Physio-Chemical and Microbial Water Quality Assessment of Selected Wells in Bida Catchment Area of Niger State, Nigeria

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Abstract: This study evaluated the quality of groundwater in Bida catchment area of Niger state, Nigeria. The study was necessitated by the need to appraise the effects of the seeming unregulated manner in which solid wastes and waste water from domestic and agricultural sources are dumped or deposited in the area. The study was carried out by collecting three water samples from three water wells in the study area at both wet and dry seasons. Based on this, laboratory tests were conducted. The results of the assessment of Physico-chemical, and Microbial parameters clearly showed that most of the parameters tested fell within the recommended WHO standard limits while for wet and dry seasons, respectively, Coliform value was found to be above standard limits for wet season whereas for dry season period, Coliform and E-coli were above the recommended limits. Based on the results, it is imperative that groundwater exploration in Bida catchment area should be deep and waste management practices should be encouraged among the people through enlightenment campaign. In addition, water treatment plants should be established in the study area to help curb unwarranted spread of water borne diseases in the study are.

Keywords: Ground water, microbial, physio-chemical, water quality, Bida Catchment

1. Introduction

As reported in (Guru *et al.,* (2011), Quality of groundwater can be assessed based on the physical (Colour, taste, odour, temperature and turbidity), Chemical (Alkalinity, Calcium Hardness, Magnesium Hardness, Calcium ion, potassium and trace elements) and Microbial parameters (i.e., Total Coliform and E-Coli). It is obvious that open dumping/depositing of solid waste and waste water are the major factors that affect water quality alteration in developing countries like Nigeria (Mohammed, 2011). Solid wastes are residues from homes, business and institutions and are referred to as trash, garbage, rubbish, refuse, and discards (Omotonmwan and Eseigbe, 2009).

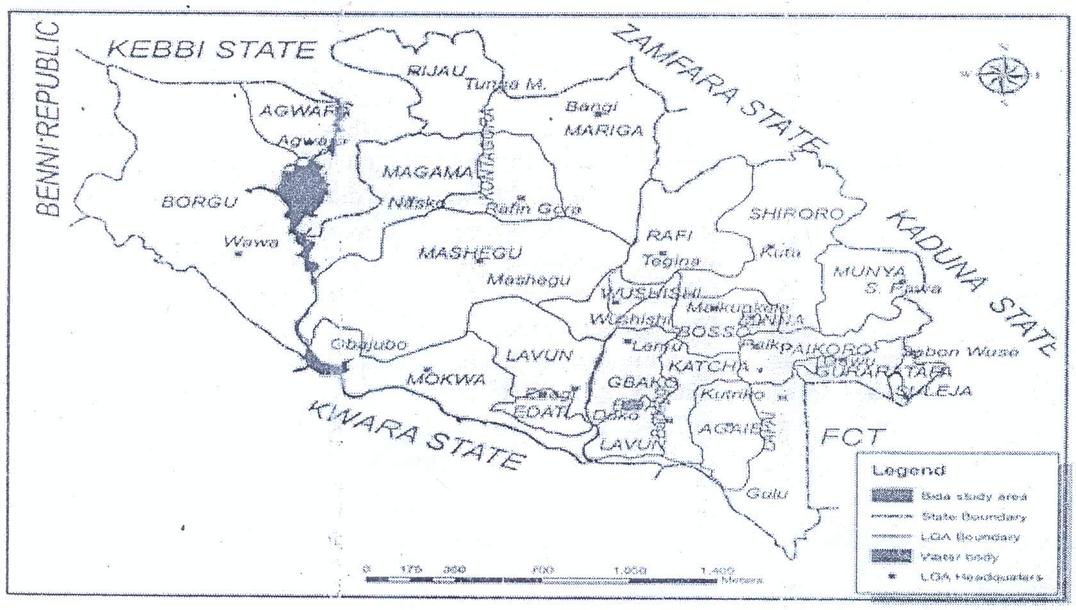
Liquid wastes are wastes dissolved in water which are usually from industrial processes known as effluent, domestic liquid, acid waste and waste oil from workshops (NISP, 2003). Contamination of water bodies are issues of serious environmental concern (Akpoveta *et al.*, 2010). This is due to the fact that urban population is increasing every day as a result of rural – urban migration necessitated by various factors. The absence of or rather inadequacy of other source of water supply like pipe born water today in various part of Nigeria has made groundwater an important source of water supply for the populace (Adelekan, 2010). Open dumping or depositing of solid waste and waste water in Bida catchment area of Niger state is becoming a serious problem that needs to be addressed since it can cause adverse effect on the quality of ground water in the area.

This work evaluated the quality of ground water (Hand dug well and drilled bore holes) in Bida catchment area of Niger state. This was done to obtain information regarding the quality of groundwater being used for both irrigation and human consumption in the study area.

2. Methodology

2.1 Description of the Study Area

The study area Bida mainly is occupied by the Nupe people of Nigeria, whose common source of water for domestic and agricultural purpose are from groundwater and surface water systems spread around the area. Bida lies on latitude 9^0 06^1N and longitude 6^0 1^1E and it is located in the southern part of Niger state as shown in Figure 1.



Source: Niger State Water Board

Fig.1: Map of Niger State Showing the Study Area (Bida)

This geographically places the area almost in the centre of Nigeria. Bida is generally regarded as the capital of Nupe land in Nigeria. Its rapidly increasing population was estimated to be more than 600,000 people (Shehu, 2001). Geographically, this location shares boundaries with the Federal Capital Territory (FCT) in the south east of Bida and Minna towards Suleja. The Bida Basin is a NW-SE trending intracratonic structure extending from Kontagora in Niger State in the north to the area slightly beyond Lokoja in the south. It is delimited in the NE and SW by the basement complex and merges with the Anambra and Sokoto Basins to the SE and NW respectively. Its sedimentary fill comprises post-orogenic molasse and thin unfolded marine sediments (Ladipo, 1988). The basin is a gently down-warped trough whose origin is closely connected with Santonian orogenic movements in SE Nigeria and the Benue valley. The basin trends perpendicular to the main axis of the Benue Trough and the Niger Delta Basin and is regarded as the NW extension of the Anambra Basin, both of which were major depocentres during the third major transgressive cycle in the Late Cretaceous Interpretations of Landsat images and borehole logs, as well as geophysical data suggest that the basin is bounded by a system of linear faults trending NW-SE (Udensi and Osazuwa, 2004).

2.2 Sample Collection

Groundwater samples were collected in six, 1 litre hand plastic and Screw – capped bottles that have been sterilized to avoid any contamination by physical, chemical and microbial means. Three of the six samples were collected during wet and the other three during dry seasons from different locations (Efu Madami; Park, and Esso) around Bida catchment area of Niger state as indicated in Figure 2 below.

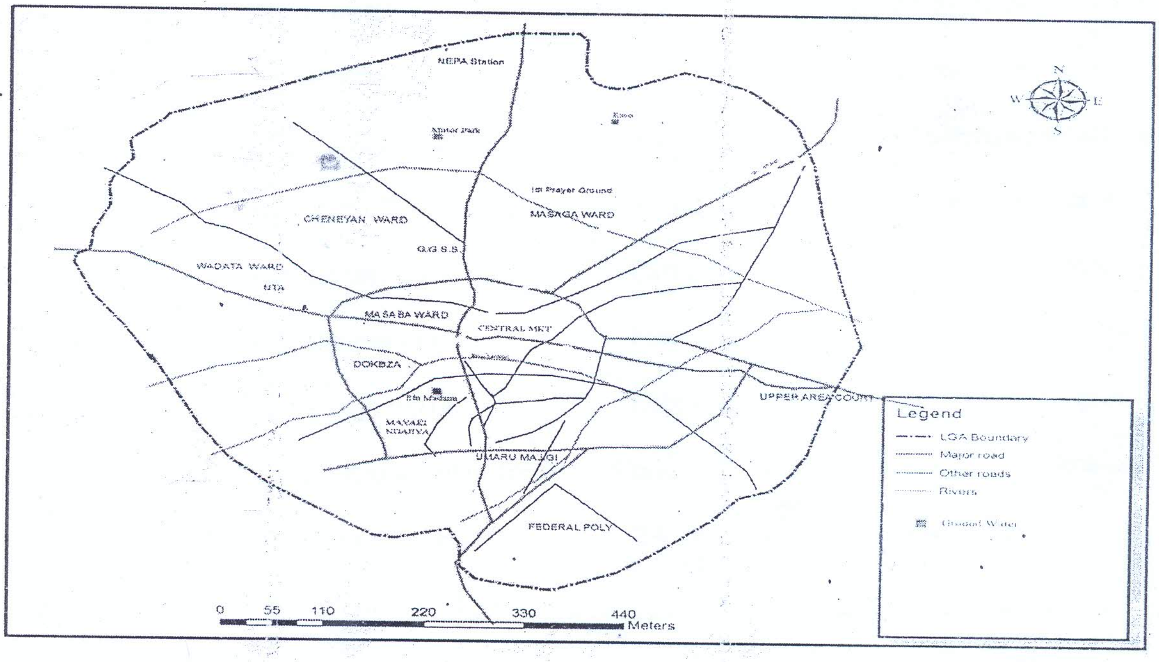


Fig.2: Location Map of Bida showing points of Ground Water Sample Collection

Three of the containers used for sample collection during wet season (August, 2011) were labeled GWI_w, $GWII_w$, and $GWIII_w$ while the other three containers used during dry season (March, 2012) were labeled GWI_d, $GWII_d$, and $GWIII_d$. These samples were then taken to the laboratory immediately for analysis. However, Table 1 shows the Elevation and Coordinates (Longitude and Latitude) of the various locations where groundwater samples were collected for laboratory analysis in the study area.

Table 1: Elevation and Coordinates (Longitude and Latitude) of sample locations

Sample No	Location	Elevation	Latitude	Longitude
a	Motor park	152m	09°05□47.6□□	06°00□31.9
b	Eso	134m	09°03□42.3□	06°00□32.9
c	Efu Madami	140m	09°04□37.9□□	06°00□19.3□□

2.3 Laboratory Analysis

The determination and analyses of the physico-chemical and microbial parameters were carried out according to the standard methods for the examination of water and waste water (APHA, 1989). The various parameters and laboratory test methods used is presented in Table 2.

Table 2: Parameters and their test methods

Parameters	Test Methods	Parameters	Test Methods
Conductivity	EC/TDS meter	Sulphate	Turbid metric method
Temperature	Thermocouple Thermometer	Magnesium Hardness	EDTA Titration method
pH	pH meter	Sodium	Flame Photometer
Turbidity	Turbidity meter	Iron	Phenanthroline method
TDS	EC/TDS meter	Potassium	Flame Photometer
Dissolved Oxygen	Dissolved Oxygen meter	Ammonia	Nesslerization method
Chloride	Argentomeric Titration meter	Bicarbonate	Titrimetric method
Total Hardness	EDTA Titrimetric method	Carbonate	Titrimetric method
Alkalinity	Titrimetric method	Fluoride	Colorimetric method
Calcium Hardness	Titration with EDTA	Copper	Neocuprine method
Nitrate	Cadmium Reduction method	Coliform	Membrane Filtration Techniques
Calcium ion	EDTA Titration method	E-Coli	
Magnesium ion	EDTA Titration method		

2.4 Statistical Analysis

The results obtained for the Physio-Chemical and Bacteriological parameters from laboratory test were analyzed statistically using descriptive statistics from SPSS package, 15.0 versions.

3. Results and Discussion

The statistical summary of the results of the Physio-Chemical and Bacteriological analysis are presented in Tables 3 and 4.

Table 3: Summary of the wet season groundwater quality parameters from Bida Catchment area of Niger state

Parameters	GWI	GWII	GWIII	Mean	Std Dev.	WHO	FAO
Conductivity	784	439	98	440.33	343.00	-	-
Temperature	27.0	27.0	27.0	27.00	0.00	25-29	25
pH	6.66	6.58	6.62	6.62	0.04	6.5-8.0	6-8.5
Turbidity	1.60	2.42	0.85	1.62	0.79	5	
TDS	5546.4	305.9	68.3	1973.53	3096.47	1000	0-2000
Dissolved Oxygen	6.03	6.10	5.20	5.78	0.50	-	
Chloride	65.2	122.3	57.1	81.53	35.54	250	-
TH	110.1	35.1	18.2	54.47	48.92	500	-
Alkalinity	29.0	70.0	15.0	38.00	28.58	-	-
CaH	61.2	22.0	13.1	32.10	25.59	75	-
Nitrate	2.12	1.59	1.99	1.90	0.28	50	-
Calciun ion	23.0	8.10	9.48	13.53	8.23	-	-
Magnesium ion	11.9	3.19	1.24	5.44	5.68	-	-
Sulphate	3.00	4.00	10.0	5.67	3.79	250	-
Mg Hardness	48.9	13.1	5.1	22.37	23.32	50	-
Sodium	2.5	13.5	4.5	6.83	5.89	200	-
Iron	0.10	0.04	0.18	0.11	0.07	0.3	-
Potassium	4.69	4.69	3.35	4.21	0.75	-	0-2
Ammonia	0.48	0.36	0.45	0.43	0.06	-	-
Bicarbonate	29.0	70.0	15.0	38.00	28.58	-	0-6
Carbonate	0.00	0.00	0.00	0.00	0.00	-	0-30
Fluoride	0.10	0.01	0.06	0.06	0.05	1.5	-
Copper	0.02	0.01	0.00	0.01	0.01	5	-
Coliform	56	1	26	27.67	27.54	0	-
E-Coli	0	0	0	0.00	0.00	0	-

GWI = Groundwater (Efu madami), GWII = Groundwater (Park), GWIII = Groundwater (Esso)

WHO = World Health Organization, FAO = Food and Agricultural Organization, S. D. = Standard Deviation

All Units are in mg/l except Conductivity (µs/cm), Tempt (°C), Turbidity (NTU), and E-Coli & Coliform (cfu/100ml).

Table 4: Summary of the dry season groundwater quality parameters from Bida Catchment area of Niger State

Parameters	GWI	GWII	GWIII	Mean	Std Dev.	WHO	FAO
Conductivity	67	130	69	88.67	35.81	-	0-3
Temperature	29.6	29.7	29.6	29.63	0.06	25-29	25
pH	5.70	5.30	5.90	5.63	0.31	7.0- 8.5	6.0-8.5
Turbidity	6.24	1.49	2.72	3.48	2.47	50	-
TDS	43.5	87.1	46.2	58.93	24.43	1000	0-2000
DO_2	5.21	3.84	3.96	4.34	0.76	-	-
Chloride	154.3	24.8	26.5	68.53	74.28	200	-
Total Hardness	120	14	16	50.00	60.63	100	0-1.18
Alkalinity	21	7.0	9.0	12.33	7.57	-	-
Calcium Hardness	56	6.0	8.0	23.33	28.31	75	-
Nitrate	71.6	11.1	15.6	32.77	33.71	50	-
$Calcium^{2+}$	22.4	2.41	3.21	9.34	11.32	-	-
$Magnesium^{2+}$	15.6	1.95	1.95	6.50	7.88	-	0-1
Sulphate	0.00	2.0	0.00	0.67	1.15	250	0-2.4
Mg Hardness	64	8.0	8.0	26.67	32.33	50.00	0-2.4
Sodium	74.9	8.10	7.09	30.03	38.86	200	-
Iron	0.09	0.04	0.00	0.04	0.05	0.30	0-0.6
Potassium	44.8	7.46	7.46	19.91	21.56	-	-
Ammonia	19.6	3.04	4.28	8.97	9.22	-	0-2
Bicarbonate	21	7.0	9.0	12.33	7.57	-	-
Carbonate	0.00	0.00	0.00	0.00	0.00	-	-
Fluoride	0.14	0.13	0.12	0.01	1.5	1.50	-
Copper	0.00	0.00	0.00	0.00	5	5.00	-
Coliform	140	3	44	70.32	0	0.00	-
E-Coli	22	0	0	12.70	0	0.00	-

GWI = Groundwater (Efu madami), GWII = Groundwater (Park), GWIII = Groundwater (Esso)

WHO = World Health Organization, FAO = Food and Agricultural Organization, S. D. = Standard Deviation

All Units are in mg/l except Conductivity (µs/cm), Tempt (^{0}C), Turbidity (NTU), and E-Coli & Coliform (cfu/100ml).

Electrical conductivity is the measure of the capacity of water to conduct electricity. The analysis carried out during wet season depicted that values obtained ranged from a minimum of 98µS/cm to a maximum of 784µS/cm at Esso and Efu Madami locations respectively. Similarly, dry season values ranged from a minimum of 67µS/cm to a maximum of 130µS/cm at Efu Madami and Park locations. Conductivity of groundwater at wet season indicated a higher mean value of 440µS/cm than at dry season with a mean value of 88.67µS/cm. The high value of EC at wet season than at dry season may be as a result of gradual deposition of salt over the years.

Temperature values obtained from the analysis carried out on groundwater during wet season showed that there is no variation in temperature at the three locations in the study area. Similarly, at dry season temperature of groundwater was similar at Efu Madami and Esso, but slightly different from that at Park location. This vividly indicated that values of temperature obtained fall within the recommended limit for drinking water quality ranging from 25 – 29°C by WHO (2004) as depicted (Tables 3 and 4), but slightly above the permissible limit of 25°C by FAO (2000). It is important to note that temperature has no deleterious impact on the consumer; hence, the groundwater is suitable for domestic purposes.

The pH values obtained during wet season ranged from a minimum of 6.58 to a maximum of 6.66 at Park and Efu Madami locations. This showed that the values fall within the permissible limit by WHO (2004) and FAO (2000) standards. Hence, water is suitable for domestic and irrigation purposes. Dry season pH values ranged from a minimum of 5.30 to a maximum of 5.90 at Park and Esso locations (Tables 3 and 4). The values therefore, falls below WHO (2004) and FAO (2000) recommended limit which gives the necessity for the addition of soda ash or lime to make it suitable for the proffered purpose. The mean values clearly indicated that wet season pH was higher than dry season in the study area.

Turbidity concentration in groundwater ranged from a minimum of 0.85NTU to a maximum of 2.42NTU at Esso and Park locations. Turbidity at dry season ranged from a minimum of 1.49NTU to a maximum of 6.24NTU at Park and Efu Madami locations. Comparing the values obtained for both wet and dry seasons, within the permissible limit of WHO (2004), it suffices to note that the groundwater is suitable for domestic purposes since values are below the permissible limit of 5NTU, except turbidity at Efu Madami which was slightly above the acceptable limit. However, the water can still be used since water with turbidity up to 25NTU can be used for the domestic purpose in the absence of other options. Similarly, groundwater at dry season recorded a higher turbidity concentration with a mean value of 3.48NTU than at wet season with a mean value of 1.62NTU. High turbidity values in water normally cause problem with water purification process such as flocculation and filtration, which may increase treatment cost.

Total Dissolved Solids (TDS) referred only to the solids in solution or the solids remaining in the filtrate after all the suspended solids have been removed from the filter. Total Dissolved Solids of the groundwater samples are due to vegetable decay, evaporation, disposed of effluent and chemical weathering of rocks. Total dissolved solids in water are composed majorly of carbonates, bicarbonates, chlorides, phosphates and nitrates of calcium, magnesium, sodium, potassium and manganese, organic matter, salt and other particles (Guru *et al.*, 2011). However, based on the analysis carried out during wet season, total dissolved solids ranged from a minimum of 68.3mg/l to a maximum of 5546.4mg/l at Eso and Efu Madami locations. The higher concentration of TDS at Efu Madami may also cause gastrointestinal irritation in human and could have laxative effect upon transit (WHO, 2004). At dry season, the concentration of total dissolved solids (TDS) ranged from a minimum of 43.5mg/l to a maximum of 87.1mg/l at Efu Madami and Park locations. Groundwater at both seasons was found suitable for domestic purposes, since its values falls below the recommend limit by WHO (2004) and FAO (2000) Standards, except at Efu Madami during wet season that recorded a higher value than the recommended limit. This condition clearly qualifies groundwater in that area not suitable for drinking but suitable for agriculture.

The recorded values for both wet and dry seasons indicated that groundwater in the study area were less contaminated with total dissolved solids (TDS) at dry season than at wet season.

Dissolved Oxygen (DO) in ground water during wet season ranged from a minimum of 5.20mg/l to a maximum of 6.10mg/l at Eso and Park locations respectively. Dry season value of DO ranged from a minimum of 3.84mg/l to a maximum of 5.21mg/l at Park and Efu Madami locations. The result therefore, showed that ground water has higher dissolved oxygen at wet season than at dry season as the mean value for wet and dry seasons recorded are 5.78mg/l and 4.34mg/l, respectively. The low concentration of DO in water might be the result of the presence of microorganisms in the water; whereas high concentration might be resulted from the ability of water to hold oxygen or the absence of microorganism in the water.

Chloride (Cl) can be seen as a substance that is widely distributed naturally, as sodium (NaCl) and potassium (KCl) salts. Concentration of chloride above recommended limit makes water to have a bad taste and also may cause corrosion in the distribution system. However, based on the analysis carried out on ground water during wet season, chloride concentration ranged from a minimum of 57.1mg/l to a maximum of 122.3mg/l at Eso and Park locations respectively. Similarly, chloride concentration during dry season ranged from a minimum of 24.8mg/l to a maximum of 154.3mg/l at Park and Efu Madami locations. Chloride concentration of ground water for both seasons falls below the permissible limit by WHO (2004) standard; hence, groundwater in the study area is suitable for domestic purpose. Consequently, ground water at wet season recorded a higher chloride concentration with a mean value of 81.53mg/l than at dry season with a mean value of 68.53mg/l.

Hardness is primarily due to the presence of carbonate, sulphates, and chlorides of calcium and magnesium. Hardness could lead to scaling of hot water pipes, boilers and other house hold appliances. Total hardness of ground water in the study area during wet season ranged from a minimum of 18.2mg/l to a maximum of 110.1mg/l at Esso and Efu Madami locations respectively. Similarly, at dry season, total hardness ranged from a minimum of 14mg/l to a maximum of 120mg/l at Park and Efu Madami locations. The values were found to have exceeded the permissible limit at Efu Madami during the two seasons. This could be as a result of the accumulation of salts in the well. However, the mean concentration for total hardness at wet season is found higher than the mean concentration at dry season in the study area.

Alkalinity concentration in ground water during wet season ranged from a minimum of 15mg/l to a maximum of 70mg/l at park and Esso locations. Similarly, at dry season, alkalinity ranged from a minimum of 7mg/l to a maximum of 21mg/l at park and Esso locations respectively. The mean values for both season clearly showed that wet season groundwater was more concentrated than dry season ground water.

The concentration of calcium hardness in ground water during wet season ranged from a minimum of 13.10 mg/l to a maximum of 61.20mg/l at Esso and Efu Madami locations. Similarly at dry season, the concentration of calcium hardness ranged from a minimum of 6.0mg/l to a maximum of 56mg/l at Park and Efu Madami locations. It is therefore; clear that groundwater in the study area for both seasons was suitable for domestic use, since the calcium hardness values falls below permissible limit by WHO (2004) Standards. Besides, groundwater at wet season recorded a higher chloride concentration with a mean value 81.53mg/l than at dry season with a mean value of 68.53mg/l.

Nitrate is a form of nitrogen and a vital nutrient for growth, reproduction and the survival of organisms. The major toxic effect of nitrate contamination in drinking water is methaemoglobinaemia, which leads to reduced oxygen transfer to the body tissues. Nitrate concentration during wet season in the study area ranged from a minimum of 11.1mg/l to a maximum of 71.6mg/l at Park and Efu Madami locations respectively. Nitrate concentrations during wet season falls below the permissible limit of 50mg/l by WHO (2004), whereas, the concentration of nitrate at Efu Madami during dry season exceeded the permissible limit of 50mg/l. however, the rate of nitrate concentration in ground water during wet season in the study area permits the use for domestic use, but the concentration of nitrate at Efu Madami was not suitable for use for domestic purpose. The mean concentration of nitrate at wet season was lower than the nitrate concentration in ground water at dry season. This was because nitrates are usually built up during dry seasons and high concentrations of nitrates are only observed during early wet seasons. The reason for this, is that initial rains flush out deposited nitrates from near surface soils and nitrate concentration is minimized drastically as wet season progresses. High concentration of phosphate and nitrate may result to eutrophication, which eventually increases algae growth and ultimately minimizes dissolved oxygen levels in the water.

Calcium ion concentration obtained for groundwater during wet season ranged from a minimum of 8.10mg/l to a maximum of 23.0mg/l at Park and Efu Madami location. Similarly, at dry season, calcium ion concentration obtained ranged from a minimum of 2.41mg/l to a maximum of 22.4mg/l at Park and Efu Madami locations. However considering the mean values obtained for groundwater at both seasons clearly confirm that ground water at wet season contains higher calcium ion concentration than at dry season in the study area.

Magnesium ion concentration obtained for groundwater during wet season ranged from a minimum of 1.24mg/l to a maximum of 11.9mg/l at Eso and Efu Madami locations. In the same vein, magnesium ion concentration obtained in ground water during dry season ranged from a minimum of 1.95mg/l at Eso and Park to a maximum of 15.6mg/l at Efu Madami locations. However, from the mean values obtained at wet season and dry season, it has been observed that dry season recorded higher concentration than ground water at wet season in the study area.

Sulphate concentration in groundwater during wet season ranged from a minimum of 3.0mg/l to a maximum of 10.0mg/l at Efu Madami and Eso locations. Similarly, the results showed that there was no sulphate concentration in the groundwater for dry season periods at both Efu Madami and Eso. But it was found to be 2.0mg/l at Park. Comparing the values obtained for both seasons with the recommended limit by WHO (2004) and FAO (2000) standards, it is glaring that groundwater for both seasons was suitable for domestic irrigation purposes since the values are below that of WHO (2004) and FAO (2000) standards. However, from the mean value obtained for wet and dry season, it was observed that wet season groundwater was more concentrated with sulphate than the dry season groundwater in the study area

The concentration of magnesium hardness in ground water during wet season ranged from a minimum of 5.10mg/l to a maximum of 48.90mg/l at Eso and Efu Madami locations. Similarly, at dry season, the concentration of magnesium hardness in ground water ranged from a minimum of 8.0mg/l at Park and Eso to a maximum of 64.0mg/l at Efu Madami locations. However, groundwater during dry season possess a higher concentration of magnesium hardness with a mean value of 26.67mg/l than at wet season with a mean value of 22.37mg/l. groundwater at both season was therefore, suitable for domestic and public purposes, since values fall below the permissible limit of 50mg/l by WHO (2004).

Sodium (Na) concentration present in ground water during wet season in the study area ranged from a minimum of 2.5mg/l to a maximum of 13.50mg/l at Efu Madami and Park locations. Similarly, at dry season, sodium concentration in ground water ranged from a minimum of 7.09mg/l to a maximum of 74.90mg/l at Eso and Efu Madami locations. The sodium concentration in ground water at dry season possesses a higher mean value of 30.03mg/l relatively compared to 6.83mg/l for wet season. however, groundwater in the study area is suitable for domestic and public uses, since values fall below the permissible limit by WHO (2004) and FAO (2000) Standards.

Iron (Fe^{2+}) is the most abundant heavy metal and excessive of it in water gives it a bad taste and can also cause staining of laundry and plumbing fixtures. It is identified as an essential element in human nutrient and deficiencies of it can lead to impaired mental development in children, it also reduces work performance in adults and in severe cases, anemia or impaired oxygen delivery. Iron concentration in groundwater at wet season ranged from a minimum of 0.04mg/l to a maximum of 0.18mg/l at Park and Efu Madami locations respectively. At dry season, iron concentration in groundwater does not show up at Eso location but 0.04mg/l and 0.09mg/l were recorded at Park and Efu Madami locations respectively. Groundwater at both seasons therefore, was suitable for domestic and irrigation purposes, since values fall below the permissible limit of 0.3mg/l by WHO (2004). However, groundwater at wet season recorded higher iron concentration with a mean value of 0.11mg/l than dry season concentration with a mean value of 0.04mg/l.

Potassium (K^{+}) concentration in groundwater during wet season in the study area ranged from a minimum of 3.35mg/l at Eso to a maximum of 4.69mg/l at Park and Efu Madami locations. Similarly, potassium concentration in ground water during dry season ranged from a minimum of 7.46mg/l at Park and Esso to a maximum 44.8mg/l at Efu Madami. However, based on the values obtained for potassium concentration for both seasons groundwater was not suitable for domestic and public purposes, since the values are higher than the permissible limit by WHO (2004) and FAO (2000) Standards. The mean values estimated for both seasons clearly indicated that groundwater purposes since the values are below that of WHO (2004) and FAO (2000) standards. However, from the mean value obtained for wet and dry season, it was observed that wet season groundwater was more concentrated with sulphate than the dry season groundwater in the study area

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Sodium (Na) concentration present in ground water during wet season in the study area ranged from a minimum of 2.5mg/l to a maximum of 13.50mg/l at Efu Madami and Park locations. Similarly, at dry season, sodium concentration in ground water ranged from a minimum of 7.09mg/l to a maximum of 74.90mg/l at Eso and Efu Madami locations. The sodium concentration in ground water at dry season possesses a higher mean value of 30.03mg/l relatively compared to 6.83mg/l for wet season. however, groundwater in the study area is suitable for domestic and public uses, since values fall below the permissible limit by WHO (2004) and FAO (2000) Standards.

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Potassium (K^+) concentration in groundwater during wet season in the study area ranged from a minimum of 3.35mg/l at Eso to a maximum of 4.69mg/l at Park and Efu Madami locations. Similarly, potassium concentration in ground water during dry season ranged from a minimum of 7.46mg/l at Park and Esso to a maximum 44.8mg/l at Efu Madami. However, based on the values obtained for potassium concentration for both seasons groundwater was not suitable for domestic and public purposes, since the values are higher than the permissible limit by WHO (2004) and FAO (2000) Standards. The mean values estimated for both seasons clearly indicated that groundwater was highly contaminated at dry season than at wet season in the study area.

Ammonia concentration in groundwater during wet season ranged from a minimum of 0.36mg/l to a maximum of 0.48mg/l at Park and Efu Madfami locations respectively. Similarly, at dry season, ammonia concentration in groundwater ranged from a minimum of 3.04mg/l to a maximum of 19.6mg/l at Park and Efu Madami locations respectively. The mean concentration of ammonia recorded higher value in ground water at dry season than at wet season in the study area.

Bicarbonate concentration in groundwater in the study area during wet season ranged from a minimum of 15.0mg/l to a maximum of 70mg/l at Eso and locations respectively. Consequently, at dry season, bicarbonate concentration in groundwater ranged from a minimum of 7.0mg/l to a maximum of 21mg/l at and Efu Madami locations. The estimated mean concentration of bicarbonate in groundwater in the study area at wet season recorded a higher value than at dry season. Carbonate was not detected in groundwater at both wet and dry seasons in all locations.

Fluoride affect bone development and excessive concentration results to dental or in critical level skeletal fluorosis. Skeletal fluorosis is a painful disease that results to physical impairment. However, too little of fluoride has also been affiliated with dental caries and other dental health problems. Fluoride concentration in groundwater during wet season in the study area ranged from a minimum of 0.01mg/l to a maximum of 0.10mg/l at Park and Efu Madami locations. Similarly, fluoride concentration during dry season ranged from a minimum of 0.12mg/l to a maximum of 0.14mg/l at Eso and Efu Madami locations respectively. Groundwater in the study area at both seasons was suitable for domestic and public purposes, since all three values fall below the permissible limit by WHO standards.

Copper is highly essential element in human metabolism and deficiencies of it leads to a variety of clinical disorders, including nutritional anemia in infants. Following the analysis conducted on ground water during wet season, copper concentration in groundwater ranged from a minimum of 0.0mg/l to a maximum of 0.02mg/l at Eso and Efu Madami locations. Consequently, at dry season, copper concentration was not found in ground water at the three locations. Therefore, groundwater at both seasons was suitable for domestic purposes, since values falls below permissible limit of 1mg/l by WHO (2004) Standard.

The total coliform count found in groundwater at the three locations in the study area were 56cfu at Efu Madami, 1cfu at Park, and 26cfu at Esso per 100ml of water which showed that groundwater in the study area during wet season requires serious disinfection before it can be used for domestic purpose. The higher count of total coliform in groundwater in the study area may be as a result of high concentration of dissolved oxygen in the water. Similarly, groundwater at dry season contains high coliform count at the three locations in the study area above the recommended limit of 0cfu per 100ml of water sample by WHO (2004), which also requires disinfection before use. However, the recorded count of coliform falls below the recommended limit of 1000cfu per 100ml of water by FAO (2000) Standard for irrigation water quality hence, groundwater for both seasons is suitable for irrigation in the study area.

E-coli count was not detected in groundwater during wet season. This indicates that the groundwater is fit for domestic purpose. Similarly, E-coli count was also not detected in groundwater during dry season at Park and Esso locations. These conditions makes groundwater in the study area fit for domestic uses except at Efu Madami location with E-coli count of 22cfu per 100ml of water sample. The simple implication of this is that groundwater in this particular area is unsuitable for drinking and irrigation purposes. It is thus possible for vegetables irrigated with this water to be contaminated and hence may pose health hazards.

3.1 Converted ions and calculated parameters for Irrigation Water Quality

Tables 5 and 6, represents statistical summary of some converted ions (mg/l to meq/l) and calculated parameters for groundwater analyzed during wet and dry seasons respectively. These results are strictly for irrigation purpose.

Table 5: Statistical summary of some ions converted from mg/l to meq/l and calculated parameters for ground water at wet season in the study area

Parameters	GWI	GWII	GWIII	Mean	S. D.	FAO
Ca^{2+}	1.15	0.41	0.47	0.68	0.41	0-20
Mg^{2+}	0.99	0.27	0.10	0.45	0.47	0-5
So_4^-	0.06	0.08	0.21	0.12	0.08	0-20
Na^+	0.11	0.59	0.19	0.29	0.26	0-40
Hco_3^-	0.48	1.15	0.250	0.63	0.47	0-10
Cl^-	1.84	3.45	1.61	2.3	1.00	0-30
SAR	0.11	1.02	1.89	1.01	0.89	0-9
ESP	4.64	42.45	22.35	23.15	18.92	
SCR	-1.66	0.47	-0.32	-0.5	1.08	

GWI = Groundwater (Efu madami), GWII = Groundwater (Park), GWIII = Groundwater (Esso)
FAO = Food and Agricultural Organization, S. D. = Standard Deviation
All Units are in meq/l.

The maximum values obtained for ions (Ca^{2+}, Mg^{2+}, SO_3^-, Na^+, HCO_3^-, and Cl^-) concentration in ground water at both wet and dry seasons fall within the permissible range by FAO (2000) Standard. Therefore, groundwater in the study area is suitable for irrigation purpose.

Sodium Absorption Ratio (SAR) obtained for ground water during wet season ranged from a minimum of 0.11meq/l to a maximum of 1.89meq/l (Table 5), at Eso and Efu Madami locations. Similarly, at dry season, Sodium Adsorption Ratio ranged from a minimum of 0.10meq/l to a maximum of 2.96 meq/l, for both Eso and Efu

Madami locations, respectively (Table 6). The maximum values for both seasons clearly showed that Sodium Adsorption Ratio (SAR) for ground water is suitable for irrigation purpose since maximum values fall between 0 and 9meq/l as permitted by FAO (2000) standard. From the mean values obtained and tabulated (Tables 5 and 6), Sodium Adsorption Ratio (SAR) for ground water at dry season is higher than that of wet season in the study area.

Exchangeable Sodium Residue (ESR) obtained for ground water during wet season ranged from a minimum of 4.64meq/l to a maximum of 42.45meq/l (Table 6), at Efu Madami and Motor park locations. Similarly, at dry season, it ranged from a minimum of 7.27meq/l to a maximum of 47.7meq/l at Eso and Efu Madami locations.

Table 6: Statistical summary of some ions converted from mg/l to meq/l and calculated parameters for groundwater at dry season for irrigation purpose in the study area.

Parameters	GWI	GWII	GWIII	Mean	Std Dev.	FAO
Ca^{2+}	1.12	0.12	0.16	0.47	0.57	0-20
Mg^{2+}	1.30	0.16	0.16	0.54	0.66	0-5
So_4^-	0.00	0.04	0.00	0.01	0.02	0-20
Na^+	3.26	0.35	0.31	1.31	1.69	0-40
Hco_3^-	0.34	0.12	0.15	0.2	0.12	0-10
Cl^-	4.35	0.69	0.75	1.93	2.09	0-30
SAR	2.96	0.95	0.10	1.34	1.47	0-9
ESP	47.73	42.68	7.27	32.56	22.05	
SCR	-2.08	-0.16	-0.17	-0.8	1.11	

GWI = Groundwater (Efu madami), GWII = Groundwater (Park), GWIII = Groundwater (Esso)

FAO = Food and Agricultural Organization, S. D. = Standard Deviation

All Units are in meq/l.

Sodium Carbonate Residue (SCR) for ground water during wet season ranged from a minimum of -1.66meq/l to a maximum of -0.47meq/l (Table 5), at Efu Madami and Park locations respectively. Similarly, at dry season, Sodium Carbonate Residue (SCR) ranged from a minimum of -2.08meq/l to a maximum of -0.16meq/l (Table 6), at Efu Madami and Park locations. The maximum values obtained at both seasons fall below zero, that is, (SCR<0). This clearly indicated that ground water is not alkaline as permitted by standard (Egharevba, 2009), except at Park location that was greater than zero hence, water is suitable for irrigation purpose. However, from the mean value obtained for both season indicated that water at wet season has higher Sodium Carbonate Residue (SCR) than dry season ground water.

4. Conclusions

Based on the analysis, the following conclusions were drawn:

I. The maximum values of Physio-chemical and Microbial parameters for wet season groundwater were within the recommended limit of WHO (2004) and FAO (2000) standards for drinking and irrigation water quality The quality of water in the study area is compromised; that is, it is not suitable for use since total dissolved solids (5546.4mg/l) and total *coliform* (1.00cfu/100ml – 56.00cfu/100ml) were above the recommended limit by WHO (2004) and FAO (2000) standards for drinking and irrigation water quality.

II. Maximum values of parameters for dry season groundwater fell within the permissible limits of WHO (2004) and FAO (2000) standards though the quality of water is not fit for domestic and irrigation purposes since values for nitrate (71.60mg/l); magnesium hardness (64.00mg/l); total *coliform* (3.00cfu/100ml -140.00cfu/100ml); and *E-coli* (0-22.00cfu/100ml) are above recommended limits of WHO (2004) and FAO (2000) standards.

III. The high contamination of groundwater at wet season than dry season could be as a result of leaching from waste materials carelessly dumped around the study area into the groundwater.

Recommendations

Based on the conclusions drawn, the following recommendations can be proffered, namely:-

Adequate measures like building of water treatment plants should be ensured for a sustainable or enhanced water quality; at least for domestic and agricultural purposes.

The culture of disposing waste water and solid waste carelessly in the area should be discouraged through proper enlightenment campaign. This can be done by providing improved dust-bins for collecting solid wastes or incinerators, and suck-away pits dug far away (at least 20m) from groundwater systems.

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