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Physicochemical Analyses of Different Sources of Drinking Water in Okene Local Government Area of Kogi State, Nigeria

M. O. Aremu[1*], G. O. Majabi[2], J. O. Oko[1], O. D. Opaluwa[2], B. L. Gav[3] and B. G. Osinfade[4]
[1]Department of Chemical Sciences, Federal University Wukari, PMB 1020, Taraba State, Nigeria
[2]Department of Chemistry, Nasarawa State University, PMB 1022, Keffi, Nigeria
[3]Department of Chemistry, University of Agriculture, Makurdi, Nigeria
[4]Department of Science Laboratory & Technology, Federal Polytechnic, Ilaro, Nigeria
*Corresponding author email: lekearemu@gmail.com

Abstract

The water quality of three different sources of drinking water (stream, hand–dug well and borehole) collected within the Okene local government area of Kogi State, Nigeria was investigated by determining some physicochemical parameter of the water samples using standard analytical techniques. The results of physicochemical parameters (pH, temperature, turbidity, conductivity, alkalinity, total dissolved solids, total suspended solids, total solids, bicarbonate, chloride and dissolved oxygen) for both dry and wet seasons revealed high spatial variations in the concentrations of physicochemical parameters. Alkalinity was not recorded in all the three different sources of water samples for both seasons however, other physicochemical parameter values fall within the acceptable values of EU and SON standard limits except turbidity values in two sources (stream and borehole) which are higher than SON acceptable limit. Therefore, it is imperative that the water sources should be monitored regularly and be subjected to further treatments in order to reduce the concentrations of the few identified pollution indicators that may pose some dangers to the health of people living in this area.

Keywords: Stream, hand–dug well, borehole, physicochemical parameters.

1. Introduction

Water pollution is the contamination of water bodies such as lakes, rivers, oceans and groundwater. It occurs when pollutants are discharged directly or indirectly into water bodies without adequate treatment to remove the harmful compounds. Water pollution is a major problem in the global context. The consequence of pollution leads to worldwide death and spreading of diseases (Egboh & Emeshili, 2007; Aremu *et al*., 2008). Acute problems of water pollution is not only in developing countries but also a continue struggle in industrialized nations. Water is typically referred to as polluted when it is impaired by anthropogenic contaminants and does not support human use and undergoes a marked shift in its ability to support its constituent biotic communities (Akhionbare, 2004; Lenntech, 2006). National phenomena such as volcanoes, storms and earthquake also cause major changes in water quality as well as the ecological status of water (Olayinka and Alo, 2004; Aremu, 2008).

The quality of water for human consumption and other functions of human activities cannot be over–emphasized. There are various organizations as well as research institutes which carried out research annually in order to minimize water borne diseases which lead to loss of lives daily. The main causes of water pollution emanated primarily from local sources such as population growth, poor land use system, agricultural activities, industrialization and other anthropogenic impacts (Oludare *et al.,* 1998; Aremu *et al.,* 2011). Some solutions preferred by water scientist to control the problems due to poor environment characterized by numerous activities are yet to meet the healthy condition of the people (Okuo *et al*., 2007; Aremu & Inajoh, 2007). The area under investigation cannot be left out as a result of lack of quality water supply.

The potable water supply in Okene local government area of Kogi State has been characterized by poor or low productivity and as a result, the populace do not enjoy potable water supply as most people depend on various alternative water sources. The qualities of these sources are generally not guaranteed and cases abound where health problems have risen due to consumers drinking from such sources. The major sources of water supply are from streams, wells and boreholes. Only few people who are privileged have access to pipe borne water provided by the State government due to low productivity, small coverage and insufficient service delivery.

Thus, the specific objectives of this research work were to assess the levels of physicochemical parameters (pH, temperature, turbidity, conductivity, alkalinity, total solids, bicarbonate, chloride and dissolved oxygen) in the water bodies of stream, hand–dug well and borehole which are the sources of drinking water in Okene local

government area of Kogi State, Nigeria. This kind of study is imperative as there has not been any major record on this aspect of research in the area.

2. Materials and Methods

2.1 Study area

Okene local government area (LGA) in Kogi State, Nigeria is located within latitude 07° 17' to 07° 35' North and longitude 06° 05' to 06° 30' East (Fig 1). The LGA shares boundaries with Adavi, Ajaokuta, Ogori Magongo LGAs in Kogi State and Okpella in Edo State. It is located in the north–central geopolitical zone of Nigeria known as middle belt region. The LGA is made up of different ethnic groups each with a distinct cultural heritage; the major tribe is the Ebira while the minority tribes include the Igbo, Igala, Hausa and Yoruba that are interspersed among the major tribes. The major occupations of the indigenes are farming for men while the women engage in weaving cloth. The minority tribes are traders.

Okene LGA has a typical climate of the tropical zone due to its location: The physical features of the area are mainly mountains and hills with rocks as well as undulating highlands of average height. Mineral resources such as iron ore and precious stones are found in the area. The climate is characterized by two distinct seasons (dry and wet). The dry season is between the month of October and March while the rainy season is from April to September. The months of December, January and February are cold due to the blowing of harmattan wind from the northern part of Nigeria.

2.2 Sample source

A total of twelve samples were selected from four different geographical zones of Okene LGA. These comprise of one stream, hand–dug well and borehole samples from each zone. The towns where samples were collected include Ageva, Okengwe, Idoji and Inike.

2.3 Sample collection, treatment and preservation

The water samples obtained for the assessment span through the two seasons of the year that is, the dry and wet seasons. The samples for the dry season were collected between October, 2009 and February, 2010 while that of wet season commenced in April, 2010 and ended in July, 2010. Polythene containers were washed with detergent solution followed by several rinses with tap water and finally with distilled water (APHA, 2002). Then the containers are rinsed with the water samples to be used. Water samples from streams, hand–dug wells and boreholes were collected and stored in clean polythene containers. Preservation of samples was carried out as prescribed by APHA (2002) methods. The samples were taken in pre–cleaned 1 litre polythene plastic kegs and acidified (pH 1.5) with Analar grade concentrated nitric acid. They were kept in ice chests and transported to the laboratory where they were further preserved in a refrigerator before analyses.

2.4 Physicochemical analysis

The water sample temperature was taken immediately at the site of collection using a simple thermometer calibrated in degree Celsius, pH was measured using a BNC pH meter and electrical conductivity model NATOP PB5 (London, UK). Other physicochemical parameters that were later determined in the preserved water samples were: total hardness and alkalinity by titrimetry method (APHA, 2002), total dissolved solids by gravimetric method; chloride ion was measured by chloride ion meter (Model KRK, Cl–52, Japan), bicarbonate, turbidity and dissolved oxygen by APHA (2002) methods. All the chemicals used were of analytical reagent grade and obtained from British Drug Houses (BDH, London). Names of towns (as appropriate) were used in the various Tables.

2.5 Statistical analysis

The data generated from all the physicochemical analysis were analyzed statistically (Steel and Torrie, 1960). Parameters evaluated were grand mean, standard deviation and coefficient of variation. All the determinations were in triplicate.

3. Results and Discussion

The result of physicochemical analysis of the four selected streams for dry and wet seasons is shown in Tables 1. It was revealed that chloride was the most abundant chemical parameter for both seasons. Its values varied

betwen 50 mgL^{-1} to 180 mgL^{-1} at dry season but ranged from 40.0 mgL^{-1} to 60.0 mgL^{-1} in wet season. This parameter was followed by temperature with ranged values from 26.1°C to 29.5°C (dry season) and 24.8°C to 29.2°C (wet season). Turbidity values increase in wet season with varying values of 0.20 NTU to 52.0 NTU compared to dry season values. Total solids had values (0.73 mgL^{-1} – 1.34 mgL^{-1}) in wet season greater than ranged values of 0.33 mgL^{-1} – 0.97 mgL^{-1} in dry season. Also, total suspended solids (0.40 mgL^{-1} – 0.49 mgL^{-1}) in wet season greater than that of 0.21 mgL^{-1} – 0.29 mgL^{-1} in dry season. Dissolved oxygen varied from 6.0 mgL^{-1} – 12.0 mgL^{-1} in dry season while it ranged from 7.0 mgL^{-1} – 10.0 mgL^{-1} in wet season.

Alkalinity was not present for both seasons. Electrical conductivity has a uniform reading of 1.0 µs/cm in all the stream samples for both seasons. The least parameter for dry and wet seasons was bicarbonate with values varied from 0.01 to 0.06 mgL^{-1} (dry season) and 0.08 – 0.58 mgL^{-1} (wet season). There is wide spatial variation in the values obtained for the parameters determined with sample location as presented by the co-efficient of variation percent (CV %), which ranged between 6.1 % in temperature to 66.7 % each in total dissolved solids and bicarbonate for stream water sample (dry season) while 0.4 % in total dissolved solids and 73.8 % in turbidity (wet season).

Table 2 displays the results of physicochemical parameters of hand-dug well samples for dry and wet seasons. The data on the Table showed that chloride had the highest concentration value in all the samples collected for both seasons. Its values varied from 40.0 to 180 mgL^{-1} (dry season) and ranged from 30.0 mgL^{-1} to 60.0 mgL^{-1} (wet season). The presence of chloride where it does not occur naturally indicates possible water pollution. High level of chloride kills plants and wild life (Oboh and Edema, 2007). Temperature for both seasons ranged from 26.2°C to 29.8°C (dry season) while it varied from 26.9°C to 30.4°C (wet season). Increase in temperature may be due to increase in microbial activities. Dissolved oxygen varied from 7.0 to 12.0 mgL^{-1} during dry season and 6.0 to 12.0 mgL^{-1} in wet season. The values of turbidity for dry season were 0.25 - 1.93 NTU (no value was recorded in the stream from Idoji area) and wet season (0.30 - 2.10 NTU). Turbidity is mainly a function of the suspended materials in water which range from colloidal to coarse dispersion (Aremu *et al.*, 2006).

The conductivity value of the samples analyzed had a constant reading of 1.0 µs/cm while alkalinity was not detected in all the samples for both seasons (Table 2). The concentrations of bicarbonate were still low in the hand–dug well for both seasons with coefficient of variation value of 66.7% followed by total dissolved solids (62.2 %) for dry season. Total dissolved solid ranged between 0.36 - 0.77 mgL^{-1} in dry season and 0.10 - 0.97 mgL^{-1} in wet season. Total suspended solids had varying values of 0.17 – 0.31 mgL^{-1} for dry season and 0.37 – 0.51 mgL^{-1} in wet season. Total solid ranged from 0.36 – 0.94 mgL^{-1} (dry season) and 0.61 – 1.34 mgL^{-1} for wet season. Turbidity had 54.3% as the highest coefficient variation value at wet season followed by total dissolved solids (53.2 %) and the least value was temperature (6.2 %).

The physicochemical parameters for four borehole water samples are presented in Table 3. The results showed that chloride had ranged values from 40.0 - 80.0 mgL^{-1} (dry season) but varied from 40.0 mgL^{-1} in both Okengwe and Idoji to 60.0 mgL^{-1} in Ageva (wet season). Temperature varied from 26.0 to 29.6°C during dry season while it ranged from 20.1 to 28.0°C in wet season. The dissolved oxygen for all the samples had ranged values of 4.0 to 9.0 mgL^{-1} (dry season) and 6.0 to 11.0 mgL^{-1} (wet season). Dissolved oxygen carries out various biochemical changes and many ecologists have discussed its effect on metabolic activities of organisms (Egereonu & Dike, 2007). The pH values ranged from 6.42 in Ageva to 6.83 in Inike (dry season) while they varied from 6.28 to 6.96 during wet season. The only parameter in the samples for both seasons that was found not to be present was alkalinity. Total dissolved solids had ranged values of 0.41 – 0.93 mgL^{-1} in dry season and 0.55 – 0.78 mgL^{-1} (wet season). The varying values of total suspended solids for both seasons were 0.18 – 0.35 mgL^{-1} (dry season) and 0.38 – 0.55 mgL^{-1} in wet season. Total solids values during dry season were 0.41 – 0.93 mgL^{-1} and 1.01 – 1.33 mgL^{-1} in wet season. Bicarbonate was highly varied parameter with 71.4% followed by total dissolved solids (32.5%) while the least was temperature (5.4%) in all the dry season samples. When compared to wet season samples, the highest coefficient variation was turbidity (95.5%) followed by bicarbonate (44.9%) and the lowest value was total solid (10.7%).

Table 4 shows the comparison of physicochemical parameters of streams, hand-dug wells and boreholes for dry and wet seasons. The pH values ranged between 6.50 in stream to 7.03 in hand–dug well water samples (dry season) and ranged between 6.43 to 7.03 (wet season). These values fall within the SON (2007) and EU (1998) recommended limit of 6.5 to 8.5. These pH values showed that the surface and groundwater in the area are safe for agricultural, recreational and domestic uses (Oludare *et al.*, 1998; Egbu, 2004). The conductivity parameter of all the water samples have a uniform value of 1.0 µs/cm for both dry and wet seasons and therefore fall below the recommended value of 1000 µs/cm and 250 µs/cm for SON (2007) and E U (1998), respectively.

The total dissolved solids values for dry and wet seasons ranged between 0.39 mgL^{-1} in stream sample to 0.45 mgL^{-1} in hand-dug well sample and 0.62 mgL^{-1} in well sample to 0.65 mgL^{-1} in borehole sample, respectively. These values fall below each acceptable value of 500 mgL^{-1} (SON, 2007; EU, 1998). This shows that the water samples collected from the area meet both the human and domestic requirement (Atolaiye & Aremu, 2008). Total solids for both dry and wet seasons are far below the stipulated values of 1500 mgL^{-1} (SON, 2007). Its mean values ranged from 0.64 mgL^{-1} in both streams and boreholes to 0.69 mgL^{-1} for that of well samples (dry season). Also, mean values ranged from 1.05 mgL^{-1} in hand-dug well to 1.12 mgL^{-1} in borehole samples (wet season). The bicarbonate mean values ranged from 0.03 mgL^{-1} in streams and hand-dug wells to 0.07 mgL^{-1} in boreholes (dry season). But they varied from 0.084 mgL^{-1} in stream to 0.122 mgL^{-1} in borehole samples (wet season). These values fall within the recommended value of 150 mgL^{-1} (SON, 2007). Water has been classified on the basis of hardness as follows: water having 0.75 mg $CaCO_3L^{-1}$ as soft, 75–150 mg $CaCO_3L^{-1}$ as hard and >300 mg $CaCO_3L^{-1}$ as total hardness (Aremu *et al.,* 2011). Base on this, all the water samples in this study can be classified as soft water. The concentration of chloride varied from 60.0 mgL^{-1} in borehole samples to 102.5 mgL^{-1} in streams at dry season while that of wet season ranged from 47.5 mgL^{-1} in boreholes to 52.5 mgL^{-1} in streams. These values fall below the accepted values of 250 mgL^{-1} for both SON (2007) and EU (1988) standard limit. Chlorides are sourced from the rocks, herbicides and pesticides, agricultural run-offs and seas as sea salts. The presence of chloride in water depends on the geochemical conditions of the area earmarked for the research. Chloride is more stable component in water but its concentration is unaffected by most natural or biological processes; their amount in water is useful measure in water samples. Chloride can range from <10 mgL^{-1} to >2500 mgL^{-1} (in sea water) (Templeton, 1984; Oludare *et al*., 1998; Adeyeye & Abulude,2004; Aremu *et al.,* 2011). Only alkalinity was not recorded in all the water samples collected from the three sources for the two seasons. The mean values of total suspended solids varied between 0.24 mgL^{-1} in hand-dug wells to 0.25 mgL^{-1} in streams and boreholes at dry season and 0.43 mgL^{-1} in hand-dug well to 0.47 mgL^{-1} in bore holes during wet season.

4. Conclusion

This work has presented physico-chemical parameters (pH, temperature, turbidity, conductivity, alkalinity, total dissolved solids, total suspended solids, total solids, bicarbonate, chloride, dissolved oxygen) determined in the stream, hand-dug well and borehole water samples located in Ageva, Okengwe, Inike, and Idoji in Okene Local Government Area of Kogi State, Nigeria. The results revealed that physico-chemical parameters like pH, electrical conductivity, total dissolved solids, total suspended solids, total solids, bicarbonate and chloride contents were found mostly within the limits set up by the Standard Organization of Nigeria and European Union standard regulatory bodies for drinking and domestic waters (SON, 2007; EU, 1998). Alkalinity was not detected in all the water samples analyzed. The amount of turbidity in all the water samples was found not to be present for dry season while high values were recorded at wet season. However, it is imperative that these sources should be monitored regularly and be subjected to further treatments to reduce drastically the concentrations of the few identified pollution indicators that may pose some dangers to health and society despite some pollution parameter values that are within the acceptable range of both SON (2007) and EU (1998).

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Table 1: Physico-Chemical Analysis of Four Streams in Okene Local Government Area

Parameter	Ageva	Okengwe	Idoji	Inike	Mean	S D	C V%
Dry Season							
pH	6.40	6.20	6.50	6.90	6.50	0.29	35.2
Temperature (^oC)	26.1	27.5	29.2	29.5	28.1	1.58	6.1
Turbidity(NTU)	18.1	50.0	ND	25.8	NA	NA	Na
Conductivity (μscm^{-1})	1.0	1.0	1.0	1.0	1.0	na	Na
Alkalinity (mgL^{-1})	ND	ND	ND	ND	NA	na	Na
Total dissolved solids (mgL^{-1})	0.77	0.40	0.35	0.04	0.39	0.29	66.7
Total suspended solids(mgL^{-1})	0.22	0.21	0.29	0.29	0.25	0.04	16.0
Total solids (mgL^{-1})	0.97	0.61	0.64	0.33	0.64	0.26	35.9
Bicarbonate (mgL^{-1})	0.01	0.02	0.03	0.06	0.03	0.02	66.7
Chloride (mgL^{-1})	180.0	60.0	120.0	50.0	102.5	60.2	10.3
Dissolved Oxygen. (mgL^{-1})	6.0	11.0	7.0	12.0	9.0	2.94	28.3
Wet Season							
pH	6.80	7.10	6.90	7.30	7.03	0.22	54.2
Temperature (^oC)	24.8	25.5	29.2	28.5	27.0	2.17	7.0
Turbidity (NTU)	20.1	52.0	0.20	28.4	25.2	21.44	73.8
Conductivity (μscm^{-1})	1.0	1.0	1.0	1.0	1.0	NA	NA
Alkalinity (mgL^{-1})	ND	ND	ND	ND	NA	NA	NA
Total dissolved solids (mgL^{-1})	0.94	0.80	0.57	0.24	0.64	0.31	0.4
Total suspended solids(mgL^{-1})	0.40	0.41	0.49	0.49	0.45	0.05	9.3
Total solids (mgL^{-1})	1.34	1.21	1.06	0.73	1.09	0.26	21.1
Bicarbonate(mgL^{-1})	0.09	0.58	0.08	0.11	0.21	0.24	22.6
Chloride (mgL^{-1})	60.0	40.0	50.0	60.0	52.5	9.57	15.8
Dissolved Oxygen. (mgL^{-1})	7.0	8.0	10.0	10.0	8.75	1.50	15.7

SD = Standard deviation, CV% = Co-efficient of variation percent, ND = Not detected, NA = Not applicable

Table 2: Physico-Chemical Analysis of Four Hand-Dug Well in Okene Local Government Area

Parameter	Ageva	Okengwe	Idoji	Inike	Mean	S D	C V %
Dry Season							
pH	6.50	6.70	6.10	6.80	6.53	0.31	4.0
Temperature (^oC)	26.4	26.2	29.6	29.8	28.0	1.92	60.7
Turbidity (NTU)	0.63	0.25	ND	1.93	NA	NA	NA
Conductivity (μscm^{-1})	1.0	1.0	1.0	1.0	1.0	NA	NA
Alkalinity (mgL^{-1})	ND	ND	ND	ND	NA	NA	NA
Total dissolved solids (mgL^{-1})	0.36	0.77	0.5	0.63	0.57	0.18	62.2
Total suspended solids (mgL^{-1})	0.24	0.17	0.31	0.22	0.24	0.06	20.8
Total solids (mgL^{-1})	0.60	0.94	0.36	0.85	0.69	0.26	33.3
Bicarbonate (mgL^{-1})	0.004	0.06	0.04	0.05	0.04	0.02	66.7
Chloride (mgL^{-1})	180.0	40.0	120.0	40.0	95.0	68.1	62.0
Dissolved Oxygen. (mgL^{-1})	8.0	12.0	10.0	7.0	9.25	2.22	20.7
Wet Season							
pH	6.20	6.10	6.60	6.80	6.43	0.33	11.7
Temperature (^oC)	30.4	27.6	26.9	28.7	28.3	1.52	6.2
Turbidity (NTU)	1.80	0.45	0.30	2.10	1.16	0.92	54.3
Conductivity (μscm^{-1})	1.0	1.0	1.0	1.0	NA	NA	NA
Alkalinity (mgL^{-1})	ND	ND	ND	ND	NA	NA	NA
Total dissolved solids (mgL^{-1})	0.56	0.97	0.10	0.83	0.62	0.38	53.2
Total suspended solids(mgL^{-1})	0.42	0.37	0.51	0.42	0.43	0.06	11.9
Total solids (mgL^{-1})	0.98	1.34	0.61	1.25	1.05	0.33	26.7
Bicarbonate (mgL^{-1})	0.07	0.10	0.09	0.11	0.02	0.02	15.8
Chloride (mgL^{-1})	50.0	30.0	60.0	60.0	50.0	14.1	24.6
Dissolved Oxygen. (mgL^{-1})	9.0	6.0	12.0	9.0	9.0	2.45	23.6

SD = Standard deviation, CV% = Co-efficient of variation percent, ND = Not detected, NA = not applicable

Table 3: Physico-chemical analysis of four bore-hole water samples in and around Okene Local Government Area

Parameter	Ageva	Okengwe	Idoji	Inike	Mean	S D	C V %
Dry Season							
pH	6.42	6.62	6.70	6.83	6.64	0.12	32.3
Temperature (^oC)	27.1	26.0	29.3	29.6	28.0	1.51	5.4
Turbidity (NTU)	ND	0.42	30.3	0.20	NA	NA	NA
Conductivity (μscm^{-1})	1.0	1.0	1.0	1.0	1.0	NA	NA
Alkalinity (mgL^{-1})	ND	ND	ND	ND	NA	NA	NA
Total dissolved solids (mgL^{-1})	0.23	0.35	0.58	0.42	0.40	0.13	32.5
Total suspended solids (mgL^{-1})	0.18	0.20	0.35	0.26	0.25	0.07	28.0
Total solids (mgL^{-1})	0.41	0.55	0.93	0.68	0.64	0.19	29.7
Bicarbonate (mgL^{-1})	0.07	0.03	0.02	0.15	0.07	0.05	71.4
Chloride (mgL^{-1})	80.0	50.0	70.0	40.0	60.0	15.8	26.3
Dissolved Oxygen. (mgL^{-1})	9.0	8.0	4.0	6.0	6.75	1.92	28.4
Wet Season							
pH	6.35	6.85	6.28	6.96	6.61	0.02	25.2
Temperature (^oC)	20.1	26.0	27.4	28.0	25.4	3.13	12.3
Turbidity (NTU)	1.0	0.62	33.2	28.0	15.7	15.0	95.5
Conductivity ($uscm^{-1}$)	1.0	1.0	1.0	1.0	NA	NA	NA
Alkalinity (mgL^{-1})	ND	ND	ND	ND	NA	NA	NA
Total dissolved solids (mgL^{-1})	0.63	0.55	0.78	0.62	0.65	0.08	12.9
Total suspended solids (mgL^{-1})	0.38	0.50	0.55	0.46	0.47	0.06	13.2
Total solids (mgL^{-1})	1.01	1.05	1.33	1.08	1.12	0.12	10.7
Bicarbonate (mgL^{-1})	0.13	0.084	0.064	0.21	0.12	0.06	44.9
Chloride (mgL^{-1})	60.0	40.0	40.0	50.0	47.5	8.29	17.5
Dissolved oxygen. (mgL^{-1})	8.0	11.0	6.0	8.0	8.25	1.79	21.7

SD = Standard deviation, CV% = Co-efficient of variation percent, ND = Not detected, NA = not applicable

Table 4: Levels of Physico-Chemical Parameters in the Streams, Hand-Dug Wells and Bore-Holes Water Samples Compared

Parameters	Streams	Hand-dug wells	Bore-holes	SON Standard	EU Standard
Dry Season (Mean Value)					
pH	6.50	7.03	6.64	6.5 - 8.5	6.5 – 8.5
Temperature (^oC)	28.1	28.0	28.1	Ambient	25
Turbidity (NTU)	NA	NA	NA	5.0	na
Conductivity (μscm^{-1})	1.0	1.0	1.0	1000	250
Alkalinity (mgL^{-1})	NA	NA	NA	na	na
Total dissolved solids (mgL^{-1})	0.39	0.57	0.40	500	500
Total suspended solids(mgL^{-1})	0.25	0.24	0.25	500	500
Total solids (mgL^{-1})	0.64	0.69	0.64	1500	na
Bicarbonate (mgL^{-1})	0.03	0.04	0.07	150	na
Chloride (mgL^{-1})	102.5	95.0	60.0	250	250
Dissolved Oxygen. (mgL^{-1})	9.0	9.25	6.75	na	75
Wet Season (Mean Value)					
pH	7.03	6.43	6.61	6.5 - 8.5	6.5 – 8.5
Temperature (^oC)	27.0	28.3	25.4	Ambient	25
Turbidity (NTU)	25.2	1.16	15.7	5.0	na
Conductivity (μscm^{-1})	1.0	1.0	1.0	1000	250
Alkalinity (mgL^{-1})	NA	NA	NA	na	na
Total dissolved solids (mgL^{-1})	0.64	0.62	0.65	500	500
Total suspended solids (mgL^{-1})	0.45	0.43	0.47	500	500
Total solids (mgL^{-1})	1.09	1.05	1.12	1500	na
Bicarbonate (mgL^{-1})	0.21	0.095	0.122	150	na
Chloride (mgL^{-1})	52.5	50.0	47.5	250	250
Dissolved Oxygen.(mgL^{-1})	8.75	9.0	8.25	na	75

Standard Organization of Nigeria (SON, 2007); European Union (EU, 1998); NA = Not applicable; na = not available.

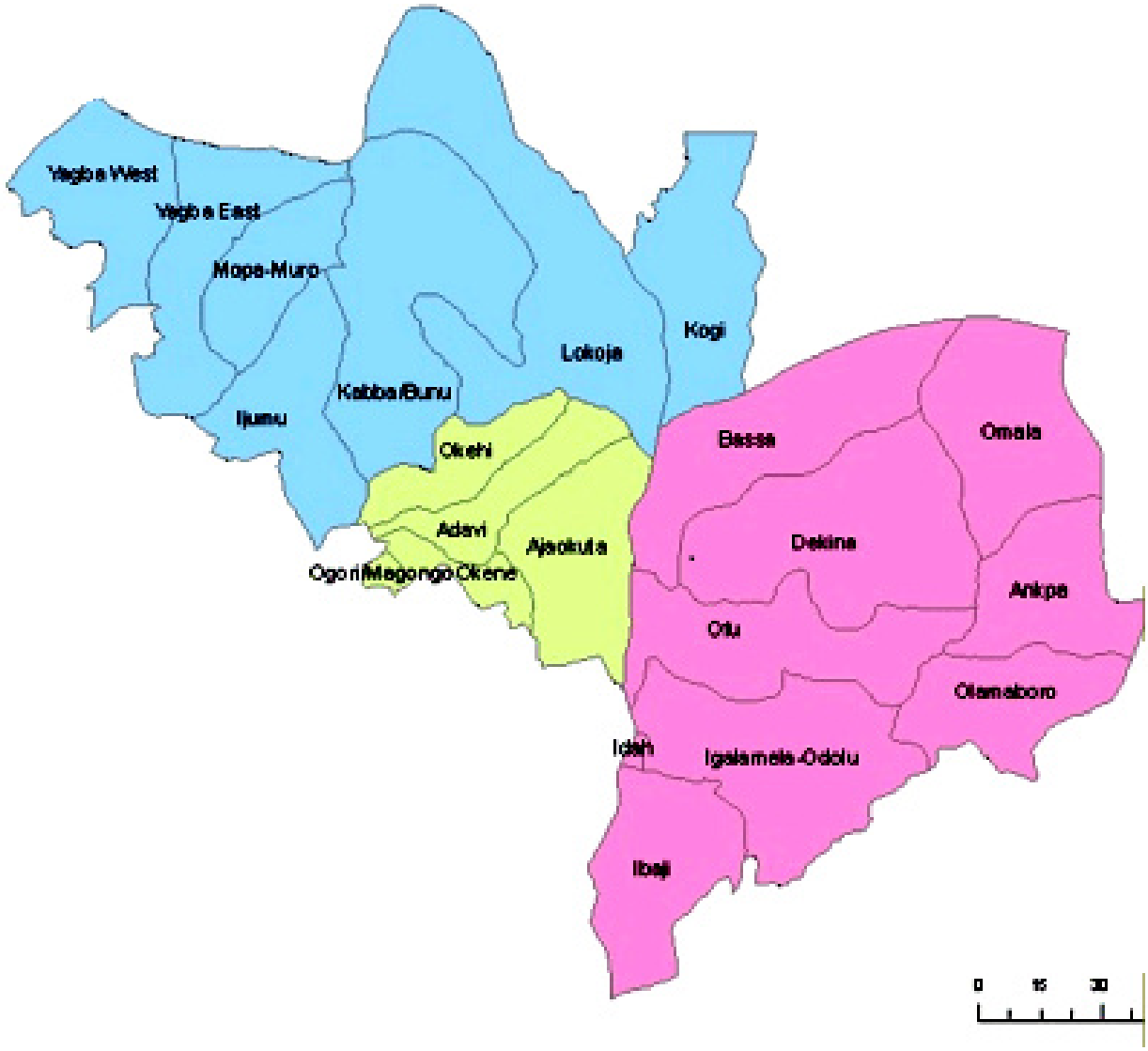

Fig. 1: Map of Kogi State, Nigeria showing the study areas