# INTEGRATED ASSESSMENT OF GROUNDWATER QUALITY AND ENVIRONMENTAL SUSTAINABILITY: A MULTI-CRITERIA DECISION ANALYSIS APPROACH IN ILEJA AREA (ARAROM SEASIDE), SOUTHWESTERN, NIGERIA

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## ABSTRACT

*Groundwater serves as an important resource in the coastal regions to meet domestic, irrigational, and industrial needs of the inhabitants of Ilaje area, southwest Nigeria. There is an urgent need to evaluate the physicochemical properties of the resource source from the coastal plain sands' aquifer in Araromi seaside and its environs. For this evaluation, twenty-nine samples were collected from hand dug wells in Ilaje area, Southwestern Nigeria and subjected to the determination of physicochemical parameters (temperature, pH, EC, TDS) and major ions ($Na^+$, $K^+$, $Ca^{2+}$, $Mg^{2+}$, $Cl^-$, $SO4^{2-}$, $NO^{3-}$, $HCO^{3-}$) in accordance with recommended standards and procedures. The results of the dissolved ions in all the twenty-nine water samples were found to be below the permissible limit except for potassium which occurs at a value beyond the permissible 12 mg/l recommended by WHO. This indicates good water quality. The cationic concentration of the samples is in this order; $Na^+ > K^+ > Mg^{2+} > Ca^{2+}$ and the anionic concentration; order $HCO^{3-} > Cl^- > SO4^{2-} > NO^{3-}$. This supports the suitability for irrigation usage of the water as shown by results obtained from magnesium adsorption ratio and sodium adsorption ratio. The groundwater in Araromi seaside and its environs is mostly alkaline, soft because it has calcium concentration that is less than 60mg/l. Based on the present study, the water in Araromi seaside and its environs is under no threat to its inhabitants.*

***Keyword**: Groundwater, Coastal region, Physiochemical parameters, Ileja, Araromi Seaside.*

## 1. INTRODUCTION

Water is a valuable and widely used resource [26]. Water could be groundwater or surface water. Access to water sources in Nigeria reveals that 48% (approximately 67 million Nigerians) rely on surface water for domestic use, 57% (79 million) use hand-dug wells, 20% (27.8 million) rainwater, 14% (19.5 million) have access to piped water, and 14% have access to borehole water sources. Groundwater is an important untapped natural resource [16]. Groundwater, as an essential water resource, offers a consistent supply that is not prone to drying out throughout the dry season, unlike surface water [34],[35].

Apart from its continual availability, it has good quality and requires little to no treatment in most circumstances [4]. Groundwater plays an important role since over two billion people rely directly on aquifers for drinking water, and irrigated agriculture, which relies heavily on groundwater, produces 40% of the world's food [21]. It accounts for around 50% of livestock and irrigation consumption and slightly less than 40% of water supply, but in rural areas, groundwater accounts for 98% of domestic water use [33]. It also has industrial applications or uses [3].

Drinking groundwater polluted with heavy metal ions is harmful to the body [22]. This gives credence to the report's assertion that without clean water, people's health and livelihoods suffer significantly [22]. Many people across the world, particularly those living in rural regions among the poorest and most vulnerable, lack access to safe, clean drinking water. Water pollution causes around 80% of all infections and deaths in impoverished countries [5],[3].

According to [7], the natural history of geological settings, hydraulic gradient, rate of groundwater extraction, and its recharging all have an impact on the amount of seawater intrusion. The baseline data required to assess the sustainability of water resources for human use is provided by groundwater chemistry monitoring [35],[34]. [1] also stated that determining a water body's productivity and other features requires an understanding of its physicochemical regime. This provides the basis for the study of the Ilaje area (araromi seaside) groundwater.

The aim of this paper is to examine the physicochemical properties of groundwater in the study region to ascertain the concentration of main ions and their relative order, as well as the groundwater's appropriateness for irrigation activities and human use.

### 1.2. Location of the study area

The study area, Araromi seaside (Ileja area) and its surrounding communities, is located in Ilaje Local Government Area, Ondo state, Southwestern Nigeria. The area lies between latitude $6^{0}16'$N and $6^{0}22'$N and longitude 4°26'E and 4°34'E (Fig.1 and Fig. 2). The important settlements are Araromi and Oke Siri. Accessibility to the study area and its environs is through the presence of major roads and the use of boat.

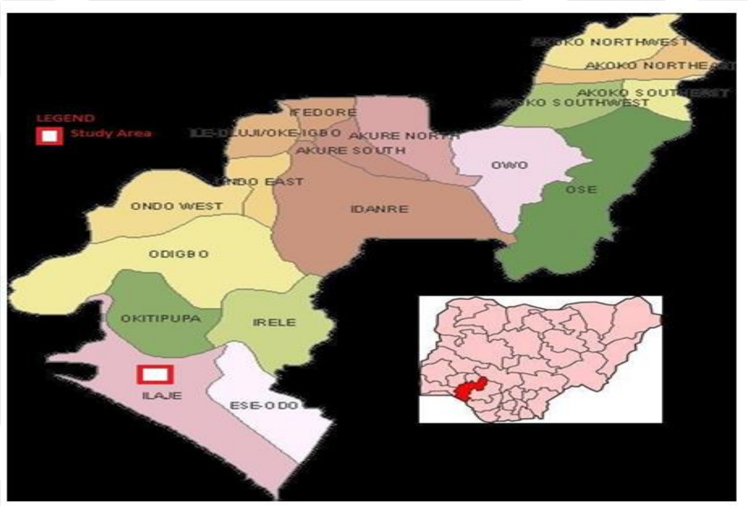


**Fig -1:** Map of Nigeria showing the study area.

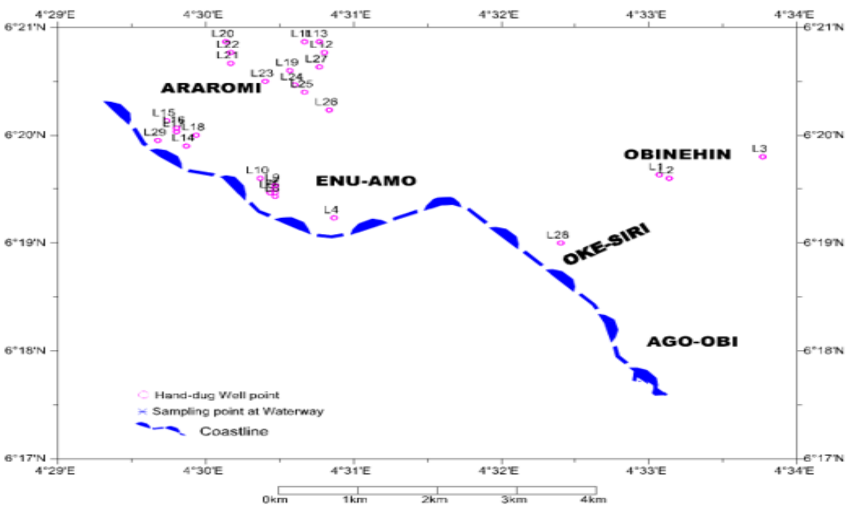


**Fig -2**: Map of the study area showing the sample points.

### 1.3. Geologic setting of the study area

Ilaje is a sedimentary topography that is within the eastern part of the Dahomey Basin. There were three identified chronostratigraphic units. They are the Tertiary sequence, the Createaceous sequence, and the pre-lower Cretaceous folded sequence [24],[6]. The Abeokuta Group makes up the Cretaceous strata as assembled from outcrop and borehole data. The Abeokuta Group, which consists of the Ise, Afowo, and Araromi Formations, makes up the geologic sequence [24]. The basement complex is covered in an unconformable layer of coarse conglomerate sediments known as the Ise Formation. The transitional to marine sands and sandstone with thick, varying interbedded siltstone and shales makes up the Afowo Formation.

The Ewekoro Formation, Ilaro Formation, Oshosun Formation, Coastal Plain Sands (Benin Formation), and Quarternary Coastal Alluvium are the sediments that make up the Tertiary Period. Whereas the Akinbo and Oshosun Formations are composed of flaggy geysers and black shales, the Ewekoro Formation is composed of fossiliferous well-bedded limestone. The Ewekoro and Akinbo Formations' boundaries are defined by phosphatic beds and glaciconitic rock bands. Most of the coarse sandy estuary, deltaic, and continental strata make up the Ilaro Formation. While the Quarternary Coastal Alluvium is made up of an alternating sequence of sand and silt/clay, the Coastal Plain Sands are formed of clay/sandy clay and clayey sand/sand [13].

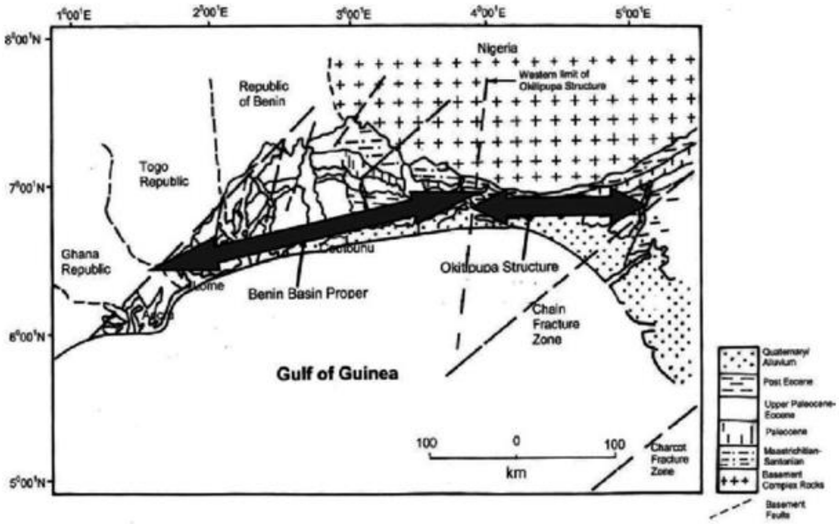


Fig -3: Simplified regional map of Dahomey basin [13].

### 1.4. Hydrogeology of the Study Area

Ilaje is a sedimentary topography in Ondo state, Nigeria's southwestern region, that is part of the Dahomey basin. The Dahomey basin has many aquifers [22],[23]. The basin's principal aquifers are the recent alluvium deposits, Coastal Plain Sands Ilaro, and Ewekoro Formations [18]. Sand, sandstone, clayey sand, and dissolved/fractured limestone make up the aquifer units, which are both unconfined and confined. The Coastal Plain Sands are the most heavily mined for groundwater in Ilaje. Hand-dug wells are used to get water from this deposit for home purposes [7].

## 2. MATERIALS AND METHODOLOGY

Water samples were collected from publicly accessible, hand-dug wells in Araromi and surrounding areas. Twenty-nine hand dug wells were selected, and water samples were collected from each. Each sample was collected in a new, factory-fresh 1L plastic bottle with the top tightly secured. Plastic sample bottles were rinsed with this well water or stream to ensure homogeneity. This is done before sampling to avoid the water's chemistry from becoming polluted or altered. Water samples from the wells were collected using a plastic fetcher, whilst water samples from the river were retrieved straight from the waterway using plastic sample bottles. The water sample in one of the kegs was chemically stabilized with a drop of strong nitric acid, while the other was stored in an ice chest to maintain the water's chemistry prior to analysis. Samples were handled and preserved in line with established procedure.

The samples were delivered to the laboratory and stored in the refrigerator. Laboratory analyses began the same day and within two hours after arriving at the laboratory. The investigations were carried out at the Geochemistry Laboratory of the Federal University of Technology in Akure.

## 3. RESULTS AND DISCUSSION

### 3.1. Physicochemical Parameters

Table 1 shows that the electrical conductivity (EC) ranges from 34 to 1084 µs/cm, with an average of 346.03 µs/cm. The TDS varies from 17 to 542 mg/l, with the average being 174.10 mg/l. The pH values of the groundwater samples collected in the study area range from 7.58 to 8.76. The mean value obtained was 8.02, indicating that around 16 of the wells investigated had pH levels lower than this mean value.
The study's sampled wells had electrical conductivity values that met [36] guideline of 1500µs/cm for drinking water. High EC in groundwater may indicate nutrient enrichment [1], [29].
The quantity of dissolved solids in the water determines its Total Dissolved Solids (TDS) value. Only the well at site 10 has TDS of 542 mg/l, which exceeds the WHO (2011) recommended 500 mg/l. High TDS levels may be caused by human sources such as home sewage, septic tanks, and agricultural operations [9]. TDS in groundwater is normally not dangerous to humans, although excessive concentrations may damage those suffering from renal and heart illness [9]. Water with TDS less than 500mg/l may be deemed "fresh water" [10]. This water is suitable for drinking and irrigation since it does not impact the osmotic pressure of the soil solution.
The pH of a water body is critical because it influences the creatures that live in the aquatic ecosystem [5], [32]. These values indicate that the water comes from an alkaline environment. The wells' pH is within the 6.5-8.5 range suggested by [36] for Drinking water. Alkalinity in water produces unpleasant taste, encrustation in water pipes and water-using appliances, and reduces chlorine's efficacy as a disinfectant.

**Table-1:** Physicochemical parameters measurement.

| Location | Town | T (⁰C) | pH | EC(ΩS/cm) | TDS(mg/l) |
|---|---|---|---|---|---|
| L1 | Obinehin | 31.48 | 7.58 | 203 | 145 |
| L2 | Obinehin | 28.65 | 7.64 | 436 | 228 |
| L3 | Obinehin | 28.67 | 8.01 | 337 | 169 |
| L4 | Enu-Amo | 27.85 | 8.42 | 871 | 437 |
| L5 | Enu-Amo | 30.76 | 8.76 | 453 | 227 |
| L6 | Enu-Amo | 25.59 | 8.15 | 922 | 461 |
| L7 | Enu-Amo | 28.07 | 8.42 | 602 | 293 |
| L8 | Enu-Amo | 27.49 | 8.54 | 386 | 193 |
| L9 | Enu-Amo | 27.6 | 7.87 | 798 | 399 |
| L10 | Enu-Amo | 27.7 | 7.83 | 1084 | 542 |
| L11 | Araromi | 27.13 | 8.15 | 276 | 138 |
| L12 | Araromi | 27.48 | 8.12 | 254 | 127 |
| L13 | Araromi | 27.64 | 8.54 | 34 | 17 |
| L14 | Araromi | 25.87 | 8.27 | 234 | 117 |
| L15 | Araromi | 26.71 | 8.16 | 175 | 88 |
| L16 | Araromi | 27.36 | 8.51 | 71 | 35 |
| L17 | Araromi | 28.9 | 7.6 | 127 | 64 |
| L18 | Araromi | 26.5 | 7.66 | 314 | 157 |
| L19 | Araromi | 29.22 | 7.85 | 118 | 59 |
| L20 | Araromi | 25.88 | 8.16 | 183 | 91 |
| L21 | Araromi | 27.27 | 7.64 | 283 | 142 |
| L22 | Araromi | 28.52 | 7.59 | 327 | 164 |
| L23 | Araromi | 28.27 | 7.88 | 432 | 216 |
| L24 | Araromi | 28.07 | 8.29 | 96 | 49 |
| L25 | Araromi | 26.61 | 7.98 | 79 | 27 |
| L26 | Araromi | 26.62 | 7.91 | 87 | 44 |
| L27 | Araromi | 26.64 | 7.56 | 271 | 129 |
| L28 | Oke-Siri | 29.92 | 7.61 | 325 | 163 |
| L29 | Araromi | 23.54 | 7.98 | 257 | 128 |

### 3.2. Major anions

The major anions studied are bicarbonate, sulfate, nitrate, and chloride data are presented in Table 2. The levels of these ions vary from 32 to 832 mg/l, 0.48 to 41 mg/l, 0.09 to 0.90 mg/l, and 5.10 to 745.30 mg/l, respectively. The average values are 377.69 mg/l, 12.95 mg/l, 0.27 mg/l, and 220.22 mg/l, respectively. Approximately 24% of the wells had bicarbonate levels that exceed WHO's recommended acceptable limits [36]. The main source of this ion is carbonate dissolution [26]. [30].
The [36] chloride limit is 250 mg/l, and the mean value of the sampled wells falls below this threshold for drinking water. Eight of the sampled wells contain chloride values that exceed the WHO's threshold. [19] believed chloride levels above 50 mg/l to be indicative of saltwater intrusion, although [33] indicated that chloride levels above 40 mg/l in coastal aquifers indicate saltwater intrusion. According to [27], higher chloride concentrations in soil can also be caused by contamination from domestic sewage waste, sand leaching, and saline residues. The sulphate levels in the sampled wells are less than WHO's allowed guideline of 250 mg/l for sulphate in drinking water. Sulphate occurs naturally in water as a byproduct of the leaching of gypsum and other minerals. It can also be caused intentionally by the inappropriate disposal of industrial wastes and home sewage [20]. Higher sulphate concentrations might induce gastrointestinal discomfort, especially when magnesium and salt ar e present in drinking water sources [39]. The nitrate levels are below the WHO's allowed guideline of 50 mg/l for drinking water. Nitrate occurs in groundwater at extremely low concentrations, indicating that considerable concentrations come from anthropogenic sources. Possible sources of nitrate in groundwater include fertilizer application, septic tank use, animal farming, atmospheric deposition, industrial and wastewater discharges [17]. Nitrate in groundwater is a serious problem because it causes methemoglobinemia in babies. High nitrate levels in drinking water are the cause of blue baby sickness in babies [2]. The study found that the area's groundwater contains dissolved anionic species in the following order: $HCO^{3-}$>$Cl^{-}$>$SO_4^{2-}$>$NO^{3-}$. The higher the concentration of bicarbonate in water, the greater the dominance of mineral dissolution [39].

### 3.3. Major cations

Table 2 show the data of Calcium, magnesium, potassium, and sodium that are examined. The concentrations of these ions vary from 1.632 to 19.584 mg/l, 0 to 44.64 mg/l, 7.9531 to 39.1914 mg/l, and 1.26 to 149.82 mg/l, respectively. Their averages are 8.356 mg/l, 9.22 mg/l, 22.75 mg/l, and 52.60. The WHO's acceptable levels for calcium, magnesium, sodium, and potassium in drinking water are 75 mg/l, 150 mg/l, 200 mg/l, and 12 mg/l, respectively. Except for potassium, which surpasses the WHO limit of 12mg/l, none of the wells studied have cations readings that are higher than that.
According to [36], soft water is defined as water with a calcium content of less than 60mg/l. All of the well’s sample in the study region had calcium concentrations that were lower than this threshold. This signifies that all of the water falls into the soft water category. [33] hypothesized that a high magnesium content in home water might cause diarrhea. The coastal region's sedimentary rocks contain limestone, dolomite, gypsum, anhydrates, and clay minerals, which increase the calcium and magnesium concentration of groundwater.
Excess Sodium content in any water sample can be connected to salty water incursions, discharge of household and industrial effluents on to the ground or water bodies [8]. According to [15] the high content of potassium in groundwater is caused by salty water intrusion and anthropogenic causes.
The dissolved cationic species in the groundwater of the research region is in the following order: $Na^{+}$> $K^{+}$> $Mg^{2+}$> $Ca^{2+}$. The replacement of calcium and magnesium ions by sodium ion in the groundwater may be the explanation for reduced amounts of calcium and magnesium [12].

**Table -2:** Values of cations and anions in ppm (mg/l)

| Location | Town | HCO3 (ppm) | Cl (ppm) | NO3 (ppm) | SO4 (ppm) | Ca (ppm) | Mg (ppm) | K ppm | Na ppm |
|---|---|---|---|---|---|---|---|---|---|
| L1 | Obinehin | 373.00 | 148.04 | 0.35 | 11.33 | 6.53 | 2.88 | 22.77 | 149.82 |
| L2 | Obinehin | 424.00 | 224.61 | 0.44 | 2.46 | 11.42 | 7.68 | 18.93 | 113.13 |
| L3 | Obinehin | 460.00 | 658.52 | 0.05 | 17.56 | 7.34 | 12.00 | 7.95 | 89.76 |
| L4 | Enu-Amo | 412.00 | 561.53 | 0.40 | 15.10 | 13.87 | 0.48 | 35.63 | 87.70 |
| L5 | Enu-Amo | 600.00 | 393.07 | 0.90 | 7.11 | 15.50 | 20.64 | 22.87 | 87.39 |
| L6 | Enu-Amo | 520.00 | 326.71 | 0.17 | 6.15 | 8.16 | 11.04 | 24.69 | 24.45 |
| L7 | Enu-Amo | 548.00 | 525.79 | 0.23 | 10.18 | 17.14 | 27.36 | 27.18 | 87.93 |
| L8 | Enu-Amo | 628.00 | 336.92 | 0.50 | 41.00 | 17.95 | 6.24 | 38.02 | 87.72 |
| L9 | Enu-Amo | 808.00 | 326.71 | 0.67 | 0.48 | 3.26 | 19.68 | 22.66 | 33.88 |
| L10 | Enu-Amo | 832.00 | 745.30 | 0.37 | 24.85 | 20.40 | 24.96 | 24.79 | 62.66 |
| L11 | Araromi | 32.00 | 117.41 | 0.11 | 17.82 | 8.98 | 9.12 | 21.31 | 31.22 |
| L12 | Araromi | 76.00 | 51.05 | 0.39 | 18.09 | 4.90 | 4.80 | 22.84 | 86.39 |
| L13 | Araromi | 424.00 | 45.94 | 0.17 | 2.90 | 5.71 | 3.36 | 15.07 | 23.82 |
| L14 | Araromi | 444.00 | 163.36 | 0.13 | 7.11 | 12.24 | 5.76 | 22.71 | 1.26 |
| L15 | Araromi | 224.00 | 122.52 | 0.14 | 18.44 | 4.90 | 3.84 | 21.17 | 36.12 |
| L16 | Araromi | 220.00 | 525.79 | 0.24 | 5.36 | 5.71 | 3.84 | 14.91 | 16.19 |
| L17 | Araromi | 200.00 | 102.10 | 0.14 | 16.51 | 4.08 | 5.28 | 23.38 | 20.59 |
| L18 | Araromi | 416.00 | 56.15 | 0.31 | 3.42 | 19.58 | 0.96 | 21.05 | 17.39 |
| L19 | Araromi | 248.00 | 51.05 | 0.26 | 13.61 | 3.26 | 8.16 | 21.07 | 37.99 |
| L20 | Araromi | 284.00 | 30.63 | 0.14 | 19.84 | 2.45 | 4.80 | 23.75 | 25.89 |
| L21 | Araromi | 568.00 | 433.91 | 0.40 | 27.83 | 4.08 | 12.96 | 22.70 | 47.25 |
| L22 | Araromi | 124.00 | 10.21 | 0.25 | 12.99 | 1.63 | 2.40 | 20.79 | 32.71 |
| L23 | Araromi | 172.00 | 51.31 | 0.09 | 6.76 | 7.34 | 0.96 | 20.69 | 20.95 |
| L24 | Araromi | 120.00 | 56.15 | 0.09 | 16.86 | 7.34 | 0.00 | 20.72 | 38.35 |
| L25 | Araromi | 280.00 | 20.42 | 0.35 | 5.71 | 6.53 | 6.24 | 23.12 | 22.57 |
| L26 | Araromi | 168.00 | 5.10 | 0.10 | 20.11 | 6.53 | 2.88 | 22.04 | 50.69 |
| L27 | Araromi | 376.00 | 25.52 | 0.12 | 5.00 | 5.71 | 8.64 | 16.63 | 142.80 |
| L28 | Oke-Siri | 748.00 | 245.03 | 0.14 | 11.06 | 4.90 | 44.64 | 39.19 | 25.02 |
| L29 | Araromi | 224.00 | 25.52 | 0.14 | 10.01 | 4.90 | 5.76 | 21.19 | 23.82 |

### 3.4 Magnesium adsorption ratio

The MAR values for the groundwater sample vary from 0 to 93.826%, with a mean value of 56.86% (Table 3). Four wells (17%) had MAR values lower than 50%. According to the MAR standard, this indicates that they are acceptable for irrigation applications. Wells with MAR more than 50% are unsuitable for irrigation.

Soil with high quantities of exchangeable $Mg^{2+}$ causes infiltration issues [11]. MAR levels more than 50 are deemed hazardous and inappropriate for irrigation [14].[11]. The presence of $Mg^{2+}$ salts in irrigation water mitigates the negative effects of sodium by improving soil permeability [14],[25].

**Table-3**: Values of magnesium adsorption ratio (MAR)

| Location | Ca(epm) | Mg(epm) | MAR |
|---|---|---|---|
| L1 | 0.33 | 0.24 | 42.37 |
| L2 | 0.57 | 0.64 | 52.84 |
| L3 | 0.37 | 1.00 | 73.14 |
| L4 | 0.69 | 0.04 | 5.45 |
| L5 | 0.78 | 1.72 | 68.93 |
| L6 | 0.41 | 0.92 | 69.28 |
| L7 | 0.86 | 2.28 | 72.69 |
| L8 | 0.90 | 0.52 | 36.68 |
| L9 | 0.16 | 1.64 | 90.95 |
| L10 | 1.02 | 2.08 | 67.10 |
| L11 | 0.45 | 0.76 | 62.87 |
| L12 | 0.24 | 0.40 | 62.03 |
| L13 | 0.29 | 0.28 | 49.51 |
| L14 | 0.61 | 0.48 | 43.96 |
| L15 | 0.24 | 0.32 | 56.66 |
| L16 | 0.29 | 0.32 | 52.84 |
| L17 | 0.20 | 0.44 | 68.32 |
| L18 | 0.98 | 0.08 | 7.55 |
| L19 | 0.16 | 0.68 | 80.65 |
| L20 | 0.12 | 0.40 | 76.57 |
| L21 | 0.20 | 1.08 | 84.11 |
| L22 | 0.08 | 0.20 | 71.02 |
| L23 | 0.37 | 0.08 | 17.89 |
| L24 | 0.37 | 0.00 | 0.00 |
| L25 | 0.33 | 0.52 | 61.44 |
| L26 | 0.33 | 0.24 | 42.37 |
| L27 | 0.29 | 0.72 | 71.60 |
| L28 | 0.24 | 3.72 | 93.83 |
| L29 | 0.24 | 0.48 | 66.23 |

**3. 5 Sodium adsorption ratio (SAR)**

Table 4 show that the sodium absorption ratio values in the groundwater sample ranged from 0.10 to 17.31. It has an average value of 4.71. These wells lie between good and exceptional for irrigation purposes.
There is a strong correlation between sodium adsorption ratio (SAR) values for irrigation water and the amount to which sodium is absorbed by soils. If irrigation water is rich in sodium and low in calcium, the cation exchange complex may become saturated with sodium, destroying soil structure through clay particle dispersion [28].

**Table-4**: Values of Sodium adsorption ratio (SAR)

| Location | Ca(epm) | Mg(epm) | Na(epm) | SAR |
|---|---|---|---|---|
| L1 | 0.33 | 0.24 | 6.51 | 17.31 |
| L2 | 0.57 | 0.64 | 4.92 | 8.94 |
| L3 | 0.37 | 1.00 | 3.90 | 6.68 |
| L4 | 0.66 | 0.04 | 3.81 | 8.90 |
| L5 | 0.78 | 1.72 | 3.80 | 4.81 |
| L6 | 0.41 | 0.92 | 1.06 | 1.84 |
| L7 | 0.86 | 2.28 | 3.82 | 4.32 |
| L8 | 0.90 | 0.52 | 3.81 | 6.41 |
| L9 | 0.16 | 1.64 | 1.47 | 2.19 |
| L10 | 1.02 | 2.08 | 2.72 | 3.09 |
| L11 | 0.45 | 0.76 | 1.36 | 2.47 |
| L12 | 0.24 | 0.40 | 3.76 | 9.36 |
| L13 | 0.29 | 0.28 | 1.04 | 2.75 |
| L14 | 0.61 | 0.48 | 0.05 | 0.10 |
| L15 | 0.24 | 0.32 | 1.57 | 4.18 |
| L16 | 0.29 | 0.32 | 0.70 | 1.81 |
| L17 | 0.20 | 0.44 | 0.90 | 2.23 |
| L18 | 0.98 | 0.08 | 0.76 | 1.47 |
| L19 | 0.16 | 0.68 | 1.65 | 3.60 |
| L20 | 0.12 | 0.40 | 1.13 | 3.11 |
| L21 | 0.20 | 1.08 | 2.05 | 3.63 |
| L22 | 0.08 | 0.20 | 1.42 | 5.36 |
| L23 | 0.37 | 0.08 | 0.91 | 2.72 |
| L24 | 0.37 | 0.00 | 1.67 | 5.50 |
| L25 | 0.33 | 0.52 | 0.98 | 2.13 |
| L26 | 0.33 | 0.24 | 2.20 | 5.86 |
| L27 | 0.29 | 0.72 | 6.21 | 12.38 |
| L28 | 0.24 | 3.72 | 1.09 | 1.09 |
| L29 | 0.24 | 0.48 | 1.04 | 2.43 |

### 3.6 Kelley's ratio (KR)

Table 5 show that the Kelley's ratio values for the wells range from 0.0502 to 11.50. The mean value is 2.644. Only five wells meet the less than one criterion for irrigation water quality.
Water with a KR value of less than 1 is deemed appropriate for irrigation. Five wells in the study's area had KP values less than one, making them acceptable for irrigation usage. A Kelley's ratio greater than 1 suggests an overabundance of salt in water. High sodium ion concentrations in water influence soil permeability and cause infiltration issues. This is because sodium, when present in the soil in exchangeable form, substitutes calcium and magnesium adsorbed on soil clays, causing soil particles to disperse.

**Table-5**: Values of Kelley's ratio (KR)

| Loc | Ca(epm) | Mg(epm) | Na(epm) | KR |
|---|---|---|---|---|
| L1 | 0.3264 | 0.24 | 6.513913 | 11.50055 |
| L2 | 0.5712 | 0.64 | 4.918696 | 4.06101 |
| L3 | 0.3672 | 1 | 3.902609 | 2.854453 |
| L4 | 0.6936 | 0.04 | 3.813043 | 5.197715 |
| L5 | 0.7752 | 1.72 | 3.799565 | 1.52275 |
| L6 | 0.408 | 0.92 | 1.063043 | 0.800485 |
| L7 | 0.8568 | 2.28 | 3.823043 | 1.218772 |
| L8 | 0.8976 | 0.52 | 3.813913 | 2.690401 |
| L9 | 0.1632 | 1.64 | 1.473043 | 0.816905 |
| L10 | 1.02 | 2.08 | 2.724348 | 0.878822 |
| L11 | 0.4488 | 0.76 | 1.357391 | 1.122925 |
| L12 | 0.2448 | 0.4 | 3.756087 | 5.825197 |
| L13 | 0.2856 | 0.28 | 1.035652 | 1.831068 |
| L14 | 0.612 | 0.48 | 0.054783 | 0.050167 |
| L15 | 0.2448 | 0.32 | 1.570435 | 2.780515 |
| L16 | 0.2856 | 0.32 | 0.703913 | 1.16234 |
| L17 | 0.204 | 0.44 | 0.895217 | 1.390089 |
| L18 | 0.9792 | 0.08 | 0.756087 | 0.713828 |
| L19 | 0.1632 | 0.68 | 1.651739 | 1.958894 |
| L20 | 0.1224 | 0.4 | 1.125652 | 2.154771 |
| L21 | 0.204 | 1.08 | 2.054348 | 1.599959 |
| L22 | 0.0816 | 0.2 | 1.422174 | 5.050333 |
| L23 | 0.3672 | 0.08 | 0.91087 | 2.036828 |
| L24 | 0.3672 | 0 | 1.667391 | 4.540826 |
| L25 | 0.3264 | 0.52 | 0.981304 | 1.159386 |
| L26 | 0.3264 | 0.24 | 2.203913 | 3.891089 |
| L27 | 0.2856 | 0.72 | 6.208696 | 6.174121 |
| L28 | 0.2448 | 3.72 | 1.087826 | 0.274371 |
| L29 | 0.2448 | 0.48 | 1.035652 | 1.42888 |

## 4. CONCLUSIONS

The present study assessed the physicochemical characteristics of open hand dug well quality in Ilaje, Ondo state, Nigeria. The WHO drinking water quality standards adopted show that TDS, EC, pH, all anions, and cations tested, except for potassium, have values that are within the permissible limits. The water observed in the study area indicates insignificant pollution as observed from sodium adsorption ratio (SAR) results and are good for irrigation. The magnesium adsorption ratio (MAR) results show that only five wells are suitable for irrigation. The results obtained from soluble sodium percentage and Kelley's ratio show that the water is not good for irrigation because most of them of the wells are beyond the recommended standards. All the water in Araromi and its environs are soft water because their calcium concentrations fall within 60mg/l which is the concentration at which any water can be called soft as recommended by WHO.

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