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Saltwater Intrusion from Atlantic Ocean into coastal Aquifers in parts of Nigerian Dahomey Basin

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Abstract
The study of saltwater intrusion was carried out in Dahomey basin of coastal area of southern Nigeria. In the last three decades, aquifers in this area been deteriorated by saltwater intrusion which resulted in the contamination of freshwater along the coast of the Atlantic Ocean. Hydrogeochemical analysis were carried out on thirty-one groundwater samples and twenty-seven dissolved constituents were determined in the laboratory. The results showed that the groundwater samples were highly enriched with magnesium chloride indicating saltwater intrusion and this reduces the storage of freshwater in the aquifers. Magnesium chloride was responsible for the contamination of the freshwater. Ghyben – Herzberg relation has been used to estimate the depth to saltwater based on the thickness of the freshwater zone above the sea level. The depth of the freshwater – saltwater interface in Dahomey basin is directly proportional to the elevation of the water table above the sea level. The density difference and over-pumping of freshwater creates interface causing the mixing of the two fluids. There are three aquifers, the two deeper aquifers were contaminated and most of the boreholes nearer the seashore were abandoned because their water are not drinkable. Cluster analysis shows four groups: group 1, 2, 3 and 4, water from locations 1, 5, 9, 25, 26, 31, 21 and 10 gave rise to the fourth cluster group. Group 4 represents 25.8 % of the groundwater samples. It electrical conductivity average was 227.8 µS/cm, dominant ion was chloride and water here are more polluted than the first three groups.

Keywords: Saltwater, Atlantic Ocean, Permeability, Boreholes, Surface Water

1. Introduction

Water is one of the most essential natural resources that life depends on for support. The hydrosphere as surface water and groundwater support life or plants and animals on this planet earth. Natural water is for drinking, washing and other domestic purposes. However, without water, plants and animals will gradually go into extinction. Because water is renewable and abundantly available to mankind this make people to easily forget its importance and irreplaceability to their lives. Surface water may occur in streams, rivers, lakes, seas and oceans while groundwater is the water that occur in the phreatic water zones in both inland and coastal aquifers. A large percentage of the world's population is dependent upon groundwater resources and utilizes them via public water supply or private domestic wells and boreholes. However, groundwater resources are presently insufficient for human needs in many regions of the world due to various contamination problems. Sources of contamination include leachate from municipal landfills, leaky underground storage tanks that store saline water and natural brine from ocean (Hanf *et al.*, 2005; Penny *et al.*, 2003; Hogan, 2006) [9, 22, 11]. In the land aquifers, when the fresh groundwater is withdrawn by pumping wells at a faster rate than it can be replenished, a draw-down of the water table occurs with a resulting decrease in the overall hydrostatic pressure. When this happens near an ocean coastal area, saltwater from the ocean intrudes into the freshwater aquifer. Increasing salt intake has substantial negative impacts on human health and well-being and high salt intake is a major risk factor for increased blood pressure (Mashura, 2019) [15]. The purpose of this research is to identify factors responsible for saltwater intrusion in the coastal aquifers in Dahomey basin of Nigeria. People that have worked on saltwater intrusion includes Glover, 1959 [8], Huyakorn, 1987 [12], Westbrook *et al* 2004, Hogan *et al* 2006 [11], Gaaloul *et al*, 2012 [6], Naderi *et al* 2013 [16], Felisa *et al* 2013 [5] Rahaman and Bhattacharya, 2014 [24], among others.

1.2 Basic principles of Groundwater Flow

Darcy's law states that the rate of flow of groundwater is proportional to the potential gradient and inversely proportional to length of flow. Darcy's law is a simple proportional relationship between the instantaneous discharge rate through a porous medium and the pressure drop over a given distance. The flow is proportional to the head difference:

$$V \alpha\ i$$

Groundwater flow is inversely proportional to the flow length

$$V \alpha\ 1/dl$$

Darcy's law can be expressed mathematically as:

$$V = ki$$

Where,

$$V = Velocity\ of\ flow$$
$$K = Hydraulic\ conductivity\ or\ permeability$$
$$i = dh/dl = Hydraulic\ gradient$$

The hydraulic gradient provides the driving force that keeps the groundwater in motion against internal friction. Groundwater therefore flows from regions of high hydraulic head to areas of low hydraulic head. Because groundwater flows through a porous media, the rate of flow depends on permeability of the soil which is the degree of are interconnectedness of pore spaces. The property of interest in groundwater flow is the permeability, **k**, which is a measure of the ease with which a fluid flows through the soil matrix.

2. Geology and hydrogeology of the study area

2.1 Regional Stratigraphy of the study Area: The study area lies on the central part of the Dahomey Basin and is underlain by clastic sediments which lie unconformably on the crystalline Basement Complex. The Dahomey basin stretches from Southeastern Ghana through Togo and Republic of Benin to Southwestern Nigeria. It is separated from the Niger Delta by a subsurface Basement high referred to as the Okitipupa Ridge. Omosuyi (2001) [19] identified the predominant rock types as shale and sandstones, and minor rocks as limestone and unconsolidated sediments with age range of Albian to recent. Abeokuta Group is consisting of Ise, Afowo and Araromi Formation (Fig 1).

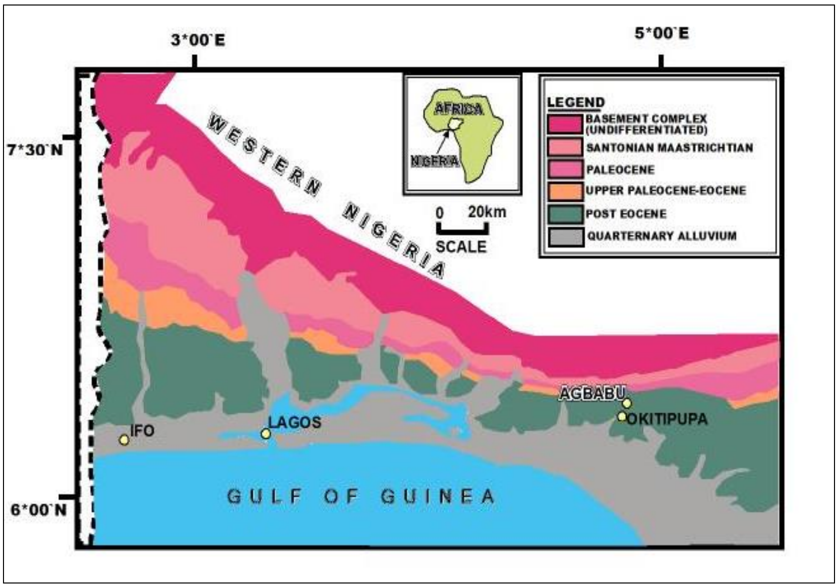


Fig 1: Geological map of the study area (Modified after Ajayi *et al.* 1989)

Omatsola and Adegoke (1981) [20] proposed that the Dahomey basin comprises of a series of horst and grabben. Abeokuta Group: This is cretaceous, most abundant and oldest and uncomformably overlies the Basement complex. It is made up of conglomerates, sandstones, sandy limestone, clays and shale. Age is from Neocomian to Paleocene (Omatsola and Adegoke, 1981) [20].

Abeokuta Group is made up of 3 lithological units namely:
Basal Ise Formation
Middle Afowo Formation
Upper Araromi Formation

Ise Formation: This is one of the Formations in the Abeokuta Group and the oldest sedimentary unit found in Southwestern Nigeria overlying the basement complex. It is made up of conglomerate at the bottom, gritty to medium grained loose sand capped by kaolinitic clay formed as a result of regressive phase (Omatsola and Adegoke 1981) [20]. The maximum thickness is 1865 meters, the grains are sub-angular to sub-rounded, poorly sorted and positively skewed. The age is Neocomian. The coarseness of the loose sand and gritty sandstones upward from the base of the Formation is an indication of its relation with the Basement Complex. The intercalation of clay unit is additional evidence to confirm that Ise Formation was derived from continental environment.

Afowo Formation: Directly overlies Ise Formation and in some places overlies the Basement Complex. This unit is made up of coarse to medium grained sandstone with variable but thick interbeded shales, siltstones and clay. The shale component increases progressively from bottom to top. The lower portion is thought to be transitional with mixed brackish to marginal horizon alternating with well sorted, sub-rounded, clean loose fluvial sands. This is probably indicative of a lithoral or estuarine near-shore environment of deposition in which water level fluctuate fairly rapidly.

Araromi Formation: The Araromi Formation overlies Afowo Formation and is the youngest of the cretaceous sediment in the Eastern Dahomey basin (Omatsola and Adegoke 1981) [20] and sometime it is referred to as Araromi shale. This Formation is composed of fine to medium grained sandstone at the base overlain by shale and siltstone with an alternating band of limestone, marl, sand and coal towards the top (Elueze and Nton, 2004) [4]. The shales are light grey to black, lightly fissile, well laminated and mostly marine with high organic content indicating a quiet marine environment of deposition.

Akinbo Formation: The age of this Formation is Paleocene and the Formation is made up of fossiliferous shale, shale and limestone. Akinbo Formation overlies Araromi Formation. It consists of clayey shale sequence. The shale sequence is glauconitic gray shale. The Akinbo Shale is characterized by greenish grey, thickly laminated and very richly fossiliferous shale. This difference may probably be due to differences in the environment of the depositional basin.

Oshosun /Ilaro Formation: Is made up of Sandstone, Mudstones, Glauconites and Phosphates. Their age is Eocene. This sandstone is massive, yellowish, poorly consolidated, cross bedded which is fine to medium grained and poorly sorted. Jones and Hockey (1964) [14] suggest that the sequence consists of coarse sand of estuarine, deltaic and continental environments that display rapid lateral facies change. They also suggested that the sands are generally white and mineralogically composed of pure quartz with sub rounded to rounded grains. The texture mostly indicates beach or shoreline and near shore environment.

Alluvial deposit/ Benin Formation: this is the youngest geologic formation in Dahomey basin, the age is recent**.** It consists of soft, very poorly sorted clayey-sands, pebbly sands, sandy clays and rare thin lignite. The sands are in parts cross bedded with transitional to continental characteristics. It is non-fossiliferous, but contains plant remains which have been used to assign Oligocene to recent age to the Formation.

Table 1: Summary of the Stratigraphy of the Dahomey Basin (Omatsola and Adegoke 1981) [20]

Age	Stratigraphy	Lithology
Recent	Alluvial deposit/ Benin Formation	Sands, Clay lenses, Lignite, Shale
Oligocene	Ijebu/Ogwashi-Asaba Formation	Sands, Limestone, Bituminous sands
Eocene	Ilaro Formation	Sandstone
	Oshosun Formation/ Ameku Formation	Sandstone, Mudstones, Glauconites and Phosphates
Paleocene	Akinbo Formation	Shales, Fossilliferous Shales
		Limestone, Quartzs, Glauconites
Maestrictian	Araromi Formation	Sand, Shales, Siltstone Limestone, Bituminous sands
Turonian	Afowo Formation	Sandstones, Shales, Siltstones, Clay
Barrenian	Ise Formation	Sands, Grits, Siltstone
Precambrian	Basement Complex	

2.2 Definition of Aquifer: These are permeable rock formations which store groundwater and transmit sufficient quantity of it to a pumping well. Aquifers can be divided into two groups namely confined and unconfined aquifers. Confined aquifers are those aquifers that are sandwich between two impermeable layers, while unconfined aquifers are those which groundwater occurs under atmospheric pressure. Groundwater in the Atlantic coastal zone of Dahomey basin in the intermediate and deeper aquifers occurs in confined condition and the one at the upper layer occurs under unconfined aquifers. Where water completely fills the pore spaces of an aquifer that is overlain by a confining unit, the aquifer is referred to as confined.

2.3 Hydrogeology and aquifer types in the study Area: The occurrence of groundwater in the area is controlled by diverse geological factors such as structures, geological sequences and stratigraphic disturbances of hydrogeological units. The alluvial deposits, called coastal plain sands consist of unconsolidated sediment of coarse to medium grained gravel and sand which served as groundwater reservoirs. Idowu *et al.* (1999) [13] identified other groundwater aquifers in Abeokuta Group which consist of fine to coarse grained sands with admixture of gravel and also in Ilaro Formation within the fine to medium grained sands. Depths, thickness and continuities of aquifers in the study area are variable due to lateral facies changes. Boreholes and hand dug wells that penetrate through the thickness of the alluvial materials served the major source for their water supply. The depth to water table is highly variable, being as shallow as 3 meters and as deep as 20 meters below the ground surface. Groundwater flows from the recharge area in the upper hills toward the central parts of the basin. Groundwater abstractions from numerous wells and boreholes provide for their domestic needs. Some of the water has taste and some are oily, particularly those which are close to the seashore. The surface water in the study area runs through the river channels and flows into Atlantic Ocean. The prolific aquifers occurred mostly in the coarser, highly permeable geologic material such as sand, gravel, sandstone and limestone. The other rock types such as shale, siltstone and mudstone were aquicludes. The presence of water in the aquiferous zone occurs under confined condition (Idowu *et al.,* 1999) [13].

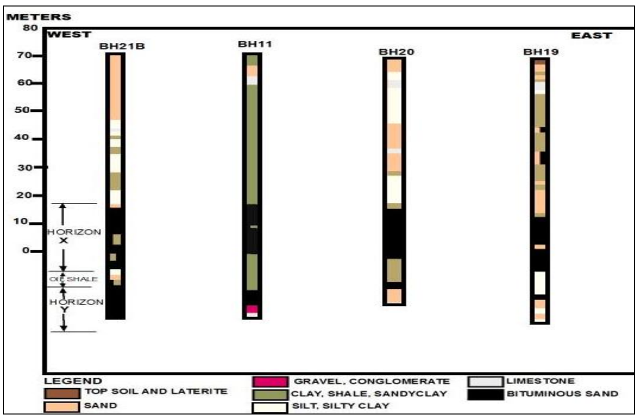
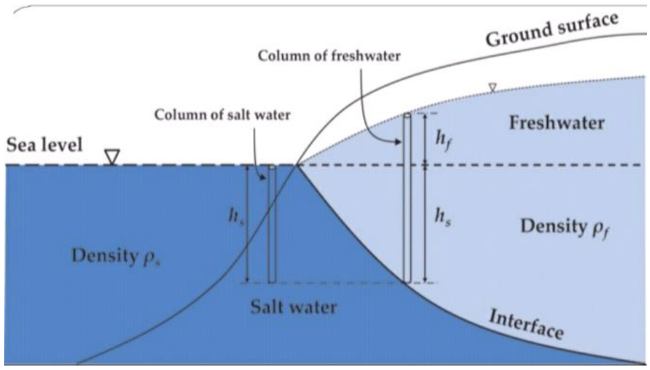


Fig 2: Schematic geological west – east cross section of stratigraphic sequence in some boreholes (Modified after *et al.* Adegoke, 1980) [1]

Onwuka (1990) [21] outlined three main Hydro – stratigraphic units in the Nigerian section of the Dahomey basin: upper aquifer (alluvium and coastal plain sands) middle aquifer (Ilaro and Ewekoro Formations) and the lower aquifer (Abeokuta Group) lying directly on the Basement Complex. In the Southern part of the study area such as Ilutitun, Ikoya, Igbotako, Irele, Okitipupa and Iju odo, aquifer occurred at greater depth and people in these areas only have access to groundwater through boreholes. However, at the Northern part, such as Ode-Aye, Ilubirin and Agbabu upper aquifer made up of alluvium and coastal plain sands are present. Hand dug wells are common in these areas. During this research programmes, 27 hand dug wells depth were measured at Ilubirin, Igbotako, Agbabu, Ode – Aye and Igbaje towns. Four water from the well were not saline, this may be due to non – saline water intrusion into the coastal aquifers. Water samples from the deeper boreholes were saline; this may be due to salt water intrusion as a result of their nearness to the Atlantic Ocean.

3. Materials and methods

3.1 Ghyben – Herzberg theory: The first physical formulations of saltwater intrusion were made by W. Badon-Ghyben (1888) [7] and A Herzberg (1901) [10]. Both at different occasion observed that the depth of the interface of fresh water – saltwater in the coastal aquifers is directly proportional to the elevation of the water table above sea level and this is called the Ghyben–Herzberg relation. They derived analytical solutions to approximate the intrusion behaviour, which are based on a number of assumptions that do not hold in all field cases.



$$\rho_s gz = \rho_f g(h_f + z)$$

Where

ρf = freshwater density = 1.0g/cm^3
ρs = saltwater density = 1.025g/cm^3
Z = height of saltwater column
hf = hydraulic head above sea level
$hf + z$ = height of freshwater column

$$z = \rho f * hf / (\rho s - \rho f)$$

$$z = 40hf$$

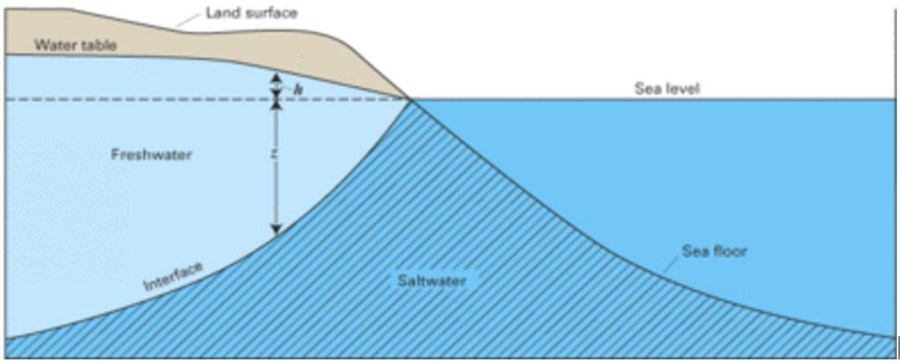


Fig 3: Ghyben–Herzberg relation diagram (Wikipedia)

If:

h =thickness of the freshwater zone above sea level
z = thickness of the freshwater zone below the sea level
ρf = density of freshwater (1.000g/cm3)
ρs = density of saltwater (1.025g/cm3)

then z can be expressed mathematically as:

$$z = \rho s * h / (\rho s - \rho f)$$

Then z can be simplified as:

z = 40h

When water is pumped from the borehole at faster rate than the recharge rate, which means outflow is higher than inflow. Drawdown will be created in the well and the drawdown will continue to increase as the pumping rate in the well increases, then the interface migrates hinterland and stagnation point to the ocean side. When drawdown is lower below the interface, saltwater from the ocean moves into the well causing saltwater intrusion into the well. However, under non - pumping conditions, the classic vertical saltwater circulation cell is developed by combining buoyancy forces and hydrodynamic dispersion (Pool and Carrera, 2011) [23].

3.2 Hydrogeochemical investigations

Thirty-one groundwater samples were collected from hand dug wells and boreholes from the study area for analyses. Two litres of water samples were collected using polythene bottles. Water sampling points were located using Global Positioning System (GPS). Twenty-seven physico-chemical analyses were determined using the established method of analyses (APHA, 1998) [3]. pH, EC, TDS, and temperature were measured in the field using PH 2603. Bicarbonate, SO4, Cl, PO4 NO3, total hardness, alkalinity, turbidity, calcium, oil and grease and Mg were determined by wet analyses. Cd, Pb, Cr, Cu, Fe, Zn, Mn, were determined by Atomic Absorption Spectrophotometer while Na and K were determined by flame Photometric methods.

4. Results and discussion

The results of the hydrogeochemical investigation carried in the study Area are presented as compound and anion contents in Table 2 and metallic constituents in Table 3.

Table 2: Compound and anion constituents of Groundwater in Dry Season

S. No	HCO_3^-	Total Alkalin $CaCO_3$	Cl^-	Turbid NTU	NO_3^-	PO_4^{2-}	SO_4^{2-}	Oil and Grease	Calcium Hard as $CaCO_3$	Total Hard
1	9.15	9.15	17.73	0.001	0.01	0.21	0.29	176.65	27.00	37.83
2	21.35	21.35	21.27	0.022	0.07	0.19	0.26	61.25	13.00	19.18
3	24.4	24.4	17.73	0.006	0.01	0.29	0.21	24.40	13.00	18.94
4	36.6	36.6	31.91	0.004	0.022	0.12	0.09	21.35	20.00	30.45
5	54.90	54.90	56.72	0.007	0.05	0.52	0.27	54.90	47.00	69.95
6	30.50	30.50	35.45	0.002	0.02	0.24	0.15	30.50	9.00	21.11
7	48.80	48.80	53.18	0.001	0.04	0.55	0.25	48.80	15.00	23.19
8	30.50	30.50	23.81	1.24	0.15	0.52	0.27	30.50	10.00	15.95
9	97.6	97.60	33.81	0.015	0.08	0.48	0.21	97.60	16.00	26.54
10	41.50	41.50	52.18	0.001	0.03	0.20	0.16	91.50	9.00	15.28
11	36.60	36.60	38.99	0.004	0.05	0.21	0.11	36.60	10.00	17.41
12	48.80	48.80	38.99	0.015	0.01	0.24	0.10	48.80	9.00	14.80
13	54.90	54.90	28.36	0.003	0.02	0.17	0.14	54.90	7.00	10.78
14	112.85	112.85	28.36	0.009	0.01	0.33	0.16	112.85	10.00	14.74
15	85.40	85.40	31.91	0.013	0.02	0.42	0.12	85.40	8.00	11.45
16	61.00	61.61	28.36	0.002	0.06	0.82	0.41	61.00	8.00	11.94
17	36.60	36.60	31.91	0.026	0.01	0.22	0.26	0.77	5.00	9.43
18	48.80	48.80	42.54	0.012	0.01	0.27	0.32	0.72	5.00	7.97
19	36.60	36.60	42.54	0.009	0.05	0.44	0.52	0.96	4.00	5.84
20	73.20	73.20	46.09	0.007	0.26	0.20	0.01	0.34	10.00	18.14
21	85.40	85.40	20.27	0.008	0.11	0.32	0.45	4.83	25.00	38.91
22	54.90	54.90	53.18	0.019	0.12	0.27	0.08	2.14	4.00	6.57
23	27.10	27.10	49.63	0.004	0.05	0.52	0.22	2.20	4.00	6.33
24	36.60	36.60	38.99	0.002	0.05	0.4	0.06	0.29	6.00	8.64
25	30.50	30.50	50.27	0.013	0.01	0.18	0.10	0.70	13.00	22.83
26	24.40	24.40	40.27	0.037	0.20	0.27	0.20	0.32	41.00	23.75
27	24.40	24.40	46.09	0.005	0.02	0.30	0.25	0.68	7.00	12.00
28	18.30	18.30	46.09	0.003	0.04	0.26	0.09	0.19	4.00	5.81
29	12.40	12.40	42.54	0.004	0.25	0.35	0.27	2.16	4.00	8.27
30	18.30	18.30	8.99	0.007	0.06	0.19	0.08	0.32	5.00	7.97
31	18.30	18.30	3.55	0.001	0.03	0.24	0.13	2.22	17.00	27.46

Table 3: Metallic constituents of Groundwater in Dry Season

S. No	Mg^{2+}	Ca^{2+}	Na^+	K^+	Zn^{2+}	Total Fe	$Cr6^+$	Pb^{2+}	Cd^{2+}	As^{3+}	Ni^{2+}	Cu^{2+}	Mn^{2+}
1	0.01	10.82	16.29	5.23	0.05	BD	.016	.001	0.04	.00	BD	BD	BD
2	0.97	5.21	21.01	9.13	0.24	BD	.019	.001	0.04	.001	BD	BD	BD
3	0.73	5.21	13.76	2.56	0.52	BD	.017	.000	0.07	.002	BD	0.73	BD
4	2.43	8.02	12.00	3.76	0.06	BD	.018	.002	0.0	.003	0.51	BD	BD
5	4.13	18.82	20.01	3.99	0.11	0.07	.018	.000	BD	.001	BD	1.31	BD
6	8.51	3.60	7.30	8.73	0.03	0.29	.017	BD	BD	.002	0.27	1.05	BD
7	2.18	6.01	11.06	9.40	0.19	BD	.019	.001	0.05	.002	0.41	BD	BD
8	1.94	4.01	7.99	19.86	0.57	0.27	.017	.002	0.03	.003	BD	BD	0.34
9	4.13	6.41	10.21	8.10	0.23	0.10	‘019	.001	0.05	.003	BD	BD	0.03
10	2.67	3.61	6.35	9.90	0.21	0.11	.016	.003	BD	.003	BD	BD	BD
11	3.40	4.01	7.42	9.95	0.25	0.24	.015	.001	0.11	.001	BD	0.96	0.22
12	2.19	3.61	10.26	14.71	0.20	0.55	.012	.000	0.02	.001	BD	BD	0.11
13	0.97	2.81	9.99	17.48	0.16	0.66	.013	BD	0.04	.001	BD	BD	0.28
14	0.73	4.01	12.19	3.12	0.34	0.23	.015	.00	0.0	.00	BD	BD	0.0
15	0.24	3.21	11.56	4.88	0.20	0.33	.011	.002	0.06	.003	BD	1.18	0.17
16	0.73	3.21	10.13	15.53	BD	0.23	.013	.002	0.01	.003	BD	1.53	0.31
17	2.43	2.00	3.25	5.44	BD	0.24	.017	.003	0.16	.002	1.08	0.39	0.39
18	0.97	2.00	5.83	5.32	0.24	0.27	.017	.003	0.09	.003	BD	0.23	0.23
19	0.24	1.60	9.21	7.43	BD	0.09	.015	.003	0.13	.002	BD	0.56	0.56
20	4.13	4.01	7.91	8.10	B/D	B/D	.021	.001	0.06	.001	B/D	1.78	0.30
21	3.89	10.02	7.48	17.48	0.01	BD	.007	.001	0.13	.001	B/D	1.41	0.64
22	0.97	1.60	11.11	6.71	0.00	0.44	.013	.003	B/D	.003	B/D	1.99	0.18
23	0.73	1.60	8.31	5.98	B/D	0.42	.019	.002	B/D	.003	0.13	2.38	0.46
24	0.24	2.40	12.90	7.72	B/D	0.26	.021	.003	0.02	.003	B.D	BD	0.59
25	4.62	5.21	10.52	7.02	0.19	0.22	.012	.001	0.18	.001	B.D	BD	0.64

26	6.32	16.43	12.25	9.87	BD	0.42	.013	.003	0.07	.002	BD	BD	BD
27	2.19	2.81	19.81	8.72	BD	0.27	.011	.003	0.24	.001	BD	1.38	0.14
28	0.24	1.60	7.22	2.01	0.39	0.08	.021	.001	BD	.003	5.27	1.49	B.D
29	2.67	1.60	8.51	3.81	0.01	0.30	.017	.001	0.04	.002	BD	2.40	0.25
30	0.97	2.00	11.24	3.73	0.15	0.21	.011	.003	0.03	.00	BD	BD	BD
31	3.65	6.81	11.48	6.73	0.08	0.32	.021	.002	0.06	.001	BD	0.62	0.50

4.1 Cluster analysis

The cluster analysis of groundwater is also composed of four groups (Ogunribido, 2014) [18].

Group 1

Group 1 consists of wells 17, 24, 27, 29, 30, 18, 22, 19, 23, 28, 3, 13, 16 and 7, this account for 45.1% of the total groundwater. The mean concentration of the electrical conductivity in the water samples was 65.3 µS/cm. This water group was chloride dominated; the dendrogram shows that association between these cases is significant.

Group 2

Cluster 2 was made of wells 6, 8, 4, 12, 20 and 11 and this represent 19.4 % of the groundwater sample in the study area. The mean concentration of electrical conductivity was 27.4 µS/cm.

Group 3

This third group of the cluster was represented by groundwater samples from wells 14 and 15 and this accounted for 6.5 % of the groundwater samples in the study area. The dominant ion was bicarbonate. The mean electrical conductivity was 107.5 µS/cm.

Group 4

The affinity of wells in the study locations 1, 5, 9, 25, 26, 31, 21 and 10 gave rise to the fourth cluster group in groundwater samples. This represents 25.8 % of the total groundwater samples. The mean electrical conductivity was 227.8 µS/cm and the dominant ion in the water was chloride. Group 4 type contains the highest dissolved constituents showing that they were the highest polluted water in the study area.

** * * H I E R A R C H I C A L C L U S T E R A N A L Y S I S * * * * * * * * * * * *

Dendrogram using Average Linkage (Between Groups)

Rescaled Distance Cluster Combine

C A S E 0 5 10 15 20 25
Label Num +---------+---------+---------+---------+---------+

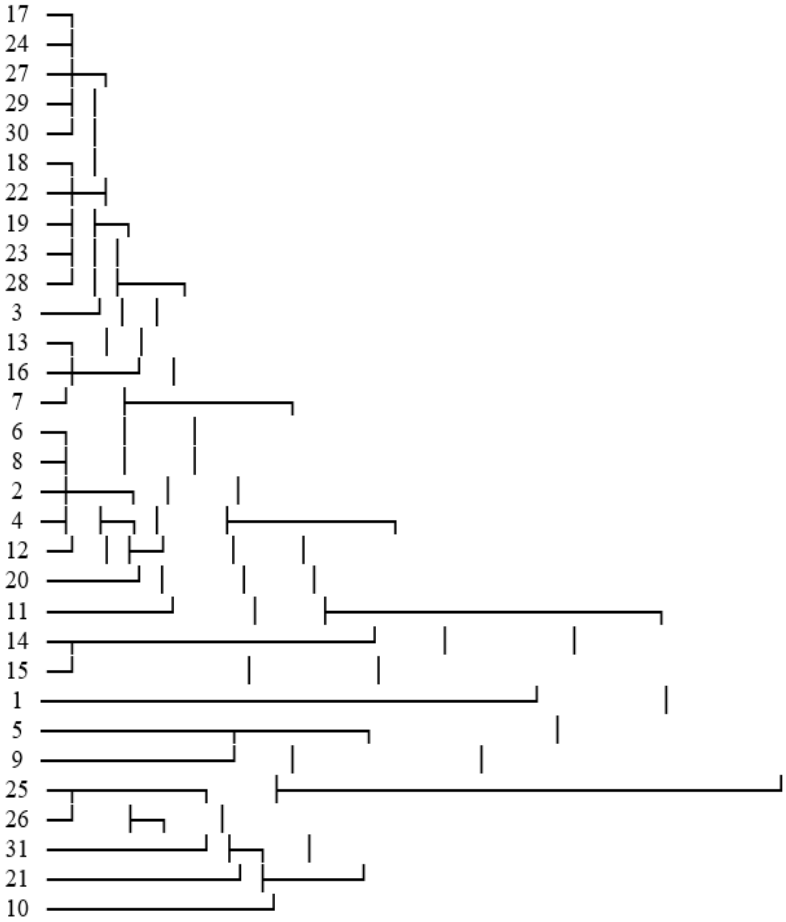


Fig 4: Dendrogram for groundwater in dry season

4.2 Correlation coefficient

Magnesium and Chloride: There was a positive correlation between Mg^{2+} and Cl^- in the groundwater samples (Table 4). The principal sources of magnesium in water were magnesium bearing minerals in rocks and secondary sources were animal, domestic and industrial wastes. Magnesium also shows positive and significant correlation with all the analyzed parameters except SO_4^{2-}. The $MgCl_2$ correlation shows the influence of seawater and groundwater mixing. The correlation coefficient between magnesium and chloride was around 0.96. Anthropogenic factor due to over abstraction of fresh water was responsible for the saltwater intrusion. This also shows a high correlation of TDS and electrical conductivity. The dissolved constituents that was responsible for the high TDS was as a result a of the dissolved magnesium and chloride ions that were present in the groundwater samples.

Table 4: Correlation Matrix of Groundwater in Dry Season

Parameters	HCO^-_3	$C1^-$	NO^-_3	PO^{2-}_4	SO^{2-}_4	Ca^{2+}	Hard	TH	Mg^{2+}	Oil	Na^+	K^+	pH	Ec	TDS	Temp
HCO^-_3	1															
Cl^-	0.28	1														
NO^-_3	0.05	0.33	1													
PO^{2-}_4	0.13	0.1	0.04	1												
SO_4^{2+}	0.18	0.05	0.09	0.33	1											
Ca^{2+}	-0.05	0.15	0.08	0.05	-0.01	1										
Ca Hard	-0.05	0.15	0.08	0.05	-0.01	1	1									
T.H	0	0.12	-0.04	0.08	-0.01	0.91	0.91	1								
Mg^{2+}	0.05	0.3	0.14	0.1	-0.01	0.33	0.33	0.41	1							
Oil	-0.21	-0.24	-0.1	-0.11	0.11	0.27	0.27	0.27	-0.15	1						
Na^+	-0.2	0.05	-0.09	0.14	0.05	0.24	0.24	0.22	-0.03	0.28	1					
K^+	0.9	0.15	0.12	0.12	-0.05	0.11	0.11	0.12	0.23	0.2	-0.07	1				
pH	-0.13	0.24	-0.04	0.01	-0.22	0.14	0.14	0.12	0.17	0.09	0.2	0	1			
Ec	0.08	0.4	0.08	-0.06	-0.04	0.65	0.65	0.67	0.61	-0.13	-0.03	0.13	0.16	1		
TDS	0.07	0.34	0.05	-0.04	-0.3	0.68	0.68	0.69	0.58	-0.11	0.02	0.07	0.16	0.95	1	
Temp	0.23	-0.07	-0.01	0.16	0.09	0.19	0.19	0.25	0.18	0.12	0.07	0.27	-0.05	-0.05	-0.02	1

5. Conclusion

The upper layer aquifer is free from saltwater intrusion while the intermediate and the bottom aquifers were affected by saltwater intrusion. The saline condition in the coasters aquifers around the Atlantic Ocean was due MgCl2 salt rather than the common salt (NaCl2) from the correlation coefficient of hydrogeochemical investigation of the study Area. The dissolved constituents that was responsible for the high TDS was as a result a of the dissolved magnesium and chloride ions that were present in the groundwater samples. The source of the magnesium and chloride ions could be trace to the dissolution of rock minerals due to water – rock interaction. Under non -pumping conditions, the classic vertical saltwater circulation cell is developed by combining buoyancy forces and hydrodynamic dispersion. From cluster analyses, group 4 type contains the highest dissolved constituents showing they were the highest polluted water in the study Area. Over pumping of water from the wells in the study Area were responsible for the saltwater intrusion.

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