International Journal of Sciences

Research Article Volume 9 – October 2020 (10)

Quality Assessment of Water of Ajali Sandstone Aquifer Systems for Possible Industrial Establishments

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Abstract: Physico-chemical analyses of water samples from Ajali Sandstone aquifer units were carried out in order to assess the suitability of the water for various industrial purposes, determine seasonal effects on the water quality and quality distribution pattern within the study area. The study area covers an area extent of about 2,156 km^2. Techniques of American Public Health Association, and Trivedy and Goel were mainly employed in the analyses. The concentrations of major Physico-chemical parameters and properties of the water analyzed include those that are related to the selected industries considered in this study. Other parameters and properties are those that may affect very few of these industries. The results obtained from the study indicated that the quality of the water remained nearly constant throughout the seasons except for total hardness concentrations which were slightly higher during dry seasons while pH, sulphate, electrical conductance and total dissolved solids concentrations were slightly lower during dry season. Distributional variation in water was very insignificant that it cannot affect the usefulness or suitability of the water for various industrial standards. The results also revealed that the changes in the water quality distribution patterns were not in systematic manner. Only the taste, odour, and fluoride as major parameters met the standards for various industries where they were considered. For other major parameters, the water requires some degree of treatments to bring the water to required standard limits but the extent of treatment depends on the parameter and industry concerned. Generally, the water is fresh, soft to moderately hard, slightly acidic and may not pose adverse health hazard to users. Corrosive risk is moderate and the chances of incrustation of distribution system are narrow. The water has no significant aesthetic problem. Water of Ajali Sandstone aquifer units needs little or no treatment before use for air condition, boiler feeds, drinking, general food processing, and ice manufacturing industries. For other industries the water requires some degree of treatments before use as chemical or industrial processing water.

Keywords: Groundwater, Ajali, Quality, Assessment, Parameters, Industry**,** Establishment

1. Introduction

Diversification of nation's economy is a welcomed means of improving economic growth of the nation. There has been increase in demand from different quarters of the country to diversify country's economy in order to promote the nation's economic growth. It is globally accepted that nation's economy is partly determined by the number of reliable and viable industries established within the country. Availability of water is a basic necessity in establishment of certain industries and groundwater resource has been, and is still the main source of water for domestic supply and potential industrial water in the study area.

Naturally, all ground waters contain salts in solution that were derived from location and past movement of water and suitability of groundwater for various uses is determined by the type and amount of dissolved materials it contains as no water is pure for all industries. Purity of water depends on the intended use (Patil et al., 2012). Water quality required by chemical industrial processes varies widely even within some industries depending on processes involved and water for each process is required to meet certain safety standard. Thus, the quality of water in terms of physical and chemical parameters is crucial before use for various industrial purposes as no single water of specific quality can meet all the quality standards for all industries, (Todd, 1980: Hem, 1985: EUEPA, 2001: Sargaonkra and Deshpondev, 2003)**.** It is then technically necessary to treat water to bring it to the standard required by the process concerned before use. However, if the water requires extensive treatment it may not be economically feasible to utilize the supply (Hamill and Bell, 1986).

The industrial processes and major chemical constituents, physical properties and indices that were considered in this study are those which may have adversely affect the aesthetic quality and appearance of the industrial waters, impose health hazards on

Published at: http://www.ijsciences.com/pub/issue/2020-10/
DOI: 10.18483/ijSci.2388; Online ISSN: 2305-3925; Print ISSN: 2410-4477

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consumption and affect various industrial processes such as listed in Table 1.

The availability and reliability of groundwater for establishment of viable industries have been a serious threat to the development of the economy. Various industries have been closed down probably because the water used as processing materials are not of right quality or that they are not reliable in terms of seasonal changes. Some constituents of water are very poisonous when even taken as trace elements while some major constituents are very toxic when high in concentration. These when not properly taken care of or improved may affect water's usefulness for various purposes. Variations of water quality due to seasonal and or areal distributions have been a major problem affecting reliability and effective establishment of industries in many localities by increasing treatment rate, hence, cost of production and time.

The main aim of this study is to assess groundwater quality of Ajali Sandstone aquifer systems for possible use in various industrial processes, determine both seasonal and lateral variation effects on the water quality of water regarding industrial processes. The quality will be compared with established and existing international standards for the selected industries. The study will aid in the effective management of groundwater resources by providing information on the physic-chemical qualities of Ajali aquifer system and assists investors in taking valid decisions while considering industrial establishments.

The study area is located between latitudes 06^{o} 03' and 07^{o} 04'N and longitudes 007^{o} 18' and 007^{o} 30'E, in Enugu State, Southeastern Sedimentary Basin, Nigeria. It covers an area of about 2,156 km^{2} and consists of four geological formations (Fig.1).

The study area features two major seasons: dry season which usually lasts from late October to April and rainy season which lasts from May to early October. Ajali Formation is the most important geologic unit that bears aquifer of regional distribution within the study area with excellent hydraulic characteristics that makes it suitable source for large scale groundwater abstraction (Okogbue, 1988). Ajali Formation aquifer sand units are mineralogical mature and texturally sub-mature. Petrographic and mineralogical analyses indicated that polycrystalline quartz of sand-size grains are the dominant framework mineral. Rock fragments are rare but where they occur they occur as soft micaceous material with some sand-sized clay balls. Feldspar minerals are practically absent (Hoque and Ezepue, 1977). Boreholes penetrating Ajali Formation within the studied area encountered Ajali aquifer units at average depths of 160 and 200m.

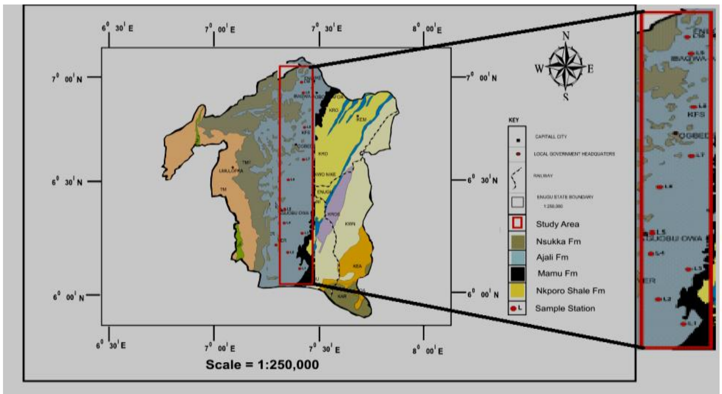

Fig. 1: Geologic map of Enugu State showing sampling stations

Generally, ground water only undergoes appreciable fluctuation in temperature at shallow depth, beneath which temperature remains constant. The depth at which temperatures are more or less uniform occurs at about 10m in tropics, increasing to 20m in polar region and ground water, except for shallow aquifer waters is generally free from pathogenic bacteria and virus. Dissolution of silicates other than quartz and clay accounts for most silica present in solution in groundwater and silica is only slightly soluble in water (Hamill and Bell, 1986). Water problems with respect to industries though complex can be classified into salinity, hardness, corrosiveness, toxity and miscellaneous.

Factors influencing corrosion of materials are: acidic water with pH below 7, high total dissolved solids in excess of 1000 mg/l, and presence of hydrogen sulfide, carbon-dioxide in excess of 50 mg/l and chloride in excess of 300 mg/l (Bouwer, 1978). To be potable means that the water must be significantly free from colour, turbidity, tastes and of moderate temperature and well aerated. Moreover, water should not pose any health hazard (Fair et al., 1971). Several types of organic matter may occur in groundwater but rarely in amount greater than 15mg/l (Walton, 1970: Hamill and Bell, 1986). Incrustation of materials is caused by carbonate hardness greater than 300ppmmmmm or total iron content greater than 2mg/l. Furthermore, manganese greater than 0.1 mg/l would lead to incrustation (Johnson, 1983). Nitrate, nitrite and ammonia as organic nitrogen occur in negligible small concentration not exceeding 5mg/l and are not often seen in ground water except where fertilizers are applied or from water of high organic content (Walton, 1970).

2. Materials and Methods

A total of twenty groundwater samples from boreholes completed in Ajali Formation aquifer systems (>100m deep) were collected and analyzed during this study. First set of ten borehole water samples were randomly collected during the peak of rainy season from pre-selected boreholes within the study area (Fig.1). Second set of ten borehole water samples were collected during peak of dry season from the same boreholes as in the first set of borehole water samples. The water samples were collected in sterilized and cork fitted polyethylene bottles and glasses of one liter capacity each per borehole for non-heavy metals and heavy metals respectively. Before collecting water sample from any of the pre-selected boreholes enough water pumping excise was performed to ensure that stagnant water in the borehole was discharged and true representative of formation water was subsequently collected. Samples were collected from locations where boreholes were accessible mainly from private owned boreholes within urban and semi-urban areas.

At each collection point, sampling bottle and glass were rinsed thoroughly with groundwater to be analyzed and filled with borehole water samples and then corked tightly. Collected samples were protected from direct sunlight during transportation, re-fridgenated at 4^{o}C and in the laboratory glass- wares used for analyses were sterilized for 15 minutes in an autoclave at 121^{o}C and all samples were analyzed within 24 hours of collection. For unstable parameters such as temperature, electrical conductivity (EC), and pH measurements were performed in the field in order to get dependable results using thermometer, Mettler Toledo Compact seven, conductivity and pH meter respectively. All the metals were analyzed using Atomic Absorption Spectrophotometer (model-Buck Scientific 210 VGP) and all anions analyzed using Ultra Violet Spectrophotometer (model-Ultra Spec 2100PRO). Sodium and potassium were determined by Flame photometric method. Fluoride concentration was measured using Spectrophotometer while dissolved oxygen (DO) and biochemical oxygen demand (BOD) were determined using HI9146 Dissolved Oxygen Meter. Total hardness was determined using titration method while Total dissolved solids was determined by method of difference. Most of the physic-chemical, parameters were determined by standard methods prescribed by Trivedy and Goel, 1986: American Public Health Association (APHA), 1998.

Limits of salt concentrations, recommended by the American Water Works Association, 1971 in various industries are given in Table 1.

Table 1: Ranges in Recommended Limiting Concentrations for some industrial process waters (units are mg/l, except as noted)

Industry or Use.	Turbidity (NTU)	Colour –Unit	Taste and odour (threshold)	Dissolved solid	Hardness ($CaCO_3$)	Alkalinity as $CaCO_3$)	PH (units)	Chlorides (Cl),	Sulphates (SO$_4$	Iron as (Fe)	Manganese (Mn)	Fluorides as (F)	Other requirements
Air conditioning	-	-	Low	-	-	-	-	-	-	0.5	0.5	-	Not corrosive or slime promoting
Baking	10	10	None-low	-	A	-	-	-	-	0.2	0.2	-	Potable
Boiler feed													Potable if steam is used for preparation
Brewing	0-10	0-10	None – low	500 – 1500 b	C	75-80d	6.5 - 7.0e	60-100	-	0.1	0.1	1.0	
Carbonated beverages	1-2	5-10	None-low	850	200-250	50-130	-	250	250	0.1 - 0.2	0.2	0.2 - 1.0	Potable; COD 1.5; organic matter, infinitesimal; algae and protozoa, none
Confectionery	-	-	Low-none	50-100	S0ft	-	>7.0	-	-	0.2	0.2	-	Potable
Dairy	-	Non e	None	500f	180	-	-	30	60	0.1 - 0.3	0.03-0.1	-	Potable; NO_3-N, 5.5 ; NO_2-N,0; NH_3, trace only; COD as $KMnO_4$, 12
Drinking	5	15	3, inoffen sive	500	-	-	-	250	250	0.3	0.05	1.4 - 2.4 g	Potable
Food canning and freezing	1-10	-	None to low	850	h	30-250	>7.0	-	-	0.2	0.2	1.0	Potable; free from saprophytic organisms; NaCl, 1,000-1,500; NO_3-N, 28; NH_3-N,0.4
Food equipment, washing	1	5-20	None	850	10	-	-	250	-	-	-	1.0	Potable; organic matter, infinitesimal
Food processing, general	1-10	5-10	Low	850	10-250	30-250	-	-	-	0.2	0.2	1.0	Potable
Ice manufacturing	5	5	Low	170-1,30 0	-	-	-	-	-	0.2	0.2	I	Potable; SiO_2,10
Paper and pulp	10	5	-	200	100j	75	-	-	-	0.1	0.05	-	Soluble SiO_2, 10; free CO_2,10; residual Cl_2,2
Laundering	-	-	-	-	0-50	60	6.0-6.8e	-	-	0.2 - 1.0	0.2	-	
Paper, groundwood	50k	30	--	500	200	150	-	75	-	0.3	0.1	-	Soluble SiO_2, 50; free CO_2,10
Paper, kraft, bleached	40	25	-	300	100	75	-	200	-	0.2	0.1	-	Soluble SiO_2.50; free CO_2,10
Paper, kraft, unbleached	100	100	-	500	200	150	-	200	-	1.0	0.5	-	Soluble SiO_2,100; free CO_2,10
Paper, soda and sulfate pulps	25k	5	-	250	100l	75	-	75	-	0.1	0.05	-	Soluble SiO_2,20; free CO_2,10
Rayon and acetate, fiber pulp	5	5	-	100f	8	50-75	-	-	-	0.0 5	0.03	-	Al_2O_3,8; Si, 25; Cu,5

production													
Rayon manufacture	0.3	-	-	-	55	-	7.8-8.3	-	-	0.0	0.0	-	
Sugar	-	-	-	Low	Low	-	-	20	20	0.1	-	-	Ca, 20; Mg, 10; bicarbonate, as $CaCO_3$, 100; sterile, no saprophytic organisms.
Tanning	20	10-100	-	-	50-5000	130	6.0-8.0	-	-	0.1-0.2	0.1-0.2	-	Bicarbonate hardness, low; COD, 8; heavy metals, none; Ca,10;Mg,5; bicarbonate, as $CaCO_3$,200
Textile	0.3-25	0-70	-	-	0-50	-	-	100	100	0.1-1.0	0.05-1.0	-	

Note: (a) some calcium is necessary for yeast action. Too much hardness retard fermentation, but too little softens the gluten to produce soggy bread. Water of zero hardness is required for some cakes and crackers; (b) Not more than 300mg/l of any one substance; (c) $CaSo_4$ less than 100 to 500 mg/l ; $MgSo_4$ less than50 to 200 mg/l.(d) For dark beer alkalinity as $CaCO_3$ may be 80 to 150 mg/l. (e) Range, lower to upper limits (f) Total solids (g) Tolerance limit depends on annual average of maximum daily air temperature for a minimum of 5 years (h) For legumes, 25 to 75; for fruits and vegetables, 100 to 200 ;for peas, 200 to 400 (I) 1.5 mg/l of fluoride have been reported to cause embrittlement and cracking of ice (J) Calcium hardness, 50 (k) No gritty material l Calcium hardness, 50; magnesium hardness , 50. The stated values are general averages only. There may be much local variance.

3. **Results**

The results of the physic-chemical parameters of the different water samples of boreholes analyzed during dry and rainy seasons are as shown in Tables 2 and 3 respectively.

Table 2: The physico-chemical results of borehole waters analyzed during dry season.

Parameter	UNIT	**L_1**	**L_2**	**L_3**	**L_4**	**L_5**	**L_6**	**L_7**	**L_8**	**L_9**	**L_{10}**	**Min.**	**Max.**
Colour	TCU	5	3	1.0	5	4	5	3	4	1.0	5	1.0	5
Odour	-	None	None	None	None	None	None	None	None	None	None	None	None
Taste	-	None	None	None	None	None	None	None	None	None	None	None	None
Temperature	°C	26	27	28	27	26	26	27	27	28	27	26	28
Turbidity	NTU	0.8	0.8	0.7	0.9	1.0	4.5	0.9	2.5	0.7	0.8	0.7	4.5
Alkalinity ($CaCO_3$)	Mg/L	200.00	150.00	100.00	200.00	150.0	50.00	50.00	50.00	50.00	100.00	50.00	200.00
BOD	Mg/L	0.29	0.27	0.42	0.26	0.37	0.44	0.38	0.38	0.31	0.25	0.25	0.44
Chloride (Cl^-)	Mg/L	21.84	20.85	16.87	19.36	18.86	19.86	18.86	18.37	18.36	21.35	16.87	21.84
DO	Mg/L	6.85	7.11	7.10	7.22	6.87	6.85	6.71	7.01	7.18	6.97	6.71	7.22
EC.	µ S/ Cm	22.3	39.5	38.8	41.2	48.6	13.03	23.2	20.00	22.2	40.20	13.03	48.6
Fluoride(F^-)	Mg/L	0.35	0.30	0.40	0.21	0.33	0.28	0.28	0.42	0.28	0.35	0.21	0.42
Iron(F^{2+})	Mg/L	BDL	0.14	0.06	0.12	BDL	BDL	BD	BDL	BDL	BDL	BDL	0.14
Manganese (M^{2+})	Mg/L	0.08	BDL	BDL	0.02	BDL	0.01	0.17	0.15	BDL	0.12	BDL	0.17
Nitrate (NO_3^-)	Mg/L	1.13	1.05	2.66	2.78	2.75	1.04	1.02	1.15	1.10	1.21	1.02	2.78
pH		4.98	5.06	4.58	5.82	4.83	4.68	4.47	4.65	5.70	5.74	4.47	5.82
Sulphate (SO_4)	Mg/L	23.83	25.05	34.98	98.55	31.02	34.42	27.77	51.92	28.65	32.10	23.83	98.55
Total Hardness ($CaCO_3$)	Mg/L	28.00	84.00	72.00	22.00	54.00	26.08	90.00	42.00	46.00	100.00	22.00	100.00
TDS	Mg/L	20.00	20.00	BDL	20.00	20.00	20.00	BDL	40.00	BDL	BDL	BDL	40.00

Key: BDL (Below Detecting Level- indicating zero values in this study); L_1-L_{10} (Locations); BOD (Biochemical Oxygen Demand); EC (Electrical Conductance); DO (Dissolved Oxygen) ; pH (Hydrogen ion); TDS (Total Dissolved Solids).

Table 3: The physico-chemical results of borehole water analyzed during rainy season.

Parameters	Unit	**L_1**	**L_2**	**L_3**	**L_4**	**L_5**	**L_6**	**L_7**	**L_8**	**L_9**	**L_{10}**	**Min.**	**Max.**
Colour	TCU	5	4	1.1	5	5	5	5	5	1.7	4	1.1	5
Odour	-	None	None	None	None	None	None	None	None	None	None	None	None
Taste	-	None	None	None	None	None	None	None	None	None	None	None	None
Temperature	°C	26	27	26	28	27	27	26	28	27	28	26	28
Turbidity	NTU	0.5	0.9	0.7	0.8	1.0	4.5	1.5	2.0	0.8	0.9	0.5	4.5
Alkalinity ($CaCO_3$)	Mg/L	100.00	75.00	100.00	50.00	25.00	50.00	25.00	100.00	50.00	50.00	25.00	100.00
BOD	Mg/L	0.40	1.80	0.32	0.25	0.60	0.31	0.28	0.38	BDL	BDL	BDL	1.80
Chloride (Cl^-)	Mg/L	63.83	46.10	19.86	86.38	29.79	21.84	29.79	26.81	24.82	30.78	19.86	86.38
DO	Mg/L	21.20	20.60	19.40	18.40	18.80	19.20	19.20	21.00	19.40	17.50	17.50	21.20
EC.	µ S/ Cm	256.00	204.00	12.64	136.10	38.30	15.00	20.80	18.40	26.00	48.10	12.64	256.00
Fluoride(F^-)	Mg/L	0.4	0.3	0.5	0.2	0.3	0.3	0.28	0.4	0.28	0.35	0.2	0.5
Iron(F^{2+})	Mg/L	BDL	BDL	BDL	BDL	BDL	BDL	0.03	BDL	BDL	BDL	BDL	0.03
Manganese (M^{2+})	Mg/L	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Nitrate (NO_3^-)	Mg/L	1.79	1.42	1.46	1.59	1.40	1.43	1.47	1.47	1.47	1.56	1.40	1.79
Ph		5.80	6.08	5.54	5.29	6.11	6.19	6.26	6.42	5.52	6.51	5.29	6.51
Sulphate (SO_4^{2-})	Mg/L	40.79	40.81	50.65	12.29	83.27	104.03	83.54	50.29	36.32	39.98	12.29	104.03
Total Hardness ($CaCO_3$)	Mg/L	16.00	13.00	11.20	9.60	3.00	2.40	10.60	2.00	8.60	10.00	2.00	16.00
TDS	Mg/L	60.00	180.00	60.00	140.00	150.00	80.00	60.00	32.00	140.00	200.00	32.00	200.00

Key: BDL (below detecting level indicating zero values in this study); L_1-L_{10} (Locations); BOD (Biochemical Oxygen Demand); EC (Electrical Conductance); DO (Dissolved Oxygen); pH (Hydrogen ion); TDS (Total Dissolved Solids).

From the results it can be seen that the values of all parameter in all the water samples are: colour (1.1 to 5.0 TCU), taste and odour (unobjectionable) Temperature values seemed to be nearly constant ranging from minimum of 26 ^oC to maximum of 28 ^oC. The observed turbidity values (0.5 and 4.5NTU), total dissolved solids (0 to 200mg/l), (total hardness as $CaCO_3$ (2.0 to 100mg/l). Alkalinity values as $CaCO_3$) were found to be between 25 and 200mg/l, while value of hydrogen ion (pH) constituent of water samples tested was moderately low ranging from minimum of 4.47 to maximum value of 6.51unit for the entire water samples. Moderately low pH values may be associated with small amounts of mineral acids from sulfide sources or with organic acids. Chloride and sulphate values of all the waters analyzed varied between 16.87 and 86.36mg/l and from 23.88 to 104.30mg/l respectively. Iron (Fe^{2+}) values were below detecting limit in 16 (80%) water samples analyzed but ranged from 0.0 to 0.14mg/l. Manganese (0.0 and 0.17 mg/l). Tables 2 and 3 indicated that the values of fluoride in all the tested water samples varied between 0.2 and 0.5mg/l. The value of biological oxygen dissolved (BOD) and dissolve oxygen (DO) were found to be in the range between 0.25 and 1.80 mg/l and 0.71 and 21.20mg/l. The value of EC varied from 12.64 to 256.00 mg/l. Value of nitrate in the present study ranged between 1.02 and 2.78 mg/l while bicarbonate ranged between 24.99 and 99.99mg/l.

Other constituents and properties of the water that were considered in very few industrial processes are: corrosiveness, incrustation, potability, organic matter contamination, presence of microorganisms, salinity, and silica. Factors controlling these properties are mainly the concentrations of some physic-chemical parameters

4.0 Discussions

Turbidity and colour values met with the required standard limits except in rayon manufacture and dairy industry respectively. For taste and odour the values indicated that the water was suitable for all industrial processes where they were considered. The values indicate that the water contained less suspended and organic matters. Total dissolved solids (TDS) values were exceedingly below 1000mg/l**)** indicating that the water is fresh water (Hem, 1970: Freeze and Cherry, 1979) probably because the water had short resident time and or the rock and water reactions had reached equilibrium. The value shows that all the water samples tested in this study conformed to the recommended limits set by (American Water Works Association, 1971), for all the industries where the value of TDS was needed except for production of rayon and acetate fiber**.** According to WHO (1984) water containing less than 250mg/l of total dissolved solids is generally good for household and for many industrial purposes**.** Total hardness as $CaCO_3$ results showed that the water was soft to moderately hard (Hem, 1970) indicating that the water requires some degree of treatments for cakes and crackers, legumes, peas, paper and pulp, laundry, textile, food equipment washing and rayon-acetate fiber productions. Alkaline content of the waters does not fall within the recommended limits for most of the industries including brewing; carbonated beverages; paper and pulp, fine; laundry; tanning; paper groundwood; paper, kraft, bleached; paper, kraft, unbleached; paper, soda and sulphate pulps; rayon and acetate, fiber pulp production but needs some treatments for alkaline before use for the above industries. The range of 4.45 to 6.51 for pH indicates that the water is slightly acidic (Ezeigbo and Obiefuna, 1995), hence below the recommended ranges for almost all the industrial processes where the concentrations standards were required. Chandeluri et al., (2010) stated that extremes of pH concentrations of water can affect the potability of the water but corrosiveness effect on the distribution system is more problematic. WHO (1989) observed that water with low pH may cause impairment or malfunctioning of certain physico-chemical treatment plants. The values of chloride indicated that the water needs some treatment of chlorine before use for dairy; sugar; paper, groundwood; paper, soda and sulphate pulp industrial processes**.** Sulphate results indicated that the water needs some degree of treatment to bring the water to the standard limit for dairy industrial processes. The iron content of the water showed that the water required treatment for iron for use in brewing; paper and pulps, fine; sugar; rayon manufacture; paper, soda and sulphate pulps industrial purposes while treatment of the water for manganese for use in brewing; drinking; paper and pulps, fine; dairy, rayon manufacturing, paper groundwood, paper kraft bleached, paper soda and sulphate industrial processes was necessary**.** Fluoride content of the water indicated that the water met the standards limits for all the industrial processes where fluoride concentrations were considered.

Considering the recorded values of all the parameters that control the corrosiveness of water only pH value that did not conform to the required limit of (4.47-6.51mg/l). This indicates that the water is slightly corrosive with moderate risk. The low values of total dissolved solids (0.00-200.00mg/l) and electrical conductance (12.64-256.00) indicated that the water was fresh, hence, met with all standards for industries where the salt quality of the water was considered. Since the values of total hardness is less than 300mg/l, iron less than 2mg// and only 15% of the waters contain manganese in concentration greater than 0.1mg/l chances of incrustation is narrow.

From tables 2 and 3, the water was potable except that pH value 4.47-6.51unit did not comply with the ranges recommended for most of the industrial processes where pH value for potability property of processing water were required. Low values of dissolved oxygen (6.71-19.47 mg/l) in the water and the depth of boreholes being greater than 100m suggest that microorganisms' activities were low in the water, thus, the water is assumed to contain little or no pathogenic and saprophytic organisms. Presence of pathogenic organism (if any) in ground water should be attributed to poor borehole construction, completion and development and or contaminants from human activities (Walton, 1970: Ishiaku and Ezeigbo, 2000). The low nitrate and sulphate concentration values (1.02 to 2.78mg/l) and (23.88 to104.03mg/l) respectively, and the general low iron and manganese concentration values (0-0.14mg/l and 0-0.17mg/l) respectively may be assumed to be indicative of low organic activity (Okafor, 1994). Quartz mineral forming more than 90% of the aquifer component and the total, dissolve solids values being low (0.00-200.00mg/l), is an indication of short resident time, hence, silica content of the water is assumed to be low. Over time equilibrium must have reached between rock and water interactions in Ajali Sandstone aquifer system as the temperature was nearly constant. Low concentrations nitrate, sulphate, colour, DO and BOD indicated minimal concentration of organic matter in the water which in turn determines the concentration of hydrogen sulphide.

Since there is indication minimal organic concentration and the water is odourles it is an indication that the water contains hydrogen sulphide concentration was less than 1.0mg/l (Hamill and Bell, 1986).

The results obtained from the study indicated that the quality of the water remained nearly constant throughout the seasons except for total hardness concentrations which were slightly higher during dry seasons while pH, sulphate, electrical conductance and total dissolved solids concentrations were slightly lower during dry season. Distributional variation in water was very insignificant that it cannot affect the usefulness or suitability for various industrial standards. Physic-chemical concentrations do not change in systematic manner rather randomly. The insignificant variations were assumed to be due to the variations in degree of natural attenuation and dilution and also probably due to uncontrolled waste disposals practices and general human activities that may lead to water point source contaminations which vary from place to place.

5. Conclusions

For the taste, odour, and fluoride, silica, organic matter, salinity, incrustation properties, the water met the standard for various industries where they were considered. For other parameters, the water requires some degree of treatments to bring the water to required standard limits but the extent of treatment depends on the parameter and industry concerned. Generally, the water is fresh, soft to moderately hard, slightly acidic and may not pose adverse health hazard. Corrosive risk is moderate and the chances of incrustation of distribution system are narrow. The water has no significant aesthetic problem. Water of Ajali Sandstone aquifer units needs little or no treatment before use for air condition, boiler feeds, drinking, general food processing, and ice manufacturing industries. For other industries the water requires some degree of treatments before use as chemical or industry processing water.

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