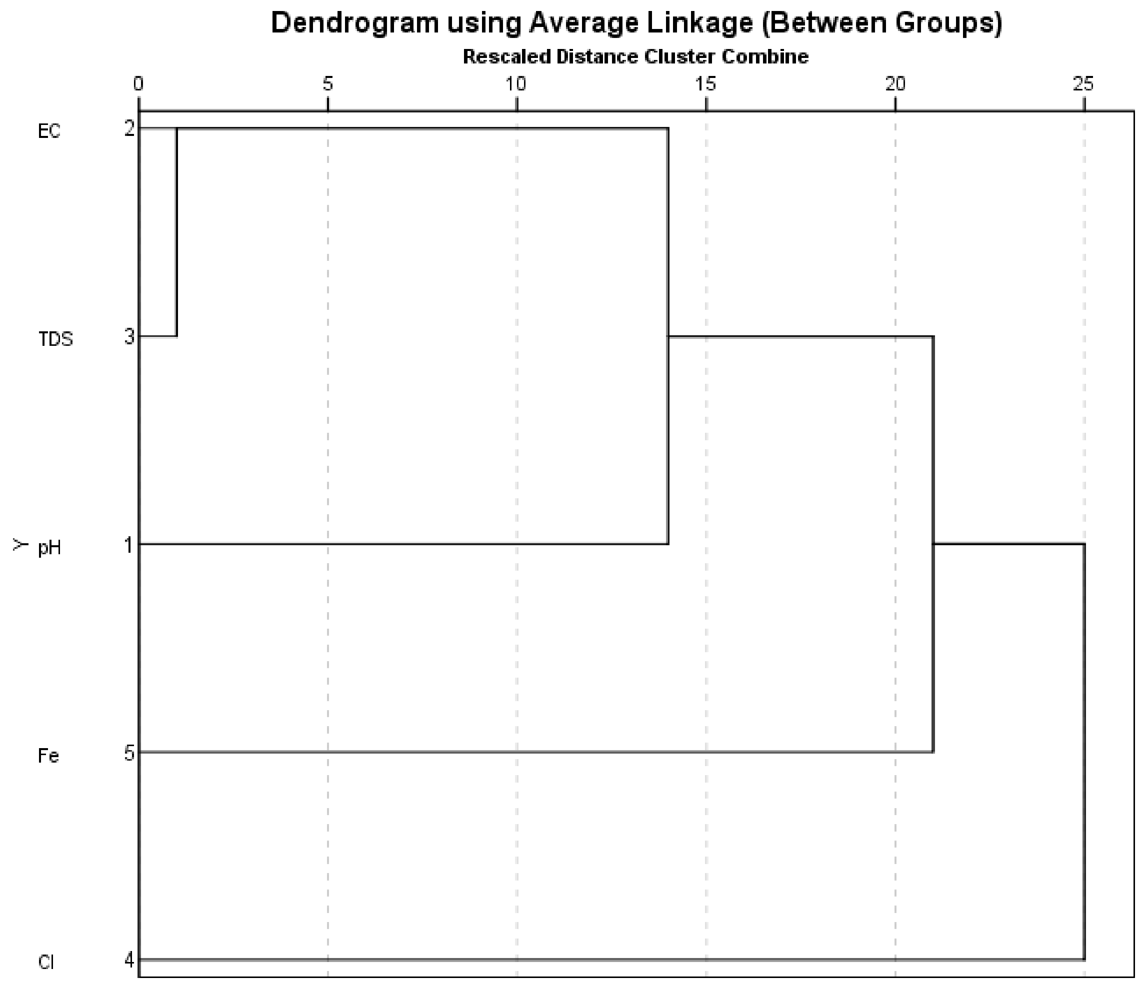

Figure 7. Dendrogram of water quality parameters.

For each sample assessed, the sum of the quality rating and weighted parameters being considered was multiplied by a constant related to the sample's sensitivity features (k constant) based on appearance and water odor (Table 2) and then divided by the total weighted parameters, which gives the WQI. The parameters used in the study are presented in Table 2.

The quality scale for WQI indices have been classified into five types by some authors and it is presented in Table 3. In Figure 8, the WQI for the three year of study is presented. All water samples showed excellent quality with WQI < 50. This suggests that the groundwater samples are yet to be contaminated based on the studied parameters.

Table 2. Constant values assigned by characteristic of water.

Groundwater condition based on visual appearance	Constant (*k*) value
For clear waters without apparent contamination	1
For waters with slight color, slight scum, and slightly turbid	0.75
For water with appearance of pollution and a strong odor	0.50
For dark waters that present fermentation and with a strong odor	0.25

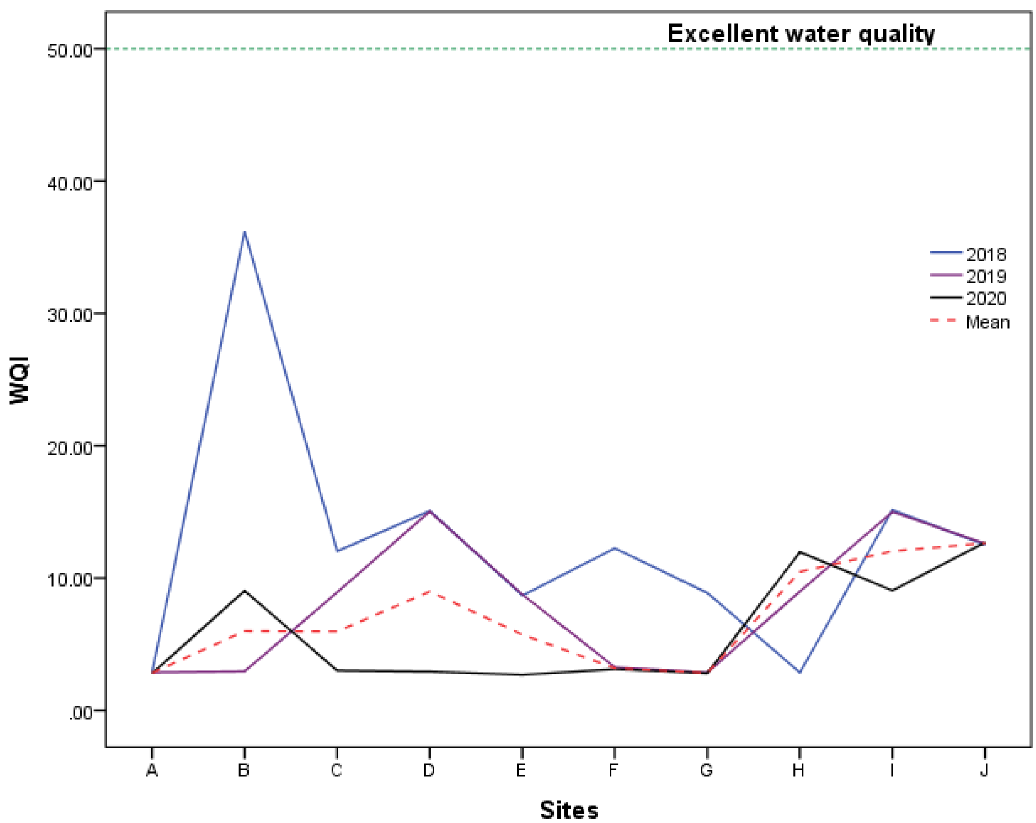

Figure 8. Water Quality Index in the three year of study

Table 3. Classification for water quality according to the WQI levels.

WQI level	WQI scale	Use
0-50	Excellent water quality	Can be consumed without necessary purification
50.5-100	Good water quality	Requires minor purification for consumption

100.5-200	Poor water quality	Requires intermediate purification for consumption
200.5-300	Very poor water quality	Dubious safety for consumption without significant purification
300.5 and above	Unsuitable for drinking	Unacceptable for consumption at all

3. 4. Health risk assessment

The health risks assessment was done based on the Fe content in the ground water. The average daily dose (ADD) due to exposure to Fe resulting from ingestion of contaminated groundwater was determined using Eq. 2.

$$ADD = \frac{\text{Cw X RI X FE X DE}}{\text{Bw X AT}} \text{ in mg/L/day} \tag{2}$$

where, ADD: average daily dose of metals through ingestion of water (mg/L/BWday); Cw: average concentration of the estimated Fe in water (mg/L); RI: ingestion rate is (2.2 L/day for adults; 1.8 L/day for children) obtained; FE: exposure frequency (365 days/year); DE: exposure duration (70 years for adults; and 6 years for children); B_W: average body weight (70 kg for adults; 15 kg for children); AT: averaging time (365 days/year × 70 years for an adult; 365 days/year × 6 years for a child) as described in earlier reports (Ibe et al., 2018; Ibe et al., 2019b).

The potential non-carcinogenic risk was calculated as hazard quotient (HQ), due to exposure to Fe. Hazard quotient (HQ) toxicity potential was evaluated as the ratio of ADD to reference dose (RfD), expressed according to Eq. 3. The reference dose Fe = 0.009 mg/L/day (USEPA, 2016).

$$HQ = \frac{ADD}{RfD} \text{ x } 10^{-3} \tag{3}$$

The results for the computed ADD and HQ are presented in Tables 4 and 5. Generally, when ADD and HQ are less than 1, it is assumed to be safe and taken as not significant non-carcinogenic risks (USEPA 1993). The obtained ADD and HQ were less than 1 and it could be said that the consumption of Fe via these water sources is safe and would pose no non-carcinogenic health risks.

Table 4. Average daily dose (mg/L/BWd) of heavy metal (Fe) at different locations for adults and children.

SITES	2018		2019		2020	
	Adult	**Children**	**Adult**	**Children**	**Adult**	**Children**
A	0.00	0.00	0.00	0.00	0.00	0.00
B	3.46E-3	0.0132	0.00	0.00	6.29E-4	2.4E-3

C	9.43E-4	3.60E-3	6.29E-4	2.40E-3	0.00	0.00
D	1.26E-3	4.80E-3	1.26E-3	4.80E-3	0.00	0.00
E	6.29E-4	2.4E-3	6.29E-4	2.40E-3	0.00	0.00
F	9.43E-4	3.60E-3	0.00	0.00	0.00	0.00
G	6.29E-4	2.4E-3	0.00	0.00	0.00	0.00
H	0.00	0.00	6.29E-4	2.4E-3	9.43E-4	3.60E-3
I	1.26E-3	4.80E-3	1.26E-3	4.80E-3	6.29E-4	2.4E-3
J	9.43E-4	3.60E-3	9.43E-4	3.60E-3	9.43E-4	3.60E-3

Table 5. Computed Hazard Quotients (HQ) from Consumption.

SITES	2018		2019		2020	
	Adult	Children	Adult	Children	Adult	Children
A	0.00	0.00	0.00	0.00	0.00	0.00
B	0.384	1.467	0.00	0.00	0.070	0.267
C	0.105	0.400	0.070	0.267	0.00	0.00
D	0.140	0.533	0.140	0.533	0.00	0.00
E	0.070	0.267	0.070	0.267	0.00	0.00
F	0.105	0.400	0.00	0.00	0.00	0.00
G	0.070	0.267	0.00	0.00	0.00	0.00
H	0.00	0.00	0.070	0.267	0.105	0.400
I	0.140	0.533	0.140	0.533	0.070	0.267
J	0.105	0.400	0.105	0.400	0.105	0.400

4. CONCLUSION

The study has shown that in the last three years the groundwater quality of Ota is excellent with physicochemical parameters such as electrical conductivity, total dissolved solids, chloride and iron conforming to World Health Organization standards. However, the ground water is acidic and could indicate potential contamination by organic materials. We recommend future studies on the assessment of heavy metal levels and other important parameters not covered in this study.

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