Supported by tetfund TERTIARY EDUCATION TRUST FUND

GEOPHYSICAL AND GEOCHEMICAL CHARACTERIZATION OF GROUNDWATER QUALITY STATUS OF ORU-IJEBU SOUTH-WEST NIGERIA

[1.]Ishola S. A., [1.]Olufemi S.T and [2.]Ajetumobi A.E
[1.]Department of Earth Sciences, Olabisi Onabanjo University Ago-Iwoye, P.M.B 2002, Ago-Iwoye, Ogun State, Nigeria
[2.]Department of Physics, Olabisi Onabanjo University Ago-Iwoye, P.M.B 2002, Ago-Iwoye, Ogun State, Nigeria
Corresponding Author: ishola.sakirudeen@oouagoiwoye.edu.ng

Received: April 16, 2024 Accepted: June 28, 2024

Abstracts: Subsurface geophysical investigation was carried out in Oru-Ijebu with the principal purpose of evaluating aquifer protective capacity of the overburden units in the area which involved forty (40) Vertical Electrical Sounding (VES) adopting Schlumberger configuration with the maximum electrode spacing of 100m at each point using OMHEGA Allied Resistivity meter while twenty(20) water samples comprising of 10 hand-dug wells and 10 boreholes were collected and subjected to geochemical analyses using Inductively Coupled Plasma-Optical Emission Spectrometry; results were compared to the drinking water standard set by appropriate health agencies. Parameters such as aquifer resistivity, aquifer thickness, overburden thickness and longitudinal conductance were calculated and used for evaluating the yields and vulnerability of the aquiferous zone to contaminant seepages. From the data interpretation, the overburden thickness ranges from 1.7 m to 24.7 m, the traverse resistivity ranges from 20.42 to 1625.73 while the coefficient of anisotropy varies from 01.8 (VESORU21) to 1.64 (VESORU29). The result also revealed that 72 % of the investigated which comprises of 27 investigated locations were found to be within poor protective capacity zones, 5 % which comprises of 2 investigated locations were found within the weak protective zones while 23 % which comprises of 9 investigated locations falls within the moderate protective zones. None of the investigated locations falls within the Good Zones. The longitudinal conductance illustrates the impermeability of the confining layers which is generally < 1.0 Siemens; values >1.0 Siemens would indicate zones in which the confined aquifer would be protected; in comparison, the values of S < 1.0 would indicate zones of probable risks of groundwater contamination. These analyses revealed that the water quality status in the study area is not suitable for human consumption due to the elevated concentrations of Fe^{3+} with mean values of 0.35±0.05 and 0.34±0.04; P with 5.92±0.44 and 5.88±0.75 respectively for boreholes and hand-dug wells. Advance water treatment techniques like nanofiltration and reverse osmosis should are therefore recommended for overall chemical treatment of Oru-Ijebu groundwater system before usage.

Keywords: Groundwater; Ijebu south; Nigeria; Quality Status

Introduction

Water is essential to human existence which is absolutely necessary for all living organisms to exist. Groundwater is the best and most suitable freshwater supply for human use (Akmal and Jamil, 2021). Unintentional urbanization and overcrowding, loose exploration regulations, and inappropriate disposal of solid and liquid wastes all contribute to the influx of toxic materials into subterranean water supplies (Pallen, 1996). The main sources of groundwater contamination are the unregulated disposal of industrial wastes and the use of chemical components in agriculture (Pallen, 1996). In Nigeria, groundwater is used to supply a large portion of drinking water via hand-dug wells and boreholes. Groundwater is the only source of drinking water in many rural areas and parts of urban areas, exposing a large population to the risk of consuming contaminated water. Groundwater quality is influenced by natural factors such as aquifer lithology, groundwater velocity, recharge water quality, and interaction with other types of water or aquifers, as well as by human activities and the environment. The environment has a significant impact on human health and development, and acute effects from exposure to environmental contaminants have been linked to specific environmental hazards with a health effect, such as benzene and leukemia (WHO, 2011; Babiker et al., 2007). Understanding the history and variations in environmental contamination can be aided by examining temporal patterns in environmental danger. Industries have sparked a surge of interest among environmentalists and planners concerned with the environmental consequences of industry. According to Scott, (1998), the environmental repercussions of developing-world businesses have mostly gone unnoticed. Although the development of such firms is considered as a method to offer employment and income, there is little research available to assist decision makers on the environmental effect and sustainability of such sectors. The high rate of industrialization, which has become necessary in a country like Nigeria, is a major cause of groundwater pollution. Effluents from industry, home sewerage, waste sites, and fertilizers all contributed to groundwater pollution by reaching the subterranean aquifer and posing a risk to receptors (Rohul-Amin et al., 2012). Once contaminated, the groundwater aquifer system tends to persist for a long time, even if the source of contamination; whether industrial or household wastewater dumping or recycling, is removed. Groundwater quality is an essential component in groundwater use for agricultural, industrial, residential, and drinking purposes (Nalbantçılar and Pınarkara, 2015). Leachate is a liquid or water-soluble compound formed in a dumpsite as a result of waste decomposition. Runoff from rainfall or wet precipitation redistributes this water-soluble matter in the environment. Leachate may migrate from the dumpsite and seep into the soil, contaminating soil and groundwater and endangering human health and environment (Butt et al., 2022; WHO, 2008). Climate (rainfall), topography (run-on/runoff), and vegetation are all factors that influence leachate generation (Rohul-Amin et al., 2012). Groundwater development is a natural process that can take years. The type of rock and soil through which groundwater has passed, as well as any potential human contamination; all have an impact on its quality.

Study Area

Location and Accessibility

The study area is located in Oru-Ijebu between longitudes 6°56"N and 6°58"N and latitude 3°56"E and 3°51"E within the South Eastern part of Ogun state, where it shares a common boundary with Oyo state (Fig. 1). Ijebu-igbo is the local government headquarters of this area and other towns within the district include Ijesha-Ijebu, Ago-iwoye, Mamu. The area falls within the basement complex rock of Nigeria. The area extent is 10.5 km^2. The relief is moderately low forming ridges in some places an undulated plain dotted with small isolated hills or hills rocks are noticed generally within Ago Iwoye. The general level of surface rises Northwards from about 0 to 500 feets above the coast northward to the area of the crystalline rocks (Ishola et al., 2024).

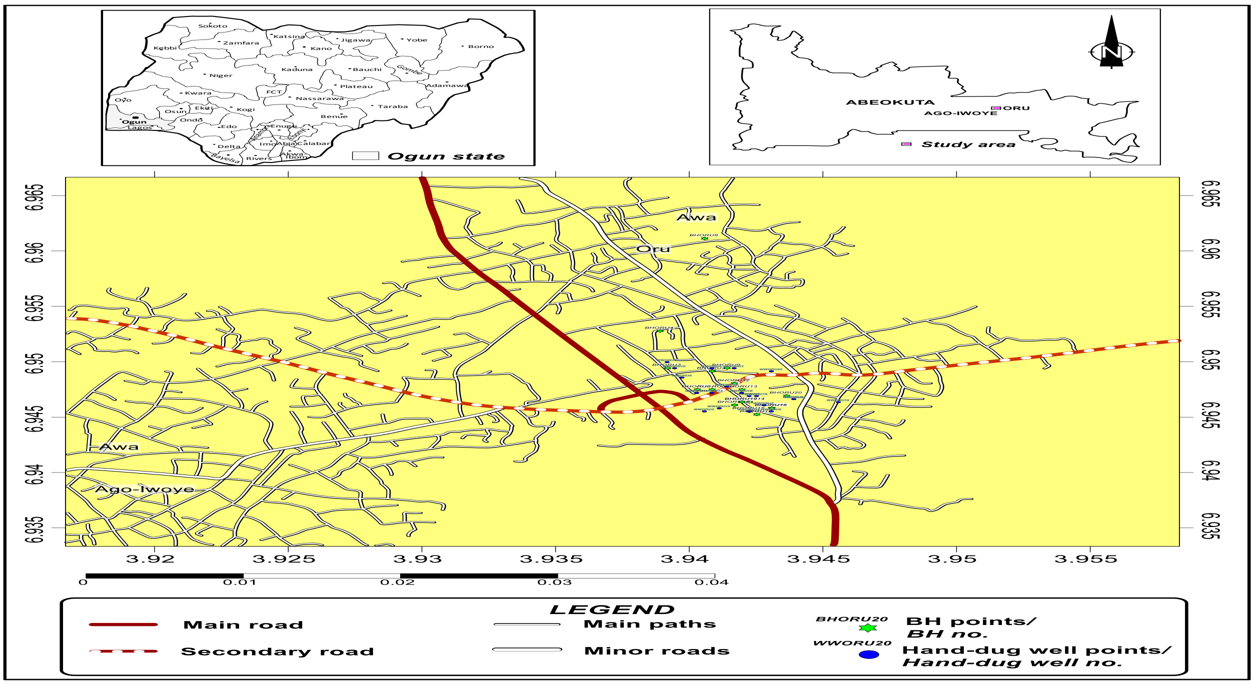

Fig. 1. : Location and Accessibility Map

Geology of the Study Area

The topography of the study area is generally undulating ranging from high to low relief. Highest peaks are 112 m and lowest peak is 40 m. The drainage patterns are dendritic and reflect the land forms, soil types and their occurrences. It should be noted that the drainage pattern of any area is influenced by the topography. It is also characterized by a double rainfall with peaks falling between June and September. December and January are relatively dry. The temperature is within the range of 26 ^{0}C to 36 ^{0}C (Ishola et al., 2024).

Oru-Ilaporu type is found locally in the basement complex rock in the southwest Nigerian state of Ogun. The major rocks found in the study area include; Granite Gneiss, Banded Gneiss and Pegmatite; Pegmatite being the most common type of rock in the research region. The majority of the rocks in this area have undergone varying degrees of weathering, from recently formed formations to heavily weathered ones. Numerous related minerals have been identified, each with unique diagnostic features. These include quartz, biotite, hornblende feldspar, plagioclase, muscovite, and microcline feldspar (Ishola et al., 2024).

Material and Methods

The Terrameter model SAS 300B was used to acquire forty (40) Vertical Electrical Soundings (VES) soundings using the Schlumberger configuration, and maximum electrode separation (AB/2) is restricted to 100 m. The Schlumberger configuration consists of a linear electrodes array (AMNB) as shown in Figure 4. Potential electrodes M and N are kept fixed at the centre of the array while current electrodes A and B are moved outward symmetrically (Telford, 1990). The operational principle lay on the fact that ground injection of current through current electrodes A and B enables the measurement of the potential drop between potential probes M and N. The current penetrates deeply into the ground as the electrode A and B spacing increases (Ishola et al., 2024). The interpretation of result was carried out both qualitatively and quantitatively the qualitative interpretation was achieved by plotting the obtain Resistivity data on the log-log paper which relate the resistivity data to the geology of the study area while quantitative interpretation is referring to a curve matching and computer assisted program called iteration The 1-D forward modeling adopted for the VES interpretation is called Resist (software version 1.0) program. I-D forward modeling (1DF) is a computer program that provides a way for the user to interactively model vertical electrical sounding data by changing the geologic conditions and parameter that control earth resistivity responses (Pirttijärvi, 2009). The interpretation of forty (40) Schlumberger sounding conducted in the study area indicated that the lithological layers vary from 2-4 layers. The subsurface layers within this study area include Topsoil, Clayey sand, Clay, Sandy clay and Fresh Basement based on their corresponding resistivity values obtained during the interpretation. The summary of the lithological parameter which includes thickness, depth, resistivity, and curve type were obtained from the screen graphic by eliminating the generation of anomalous layers caused by noise in the field data.

Groundwater samples were collected from existing and functional 10 dug wells and 10 boreholes in the investigated locations within the study area to determine physical and chemical parameters such as pH, Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Total Solids (TS), Conductivity, Temperature, Hardness, Alkalinity, major elements, trace elements (Anions and Cations inclusive). The field equipment used includes hand-held global positioning system receiver, field note, Plastic bottles (20 pieces), Masking Tape, Permanent marker, Clinometer Base map and Measuring tape. Measurements of the physical parameters were done in-situ. The plastic bottles were first properly cleansed with sanitizer and rinsed with the water to be collected at the sample station. Two distinct samples were obtained from each site, one from the investigated borehole and one from each of the existing hand-dug wells. Masking tape was used to identify the bottles. The depth to groundwater level and total depth were measured using a measuring tape for each hand dug well (Fig. 2).

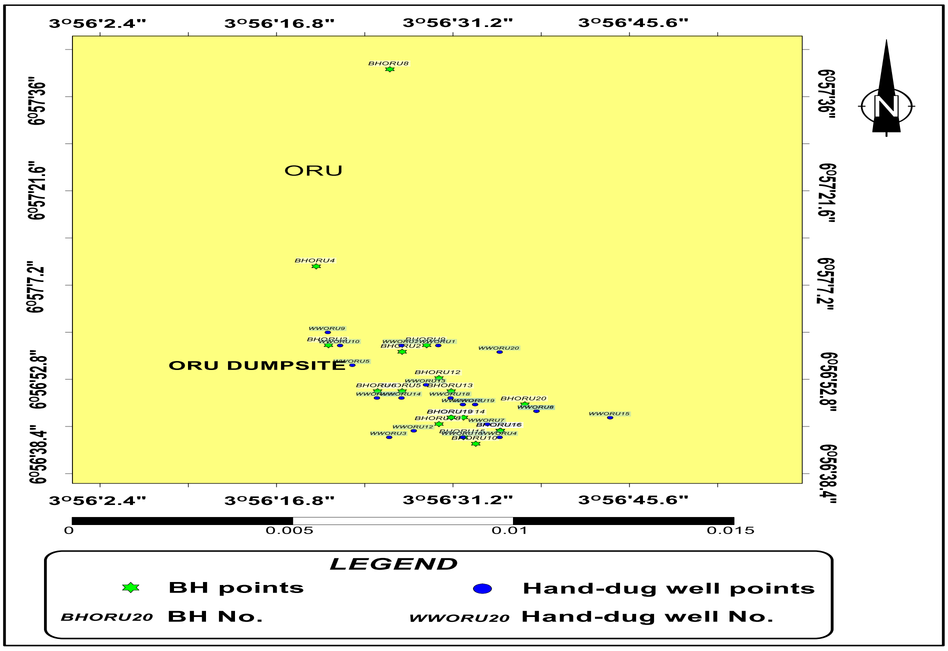

Fig. 2a: Data Acquisition Map showing the sampling Points

After collection, the water samples were taken to the laboratory both for the physico-chemical and Elemental analyses using Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES) was used to analyze the anions, while Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) was used to analyze the cations.

Result and Discussion

Groundwater Protection using Geophysical Method

Some of the Vertical Electric Sounding (VES) Curves obtained from the study area are displayed below in Figure 2b. The curves displayed the top soil, thickness, resistivity of the weathered layer from which the aquifer parameters were determined for estimating the overburden thickness and depth to the aquiferous zone in the investigated area.

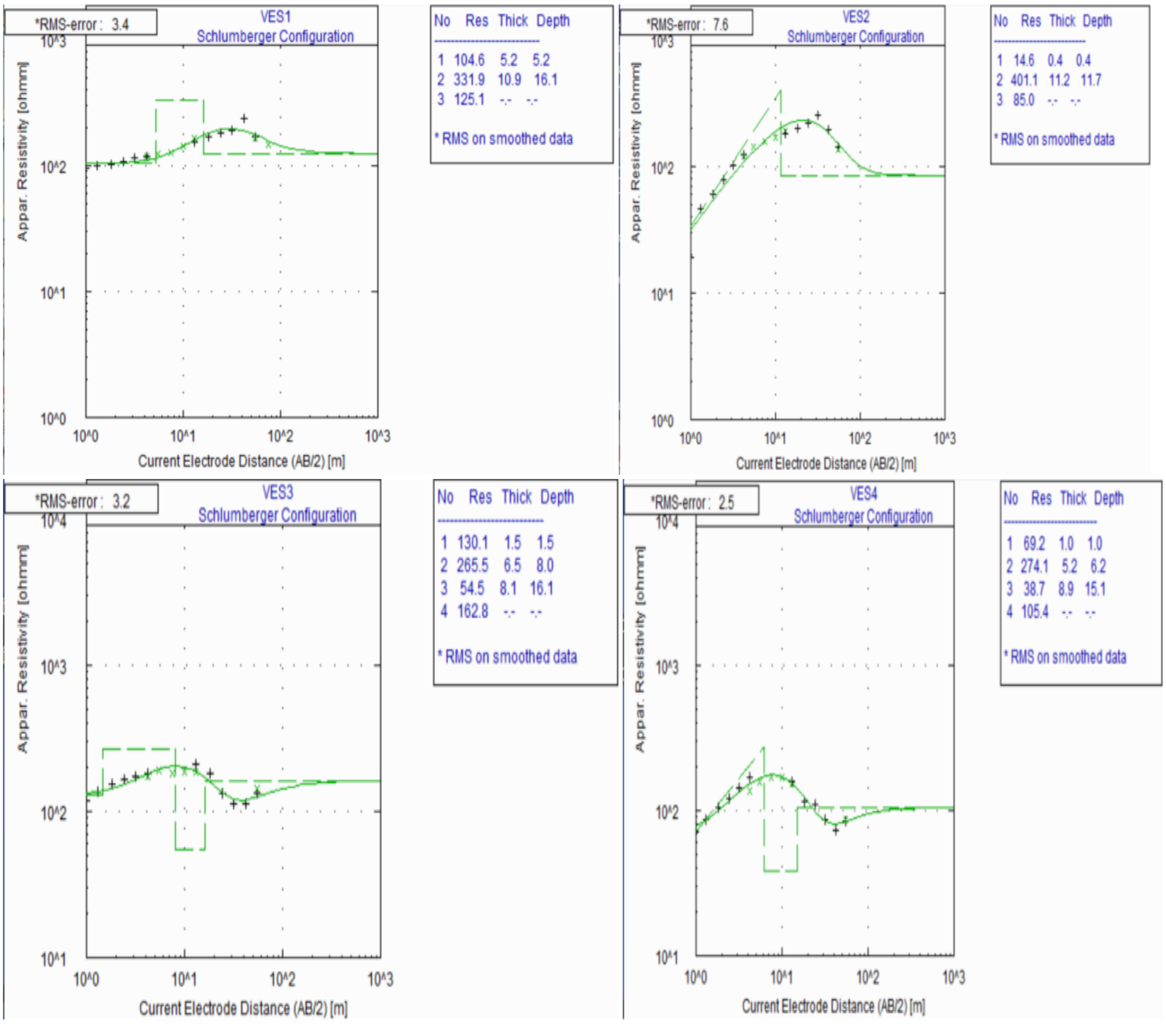

Fig. 2b: Typical Type Curves of the Study Area (VESORU1-VESORU4)

The cardinal focus of groundwater potential assessment in the crystalline basement area is the actual delineation and interconnectivity of the overburden rocks and the fractured basement of the reservoir rocks (Ishola *et al.*, 2021; Bayewu *et al.*, 2018; Ishola *et al.*, 2016; Leaky *et al.*, 2005). Olayinka (1996; Omosuyi, 2000; Meju *et al.*, 1999) once observed that the resistivity of the basement cannot be solely relied on for the identification of promising and prolific aquifer within the basement terrain. Hence, the consideration of its reflection coefficient as a determining factor of aquifer parameter is highly significant in evaluating the groundwater potential zones in the study area. Reflection coefficients reveal the degree of fracturing of the underlying basement better than depending solely on the resistivity values. In the basement terrain, good aquiferous zones are usually found either where the overburden is relatively thick and/or where the reflection coefficient is low (< 0.8). In this study, three basic criteria were later considered in assessing the prospective points for groundwater potential zones in a given reservoir of the study area (Bayewu *et al.*, 2018; Ishola *et al.*, 2016; Omosuyi, 2000).

i. Zones where the overburden thickness displayed greater than or equal to (> 13 m) and with reflection coefficient less than (> 0.8) are categorized as areas with high groundwater yield.

ii. Zones where the overburden thickness displayed greater than or equal to (≥ 13 m) and with reflection coefficient greater than or equal to (≥ 0.8) are categorized as areas with medium groundwater yield.

iii. Zones where the overburden thickness displayed less than 13 m and with reflection coefficient either less than or equal to (< 0.8) are categorized as areas with low groundwater yield.

The calculated Dar Zarrouk parameters for the study area are shown overburden thickness from the calculated result, the overburden thickness ranges from 1.7 m to 24.7 m, longitudinal conductance value of this study location varies between 0.0138 Ω^{-1} to 0.5468 Ω^{-1}, traverse resistance the in the study area varies from 167.17 Ωm to 22109.98 Ωm. reflection coefficient the reflection coefficient of the study ranges from 0.26-0.88, the longitudinal resistivity of this study ranges from 24.99 to 782.61, the traverse resistivity ranges from 20.42 to 1625.73 while the coefficient of anisotropy varies from 0.18 (VESORU21) to 1.64 (VESORU29); locations where the coefficient of anisotropy are less than 1.5 are considered as potential aquifers for groundwater development while locations whose coefficient of anisotropy values are around 1.0 are equally recognized as viable groundwater potential zones (Ishola *et al.*, 2016). In the entire investigated area 72 % which comprises of 27 investigated locations were found to be within poor protective capacity zones, 5 % which comprises of 2 investigated locations were found within the weak protective zones while 23 % which comprises of 9 investigated locations falls within the moderate protective zones (Table 1 and Table 2). It is noteworthy to report that none of the investigated locations falls within the Good, Very Good and Excellent Zones. This reveals the vulnerability status of Oru-Ijebu aquiferous zones to contaminant seepages from the surface and near surface as they are migrated and dispersed with the unprecedented impacts on the subsurface groundwater system. Also, in terms of groundwater yield of the study area, 77 % which comprises of 31 investigated locations falls within low groundwater potential yield zone, 8 % which comprises of 3 investigated locations are found within medium groundwater potential yield zone while 15 % which comprises of 6 investigated locations falls within high groundwater potential yield zone (Table 1 and Table 2).

Table 1: Groundwater Potential Estimation Table

Total Longitudinal Unit Conductance (mhos)	**Identified VES Points in Oru-Ijebu**	**Overburden Protective Capacity**
< 0.10	VESORU1, VESORU2, VESORU3, VESORU4, VESORU5, VESORU6,VESORU7,VESORU8, VESORU9, VESORU10, VESORU11, VESORU13, ,VESORU14, VESORU15, VESORU16, VESORU17, VESORU19, VESORU20, VESORU21, VESORU22, VESORU24, VESORU26, VESORU27, VESORU28, VESORU29, VESORU31, VESORU32, VESORU37, VESORU38, VESORU39, VESORU40	Poor
0.1-0.19	VESORU12 and VESORU38	Weak
0.2-0.69	VESORU18, VESORU23, VESORU25, VESORU30, VESORU33, VESORU34,VESORU35, and VESORU36	Moderate
0.7-1.0	NIL	Good
5-10	NIL	Very Good
> 10	NIL	Excellent

Longitudinal conductance/protective capacity rating Oladapo et al., 2004; Oladapo and Akintorinwa, 2007 and Abiola et al., 2009.

Table 2: Groundwater Protection Zones across the VESORU Points

VESORU Stations	**Transverse Resistivity**	**Coefficient of Anisotropy**	**Reflection Coefficient**	**Yield Remarks**	**Longitudinal Conductance**	**Protective Capacity Rating**
VESORU1	258.49	1.15	0.45	**Low**	0.0826	Poor
VESORU2	384.46	1.35	0.65	**Low**	0.0553	Poor
VESORU3	119.31	0.52	0.50	**Low**	0.0360	Poor
VESORU4	98.97	0.47	0.46	**Low**	0.0334	Poor
VESORU5	102.43	0.43	0.48	**Low**	0.0282	Poor
VESORU6	144.35	0.43	0.58	**Low**	0.0138	Poor
VESORU7	58.28	0.61	0.77	**Medium**	0.0971	Poor
VESORU8	54.74	0.66	0.41	**Low**	0.1026	Poor
VESORU9	64.67	0.51	0.73	**Low**	0.0710	Poor
VESORU10	105.57	0.67	0.67	**Low**	0.0485	Poor
VESORU11	11.77	0.26	0.80	**Medium**	0.0811	Poor

VESORU12	86.27	1.04	0.39		**Low**		0.1656		**Weak**
VESORU13	60.83	0.52	0.73		**Low**		0.0575		Poor
VESORU14	174.05	2.21	0.71		**Low**		0.0475		Poor
VESORU15	102.52	0.67	0.67		**Low**		0.0740		Poor
VESORU16	143.30	0.76	0.72		**Low**		0.0726		Poor
VESORU17	33.18	0.35	0.88		**High**		0.0419		Poor
VESORU18	36.62	0.91	0.82		**High**		0.2905		**Moderate**
VESORU19	49.23	0.40	0.76		**Medium**		0.0484		Poor
VESORU20	59.31	0.55	0.44		**Low**		0.0923		Poor
VESORU21	18.56	0.18	0.74		**Low**		0.0386		Poor
VESORU22	1625.73	1.9	0.87		**High**		0.0308		Poor
VESORU23	33.91	1.12	0.81		**High**		0.2563		**Moderate**
VESORU24	39.36	0.33	0.82		**High**		0.0327		Poor
VESORU25	669.86	1.07	0.34		**Low**		0.4075		**Moderate**
VESORU26	154.06	1.39	0.26		**Low**		0.0353		Poor
VESORU27	50.36	0.49	0.46		**Low**		0.0600		Poor
VESORU28	64.64	0.53	0.53		**Low**		0.0849		Poor
VESORU29	158.36	1.64	0.62		**Low**		0.0492		Poor
VESORU30	890.62	1.39	0.60		**Low**		0.4197		**Moderate**
VESORU31	202.91	1.09	0.16		**Low**		0.0676		Poor
VESORU32	175.74	1.13	0.05		**Low**		0.0813		Poor
VESORU33	49.32	1.04	0.55		**Low**		0.3755		**Moderate**
VESORU34	33.91	1.15	0.73		**Low**		0.3962		**Moderate**
VESORU35	35.47	1.08	0.79		**Low**		0.4142		**Moderate**
VESORU36	38.41	1.07	0.63		**Low**		0.5468		**Moderate**
VESORU37	39.16	0.36	0.84		**High**		0.0388		Poor
VESORU38	20.42	0.47	0.68		**Low**		0.1623		**Weak**
VESORU39	44.25	1.10	0.72		**Low**		0.2339		**Moderate**
VESORU40	33.95	0.38	0.66		**Low**		0.0461		Poor

Groundwater Quality Status using Geochemical Method

The concentration of K^+ recorded at Oru ranges between 0.542±0.507 mg/L to 0.505±0.024 with minimum and maximum ranging from 0.42- 0.62 in hand-dug well and boreholes respectively. The mean concentration of PO_4 recorded at Oru from the borehole samples ranges from 6.777± 0.537 mg/L with minimum value observed as 5.8 mg/L while the maximum value 7.94 mg/L while the mean concentration of samples from hand dug wells ranged from 7.642±0.489mg/L with minimum and maximum value recorded in boreholes 0.4-8.5 mg/L. In hand-dug wells, the mean concentration of SO_4 was found to be 10.751±0.82, with a range of values from 9.25 to 12.42. In boreholes, the mean concentration was found to be 8.113±0.850, with a range of values from 6.9 to 9.7. The phosphorus content of the samples taken from hand-dug wells ranges from 5.92±0.435, exceeding all recommended standards for drinking water taken into consideration. Similarly, the phosphorus content of the boreholes 9 samples exhibited 5.922±0.044, exceeding all recommended standards for drinking water considered. The samples taken from hand-dug wells had an alkalinity mean concentration ranging from 263.86±61.8, which is much higher than the United States Environmental Protection Agency (USEPA), National Agency for Food and Drug Administration and Control (NAFDAC), World Health Organization (WHO), and Nigeria Standard for Drinking Water Quality (NSDWQ)
recommended standards for drinking water—with the exception of National Environmental Standards and Regulations Enforcement Agency (NESREA), where the alkalinity level is not up to standard (Tables 3a and 3b). The average alkalinity content in boreholes is between 249.33±96.04, which is more than the NAFDAC and WHO recommended guideline for drinking water, but within the range of the NESREA standard and below the NSDWQ standard (Tables 4a and 4b). The mean content of Fe in the borehole samples ranged from 0.351±0.054, which is slightly higher than the recommended standard set by the USEPA, NAFDAC, WHO, NESREA, and NSDWQ for drinking water. The range of Fe detected in the samples taken from the hand-dug wells was found to be 0.343±0.042, which is within the range of suggested standards taken into consideration (Table 4a and Table 4b). The concentrations of each of the analyzed parameter for physico-chemical and Elemental parameters are respectively displayed in Figure 3 and 4.

Table 3a: Chemical Parameters of Oru Hand-Dug Wells and Approved Health Agencies Recommended Standard

Elemental Parameters (mg/L)	MAX	MIN	Mean± S.D	USEPA	NAFDAC	WHO	NESREA	NSDWQ
Na	0.51	0.3	0.417±0.058	NA	200	<200	NA	200
K	0.62	0.43	0.542±0.507	200	10	200	250	NA
Ca	0.29	0.22	0.252±0.	75	75	100	75	NA
Fe	0.42	0.28	0.343±0.042	0.3	0.3	0.3	0.3	0.3
Zn	0.26	0.42	0.326±0.039	NA	NA	0.01	NA	NA
Pb	0.001	0.001	0.001±0	0.01	0.01	0.01	0.01	0.01
S	9.42	7.48	8.558±0.485	NA	NA	250	NA	NA
N	0.001	0.001	0.001±0	NA	0.05	0.02	0.05	NA
Cu	0.03	0.01	0.02±0.008	1.3	1.0	2.0	NA	1.0
P	7.51	4.96	5.888±0.749	0.01	0.005	0.003	0.003	0.001
Cd	0.001	0.001	0.001±0	0.005	0.005	0.003	0.003	0.001
Al	0.03	0.002	0.019±0.008	0.2	0.5	0.2	NA	NA
Si	0.001	0.001	0.001±0	NA	NA	NA	NA	NA
I	0.001	0.001	0.001±0	NA	NA	NA	NA	NA
Po_4	8.5	6.5	7.642±0.489	NA	NA	NA	NA	NA
So_4	12.42	9.25	10.751±0.82	250	100	400	500	200
No_3	0.007	0.004	0.005±0.009	10	10	50	45	NA

Table 3b: Chemical Parameters of Oru Boreholes and Approved Health Agencies Recommended Standard

Elemental Parameter (mg/L)	MAX	MIN	Mean± S.D	USEPA	NAFDAC	WHO	NESREA	NSDWQ
Na	0.47	0.33	0.389±0.39	NA	200	<200	NA	200
K	0.54	0.45	0.505±0.024	200	10	200	250	NA
Ca	0.35	0.23	0.279±0.032	75	75	100	75	NA
Fe	0.43	0.26	0.351±0.054	0.3	0.3	0.3	0.3	0.3
Zn	0.37	0.2	0.295±0.048	NA	NA	0.01	NA	NA
Pb	0.001	0.001	0.001±0	0.01	0.01	0.01	0.01	0.01
S	7.94	5.66	6.67±0.776	NA	NA	250	NA	NA
N	0.06	0.03	0.047±0.009	NA	0.05	0.02	0.05	NA
Cu	0.001	0.001	0.001±0	1.3	1.0	2.0	NA	1.0
P	6.84	5.1	5.922±0.044	0.01	0.005	0.003	0.003	0.001
Cd	0.001	0.001	0.001±0	0.005	0.005	0.003	0.003	0.001
Al	0.02	0.01	0.014±0.005	0.2	0.5	0.2	NA	NA
I	0.05	0.02	0.037±0.010	NA	NA	NA	NA	NA
Po_4	7.94	5.8	6.78±0.537	NA	NA	NA	NA	NA
So_4	9.7	6.9	8.113±0.850	250	100	400	500	200
No_3	0.006	0.003	0.005±0.001	10	10	50	45	NA

Table 4a: Physicochemical Parameters of Oru Hand-Dug Wells and Approved Health Agencies Recommended Standard

Physico-Chemical Parameters	MAX	MIN	Mean	USEPA	NAFDAC	WHO	NESREA	NSDWQ
pH	5.58	4.26	5.137 ±0.341	6.50-8.50	6.50-8.50	6-5-9.5	7.00-8.50	6.50-8.50
Temp (°C)	28.7	20.2	27.16±1.729	2700	2700	2700	NA	NA
EC(μScm^{-1})	168.5	140.3	159.52±8.87	1200	1000	1200	NA	900
TDS(mg/L)	0.02	0.01	0.016±0.005	500	500	100	1500	500
TSS(mg/L)	0.02	0.01	0.014±0.005	NA	NA	>10	>10	NA
TS(mg/L)	0.04	0.01	0.027±0.010	N.A	NA	1500	NA	NA
Turbidity(NTU	0.02	0.01	0.014±0.005	5.0	5.0	<4	5.0	5.0
Alkalinity(mg/L)	361.2	180.5	263.86±61.8	100	100	200	500	100
TH(mg/L)	0.62	0.39	0.502±0.060	NA	100	<200	100-300	500

Table 4b: Physico-chemical Parameters of Oru Boreholes and Approved Health Agencies Recommended Standard

Physico-chemical parameters	MAX	MIN	MEAN±SD	USEPA	NAFDAC	WHO	NESREA	NSDWQ
pH	5.58	5.22	5.453±0.082	6.50-8.50	6.50-8.50	6-5-9.5	7.00-8.50	6.50-8.50
EC(μScm^{-1})	177.3	144.5	163.32±10.71	2700	2700	2700	NA	NA
TDS (mg/L)	0.02	0.01	0.014±0.005	1200	1000	1200	NA	900
TSS (mg/L)	0.01	0.01	0.01±0	500	500	100	1500	500
TS (mg/L)	0.03	0.02	0.024±0.005	NA	NA	>10	>10	NA
Salinity(mg/L)	164.5	35.5	98.33±38.02	NA	NA	1500	NA	NA
Turbidity(NTU)	0.02	0.01	0.012±0.004	5.0	5.0	<4	5.0	5.0
Temp (°C)	27.5	25.5	26.65±0.525	100	100	200	500	100
Alkalinity(mg/L)	433.8	144.4	249.33±96.04	NA	100	<200	100-300	500
TH(mg/L)	0.59	0.43	0.50±0.053	6.50-8.50	6.50-8.50	6-5-9.5	7.00-8.50	6.50-8.50

NAFDAC: National Agency for Food and Drug Administration and Control
WHO: World Health Organization
NSDWQ: Nigeria Standard for Drinking Water Quality
NESREA: National Environmental Standards and Regulations Enforcement Agency
USEPA: U.S. Environmental Protection Agency

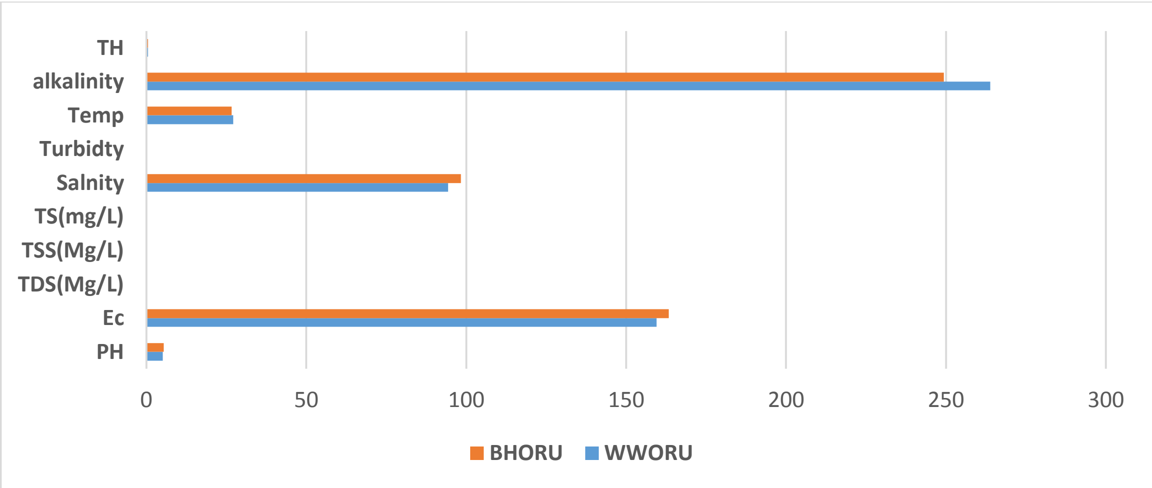

Fig. 3: Chart showing the Physico-Chemical Parameters of Oru-Ijebu Groundwater

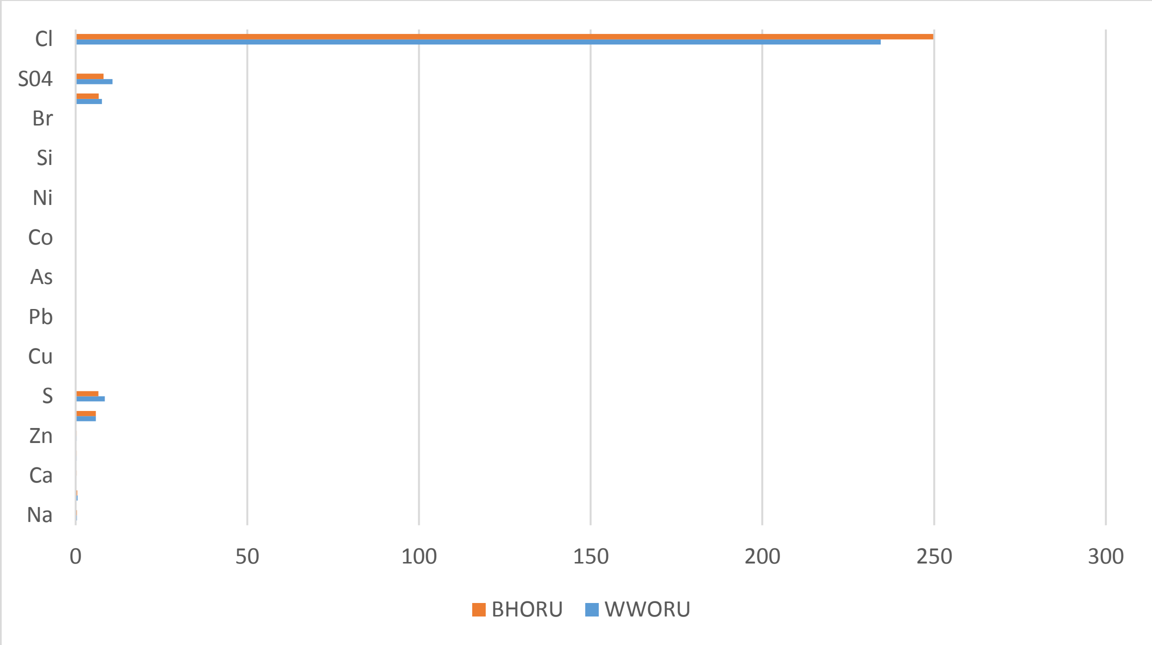

Fig. 4: Chart showing the Major elements and heavy metals of Oru-Ijebu Groundwater

Conclusion

The study area is overlain principally by materials of weak protective capacity and only small area (23%) is of moderate protective capacity. It is therefore evident that groundwater in most part of the area is vulnerable to pollution that may arise from runoff water, sewage system, effluent and indiscriminate waste disposal in the study area. Therefore, the revelations in the study area are possible indications that the groundwater quality may have been impaired which necessitated the need for borehole water to be randomly sampled for contaminant loads based on this investigation. The relative abundance of the majority of cations in the samples from boreholes follows this sequence - P >K^+>N>Na^+>Ca^{2+} while that of the anions follow this sequence Cl^- > SO_4^{2-}> PO_4 > $NO_3^-$and in hand-dug wells the relative abundance of the majority of cations follow this sequence- P >K^+>Na^+ >Ca^{2+} >N while that of the anions follow this sequence- Cl^->SO_4^{2-} >PO_4>NO_3^- and according to the standards considered they were all below standards. The study concludes by analyzing the degree of contamination through a number of methods, including geochemical and physio-chemical analyses, statistical analyses of the major elements and heavy metals found in the water samples in the study area, and comparisons with drinking water standards set by the WHO, NESREA, USEPA, NSDWQ, and NAFDAC. With the exception of Fe, which is beyond the permitted limits in boreholes but within the norm in hand-dug wells, this study's findings show that the majority of the identified parameters are greater than all approved standards. Additionally, the allowed standards for phosphorus in hand-dug wells and boreholes are significantly exceeded. The continued use of these water sources without proper treatment due to the elevated levels of the aforementioned criteria presents a major health risk to the residents.

Recommendation

The local authority in Oru-Ijebu community should be alerted on the elevated concentrations of heavy metals most notably Fe^{3+} and its dangerous health implications of its consumption without treatment so that alternative arrangement can be provided. Advance water treatment techniques like nanofiltration and reverse osmosis should be employed for overall chemical treatment of Oru-Ijebu groundwater system before usage.

References

Abiola, O., Enikanselu, P.A and Oladapo, M.I. (2009). Groundwater Potential and Aquifer Protective Capacity of Overburden Units in Ado-Ekiti, Southwestern Nigeria. *International Journal of Physical Sciences*. 4: 120-132.

Akmal, T. and Jamil, F. (2021). Assessing health damages from improper disposal of solid waste in metropolitan Islamabad-Rawalpindi,Pakistan. *Sustainability* **13**, 2717.

Bayewu, O.O., Moroof O.O., Ganiyuo.M., Lanyan T.A., S.O Ariyo And Fatoba, J.O. (2018). Assessment of Groundwater Prospect and Aquifer Protective Capacity using Resistivity Method in Olabisi Onabanjo University Campus Ago-Iwoye, Southwestern Nigeria. *NRIAG Journal of Astronomy and Geophysics*, 7:2, 347-360, DOI:10.1016/J.NRJAG.2018.05.002

Butt, N. A. (2022). Geophysical and geochemical characterization of solid waste dumpsite:

Babiker I.S, Mohamed A.M, Hiyama T. (2007). Assessing groundwater quality using GIS.Water Resources Management.2007; 21(4):699–715. A case study of Chowa Gujar, Peshawar (Indus Basin). *Sustainability* 14, 1443.

Ishola S.A., Makinde V., Aina J.O., Ayedun H., Akinboro F.G.,Okeyode I.C., Coker J.O., and Alatise O.O (2016). Aquifer Protection Studies and Groundwater Vulnerability Assessment in Abeokuta South Local Government Area, South-West Nigeria, *Journal of Nigerian Association of Mathematical Physics,* © J.of NAMP Vol 33, (January, 2016), pp 347-362

Ishola S.A (2019). Characterization of Groundwater Resource Potentials using Integrated Techniques in Selected Communities within Ewekoro Local Government Area South-West Nigeria. *Depatment of Physics, FUNAAB Ph.D Thesis*.

Ishola, S.A., Makinde, V., Gbadebo, A.M., Mustapha, A.O and Orebiyi E.O (2021). Quality Assessment of Groundwater System in Itori Community of Ewekoro Local Government Area, South-West Nigeria. *International Journal of Science and Technology in Science and Technology Publishing (SCI & TECH)* ISSN: 2632-1017, Vol. 5, Issue 12 December-2021 pp 1060-1061. www.scitechpub.org

Lenkey, L., Hamori, Z. and Mihalffy, P. 2005. "Investigating the Hydrogeology of a Water-Supply area using Direct-Current Vertical Electrical Soundings". *Geophysics.* 70(4):H1-H19.

Meju, M.A., Fonts, S.L., Oliveira, M.F.B., Lima, J.P.R., Ulugerger, E.U., Carrasquilla, A.A., (1999). Regional Aquifer Mapping Using Combined VES-TEM-AMT-EMAP Methods in the Semi-Arid Eastern Margin of Parnaiba Basin, Brazil. *Geophysics* 64(2), 337-356.

Nalbantçılar M.T, Pınarkara S.Y.(2015). Impact of industry on groundwater contamination: a case study in Konya city, Turkey. *Global NEST Int J*. 2015;17(4):796–815.

Oladapo M.I, Mohammed M.Z, Adeoye O.O, Adetola B.A. 2004. Geoelectrical investigation of the Ondo State Housing Corporation Estate, Ijapo Akure, Southwestern Nigeria. *J Min Geol* 40(1):41–48. Google Scholar

Oladapo, M.I., and Akintorinwa, O. J. (2007). Hydrogeophysical Study of Ogbese , Southwestern, Nigeria, Glob. *Journal of Pure Applied. Sci*. 13(1), 55-61.

Omosuyi, G.O. (2000). Investigation of the Geoelectric Parameter, Dar-Zarrouk Parameters and Aquifer Characteristics of Some Parts of North-Central Nigeria. *Journal of Sci. Eng. and Tech. 7(4)*, Pp. 2835−2848.

Pallen, D.(1996).Environmental Assessment Manual for Community Development Projects. Ottawa: Asia Branch, Canadian International Development Agency. 1996.

Pirttijärvi, M 2009 "Joint Interpretation of Electromagnetic and Geoelectrical Soundings Using 1-D Layered Earth Model, User's Guide to Version 1.3," *Oulu, 2009*, 48 p.

Rohul-Amin S.S, Anwar Z, Khattak J.Z.K. (2012). Microbial analysis of drinking water and water distribution system in New Urban Peshawar. *Curr Res J Biol Sci.* 2012;4 (6):731–737.

Telford, W. M.. Geldart L. P and. Sheriff, R. E (1990). "Applied Geophysics," *Cambridge University Press, Cambridge, 199*0, 870 p. doi:10.1017/CBO9781139167932

WHO (2011).World Health Organization Guidelines for Drinking Water Quality: Incorporating first addendum Vol. 1-Recommendations 4th Edition, Geneva

WHO (2008). World Health Organization. Safe water, better health cost benefits and sustainability of interventions to protect and promote health. http://www.uliqlibdoc.who.int'publications/2008/978924 1 59635 (retrieved on 10-1-2009).