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Physicochemical Assessment of Aquifers in Agbor Metropolis, Delta State, Southern Nigeria

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ABSTRACT

Water Pollutants may be physical or chemical and may pose health hazards to human and livestock when used for drinking and other domestic purposes. Hence, the physiochemical characteristics of aquifers from various locations in Agbor metropolis were determined to ascertain their suitability for domestic uses. A total of eighty-four (84) water samples: twenty-eight (28) per month, was collected in the months of October, November and December, 2018 and analysed using standard methods for water and wastewater analysis. The results of the study revealed that the aquifers are soft, fresh, and contaminated with heavy metals: Fe (0.00-0.70 mg/l), Cr (0.00-0.11 mg/l) and Mn (0.00-0.50 mg/l). The hardness values ranged from 16.00 to 126.00 mg/l and 30.00 to 640.00 mg/l for borehole and well water samples respectively. The electrical conductivity (E.C.) values range from 9.56 to 181.30 μScm^{-1} for the borehole water samples while that of the well water samples range from 3.65 to 58.00 μScm^{-1}. The DO values range from 2.30 to 78.03 mg/l and 2.60 to 6.10 mg/l for borehole and the well water samples respectively. It is recommended that these water sources be protected from further contamination. Also, bacteriological assessment of these aquifers should be carried out in the identified sample locations since Mn and Cr contaminations are indicators for microbial contamination.

1. INTRODUCTION

Fresh water is the most useful water resource that is essential to man for domestic, industrial and agricultural purposes. Fresh water exists as surface as well as groundwater and, usually, unevenly distributed over the earth's surface, just as other natural resources. Nigeria in general and Delta State in particular is a water-rich geographical area with numerous rivers, lakes, streams, boreholes, and hand-dug wells (Amitaye and Uche, 2018). The quality of most of these water sources is unknown or unverifiable thus, the need to evaluate fresh water sources based on physical, chemical and bacteriological indicators.

Water of good quality is crucial to maintaining good health and hygiene and by large, for sustainable socio-economic development (Abdo et al., 2010; Amitaye, 2011). It has a broad impact on health, food, energy and economy (Gleick, 1998). Fresh water is a major constituent of man and other organisms. It is involved in almost every physiological activity essential for proper homeostatic functions in man. Fresh water is domestically used for drinking, bathing, washing, cooking and maintaining personal hygiene (Egboh and Emeshili, 2007); industrially for productions and hydro-power generation; and agriculturally for irrigation and livestock purposes (Torcellini et al., 2003; Manahan, 2005) There is barely any activity of man that excludes water utilization. Thus, the place of good water quality for sustainable health development cannot be overemphasized.

Groundwater is an important source of water throughout the world. It is estimated that groundwater sources provide between 95 and 100 percent of potable water supplies in some developing countries (example: Oman and Cuba) whereas most regions of the world obtain 30-50 percent of their potable water supplies from groundwater sources (Hydrologists Without Borders, 2008). Even in Canada, a country with abundant surface water resources, 30 percent of the population relies on groundwater for domestic use (Jeremiah, 2008). In Obiaruku, Delta State, almost all the consumed fresh water comes from groundwater (Amitaye and Uche, 2013; Amitaye and Uche, 2017). The trend is indifferent in almost all Sub-Saharan African cities.

Despite its importance throughout the developed and developing world, ground water contamination by natural and anthropogenic substances is common (Mengxiong, 1987; Rim-Kukeh et al., 2004; Okuo et al., 2007; Narayanan, 2009; Amitaye and Uche, 2013). Anthropogenic groundwater contaminants were often generated in various industrial processes prior to their disposal to the subsurface (Carroll, 2009). Common groundwater contaminants include the use of polychlorinated biphenyls (PCB) in electrical transformers, heavy metals as paint additives or in metal plating and smelting operations, pesticides for agriculture, and chlorinated solvents in dry cleaning installations (National Research Council, 1997). All of these operations have caused subsurface contamination due to improper disposal of hazardous chemicals.

Common disposal practices included accidental releases due to leaky underground storage tanks or compromised landfill liners; and intentional releases due to underground storage systems designed to slowly leach liquids from (solid wastes) into the subsurface, subsurface injection wells, or land application of contaminants (National Research Council, 1997; National Research Council, 2005). These contaminants have the potential to induce serious health problems and even death. For example, PCBs, and the chlorinated solvent and trichloroethylene (TCE), are carcinogens (National Research Council, 2006); pesticides have been found to cause birth defects (Eskenazi and Castorina, 1999), and lead and some other heavy metals can impair organ development in fetuses (National Research Council, 1993). In all, fresh water contaminations cause serious health and environmental problems.

As water sources become more stressed due to population growth and climate change, incidence of water contamination and pollution may increase substantially. To minimize or forestall water pollution episode, the first step in this direction would be to determine the quality parameters of available fresh water resources, particularly, groundwater sources, to ascertain their desirability and potability. The second step for improving sustainable access to improved water is to create community awareness of their water supply and sanitation services (Mtinda, 2007). Improving the water supply coverage and quality has a number of consequences in addition to the fact that investigating the socioeconomic and other factors affecting water consumption patterns provides guidance for policy makers and those in various agencies implementing water related projects. These two lines of action guided the present study to ascertain the potability of aquifers in

Agbor metropolis, Delta state, Southern-Nigeria. Therefore, the aim of the study is to ascertain the suitability of aquifers from Agbor metropolis for domestic uses.

2. MATERIALS AND METHODS

2.1. The Study Area

Agbor metropolis spreads out on hills and a deep valley (the Orogodo valley). The metropolis is geographically located at latitude 6°16' North and longitude 6°9' East. The area is laterite-rich with good loamy soil for agricultural productions. Most persons in the area are farmers with some civil servants and traders. The study area is also a beehive of commercial as well as academic activities. It houses a college of education, school of nursing and other numerous institutions.

2.2. Study Population

The population consists of all groundwater resources in Agbor metropolis which are extractable through borehole and well water sources.

2.3. Sample Size

A total of twenty-eight (28) water samples were examined per month: fourteen (14) boreholes and fourteen (14) artificial wells for three months. The boreholes and artificial wells were selected on the bases of population density and the volume of economic activities.

2.4. Sample Collection and Preservation

The water samples were collected during the day between 7:00 hrs and 15:00 hrs from the months of October to December, 2018 for analyses. Plastic containers of 2 litre capacity were used for sample collection. The containers were pre-washed with detergent, rinsed with distilled water and then with 5% nitric acid and finally with distilled water. The plastic containers were further rinsed(twice) with the water sample at each sampling point.

The groundwater (borehole and well water) was pumped out and allowed to run for about 20-minutes before the water sample was collected. This was done to obtain a true representation of the groundwater regime of each sampling points.

2.5. Physiochemical Characterization

At each sampling points, little amount of the water sample was placed in a beaker and the pH, dissolved oxygen (DO), electrical conductivity (EC) and temperature were respectively determined in-situ with a multimeter (HANANA model), while the other chemical parameters were determined at the Post Graduate laboratory, Department of Chemistry, University of Benin, Edo State by standard methods (American Public Health Association, 1998).

2.6. Heavy Metals Determination

Another set of plastic containers, of 1 litre capacity, were properly prepared against contamination. The samples for heavy metal analyses were collected in the 1-litre capacity containers and preserved with 5ml concentrated nitric acid (HNO_3), to halt microbial activities and loss of metals by precipitation and adsorption. The metals were determined using Perkin Elmer Atomic Absorption Spectrophotometer (Buck Scientific Model 200A/210) by standard methods (American Public Health Association, 1998).

3. RESULTS AND DISCUSSION

The results of water analyses are summarized in Tables 1-6. Of the water quality parameters examined, electrical conductivity (E.C.), hardness, and alkalinity were within the desirable limits for drinking water (World Health Organisation, 2004). The electrical conductivity values ranged from 9.56 to 181.30 μScm^{-1} for the borehole water samples. This result shows that groundwater from Agbor metropolis is fresh. Also, the E.C values varies directly with the depth to the aquifer though, wastes discharge from automobile exhaust and workshops, and battery worksites contributed to variation in the E.C values (Ugbune, 2010; Amitaye and Uche, 2013). The borehole water sample (AOB_1) has the highest E.C. value as well as the chloride ion concentration (Table 1). The high electrical conductivity value of this sample may be due to chlorides of sodium, potassium, and calcium among other cations. This explains why this borehole water sample (AOB_1) is the hardest of all the studied borehole water samples (Okuo et al., 2007; Amitaye and Uche, 2017).

All the borehole water samples are soft and there is no clear-cut relationship between E.C. values, hardness and chloride concentrations for the water samples. This implies that water quality from Agbor metropolis is being degraded from several different contaminant sources. This also implies that borehole water sources from Agbor metropolis are fresher and harder than borehole water sources from neighbouring towns of Umutu (Egboh and Emeshili, 2007) and Obiaruku (Amitaye and Uche, 2017) respectively.

Most of the borehole water samples are mildly acidic with values ranging from 3.42 to 8.37 (Table 1). Borehole water sample (AAB_2) has the highest pH value (8.37) with good buffer capacity among the borehole water samples examined. This sample was collected about 1 km from Orogodo river and less than ½ km from Agbor main market. This does not imply that the alkalinity value was entirely due to contaminants from the main market because other borehole water samples: AAB_1, NRB_1, NRB_2, and NRB_3 collected around the main market areas have little or no buffer capacity against pH adjustment. The alkalinity value of this sample may be due to the construction wastes emanating from maintenance operation on a minor road adjacent to the sample location (AAB_2).

On the other hand, the well water samples are fresher than the borehole water samples. The E.C. values for the well water samples ranged from 3.65 to 58.00 μScm^{-1}. The low E.C. values of the well water samples may rise from the fact that the wells are not natural but artificial hence, there is little or no contact with soil minerals which are known to induce cations and anions into water sources by contact.

Also, the pH value of the well water samples is higher than that of the borehole water samples. This was unexpected because rain water from Agbor metropolis is mildly acidic (Uche et al., 2018). Most of the well water is product of rainfalls and so the alkaline pH value for the well water may result from long term storage in wells made of concrete walls. The pH values for the well water samples range from 4.01 to 9.30. The pH range of 6.40-9.30 is for water from concrete (ring) wells. The variations in pH values among the well water samples are not unconnected to the thickness of concrete separating the water from the natural geological materials. The DO values range from 2.60-6.10 mg/l and 2.30-78.03 mg/l for the well and borehole water samples respectively (Table 3). This indicates that almost all the water samples are saturated with oxygen hence; these water sources are suitable for aquacultures, bathing, cooking, and animal husbandry and for irrigation purposes (Sharma et al., 2010).

Nevertheless, about 43% of the borehole water samples are rich in organic matter. The BOD values for the borehole and well water samples are in the range of 2.10 to 3.90 mg/l though the borehole water is safer than the well water in terms of BOD. About 86% of the well water samples have BOD values (Table 2) above the maximum permissible limits of 3 mg/l recommended by World Health Organisation, (2004) and Federal Environmental Protection Agency, (1991) for drinking water.

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The BOD value measures the levels of organic matter in water for over 5 days period. Hence, long term storage of well water may cause it to be unfit for drinking as it may encourage rapid microbial growth and ultimately, water borne outbreak.

Of the six heavy metals determined in the water samples, copper (Cu) loads is below the WHO desirable limits for drinking water. The effects of drinking water rich in copper include vomiting, diarrhea, jaundice, extensive liver damage and hemoglobinura (Niels et al., 2002; Sharma, 2006). Iron (Fe) is a trace element essential in the formation of haemoglobin. About 90% of the borehole water samples and 50% of well water samples are contaminated with iron.

Table 1: Physio-chemical characteristics of borehole

Sample code	pH value	E.C. (μScm^{-1})	Temperature (^oC)	Depth (Ft)	DO	BOD	Cl^-	Hardness (as $CaCO_3$)	Total Alkalinity (as $CaCO_3$)
AAB_1	4.70	13.83	24.6	360	3.50	2.90	124.25	85.00	ND
AAB_2	8.37	32.10	23.8	200	5.20	2.10	177.75	60.00	10.00
AOB_1	3.42	181.30	28.3	340	3.70	3.90	213.00	126.00	NDL
AOB_2	5.30	22.00	28.7	335	4.90	3.00	124.25	46.00	NDL
AOB_3	5.30	18.49	25.8	330	7.80	2.70	106.50	28.00	NDL
NRB_1	4.78	13.09	24.8	330	2.30	2.30	71.00	42.00	NDL
NRB_2	4.55	14.80	25.0	150	3.80	3.30	88.75	60.00	NDL
NRB_3	3.58	114.20	24.9	130	4.10	3.00	195.25	34.00	NDL
OB_1	3.69	94.10	25.6	120	5.60	2.90	177.50	60.00	NDL
OB_2	4.13	12.13	27.6	360	3.80	3.30	105.50	16.00	NDL
OB_3	4.03	41.40	26.4	380	3.20	2.90	106.50	40.00	NDL
ALB_1	4.87	9.56	25.3	320	5.50	3.10	124.25	94.00	NDL
ALB_2	4.58	21.60	24.9	330	3.70	2.40	177.50	90.00	NDL
ALB_3	4.66	21.40	24.8	328	4.60	2.80	17.75	46.00	NDL

E.C. = Electrical Conductivity, DO = Dissolved Oxygen; BOD = Biological Oxygen Demand; Cl^- = Chloride; AA= D.D.P.A; AO = Agbor-Obi; NR = Near River (Orogodo river); AL = Alihame areas; O = Owa-Nta; B = Borehole water, W = artificial well; NDL= Not within Detection limit

(DO, BOD, Cl-, hardness and total alkalinity are in mg/l)

Table 2: Physiochemical characteristics of water from artificial wells (W)

Sample code	P^H value	E.C. (μScm^{-1})	Temperature (^oC)	Depth (Ft)	DO	BOD	Cl^-	Hardness (as $CaCO_3$)	Total alkalinity (as $CaCO_3$)
AAW_1	9.27	40.40	24.0	40	3.50	2.10	35.50	190.00	28.00
AAW_2	4.01	58.00	24.0	30	5.60	3.10	124.25	640.00	NDL
AOW_1	6.47	24.30	26.2	38	2.60	3.30	35.50	34.00	NDL
AOW_2	6.40	15.41	28.0	35	4.30	3.20	53.25	32.00	NDL
AOW_3	6.50	3.65	25.8	30	4.50	3.30	266.25	36.00	NDL
NRW_1	6.72	24.50	25.2	35	5.30	3.60	71.00	36.00	NDL
NRW_2	8.81	41.20	25.8	40	6.10	3.90	18.75	52.00	12.55
NRW_3	7.83	46.90	26.2	36	5.20	3.60	17.75	64.00	8.12
OW_1	8.37	34.70	25.6	35	3.90	3.20	17.95	36.00	9.05
OW_2	8.93	26.40	26.3	38	5.40	2.90	35.50	73.00	13.05
OW_3	8.48	36.60	26.0	35	3.70	3.20	17.75	40.00	10.00
ALW_1	8.55	34.30	24.8	40	5.30	3.70	88.75	30.00	13.10
ALW_2	9.30	46.40	25.2	42	4.90	3.60	17.85	60.00	68.00
ALW_3	8.99	37.50	25.0	38	5.30	3.00	18.15	56.00	14.15

E.C. = Electrical Conductivity, DO = Dissolved Oxygen; BOD = Biological Oxygen Demand; Cl^- = Chloride; AA= D.D.P.A; AO = Agbor-Obi; NR = Near River (Orogodo river); AL = Alihame areas; O = Owa-Nta; B = Borehole water, W = artificial well; NDL= Not within Detection limit
(DO, BOD, Cl-, hardness and total alkalinity are in mg/l)

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Table 3: Comparison of results of the study with WHO standards

Parameters	Range		WHO standards	
	BW	WW	Desirable level	Max. allowed level
Temperature (ºC)	23.8 -28.7	24.0 -28.0		
E.C (µScm^{-1})	9.56 -181.30	3.65 -58.00	900	1200
Hardness as mg/l $CaCO_3$	16.00-126.00	30.00-640.00	100	500
Cl^- (mg/l)	17.75-213.00	17.75 -266.25	200	500
DO	2.30-7.80	2.60-6.10	3.0 -8.0	4.0 -8.0
BOD	2.10-3.90	2.10 -3.90	<3	<3
pH	3.42 -8.37	4.01-9.30	6.0-8.5	6.5-8.5
Alkalinity (as mg/l $CaCO_3$)	NDL-10.0	NDL -68.00	100	100
Lead (Pb)	NDL-0.10	NDL-0.01	0.01	0.01
Chromium (Cr)	NDL-0.18	NDL-0.20	0.05	0.05
Iron (Fe)	NDL-0.40	NDL-0.70	0.01	0.30
Copper (Cu)	NDL-0.30	NDL-0.10	0.50	2.00
Zinc (Zn)	NDL-1.20	NDL-0.70	0.01	3.00
Manganese (Mn)	NDL-0.04	NDL-0.50	0.01	0.40

WW = Well water, BW = Borehole water

Table 4: Heavy metal concentrations in water from borehole sources

Analyte (mg/l)	Sample location/Code													
	AAB_1	AAB_2	AOB_1	AOB_2	AOB_3	NRB_1	NRB_2	NRB_3	OB_1	OB_2	OB_3	ALB_1	ALB_2	ALB_3
Pb	NDL	0.01	NDL	NDL	NDL	NDL	NDL	NDL	0.10	NDL	NDL	NDL	NDL	NDL
Cr	0.10	0.05	0.12	NDL	0.11	0.12	0.03	0.06	0.18	0.12	NDL	0.12	0.03	0.16
Fe	NDL	0.10	0.40	0.20	0.20	0.20	0.30	0.20	0.12	0.40	0.20	0.10	0.30	0.10
Cu	0.10	NDL	0.10	NDL	NDL	NDL	0.10	NDL	0.10	0.10	0.30	0.10	0.10	0.10
Zn	NDL	0.10	0.10	0.10	NDL	0.10	NDL	0.10	0.20	1.20	0.40	0.70	NDL	NDL
Mn	0.03	NDL	0.01	NDL	NDL	NDL	NDL	0.01	0.02	0.03	NDL	0.04	0.02	0.02
Total	0.23	0.26	0.73	0.30	0.31	0.42	0.43	0.37	0.72	1.85	1.10	1.06	0.46	0.38

NDL = Not within detection limit

Table 5: Heavy metal concentrations of well water sources

	Sample Location/Code														WHO standards	
Analyte (mg/l)	AA W_1	AA W_2	AO W_1	AO W_2	AO W_3	NR W_1	NR W_2	NR W_3	OW_1	OW_2	OW_3	ALW 1	ALW 2	ALW 3	Desirable limit	Maximum limit
Pb	NDL	NDL	NDL	NDL	0.01	NDL	NDL	NDL	NDL	NDL	NDL	NDL	NDL	NDL	0.01	0.01
Cr	NDL	NDL	0.04	0.04	0.07	0.20	0.03	NDL	NDL	0.06	NDL	0.11	0.07	0.01	0.05	0.05
Fe	0.20	0.70	NDL	0.12	0.14	0.20	0.50	NDL	NDL	NDL	NDL	0.60	0.20	0.32	0.01	0.30
Cu	NDL	0.10	NDL	NDL	NDL	NDL	NDL	0.10	NDL	NDL	NDL	0.10	0.10	NDL	0.50	2.00
Zn	0.20	NDL	NDL	NDL	0.70	0.10	0.30	NDL	NDL	NDL	NDL	0.40	NDL	0.20	0.01	3.00
Mn	0.50	NDL	NDL	NDL	0.03	0.01	0.04	0.02	0.05	0.03	0.02	0.02	0.04	0.20	0.01	0.40
TOTAL	0.90	0.80	0.04	0.16	0.95	0.51	0.87	0.12	0.05	0.09	0.02	1.23	0.41	0.73	0.59	5.76

NDL = Not within detection limit

All the borehole water samples are contaminated with chromium. Greater chromium concentrations were reported at Alihame areas is due to indiscriminate discharge of solid wastes. About 98% of the well water samples have chromium levels below the desirable limits of chromium in drinking water (World Health Organisation, 2004). Only sample AOW3 has Cr level (Table 5) above the desirable limits in drinking. More than 80% of the borehole water samples and all well water samples either have concentrations below detection limit or desirable limits for drinking water. Chronic Mn poisoning leads to psychiatric disorders (Sharma, 2006). Mn contaminations are known to encourage growth of microbes and induce bitter taste into water (American Public Health Association, 1992). The levels of Mn range from NDL to 0.04mg/l in borehole water. About 72% of well water samples are contaminated with Mn. The levels of Mn in well water range from NDL to 0.50mg/l of which more than 71% of well water samples are contaminated. The implication is that well water samples may have higher heterotrophic bacterial counts than borehole water samples since the well water samples have greater Mn concentrations.

There is no strong correlation among the studied metals (Table 6). This shows that water sample contamination with metals results from several different contaminant sources such as indiscriminate solid wastes disposal, storm water runoffs, vehicular emission and wears; wastes from battery worksites, automobile workshops and agricultural applications.

Table 6: Coefficient of correlation among the heavy metals

	Pb	Cr	Fe	Cu	Zn	Mn
Pb	1.0000	0.3730	-0.1120	0.1008	0.0485	-0.0518
Cr		1.0000	0.0011	0.0535	0.2264	-0.2537
Fe			1.0000	0.2088	0.2595	0.0133
Cu				1.0000	0.2224	-0.1975
Zn					1.0000	0.0706
Mn						1.0000

4. CONCLUSION

Based on the above results, the groundwater resources from Agbor metropolis is soft, fresh with low buffer capacity. The aquifer is contaminated with heavy metals zinc, iron, manganese, and chromium hence, bacterial contamination of the aquifer is feasible. It is therefore recommended that these water sources be protected from further deterioration by anthropogenic activities. Also, bacteriological assessment of the aquifers should be carried out since the present study revealed the possibility for microbial contamination due to the present of manganese.

5. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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