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Hydrochemical Studies of Surface Water and Groundwater in Lagos State, Southwest Nigeria.

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Abstract: *A total of seven surface water and seven groundwater samples were analysed. Na^+ and K^+ were analysed using a Flame Photometer while Ca^{2+} and Mg^{2+} were analysed using a Flame Atomic Absorption Spectrophotometer (FAAS). CO_3^{2-} and HCO_3^- were analysed by acid titration and SO_4^{2-} was determined by turbidimetric method of analysis while Cl^- was determined by argentometric titration.Concentrations of the analysed cations and anions in surface water samples were ranged as follows: Ca^{2+} (48.1-813 mgL^{-1}), Mg^{2+} (17.5-296 mgL^{-1}), Na^+ (34.90-9306 mgL^{-1}), K^+ (1.65-275.4 mgL^{-1}), HCO_3^- (80.0-285 mgL^{-1}), Cl^- (248.2-14995 mgL^{-1}), SO_4^{2-}(26-1200 mgL^{-1}) and NO_3^-(1.8-10.5 mgL^{-1}). The results of the cations and anions analysis in groundwater samples ranged as follows: Ca^{2+} (32.1-61.3 mgL^{-1}), Mg^{2+} (11.7-24.3 mgL^{-1}), Na^+ (84.3-179 mgL^{-1}), K^+ (0.48-3.65 mgL^{-1}), HCO_3^- (150-550 mgL^{-1}), Cl^- (106.4-744.5 mgL^{-1}), SO_4^{2-} (11-72 mgL^{-1}) and NO_3^- (1.3-18.8 mgL^{-1}). The results revealed that elevated values of sodium and chloride was observed in the studied surface and groundwater samples, hence indicating Na-Cl water type, which is typical of marine deep water.The study also revealed that the ions present in these water bodies are dominantly controlled by chemical weathering and not precipitation processes.*
Keywords*: Hydrochemical, Surface water and Groundwater,Lagos,Nigeria*

I. Introduction

Water is the most abundant substance in the world as it covers about 70% of the earth's surface. Fresh water bodies are interconnected to the atmosphere, the oceans and aquifers through theglobal hydrological cycle (Alekseevskiy, 2000). The earth's hydrological cycle is driven by evaporation and gravity on which ecosystems and human societies depends. Growing populations may put stress on nature waters by impairing both the quality of the water and the hydrological budget (Ademoroti, 1996). Underground ice in the permafrost zone contains 0.82% of fresh water. The major sources of water are rainfall, surface water – rivers,lakes and groundwater- well, bore wells etc. Due to moisture circulation on earth, water is constantly moving at an extremely slow rate. The rate of water renewal is highest for living organisms (a few hours). The period of water renewal in rivers and reserviors are 19 and 52 days respectively. Water rotation period in other water bodies is essentially greater - up to 5 years for swamps and 17 years for lakes. The most invariable water bodies are glaciers and underground ice (Eizenberg and Kauzman, 2007).

Water is chemically pure only in exclusive cases. Naturally, it always contains some dissolved and suspended matter. The range of chemical compounds in water is very diverse, as there is variation in the content of the principal ions, dissolved gases, biogenic and organic substances as well as microelements (Girard, 2003). In general, water components have natural or anthropogenic origins. Each kind of water body has characteristic properties: salinity, alkalinity, hardness, acidity, corrosive properties. Natural and anthropogenic factors have an influence on water quality which depends on both mineralization, dissolved and suspended matter (Ikhane, 2010). The mineral substances dissolved in water are divided into macro-component (Na^+, K^+ , Ca^{2+}, Mg^{2+} and SO_4^{2-}, Cl^- , HCO_3^-, CO_3^{2-}) and micro-component (ions of lithium, rubidium, caesium and anions – bromine, iodine, fluorine, boron and ions of heavy metals). Certain combination of anions and cations in water distinguishes the hydrochemical water types (Hartman, 2005). The basic purposes for which water is domestically required include drinking, cooking, bathing and general sanitation such as laundry, flushing of closets and other household chores, whereas, for agricultural purposes, it is essentially used for irrigation and livestock.

This present study is borne out of the need to evaluate some surface water and groundwater sources in certain areas of Lagos state in order to determine their suitability fordomestic and agricultural purposes.

II. Study Area

The study was conducted within the Lagos mega city.Lagos state is the smallest state in Nigeria, with a total land area of 3,475 square kilometres (1,342 square miles). However, it is the most populous city in Nigeria, the largest and second fastest-growing city in Africa and the seventh in the world. Geographically, Lagos state shares its northern and eastern boundaries with Ogun state, its western boundary with Republic of Benin, and its southern boundary with the Atlantic Ocean.

Water samples were collected from seven streams and seven well locations in Lagos area in March 2015. The sampling area covers Shomolu,Lagos- Mainland, Surulere, Amuwo-Odofin, Ajeromi-Ifelodun, Apapa, Ikeja and Ikorodu local governments.

Fig 1: Location and geological map of Lagos showing the study areas

III. Materials and Methods

The collected water samples were brought to the laboratory and stored in a well labelled polyethylene bottle that has been previously soaked in 10% HNO_3anddeionized water. The samples for cation analysis were acidified with nitric acid while those for anions were cooled in an ice chest to 4^oC and further refrigerated prior to laboratory analysis.

The samples were analysed for different physicochemical parameters such as pH, electrical conductivity and total dissolved solids and also for anions such as sulphate, chloride, carbonate and bicarbonate using the standard procedure for water and waste water analysis (APHA, 1999).Samples were analysed in duplicate and descriptive statistics of data obtained was carried out using Microsoft Excel packages. Mean values of parameters for each location were compared with other sampling locations and also with WHO and NIS standards for drinking water. Microsoft Excel packages were also used for constructing the bar charts for the relative composition of major ions in surface and groundwater, Wilcox diagram and GW MOD 200 software was used to plot the piper diagrams. Pearson's correlation coefficient was also used to analyse the correlation of surface and groundwater parameters.

IV. Results and Discussion

Table 1: Concentration of cations and anions in ground waters in some selected local government areas in Lagos State.

Site Name	pH	TDS (mg/L)	EC (μS/cm)	Temp (°C)	Ca^{2+} (mg/L)	Mg^{2+} (mg/L)	Na^+ (mg/L)	K^+ (mg/L)	HCO_3^- (mg/L)	Cl^- (mg/L)	SO_4^{2-} (mg/L)	NO_3^- (mg/L)	CO_3^{2-} (mg/L)
Ojodu Well	7.0	112	204	28.2	32.1	11.7	84.3	0.49	240	106.4	11	4.4	<1
Majidun Well	7.3	943	1715	28.3	54.1	19.7	136	0.87	480	230.4	25	3.4	<1
Surulere Well	7.2	577	1049	28.5	56.1	20.4	110	1.98	550	319.1	16	1.3	<1
Mainland Well	7.1	400	728	28.1	44.9	16.3	97.6	0.65	290	205.6	54	18.8	<1
Ifelodun Well	6.9	1551	2820	28.3	61.3	22.3	179	3.65	210	744.5	72	3.9	<1
Bariga Well	6.6	342	623	29.0	38.4	16.7	92.8	0.48	150	148.9	67	6.3	<1
Somolu Well	6.7	537	978	28.2	59.2	24.3	100	1.34	180	198.5	68	14.0	<1
WHO (2011) Acceptable range	6.5 - 9.5	<1500	<1500	-	<200	<150	<200	<600	<600	<600	500	50	-

Table 2: Concentration of cations and anions in surface waters in some selected local government areas in Lagos State.

Site Name	pH	TDS (mg/L)	EC (µS/cm)	Temp (°C)	Ca^{2+} (mg/L)	Mg^{2+} (mg/L)	Na^{+} (mg/L)	K^{+} (mg/L)	HCO_3^- (mg/L)	Cl^- (mg/L)	SO_4^{2-} (mg/L)	NO_3^- (mg/L)	CO_3^{2-} (mg/L)
Lagoon Surface Water	7.1	16330	29700	29.1	745	271	9103	224.1	210	14180	700	2.3	<1
Ojodu Surface Water	5.9	365	664	30.2	48.1	17.5	34.90	1.650	80.0	248.2	26	4.4	<1
Eti-Osa Surface Water	7.2	28380	51600	31.0	813	296	9306	275.4	280	14995	1200	2.7	<1
Majidun Surface Water	6.8	5650	10280	31.1	249	90.3	430.0	24.87	170	3332	510	1.9	<1
Bariga Surface Water	6.4	20460	37200	29.2	794	287	9200	245.6	285	13471	700	10.5	<1
Amuwo – Odofin Surface Water	6.7	10670	19400	28.6	330	156	3400	65.44	200	5420	630	2.5	<1
Apapa Surface Water	6.8	10420	18950	28.5	324	139	2940	43.86	196	4790	590	1.8	<1
WHO (2011) Acceptable range	6.5 - 9.5	<1500	<1500	-	<200	<150	<200	<600	<600	<600	500	50	-

4.1 Physicochemical Properties of Ground Water Samples Collected in Lagos State.

The pH values of all the ground water samples collected showed that they arewithin the acceptable range according to WHO standards (Table 1). Total dissolved solids (TDS) and Electrical conductivity (EC) had low values in all the ground water samples except that collected from Ifelodun well. The elevated TDS value of Ifelodun well indicates high concentration of dissolved ion which could make the water to be corrosive, salty and brackish (Adeoyeet al., 2012). Sulphate and bicarbonate values for all the ground water samples collected were within the WHO permissible limits of 250 mg/L and 600 mg/L respectively (Figure 2). All cations (Calcium, Magnesium, Sodium and Potassium) determined in the ground water samples were below their respective WHO limits. Calcium and magnesium are essential elements needed in good quantity by human body, calcium functions in teeth and bone formation, neuro-vascular, extractability, good functioning of the body coagulability (Tijani, 2007). Chloride content from most ground water samples collected were within the WHO permissible limits of 600 mg/L except the ground water samples collected from Ifelodun. High chloride content in drinking water may indicate possible pollution from sewage leaching into the ground water bodies.

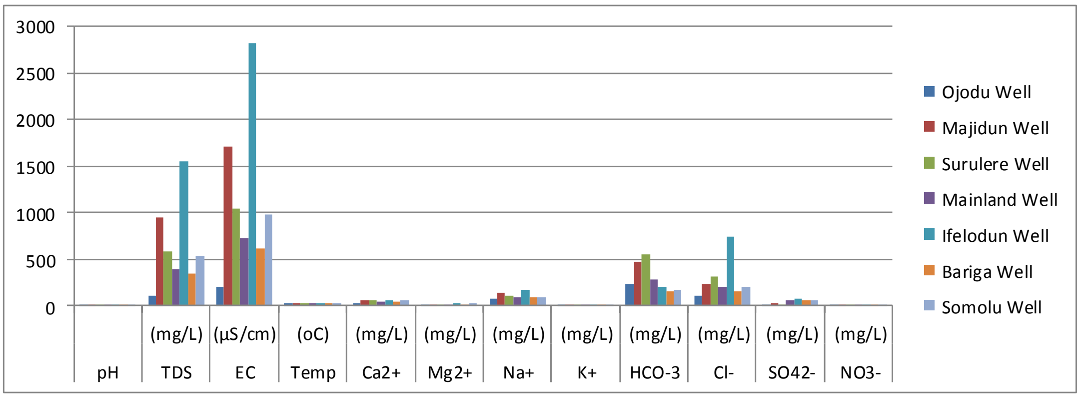

Figure 2: Graphical representation of physicochemical parameters of ground waters in Lagos State.

4.2 Physicochemical Properties of Surface Water Samples Collected in Lagos State.

The pH values for surface waters samples range from 5.9 – 7.1, total dissolved solids (TDS), 365 – 28380 mg/L, electrical conductivity (EC), 664 – 51600 µS/cm, calcium, 48.1 – 813 mg/L, magnesium 17.5 – 296 mg/L, sodium (Na), 34.90 – 9306 mg/L, potassium (K), 1.65 – 275.4 mg/L, bicarbonate (HCO_3^-), 80.0 – 285 mg/L, chloride (Cl^-), 248.2 – 14995 mg/L, sulphate (SO_4^{2-}), 26 – 1200 mg/L and Nitrate (NO_3^-), 1.8 – 10.5 mg/L.

Table 2 shows the result of the physicochemical parameters analysed for surface waters collected in Lagos from different sampling point.

The pH of the surface water samples followed a W-shaped trend indicating phases of variations over the sampling locations, Surface water samples from Lagos lagoon and Eti-osa were slightly alkaline in nature while that of Ojodu was found to be appreciably acidic. There is a significant increase in temperature values in the surface waters. High temperature had been associated with degradation of wastes (Baotong,1983). Alabaster and Lloyd (1980) have attributed high water temperature to insulating effect of nutrient load resulting from industrial discharges.

TDS and EC have high values in most of the sample locations with exception of sample collected at Ojodu. The levels of cations (Ca^{2+}, Mg^{2+}, Na^+ and K^+) and anions (HCO_3^- , Cl^-,and SO_4^{2-}) were all above the permissible limits of WHO, only surface water sample collected form Ojodu was within the permissible limits (Figure 3). Magnesium concentration exceeding 125 mg/L in water according to Orewole et al., (2007) may have a laxative effect in some people. High concentration of Calcium in these locations can be due to sewage disposal, industrial waste water discharge and weathering of Ca^{2+} minerals (limestone and feldspar) from basement rocks. The content of Na^+ present can be attributed to erosion of salt deposits from sodium bearing minerals and discharges from sewage effluent (Okunola et al. 2009). High levels of chloride could be attributed to urbanization, raw untreated sewage and waste generation. The level of Nitrate were generally low in all the sample locations.

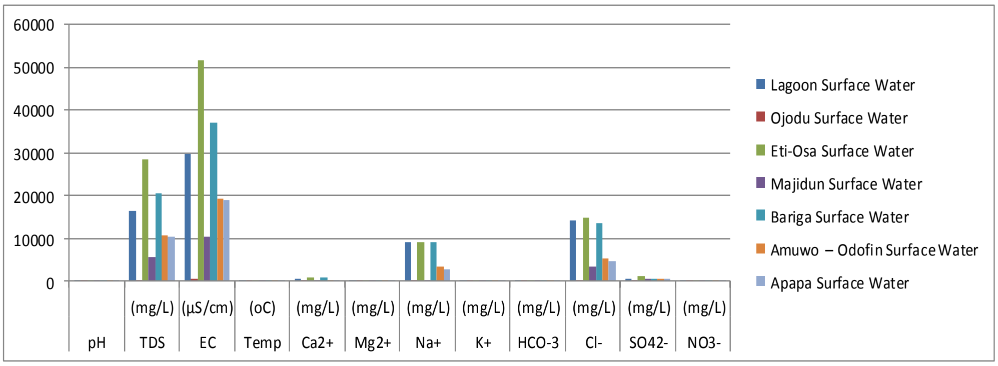

Figure 3: Graphical representation of physicochemical parameters of surface waters in Lagos State.

1.3 HydroChemical Characterisation of Ground Water Using the Piper Plot

Table 3: Concentration of cations and anions in ground waters (Meq/L) in some selected areas in Lagos state.

Site Name	Ca^{2+}	Mg^{2+}	Na^+	K^+	HCO_3^-	Cl^-	SO_4^{2-}
Ojodu Well	1.61	0.97	3.67	0.01	3.936	3.00	0.23
Majidun Well	2.71	1.64	5.91	0.02	7.872	6.49	0.52
Surulere Well	2.81	1.70	4.78	0.05	9.02	8.99	0.33
Mainland Well	2.25	1.36	4.24	0.02	4.756	5.79	1.12
Ifelodun Well	3.07	1.86	7.78	0.09	3.444	20.97	1.50
Bariga Well	1.92	1.39	4.03	0.01	2.46	4.19	1.40
Somolu Well	2.96	2.02	4.35	0.03	2.952	5.59	1.42

Table 4: Concentration of cations and anions in ground waters (Meq/L %) in some selected areas in Lagos state.

Site Name	Ca^{2+}	Mg^{2+}	Na^+	K^+	HCO_3^-	Cl^-	SO_4^{2-}
Ojodu Well	25.72	15.50	58.63	0.16	54.93	41.86	3.21
Majidun Well	26.36	15.95	57.49	0.19	52.90	43.61	3.49
Surulere Well	30.09	18.20	51.18	0.54	49.18	49.02	1.80
Mainland Well	28.59	17.28	53.88	0.25	40.77	49.63	9.60
Ifelodun Well	23.98	14.53	60.78	0.70	13.29	80.92	5.79
Bariga Well	26.12	18.91	54.83	0.14	30.56	52.05	17.39
Somolu Well	31.62	21.58	46.47	0.32	29.63	56.11	14.25

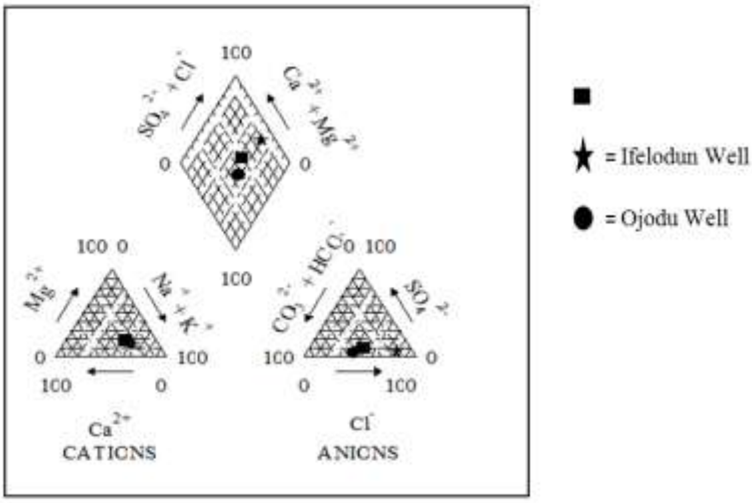

Figure 4: Piper diagram of ground waters from Ojodu, Ifelodun and Mainland.

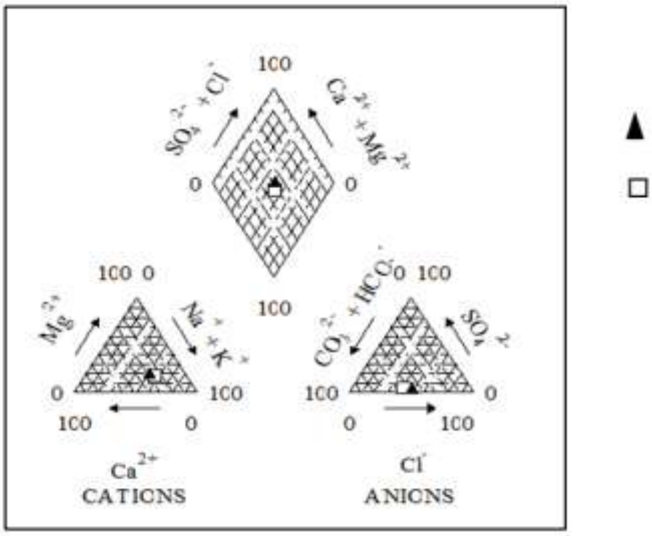

Figure 5: Piper diagram of ground waters from Surulere and Majidun

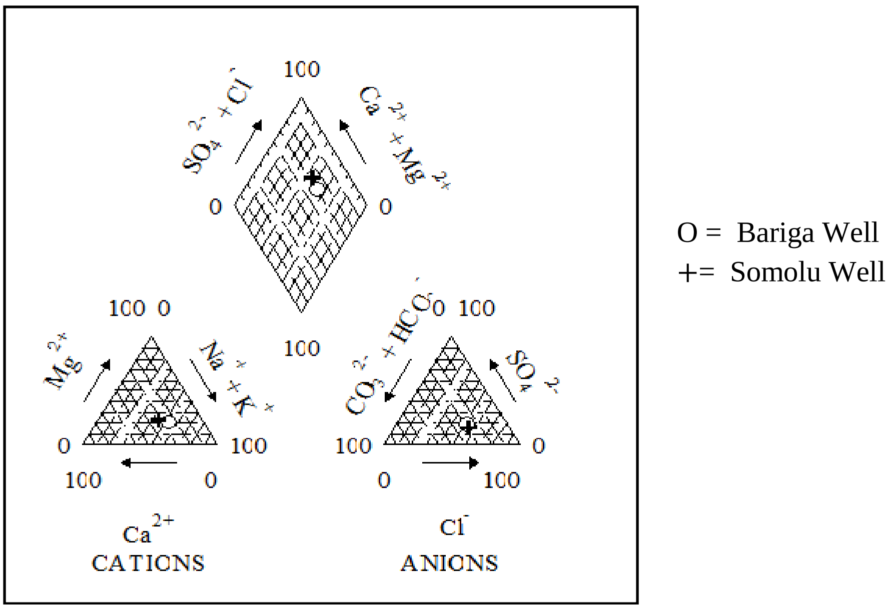

Figure 6: Piper diagram of ground waters from Bariga and Somolu

Tables 3 and 4 show the concentration of cations and anions in Meq/L and Meq/L% respectively. These values where used in plotting the Piper diagram for ground water. Figures 4 to 6 show the Piper plot for the different ground water samples. Based on these plots, 2 types of water types where identified: Na-Cl and Na-Cl-HCO_3 (mixed water type).

The ground water samples from Mainland, Ifelodun, Bariga and Somolu were found to be Na-Cl types. This water typeis made up of combined concentration of alkali metal (Na) and chloride, greater than 50 percent of the total Meq/L. Very concentrated water samples of this hydrochemical faces are considered brackish or an extreme case saline, they are typical of marine sources (Piper, 1944).

Ground water from Ojudu, Majidun and Surulere are typical of mixed water types. In this water type, no specific cation-anion exceeds 50 percent of the total dissolved constituent load, such water could result from multiple mineral dissolution or mixing of two chemical distinct ground water bodies. Hence the water types of the ground water studied is in the following order: Na-Cl > Na-HCO_3-Cl.

4.4 Hydrochemical Characterisation of Surface Water Using the Piper Plot

Table 5: Concentration of cations and anions in surface waters (Meq/L) in some selected areas in Lagos tate.

Site Name	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO^{-}_3	Cl^{-}	SO_4^{2-}
Lagoon Surface Water	37.25	22.57	395.80	5.74	3.444	399.45	14.58
Ojodu Surface Water	2.41	1.46	1.52	0.04	1.312	6.99	0.54
Eti-Osa Surface Water	40.65	24.66	404.62	7.05	4.592	422.41	25.00
Majidun Surface Water	12.45	7.52	18.70	0.64	2.788	93.86	10.62
Bariga Surface Water	39.70	23.91	400.02	6.29	4.674	379.48	14.58
Amuwo – Odofin Surface Water	16.50	12.99	147.83	1.68	3.28	152.68	13.12
Apapa Surface Water	16.20	11.58	127.83	1.12	3.214	134.93	12.29

Table 6: Concentration of cations and anions in surface waters (Meq/L %) in some selected areas in Lagos state.

Site Name	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO^{-}_3	Cl^{-}	SO_4^{2-}
Lagoon Surface Water	8.07	4.89	85.79	1.24	0.82	95.68	3.49
Ojodu Surface Water	44.38	26.89	27.99	0.74	14.84	79.05	6.11
Eti-Osa Surface Water	8.52	5.17	84.83	1.48	1.02	93.45	5.53
Majidun Surface Water	31.67	19.13	47.57	1.63	2.60	87.50	9.90
Bariga Surface Water	8.45	5.09	85.13	1.34	1.17	95.17	3.66
Amuwo – Odofin Surface Water	9.22	7.26	82.59	0.94	1.94	90.30	7.76
Apapa Surface Water	10.34	7.39	81.56	0.71	2.14	89.69	8.17

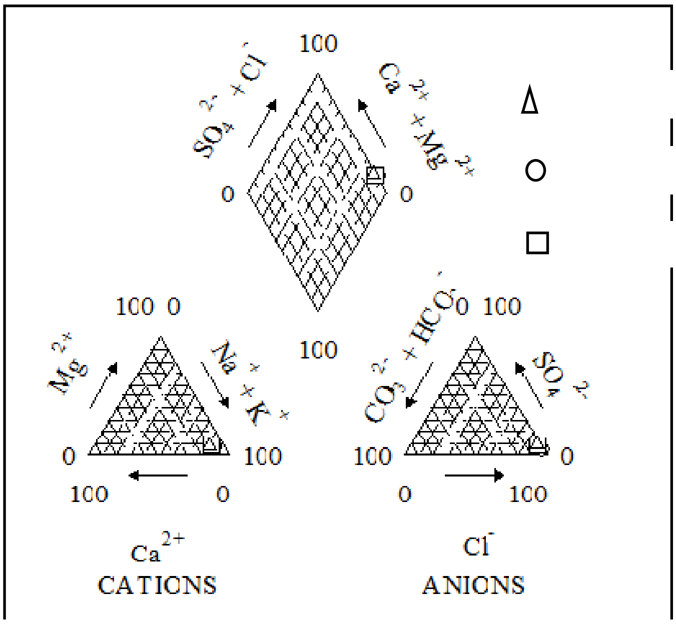

Figure 7: Piper diagram of surface waters from Apapa, Bariga and A-odofin

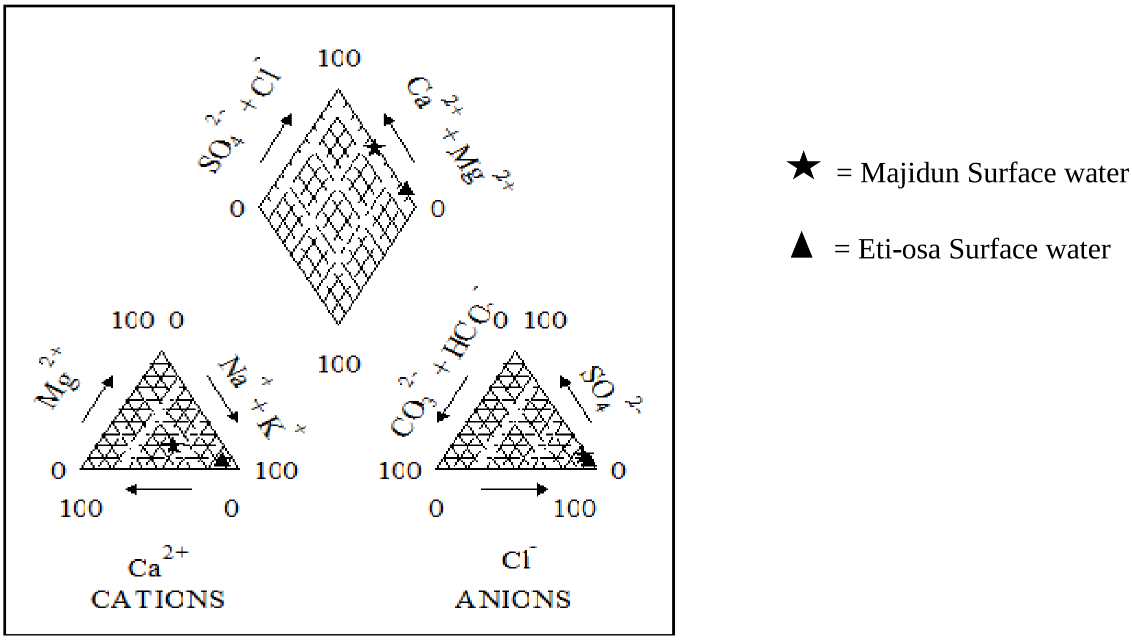

Figure 8: Piper diagram of surface waters from Majidun and Eti-osa

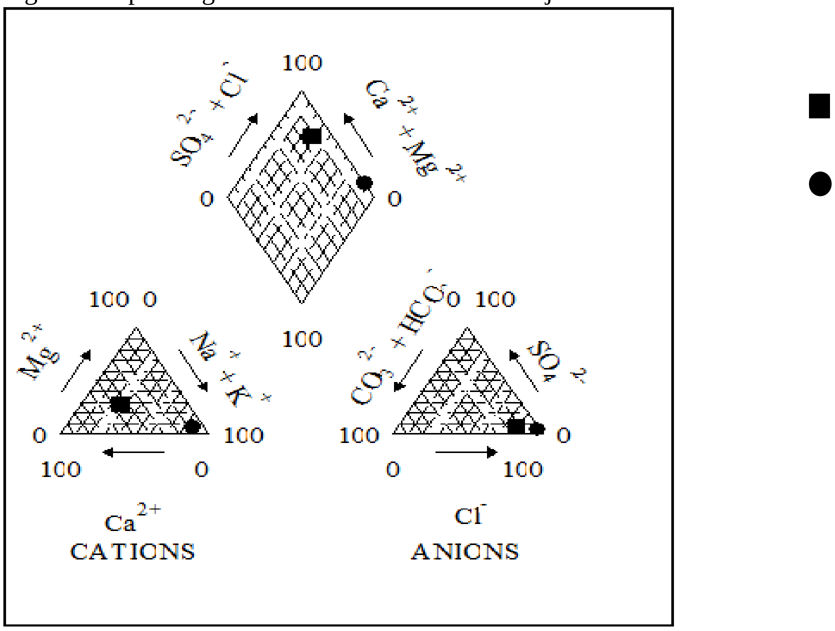

Figure 9: Piper diagram of surface waters from Ojodu and Lagoon

From Tables 5 and 6, the dominant cation and anion in the studied surface water are Na^+ and Cl^- respectively. This can be attributed to chemical a weathering of albite and kaolinite found in basement rocks (Okunlola et al. 2009) and also to also to the dissolution of halite(sodium chloride) which occurs as grains disseminated in unconsolidated bedrock deposits.

Na-Cl water types was the dominant water types in the studied surface water in Lagos state. (Figures 7 to 9). Majidun, Bariga, A-odofin and Apapa surface water were all of the type Na-Cl. This water type is typical of marine deep water (Piper, 1944). Only surface water from Ojodu area was found to be a mixed water type.

4.5 Factor Controlling the Distribution of Aqueous Ions in Selected Surface And Ground Water in Lagos State Using the Gibbs Diagram.

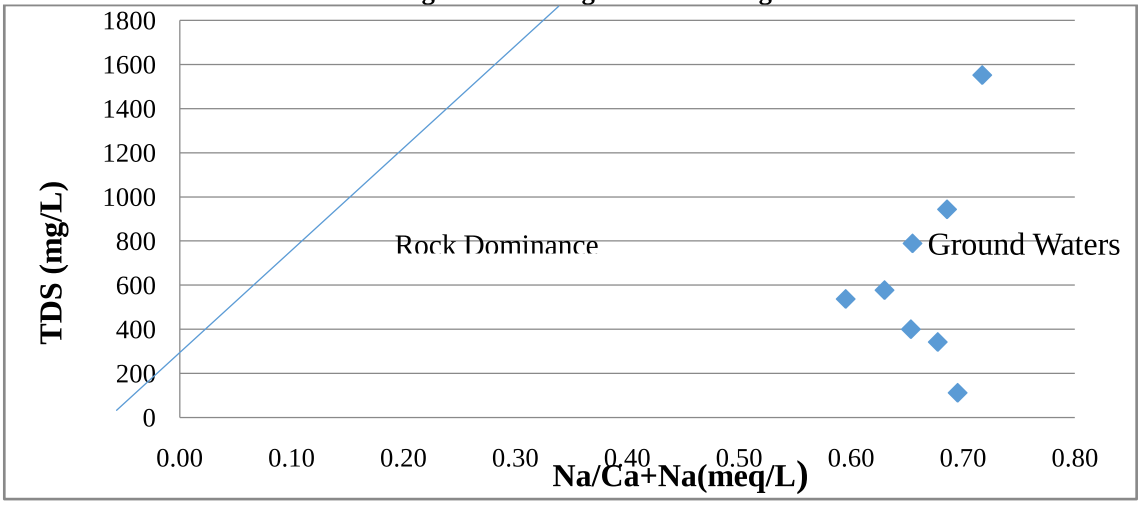

Figure: 10: Gibbs diagram of ground waters in Lagos state.

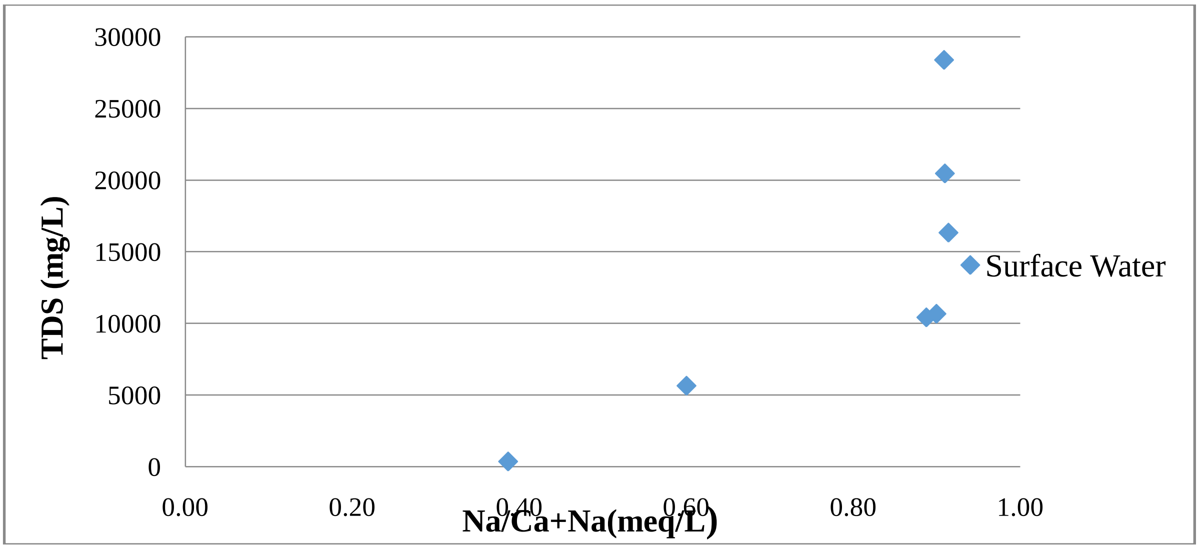

Figure 11: Gibbs diagram of surface waters in Lagos state.

Gibbs diagram was also used to show the controlling factors of aqueous ion in the studied surface and ground waters. From the plot above (Figures 10 & 11), it was shown that all the aqueous ions that gave rise to the water types are from chemical weathering of basement rocks (TDS < 100) and none of the aqueous ion of was from precipitation process.

4.6 Classification of Water Types or Irrigation Purposes Using the Wilcox Diagram.

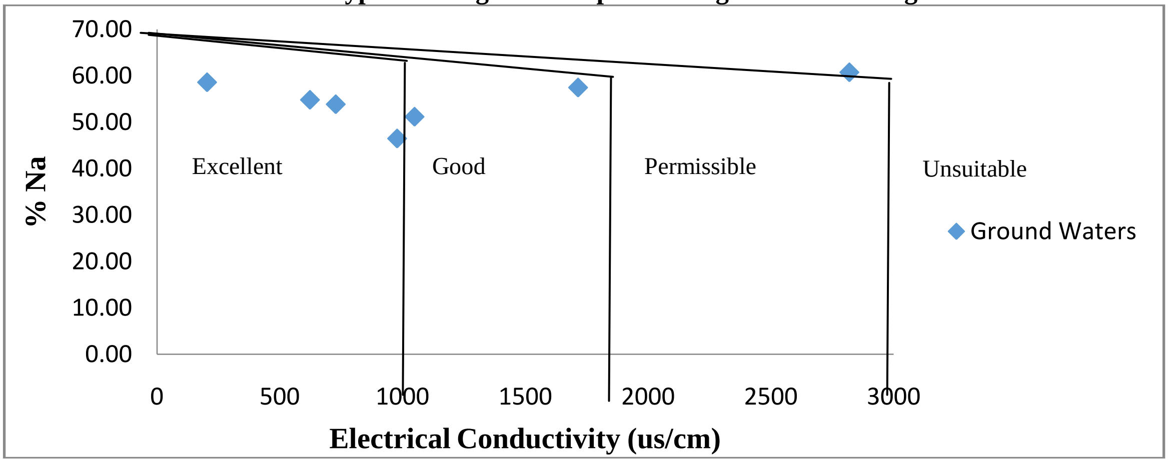

Figure 12: Wilcox diagram of ground waters in Lagos state.

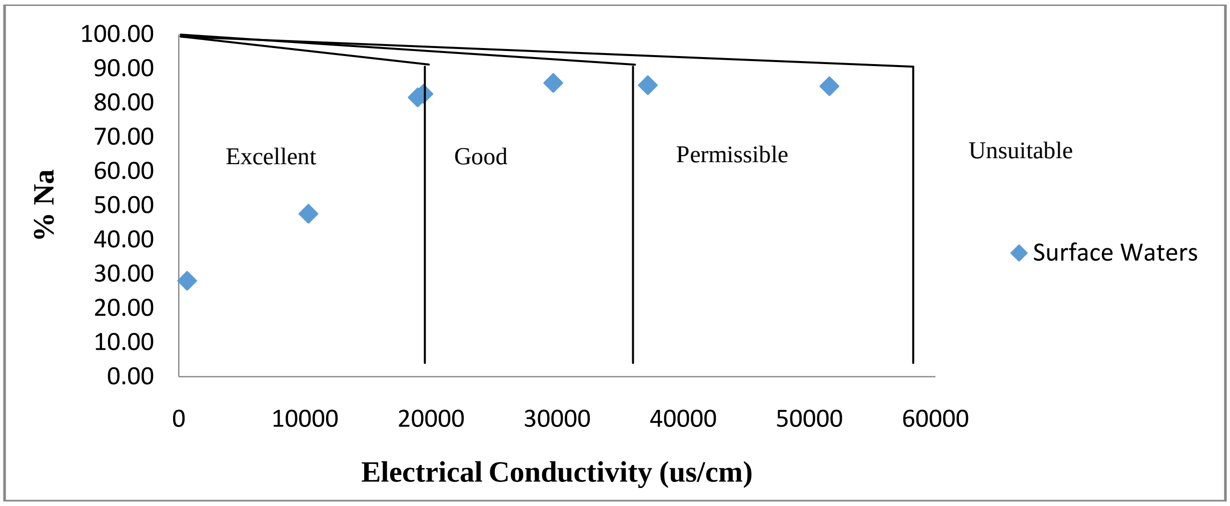

Figure 13: Wilcox diagram of surface waters in Lagos state.

Wilcox diagram was also plotted for the surface and ground waters in Lagos state (Figures 12 & 13). From the plot, it can be deduced that the ground water and surface water samples are within the excellent to permissible class (Wilcox, 1955). Hence they are suitable for irrigation purposes.

V. Conclusion

Elevated values of sodium and chloride was observed in the studied surface and ground water, hence giving rise to Na-Cl water type, which is typical of marine deep water. Na-Cl was the dominant water type in surface and ground water in Lagos state. The study also reveals that the ions present in these water bodies are dominantly controlled by chemical weathering and none from precipitation processes. High proportion of these cations and anions could be attributed to sewage disposal into these water bodies. Hence necessary actions should be ensured around the catchment area of these water bodies.

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