Environment and Natural Resources Research; Vol. 5, No. 1; 2015
ISSN 1927-0488 E-ISSN 1927-0496
Published by Canadian Center of Science and Education

Geochemical Characteristics and Quality of Groundwater Around Okemesi Fold Belt, South Western Nigeria

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Received: September 28, 2014 Accepted: October 9, 2014 Online Published: February 20, 2015

doi:10.5539/enrr.v5n1p46 URL: http://dx.doi.org/10.5539/enrr.v5n1p46

Abstract

This study involves the determination of the hydrochemical character and quality of springs, shallow and deep wells around the Okemesi fold belt, south western Nigeria. This is with a view to elucidate their nature, type and evaluate portability, and suitability for agricultural and industrial purposes. The Okemesi fold belt is underlain by schistose rocks, mainly mica schist, quartz schist, and quartzite with minor amphibolites and gneisses.

The major hydrochemical water type are Na – (K) – Cl – (SO_4) and Ca – (Mg) – (Cl) – SO_4 water facies constituting about 52% and 47% respectively. The study showed that almost all of the physico-chemical parameters such as total dissolved solid TDS (18.75 - 790.50 mg/l), electrical conductivity EC (25 - 1054 µs/cm), pH (5.4 - 7.4), temperature (24.8 - 29.5°C), turbidity (2.2 - 40.5 N.T.U), total hardness (10 - 274 mg/l), total alkalinity (18 - 274 mg/l), dissolved oxygen (1.8 - 7 mg/l), chlorine demand (1.56 - 4.75 mg/l); and bacteriological analysis (5 - 80 MPN) results were within the World Health Organization (WHO) limits recommended for drinking water. However, some groundwater samples have Ni^+ and K^+ concentrations slightly above the recommended standard.

These physico-chemical parameters, especially cations: Ca^{2+} (1.6 - 72.8 mg/l), Mg^{2+} (0 - 4.39 mg/l), Na^+ (1.63 - 75.0 mg/l), K^+ (0 - 108.3 mg/l) , Si (4.0 - 10 mg/l), Cu (0 - 0.391 mg/l), Zn (0 - 0.29 mg/l), Cd (0 - 0 mg/l), Pb (0 - 0 mg/l), Fe (0.1 - 0.1 mg/l), Ni (0 - 0.043 mg/l) and anions such as HCO_3 (6.1 - 79.3 mg/l), Cl^- (5 - 109 mg/l), SO_4^{2-} (38 - 76 mg/l), NO_3^{2-} (0 - 0 mg/l) and PO_4^{3-} (0.005 - 0.03 mg/l) seem to reflect the chemical nature of the underlying rock units suggesting dissolution, weathering and water – soil / rock interaction processes.

Keywords: springs, wells, physico-chemical, hydrochemical, quality

1. Introduction

As water percolates through the rocks, some ionic exchanges take place and invariably the water takes into solution in different concentrations some elemental composition of the rocks. (Abimbola et al., 2002) Therefore, the chemical property, and also bacteriological composition of groundwater is important amongst other criteria in the assessment of the quality of waters. While it is generally accepted that water bodies, rivers, lakes, dams and estuaries are continuously subject to dynamic state of change with respect to the geological age and geochemical characteristics (Adefemi & Awokunmi, 2010), the availability of good quality water derived from these sources is an indispensable feature for preventing diseases and improving quality of life (Oluduro & Adeyowe, 2007). It is now generally recognized that the quality of water is just as important as its quantity (Fan & Steinberg, 1996; Gbodo & Ogunyemi, 1999; Abimbola et al., 2002, 2008; Tredoux et al., 2001; Adelana & Olasehinde, 2003; Adeyemi et al., 2003). Also apart from the fact that water quality is a function of physical, chemical and biological parameters, it is also subjective, as it depends on the particular intended use (Tijani, 1994). Therefore, water quality standards differ for various uses such as domestic (drinking), agriculture (irrigation) and industries.

The most significant geo hydraulic influence on groundwater chemistry arises from the source and circulation of groundwater itself (Amadi et al., 1989). Natural water contains some types of impurities whose nature and amount vary with source of water (Adeyemi et al., 2003). Metals for example, are introduced into aquatic system through several ways which include, weathering of rocks and leaching of soils, dissolution of aerosol particles from the atmosphere and from several human activities, including mining, processing and the use of metal based materials (Ipinmoroti, 1993; Adeyeye, 1994; Asaolu et al., 1997).

There has been some studies on rock composition, structure and association around Okemesi, southwestern Nigeria (Okunlola & Okoroafor, 2009; Ayodele & Odeyemi, 2010;) but little or none has been carried out on the quality of water in this region Hence the need for this study, which is aimed at elucidating the nature, origin and uses of the springs, shallow and deep well water in the study area..This involves the determination of the the physical and chemical properties together with bacteriological load in the groundwater.

The petrogenetic features of the schistose rocks around the Okemesi fold belt area of investigation, which is part of the Ife-Ilesha schist belt has been described as one of the most complex lithological and structural frameworks amongst the Nigeria's metasedimentary belts (Olobaniyi, 2003; Okunlola & Okoroafor, 2009).

Okemesi is located in areas of high relief, (Figure 1) as a result, runoff is high and infiltration rates are low. Hence, some of the hand dug wells and boreholes are concentrated at the center of the fold belt, while the rivers and the springs follow a dendritic pattern (Figure 1).

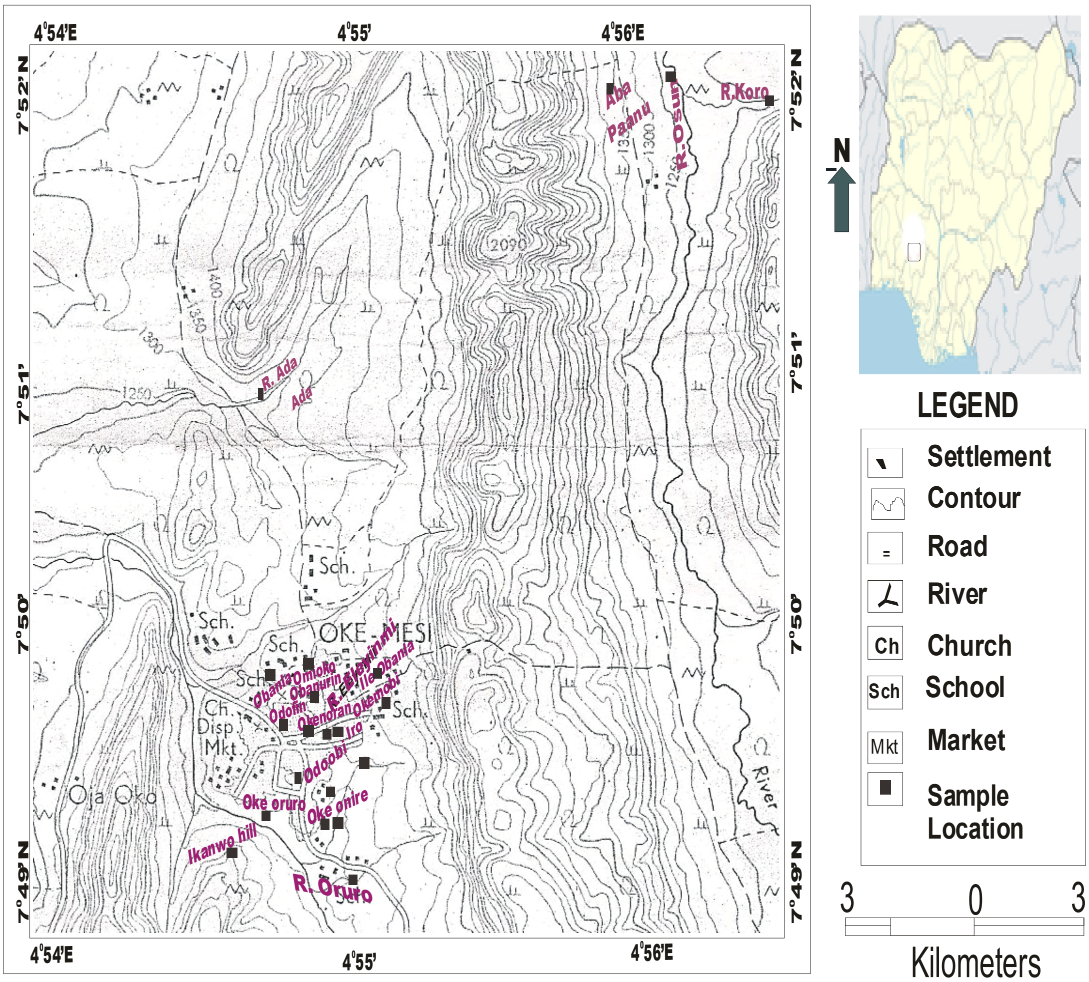

Figure 1. Map of sampling locations of surface and sub surface waters around Okemesi

The area of investigation lies completely within the 1: 50,000 sheet 253 (Ilesha NE) between latitude 7^{0} 49'- 7^{0} 52' and longitude 4°54'- 4°56', with the elevation ranging from 318 - 484m above the sea level. Okemesi is the largest town in the area. Other settlements in this area include Ajindo, Koro and Ada. The area is a planned settlement in spite of its rugged relief (Figure 1) and well serviced by a network of roads and footpaths (Figure 2).

A dendritic drainage system, upon which a trellis pattern has been super imposed mainly due to structural configuration characterize the area. Few large rivers and consequent streams that have their source from the nearby springs, together with deep and shallow wells present, are perennial, while small streams are seasonal with little or no meandering system (Figure 3). They flow westerly and a few northerly. The springs flow in a radial manner away from central range of schistose outcrops of Okemesi fold belt. Specifically, rivers like Oruro, Eleyinmi and Koro have utilized fractures in the area and cut across the divide.

Geomorphologically, the area forms an oval topographic feature with enclosing schistose and the surrounding gneissic complex (Figure 4). The range is broken in places by rivers, like Osun and Ada which have cut steep valleys and run almost at right angles to the trend of the range. The climate is typically equatorial, hot, dry and wet with mean monthly temperature around 27°C (80°F). Cloudiness and heavy precipitation help to moderate the daily temperature. It experiences about seven months (April-November) of torrential rain and associated high runoff and erosion, while December to March are often characterized by dry conditions.

1.1 Geological Setting:

Geologically, the study area is around the Okemesi fold belt of Ife – Ilesha schist belt within the Pre – Cambrian to Late Proterozoic Basement Complex rocks of southwestern Nigeria which in turn is part of the Pan – African mobile belt lying east of West African Craton (Jones & Hockey, 1964; Odeyemi, 1976; Rahaman, 1976). The major rock units in the area of investigation are ampibolite, banded gneiss, mica schist, quartz schist and quartzite (Okunlola & Okoroafor, 2009) (Figure 4). The details of the geological setting are contained in the aforementioned reference.

The basement rocks are commonly considered as poor aquifers because of their crystalline nature which leads to low porosity and permeability. However, appreciable porosity and permeability are developed through fracturing and weathering of the rocks (Davis & Deweist, 1966). This makes an otherwise barren rock to function as groundwater aquifer (Abimbola et al., 2002). The rocks in the area of investigation have undergone different tectonic episodes and have as a result responded differently to tectonic deformation that has affected the terrain, hence the numbers and sizes of lineaments (fractures) (Ayodele & Odeyemi, 2010) giving rise to the springs.

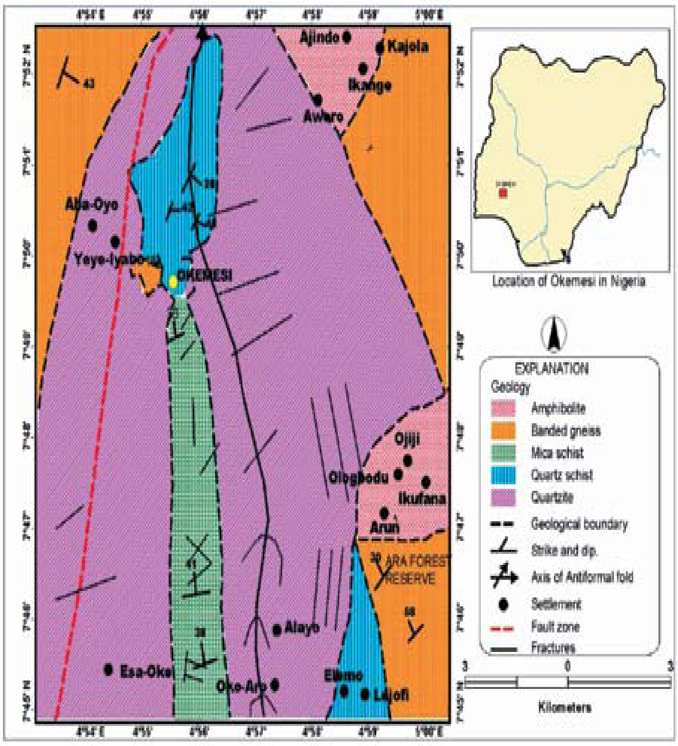

Figure 2. Geological map of Okemesi fold belt (after Okunlola & Okoroafor, 2009)

2. Materials and Methods

A total of twenty one representative samples of surface and groundwater were collected around Okemesi, Koro, Ajindo and Ada. Comprising 2 springs, 10 hand dug wells, 5 boreholes and 4 rivers which constitute the major water supply for the inhabitant. Sampling was done before the onset of heavy rain to minimize dilution effect. At each location, an aliquot of water to be sampled was used to rinse the plastic container to avoid contamination before collecting the water into 2 well drained separate clean new set of plastic containers or bottles, one for the determination of anions while the other set of samples were for cations and these were acidified immediately with two drops of HNO_3 in order to prevent loss of metals, bacterial and fungal growth. The first set was also stored in the refrigerator before bacteriological analysis.

The electrical conductivity, pH and temperature as a sensitive physico-chemical parameters were determined directly in the field using digital Hack pH meter while the location coordinates and elevation were determined by Ground Positioning System (GPS). Turbidity was determined by hack turbidity meter. Total hardness, total alkalinity, chlorine demand, dissolved oxygen, NO_3^{2-} and SO_4^{2-} Ca^{2+}, Mg^{2+}, Fe^{3+}, HCO_3 and silica were determined by titrimetry method at the Central Laboratory, Water Corporation of Oyo State, Nigeria. The laboratory method used for the detection and enumeration of total coliform count is the multiple tube method.

Cations such as K^+ and Na^+ together with the trace elements such as Cu, Zn, Cd, Pb, and Ni were analyzed using the Atomic Absorption Spectrometer (Bulk scientific 210/211 VGP AAS), 220GF Graphite Furnace and 220AS Autosampler at the Agronomy laboratory, University of Ibadan, Oyo state, Nigeria while PO_3^{2-} was analyzed by Ascorbic Acid method before determining its content in the solution by Spectrophotometer 70 at 882mμ. The detection limits of the metals are 0.001mg/l while for K^+ and Na^+ is 0.01mg/l

3. Results and Discussion

The data for physical, chemical and bacteriological parameters of both groundwater and surface water in the study area are presented in the Tables 1, 2, 3 and 4 respectively.

Table 1. The result of physical characteristics of surface water and groundwater around Okemesi

SAMPLE ID	NORTHINGS	EASTINGS	E (m)	TDS (mg/l)	EC μS/cm	pH	T (°C)	TU (N.T.U.)	TH (mg/l)	TA (mg/l)	DO (mg/l)	CD (mg/l)
RL1	N7°50′ 59″	E4°55′ 6.8″	318	42.0	56	7.4	25.5	15.2	20	30	6.7	2.296
WL2	N7°49′ 27″	E4°55′ 31.6″	402	114.75	153	6.5	29.5	6.8	68	68	4.4	2.169
RL3	N7°52′ 46″	E4°56′ 37.7″	380	19.35	129	7.4	25.8	7.5	32	66	3.8	4.75
WL4	N7°52′ 49″	E4°56′ 32.7″	398	51.0	68	6.0	26.3	14.2	50	38	4.3	1.585
RL5	N7°52′ 19″	E4°58′11.5″	441	401.25	535	6.7	25.4	14.2	252	274	1.8	2.196
WL6	N7°49′ 27″	E4°55′14.9″	395	179.25	239	6.5	27.6	5	40	18	3.2	2.308
RL8	N7°49′ 22″	E4°55′ 22″	396	50.25	67	6.5	25.0	2.2	30	24	4.0	2.558
SPL9	N7°49′ 15″	E4°55′ 3.8″	484	18.75	25	5.4	24.8	28.2	16	18	5.4	2.67
WL10	N7°49′ 20″	E4°55′ 21.8″	396	113.25	151	5.6	25.5	32.5	54	36	3.6	2.919
BL11	N7°49′ 21″	E4°55′ 13.6″	414	53.25	71	6.2	27.0	2.6	26	36	6.4	2.121
BL12	N7°49′ 12″	E4°55′ 19.7″	421	37.5	50	6.1	28.0	2.2	10	28	7.0	1.946
WL13	N7°50′ 04″	E4°55′ 27.3″	420	150.75	201	6.3	27.2	2.5	52	22	6.4	1.696
SPL14	N7°50′ 08″	E4°55′ 28.3″	443	43.4	62	6.0	25.3	8.4	16	32	3.7	1.946
WL15	N7°49′ 53″	E4°55′ 37.7″	431	123.75	165	5.7	27.5	2.2	38	20	5.5	2.162
RL16	N7°49′ 45″	E4°55′ 33.0″	399	104.25	139	6.1	25.8	17.6	46	138	6.9	2.296
BL17	N7°49′ 46″	E4°55′ 27.3″	408	642	856	6.0	26.8	7.5	274	144	3.4	1.56
BL19	N7°49′ 55″	E4°55′ 19.4″	414	790.5	1054	6.0	27.5	4.6	158	60	5.0	2.196
WL20	N7°49′ 54″	E4°55′ 20.3″	413	511.5	682	6.3	27.9	2.2	224	184	2.4	2.169
WL21	N7°50′ 06″	E4°55′ 27.9″	413	75	100	6.5	25.7	40.5	30	54	3.7	2.308
WL23	N7°49′ 57″	E4°55′ 23.3″	414	472.5	630	6.4	27.8	2.3	90	84	3.4	2.296
WL25	N7°49′ 44″	E4°55′ 25.2″	417	402.75	537	7.2	28.7	30.4	164	140	5.0	2.196

RL- river location	E- elevation	TU- turbidity	TH- total hardness
WL- well location	TDS- total dissolve solid	T- temperature	DO- dissolved oxygen
BL- borehole location	EC- electrical conductivity	CD- chlorine demand	SPL- spring location
SAR- sodium absorption ratio	TA- toltal alkalinity	S/N-serial number	

Table 2. The result of chemical characterstics (cations and trace metals) of surface water and groundwater around okemesi

SAMPLE ID	Ca^{2+} (mg/l)	Mg^{2+} (mg/l)	Na^{+} (mg/l)	K^{+} (mg/l)	Cu (mg/l)	Zn (mg/l)	Cd (mg/l)	Pb (mg/l)	Fe (mg/l)	Ni (mg/l)
RL1	4.80	0.195	5.23	2.11	0.039	0.000	ND	ND	<0.1	0.015
WL2	16.0	0.683	6.86	8.49	0.021	0.000	ND	ND	<0.1	0.014
RL3	9.60	0.195	8.56	6.17	0.016	0.006	ND	ND	<0.1	0.004
WL4	12.0	0.488	6.95	8..27	0.391	0.080	ND	ND	<0.1	0.043
RL5	28.8	4.390	25.3	1.43	0.018	0.000	ND	ND	<0.1	0.006
WL6	9.60	0.390	22.00	16.20	0.016	0.006	ND	ND	<0.1	0.004
RL8	4.00	0.488	6.120	3.68	0.020	0.000	ND	ND	<0.1	0.025
SPL9	4.00	0.146	1.630	0.000	0.036	0.001	ND	ND	<0.1	0.007
WL10	21.6	0.000	4.100	3.860	0.037	0.027	ND	ND	<0.1	0.011
BL11	4.80	0.342	3.550	1.870	0.000	0.005	ND	ND	<0.1	0.014
BL12	1.60	0.146	2.760	4.660	0.002	0.005	ND	ND	<0.1	0.000
WL13	12.0	0.537	4.450	25.40	0.017	0.000	ND	ND	<0.1	0.018
SPL14	1.60	0.293	6.300	1.400	0.066	0.001	ND	ND	<0.1	0.000
WL15	28.8	0.439	17.70	4.92	0.032	0.013	ND	ND	<0.1	0.033
RL16	8.00	0.439	8.840	2..960	0.014	0.001	ND	ND	<0.1	0.018
BL17	72.8	2.245	34.00	23.60	0.019	0.020	ND	ND	<0.1	0.028
BL19	36.0	1.650	75.00	108.3	0.004	0.028	ND	ND	<0.1	0.029
WL20	64.0	1.562	32.10	48.20	0.048	0.000	ND	ND	<0.1	0.033
WL21	5.60	0.390	7.050	3..320	0.051	0.007	ND	ND	<0.1	0.016
WL23	20.8	0.927	41.70	86.60	0.000	0.018	ND	ND	<0.1	0.000
WL25	48.0	1.075	27.60	46.60	0.004	0.29	ND	ND	<0.1	0.026

ND - NOT DETECTED. Cd and Pb are below detection limits.

Table 3. The result of chemical characterstics (anions) of surface water and groundwater around okemesi

S/N	SAMPLE ID	SAR	SiO_2 (mg/l)	HCO_3^- (mg/l)	Cl^- (mg/l)	SO_4^{2-} (mg/l)	NO_3^{2-} (mg/l)	PO_4^{3-} (mg/l)
1	RL1	2.38	9.0	12.2	12.5	<35.0	0.000	0.011
2	WL2	1.68	9.0	24.4	11.5	<35.0	0.000	0.009
3	RL3	2.74	4.0	24.4	12.0	<35.0	0.000	0.014
4	WL4	1.97	<4.0	6.10	10.5	<35.0	0.000	0.020
5	RL5	4.39	10	42.7	19.0	38.0	0.000	0.016
6	WL6	6.96	4.0	12.2	29.5	<35.0	0.000	0.019
7	RL8	2.89	4.0	18.3	5.00	<35.0	0.000	0.012
8	SPL9	0.80	8.0	6.10	9.50	<35.0	0.000	0.005
9	WL10	0.88	8.0	6.10	15.0	<35.0	0.000	0.028
10	BL11	1.57	8.0	30.5	12.5	<35.0	0.000	0.016
11	BL12	2.08	6.0	12.2	8.50	<35.0	0.000	0.018
12	WL13	1.26	8.0	18.3	18.0	<35.0	0.000	0.030
13	SPL14	4.58	8.0	6.10	10.5	<35.0	0.000	0.020
14	WL15	3.27	8.0	12.2	20.0	<35.0	0.000	0.014
15	RL16	3.04	4.0	24.4	18.5	<35.0	0.000	0.019
16	BL17	3.92	8.0	36.6	67.0	70.0	0.000	0.020
17	BL19	12.22	6.0	24.4	109.0	<35.0	0.000	0.015
18	WL20	3.96	4.0	79.3	39.5	<35.0	0.000	0.016
19	WL21	2.88	8.0	12.2	16.5	76.0	0.000	0.020
20	WL23	8.95	4.0	30.5	51.0	53.0	0.000	0.015
21	WL25	3.94	<4.0	54.9	16.2	38.0	0.000	0.012

Table 4. The result of the bacteriological analysis around Okemesi

S/N	SAMPLE ID	CHLORINE RESIDUAL	COLONY COUNT (MPN)	MPN COLIFORM ORGANISM	LOCATION	ROCK TYPE
1	RL1	0	30	30	Ada	Quartz schist
2	WL2	0	80	80	Oke Onire 1	Mica schist
3	RL3	0	40	40	Aba Paanu	Quartzite
4	WL4	0	10	10	Aba Paanu 2	Quartzite
5	RL5	0	20	20	Ajindo/Koro	Amphibolite
6	WL6	0	20	20	Oke Onire 2	Mica schist
7	RL8	0	20	20	Oke Onire 3	Quartzite
8	SPL9	0	10	10	Ikanwo	Quartzite
9	WL10	0	40	40	Oke Oruro	Mica schist
10	BL11	0	20	20	Oke Onire 4	Quartzite
11	BL12	0	10	10	Oke Onire 5	Quartzite
12	WL13	0	20	20	Ile Obanla	Banded gneiss
13	SPL14	0	5	5	Omioko	Quartz schist
14	WL15	0	10	10	Okemobi	Quartz schist
15	RL16	0	20	20	Eleyinmi	Quartz schist
16	BL17	0	10	10	Iro	Mica schist
17	BL19	0	20	20	Odofin	Banded gneiss
18	WL20	0	40	40	Obanurin	Banded gneiss
19	WL21	0	30	30	Okenoran	Mica schist
20	WL23	0	10	10	Obanla	Quartz schist
21	WL25	0	30	30	Odoobi	Mica schist

The summary of the various parameters, their mean values as compared to the values of WHO (2004) standards is shown in table 5, while the result of the bacteriological analysis as compared with World Health Organization (W.H.O) 2004 Bacteriological Standard for Drinking Water is in Table 6.

The mean concentration of the cations is in the order $Ca^{2+} > K^{+} > Na^{+} > Mg^{2+}$ and the mean concentration of anions is in the order $SO_4^{2-} > Cl^{-} > HCO_3 >$ Silica $> PO_4^{3-} > NO_3^{2-}$ while the trace metals mean concentration is in the order of Fe > Cu > Zn> Ni > Cd > Pb and that of coliform mean concentration is 24ppm. Although all the analyzed parameters have concentration values less than the World Health Organization (WHO, 2004) recommended limits, K^{+} in locations WL6 (16.20mg/l), WL13 (25.40mg/l), BL17 (23.6mg/l), BL19 (108.3mg/l), WL20 (48.2mg/l), WL23 (86.6mg/l), and WL25 (46.6mg/l) were observed to have the concentration value above WHO standard recommended limit (Table 5). These are all groundwater. Generally the concentration of calcium is much higher in the deep wells than the surface waters. for instance, sample BL17, BL19,WL20, and WL25 have calcium concentration of 72.8mg/l, 36.8mg/l, 64.0mg/l, and 48.0mg/l respectively while RL1, RL3, SPL9 and SPL14 have calcium concentration 4.8 mg/l, 9.6 mg/l, 4.0 mg/l, and 1.6 mg/l respectively.

Table 5. Summary of the physical and chemical parameters of waters around okemesi compared with WHO (2004) standard

PARAMETERS	N	MINIMUM	MAXIMUM	MEAN	STANDARD DEVIATION	HIGHEST DESIRABLE LEVEL (WHO)	MAXIMUM PERMISSIBLE LEVEL (WHO)
ELEVATION (m)	21	318.00	484.001	410.33	NC		
TDS (mg/l)	21	18.75	790.50	209.38	229.227	500	1000
EC (µS/cm)	21	25	1054	284.59	302 .015	1000	1400
Ph	21	5.4	7.4	6.32	0.532	7.0 – 8.5	6. 5 – 9. 2
TEMP (°C)	21	24.8	29.5	26.70	1.312	variable	variable
TURB (N.T.U.)	21	2.2	40.5	11.85	NC	5	NM
TH (mg/l)	21	10	274.00	80.48	82.197	NM	NM
TA (mg/l)	21	18	274.00	72.10	67.292	NM	NM
DO (mg/l)	21	1.8	7.00	4.57	NC	NM	NM
CD (mg/l)	21	1.56	4.75	2.30	NC	NM	NM
MPN (PPM)	21	5	80	23.57	NC	NM	NM
SAR	21	0.8	12.22	3.64	NC	NM	NM
Ca^{2+} (mg/l)	21	1.6	72.80	19.73	20.351	75	200
Mg^{2+} (mg/l)	21	0.00	4.39	0.84	0. 998	39	150
Na^{+} (mg/l)	21	1.63	75.0	16.56	17.958	150	200
K^{+} (mg/l)	21	0.00	108.30	19.43	29.614	10	15
SiO_2 (mg/l)	21	4.0	10.00	6.74	2.137	20	NM
HCO_3^- (mg/l)	21	6.1	79.30	23.53	18.227	500	1000
Cl^- (mg/l)	21	5.0	109	24.37	24.614	200	500
SO_4^{2-} (mg/l)	21	38	76	55	11.773	150	250
NO_3^{2-} (mg/l)	21	ND	0.00	0.00	NC	20	45
PO_4^{3-} (mg/l)	21	0.005	0.03	0.02	0.006	NM	NM
Cu (mg/l)	21	ND	0.391	0.04	0.082	1.0	1. 5
Zn (mg/l)	21	ND	0.29	0.02	0.064	0.2	5.0
Cd (mg/l)	21	ND	0.00	0.00	NC	0	0.005
Pb (mg/l)	21	ND	0.00	0.00	NC	0	0.05
Fe (mg/l)	21	0.10	0.10	0.10	NC	0..3	1. 0
Ni (mg/l)	21	0.00	0.043	0.016	0.012	0	0.02

NC – NOT CALCULATED NM – NOT MENTIONED

Table 6. Bacteriological standard for drinking water compared with those around Okemesi area (WHO 2004)

S/N	CLASSIFICATION	MPN/100ml COLIFORM BACTERIA	SUMMARY FOR OKEMESI
1	Bacterial quality applicable to disinfection only	0-50	20
2	Bacterial quality requiring convectional methods of treatment (coagulation, filteration and di-infection)	50-5,000	1
3	Heavy pollutant requiring extensive type of treatment	5,000-50,000	-
4	Very heavy pollution, unacceptable unless special treatments designed for such water is used.	Above 50,000	-

In this study, the highest concentration of Ca^{2+} is found in borehole location BL17 at Iro, Okemesi having value of 72.8 mg/l. This may be attributed to dissolution of the water with the weathered calc-plagioclase feldspar, amphibole and pyroxene of the aquiferous zone by the groundwater. However, Mg^{2+} concentration in all the location is very low with mean value of 0.84 mg/l when compared to WHO highest desirable level of 39 mg/l for drinking water and could be attributed to generally lower dissolution of magnesium in water. Its values range from 0.146 mg/l to 2.245 mg/l in most places except in location RL5 at river Koro where the concentration is 4.390 mg/l. This river also has the highest concentration of Ca^{2+} of 28.8 mg/l for surface water. This may have incorporated the elemental component of the amphibolite in this area that the river passes through (Table 7).

Table 7. The statistical summary of average elemental composition of water sample control by rock type around Okemesi compared with WHO standard

ELEMENTS (mg / l)	AVERAGE FROM THE WATER SAMPLE OF AMPHIBOLITE (mg / l)	AVERAGE FROM THE WATER SAMPLE OF BANDED GNEISS (mg / l)	AVERAGE FROM THE WATEROF MICA SCHIST (mg / l)	AVERAGE FROM THE WATER SAMPLE OF QUARTZ SCHIST (mg / l)	AVERAGE FROM WATER SAMPLE OF THE QUARTZITE (mg / l)	W. H. O STANDARD 2004 (mg / l)
Ca^{2+}	28.8	37.33	29.07	12.80	10.13	75
Mg^{2+}	4.39	1.25	0.80	0.46	0.30	39
Na^{+}	25.3	37.18	16.94	15.85	4.93	150
K^{+}	1.43	58.97	17.01	19.598	4.11	10
SiO_2	10.0	6.0	7.17	6.60	5.70	20
HCO_3^-	42.7	40.67	24.73	17.08	16.27	500
Cl^-	19.0	55.5	25.95	33.8	9.67	200
SO_4^{2-}	38.0	35.0	48.17	38.6	35.0	150
NO_3^{2-}	0.00	0.00	0.00	0.00	0.00	20
PO_4^{3-}	0.016	0.02	0.02	0.02	0.01	
Cu	0.018	0.02	0.03	0.03	0.01	1.0
Zn	0.000	0.01	0.06	0.01	0.02	0.2
Cd	0.000	0.00	0.00	0.00	0.00	0.005
Pb	0.000	0.00	0.00	0.00	0.00	0.05
Fe	0.1	0.10	0.10	0.10	0.00	0.30
Ni	0.006	0.03	0.02	0.01	0.02	0.02

Generally, the concentration of K^+ and Na^+ varies for surface and groundwater. The highest K^+ and Na^+ concentration value of 108.3 mg/l and 75 mg/l respectively is found in borehole BL19 at Odofin while the lowest values of 0.00 and 1.63 for the two cations are found respectively at Ikanwo hills at location SPL9. This can be attributed to difference in the rock types and elevations of these two locations. While Odofin rock is banded gneiss with elevation of 414m, Ikanwo hills is quartzitic in composition with elevation of 484m above the sea level (Table 7). Hence, the borehole must have incorporated some minerals such as albite and orthoclase in the gneiss. The chloride concentration seems to have relationship with sodium and potassium in the area of investigation. This is because high concentration of chloride ion is found in area of high K^+ and Na^+. For example, sample BL19 with abnormal Cl^-, K^+ and Na^+ concentration values of 109 mg/l, 108.3 mg/l, and 75 mg/l, may have important geological control.

The source of HCO_3 with mean concentration of 23.53 mg/l can be attributed to dissolution of carbon dioxide of the air and organic matter. The lower concentration or absence of SO_4^{2-} , PO_4^{3-} , NO_3^{2-} , Fe, Cu, Zn, Cd and Pb in all the locations could be attributed to absent of industrial discharges, sewage discharge, landfill leachates and ore bodies. However, Ni concentration value is slightly above the maximum recommended value by WHO in 3 wells in location WL20, WL15 and WL4. Elevated trace metals concentrations in soils and shallow groundwater systems have been attributed to anthropogenic sources through agricultural practices (Abimbola et al., 1999: Mapanda et al., 2005; Tijani et al., 2009; Tijani, 2010) the possibility of geogenic contribution is high considering the presence of a basic rock unit associated with the gneisses in the area. The relatively higher electrical conductivity with a range of 50µs/cm to1054µs/cm in the groundwater compared to a range of 25 µs/cm to 535µs/cm in the surface water may also be due to increased water rock reaction and dissolution of solid components of the bed rock. However majority of the values are still within those for unpolluted waters

Statistical correlation using product moment coefficient and scattered plot indicates positive correlation between some pairs of parameters (Tables 8 & 9) and. Correlation studies show that calcium has positive correlation with cations: Mg (r = 0.584), Na (r = 0.633), K (r = 0.481) and some heavy metals: Zn (0.342) and Ni (0.505) indicating common source but show negative correlation with Cu (r = -0.099) suggesting different source. Also, potassium correlates positively

Table 8. Correlation coefficients for the physico-chemical parameters around Okemesi

	Ca	**Mg**	**Na**	**K**	**HCO_3**	**Cl**	**SO_4**	**SiO_2**	**PO_4**	**Cu**	**Zn**	**Ni**	**TDS**	**EC**	**pH**
Ca	1														
Mg	.584	1													
Na	.633	.531	1												
K	.481	.258	.893	1											
HCO_3	.739	.568	.455	.414	1										
Cl	.588	.407	.930	.832	.293	1									
SO_4	.294	.198	.173	.104	.063	.278	1								
SiO_2	.005	.251	-.202	-.327	-.168	-.140	.142	1							
PO4	.031	-.035	-.090	-.037	-.152	.049	.157	-.009	1						
Cu	-.099	-.107	-.190	-.167	-.252	-.184	-.064	-.220	.151	1					
Zn	.342	.049	.188	.258	.315	-.011	-.016	-.271	-.108	.138	1				
Ni	.505	.121	.258	.192	.273	.257	.032	-.157	.020	.486	.318	1			
TDS	.816	.671	.933	.815	.618	.889	.288	-.070	.013	-.216	.223	.301	1		
EC	.817	.668	.936	.817	.625	.891	.284	-.092	.006	-.224	.221	.287	.997	1	
pH	-.025	.121	.001	.022	.320	-.161	.008	-.091	-.232	-.174	.284	-.140	-.019	.015	1

Table 9. Correlations between some of the hydrochemical parameters around Okemesi

Variable	Correlation Coefficient
Mg^{2+} and Ca^{2+}	0.58
Mg^{2+} and EC	0.69
K^+ and Na^+	0.89
K^+ and EC	0.82
Na^+ and EC	0.94
TDS and Ca^{2+}	0.82
TDS and Mg^{2+}	0.67
Mg^{2+} and TH	0.87
TDS and HCO_3^-	0.62
Na^+ and Cl^-	0.93
Mg^{2+} and HCO_3^-	0.57
Na^+ and Ca^{2+}	0.63
K^+ and Cl^-	0.83
Ni and Cu	0.49
Ca^{2+} and Ni	0.51

with Na (r = 0.893), chloride (r = 0.832) and Carbonate (r = 0.414) indicating the same source and show negative correlation with silica (r = -0.327), phosphate (r = -0.037) and copper (r = -0.167). While correlation coefficient of sodium with carbonate (r = 0.455), chloride (r = 0.930), sulphate (r = 0.173), Zinc (r =0.188) and Nickel (r = 0.258) are positive, its correlation with silica (r = -0.202), phosphate (r = -0.090) and copper (r = -0.190) is negative. However, Ni has a weak positive correlation to all the ions; Calcium (r = 0.505), magnesium (r = 0.121), sodium (r = 0.258), potassium (r = 0.192), carbonate (r = 0.273), chloride (r = 0.257), sulphate (r = 0.032), phosphate (r = 0.020), and copper (r = 0.486), except silica (r = -0.070). There are relatively very strong correlation between total hardness and total alkalinity (r = 0.835), total dissolved solid and electrical conductivity (r = 0.997), total hardness and electrical conductivity (r = 0.849), calcium and total hardness (r = 0.893), magnesium and total hardness (r = 0.869).

3.1 Water Characterization

The plots of chemical parameters were carried out using trilinear Piper (Piper, 1944) and Scholler semi-log (Scholler, 1962) diagrams (Figures 3 & 4), to determine hydrochemical facies of the analyzed water sample collected around Okemesi. The Piper-Hill diagram is used to infer hydro-geochemical facies. These diagrams reveal the analogies, dissimilarities and different types of waters in the study area, which are identified and listed in Table 10. The concept of hydrochemical facies was developed in order to understand and identify the water composition in different classes. (Sadashivaiah et al., 2008). This water characterization by Piper's diagram has revealed 2 important water facies around Okemesi and these are Ca – (Mg) – (Cl) – SO_4 and Na – (k) – Cl – (SO_4) water facies.

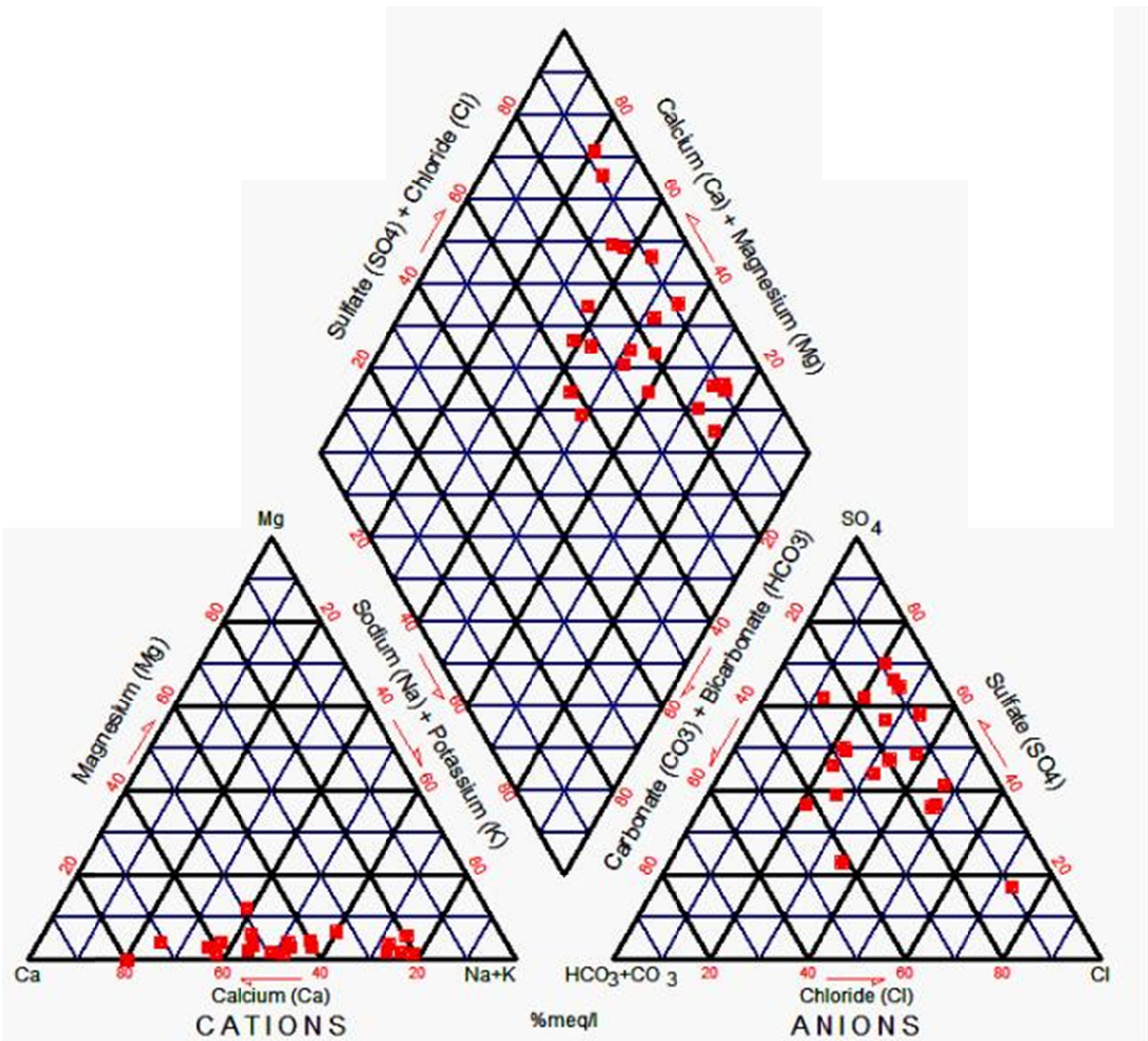

Figure 3. Piper Trilinear Diagram (1944) of hydrochemical analysis result around Okemesi

Table 10. Characterization of groundwater and surface water around Okemesi on the basis of Piper tri-linear diagram

Subdivision of the diamond	Characteristics of corresponding subdivisions of diamond-shaped fields	Percentage of samples in this category
1	Alkaline earth (Ca + Mg) Exceed alkali (Na + K)	50
2	Alkali exceeds alkaline earths	50
3	Weak acids (C03+HCO3) exceed Strong acids (SO4+Cl)	0
4	Strong acids exceeds weak acids	100
5	Magnesium bicarbonate type	0
6	Calcium-chloride type	10
7	Sodium-chloride type	52
8	Sodium-Bicarbonate type	0
9	Mixed type (No cation - anion exceed 50%)	48

Ca – (Mg) – (Cl) – SO_4 water facies constitute about 47.62% of the total water sample and is also referred to as normal alkaline earth with predominance of sulphate. This water suggests mixing process attributed to its interaction by dilution with weathered rock (Figure 5). It may also be due to anthropogenic input from inhabitant in the study area . Na – (k) – (SO_4) - Cl water facies constitute about 52.38% of the total surface and groundwater samples and as a result is predominant water type in the study area. This refers to as alkaline water with high concentration of sodium and potassium.

This water type is common in groundwater in the area and likely to have originated from the dissolution of weathered gneissic rocks and schist, that is geogenic in origin.

Table 11. Modified Wilcox Quality Classification (1995) of irrigation water compared with number of water samples collected around Okemesi

WATER CLASS	ELECTRICAL CONDUCTIVITY (US/CM)	SALINITY HAZARD	SAR	NUMBER OF SAMPLES IN THIS CATEGORY
EXCELLENT	<250	LOW	0 - 10	20
GOOD	250 – 750	MEDIUM	10 – 18	1
PERMISSIBLE	750 – 2000	HIGH	18 – 26	
DOUBTFUL	200 -3000	VERY HIGH	26 - 30	

Where,

$$SAR = Na^{+} / \frac{\sqrt{(Ca^{2+} + Mg^{2+})}}{2}$$

Table 12. Classification of water hardness modified after Todd (1980), compared with number of water samples collected around Okemesi

TOTAL HARDNESS RANGE (mg/L)	WATER CLASS	NUMBER OF WATER SAMPLES IN THIS CATEGORY
0 – 60	SOFT	14
61 – 120	MODERATELY HARD	2
121 – 180	HARD	2
> 180	VERY HARD	3

From Schoeller semi – log diagram (Figure 4), the water within the study area can be characterized as Ca –(Mg) - Na - (K) – (SO_4) – Cl water type because it constitutes about 99% of the total water types in the area. This is similar to the Piper characterization and is due to high percentage of chloride and sulphide ions in the water body, which is higher when compared to other ions within the study area.

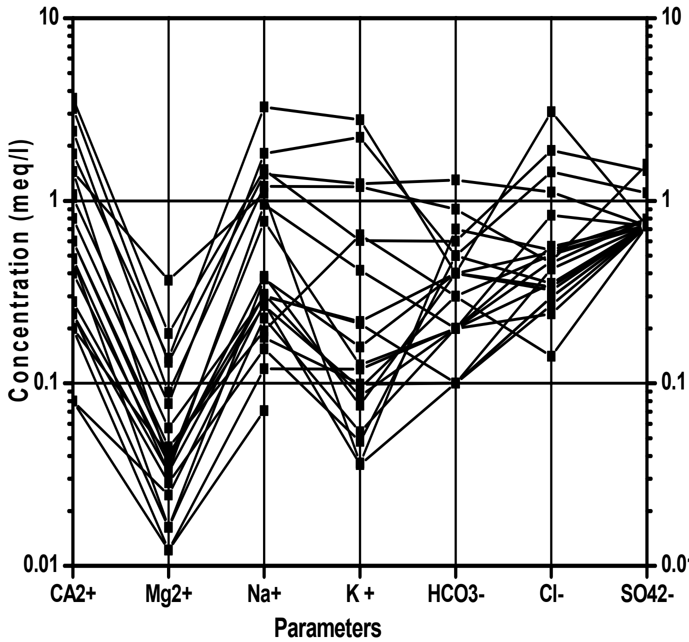

Figure 4. Scholler diagram showing chemical ions in the study area

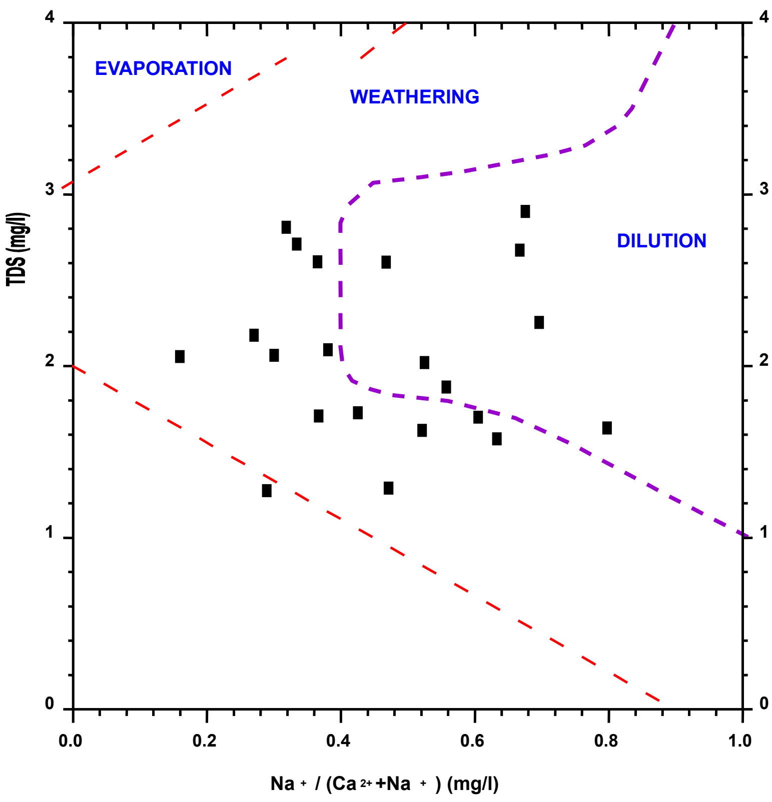

Figure 5. Modified Gibbs Diagram (1970) for the analysed water samples around Okemesi

It is also apparent that the water character around Okemesi are influenced greatly by weathering and dissolution activities of the bedrock. The higher concentration of relevant ions associated with the groundwater as compared to surface water is attributed to longer resident time of the contact between the water and the rock bodies. This leads to greater dissolution, increases concentration of solutes and enhanced weathering more in subsurface water than in surface water (Figure 5).

3.2 Water Quality and Usage

The chemical character of any water source determines to some extent its quality and usability. Geology and human activities through mining, industrialization, disposal of waste are liable to cause deterioration in the quality of surface water and groundwater of any environment especially when the groundwater is closer to the earth surfce. (Abimbola et al., 2002). Also, the standard or criteria for portable drinking water according to Davis and DeWeist (1966) include the absence of objectionable tastes, odour, colour, and substance of adverse effects. A quantitative measure of these criteria is stipulated by WHO (2004). Water quality requirements for different purposes differ; hence standards have been developed to appraise water usability for the various purposes. (Olobaniyi et al., 2007).

The result of the hydrochemical analysis shows that the surface and groundwater within the study area are chemically portable as compared with the WHO standard. Also, the quantity of trace metals present in the different water samples is low compared with the WHO Standard, this may have resulted from the low pH where most natural groundwater are mobile and the mass occur as charged metal ion which reach equilibrium with the solid phase usually a metal-hydroxide, metal carbonate or metal sulphide (Domenico and Schwartz, 1998; Oke, 2010). However, few of the samples have nickel values exceeding the highest permissible level in places especially those water sample from banded gneiss rich in amphibolitic bands (Table 2 and 7). The result of the total coliform count also show that only one of the samples has concentration above the WHO standard which may be as a result of faecal contamination in the water supply (Table 4) and (Figure 6).

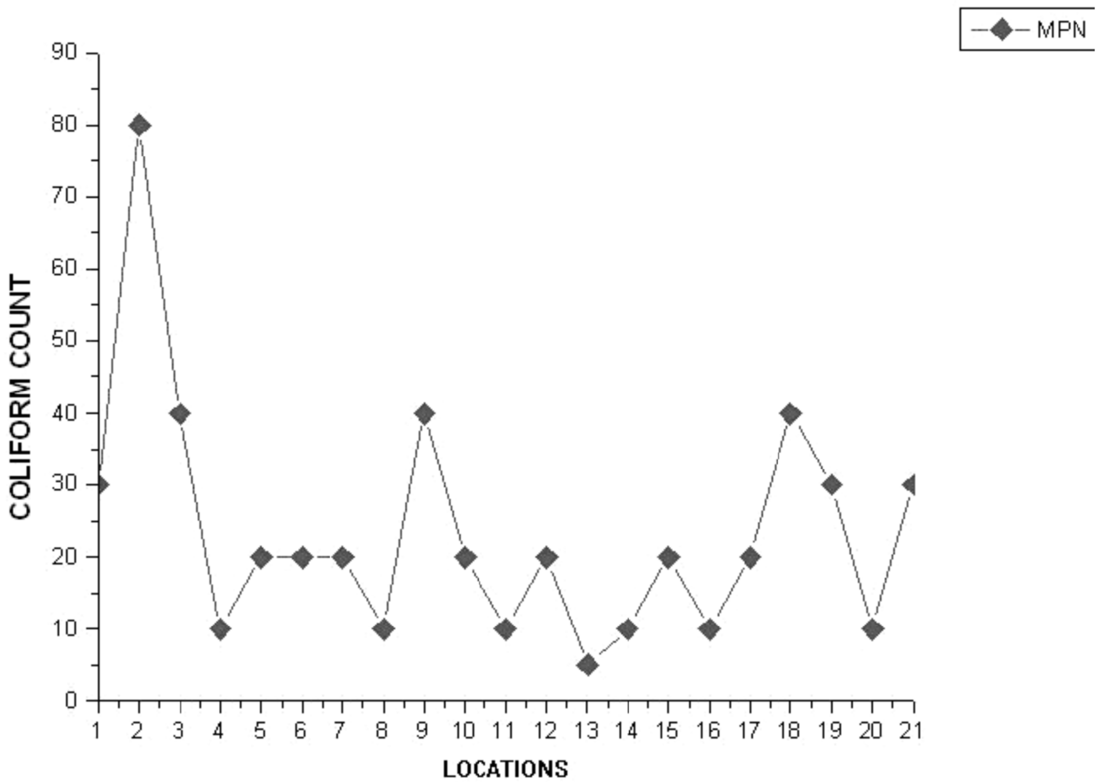

Figure 6. A plot of total coliform counts around Okemesi area against locations

3.3 Irrigation Use

The most important criteria for usage of water for irrigation purposes are total concentration of soluble salts, relative proportion of sodium to other principal cations, concentration of boron or other element that may be toxic, and under some condition, relationship of bicarbonate concentration with calcium and magnesium. These have been termed as the salinity hazard, sodium hazard, boron hazard and bicarbonate hazard (Wilcox, 1995). A better measure of the sodium hazard for irrigation is the SAR which is used to express reactions with the soil (Sadashivaiah et al., 2008). The classification of water samples from the study area with respect to SAR using Wilcox model is represented in Table 11. The SAR value of all the samples are found to be less than 10, and are classified as excellent for irrigation except in sample BL19 where SAR and electrical conductivity values are 12.22 and 1054 µs/cm respectively. This sample is within the permissible class and medium salinity hazard level. In general, all the water samples analysed are good for agricultural and irrigation purposes. However, other conditions necessary for plant growth such as amount of water, good soil type and favourable climate have to be met Also most of the samples (67%) have total hardness within 0 - 60mg/l,implying they are soft while while the rest are moderately hard (Table 12)

4. Conclusions

This study showed that most of the hydrochemical parameters in the groundwater around Okemesi are within the WHO limits for drinking water, posing no health threat to consumers. However, the levels of potassium, especially in some groundwater samples especially those of WL6 (16.20mg/l), WL13 (25.4 mg/l), BL17 (108.3 mg/l), WL20 (48.2 mg/l), WL23 (86.6 mg/l) and WL25 (46.6 mg/l), and, possibly, all the other areas such as WL4 (0.043mg/l), WL15 (0.033) and WL20 (0.033) where nickel levels exceeded the critical value of 0.02mg/l, should be closely monitored. Geological processes such as weathering and dilution of the water with rocks in this area have great impact on the quality and characteristics of the groundwater. Also a shallow well at WL 2 from Oke-Onire is found to have total coli form count of 80MPN, suggestive of heavy impact of human activity and is due to unnatural agents such as leakage of wastewaters and soak away.

Two major hydrochemical water facies were identified. These are Ca – (Mg) – (Cl) – SO_4 and Na – (K) – Cl – (SO_4) water types. Forty eight per cent of the water sources are mixed water type having either HCO_3, SO_4^{2-} or Cl^- ions as the main anions predominating (Table 11).

Generally, the groundwater quality in this area is appropriate for drinking and agricultural purposes, except in few locations highlighted.

Acknowledgements

The authors appreciate the contribution of numerous colleagues and relations in the course of this study. The kings and chiefs of the study domains are specially acknowledged.

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