www.idosr.org Oghonim *et al*

International Digital Organization for Scientific Research **ISSN: 2550-7931**
IDOSR JOURNAL OF APPLIED SCIENCES 8(3) 118-139, 2023.
https://doi.org/10.59298/IDOSR/2023/10.2.1419

Evaluation of the average values of the chemical parameters of selected borehole water Samples in Agbor, Delta State, Nigeria

[1]Oghonim Pius Akaraka Nkem, [2]Ugwu Okechukwu Paul-Chima and [1]Godwin Victor Chukwusom

[1]Department of Applied Microbiology and Brewing Faculty of Biosciences Nnamdi Azikiwe University, Awka Nigeria.
[2]Department of Publication and Extension, Kampala International University Uganda.

ABSTRACT

Chemical parameters of some borehole water samples in Agbor, Delta State were carried out to determine its potability for drinking and domestic purposes. Sixty water samples from fifteen boreholes were sampled in June and July, 2022 (rainy season); and January and February, 2023 (dry season). The chemical parameters were analyzed according to standard methods. On the average, the chemical parameters analyzed, were within the World Health Organization, 2006 standard except magnesium, hardness, potassium, cadmium, and lead values which exceeded the permissible limits.
Keywords: Chemical, borehole, water Samples, Agbor, Delta State and Nigeria

INTRODUCTION

Water is vital to many life processes and they could also serve as route through which disease- causing pathogens can be transmitted. It can also contain heavy metals and other chemical substances that may adversely affect human health. Ensuring good quality of drinking water is a basic factor for guaranteeing public health [1]. Potable water is that which is odourless, colourless, practically tasteless and free from physical, chemical and biological contaminants [2]. Water is exploited by man for several commercial, agricultural, domestic and industrial usages; and the usage of water for any activity usually depends on the cleanness of the water. The quality of water is determined by its physical, chemical and microbiological characteristics [3]. The paucity of water supply in Nigeria has forced residents to depend on shallow dug boreholes as the sources of water for drinking and domestic purposes [3]. Borehole is a type of groundwater that form an integral part of water supply systems in rural and urban areas especially in Nigeria [4]. Over one billion people lack access to clean safe water worldwide, up to 300 million rural people in Sub Sahara Africa have no access to safe water supplies and this is on the rise [5]. The only realistic option for meeting rural water demands is through groundwater exploitation [5]. Groundwater sources are commonly vulnerable to pollution, which may degrade their quality. Generally, groundwater quality varies from place to place, and this sometimes depends on seasonal changes [6]; [7]. The quality of water also depends on the types of soils, rocks and surfaces through which it moves beneath the earth. Access to potable drinking water is a major public health issue in many parts of the world especially in most developing economies (Nigeria inclusive) where water hygiene and sanitation may still be poor.The people living in these countries usually get their primary source of water from boreholes, surface waters such as streams, ponds, rivers and the open skies when it rains.

Population growth coupled with increased industrialization, livestock farming and urbanization have led to frequent contamination of rivers [8]. Due to the inability of some governments to meet the ever-increasing water demand of their populace, most people often resort to groundwater sources such as boreholes as alternative water source. Borehole water therefore, is a primary source of water in most developing nations; and the chemical, physical and biological constituents of these sources of water is a critical public health issue that needs to be ascertained on periodic basis. Borehole water serves as one of the easily accessed and cheap commercial sources of drinking water for a greater number of the Nigerian populace; and they also infer that the conformation of these sources of water to lay down microbiological standards is of public health interest because of their capacity to spread diseases within a large population. The provision of potable water to both the rural and urban population is necessary to prevent public health hazards such as the emergence and spread of waterborne pathogens [9]; [10]. Agbor in Delta State depends mostly on ground water, its abstraction account for 20% of the total water usage. Currently, demands for groundwater usage have been increasing due to population growth and diminishing opportunities to economically develop potable water supplies [11]. The management of the resource is lagging behind the pace of development, and often, very little sanitary practice is exercised in its exploitation. The current groundwater resources development and supply status is unacceptably low and needs a major transformation [12]. The digging of more boreholes in Agbor brings the need to monitor the issue of water quality that remains a major contender of its supposed existence in abundance essentially its quality is as equally important as its quantity. The quality of water is of vital concern for mankind since it is directly linked with human welfare. According to [13], the quality of public health depends to a greater extent the quality of groundwater. Physicochemical and bacteriological parameters of water indicate the safety of potable water [14] and their analysis is important for public Health and pollution studies [15].

Aim of the study

The aim of this study was to evaluate the seasonal chemical parameters of selected borehole water samples in Agbor, Delta State, Nigeria.

MATERIALS AND METHODS

Study area

Agbor is the headquarters of Ika South Local Government Area of Delta State in the South Southern part of Nigeria. Agbor has a population in excess of 250,000 people and a land mass of 685km2. The geographical coordinates of Agbor are 6.254oC latitude, 6.194oC longitude and 427ft elevation. The topography within two miles of Agbor contains only variations in the elevation with a maximum elevation of 367ft and an average elevation above sea level of 504ft. Agbor lies within the equatorial climate with two distinct seasons, the wet (April to September) and dry (October to March), high humidity of between 24oC to 27oC, which supports the rainforest vegetation. The discovery and exploration of oil in commercial quantity in Ekuku Agbor and environs have earned Agbor the status of oil producing city within the Niger Delta region of Nigeria. Agbor has the blessing of abundant natural water bodies. The people of Agbor are known for commerce and agricultural activities. Agbor hosts amenities such as University of Delta, Delta College of Nursing, 181 Army Amphibious battalion, National Psychiatric Hospital, General Hospital, Area Command of Nigeria Police Force, and the adorable Dein Royal Palace. The Dein of Agbor is the traditional ruler of Agbor Kingdom with over seventy communities [16].

A drive around the borehole locations was undertaken to enable proper capture of the accurate borehole points using the handheld Global Positioning System. The coordinates of the actual positions were acquired and inputted on the Google map. On-screen vectorization of features like towns, roads and boundaries were directly observed and recorded. The features from the Google map were zoomed to a very high resolution where all the features became very clear as represented in the samples map presented in this work. The mapping was carried out in collaboration with Geo-trust Project Services Ltd, a surveying firm in Agbor.

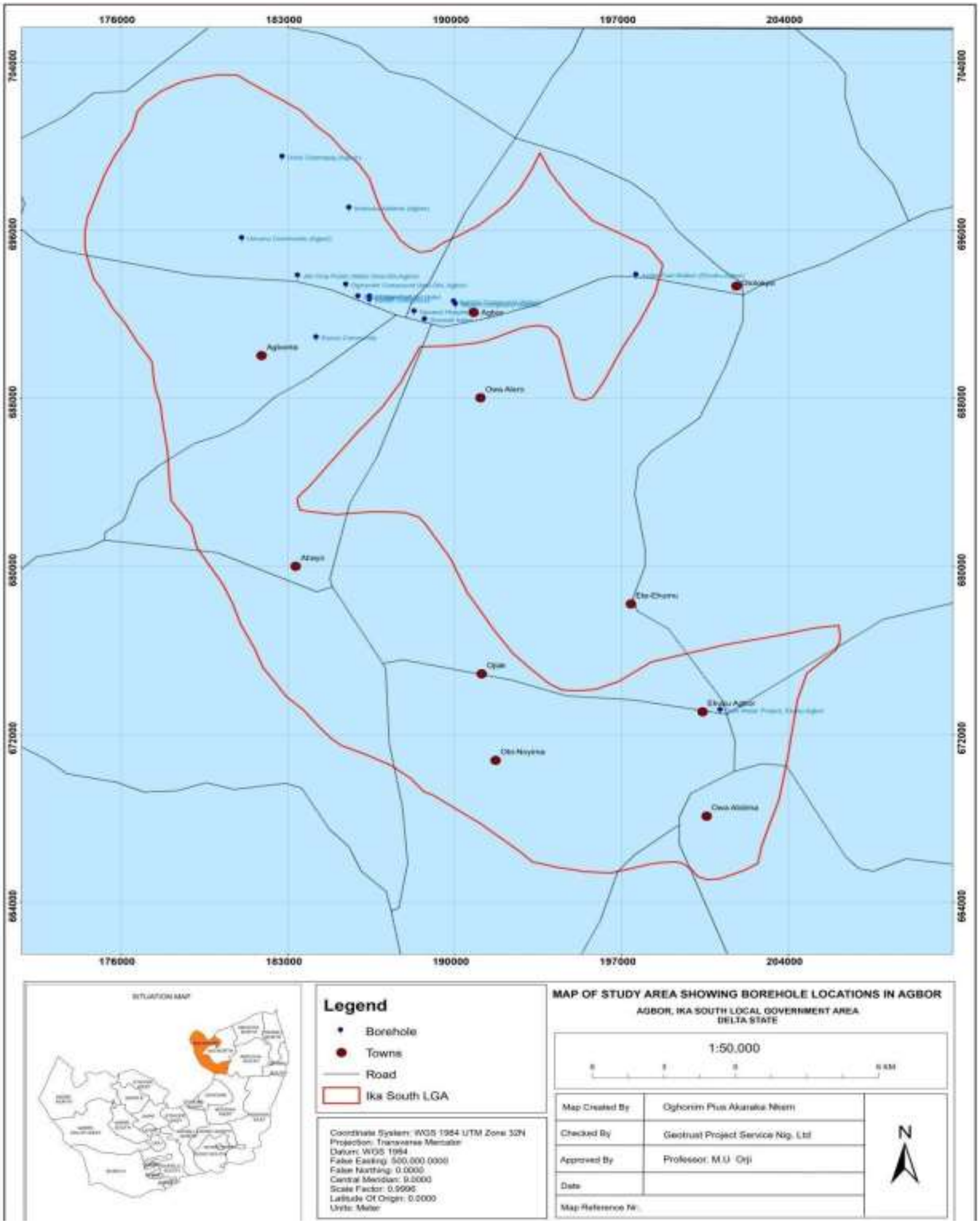

Fig. 1: Map of the study area, 2023. Source: Geo-trust Project Services Ltd.

Research center

The chemical analysis was done at Projects Development Institute (PRODA) Enugu, bacteriological analyses were done in Applied Microbiology and Brewing laboratory Nnamdi Azikiwe University, Awka, while molecular characterization was done at International Institute of Tropical Agriculture, Ibadan Headquarters, Nigeria.

Sample collection for chemical analysis

All the sampled points were selected randomly within Agbor, Delta State. Sixty (60) samples were aseptically collected from 15 different boreholes between June and July, 2022 (rainy season); January and February, 2023 (dry season). The selected borehole waters were those used for drinking and for other domestic purposes. These water samples were collected in the morning period (7am – 9am). During the rainy season, fifteen samples were collected in June, analyzed and recorded, this was repeated in July and average of the values was taken, making it a total of thirty samples. This was also done in the dry season period to give a total of sixty samples for both seasons. Samples for physicochemical analysis were collected using one-litre plastic containers. The containers were first washed with sterile water and thereafter it was rinsed with water from the respective boreholes three times before collecting the water samples. Samples for the bacteriological analysis were aseptically collected in sterilized one-litre plastic container (which was sterilized by rinsing with 70% ethanol and then with sterile water and thereafter with the respective water sample three times before collection). The water was left to rush for 2 minutes (This allows the nozzle of the tap to be flushed and any stagnant water in the service pipe to be discharged). A piece of cotton-wool soaked in ethanol and lighter was used to decontaminate the faucet of the borehole before collection. The collected samples were kept at 4°C in the cooler box packed with ice and transported to the laboratory for analysis within two hours as described by [17]. These boreholes were: Oghonim, Aziken, Agholor, Aliagwu, Dein, Golden Cocktail, Police, Ewuru, Jim Ovia, Omumu, Uvbe Ozanogo, Idumukwu, Central Hospital, Lucky Irabor, and Jodes.

Chemical analysis

The chemical parameters evaluated were total chloride, phosphate, total alkalinity, total hardness, calcium hardness, magnesium hardness nitrate, potassium, sulphate, dissolved oxygen, cadmium, lead, chromium, copper, zinc and iron. The evaluation was carried out as described by [18].

Chemical parameters

Determination of total chloride

Fifty (50) ml of the water samples were measured in 250ml conical flask and 1 ml of K_2CrO_4 indicator solution was added and titrated with $AgNO_3$ titrant to a pinkish yellow end point.The titration was repeated with distilled water blank. Mg Cl^-/l = (A-B) × N×35×450 / ml of sample. Where: A = ml titration for sample, B = ml titration for blank, N = normality of $AgNO_3$

Phosphate

Ten mls of the neutralized sample was pipetted into 50ml volumetric flask, four mls of ammonium molybdate and four mls of 10N sulphuric acid was added. Then six drops of stannous chloride were also added. The solution was shaken and made up to 50ml using distilled water, and the absorbance was read in a UV (ultra-violet) Spectrophotometer at wave length 650nm.

Determination of total alkalinity

Ten (10) ml of samples were added into a conical flask and 2 drops of bromocresol green indicator was added and titrated with 0.1N sulphuric acid solution.Total alkalinity, mg $CaCO_3$/L = B × N × 5000 / Volume of sampleWhere: B = ml titration for blank, N = normality of H_2SO_4.

Determination of total hardness

Fifty (50) millilitres of well mixed samples were poured into a conical flask and 2 ml buffer solution (Myron L6) were added followed by 1 ml inhibitor. A 0.1g of Eriochrome black T was added and titrated with standard EDTA (0.01M) till wine red colour changed to blue, then the volume of EDTA required was noted (A). The volume of the reagent blank was analyzed and noted (B).The volume of EDTA required by sample, was calculated; C = A – B (from volume of EDTA required in steps).

Total hardness as CaCO3, mg/l = C × D × 1000 / Volume of sample in 1ml C = volume of EDTA required by sample (with EBT indicator)

D = mg CaCO3 equivalent to 1ml EDTA titrant (1 ml 0.01M EDTA = 1.00 mg CaCO3)

Determination of calcium hardness

Twenty-five (25) millilitres of well mixed samples were dispensed into a 250 ml conical flask and 1 ml sodium hydroxide solution was added to raise the pH to 12.0 and a 0.1g of muroxide indicator was added. It was titrated immediately with EDTA till pink colour changes to purple. The volume of EDTA used was noted (A1). The reagent blank was taken, the ml of EDTA required was noted (B1) and kept aside, and the end-points of sample titrations were compared. The volume of EDTA required by sample was calculated using C1 = A1 – B1. Calcium hardness as CaCO3, mg/l = C1 × D × 1000 / Volume of sample in 1ml C1= volume of EDTA used by sample (with murexide indicator) D=mg CaCO3 equivalent to 1 ml EDTA titrant.

Determination of magnesium hardness

Magnesium Hardness = Total hardness as CaCO3, mg/l - Calcium hardness as CaCO3, mg/l.

Determination of nitrate

Fifty (50) mls of water samples were measured and 1ml sodium arsenite was added and shaken thoroughly. Five (5) ml were measured from the mixture above in a separate test tube and 1ml of brucinesulphate was added. 10mls of conc. sulphuric acid (H2SO4) were added and homogenized with the remaining 45 mls solution and allowed for colour development for about 30mins. The absorbance was read with the aid of a SPECTIONIC - 20 machine at a wavelength of 410nm. Calculation: Concentration / Volume of sample used × 1000 mg/l.

Determination of potassium

Fifty (50) milliliters of the water sample were filtered using Whatmann no. 1 filter paper to remove suspended solids and the potassium concentration was detected using flame photometer.

Determination of sulphate

Ten ml of homogenized water samples were measured into a clean conical flask, five ml of 2mol hydrochloric acid was added. Two ml of 0.05 mol barium chloride was also added to the above and boiled in water bath for five minutes while the test samples were covered with masking foil. The samples were allowed to cool at room temperature and 2ml of concentrated ammonia was added. Five ml of 0.01N EDTA was added and boiled for five minutes. Five ml of buffer 10 and three drops of erichrome black T indicator were also added. Titrated with 0.01mol magnesium chloride. Note that colour changes from deep blue to light purple. TV: Titratable value. Sulphate mg/l = [10-(TVx0.93)] x 96.01464 mg/l / 10

Heavy metals

(Cadmium, lead, chromium, copper, zinc and iron)

All metallic elements were determined using Atomic Absorption Spectrophotometry (AAS) manufactured by Buck Scientific. One hundred milliliters of the filtered water samples were introduced into a 250ml conical flask and digested with 2 ml of concentrated nitric acid. The digested samples were filtered into a sample bottle and aspirated into the oxyacetylene flame. The absorbance of the aspirated sample was read using the atomic absorption spectrophotometer.

Data Analysis

Data analysis was done using a two-way analysis of variance (ANOVA) to determine the disparity between the physicochemical and bacteriological parameter during both seasons.

RESULTS

Table 1. Average values of the Chemical characteristics of borehole water samples during rainy season

Borehole Location	Chloride (mg/l)	Phos. (mg/l)	Total alkalinity (mg/l)	Total hardness (mg/l)	Cal. Hardness (mg/l)	Mg. hardness (mg/l)	Nitrate (mg/l)	K (mg/l)	Sul. (mg/l)	DO (mg/l)
Oghonim	95.32	0.39	72.28	103.83	23.43	80.40	1.11	3.42	43.10	7.47
Aziken	71.40	0.29	56.74	128.07	33.77	94.30	3.43	0.00	47.49	6.77
Agholor	89.11	0.59	60.02	73.95	24.65	49.30	5.00	7.00	48.70	7.25
Aliagwu	68.79	0.37	54.47	87.69	26.19	61.50	1.62	2.02	40.34	6.28
Dein	84.50	0.26	46.17	102.25	48.83	53.42	1.61	1.40	36.15	8.11
Golden Cocktail	80.51	0.27	68.09	68.38	3.68	64.70	1.73	2.07	41.01	7.88
Police	99.47	0.41	61.24	78.98	29.78	49.20	1.19	4.09	39.60	6.80
Ewuru	116.26	0.44	30.53	62.81	25.51	37.30	5.96	5.90	44.38	7.81
Jim Ovia	81.30	6.70	65.15	124.20	48.00	76.20	6.40	6.41	60.78	6.72
Omumu	60.17	0.35	63.86	138.22	62.14	76.08	4.18	1.91	48.57	7.56
Uvbe Ozanogog	91.31	4.64	81.23	140.44	53.08	87.36	7.00	0.32	50.31	5.84
Idumukwu	101.55	0.26	50.37	117	46.40	70.60	6.66	0.00	45.21	7.86
Central Hospital	88.05	2.34	26.68	132.59	51.36	81.23	6.99	0.86	38.52	6.88
Lucky Irabor	100.61	0.47	74.80	118.02	39.83	78.19	4.72	0.24	46.27	7.04
Jodes	117.30	0.23	77.09	103.69	32.21	71.48	1.96	0.22	31.13	7.57

Average values of the chemical parameters of the Borehole water samples during the dry season. The chemical parameters of the borehole water samples investigated during the dry season were shown in Table 2. Chloride ranged from 29.34mg/l-83.00mg/l, phosphate ranged from 0.07mg/l- 3.17mg/l, total alkalinity ranged from 19.47mg/l-71.16mg/l, total hardness ranged from 26.82mg/l-114.35mg/l, calcium hardness ranged from 1.63mg/l-29.53mg/l, magnesium hardness ranged from 8.27mg/l-98.10mg/l, nitrate ranged from 0.44mg/l-4.75mg/l, potassium ranged from 0.00mg/l-4.23mg/l, sulphate ranged from 26.73mg/l-59.73mg/l and dissolved oxygen ranged from 5.00mg/l-6.67mg/l.

Table 2: Average values of the chemical characteristics of borehole water samples during dry season

Borehole Location	Chloride(mg/l)	Phosphate(mg/l)	Total alkalinity(mg/l)	Total hardness(mg/l)	Calcium hardness(mg/l)	Magnesium hardness(mg/l)	Nitrate (mg/l)	K (mg/l)	Sulphate (mg/l)	DO (mg/l)
Oghonim	39.47	0.20	47.51	55.20	04.87	50.33	2.01	0.00	40.29	6.31
Aziken	29.78	0.13	37.74	78.84	11.54	67.30	0.44	0.00	37.18	6.42
Agholor	54.61	0.18	42.62	98.61	10.42	88.19	2.19	3.51	39.20	6.67
Aliagwu	41.77	0.11	47.98	113.2	15.10	98.10	1.00	4.09	42.51	5.87
Dein	66.66	0.07	44.26	43.78	21.62	22.16	1.00	0.56	38.62	6.26
Golden Cocktail	49.49	0.08	41.83	35.09	12.36	22.73	0.98	1.01	43.11	6.51
Police	61.40	0.11	47.91	112.15	18.94	93.21	0.82	1.42	28.07	6.32
Ewuru	83.00	0.16	32.97	49.66	29.12	20.54	3.07	4.23	31.37	7.50
Jim Ovia	37.23	3.17	48.96	98.60	23.30	75.30	3.02	4.21	49.18	5.00
Omumu	39.59	0.09	41.62	38.89	25.28	09.61	0.72	2.06	28.07	6.00
Uvbe Ozanogog	29.34	2.12	62.19	26.82	01.63	25.19	4.75	1.11	39.9	5.31
Idumukwu	57.47	0.08	33.11	73.53	16.35	57.18	1.31	0.00	43.4	6.06
Central Hospital	29.40	1.10	19.47	114.35	29.53	84.82	1.94	0.20	5388	6.02
Lucky Irabor	51.41	0.11	64.33	37.65	29.38	08.27	1.57	0.06	59.73	6.06
Jodes	58.52	0.09	71.16	47.48	13.97	33.51	1.44	0.10	26.73	6.22

Average chemical parameters of the Borehole Water Samples during the both seasons compared with W.H.O (2006) standard

The average values of the chemical parameters compared with World Health Organization (2006) standard were shown in Table 3. Total chloride ranged from 49.88-99.63 mg/l and were below 250mg/l stipulated by [19], Twenty percent of the phosphate values (0.16-4.93 mg/l) were above 0.5mg/l stipulated by WHO (2006). Total alkalinity ranged from 23.07-74.12mg/l and were below the WHO (2006) acceptable standard of 250mg/l, total hardness values ranged from 51.73-123.47mg/l and were within the WHO (2006) standard of 250mg/l, calcium hardness values were below the WHO (2006) standard of 75mg/l, 66.66% of magnesium hardness were above the WHO (2006) standard of 50mg/l, nitrate values ranged from 1.00-5.87 mg/l and were within the WHO (2006) standard of 10, 20% of the average potassium in the water sample were above the WHO (2006) acceptable limits of 5mg/l, sulphate values ranged from 28.93- 54.98mg/l and were within the WHO (2006) standard of 250mg/l, and dissolved oxygen ranged from 5.57-7.65mg/l and where within the WHO (2006) standard of >5.The chemical parameters of the borehole water samples for both rainy and dry season were analyzed using two-way analysis of variance at Alpha level of 0.05 which showed that there was extreme significant difference ($p < 0.0001$) between the various drinking water samples in both rainy and dry season.

Table 3: Comparison of the average values of chemical characteristics of borehole water samples during both seasons with(W.H.O) standard.

Borehole Location	Chloride(mg/l)	Phosphate(mg/l)	Total alkalinity(mg/l)	Total hardness(mg/l)	Cal. Hardness(mg/l)	Mg. hardness(mg/l)	Nitrate (mg/l)	K (mg/l)	Sulphate (mg/l)	DO (mg/l)
Oghonim	67.39	0.29	59.89	79.51	14.15	65.36	1.56	1.71	41.69	6.89
Aziken	50.59	0.21	47.24	103.4	22.65	161.6	1.93	0.00	42.33	6.59
Agholor	71.86	0.38	51.32	86.28	17.53	68.74	3.59	5.25	43.95	6.96
Aliagwu	55.28	0.24	51.22	100.4	20.64	79.8	1.31	3.05	41.42	6.33
Dein	75.58	0.16	45.21	73.01	35.22	37.79	1.30	0.98	37.38	7.18
Golden Cocktail	65	0.17	54.96	51.73	8.02	43.71	1.35	1.54	42.06	7.19
Police	52.93	0.26	54.57	95.56	24.36	71.20	1.00	2.75	33.83	6.56
Ewuru	99.63	0.28	31.75	56.23	29.45	28.92	4.51	5.06	37.87	7.65
Jim Ovia	59.26	4.93	57.05	111.4	24.40	75.75	4.71	5.31	54.98	5.86
Omumu	49.88	0.22	52.74	88.55	43.71	42.84	2.45	1.98	38.32	6.78
Uvbe Ozanogog	60.32	3.38	71.71	83.63	27.35	56.27	5.87	0.71	45.10	5.57
Idumukwu	79.51	0.17	41.74	96.26	31.37	63.89	3.98	0.00	44.30	6.96
Central Hospital	58.72	1.72	23.07	123.4	40.44	83.02	4.46	0.53	46.02	6.45
Lucky Irabor	76.01	0.29	69.56	77.83	34.60	43.23	3.14	0.15	53	6.55
Jodes	87.91	0.16	74.12	75.58	23.09	52.49	1.7	0.16	28.93	6.89
WHO (2006)	**250**	**0.5**	**250**	**100**	**75**	**50**	**10**	**10**	**250**	**>5**

Key: Phos = Phosphate. K = Potassium. Sul = Sulphate. DO = Dissolved oxygen.

Average values of the heavy metal parameters of the Borehole water samples during rainy season

The heavy metals investigated in the borehole water samples during the rainy season were shown in Table 4. Zinc ranged from 0.06mg/l-2.17mg/l, Iron values ranged from 0.00mg/l-0.30mg/l, copper ranged from 0.00mg/l-0.20mg/l, cadmium ranged from 0.00mg/l-0.06mg/l, lead ranged from 0.00mg/l-0.07mg/l and chromium ranged from 0.00mg/l-0.04mg/l.

Table 4. Average values of the heavy metal characteristics of borehole water samples during rainy season

Borehole location	Zn (mg/l)	Fe (mg/l)	Cu (mg/l)	Cd (mg/l)	Pb (mg/l)	Cr (mg/l)
Oghonim	0.14	0.00	0.00	0.02	0.02	0.00
Aziken	2.06	0.06	0.07	0.01	0.03	0.02
Agholor	0.11	0.00	0.00	0.02	0.04	0.03
Aliagwu	0.28	0.00	0.00	0.00	0.02	0.00
Dein	0.19	0.04	0.06	0.00	0.01	0.00
Golden Cocktail	0.10	0.00	0.05	0.00	0.00	0.04
Police	0.13	0.13	0.09	0.00	0.01	0.02
Ewuru	0.14	0.00	0.01	0.02	0.01	0.01
Jim Ovia	2.17	0.30	0.17	0.00	0.07	0.03
Omumu	0.31	0.00	0.04	0.00	0.00	0.02
Uvbe Ozanogog	1.23	0.25	0.20	0.04	0.03	0.04
Idumukwu	0.32	0.00	0.01	0.00	0.00	0.00
Central Hospital	0.12	0.17	0.05	0.06	0.00	0.00
Lucky Irabor	0.18	0.12	0.14	0.00	0.01	0.02
Jodes	0.06	0.08	0.08	0.01	0.00	0.01

Average values of the heavy metal parameters of the Borehole water samples during the dry season

The heavy metals investigated in the borehole water samples during the dry season were shown in Table 5. Zinc ranged from 0.02mg/l-0.64mg/l, iron ranged from 0.00mg/l-0.16mg/l, copper ranged from 0.00mg/l-0.15mg/l, cadmium ranged from 0.00mg/l-0.02mg/l, lead ranged from 0.00mg/l-0.02mg/l and chromium ranged from 0.00mg/l-0.03mg/l.

Table 5: Average values of the heavy metal characteristics of borehole water samples during dry season

Borehole location	Zn (mg/l)	Fe (mg/l)	Cu (mg/l)	Cd (mg/l)	Pb (mg/l)	Cr (mg/l)
Oghonim	0.08	0.00	0.00	0.00	0.00	0.00
Aziken	0.13	0.02	0.03	0.00	0.01	0.01
Agholor	0.10	0.00	0.00	0.01	0.00	0.00
Aliagwu	0.11	0.00	0.00	0.00	0.01	0.00
Dein	0.09	0.00	0.04	0.00	0.00	0.00
Golden Cocktail	0.08	0.00	0.02	0.00	0.00	0.01
Police	0.07	0.04	0.03	0.00	0.00	0.02
Ewuru	0.03	0.00	0.00	0.01	0.00	0.00
Jim Ovia	0.57	0.16	0.09	0.02	0.01	0.03
Omumu	0.22	0.00	0.02	0.00	0.00	0.01
Uvbe Ozanogog	0.64	0.13	0.15	0.01	0.02	0.02
Idumukwu	0.18	0.00	0.00	0.01	0.00	0.00
Central Hospital	0.03	0.03	0.01	0.01	0.00	0.00
Lucky Irabor	0.02	0.10	0.05	0.00	0.00	0.00
Jodes	0.05	0.01	0.02	0.01	0.00	0.00

Average values of the heavy metal parameters of the Borehole water samples during both seasons compared with WHO (2006) standard

The average values of the heavy metals compared with WHO (2006) standard are indicated in Table 6. Zinc from 0.07-1.37mg/l and were within the WHO (2006) standard of 3.0mg/l, iron, and copper were within the World health Organization (2006) standard of 0.3, and 2.0 respectively. 6.66% of cadmium and 26.66% of lead in the water samples were above the WHO (2006) required limits of 0.03 and 0.01mg/l respectively, while chromium values ranged from 0.00-0.03mg/l and were within the WHO (2006) standard of 0.05mg/l. The heavy metal of the borehole water samples for both rainy and dry season were analyzed using two-way analysis of variance at Alpha level of 0.05 which showed that there was no significant difference ($p<0.0891$) between the various drinking water samples in both rainy and dry season.

Table 6: Comparison of the average values of heavy metal characteristics of borehole water samples during both seasons with(W.H.O) standard

Borehole location	Zn (mg/l)	Fe (mg/l)	Cu (mg/l)	Cd (mg/l)	Pb (mg/l)	Cr (mg/l)
Oghonim	0.11	0.00	0.00	0.01	0.01	0.00
Aziken	1.09	0.04	0.05	0.001	0.02	0.01
Agholor	0.10	0.00	0.00	0.01	0.02	0.01
Aliagwu	0.19	0.00	0.00	0.00	0.01	0.00
Dein	0.14	0.02	0.05	0.00	0.001	0.00
Golden Cocktail	0.09	0.00	0.03	0.00	0.00	0.02
Police	0.1	0.08	0.06	0.00	0.001	0.02
Ewuru	0.08	0.00	0.001	0.01	0.001	0.01
Jim Ovia	1.37	0.23	0.13	0.01	0.04	0.01
Omumu	0.26	0.00	0.03	0.00	0.00	0.01
Uvbe Ozanogog	0.93	0.19	0.17	0.02	0.02	0.03
Idumukwu	0.35	0.00	0.001	0.001	0.00	0.00
Central Hospital	0.07	0.1	0.03	0.03	0.00	0.00
Lucky Irabor	0.10	0.11	0.09	0.00	0.001	0.01
Jodes	0.05	0.04	0.05	0.01	0.00	0.001
WHO (2006)	**3.0**	**0.3**	**2.0**	**0.03**	**0.01**	**0.05**

DISCUSSION

Groundwater has been considered as a safe source of drinking water. However, nowadays, the quality of drinking water is deteriorating [20]. Groundwater exploitation is generally considered as the only realistic option for meeting dispersed rural and urban water demand. Due to inability of governments to meet the ever-increasing water demand, residents' resort to shallow wells etc as alternative water resources for domestic purposes. The effect of uncontrolled disposal systems and other bad sanitary practices in Agbor can render groundwater unsafe for human, agricultural and recreational use, hence, posing a threat to human life and is therefore against the principle of sustainable development. Therefore, the present study focuses on the seasonal evaluation of the chemical parameters of selected borehole water samples in Agbor, Delta State.The chemical characteristics of the borehole water samples in Agbor varied and this may be attributed to varying degrees of improper sanitary conditions. The variations observed in the chemical properties of the borehole water samples carried out in Nigeria could be attributed to the influences of the micro-climatic, topographic and edaphic conditions in these areas within the country.Chloride ion is a common constituent of natural water and it's generally regarded as a non-harmful constituent [21]. Though chloride is present in all natural water bodies, high concentration is an indication of pollution from sewage, industrial or intrusion of seawater or saline water into fresh water aquifer [21]. The average values of total chloride investigated during the both season (Table 6) ranged from 49.88-99.63 mg/l and is within the WHO (2006) permissible limit of 250mg/l for drinking water. Chloride in drinking water originates from natural sources (dissolving rocks) sewage and industrial effluents, urban runoff containing de-icing salt and saline intrusion [22]. High level of chloride makes water unpalatable for drinking by imparting salty taste and may harm metallic pipes [10]. A similar study conducted by [23] reported that the chloride ions ranged between 97 and 108 mg/l and are within the recommended limit. Phosphate is the chemical term for the various combinations of phosphorous and the element oxygen. Phosphate is the main nutrient for algae. The value of phosphate fluctuated from 0.23 mg/l to 6.70 mg/l during rainy season and ranged from 0.07mg/l – 3.17mg/l during dry season. The high values of phosphate during the rainy season are mainly due to rain, surface water runoff, and agriculture run off could have contributed to the inorganic phosphate content. The average phosphate level of the water samples ranged from 0.16- 4.93 mg/l. However, 20% of the phosphate values was beyond the WHO (2006) acceptable limit of 0.5mg/l. This differs from the report of [24] who reported a low phosphate concentration ranging from 0.09 to 0.347 mg/l and within the WHO (2006) standard of 0.5mg/l. The increasing concentration in my study area could be as a result of increasing agricultural activities in Agbor. Phosphate like any other nutrient is harmless in lower concentrations, but become harmful only in higher doses. Higher doses of phosphate are known to interfere with digestion in both humans and animals. Phosphate enrichment of water bodies contributes to ecological impacts and their presence in water bodies contributes to eutrophication of natural waters [25], [26]. The total alkalinity of water is its acid neutralizing capacity. The alkalinity of groundwater is mainly due to carbonates and bicarbonates [27]. The average total alkalinity obtained. from both season (Table 6) ranged from 23.07-74.12mg/l, and are within the WHO (2006), maximum permissible limit of 250mg/l for drinking water. These may be as a result of good concentration of carbonates and bicarbonates. These findings are similar to the work presented by [22] whose value ranged between 74.3 - 88.2 mg/l. Based on the values of total alkalinity of the sampled waters, it can be inferred that the water is safe for drinking.Hardness of water may not have any health implications but may affect the taste of water as well as influence its lathering ability when used for washing. The average value of total hardness ranged from 51.73- 123.47mg/l for the analysis conducted in both seasons (Table 6). All the water samples analyzed were within the WHO (2006) standard of 100mg/l except 26.66% of the samples. Interestingly, World health organization international standard for drinking water (2006) classified water with total hardness of less than 50mg/l as soft water, 50-150mg/l as moderately hard water and water above 150mg/l as hard water. Based on this, all water samples were moderately hard water and suitable for domestic use in terms of hardness. This finding is similar to the work of [28] which stated that all the water samples analyzed were moderately hard. The high mean total hardness of the borehole samples in the wet season may be due to dissolution of metallic ions such as Mg^{2+}, Ca^{2+} ions from limestone and sedimentary rocks by rainwater percolation in the soil. The ions may have originated from run-offs that infiltrated into the soil, causing leaching and weathering of limestone and feldspars in the soil. The result is the precipitation of Ca 2+ and Mg 2+ ions and other mineral constituents in the soil that can also increase the total hardness of groundwater. The low total hardness in the dry season may be as a result of low aquifer recharge, hence less dissolution of the mineral composition of the aquifer.

The values of calcium hardness obtained from the investigation of the borehole water samples during the rainy season ranged from 3.68-62.14mg/l (Table 4) while the values obtained from the analysis conducted during the dry season were from 1.63-29.53mg/l (Table 5), the average values of the calcium hardness ranged from 8.02-43.71mg/l (Table 6). These values are within the 75mg/l stipulated by [19] and are therefore considered fit for drinking in terms of calcium content. Ca ions occur in groundwater through the decomposition of sulphate, phosphate, and silicate materials and due to the dissolution of carbonate minerals [29]. Calcium ion when in suitable concentration is known to regulate a number of neuron-muscular excitability, blood coagulation, enzyme reactions, secretary processes and intracellular action of a number of hormones. Calcium, which is essential for nervous system and for the formation of bones, is commonly present in all water bodies where it usually comes from the leaching of rocks [30].The values of magnesium hardness obtained from the investigation of the borehole water samples during the rainy season ranged from 37.30-94.30 mg/l (Table 4) while the values obtained from the analysis conducted during the dry season were from 8.27-98.10mg/l (Table 5), the average values of the magnesium hardness ranged from 28.92-161.6 mg/l (Table 6). Some of the values were above the 50 mg/l stipulated by [19] and are therefore considered unfit for drinking. Calcium and magnesium are among the elements essential for human health and metabolism and should be available in normal drinking water [28]. Nitrate represents the final product of the biochemical oxidation of ammonia [31]. It is important that the level of nitrate in water is controlled to avoid eutrophication. The average nitrate concentration ranged from 1.00 to 5.87mg/l and were within the acceptable limit prescribed by [19] limit of 10.0mg/l. The presence of nitrates can be a source of concern because consumption of water with high nitrate concentrations can cause blood disorders (known as methemoglobinemia) as well as cancer in humans [32]. These findings are similar with that the report of [33] who recorded 1.21 to 8.03mg/l from groundwater samples in Zaria. The higher nitrate levels during rainy season can be attributed to leachates from nitrogen fertilizers widely used in agricultural practice, waste, notably sewage effluents, animal excrement and manure and municipal waste due to increase recharge of the water. Also, nitrate values in the water were within the WHO set limits for drinking water and similar with the work reported by [34]. The average potassium values for both seasons ranged from 0.00-5.31mg/l (Table 6) and are within the W.H.O. standard of 10mg/l. These findings are similar to the work presented by [5] who stated that all the values obtained were within the WHO (2006), maximum permissible limit of 10mg/l for drinking water.

Sulphate is a non-toxic anion present in natural water. The average sulphate levels of the water samples for both seasons ranges from 28.93 to 54.98 mg/l and were within the WHO (2006) limit of 250 mg/l. Sulphate gets into ground water through the dissolution of rocks containing sulphur and mine drainage waste. Water with sulphate levels above 500 mg/l can have a laxative effect until an adjustment to the water is made. A similar study conducted by [35] reported a sulphate level within the WHO (2006) limit of 250mg/l, the low concentration of sulphate could be attributed to the absence of sulphate anthropogenic factors in the location of the wells. Dissolved oxygen is the measure of the amount of gaseous oxygen dissolved in aqueous solution [36]. The value of dissolved oxygen (DO) fluctuates from 5.84 mg/l to 8.11 mg/l during the rainy season (Table 4) and ranged from 5.00-6.67mg/l during the dry season (Table 5). The average DO value obtained from both seasons ranged from 5.57-7.65mg/l in (Table 6). However, 100% of the values were beyond the WHO (2006) limit of 5mg/l and these corroborates with the findings of [28] whose values ranged from 29.4 to 33.5 mg/l above WHO (2006) permissible limit of >5mg/l. These may be attributed to high temperature and high microbial load in the area.

The chemical parameters of the borehole water samples for both rainy and dry season were analysed using two-way analysis of variance at Alpha level of 0.05 which showed that there was extreme significant difference ($p < 0.0001$) between the water. Heavy metals are chemical elements with a specific gravity that is at least four to five times the specific gravity of water at the same temperature and pressure [37]. Heavy metals refer to metallic chemical element that has a relatively high density and is toxic or poisonous at low concentrations [38]. The heavy metals: lead, chromium, mercury, copper, arsenic, iron, cadmium and zinc concentrations in the well waters in all the sampling sites were compared with W.H.O (2006) standard. The obtained results showed that, with the exception of lead, cadmium and arsenic the heavy metal concentrations in the well waters did not exceed WHO (2006) standard. The average zinc values in the samples for both seasons ranged from 0.07 to 1.37 mg/l and were within the WHO (2006) acceptable limit of 3.0 (Table 9). The seasonal variation in the level of the metal was insignificant. These values are similar to the findings by [39] and (Samir and Ibrahim, 2008) in Egypt. The main source of zinc into water sources is dissolved zinc from zinc related appliances such as galvanized pipes. Low levels can be attributed to less zinc load from industrial, agricultural, domestic and urban waste waters [40]. The sources of iron in water include magnetite and biotite. The concentration of Iron in the groundwater varied from 0.00- 0.30mg/L during the rainy season (Table 7) and from 0.00- 0.16mg/l during dry season (Table 8). None of the values for Iron obtained exceeded the WHO standard of 0.3mg/l WHO (2006). These values were higher than that of [22] whose values range was 0.00 – 0.05 mg/l. The high values may be attributed to the fact that the well covers were made of rusted sheets which infiltrates into the water during and after rainfall. Generally, there was an increase in the iron concentration during the rainy season compared to dry season. Anthropogenic sources of iron in the environment could be washed into the ground water during rainy season. Iron has no health significance but it affects the anaesthetics of the water and causes the consumer to reject the supply. The concentration of copper in the ground water varied from 0.00-0.20mg/l during the rainy season (Table 7) and from 0.00-0.15mg/l during dry season (Table 8). The results obtained for copper were within the WHO maximum value of 2.00mg/l (WHO, 2006).

Cadmium is a metal with no known beneficial properties that supports life. The concentration of cadmium in the ground water varied from 0.00-0.06mg/L during the rainy season and from 0.00-0.02 mg/l during dry season (Tables 7 and 8). However, 13.33% of the rainy season values were above the W.H.O. (2006) admissible limit of 0.03 mg/l, therefore not fit for human consumption. The values were below 2 mg/l to 7 mg/l reported by [41] from selected borehole waters in Zamfara State. He stated that the source of contamination may be attributed to the interaction of the groundwater and the rock layers or soil minerals. Cadmium may also enter drinking water through weathering of soil and bedrock, corrosion of galvanized pipes, atmospheric decomposition of direct discharge from industrial operation, burning of coal and house hold wastes, volcanic eruptions, leakages from landfills and from the use of fertilizers. Therefore, the presence of cadmium in the water could be attributed to any of the above factors. At low concentrations, it is toxic to plants, fishes, birds, humans etc. The average lead content of all the borehole water samples investigated during rainy and dry seasons range from 0.00-0.04mg/l (Table 9). However, 26.66% of these values are beyond the recommended limit of 0.01mg/l from WHO (2006) standard for drinking water. This result agreed with that of [42] that reported a lead concentration of 0.09 mg/l in water in a major body in Ibadan, Nigeria. This may be as a result of may be as a result of fissured water pipes,sewage effluents, automobile exhaust fumes, run off wastes and atmospheric depositions. High level of lead in water can lead to cancer, interference in vitamin D metabolism, adverse effects in mental development in infants and toxicity to the central and peripheral nervous systems. The concentration of chromium in the ground water varied from 0.00- 0.04mg/l during the rainy season and from 0.00- 0.03 mg/l during dry season (Tables 7 and 8). All the water samples for chromium were within the recommended WHO value of 0.05mg/l (WHO, 2006). The average concentration of chromium ranged from 0.00mg/l-0.03mg/l. This is in line with the report of [7] who also recorded a chromium average range of 0.00mg/l-0.02mg/l from the borehole water samples in Awka Metropolis. High level of cadmium in water could be toxic to the kidney. This low concentration may be attributed to better sanitary practices by laboratories and companies within the location. The heavy metal of the borehole water samples for both rainy and dry season were analyzed using two-way analysis of variance at Alpha level of 0.05 which showed that there was no significant difference ($p < 0.0891$) between the water samples

CONCLUSION

The examination of the chemical parameters of selected borehole water samples in Agbor, Delta State, Nigeria showed serious contamination, and this is an indication that some of the water samples may not be suitable for human consumption. The boreholes water quality did not comply well with stipulated standards for consumption and domestic uses. Therefore, health defects due to drinking of water containing high levels of these parameters may occur among the residents in the study area especially in the cases of lead, phosphate, iron, and cadmium if they accumulate beyond the acceptable concentrations in the body.

REFERENCES

Eze, S.O. and Madumere, I.C. (2012). Physicochemical and Microbiological Analysis of Water Bodies in Uturu, Abia State, Nigeria. Asian Journal of Natural and Applied Sciences, 1(4):58-65.

Engwa, A.G., Tagbo, N.R., Iyala C.P.J. and Unaegbu, M. (2015). Physicochemical and Microbial Analysis of Potable Water Sources in Enugu Metropolis. Journal of Public Health and Epidemiology, 7(3):65-70.

Agwu, A., Avoaja, A.G. and Kalu, A.U. (2013). The Assessment of Drinking Water Sources in Aba Metropolis, Abia State, Nigeria. Environmental Research, 3(4):72-6.

Calow R. C., Alan M., McDonald, Alan L., Nicol and Nick, R. S. (2011): Groundwater Security and Drought in Africa. Linking Availability, Access and Demand.

MacDonald, A. M., Davies, J., Calow, R. C. and Chilton P. J. (2005) Developing groundwater: a guide for rural water supply. (Rugby: Practical Action Publishing).

Trivedi, P., Bajpai, A. and Thareja, S. (2010). Comparative Study of Seasonal Variations in Physicochemical Characteristics in Drinking Water Quality of Kanpur, India with Reference to 200 MLD Filtration Plant and Groundwater. Natural Science journal, 8(4):1- 7.

Nwankwoala, H. O. (2011). An integrated approach to sustainable groundwater development and management in Nigeria. Journal of Geology and Mining Research, 3 (5), 123-130.

Rajana, A. (2010): Physicochemical Analysis of some Groundwater Samples of Kotputli Town Jaipur, Rajasthan India.International Journal of Environmental and Pharmaceutical Research, 1(2): 111-113.

MacDonald, A. M. and Calow, R.C. (2009) Developing groundwater for secure Water supplies in Africa. Desalination, 248, 46-56.

Kot, M. (2013). Do invading organisms do the wave? Canada Applied Math. Quarterly,10, 139-170.

Olobaniyi, S.B., Ogban, F.E., Ejechi, B.O. and Ugbe, F.C. (2004). Assessment of Groundwater Across Delta State: Effects of man, geology and hydrocarbon exploitation. Final report. Delta State University. 100p.

Cheesbrough, M. (2010). District Laboratory

Vaishali, P. and Punita, P. (2013). Assessment of Seasonal Variations in Water Quality of River Mini, at Sindhrot, Vadodara. International Journal of Environmental Sciences, 3 (14):24- 36.

Edokpayi, J.N., Odiyo, O., Msagati, T.A.M. and Potgieter, N. (2015). Temporal Variations in Physicochemical and Microbiological Characteristics of Muudi River, South Africa. International Journal of Environmental Research and Public Health, 12(4):28-40.

Josiah, J.S., Nwangwu, C.O.S., Omage, K., Akpanyung, O.E. and Amaka, D.D. (2014). Physicochemical and Microbiological Properties of Water Samples used for Domestic purposes in Okada town, Edo State, Nigeria. International Journal of Current Microbiology and Applied Sciences, 3(6):886-94.

Olajubu, F.A. and Ogunika, F. (2014). Assessment of the Physicochemical and Microbiological Properties of Borehole Water Samples from Akungba-Akoko, Ondo State, Nigeria. International Journal of Pharmaceutical Science and Research, 5(7):367-74.

Akpoveta, O.V., Okoh, B.E. and Osakwe, S. A. (2011). Quality Assessment of Borehole Water used in the Vicinities of Benin, Edo State and Agbor, Delta State of Nigeria. Current Research in Chemistry, 3: 62-69.

Practise in Tropical Countries. Part 2. 2ndedn.

APHA, (2005). American Public Health Association. Standard Methods for the examination of water and wastewater, 21st edn. Washington. Pp. 1-21.

WHO (World Health Organisation) (2006). World health organization. Guidelines for drinking water quality. Recommendation WHO, Geneva. 569-571.

Yaduvams, E. M., Rao, S. R., Ramana, C. V., and Reddy, T. B. (2017). Physicochemical Analysis of Ground Water in the Selected Area of Visakhapatnam, AP, India. International Journal Current Microbiology Applied Science, 6 (12): 1252-1258.

Nduka, J. K., Orisakwe, O. E. and Ezenweke, L. O. (2008). Some Physiocochemical Parameter of Potable Water Supply in Warri, Niger Delta Area of Nigeria. Scientific Research and Essay 3 (11): 547-551.

Bernard, E. and Ayeni, N. (2012). Physicochemical Analysis of groundwater samples of Bichi local Government Area of Kano state of Nigeria. Asian

Research publishing network Journal of science and technology 2: 324-332.
Purandara, B. K., and Shreedhar, R. (2014) Water quality assessment of Bellary Nala, Belagavi. 971-981.
Mendie, U. (2015). The Nature of Water in: The Theory and Practice of Clean Water Production for Domestic and Industrial Use. Lagos: Lacto-Medals Publishers. Pp 1-21.
Withers P, Lord E. (2002) Agricultural Nutrients Inputs to Rivers and Groundwater in the UK: Policy, Environmental Management and Research Needs, The Science of Total Environment 282: 300.
Prior, H. and Jones, P. (2002) Regulation of Surface Water Quality in a Cretaceous Chalk Catchment, UK: An Assessment of the Relative Importance of In-stream and Wetland Processes. The Science of the Total Environment 2002: 282-283.
Raju, N. J., Ram, P and Dey, S., (2009). Groundwater quality in the lower Varuna river basin, Varanasi district, Uttar Pradesh Journal of Geological Social India, 73:178.
Onwughara, N. I., Ajiwe, V. I. E. and Nnabuenyi, H. O. (2013). Physicochemical studies of water from selected boreholes in Umuahia North Local Government Area in Abia State, Nigeria. International Journal of Pure and Applied Bioscience. 1 (3): 34-44.
Cobbina, S. J., Nyame, F. K., and Obiri, S. (2012). Groundwater quality in the sahelian region of northern Ghana, West Africa Research Journal of Environmental and Earth Sciences, 4 (4): 482-491.
Agunwamba, J. C (2008), Water Engineering Systems, De—Iroil Innovation, Enugu.
Muhammad, A. B. T., Saidu, B., Ahmed, S. and Mohammed, S. A. (2013). Bacteriological and Physicochemical Properties of Borehole Water in Niger State Polytechnic, Zungeru Campus, Indian Journal of Science Research.4(1) 1-6.
Palamuleni, L. and Akoth, M. (2015) Physicochemical and Microbial Analysis of Selected Borehole Water in Mahikeng, South Africa International Journal of Environmental Research Public Health 12 (8): 8619–8630.
Taiwo, A. M., Olujimi, O.O., Bamgbose, O. and Arowolo, T. A. (2012). Surface Water Quality Monitoring in Nigeria: Situational Analysis and Future Management Strategy, DOI: 10.5772/33720 · Source: InTech.
Akujieze, C. N. and Oteze, G. E. (2006). Groundwater quality of Benin City urban aquifer, African Scientist, 7 (2): 69 – 85.
John, O. O. and Ebehiremhen. O. O. (2014) Physicochemical Characteristics and Bacteriological Studies in Hand Dug Wells in Udu Community Delta State, Nigeria Department of Animal and Environmental Biology, Journal of Environment and Earth Science 4 (22): 116-120.
Dhavran, A., and Karu, S., (2002) Pig Dung as Pond Manure: Effect on Water Quality Pond Productively and Growth of Carps in Poly Culture System. The International Centre for Living Aquatic Resources Management (ICLARM) Quarterly, Manila 25 (1):1-14.
Duruibe, J. O., Ogwuegbu, M. O. C. and Egwurugwu, J. N. (2007). Heavy metal pollution and human biotoxic effects. International Journal of Physical Sciences. 2 (5): 112-118.
Danyal, I., Blake F., Andrea W. and Rusyniak D.E. (2006). Heavy metal poisoning: Clinical presentations and pathophysiology. Clinical medicine, 26: 67-97.
Silapajarn, K., Boyd, C.E. and Silapajarn, O. (2004). Physical and chemical characteristics of pond water and bottom soil in channel in west-central Alabama. Bulletin 655: 1-46.
Ozuturk, M., Ozozen, G., Minareci, O. and Minareci, E. (2009). Determination of Heavy Metals in Fish, Water and Sediments of Avsar Dam Lake in Turkey. Iran Journal of Environmental Health. Science and Engineering, 6 (2): 73-80.
Chukwuka Clifford Odenigbo (2015) Physicochemical and Heavy Metal Assessment of Water from Selected Boreholes in Kaura-Namoda Local Government Area, Zamfara State, Nigeria. Published Master's thesis in Ahmadu Bello University, Zaria.
Adeyemo, O. K., Ayodeji, I. O and Aika-Raji, C. O. (2002). The water quality and sanitary conditions in a major abattoir (Bodija) in Ibadan, Nigeria. African Journal of Biomedical Research, 5 (12):51–55.

Oghonim Pius Akaraka Nkem, Ugwu Okechukwu Paul-Chima and Godwin Victor Chukwusom (2023). Evaluation of the average values of the chemical parameters of selected borehole water Samples in Agbor, Delta State, Nigeria. IDOSR JOURNAL OF APPLIED SCIENCES 8(3)118-139. https://doi.org/10.59298/IDOSR/2023/10.2.14189