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GEOPHYSICAL AND GROUNDWATER CHEMISTRY INVESTIGATION OF THE IMPACT OF FLOOD ON GROUNDWATER IN AJEGUNLE-IKORODU, NIGERIA

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ABSTRACT
This study explored how floods affect the quality of groundwater in Ajegunle, Ikorodu, Lagos State. The resistivity survey identified three to four geological layers consisting of topsoil, clay, sand, and sandy clay. The aquifers are made up of the second and third layers in the study area. The first aquifer is partially confined and is at a high risk of being contaminated by floods. The second aquifer, being confined, is the most dependable source of drinking water. The analysis of the groundwater chemistry showed that Arsenic, Iron, Cadmium, and Lead levels are high in the study area's groundwater during rainy seasons. The levels of these metals in the water samples surpassed the allowable limits set by the WHO. The analysis results demonstrate elevated levels of TDS, EC, Na, Cl, suggesting degradation, whereas pH, Ca, and Mg values are within acceptable limits according to regulations (WHO). The Piper and Gibbs plots were utilized in the investigation of geochemical processes. The results revealed that water in Ajegunle-Ikorodu is a mixture of Ca-Na-HCO_3 and Ca-Mg-Cl types (freshwater) based on Piper's diagram. Additionally, the Gibbs diagram indicated that evaporation is the primary factor influencing water chemistry in the area. Typically, the groundwater in the research area is deemed unsuitable for drinking unless it is treated. Hence, it is advised to avoid using water from shallow boreholes and hand dug wells in the research area. Instead, boreholes for household water use should be drilled up to 85 m deep in the second aquifer.
Keywords: Ajegunle-Ikorodu, groundwater contamination, flood, rainy season.

I. INTRODUCTION

In Nigeria, many villages, towns, and cities have been affected by severe flooding in recent years, which has been caused by increased rainfall attributed to climate change. The Ajegunle-Ikorodu region in Lagos State frequently experiences severe flooding in the rainy season. Floods often result in significant destruction to the environment, causing large losses to buildings and crops. Flooding happens when rainwater exceeds the ground's ability to absorb it or when a riverbank is overwhelmed by water [1]. The floods could last for a short or extended period, varying based on the type of flood. Flash floods, characterized by their high speed and energy, are considered the most dangerous flood type due to their ability to cause severe devastation upon occurrence. Climate change, inadequate drainage system, and Dam failures are the primary causes of floods.
Chemical elements found in flood waters contaminate surface water and groundwater. These chemical compounds can pose health risks if ingested. Poorly managed flooding can be a significant cause of groundwater pollution, especially in certain regions [2]. Unconfined aquifers are at a high risk of pollution due to being directly recharged by contaminated water. Deeper aquifers might also be impacted if they lack a substantial impermeable barrier. Frequent heavy rainfall is commonly linked to significant groundwater pollution and erosion of the soil.
Ajegunle area in Ikorodu, Lagos State has been experiencing regular flooding because of climate change (Figure 1). During flooding, usually, the focus is on the damage to human lives and property rather than the effect on groundwater quality in Ajegunle and nearby areas. Studies indicate a rise in water-related health issues in Ajegunle and the surrounding areas. Examining the effects of floods on groundwater resources is crucial to protect lives and prevent health issues like Kidney disease, Cancer, Stomach pains, Bladder problems, and Skin infections caused by water pollution. Multiple research studies have demonstrated that Nigeria's climate has experienced significant transformations, leading to erratic rainfall schedules and severe weather occurrences [3,4,5,6,7].
Continuous surveillance of groundwater condition is crucial in a flood-prone region like Ajegunle-Ikorodu to protect public health. Regular monitoring of water quality is highly significant because it can help to safeguard human and animal lives [8]. Even though monitoring water regularly might seem complex, it is highly crucial. [9]. Research has demonstrated that abnormal concentrations of heavy metals in water bodies can pose significant risks to both the environment and public health [10,11].
Evaluating the vulnerability and health risk of water contaminants is crucial in raising awareness about the dangers of groundwater pollution. Having a thorough understanding of how floods and groundwater interact is crucial for obtaining essential information needed to protect groundwater resources, particularly in flood-prone regions.
This research utilized geophysical and groundwater chemistry techniques to examine the effects of flooding on groundwater quality in Ajegunle, Ikorodu, Lagos State.

Fig 1. Ajegunle- Ikorodu flood Scene in 2023.

II. THE STUDY AREA

Ajegunle-Ikorodu is located in the southwestern part of Lagos State, Nigeria, between latitudes $6^0 40$'N and $6^0 63$'N and longitudes $3^0 91$' E and $3^0 40$'E, sets the stage for its geographic and environmental features (Figure 2). The area's geology, comprised of sedimentary rocks of the Cretaceous to Tertiary age, influences its hydrogeology and hydrology. The shallow water table, ranging from 1-5 meters below the surface, and the unconfined aquifers consisting of sand and gravel deposits, make groundwater a vital resource. However, the area's proximity to the coast also means that tidal fluctuations impact the water levels, creating a unique hydrological dynamic. The soil in Ajegunle-Ikorodu is predominantly sandy and sandy-clayey, with poor drainage and high susceptibility to erosion. This, combined with the area's flat and low-lying topography, with an average elevation of 10-20 meters above sea level, makes it prone to flooding and erosion. The coastal plain, characterized by a flat to gently sloping terrain, is also vulnerable to flooding and erosion due to its low elevation and proximity to the coast. The geomorphology of Ajegunle-Ikorodu is shaped by the interaction between fluvial and marine forces, resulting in a combination of river channels, floodplains, and coastal ridges. This unique geomorphology influences the area's hydrology, soil distribution, and vegetation patterns.

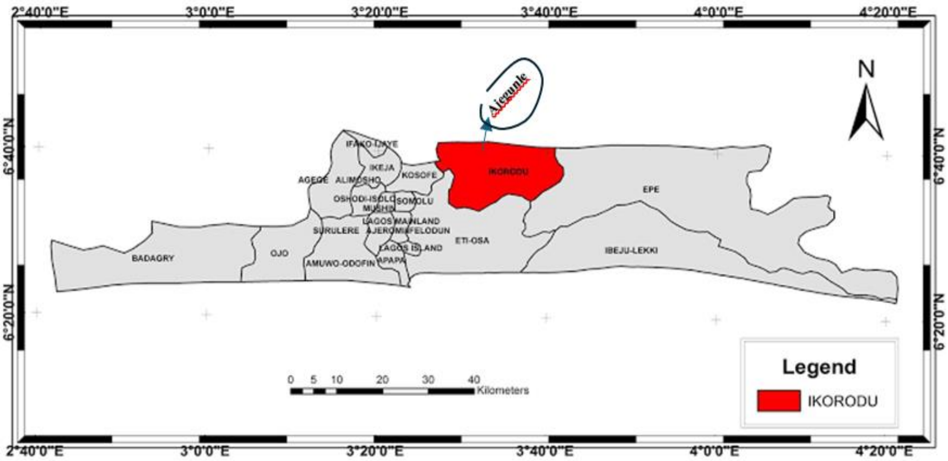

Fig 2. The study area in Lagos State in circle.

III. MATERIAL AND METHODOLOGY

The study utilized equipment like ABEM SAS1000 Terrameter, cables, Electrodes, Metre tape, GPS device, Hammers, Base maps, 12V Car Battery, Laptop, Water bottles, Filter paper, Nitric acid, Water samples, Beakers, Thermometer, Refrigerator, and Atomic Absorption Spectrophotometer (AAS).

3.1 Electrical resistivity survey

Four (4) Vertical Electrical Soundings (VES) were conducted in specifically chosen regions of the study. The depth to the groundwater and subsurface lithology of the area was assessed using a Schlumberger electrode setup. The electrical resistivity field data was analyzed with the help of IPi2win Software.

3.2 Groundwater Chemistry Analysis

The study area's water samples were gathered from the Ajegunle region within Ikorodu. These water samples underwent analysis to identify the existence and level of certain toxic chemical elements if ingested in water. There were ten (10) water samples gathered throughout the entire study area. The water samples were tested for heavy metals like Arsenic, Cadmium, Iron, and Lead. These metals can become contaminants in water when present in high levels. The amounts of these metals were measured using Atomic Absorption Spectrophotometer (AAS). The levels of these metals were measured against the global standard (World Health Organization Guidelines) for drinking water to determine their contamination level. This study evaluated the groundwater quality using [12] standard acceptable values. Additionally, the physio-chemical and hydro-geochemistry characteristics of water samples from the study area were examined.

IV. RESULTS AND DISCUSSION

4.1 Vertical Electrical Sounding (VES) Results

The vertical electrical sounding data results were used alongside existing borehole logs to accurately define the subsurface lithology in the study area. The study area showed the presence of between three to four geoelectric layers. Table 1 shows that VES 1 has resistivity values ranging from 272 to 889 Ωm and a thickness varying from 0.50m to infinity. The resistivity values for VES 2 range from 48.7 to 962 Ωm, with a thickness of 2.95 to 7.17m. The resistivity values for VES 3 range from 52.1 to 306 Ωm with a thickness of 1.36 to 4.18m, while VES 4 has resistivity values ranging from 36.8 to 907 Ωm and a thickness value from 0.56m to infinity.

The aquifers in the study area consist of two layers: the top layer is composed of topsoil, consisting of sand, clay, and humus, while the underlying layer is made of clay formation. The study area aquifers consist of sand formations in the third layer and sandy-clay formations in the fourth layer. The majority of shallow boreholes and hand dug wells were drilled down to the third layer, which corresponds to the first aquifer. In various sections of the study area, the first aquifer is partially confined. The first aquifer's close location to the surface in the study area made it vulnerable to contamination by flood water because water percolates slowly into the subsurface.

The findings from the geophysical survey (Table 1) show that the first aquifer in the research site is highly susceptible to contamination from pollutants seeping into the ground. These pollutants seeped into the groundwater via cracks, fissures, and extremely permeable and porous soil formations. The study area contains aquifers that are partially confined and fully confined. The initial aquifer, which is partially confined, is extremely vulnerable to pollution from agricultural, industrial, medical, and household sources, as well as from effluents and chemical substances.

Table 1. Vertical Electrical Sounding Results

VES	Layers	Resistivity (Ωm)	Thickness (m)	Depth (m)	Curve Type	Aquifer layer	Lithology
V1	1	272	0.50	0.50	HQ Type	4	Topsoil
	2	66.9	8.56	9.07			Clay
	3	**280**	**9.29**	**18.4**			Sand
	4	889					Sandy-Clay
V2	1	93.7	2.95	2.95	HQ Type	3	Topsoil
	2	48.7	6.92	9.87			Clay
	3	**962**	**7.17**	**11.23**			Sand
							Sandy-Clay
V3	1	96.3	1.36	1.36	HQ Type	3	Topsoil
	2	52.1	3.02	4.38			Clay
	3	**306**	**4.18**	**8.57**			Sand
							Sandy-Clay
V4	1	133	0.56	0.56	HQ Type	4	Topsoil
	2	36.8	2.81	3.37			Clay
	3	**31.5**	**4.08**	**7.45**			Sand
	4	907					Sandy-Clay

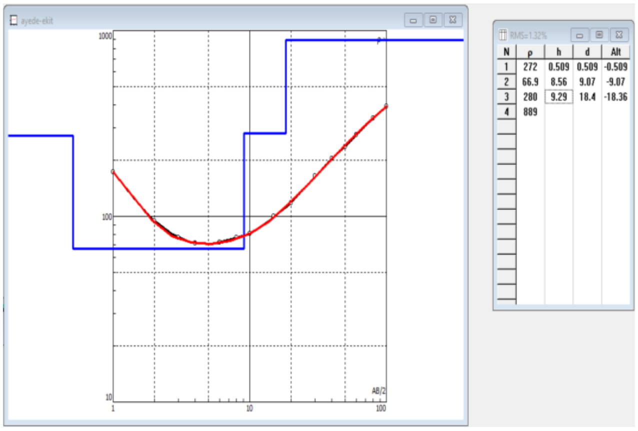

Fig 3. HQ-Type Curve common in VES Point 1

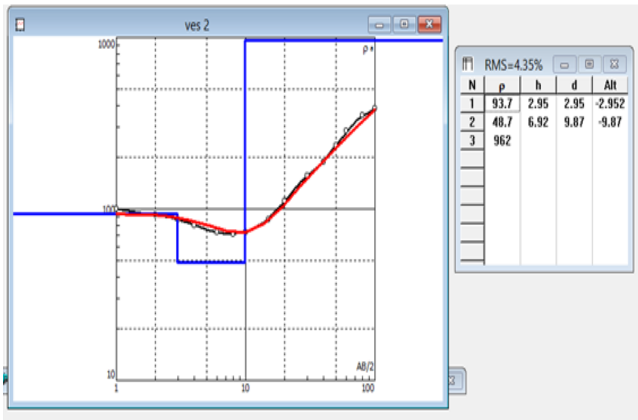

Fig 4. HQ-Type Curve common in VES Point 2

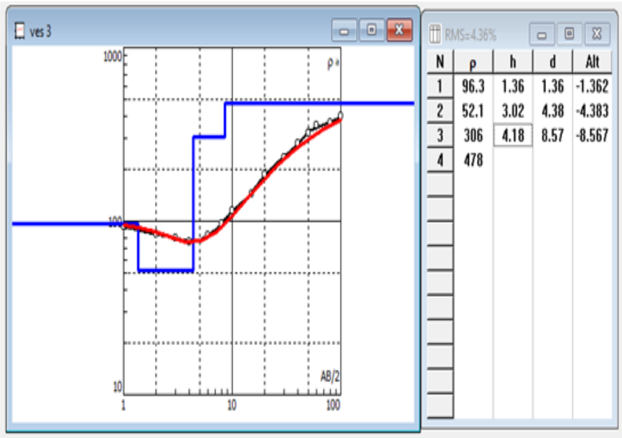

Fig 5. HQ-Type Curve common in VES Point 3

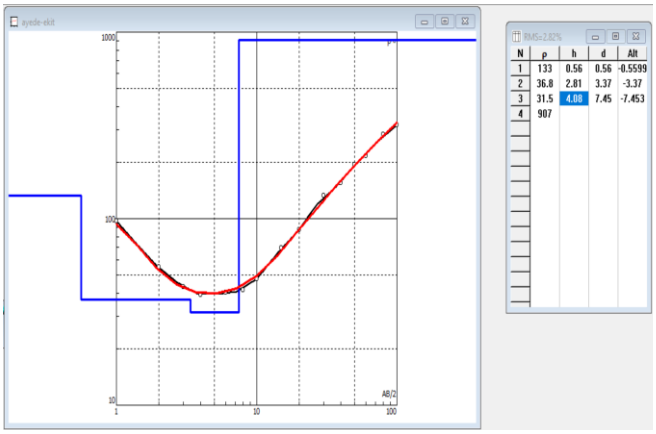

Fig 6. HQ-Type Curve common in VES Point 4

4.2 Groundwater Chemistry Analysis

(a). Heavy metals contamination in Ajegunle Groundwater

The findings from the water samples analysis revealed the presence of Lead, Iron, Cadmium, and Arsenic in the groundwater in the wet season. All water samples contained cadmium levels higher than the allowable limit [12] of 0.003 mg/L as indicated in Table 2. Hence, drinking water from the region may present a significant health hazard, as this data shows that the groundwater is severely impacted by cadmium in the rainy season.

During wet seasons, the cadmium levels in the water varied between 0.016 and 0.131 mg/L, with an average concentration of 0.074 mg/L (Table 3). Cadmium metal is utilized in the process of electroplating [11]. Ingesting high levels of cadmium can result in stomach issues, throwing up, and diarrhea. Extended exposure can potentially result in damage to the kidneys and lungs [11].

The levels of arsenic in the water samples varied from 0.022 to 0.211 mg/L in the wet seasons. The mean level of arsenic in the water during the wet season is 0.071mg/L as shown in Table 3. All the sampled water had arsenic levels above the allowed limit [12] of 0.01 mg/L, indicating pollution by arsenic during flood periods. Arsenic could have entered the groundwater from both human activities like burning fossil fuels and natural processes like the breakdown of arsenic-containing rocks. Arsenic is harmful to human health and can be carried by flood water from its original location to areas where it can seep into the ground to pollute the groundwater. Arsenic has been identified as a carcinogen that can lead to skin, lung, liver, and bladder cancer [11].

Lead concentrations in groundwater samples during wet seasons surpassed the allowable limit of 0.01 mg/L. Levels of lead in water varied from 0.27 to 2.64 mg/L in rainy seasons (Table 3). During the wet season, the water was significantly impacted by Lead, with an average concentration of 1.56 mg/L. Ingesting high levels of lead through water can result in serious health issues like problems with the heart, liver, kidneys, and nervous systems [13].

Iron is one of the most common elements found naturally on Earth. It can be found as different ores like hematite, limonite, siderite, pyrite, and magnetite. It is present in the soil at a low level and in groundwater in a dissolved state. During both wet and dry seasons in the study area, the iron concentration in the groundwater exceeded the acceptable limit [12] of 0.3 mg/L, ranging from 0.33 to 1.02 mg/L in the wet season with an average of 0.75 mg/L (Table 3). Iron heavily influences the groundwater in the research area.

The findings of the research indicated that the floodwater, which replenishes the groundwater, pollutes it with different types and levels of contaminants as it seeps into the ground.

Table 3. Results of the analyzed water samples (Rainy season heavy metal concentration)

Samples I.D	Pb	Fe	Cd	As
AJG1	1.49	0.89	0.112	0.022
AJG2	1.70	0.61	0.061	0.029
AJG3	0.69	0.44	0.031	0.081
AJG4	0.86	0.52	0.023	0.032
AJG5	1.12	0.54	0.074	0.078
AJG6	0.39	1.02	0.016	0.035
AJG7	0.27	0.62	0.042	0.051
AJG8	2.64	0.49	0.022	0.171
AJG9	2.11	0.73	0.131	0.052
AJG10	1.51	0.33	0.102	0.211
Min	0.27	0.33	0.016	0.022
Max	2.64	1.02	0.131	0.211
Mean	1.56	0.75	0.074	0.071
WHO	0.01	0.30	0.003	0.01

(b). Physiochemical Analysis

The pH of groundwater falls between 6.3 and 7.2, suggesting an alkaline nature. It was observed to be within the recommended range for drinking water set by [12].

Electrical conductance, also known as conductivity, refers to a substance's capacity for conducting an electric current. The EC spans from 935 to 1706 µS/cm. Most of the groundwater samples have an electrical conductivity (EC) that is higher than the allowed limit of 1500 µS/cm.

Total dissolved solids (TDS) indicate the overall quantity of minerals dissolved in water. Groundwater samples during flooding had Total Dissolved Solids ranging from 540 to 1003 mg/L. Most samples in the study area exceeded permissible limits because of ongoing weathering and dissolution processes.

Table 4. Results of Physiochemical and Hydrogeochemical of the analysed water samples

Sample I. D	pH	TDS	EC	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^-	SO_4^{2-}	Cl^-
AJG1	7.2	975	935	71.6	13	120	1.6	230	19	119
AJG2	6.4	770	1532	68	16.1	107	12	215	12.28	135
AJG3	6.7	875	1601	73	22	120	13	152.3	25	181.1
AJG4	6.5	780	1706	74.7	21	130	8.01	171	17.8	185
AJG5	6.3	540	1685	77	20.02	105	3.83	186.4	34	145
AJG6	6.8	755	1241	74.4	9.72	170	3.57	134	28	155
AJG7	7.8	930	1547	70.6	9.72	130	3.53	108	32	183
AJG8	7.1	1003	1533	72.4	9.16	190	3.01	153	36	210
AJG9	6.9	994	1602	73	8.57	240	3.86	230	34	157
AJG10	6.8	880	1232	72.7	15.44	120	6.64	150	32	151

(c). Hydro-geochemical classification

Presenting chemical analysis data graphically simplifies understanding by visually highlighting similarities and differences for easy comparison. Graphs can also help identify the mixing of water with diverse compositions, by plotting the analysis of major cations (Ca^{2+}, Mg^{2+}, Na^+ and K^+) and major anions (Cl^-, SO_4^{2-}, and HCO_3^-) to determine the chemical processes and type of water in the studied area. Piper and Gibbs diagrams are utilized to assess the suitability of water for drinking and irrigation purposes.

Piper diagram

The concentration of major ions dissolved in water samples determines the nature and type of water, which can be assessed by plotting data on the trilinear piper diagram [14]. (Figure 7) demonstrates that 95% of the samples fall within the Ca^++Mg^+ dominant region, with the remaining 5% in the non-dominant cation field. 95% of the anion ternary is categorized within the primary Ca^{2+}-HCO_3^- range, with the remaining 5% falling into the secondary anion field of the anion ternary. This shows that the water samples come from inland sources while there is flooding.

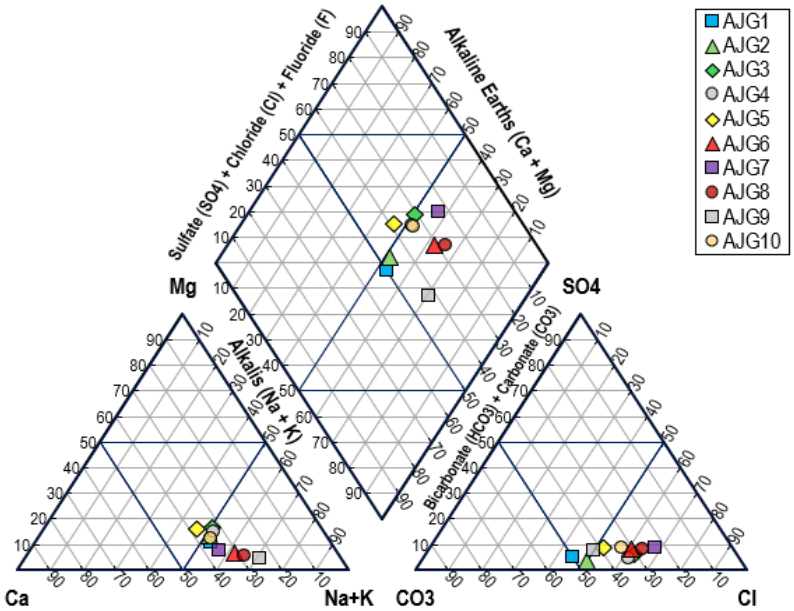

Fig 7. Piper diagram Groundwater of the study area

Gibbs plot

Understanding the connection between the chemical compounds of water and the lithology of their respective aquifers is important [15]. The plot shows the relationship between ($Na^{+}+K^{+}$)/ ($Na^{+}+K^{+}+Ca^{2+}$) and TDS, as well as $Cl^{-}/(Cl^{-}+HCO_3^{-})$ and TDS. An assessment of the water quality was conducted to determine if it is appropriate for drinking and irrigation. Based on the Gibbs diagram, the most dominant interaction in the study area is Seawater (Figure 8). Some of the samples exceed the plot preview and suggest human-caused activities. The influence of human activities on water chemistry is not clearly defined in this evaluation method or it is believed that the original Gibbs envelope suggests the effects of human activities on water chemistry are minor.

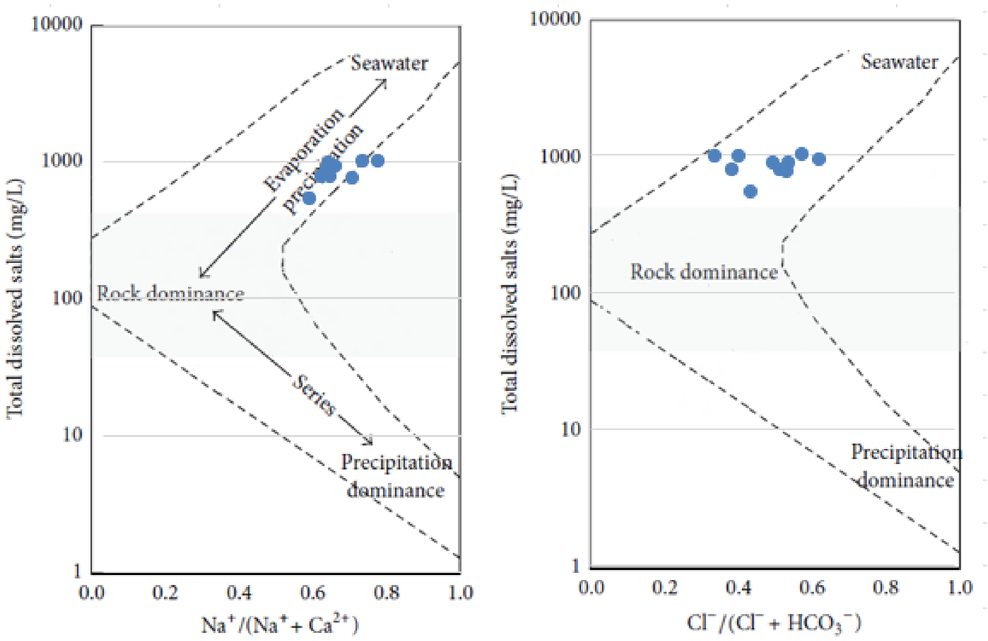

Fig 8. Gibb's plot showing the water chemistry dominance in the study area.

V. CONCLUSION

This research examined how flooding affected groundwater in Ajegunle-Ikorodu, Lagos through geophysical and groundwater chemistry methods. Results from the electrical resistivity survey demonstrated that the study site consists primarily of three to four geological strata, including topsoil, clay, sand, and sandy-clay formations. The aquifers in the study area are located in the third and fifth layers. The initial aquifer is partially restricted, while the subsequent aquifer is fully restricted. The initial aquifer is extremely vulnerable to pollution from the flood. The analysis of the groundwater chemistry revealed contamination from arsenic, cadmium, lead, and iron in the water. Therefore, the water is unsuitable for drinking unless treated. The research findings reveal that floodwater pollutes the groundwater in Ajegunle-Ikorodu via recharge processes. The order of dominance of cations observed during the study period is $Na^{+}>Ca^{2+}>Mg^{2+}>K^{+}$, while for anions it is $Cl^{-}>HCO_3^{-}>SO_4^{2-}$. The analysis revealed elevated levels of TDS, EC, Na, and Cl, suggesting deterioration, while the pH, Ca, and Mg values remain within acceptable limits according to regulations. The findings of Piper's diagram indicate that the water is a mixture of Ca-Na-HCO_3^{-} and Ca-Mg-Cl. The water samples' gibbs diagram indicates that evaporation is the primary process influencing water chemistry in Ajegunle-Ikorodu. According to the results of this study, it is crucial to highlight the need for boreholes in the research area to reach the second aquifer, which is approximately 80 meters deep. Usage of shallow boreholes and hand dug wells in the region should be discouraged due to prolonged consumption leading to serious health issues. Additionally, the Ajegunle-Ikorodu river channel needs to be altered to prevent water overflow causing flooding in the region. It is important to build high bank protectors to guide the river water efficiently along its path. A well-designed drainage system is needed in Ajegunle-Ikorodu to prevent the area from experiencing regular flooding.

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