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# Multivariate Analysis of Physico-chemical Parameters of Groundwater from Selected Communities in Yewa North Local Government Area of Ogun State, Southwestern Nigeria

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**Abstract:** The study examines physico-chemical composition of groundwater drawn from hand-dug wells in 14 communities to determine its suitability for domestic and agricultural purposes. A total of 104 samples were drawn from 52 wells each in dry and wet seasons. The samples were analyzed using standard methods for the examination of water and waste waters. The parameters analyzed are pH, temperature, electrical conductivity (EC), total dissolved solids, total hardness, calcium hardness, magnesium hardness, $PO_4^{3-}$, $NO_3^-$, $HCO_3^-$, $Cl^-$ and $SO_4^{2-}$. Mean pH ranges from 5.23 -8.40 while EC and total dissolved solids are slightly above the WHO permissible limits of 1000 $\mu Scm^{-1}$ and 500 at Igbogila (1116, 1118 $\mu Scm^{-1}$ and 580, 557) and Eggua (1060, 1112 $\mu Scm^{-1}$ and 530, 564) in both dry and wet seasons respectively. Results of the PCA indicated strong positive correlation between electrical conductivity, total dissolved solids and total hardness at 0.92, 0.92 and 0.95 respectively. Positive correlation at $P \leq 0.05$ was also observed between electrical conductivity and total dissolved solids (r=1.00), total hardness (r=0.793), nitrate (r=0.246), chloride (r=0.833), bicarbonate (r=0.365). Most of the parameters analyzed fall within the WHO permissible limits for drinking water, therefore groundwater from hand-dug wells in the study area may be suitable for both domestic and agricultural purposes.

Key words: groundwater, hand-dug wells, bailers, physicho-chemical, multivariate, Yewa North.

## I. Introduction

Water is an essential natural resource which supports the functionality of the ecosystems as well as social and economic activities. Wherever this critical natural resource exists, there is life, and where it is found in limited quantity or compromised quality, existence has to struggle [1]. Adequate supply of water in good quality, is a key determinant for health and well-being of humans, socio-economic development and ecosystem functions [2,3]. Water is not only critical to sustain life and economic development; it is also important for community well-being, and protection of cultural values [4]. Water plays a pivotal and crucial role in every aspects of life on earth. It is critical in the development of national economies, national environments, food production and food security. People and communities can survive for substantial periods of time without many essential goods; however, human beings can only live a couple of days without safe drinking water [5]. For decades, population growth with attendant increasing demand for space has made people and communities to continue to move and settle where water resources are readily accessible. This has led to the development of new techniques for accessing water including groundwater development [6].

Though access to safe drinking water is essential for the existence and preservation of life on earth and socio-economic development, greater percentage of the world population still don't have access to this life saving resources. While it is estimated that 2.1 billion (29% of global population) lack access to safe drinking water [7], over 40% of the global population without access to improved drinking water resides in Sub-Saharan Africa [8]. In Nigeria, it is estimated that 30 percent of the population are without access to safe drinking water [9].

The effect of the global coverage of access to improved drinking water is still behind in the rural areas where it is reported that 653 million people are without access [10]. This shows that the inequality with access to improved water source among urban and rural inhabitants remains a global challenge, with the population lacking access in rural areas five times higher than those in urban areas. As a matter of course, the scope and reach of human settlement away from major riparian spheres of Sub-Saharan Africa and over many other arid zones of the world, has been decided by possibility of groundwater supplies, accessed through hand-dug wells or springs [11]. Up to date, groundwater is the most sought after means of supplying water to meet the expanding demand of the rural, scattered and peri-urban communities across Sub-Saharan Africa.

Because groundwater exists in the sand, gravel and rock deposits underneath the earth`s surface, it is comparatively unblemished except contaminated due to the infiltration of polluted surface water or contaminated in-situ because of percolation of pollutants from soil.

Nigeria is endowed with enormous volume of groundwater resources which plays a significant part in the social and economic activity of the people, particularly domestic, industrial and agricultural use. The total inexhaustible groundwater potential of Nigeria is approximated at 155.8 billion cubic meters per year [12]. Groundwater, sourced through hand-dug wells and boreholes are now the major sources of daily water supplies in cities, towns and villages in Nigeria due to incommensurate provision of pipe borne water by the relevant government agencies [13]. Therefore, over the years, groundwater has continued to be the only source of daily water supply in most neighborhood in Nigeria [14]. However, groundwater resources are daily undergoing threat due to broadening human activities for instance urbanization, agriculture, mineral exploration and industrialization.

Water of poor or compromised quality has several associated economic costs, including deterioration of ecosystem services; health interconnected costs; impact on economic enterprise such as agriculture, industrial production and tourism, heightened water treatment costs; and decreased property values [1]. The above statement has necessitated the need for extensive study of groundwater quality within a given aquifer system. Meanwhile, the quality of any aquifer water is dependent on geochemical, hydrochemical, physical and biological characteristics of the water [13].

The composition of a body of groundwater may be regulated by mineral enrichment from the substrata rock, the content of its recharge constituents or the hydrologic and geologic fluctuations within the aquifers [15, 16]. Contaminated groundwater has been established as major cause of epidemics and perennial diseases in human beings [17]. Population increase and industrialization are the responsible factors for groundwater depletion [18]. Therefore, an improved understanding of groundwater quality and its dynamics is a prerequisite for discerning and evaluating the fitness of groundwater for various intent.

A close link has been identified between groundwater properties and land use [6, 19]. Land usage that have been established to have direct incursion on groundwater quality include; solid waste landfills, cemetery, on-site sanitary system and animal waste disposal sites. If leachates are discharged into groundwater from landfills or open dumpsites, it will pollute the groundwater assets [20]. Research has proven that leachates induce rise of dissolved inorganic materials such as chloride, sulphate, bicarbonates, sodium and potassium in groundwater [6, 21].

Against compelling worries around unsustainable abstraction and pollution of groundwater in multiple locations across the world, groundwater resources, if conscientiously exploited, can make an important input to meeting demands for water supply in the future.

Traditional approach of analysis of groundwater quality data is by plotting the concentration of different ions or pairs of ions to interpret the relationship between samples or variables. However, recent trends look at multivariate statistical techniques such as Principal Component Analysis (PCA), cluster analysis, factor analysis, and discriminant analysis in the study of groundwater quality.

## II. Study Area

The study area is situated in the western part of Ogun State and lies within Latitude 6°30$^{1}$N to 7°50$^{1}$N and Longitude 2°40$^{1}$ to 3°15$^{1}$E. The study area consists of 14 selected communities within the sedimentary terrain of Ogun State (Fig. 1). The area covered include Ayetoro, Joga, Ibooro, Imasai, Ibese, Igbogila, Eggua, Igan Alade, Tata, Owode Ketu, Ijoun, Ebute Igbooro, Oja-Odan and Ohunbe in Yewa North Local Government Area.

The study area is characterized by the averagely hot, humid tropical climatic zone of southwestern Nigeria. It has two recognizable seasons, specifically, the rainy season (April-October) and the dry season (November-March). The temperature is proportionately elevated throughout the dry season with the average around 30°C. The harmattan, which brings in the northeasterly winds from December to February, has relieving effects on the dry season high temperatures. Low temperatures are however, recorded throughout the rains, notably between July and August when the temperatures could be as low as 24°C [22]. The onset of the rainy season ranges from March to April and the rainfall pattern is bimodal reaching its peaks in July and September. The length of the rainy season is about 200 days ending in late October. The rain is convectional and can occasionally occur with heavy showers. The rain of the second modal is small showers and frontal. The spatial occurrence of annual rainfall ranges from 960-1200 mm [23, 24].

Productive aquifers across the coastal zone of Western Nigeria exists in sands and overburden/shallow deposits while shales and clays form the impervious horizons [25]. The hydrogeology of the study area comprises;

**Abeokuta Formation:** which are soft, gritty, white clay or tough, silicified, ferruginous sandstone (Ayetoro, Igbogila, Imashai, Joga and Ibooro).

**Ewekoro Formation**: consisting of limestone member overlain by shale (Eggua, Igan-Alade, Ibese, Ijoun, Ijale Ketu, Owode Ketu, and Tata).

**Ilaro Formation**: consisting of coarse sands, angular and poorly sorted with considerable clay formation (Oja-Odan, and Ohunbe)

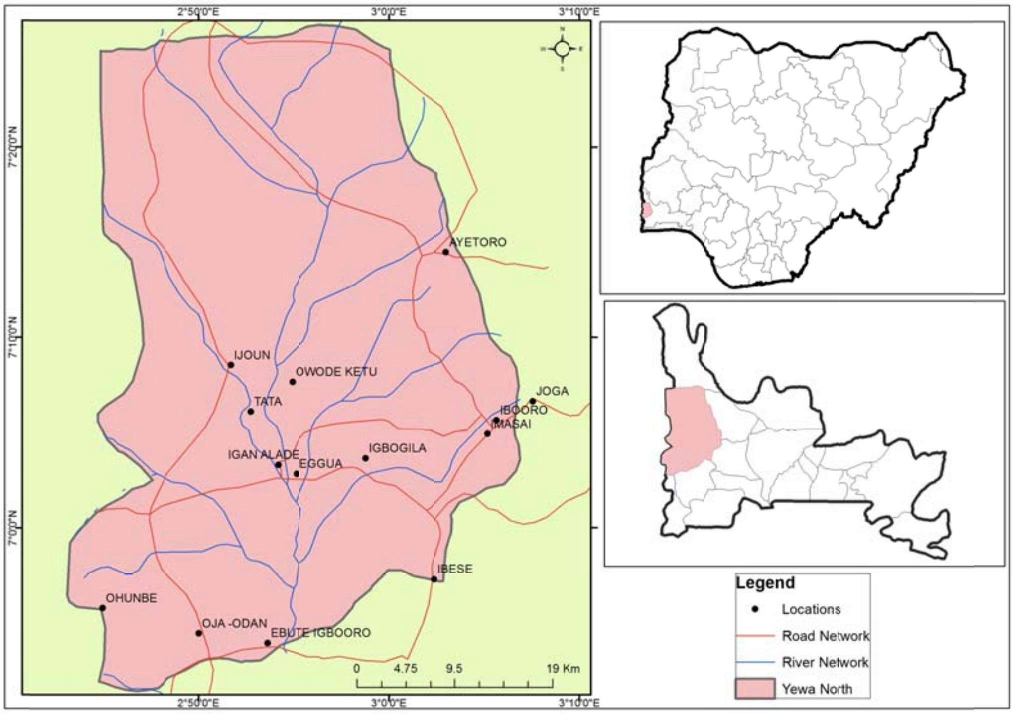


**Fig 1** Georeference Map of Study Area Showing Sample Location Points

## III. Materials and Methods

Field reconnaissance survey was conducted in order to locate hand-dug wells from 14 communities in the study area and seek permission from the owners for water sample collection. A total of 52 hand-dug wells covering the entire study area were randomly selected to give a proper coverage of the study area.

Groundwater samples were collected from hand-dug wells to cover both the wet and dry seasons. Water samples were drawn from the wells with the aid of a top filling bailer made of high density polyethylene (HDPE) bucket (Plate 3). Bailers are the most portable devices for groundwater sampling especially, from hand-dug wells. A bailer may be fabricated basically of any inflexible or plastic material, inclusive of element that are inactive to chemical pollutants [26]. The bailer was tied firmly to a cord. The cord (wire rope) used to lift and immerse the bailer is of non-reactive substance (e.g., teflon-coated wire/rope, polypropylene and stainless steel). The bailer was let down and raised gradually in order to lessen sample disturbance associated with degassing, aeration, and turbidity. Care was also taken to avoid the bailer hitting the sides of the well. Where the depths are more than 10 m the bailer is usually reeled using a tripod and pulley system (Fig.2).

The water samples were collected in a sterilized 2.5 liters' plastic container which had been originally rinsed over again with the sample water. The sample containers were properly covered and labeled to avoid sample mix up and transferred to the laboratory in ice packs.

**Fig. 2** Reeled bailer on tripod and pulley system

**Sample size**: A total of 104 samples were collected from 14 communities of the study location in both wet and dry seasons (Table: 1)

Table. 1: Sample location and sample size

| S/N | Community | Number of Samples | |
|---|---|---|---|
| | | **Wet Season** | **Dry Season** |
| 1 | Ayetoro | 4 | 4 |
| 2 | Joga | 2 | 2 |
| 3 | Ibooro | 2 | 2 |
| 4 | Imasai | 2 | 2 |
| 5 | Igbogila | 2 | 2 |
| 6 | Ibese | 4 | 4 |
| 7 | Eggua | 4 | 4 |
| 8 | Igan-Alade | 4 | 4 |
| 9 | Tata | 4 | 4 |
| 10 | Owode-Ketu | 4 | 4 |
| 11 | Ijoun | 4 | 4 |
| 12 | Ebute-Igbooro | 4 | 4 |
| 13 | Ohunbe | 4 | 4 |
| 14 | Oja-Odan | 8 | 8 |
| | **Total** | **52** | **52** |
| | **Grand Total** | **104** | |

**Sample Analysis:** Parameters recorded in the field include pH, electrical conductivity, total dissolved solids, temperature, static water level, and total well depth. The measurement of some physical and chemical parameters in situ was due to rapid changes in the measured parameters which may be caused by environmental factors. While a water sample will steadily reach equal temperature as the surrounding air, conductivity often varies with storage time and temperature.

The pH, temperature, total dissolved solids and the electrical conductivity were recorded on site using pH/Electrical Conductivity Meter (HI 98130 combo). The physico-chemical parameters were analyzed at the Federal Ministry of Water Resources Regional Water Quality Laboratory, Akure, Nigeria.

## IV. Results and Discussion

Results of the physico-chemical parameters are presented in tables 2 to 7. Mean temperature of 28.96±0.06 (Table 4) was obtained for the study area with minimum temperature of 27.50 $^0$C recorded at Joga during the dry season (Table 2) and maximum temperature of 30.70 $^0$C in Ohunbe in the wet season (Table 3). High temperature has been reported to adversely alter water quality by boosting the growth of micro-organisms which may heighten taste, odour, colour and corrosion issues [27]. Water temperatures has been classified by subjects [28] into cold (5°C), cool (16°C), tepid (26°C) and warm (58°C) while it has been revealed that drink temperature controls thermoregulatory responses as colder water activates rapid modification of core body temperature [28, 29]. Mean pH value of 6.59±0.54 (Table 4) was measured in groundwater samples from hand dug wells in the study area. This result implies that pH of groundwater from hand-dug wells in the study area is within the acceptable limits of 6.5 to 8.5 [30, 31]. pH range of 5.5 to 6.42 has been reported in groundwater around Ibese, a neighbouring community to Ilaro [17]. The mean values of turbidity measured in groundwater from hand-dug wells sampled in the study area is 5.71±15.12 NTU (Table 4). However, maximum turbidity value of 95.40 NTU was obtained in the dry season at Ijoun (Table 2). This high turbidity may be attributed to over abstraction and agitation during drawing of water from the well. Contaminated groundwater bodies can have appreciably higher turbidity and elevated turbidity level in groundwater has been detected to be linked with disease causing organisms such as viruses, parasites including some bacteria, which can induce nausea and diarrhea [32, 33].

Mean electrical conductivity (EC) 269.15±268.37 $\mu Scm^{-1}$ was recorded in groundwater from hand-dug wells sampled in the study area while mean total dissolved solids (TDS) measured was 113.54±73.39 $mgL^{-1}$ (Table 4). As reported in Table 4., electrical conductivity (EC) values above the permissible level of 1000 $\mu Scm^{-1}$ were recorded at Igbogila (1118 $\mu Scm^{-1}$) and Eggua-(1122 $\mu Scm^{-1}$) during the wet season. These results however, are still within the freshwater treshold of 0.00 – 1500.00 $\mu Scm^{-1}$ which implied that the water was good for drinking by human beings if there are no organic pollutant and not too many suspended clay components. Electrical conductivity of 1328.00±676.26 $\mu Scm^{-1}$ was reported in groundwater around Ibese [17] which fall within the study area, while conductivity value of 11.08 $\mu Scm^{-1}$ was reported in groundwater of Agbor/Owa town South South Nigeria [34]. Total dissolved solids value of 580 mg $L^{-1}$ (Table 2) recorded at Igbogila in the dry season is however, slightly above the 500 $mgL^{-1}$ permissible level recommended by [30]. Total dissolved solids level was used to classify groundwater into desirable for drinking (up to 500 $mgL^{-1}$), permissible for drinking (500-1000 $mgL^{-1}$), useful for irrigation purposes (up to 3000 $mgL^{-1}$) and unfit for drinking and irrigation at levels above 3000 $mgL^{-1}$[35]. With the above classification, the groundwater of the study area is permissible for drinking and useful for agricultural purposes including irrigation.

Table 2: Physico-Chemical Characteristics of water from hand-dug wells in Yewa North LGA (Dry Season)

| Sample Location | Temp. $^0C$ | pH | EC | TDS | Turbidity | TH | CH | MH | $PO_4$ | NO3- | $HCO_3$ | $Cl^-$ | $SO_4^{2-}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AYETORO 1 | 30.4 | 7.12 | 60 | 38 | 0 | 42 | 42 | 4 | 0.34 | 2.21 | 22 | 16 | 0.34 |
| AYETORO 2 | 29.1 | 6.83 | 70 | 40 | 0.19 | 50 | 50 | 16 | 0.24 | 2.56 | 14 | 12 | 0.24 |
| AYETORO 3 | 29.4 | 6.65 | 130 | 63 | 0.14 | 46 | 46 | 26 | 0.26 | 4.4 | 16 | 16 | 0.26 |
| AYETORO 4 | 30 | 6.45 | 50 | 22 | 0.4 | 60 | 60 | 42 | 0.19 | 2.1 | 10 | 22 | 0.19 |
| JOGA 1 | 27.5 | 6.09 | 20 | 10 | 8.13 | 40 | 16 | 24 | 0.08 | 1.38 | 12 | 14 | 0.08 |
| JOGA 2 | 29.3 | 5.67 | 530 | 260 | 0.1 | 140 | 74 | 66 | 0.1 | 1.83 | 12 | 62 | 0.1 |
| IBOORO 1 | 27.9 | 6.4 | 40 | 20 | 0.85 | 32 | 10 | 22 | 0.08 | 2.87 | 12 | 22 | 0.08 |
| IBOORO 2 | 28.7 | 6.72 | 40 | 20 | 0.9 | 40 | 14 | 26 | 0.06 | 3.01 | 8 | 17 | 0.06 |
| IMASAI 1 | 28.4 | 6.65 | 80 | 40 | 0 | 76 | 50 | 26 | 0.12 | 2.21 | 14 | 26 | 0.12 |
| IMASAI 2 | 29.8 | 5.8 | 450 | 220 | 0 | 136 | 80 | 56 | 0.14 | 1.9 | 16 | 42 | 0.14 |
| IGBOGILA 1 | 28.9 | 6.66 | 150 | 70 | 0.14 | 76 | 38 | 38 | 0.09 | 3.12 | 16 | 23 | 0.09 |
| IGBOGILA 2 | 29.4 | 6.67 | 1160 | 580 | 0.77 | 292 | 178 | 114 | 0.14 | 2.96 | 20 | 110 | 0.14 |
| IBESE 1 | 28.4 | 6.74 | 120 | 60 | 1.23 | 72 | 32 | 40 | 0.24 | 6.88 | 20 | 26 | 0.24 |
| IBESE 2 | 29.7 | 6.05 | 170 | 80 | 0 | 76 | 30 | 46 | 0.14 | 8.62 | 16 | 23 | 0.14 |
| IBESE 3 | 29.3 | 7.49 | 810 | 400 | 0 | 424 | 284 | 140 | 0.17 | 12.1 | 68 | 63 | 0.17 |
| IBESE 4 | 29.8 | 6.75 | 20 | 10 | 1.12 | 40 | 28 | 12 | 0.21 | 6.9 | 18 | 10 | 0.21 |
| EGGUA 1 | 28.8 | 6.17 | 20 | 10 | 23.6 | 38 | 14 | 24 | 0.13 | 4.11 | 20 | 10 | 0.13 |
| EGGUA 2 | 28.6 | 7.14 | 80 | 40 | 28.5 | 74 | 32 | 42 | 0.09 | 5.85 | 24 | 15 | 0.09 |
| EGGUA 3 | 29.3 | 6.93 | 420 | 210 | 0.05 | 258 | 156 | 102 | 0.1 | 2.86 | 63 | 96 | 0.1 |
| EGGUA 4 | 29.2 | 7.04 | 1060 | 530 | 0.08 | 120 | 66 | 54 | 0.12 | 3.25 | 35 | 68 | 0.12 |
| IGAN ALADE 1 | 29.5 | 8.4 | 700 | 340 | 1.61 | 202 | 108 | 94 | 0.11 | 10.2 | 58 | 73 | 0.11 |
| IGAN ALADE 2 | 28.9 | 7.58 | 310 | 160 | 2.2 | 88 | 84 | 34 | 0.08 | 4.13 | 20 | 70 | 0.08 |
| IGAN ALADE 3 | 28.9 | 7 | 110 | 50 | 25.8 | 108 | 64 | 44 | 0.16 | 3.85 | 48 | 8 | 0.16 |
| IGAN ALADE 4 | 29.1 | 6.94 | 20 | 10 | 2.81 | 24 | 16 | 8 | 0.14 | 3.04 | 14 | 7 | 0.14 |
| TATA 1 | 29.3 | 7.18 | 20 | 10 | 2.97 | 22 | 22 | 18 | 0.11 | 3.53 | 12 | 10 | 0.11 |
| TATA 2 | 30.3 | 6.76 | 50 | 23 | 0.9 | 44 | 44 | 12 | 0.15 | 4.65 | 14 | 10 | 0.15 |
| TATA 3 | 28.9 | 7.16 | 410 | 210 | 0.1 | 190 | 190 | 34 | 0.13 | 5.8 | 32 | 5 | 0.13 |
| TATA 4 | 28.6 | 7.15 | 130 | 60 | 3.3 | 40 | 40 | 14 | 0.11 | 4.04 | 16 | 26 | 0.11 |
| OWODE KETU 1 | 27.9 | 6.82 | 40 | 21 | 8.4 | 54 | 30 | 24 | 0.1 | 4.32 | 14 | 16 | 0.1 |
| OWODE KETU 2 | 28.2 | 6.68 | 610 | 300 | 0 | 244 | 172 | 72 | 0.07 | 2.46 | 38 | 73 | 0.07 |
| OWODE KETU 3 | 28.1 | 6.31 | 40 | 21 | 0.46 | 42 | 24 | 18 | 0.16 | 2.38 | 13 | 18 | 0.16 |
| OWODE KETU 4 | 28.7 | 6.9 | 310 | 160 | 0.37 | 96 | 52 | 44 | 0.15 | 7.05 | 14 | 50 | 0.15 |
| IJOUN 1 | 30.5 | 7.21 | 190 | 90 | 0.63 | 104 | 74 | 30 | 0.88 | 8.94 | 22 | 24 | 0.28 |
| IJOUN 2 | 28.5 | 7.08 | 310 | 150 | 0.64 | 142 | 128 | 14 | 0.08 | 15.7 | 20 | 54 | 0.06 |
| IJOUN 3 | 29.3 | 6.89 | 580 | 280 | 0.02 | 250 | 196 | 54 | 0.1 | 27.1 | 16 | 57 | 0.54 |
| IJOUN 4 | 28.6 | 6.22 | 20 | 11 | 95.4 | 44 | 18 | 26 | 0 | 5.08 | 18 | 8 | 2.03 |
| EBUTEIGBOORO1 | 28.3 | 7.02 | 30 | 10 | 0.86 | 80 | 30 | 50 | 0.38 | 4.32 | 21 | 12 | 0.38 |
| EBUTEIGBOORO2 | 28.5 | 6.83 | 630 | 310 | 0.3 | 208 | 114 | 94 | 0.68 | 3.86 | 62 | 124 | 0.68 |
| EBUTEIGBOORO3 | 28.9 | 6.8 | 90 | 60 | 0 | 60 | 24 | 36 | 0.82 | 13.2 | 18 | 18 | 0.82 |
| EBUTEIGBOORO4 | 28.8 | 6.78 | 370 | 180 | 0 | 146 | 68 | 78 | 0.56 | 14.1 | 24 | 30 | 0.56 |
| OHUNBE 1 | 30.3 | 6.94 | 30 | 18 | 0 | 52 | 32 | 20 | 0.11 | 3.02 | 12 | 16 | 0.11 |
| OHUNBE 2 | 29.7 | 7.16 | 80 | 40 | 0.6 | 54 | 38 | 16 | 0.13 | 2.98 | 10 | 16 | 0.13 |
| OHUNBE 3 | 30.1 | 7.05 | 50 | 30 | 0.36 | 76 | 54 | 22 | 0.1 | 1.75 | 21 | 12 | 0.1 |
| OHUNBE 4 | 30.4 | 6.91 | 30 | 20 | 0.34 | 58 | 38 | 20 | 0.08 | 4.12 | 12 | 10 | 0.08 |
| OJA-ODAN 1 | 29.1 | 8.3 | 20 | 10 | 3.68 | 50 | 28 | 22 | 0.18 | 8.64 | 12 | 38 | 0.18 |
| OJA -ODAN 2 | 28.4 | 7.43 | 80 | 50 | 0.01 | 60 | 30 | 30 | 0.15 | 11.1 | 16 | 18 | 0.15 |
| OJA-ODAN 3 | 30.5 | 7.88 | 780 | 390 | 0.08 | 254 | 132 | 122 | 0.21 | 7.48 | 12 | 75 | 0.21 |
| OJA-ODAN 4 | 29.9 | 7.63 | 290 | 140 | 0 | 108 | 80 | 28 | 0.12 | 12.3 | 32 | 42 | 0.12 |
| OJA-ODAN 5 | 29 | 6.32 | 590 | 290 | 0 | 220 | 104 | 116 | 0.26 | 21.6 | 44 | 70 | 0.26 |
| OJA-ODAN 6 | 28.4 | 7.13 | 240 | 110 | 0.19 | 124 | 70 | 54 | 0.24 | 3.9 | 28 | 24 | 0.24 |
| OJA-ODAN 7 | 28.7 | 6.89 | 170 | 80 | 0 | 80 | 54 | 28 | 0.32 | 6.28 | 18 | 25 | 0.32 |
| OJA-ODAN 8 | 29.2 | 6.47 | 510 | 250 | 0.22 | 228 | 124 | 104 | 0.45 | 3.13 | 64 | 52 | 0.45 |

EC=Electrical Conductivity, TDS=Total Dissolved Solids, TH=Total Calcium, CH=Calcium Hardness, MH=Magnesium Hardness

Table 3: Physico-Chemical Characteristics of water from hand-dug wells sampled in Yewa North LGA (Wet Season)

| Sample Location | Temp. $^0C$ | pH | EC | TDS | Turbidity | TH | CH | MH | $PO_4$ | NO3- | $HCO_3$ | $Cl^-$ | $SO_4^{2-}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AYETORO 1 | 29.7 | 6.8 | 109 | 55 | 1.86 | 90 | 34 | 56 | 0.21 | 2.46 | 22 | 18 | 0 |
| AYETORO 2 | 27.8 | 6.9 | 307 | 154 | 9.33 | 204 | 154 | 50 | 0.27 | 3.21 | 70 | 17 | 0 |
| AYETORO 3 | 27.6 | 7.4 | 136 | 68 | 3.13 | 60 | 26 | 34 | 0.19 | 4.7 | 14 | 22.9 | 0 |
| AYETORO 4 | 28.4 | 6.8 | 85 | 43 | 1.93 | 50 | 16 | 34 | 0.23 | 2.2 | 12 | 31 | 0 |
| JOGA 1 | 27.7 | 6.2 | 52 | 26 | 1.84 | 68 | 43 | 25 | 0.05 | 1.5 | 12 | 17.9 | 2 |
| JOGA 2 | 29.0 | 5.4 | 469 | 233 | 2.44 | 148 | 64 | 84 | 0.07 | 1.89 | 6 | 49 | 1 |
| IBOORO 1 | 28.5 | 6 | 82 | 40 | 2.5 | 68 | 24 | 44 | 0.08 | 3.12 | 14 | 23 | 1 |
| IBOORO 2 | 28.7 | 5.5 | 58 | 29 | 1.74 | 60 | 16 | 44 | 0.07 | 2.87 | 14 | 16 | 2 |
| IMASAI 1 | 29.4 | 6.1 | 75 | 37 | 2.24 | 92 | 66 | 26 | 0.1 | 1.1 | 20 | 16 | 0 |
| IMASAI 2 | 28.6 | 6.1 | 411 | 203 | 0.41 | 158 | 74 | 84 | 0.12 | 1.65 | 14 | 41 | 1 |
| IGBOGILA 1 | 29.2 | 6.2 | 194 | 98 | 1.45 | 404 | 240 | 164 | 0.1 | 2.56 | 18 | 222 | 2 |
| IGBOGILA 2 | 29.6 | 6 | 1118 | 557 | 0.85 | 102 | 50 | 52 | 0.12 | 3.2 | 24 | 24 | 2 |
| IBESE 1 | 28.6 | 5.8 | 420 | 209 | 0.06 | 80 | 22 | 58 | 0.26 | 7.54 | 8 | 57 | 0 |
| IBESE 2 | 29.0 | 6.8 | 207 | 103 | 0.03 | 84 | 34 | 50 | 0.18 | 8.8 | 16 | 27 | 0 |
| IBESE 3 | 28.8 | 7.7 | 658 | 326 | 0.19 | 246 | 148 | 98 | 0.21 | 11.4 | 74 | 58 | 0 |
| IBESE 4 | 29.1 | 6.6 | 192 | 95 | 1.91 | 76 | 58 | 18 | 0.23 | 6.78 | 44 | 5 | 0 |
| EGGUA 1 | 28.9 | 5.5 | 50 | 27 | 32.4 | 76 | 58 | 18 | 0.15 | 4.27 | 16 | 6 | 3.25 |
| EGGUA 2 | 28.7 | 6.6 | 219 | 109 | 8.57 | 90 | 36 | 54 | 0.1 | 6 | 32 | 42 | 2.25 |
| EGGUA 3 | 29.0 | 6.6 | 485 | 242 | 0.42 | 428 | 288 | 140 | 0.07 | 3.76 | 90 | 110 | 3.32 |
| EGGUA 4 | 29.0 | 6.9 | 1122 | 564 | 3.18 | 160 | 94 | 66 | 0.12 | 3.12 | 46 | 60 | 3 |
| IGAN ALADE 1 | 29.0 | 6.8 | 477 | 237 | 0.86 | 172 | 90 | 82 | 0.09 | 9.5 | 70 | 39 | 3 |
| IGAN ALADE 2 | 28.2 | 6.9 | 442 | 221 | 12.5 | 136 | 68 | 68 | 0.11 | 3.56 | 28 | 50 | 6 |
| IGAN ALADE 3 | 28.5 | 6.5 | 179 | 89 | 74.1 | 100 | 70 | 30 | 0.14 | 4.21 | 56 | 8 | 2 |
| IGAN ALADE 4 | 28.9 | 6.8 | 53 | 27 | 15.6 | 84 | 52 | 32 | 0.12 | 2.23 | 20 | 9.99 | 3.99 |
| TATA 1 | 29.0 | 6.6 | 48 | 23 | 9.24 | 78 | 42 | 36 | 0.09 | 1.53 | 20 | 9.99 | 1 |
| TATA 2 | 29.8 | 6.2 | 245 | 122 | 1.63 | 114 | 66 | 48 | 0.13 | 4.65 | 18 | 22.9 | 1 |
| TATA 3 | 28.6 | 6.5 | 90 | 45 | 54.6 | 104 | 40 | 64 | 0.12 | 6.3 | 26 | 8.99 | 2 |
| TATA 4 | 28.5 | 6.2 | 391 | 195 | 0.6 | 124 | 76 | 48 | 0.13 | 4.21 | 20 | 57 | 2 |
| OWODE KETU 1 | 29.2 | 7 | 129 | 65 | 10.5 | 88 | 52 | 36 | 0.08 | 3.7 | 38 | 16 | 2.54 |
| OWODE KETU 2 | 28.2 | 6.8 | 491 | 244 | 0.99 | 194 | 116 | 78 | 0.02 | 2.89 | 32 | 69 | 3 |
| OWODE KETU 3 | 28.5 | 6.4 | 85 | 45 | 1.95 | 68 | 28 | 40 | 0.12 | 2.15 | 12 | 20 | 0 |
| OWODE KETU 4 | 28.4 | 5.2 | 445 | 221 | 1.48 | 184 | 120 | 64 | 0.14 | 6.45 | 12 | 63 | 1 |
| IJOUN 1 | 30.1 | 6.5 | 287 | 143 | 0.92 | 172 | 116 | 56 | 0.34 | 9.78 | 24 | 37 | 0 |
| IJOUN 2 | 29.1 | 6.5 | 381 | 189 | 0.32 | 122 | 78 | 44 | 0.01 | 16.3 | 22 | 56.9 | 1 |
| IJOUN 3 | 29.2 | 6.3 | 584 | 292 | 0.58 | 190 | 142 | 48 | 0.45 | 25.3 | 18 | 65.9 | 1 |
| IJOUN 4 | 28.7 | 6.4 | 55 | 27 | 22.2 | 68 | 26 | 42 | 1.95 | 4.24 | 20 | 60 | 2 |
| EBUTEIGBOORO1 | 28.7 | 6.1 | 56 | 27 | 0.21 | 54 | 14 | 40 | 0.55 | 3.78 | 18 | 27 | 0 |
| EBUTEIGBOORO2 | 28.7 | 6.1 | 815 | 407 | 0.21 | 160 | 92 | 68 | 0.48 | 4.03 | 30 | 135 | 0.87 |
| EBUTEIGBOORO3 | 29.5 | 6.7 | 215 | 106 | 0.17 | 86 | 32 | 54 | 0.71 | 14 | 12 | 20 | 2.14 |
| EBUTEIGBOORO4 | 28.9 | 6.7 | 499 | 246 | 0.74 | 170 | 82 | 88 | 0.64 | 16.6 | 24 | 43 | 2.78 |
| OHUNBE 1 | 30.7 | 6.5 | 86 | 43 | 0 | 64 | 26 | 38 | 0.09 | 2.87 | 12 | 15 | 0 |
| OHUNBE 2 | 29.2 | 6.6 | 69 | 34 | 0.55 | 60 | 24 | 36 | 0.11 | 3.8 | 18 | 9.99 | 0 |
| OHUNBE 3 | 29.2 | 6.3 | 77 | 38 | 0.01 | 66 | 24 | 42 | 0.13 | 1.98 | 20 | 12 | 0 |
| OHUNBE 4 | 30.4 | 6.4 | 68 | 34 | 0.96 | 78 | 30 | 48 | 0.11 | 4.07 | 20 | 8.99 | 0 |
| OJA-ODAN 1 | 30.4 | 6.8 | 41 | 21 | 0.32 | 70 | 24 | 46 | 0.21 | 9.34 | 16 | 9.99 | 0 |
| OJA -ODAN 2 | 28.2 | 6.3 | 163 | 82 | 0.24 | 80 | 28 | 52 | 0.17 | 11.7 | 12 | 23 | 0 |
| OJA-ODAN 3 | 28.5 | 6.2 | 942 | 474 | 0.02 | 198 | 146 | 52 | 0.16 | 8.01 | 14 | 99.9 | 1 |
| OJA-ODAN 4 | 29.6 | 6.6 | 379 | 188 | 0.12 | 142 | 100 | 42 | 0.09 | 13.4 | 20 | 27.7 | 0 |
| OJA-ODAN 5 | 28.7 | 6.3 | 559 | 281 | 0.62 | 156 | 76 | 80 | 0.23 | 20.3 | 16 | 63 | 1 |
| OJA-ODAN 6 | 28.2 | 6.7 | 407 | 203 | 0 | 178 | 100 | 78 | 0.2 | 4.78 | 34 | 36 | 1 |
| OJA-ODAN 7 | 29.1 | 6.4 | 354 | 174 | 0.06 | 140 | 72 | 68 | 0.25 | 6.43 | 14 | 43.9 | 0 |
| OJA-ODAN 8 | 29.1 | 6.1 | 506 | 251 | 0.29 | 145 | 84 | 61 | 0.31 | 2.98 | 10 | 47 | 0 |

EC=Electrical Conductivity, TDS=Total Dissolved Solids, TH=Total Calcium, CH=Calcium Hardness, MH=Magnesium Hardness

Table 4: Statistics of Physico-Chemical parameters of water from hand-dug wells sampled in the study area (wet and dry seasons)

| Parameters | Mean | Range | WHO (2017) |
|---|---|---|---|
| Temperature (°C) | 28.96±0.69 | 27.50 – 30.70 | NS |
| pH | 6.59±0.54 | 5.23 – 8.40 | 6.5 – 8.5 |
| EC (μScm$^{-1}$) | 269.15±268.37 | 20.00 – 1160.00 | 1000 |
| TDS (mgL$^{-1}$) | 133.82±133.46 | 10.00 – 580.00 | 500 |
| Turbidity (NTU) | 5.71±15.12 | 0.00 – 95.40 | 5 |
| Total Hardness (mgL$^{-1}$) | 113.54±73.39 | 22.00 – 428.00 | 500 |
| Calcium Hardness (mgL$^{-1}$) | 66.28±50.97 | 10.00 – 288.00 | NS |
| Magnesium Hardness (mgL$^{-1}$) | 48.91±27.92 | 4.00 – 140.00 | NS |
| $PO_4^{3-}$(mgL$^{-1}$) | 0.19±0.22 | 0.00–1.95 | 10 |
| $NO_3^-$ (mgL$^{-1}$) | 5.56±4.89 | 1.10-27.10 | 50 |
| $HCO_3^-$(mgL$^{-1}$) | 23.03±15.98 | 6.00-90.00 | NS |
| $Cl^-$(mgL$^{-1}$) | 34.75±27.75 | 5.00-135.00 | 250 |
| $SO_4^{2-}$(mgL$^{-1}$) | 0.83±1.10 | 0.00–6.00 | 500 |

Min-Minimum, Max-Maximum, SD-Standard deviation, NS- Not Specified

Panels of tasters were also used to rate the palatability of drinking water in association to its total dissolved solids level as: excellent, if less than 300 mgL$^{-1}$; good, if between 300 and 600 mgL$^{-1}$; fair, if between 600 and 900 mgL$^{-1}$; poor, if between 900 and 1200 mgL$^{-1}$; and unacceptable, if greater than 1200 mgL$^{-1}$[36]. Therefore, the palatability of groundwater from hand dug-wells in the study area based on its total dissolved solids level (Table 4) can be rated excellent.

The results obtained from this study shows range of total hardness as 22.00 – 428.00 mgL$^{-1}$, with mean values of 113.54±73.39 (Table 4). Although Water hardness has no known adverse health effect; it might however, be expensive for domestic usage since hard water requires substantial application of soap to form lather. Based on

the mean values of hardness obtained (113.54 mgL$^{-1}$) and using McGowon classification [37], the groundwater of the study area is moderately hard (60-120 mgL$^{-1}$).

Concentration of chloride in groundwater from hand-dug wells in the study area range from 5.00 – 135.00 mgL$^{-1}$ with mean values of 34.75±27.75, while concentration of phosphate ranges from 0.00 – 1.95 with mean value of 0.19±0.22 (Table 4). Since Chloride value obtained is within the permissible limit of 250 mgL$^{-1}$ [30, 31] the usage of this water would therefore have no chloride related problems both for domestic and agricultural purposes. Chloride recorded in groundwater from hand dug wells in Abeokuta North, Ifo, Obafemi Owode and Odeda LGAs range from 7.50 - 170 mgL$^{-1}$[38] while Chloride concentration obtained in groundwater of Sagamu range from 14.18 - 99.26 mgL$^{-1}$[39]. Likewise, phosphate concentration obtained from the study area fall below the permissible level of 10 mgL$^{-1}$[30]. This result therefore, will not pose a major health worry for phosphate in groundwater of the study area since phosphate is acknowledged to be toxic both to animals and humans at exceedingly elevated levels and could lead to digestive problems[40]. While phosphate range of 0.012 – 0.086 $mgL^{-1}$ was recorded in well water samples in peri-urban areas of Obantoko Abeokuta[41], elevated phosphate values have been observed in groundwater around landfill site in Lagos[42].

The range of concentrations of Nitrate in groundwater across the study area is, 1.10 – 27.10, while the mean concentration of Nitrate obtained was 5.56±4.89 (Table 4). These values are lower than the 50 $mgL^{-1}$ permissible limit set by WHO[30]. The above results tallies with that obtained in Agbara and environs [43] which show low levels of nitrate concentrations in groundwater samples and therefore has minimal prospect of triggering any health complications when the water is consumed. However, it has been reported that the average level of nitrate in groundwater in Nigeria increased in the period 1985–2004 with 33% of sampled wells having a nitrate concentration above the permissible limit of 50 $mgL^{-1}$[44, 45].

Nitrate, which is reported to be the most prevalent form of nitrogen present in water, is commonly ushered into groundwater through broad or diffuse origins which can include: percolation of chemical fertilizers, seepage of animal manure, groundwater pollution by discharge from septic and sewage facilities. Widespread and severe nitrate pollution of shallow groundwater has been traceable to contamination from pit latrines [46], while numerous research has also reported nitrate contamination of groundwater because of shallow wells located less than 30 m from pit latrines, septic tanks or city drainage [47, 48, 49]. Exposure to high values of nitrate in groundwater can result to detrimental health effects among dwellers who use groundwater for consumption[50]. The mean of Sulphate concentration measured in groundwater from hand-dug wells in the study area 0.83±1.10 (Table 4) is below the 100 $mgL^{-1}$ the permissible limits[31]. $HCO_3^-$ concentration evaluated in groundwater of the study area ranged from 6.00 – 90.00 $mgL^{-1}$ while the mean values is 23.03±15.98 (Table 4). Bicarbonates in water is formed by the reaction of carbon dioxide in water upon carbonate rocks like limestone and dolomite; Bicarbonate ($HCO_3$-) together with carbonate ($CO_3^{-2}$) produce an alkaline environment. In combination with calcium and magnesium, they cause carbonate hardness. Although Bicarbonates are the main anions in the groundwater of the study area (Tables 4), the water is however free of Bicarbonate pollution since the values obtained are below the permissible level of 250-500 $mgL^{-1}$[31]. Bicarbonate concentration which ranged from 30.50 $mgL^{-1}$ – 122.30 $mgL^{-1}$ with an average concentration value of 60.16 $mgL^{-1}$ in dry season and 21.50 $mgL^{-1}$ to 113.20 $mgL^{-1}$ with a mean value of 56.03 $mgL^{-1}$ in wet season were reported from shallow aquifers of Hung area of Adamawa Northeast, Nigeria[51]. Mean bicarbonate level of 195 $mgL^{-1}$ were also reported in borehole samples of Yola-Jimeta metropolis [52].

According to the Duncan Multiple Range Test (DMRT) analysis, at P>0.05), there are no significant variations in the mean values of total dissolved solids and electrical conductivity obtained in groundwater drawn from hand-dug wells sampled in Joga Orile, Igan-Alade, Tata, Imasai, Eggua, Ebute Igbooro and Oja-Odan 1; electrical conductivity and bicarbonate in Tata, Imasai, Oja-Odan 1, Owode ketu and Ijoun; sulphate and bicarbonate in Igbogila, Tata and Ibooro (Table 5).

Pearson`s correlation analysis was applied for values of the physico-chemical parameters evaluated in groundwater from hand-dug wells sampled in the study area. Positive correlation at $P \leq 0.05$ was observed between electrical conductivity and total dissolved solids (r=1.00), total hardness (r=0.793), nitrate (r=0.246), chloride (r=0.833), bicarbonate (r=0.365) (Table 6). The strong positive correlation between electrical conductivity and total dissolved solids (r=1.00) indicate a common chemical behaviour.

Principal Component Analysis (PCA) of the parameters observed in groundwater from hand dug wells sampled in the study area reveals four components (Eigen value>1) which accounted for 67.23% of the total variance (Table 7). The first principal component (P1) had high contributions from electrical conductivity, total dissolved solids and total hardness. with a strong positive correlation of 0.92, 0.92 and 0.95. The three parameters are therefore the largest contributors towards the groundwater quality of the study area. According to Tsimplis[53], poor sewage systems which commonly produce chloride, phosphate and nitrate, would result to increased conductivity of the receiving water body. The second principal component (P2) explained 10.48% of the total variance attributed to static water level and total depth of the hand-dug wells sampled with a positive correlation of 0.86. The third component (P3) explains just 8.62% of the total variance which is attributed to turbidity and Sulphate.

Table 5: Mean values of physico-chemical parameters of water from hand-dug wells sampled in Yewa North LGA (wet and dry seasons)

| Location | Temp. | pH | EC | TDS | Turb. | TH | CH | MH | $Cl^-$ | $PO_4^{3-}$ | $NO_3^-$ | $SO_4^{2-}$ | $HCO_3^-$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ayetoro | 29.05$^{bcd}$ | 6.88$^{ab}$ | 118.37$^{bc}$ | 60.37$^{bc}$ | 2.12$^{ab}$ | 75.25$^{bcd}$ | 53.50$^{abc}$ | 32.75$^{bc}$ | 19.36$^{bc}$ | 0.24$^{b}$ | 2.98$^{ef}$ | 0.13$^{de}$ | 22.50$^{bc}$ |
| Joga | 28.38$^{cd}$ | 5.83$^{d}$ | 267.75$^{abc}$ | 132.25$^{abc}$ | 3.13$^{ab}$ | 99.00$^{abcd}$ | 49.25$^{abc}$ | 49.75$^{abc}$ | 35.73$^{abc}$ | 0.08$^{b}$ | 1.65$^{f}$ | 0.79$^{cde}$ | 10.50$^{c}$ |
| Ibooro | 28.4$^{5cd}$ | 6.15$^{cd}$ | 55.00$^{c}$ | 27.25$^{c}$ | 1.49$^{b}$ | 50.00$^{d}$ | 16.00$^{c}$ | 34.00$^{bc}$ | 19.50$^{bc}$ | 0.07$^{b}$ | 2.97$^{ef}$ | 0.78$^{cde}$ | 12.00$^{bc}$ |
| Imasai | 29.05$^{bcd}$ | 6.16$^{cd}$ | 254.00$^{abc}$ | 125.00$^{abc}$ | 0.66$^{b}$ | 115.50$^{abcd}$ | 67.50$^{abc}$ | 48.00$^{abc}$ | 31.25$^{abc}$ | 0.12$^{b}$ | 1.72$^{f}$ | 0.32$^{de}$ | 16.00$^{bc}$ |
| Igbogila | 29.06$^{bcd}$ | 6.56$^{b}$ | 444.13a | 220.63$^{a}$ | 7.33$^{ab}$ | 145.25$^{abc}$ | 81.00$^{ab}$ | 64.25$^{ab}$ | 47.74$^{ab}$ | 0.13$^{b}$ | 4.52$^{def}$ | 0.68$^{cde}$ | 19.00$^{bc}$ |
| Ibese | 29.10$^{bc}$ | 6.58$^{b}$ | 374.5ab | 186.50$^{ab}$ | 5.86$^{ab}$ | 170.75$^{a}$ | 106.25$^{a}$ | 64.50$^{ab}$ | 42.50$^{abc}$ | 0.15$^{b}$ | 6.46$^{bcde}$ | 1.57$^{ab}$ | 38.25$^{a}$ |
| Eggua | 28.81$^{bcd}$ | 6.78$^{ab}$ | 341.37$^{abc}$ | 170.50$^{abc}$ | 19.41$^{a}$ | 122.75$^{abcd}$ | 68.50$^{abc}$ | 54.25$^{abc}$ | 36.99$^{abc}$ | 0.11$^{b}$ | 4.45$^{def}$ | 1.93$^{a}$ | 39.50$^{a}$ |
| Igan-Alade | 28.88$^{bcd}$ | 7.12$^{a}$ | 286.37$^{abc}$ | 141.75$^{abc}$ | 16.94$^{ab}$ | 114.25$^{abcd}$ | 69.00$^{abc}$ | 49.00$^{abc}$ | 33.12$^{abc}$ | 0.12$^{b}$ | 5.09$^{cdef}$ | 1.94$^{a}$ | 39.25$^{a}$ |
| Tata | 29.13$^{bc}$ | 6.73$^{ab}$ | 173.00$^{abc}$ | 86.00$^{abc}$ | 9.17$^{ab}$ | 89.50$^{abcd}$ | 65.00$^{abc}$ | 34.25$^{bc}$ | 18.74$^{bc}$ | 0.12$^{b}$ | 4.34$^{def}$ | 0.81$^{cde}$ | 19.75$^{bc}$ |
| Owode-Ketu | 28.40$^{d}$ | 6.51$^{bc}$ | 268.75$^{abc}$ | 134.63$^{abc}$ | 3.02$^{ab}$ | 121.25$^{abcd}$ | 74.25$^{abc}$ | 47.00$^{abc}$ | 40.63$^{abc}$ | 0.11$^{b}$ | 3.93$^{ef}$ | 0.88$^{bcd}$ | 21.63$^{bc}$ |
| Ijoun | 29.25$^{b}$ | 6.64$^{b}$ | 300.87$^{abc}$ | 147.75$^{abc}$ | 15.09$^{ab}$ | 136.50$^{abc}$ | 97.25$^{a}$ | 39.25$^{bc}$ | 45.35$^{ab}$ | 0.48$^{a}$ | 14.06$^{a}$ | 0.86$^{bcd}$ | 20.00$^{bc}$ |
| Ebute-Igbooro | 28.79$^{bc}$ | 6.63$^{b}$ | 338.13$^{abc}$ | 168.25$^{abc}$ | 0.31$^{b}$ | 120.50$^{abcd}$ | 57.00$^{abc}$ | 63.50$^{ab}$ | 51.13$^{a}$ | 0.60$^{a}$ | 9.24$^{bc}$ | 1.03$^{bc}$ | 26.13$^{abc}$ |
| Ohunbe | 30.00$^{a}$ | 6.73$^{ab}$ | 61.25$^{c}$ | 32.13$^{c}$ | 0.35$^{b}$ | 63.50$^{cd}$ | 33.25$^{bc}$ | 30.25$^{c}$ | 12.49$^{c}$ | 0.11$^{b}$ | 3.07$^{ef}$ | 0.53$^{e}$ | 15.63$^{bc}$ |
| Oja-Odan 1 | 29.33$^{b}$ | 7.13$^{a}$ | 336.87$^{abc}$ | 169.37$^{abc}$ | 0.56$^{b}$ | 120.25$^{abcd}$ | 71.00$^{abc}$ | 49.25$^{abc}$ | 41.69$^{abc}$ | 0.16$^{b}$ | 10.25$^{ab}$ | 0.21$^{de}$ | 16.75$^{bc}$ |
| Oja-Odan 2 | 28.80$^{cd}$ | 6.52$^{bc}$ | 417.00ab | 204.87$^{ab}$ | 0.17$^{b}$ | 158.87$^{ab}$ | 85. 50ab | 73.63a | 45.11$^{ab}$ | 0.28$^{b}$ | 8.68$^{bcd}$ | 0.41$^{cde}$ | 28.50$^{ab}$ |
| SE | 0.207 | 0.126 | 91.978 | 45.813 | 5.277 | 25.658 | 17.825 | 9.542 | 9.373 | 0.064 | 1.395 | 0.239 | 4.990 |

abc.... Means with same alphabets along each column were not significantly different ($P>0.05$)  SE-Standard Error

Table 6: Correlation among physico-chemical and bacteriological parameters across locations and seasons in Yewa North LGA (N=120)

| Parameter | Temp. | pH | EC | TDS | Turb. | TH | CH | MH | $Cl^-$ | $PO_4^{3-}$ | $NO_3^-$ | $SO_4^{2-}$ | $HCO_3^-$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp °C | | 0.167 | 0.074 | 0.074 | -0.189* | 0.076 | 0.10 | 0.049 | -0.018 | 0.074 | 0.121 | -0.240** | -0.041 |
| pH | | | 0.028 | 0.029 | -0.066 | 0.068 | 138 | -0.035 | 0.006 | 0.063 | 0.213* | -0.121 | 0.285** |
| Electrical Conductivity ($\mu Scm^{-1}$) | | | | 1.00** | -0.203** | 0.793** | 0.724** | 0.741** | 0.833** | 0.011 | 0.246** | 0.107 | 0.365** |
| Total dissolved solids ($mgL^{-1}$) | | | | | -0.202* | 0.790** | 0.722** | 0.737** | 0.832** | 0.011 | 0.244** | 0.110 | 0.362** |
| Turbidity (NTU) | | | | | | -0.139 | -0.138 | -0.138 | -0.266 | -0.035 | -0.079 | 0.322 | 0.179 |
| Total hardness ($mgL^{-1}$) | | | | | | | 0.948** | 0.869** | 0.739 | 0.012 | 0.287 | 0.143 | 0.608 |
| Calcium hardness ($mgL^{-1}$) | | | | | | | | 0.679** | 0.666 | -0.026 | 0.291 | 0.083 | 0.584 |
| Magnessium hardness ($mgL^{-1}$) | | | | | | | | | 0.702 | 0.071 | 0.204 | 0.191 | 0.513 |
| $Cl^-$ ($mgL^{-1}$) | | | | | | | | | | 0.145 | 0.191* | 0.080 | 0.338** |
| $PO_4^{3-}$ ($mgL^{-1}$) | | | | | | | | | | | 0.212* | 0.014 | 0.044 |
| $NO_3^-$ ($mgL^{-1}$) | | | | | | | | | | | | -0.009 | 0.102 |
| $SO_4^{2-}$ ($mgL^{-1}$) | | | | | | | | | | | | | 0.268** |
| $HCO_3^-$ ($mgL^{-1}$) | | | | | | | | | | | | | |

*Correlation is significant at 5% level (2 tailed) **Correlation is significant at 1% level (2 tailed)

Temp.-Temperature, EC-Electrical conductivity, TDS-Total dissolved solids, Turb. -Turbidity, TH-Total Hardness, CH-Calcium hardness, MH-Magnessium hardness.

Table 7: PCA of physico-chemical and bacteriological parameters of water from hand-dug wells sampled in Yewa North LGA (wet and dry seasons)

| Component | P1 | P2 | P3 | P4 |
|---|---|---|---|---|
| Eigen Value | 8.14 | 2.09 | 1.72 | 1.48 |
| Variance Accounted for (%) | 40.72 | 10.48 | 8.62 | 7.41 |
| Cumulative Variance (%) | 40.72 | 51.20 | 59.82 | 67.23 |
| Static water level (m) | -0.23 | **0.86** | 0.10 | 0.33 |
| Total depth (m) | -0.24 | **0.86** | -0.09 | 0.31 |
| Temperature °C | 0.07 | 0.34 | 0.40 | 0.26 |
| pH | 0.07 | 0.34 | 0.07 | **0.69** |
| Electrical Conductivity ($\mu Scm^{-1}$) | **0.92** | 0.01 | 0.07 | 0.11 |
| Total dissolved solids ($mgL^{-1}$) | **0.92** | 0.02 | 0.07 | 0.11 |
| Turbidity (NTU) | 0.21 | 0.23 | **0.67** | 0.19 |
| Total Hardness ($mgL^{-1}$) | **0.95** | 0.01 | 0.10 | 0.12 |
| Calcium Hardness ($mgL^{-1}$) | **0.87** | 0.10 | 0.08 | 0.21 |
| Magnesium Hardness ($mgL^{-1}$) | **0.88** | 0.10 | 0.09 | 0.03 |
| Phosphate ($mgL^{-1}$) | 0.07 | 0.46 | 0.21 | 0.12 |
| Nitrate ($mgL^{-1}$) | 0.30 | 0.22 | 0.06 | 0.41 |
| Bicarbonate ($mgL^{-1}$) | 0.54 | 0.10 | 0.41 | 0.47 |
| Chloride ($mgL^{-1}$) | **0.88** | 0.04 | 0.06 | 0.27 |
| Sulphate ($mgL^{-1}$) | 0.14 | 0.51 | **0.56** | 0.0 |

## V. Conclusion

The present study considers physico-chemical parameters of groundwater samples from 52 hand-dug wells in 14 communities which falls within 3 hydrogeological zones of Southwestern Nigeria. The groundwater quality parameters were evaluated using multivariate analysis. The data were analyzed with the aid of statistical tools and it was found that electrical conductivity, total dissolved solids and total hardness which are the three largest contributors to the water quality of the groundwater from hand dug wells in the study area as well as chloride are conspicuously higher in groundwater from hand-dug wells in Igbogila. Other parameters that contributed to the water quality of the study area are turbidity and sulphate levels of the water sample. Generally, the groundwater from hand-dug wells in the study area is moderately hard, rated excellent, it is desirable for drinking by human and can be used for agricultural purposes including irrigation.

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