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Research Article

SIMPLE APPROACH TO GROUNDWATER STUDY FOR DOMESTIC USES IN RURAL AREA

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ABSTRACT

Nigeria is one of the countries facing challenges associated with water supply. In rural areas, majority depend solely on hand-dug wells for their consumption which are prone to contamination. This study is aimed to determine the potability of hand-dug wells in Eyenkorin using the geophysical and physicochemical techniques. Ten Vertical Electrical Sounding (VES) data were acquired beside ten dug wells that were used for the physicochemical analysis, with half-current electrode spacing (AB/2) which varied from 46 to 75 m. The VES results revealed that water from the wells were tapped at shallow aquifers, while the hydro-physicochemical parameters revealed higher constituents of TDS, Fe^{2+}, K^+ and NO_3^- in the analyzed samples. It is concluded that the contamination in the study area is as a result of anthropogenic and geogenic contributions. Water treatment is recommended in the study area prior to domestic usage.

Keywords: Hand-dug wells; Rural area; Nigeria; Geophysical survey; Water analysis; Groundwater study; Domestic consumption.

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1. INTRODUCTION

Water is very active such that it is controlled and altered by the medium of contact. Seventy-one percent of the earth's surface is covered by oceans and seas. The remaining portion is land which still houses underground water within its cover. The distribution of water on earth ('Blue Planet') shows that oceans covered up to 97.50% while freshwater is 2.50%. With this small amount of freshwater in our planet, only 0.3% is usable by humans. This usable freshwater could either be accessed through underground, rivers, or lakes [1].

Groundwater is the second largest storage of freshwater which is generally used by humans. Recently, groundwater has remained the major source of water supply ranging from domestic, industrial, to agricultural activities [2 – 4]. Groundwater quality changes with respect to daily, climatic, and seasonal factors. Regular check of water quality's parameters is essential because water quality's variations have repercussion on man and biota. Groundwater quality in an area is a function of its chemical, physical, and biological parameters. Quality of groundwater is as essential as its quantity. Poor water quality has adverse effect on human health and plant growth. It decreases agricultural production and reduces farmers' economy, and retards improvement in the living conditions of rural dwellers. Potable water can be defined as water that is free from chemical and microorganisms that are harmful to human health when consumed [5]. Most of rural dwellers have little or no access to potable water for domestic uses.

The aim of this study is to integrate the geophysical and hydro-physicochemical techniques in order to assess the depth to aquifer and the quality of dug well water in Eyenkorin for its domestic worthiness. The scope is limited to geophysical data acquisition and interpretation as well as collection of dug-well water for physicochemical analysis. The study was borne out of the general hygiene practices among the dwellers and the low yield of the wells during dry season. Some of the wells were at the proximity of latrines and open waste sites, while on average, more than three (3) houses depend on a dug-well, which permits usage of more than one drawers from a single well. The Electrical Resistivity (ER) technique was used for the geophysical approach, while the hydro-physicochemical approach was used primarily to assess the quality of water in the study area [5, 6]. Similar approach around the study area and south-west Nigeria have been reported by Ojoawo and Adeniran [7], Ojo et al. [8] and Olagunju et al. [9], while some of the researchers that have assessed the quality of water supply for domestic purposes include: Adekunle et al. [10], Onweluzo and Akuagbazie [11], Chinedu et al. [12], Etim et al. [13], Olafisoye et al. [14], Olatunji et al. [15], Zin et al. [16] and Adagunodo [17].

2. THE STUDY AREA AND ITS GEOLOGY

Eyenkorin is one of the rural settlements in Kwara state (a suburb of Ilorin) that has started to experience influx of people from Ogbomoso, Oyo State axis and Ilorin, Kwara state axis. Eyenkorin is a fast growing commercial and residential environment, which is on the outskirts of the state capital, located in Asa Local Government Area. The settlement is acclaimed to be the first major one that welcomes travelers and vehicles coming from the southern part of the country to the state capital of Kwara, which has a big roundabout with different roads connecting villages and other areas.

Eyenkorin falls in the basement complex terrain of Nigeria, which is of Precambrian to lower Paleozoic in age [18, 19]. This Precambrian crystalline basement complex consists gneisses and migmatities; metasediments (that is, schists, quartzizes and metavolcanics; and Pan-African (older) granite and late-stage minor pegmatitic and aplitic intrusives [20]. According to Olasehinde et al. [21], Eyenkorin, a suburb of Ilorin is situated on the undifferentiated Precambrian Basement Complex rocks of granitic and metamorphic origin. These rocks represent the deeper, fractured aquifer which is partly overlain by a shallow, porous aquifer within the lateritic soil cover [22]. The rock units form part of the regional South Western highlands of Nigeria running NW-SE parallel to the River Niger [21, 23]. The subsurface comprises the weathered, slightly weathered and fresh (fractured or unfractured) crystalline basement rocks. The oldest rocks in the area comprise gneiss complex whose principal member is biotite-hornblende gneiss with intercalated amphibolites. Other rock types are the older granite mainly porphiritic granite, gneiss and granite-gneiss and quartz schist [24].

3. MATERIALS AND METHODS

The groundwater assessment study in Eyenkorin was done by using geophysical and hydro-physicochemical approach. Ten Vertical Electrical Sounding (VES) data during the rainy season were acquired beside the ten wells that were used for this study. This number is as a result of the availability of dug wells and accessibility in the study area. VES was done in order to know the possible depth at which groundwater could be exploited with high yield in Eyenkorin. It is also done so as to determine the lithologic variations of the rocks in the study area which could have effect on the quality of water in the study area. Partial curve matching was performed on the field data using log-log paper in order to determine the lithologic trend on the field and to obtain the initial layers parameters. WinResist, an iterative Computer programme was further used on the field data to generate the final layers parameters (VES curves), which was used for hydrogeologic characterization in this study. One of the applications of VES in this present study is to assess the vulnerability of the aquifers' overburden against contaminants based on Adagunodo and Sunmonu [25].

The current electrode spacing (AB) of the Schlumberger configuration [26] used varied from 46 to 75 m. The principle governing the Schlumberger configuration for groundwater exploration has been reported in Sunmonu et al. [27], [28], [29], Adagunodo et al. [30], [31] and [32].

The water samples used for physicochemical analysis were collected from these ten hand-dug wells at the peak of rainy season when the water table would have been increased and serves as the season of optimum yield for hand-dug wells in the rural areas. The water sample in each location was collected in a well-drained 2 litre polythene bottle that has been rinsed with distilled water. Each bottle was rinsed out with same water sample from each dug-well at the point of collection, which was corked immediately after the sample has been collected. All the samples were transported to the laboratory same day for analysis. Prior to preservation, parameters such as colour, taste, odour, pH, temperature, turbidity and conductivity were determined as listed in Table 2. The remaining samples were acidified with dilute nitric acid and stored in a refrigerator prior to analysis. Other physical parameters that were determined after the preservation include Total Solids (TS), Total Dissolved Solids (TDS), Suspended Solids (SS), Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Total Hardness (TH), while the determined chemical parameters (cations and anions) are Fe^{2+}, Pb^{2+}, Cu^{2+}, Zn^{2+}, Mg^{2+}, Ca^{2+}, K^{+}, Na^{+}, SO_4^{2-}, NO_3^{-} and Cl^{-}. Analysis of all the parameters was done based on the various standard methods for water analysis [33 – 35]. The method employed for each water analysis has been summarized in Table 2. The results of the two approaches are presented as Figures and Tables.

4. RESULTS AND DISCUSSION

The results of VES data were presented as curves as shown on Fig. 1a – j. Six of the modeled curves are H-type, two are KH-type, while the remaining two are AA-type and QH-type each. Depth to bedrock of the interpreted VES ranged from 6.1 to 23.2 m, the depth to water table of the investigated wells ranged from 2.7 to 7.6 m, and the water column thicknesses ranged from

1.6 to 4.1 m. The aquifer vulnerability assessment of the present study revealed that the aquifers in Eyenkorin are highly confined apart from VES 2 and VES 5 that could permit contamination from anthropogenic sources.

From the reconnaissance survey before the data acquisition was carried out, it was noticed that some of the hand-dug wells used for the study were associated with low yield during dry season. This has led to investigating the viability of groundwater prospects in Eyenkorin using Sunmonu et al. [27] and [28] models. It was discovered that 70% of the wells have moderate yield of groundwater at depth ranging from depth of 40 to 50 m. 20% are associated with poor yield of groundwater with a depth of about 80 m while only 10% are associated with good yield of groundwater in the study area (Table 1). The wells yield problem in the dry season has been linked with the depth at which the water was being tapped in the study area. This implies that borehole would have been more productive in Eyenkorin than hand-dug well that easily dries off when the water table lowers.

The various parameters tested for in the sampled wells were presented in Table 1. The World Health Organization (WHO) [36], United State Environmental Protection Agency (USEPA) [37], and the Nigerian Standard for Drinking Water Quality (NSDWQ) [38] guidelines were used for assessing the potability of groundwater in Eyenkorin. The primary purpose of water analysis is to determine the suitability of water for the proposed use. Thus, the physical and chemical characteristics of groundwater determine its quality and utilization. The potability of water for domestic purpose is required to meet certain safety standard, which have been set by either WHO, USEPA, NSDWQ or other local health institutions. The potability of water for domestic use most of the time depends on the geographical location. The inhabitants of low salinity water areas would probably find small amounts of salts distasteful while dwellers of more arid areas have higher tolerance limits. Acceptability of water for domestic uses is influenced by its physicochemical parameters [12]. Values of Fe^{2+} in well 4, well 5, well 6 and well 8 are higher than WHO standard but lower than USEPA standard (Table 2). It was also observed that only well 9 was exempted from being higher than NSDWQ standard for Fe^{2+}. The source of Fe^{2+} in water is chiefly through the weathering processes (such as weathered magnetites, biotites and amphiboles). This is revealed from the conductive weathered layer of each VES curve, which depicts the presence of shallow aquifer where the water has been tapped from the dug wells. This is in agreement with the work of Ojoawo and Adeniran [7], which was done few kms away from the study area. K^+ values for well 4, well 5 and well 8 are higher than WHO standard. High concentration of K^+ in water could be from both geogenic and anthropogenic sources. Potassium enters a clayey zone slowly during the weathering processes in a granitic terrain [39]. K^+ could find its way to the groundwater body through the leachates of potassium based fertilizers (such as N-P-K fertilizers), since agriculture is the dominant occupation of the dwellers in the study area. From another perspective, it could also be due to the distances of the polluted wells to the waste dumps or latrines as revealed in Table 1. This present study is in agreement with the work of Olagunju et al. [9]. NO_3^- values at well 3 and 7 only fall below USEPA standard of 10 mg/L, while other locations were above the limit. When compared with WHO standard, well 4 and well 5 are higher than the NO_3^- constituent allowed to be present in potable water. By using NSDWQ standard, it was observed that well 4 and well 5 values are higher than the limit. High concentration of NO_3^- in groundwater is as a result of anthropogenic activities [6]. It could be attributed to the contamination from human wastes and agricultural practices (application of fertilizers) in the study area. This is in agreement with the result of Olafisoye et al. [5]. For TDS, only well 3 and well 5 were below USEPA standard, while none exceeded WHO standard. From another perspective, well 3 and well 7 only showed lower limit than NSDWQ standard, others were higher than the TDS threshold. The Electrical Conductivity (EC) of well 5 was found to be higher than the WHO standard, while well 4, well 5 and well 8 showed greater limit than NSDWQ standard. High concentrations of TDS and EC in water signify the presences of inorganic salts, which could be the contributions of Ca^{2+}, Mg^{2+}, K^+, Cl^- and SO_4^{2-} among others [9]. It could also result from the anthropogenic activities in the study area. Pure water is associated with low conductivity. The conductivity of water increases as the dissolved ionic constituent increases. Usage of such water for domestic activities without necessary treatment could provoke serious health hazard [6]. Anomalously strong agreement between the TDS and EC could also be linked with the gradual weathering processes of the basement rocks [5]. Anomalously high values recorded from well 4, well 5 and well 8 have been attributed to contamination from anthropogenic sources because from Table 1, the remark showed that well 4 is 2 m away from domestic effluent, well is 4 m away from dumpsite, while well 8 is 5 m away from pit latrine. Furthermore, the higher concentration of TDS recorded in almost all of the wells based on USEPA [37] standard could be a reflection of gradual weathering of basement rocks (geoegnic contamination) since the study area is in crystalline basement terrain. The geometric mean values of all the analyzed parameters showed that Fe^{2+} and K^{+} were higher than the WHO standard, Fe^{2+}, K^{+}, TDS and NO_3^{-} exceeded the USEPA standard, while Fe^{2+} and TDS were higher than the NSDWQ standard. Other parameters showed lower values than the regulated standards. High concentrations of Fe^{2+} in domestic water have been linked with rust forming colour which stains the kitchen utensils [40]. Tiwari et al. [41] also reported that it could cause serious health challenges in humans. When K^{+} is higher than the required limit in domestic water, it causes chest pain and nausea to the users [38]. High concentrations of NO_3^{-} could result to cyanosis and asphyxia (blue-baby syndrome in infants under 3-months) [38], it is also unhygienic to be consumed by the pregnant women [40]. Presence of TDS than the required limit could result to scaling in pipes and aluminum/iron materials used for cooking in the kitchen [40]. Its higher concentration in domestic water could also lead to gastro intestinal disorder, taste and stain to fabrics. The cation and anion results are in the order $Ca^{2+} > K^{+} > Mg^{2+} > Na^{+} > Zn^{2+} > Fe^{2+} > Cu^{2+} > Pb^{2+}$ and $Cl^{-} > NO_3^{-} > SO_4^{2-}$ respectively.

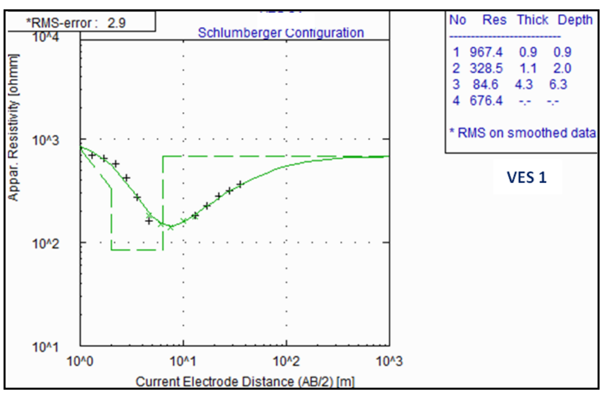

Fig. 1a. Modeled curve for VES 1.

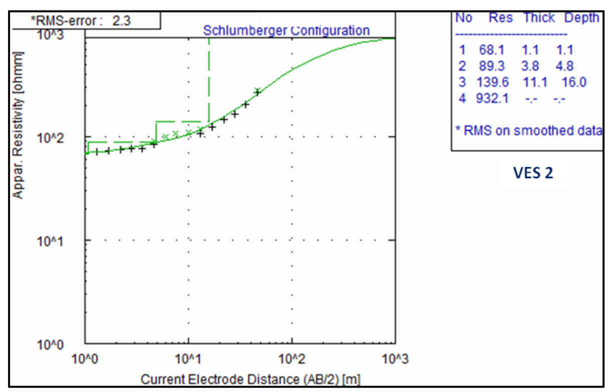

Fig. 1b. Modeled curve for VES 2.

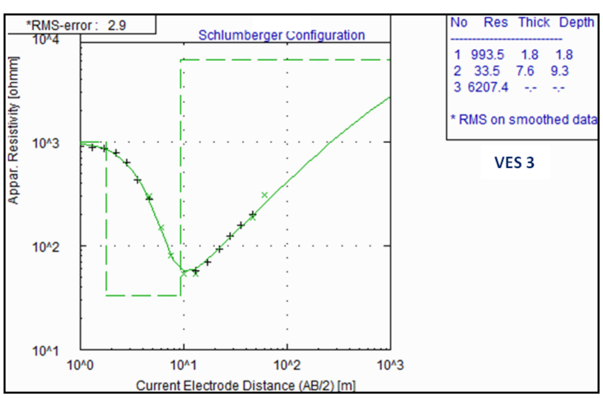

Fig. 1c. Modeled curve for VES 3.

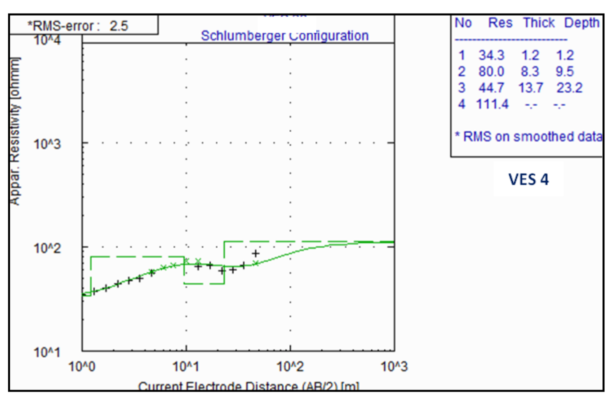

Fig. 1d. Modeled curve for VES 4.

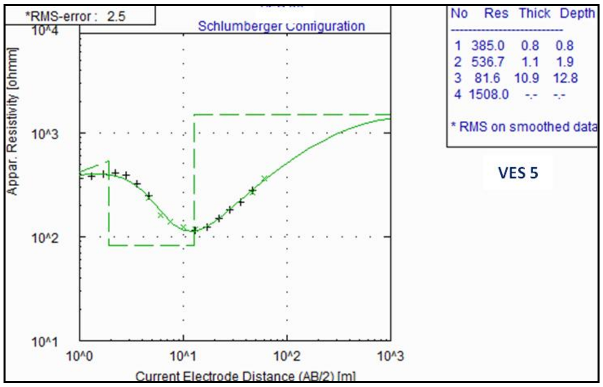

Fig. 1e. Modeled curve for VES 5.

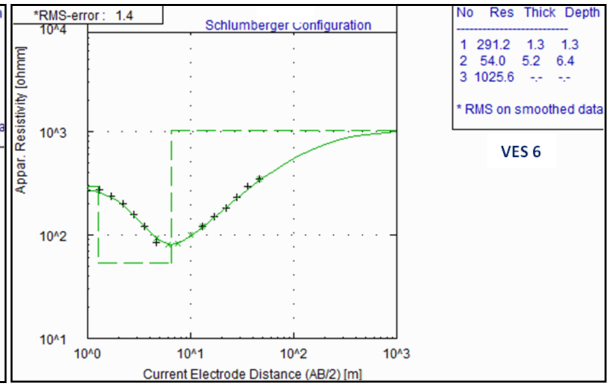

Fig. 1f. Modeled curve for VES 6.

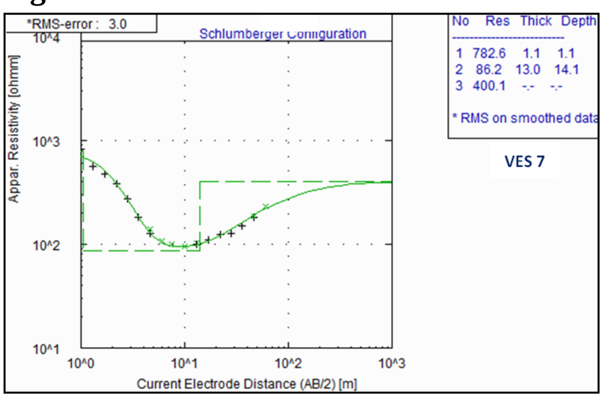

Fig. 1g. Modeled curve for VES 7.

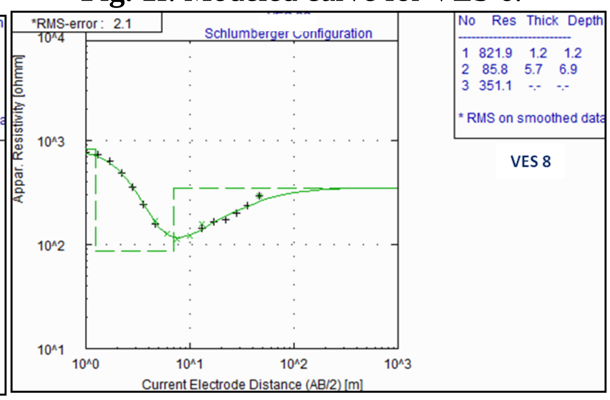

Fig. 1h. Modeled curve for VES 8.

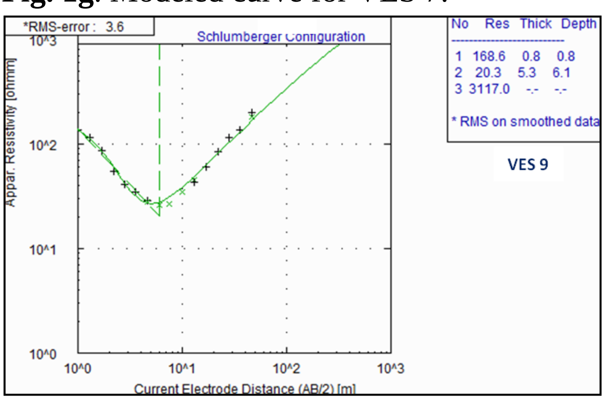

Fig. 1i. Modeled curve for VES 9.

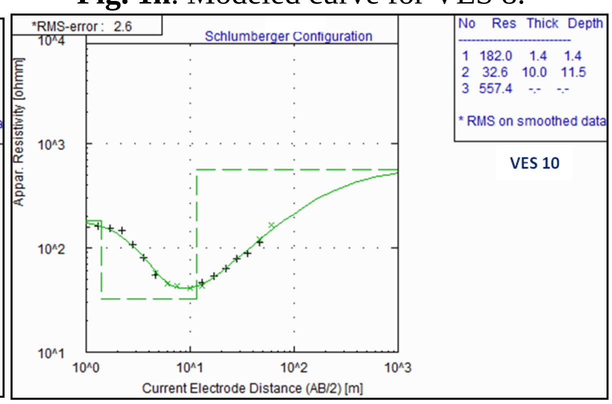

Fig. 1j. Modeled curve for VES 10.

Table 1. Physical and chemical characteristics of analyzed water in Eyenkorin during the rainy season

Parameters	W 1	W 2	W 3	W 4	W 5	W 6	W 7	W 8	W 9	W 10	Mean	Range
Depth to the water table (m)	2.9	3.3	5.1	7.6	5.5	3.2	5.9	3.7	2.7	4.1	4.4	2.7–7.6
Water Column (m)	2.1	1.6	2.6	3.6	4.1	2.6	3.9	2.4	2.1	3.7		1.6-4.1
Depth of wells (m)	2.9	3.3	5.1	7.6	5.5	3.2	5.9	3.7	2.7	4.1		2.7-7.6
Overburden thickness from VES	6.3	16.0	9.3	23.2	12.8	6.4	14.1	6.9	6.1	11.5	11.3	6.1–23.2

(m)												
Curve type from VES (m)	QH	AA	H	KH	KH	H	H	H	H	H	-	-
Groundwater Prospectivity depth (m) Based on Sunmonu et al (2012) and (2015)	Moderate yield (depth ranging from 50 to 60)	Poor yield (depth ranging from 40 to 50).	Moderate yield (depth ranging from 40 to 50)	Good yield (depth ranging from 40 to 50)	Moderate yield (depth ranging from 50 to 60)	Moderate yield (depth ranging from 40 to 50)	Moderate yield (depth ranging from 40 to 50)	Moderate yield (depth ranging from 40 to 50)	Poor yield (depth of up to 80)	Moderate yield (depth ranging from 40 to 50)	-	-
Colour	**Cl, Co**	**Cl, Co**	**Cl, Co**	**Cl, Co**	**Cl, Co**	**Cl, Co**	**Cl, Co**	**Cl, Co**	**Cl, Co**	**Cl, Co**	-	-
Taste	**Ta**	**Ta**	**Ta**	**St**	**St**	**Ta**	**Ta**	**St**	**Ta**	**Ta**	-	-
Odour	**Od**	**Od**	**Od**	**Od**	**Uo**	**Od**	**Od**	**Uo**	**Od**	**Od**		
pH	6.9	7.3	7.1	7.4	7.8	7.1	6.9	7.9	7.2	6.9	7.3	6.9-7.9
Temperature (^{0}C)	27.3	26.5	27.1	28.4	28.6	27.1	26.9	29.0	28.1	27.9	27.7	26.9-29.0
Fe^{2+} (mg/L)	0.5	0.8	1.0	2.6	4.2	1.5	1.0	2.1	0.2	0.6	1.5	0.2-4.2
Pb^{2+} (mg/L)	0.0	0.0	0.002	0.004	0.004	0.0	0.0	0.001	0.0	0.001	0.001	0.0-0.004
Cu^{2+} (mg/L)	0.0	0.2	0.1	0.4	0.9	0.0	0.0	0.5	0.0	0.0	0.2	0.0-0.9
Zn^{2+} (mg/L)	1.1	1.1	1.9	2.5	2.6	1.5	1.9	2.0	1.4	1.1	1.7	1.1-2.6
K^+ (mg/L)	13.2	10.0	11.3	30.5	45.2	10.2	11.5	27.3	10.5	6.5	17.6	6.5-45.2
Na^+ (mg/L)	3.6	6.6	6.4	6.1	7.1	9.2	3.3	9.0	1.4	4.4	5.7	1.4-9.2
Mg^{2+} (mg/L)	10.6	5.9	13.8	19.2	35.0	10.5	10.6	20.0	8.4	11.6	14.6	5.9-35.0
Ca^{2+} (mg/L)	40.0	40.0	35.6	5.2	8.3	19.2	36.8	4.1	33.5	37.8	26.1	4.1-40.0
Cl^- (mg/L)	10.6	15.8	8.5	49.5	65.5	28.0	26.2	67.2	25.0	42.5	33.9	8.5-67.2
SO_4^{2-} (mg/L)	5.2	1.7	0.5	8.7	15.6	1.5	1.2	10.5	4.8	3.6	5.3	0.5-15.6
NO_3^- (mg/L)	13.0	14.0	0.5	50.2	66.9	13.0	7.5	43.0	11.0	12.5	23.2	0.5-66.9
TS	1100	1059	1115	1530	1790	1000	878	1400	790	1020	1168.2	790-1790
TDS	860	520	230	950	805	610	417	700	550	590	623.2	230-950
SS	1000	1000	700	1100	1450	860	750	920	690	1000	1009.3	690-1450
DO	98.2	76.5	85.7	85.0	100.0	88.0	75.0	89.0	50.2	68.3	81.6	50.2-100.0
BOD	1.5	0.8	0.2	5.5	6.9	1.8	2.6	4.7	1.0	1.5	2.7	0.2-6.9
COD	0.6	0.2	0.5	4.5	7.8	2.4	1.3	5.0	2.0	1.9	2.6	0.2-6.9
TH	49.0	45.0	49.0	75.0	92.5	55.5	52.0	83.4	50.0	49.0	60.0	45.0-92.5
Turbidity	0.0	0.5	0.6	1.9	3.5	0.2	0.5	2.0	0.0	0.9	1.0	0-3.5
Conductivity ($mScm^{-1}$)	0.56	0.38	0.95	1.00	1.53	0.49	0.17	1.28	0.19	0.91	0.75	0.17-1.53
Remarks	-	-	-	2 m away from domestic effluent	4 m away from dumpsite	-	-	5 m away from pit latrine	-	-	-	-

Cl = Clear; Co = Colourless; Ta = Tasteless; Od = Odourless; St = Salty taste; Uo = Undesirable odour

Table 2. Summary of the results of the method employed and standards of potable drinking water

Parameters	Method Employed	WHO (2006)	USEPA (1976)	NSDWQ (2007)	Present Study
Colour	Manual	Cl, Co	Cl, Co	Cl, Co	Cl, Co
Taste	Manual	Utc	Utc	Utc	Ta, St
Odour	Manual	Utc	Utc	Utc	Od, Uo
pH	pH meter (APHA 4500 – H)	6.8 – 8.5	5.0 – 9.0	6.5 – 8.5	7.3
Temperature (°C)	Thermometer	24.5 – 39.7	-	Ambient	27.7
Fe^{2+} (mg/L)	Atomic absorption spectrophotometry (APHA 3120 - B)	1.0	300	0.3	1.5
Pb^{2+} (mg/L)	Atomic absorption spectrophotometry (APHA 3120 - B)	1.05	-	0.01	0.001
Cu^{2+} (mg/L)	Atomic absorption spectrophotometry (APHA 3120 - B)	1.5	-	1.0	0.2
Zn^{2+} (mg/L)	Atomic absorption spectrophotometry (APHA 3120 - B)	4.0	-	3.0	1.7
K^{+} (mg/L)	Atomic absorption spectrophotometry (APHA 3500 - KB)	15	-	-	17.6
Na^{+} (mg/L)	Atomic absorption spectrophotometry (APHA 3500 - NaB)	200	-	200	5.7
Mg^{2+} (mg/L)	Atomic absorption spectrophotometry (APHA 3500 - MgB)	150	-	0.20	14.6
SO_4^{2-} (mg/L)	Spectrophotometry (APHA 4500 SO_4 B)	400	25	100	5.3
NO_3^{-} (mg/L)	Spectrophotometry (APHA 4500 NO_3 B)	50	10	50	23.2
Suspended Solids (mg/L)	Spectrophotometry (APHA 2540 - D)	30	-	-	1009.3
Total Dissolved Solids (mg/L)	Gravimetry (APHA 2540 - B)	1000	500	500	623.2
Cl^{-} (mg/L)	Titrimetry (APHA 4500 - B)	600	250	250	33.9
DO (mg/L)	Titrimetry (APHA - O)	-	-	-	81.6
BOD (mg/L)	Titrimetry (APHA 5210 - B)	10	-	-	2.7
COD (mg/L)	Titrimetry (APHA 5220 - B)	40	-	-	2.6
Total Hardness (mg/L)	Titrimetry (APHA 2340 - B)	500	-	150	60.0
Turbidity (mg/L)	Turbidimeter (APHA 2130 - B)	5.0	-	5.0	1.0
Conductivity (µS/cm)	Conducting meter (APHA 2510 - B)	1500	-	1000	750

Cl = Clear; Co = Colourless; Ta = Tasteless; Od = Odourless; St = Salty taste; Uo = Undesirable odour; Utc = Unobjectionable to consumer

5. CONCLUSION

A simple approach to water assessment for domestic uses through geophysical and physicochemical approaches has been presented. Since anomalously high values of Fe^{2+}, K^{+}, TDS and NO_3^{-} have been recorded in the sampled water, it is concluded that Eyenkorin well water is not totally safe for consumption without treatment. The interpretation of VES has revealed that the water was tapped from a conductive shallow aquifer (weathered layer), which has resulted to the elevated concentration of Fe^{2+} in the analyzed water from the physicochemical approach. Deep hand-dug well and borehole development are recommended in the areas of shallow sub-hydrologic basin. Boiling of water before drinking would also go a long way in reducing the incidence of cholera, Typhoid fever and other water borne diseases. Well should also be properly sited far from the sewage pits.

6. REFERENCES

[1] Bogaard T.A., Mkhandi S., Parida B.P. and Winsemius H.C. (2008). Water Resources Assessment in Sub-Saharan Africa: Prediction in Ungauged and Data Scarce Basins. *Training Course Report, Waternet Course*, 21 – 25 January, 2008, Dar es Salaam, Tanzania.

[2] Iduma R.E.O., Abam T.K.S., Uko E.D. (2017). Geostatistical study of the Spatial Variability of Groundwater Parameters in Afikpo and Ohaozara, Southeastern Nigeria. *International Journal of Water Resources and Environmental Engineering*, 9(4), 72 – 85.

[3] Oladejo O.P., Sunmonu L.A., Ojoawo A., Adagunodo T.A. and Olafisoye E.R. (2013). Geophysical Investigation for Groundwater Development at Oyo State Housing Estate Ogbomosho, Southwestern Nigeria. *Research Journal of Applied Sciences, Engineering and Technology*, 5(5), 1811–1815.

[4] Oladejo O.P., Sunmonu L.A. and Adagunodo T.A. (2015). Groundwater Prospect in a Typical Precambrian Basement Complex using Karous-Hjelt and Fraser Filtering Techniques. *Journal of Industrial Engineering Research*, 1(4), 40–49.

[5] Olafisoye E.R., Sunmonu L.A., Ojoawo A., Adagunodo T.A., Oladejo O.P. (2012), Application of Very Low Frequency Electromagnetic and Hydro-physicochemical Methods in the Investigation of Groundwater Contamination at Aarada Waste Disposal Site, Ogbomoso, Southwestern Nigeria. *Australian Journal of Basic and Applied Sciences*, 6(8), 401–409.

[6] Olafisoye E.R., Sunmonu L.A., Adagunodo T.A. and Oladejo O.P. (2013). Impact Assessment of Solid Waste on Groundwater: a Case Study of Aarada Dumpsite, Nigeria. *ARPN Journal of Earth Sciences*, 2(2), 45–53.

[7] Ojoawo A.I., Adeniran G.S. (2016). Geophysical and hydro-physicochemical analysis of groundwater quality at Gbede mining site, Ogbomoso South West Nigeria. International Journal of Scientific and Engineering Research, 7(8): 1156 – 1166.

[8] Ojo A.O., Oyelami C.A., Adereti A.O. (2014). Hydro-geochemical and geophysical study of groundwater in the suburb of Osogbo, South Western Nigeria. J.Earth Sci. Clim. Change, 5(6): 1000205. doi: 10.4172/2157-7617.1000205.

[9] Olagunju E., Ariyibi E., Awoyemi M., Adebayo A., Dasho O., Adenika C. (2017). Application of geochemical and geophysical approach to environmental impact assessment: a case study of Emirin active open dumpsite, Ado-Ekiti Southwestern Nigeria. Model. Earth System. Environ. doi: 10.1007/s40808-017-0381-1.

[10] Adekunle I. M., Adetunji M. T., Gbadebo A. M. and Banjoko O. B. (2007). Assessment of Groundwater Quality in a Typical Rural Settlement in Southwest Nigeria. *Int. J. Environ. Res. Public Health*, *4(4)*, 307-318.

[11] Onweluzo J. C. and Akuagbazie C. A. (2010). Assessment of the quality of bottled and sachet water Sold in nsukka town. *Agro-Science Journal of Tropical Agriculture, Food, Environment and Extension*: 9(2) 104 – 110.

[12] Chinedu S.N., Nwinyi O.C., Oluwadamisi A.Y. and Eze V.N. (2011). Assessment of water quality in Canaanland, Ota, Southwest Nigeria. *Agric. Biol. J. N. Am*., 2(4): 577 – 583.

[13] Etim E.E., Odoh R., Itodo A.U., Umoh S.D. and Lawal U. (2013). Water quality index for the assessment of water quality from different sources in the Niger Delta region of Nigeria. *Frontiers in Science*, 3(3): 89 – 95.

[14] Sunmonu L.A., Olafisoye E.R., Adagunodo T.A., and Alagbe O.A. (2013). Geophysical and Hydro-physicochemical Evaluation of Hand-dug Wells near a Dumpsite in Oyo State, Nigeria. *Archives of Applied Science Research*, 5(6), 29–40.

[15] Olatunji J.A., Odediran O.A., Obaro R.I. and Olasehinde P.I. (2015). Assessment of groundwater quality of Ilorin metropolis using water quality index approach. *Nigerian Journal of Technological Development*, 12(1): 18 – 21.

[16] Zin M.S.M., Juahir H., Toriman M.E., Kamarudin M.K.A., Wahab N..A. and Azid A. (2017). Assessment of water quality status using univariate analysis at Klang and Juru river, Malaysia. J. Fundam. Appl. Sci., 9(2S), 93 – 108.

[17] Adagunodo T.A. (2017). Groundwater Contamination: Performance, Effects, Limitations and Control. Chapter 3 in Book: Groundwater Contamination: Performance, Limitations and Impacts, 1 – 135. ISBN: 978-1-153611-017-3; 978-1-53611-003-6. Editor: Anna L. Powell © 2017 Nova Science Publishers, Inc. Pp. 33 – 64.

[18] Rahaman MA (1976). Review of the Basement Geology of South-Western Nigeria. Geology of Nigeria (C.A. Kogbe, ed): *Elizabethan Publishing Co*. Lagos.

[19] Oluyide PO (1979). Report on the Igbeti Marble, Oyo State of Nigeria. *Report GSN*, 1569, (unpublished).

[20] Oluyide PO, Nwajide CS, Oni AO (1998). The Geology of the Ilorin Area. *Bulletin No. 42 of Geological Survey of Nigeria*, Published by Federal Government of Nigeria.

[21] Olasehinde PI, Virbka P, Esan A (1998). Preliminary Results of Hydrogeological Investigations in Ilorin area, South Western Nigeria – Quality of Hydrochemical Analysis. *Water Resour. J. Natl. Assoc. Hydrogeol*. 9:51-61.

[22] Annor AE, Olasehinde PI (1996). Vegetation Niche as a Remote Sensor for Subsurface Aquifer: A Geological-Geophysical Study in Jere Area, Central Nigeria. *Water Resour. J. Natl. Assoc. Hydrogeol*. 7(1&2):26-30.

[23] Offodile ME (1987). An Approach to Groundwater Study and Development in Nigeria. Published by Mecon Services Ltd, Jos, Nigeria.

[24] Sule B.F., Balogun O.S. and Muraina L.B. (2013). Determination of hydraulic characteristics of groundwater aquifer in Ilorin, North Central Nigeria. *Scientific Research and Essays*, 8(25): 1150 – 1161.

[25] Adagunodo T.A. and Sunmonu L.A. (2012). Geoelectric Assessment of Groundwater Prospect and Vulnerability of Overburden Aquifers at Adumasun Area, Oniye, Southwestern Nigeria. *Archives of Applied Science Research*, 4(5), 2077–2093.

[26] Koefoed O. (1979). Geosounding Principle I. Resistivity Sounding Measurements. Amsterdam: Elsevier Scientific Publishing.

[27] Sunmonu L.A., Adagunodo T.A., Olafisoye E.R. and Oladejo O.P. (2012), The Groundwater Potential Evaluation at Industrial Estate Ogbomoso Southwestern Nigeria. *RMZ-Materials and Geoenvironment*, 59(4), 363–390.

[28] Sunmonu L.A., Adagunodo T.A., Adeniji A.A., Oladejo O.P. and Alagbe O.A. (2015). Geoelectric Delineation of Aquifer Pattern in Crystalline Bedrock. *Open Transactions on Geosciences*. 2(1) 1–16.

[29] Sunmonu L.A., Adagunodo T.A., Bayowa O.G. and Erinle A.V. (2016). Geophysical Mapping of the Proposed Osun State Housing Estate, Olupona for Subsurface Competence and Groundwater Potential. *Journal of Basic and Applied Research*, 2(2), 27–47.

[30] Adagunodo T.A., Sunmonu L.A., Ojoawo A., Oladejo O.P. and Olafisoye E.R. (2013). The Hydro Geophysical Investigation of Oyo State Industrial Estate Ogbomosho, Southwestern

Nigeria Using Vertical Electrical Soundings. *Research Journal of Applied Sciences, Engineering and Technology*, 5(5), 1816–1829.

[31] Adagunodo T.A., Adeniji A.A., Erinle A.V., Akinwumi S.A., Adewoyin O.O., Joel E.S., Kayode O.T. (2017). Geophysical Investigation into the Integrity of a Reclaimed Open Dumpsite for Civil Engineering Purpose. Interciencia Journal, 42(11): 324 – 339.

[32] Adagunodo T.A., Akinloye M.K., Sunmonu L.A., Aizebeokhai A.P., Oyeyemi K.D., Abodunrin F.O. (2018). Groundwater Exploration in Aaba Residential Area of Akure, Nigeria. Frontiers in Earth Science, 6: 66. https://doi.org/10.3389/feart.2018.00066.

[33] ICMR (1975). Manual of standards of quality for drinking water supplies. *Indian Council of Medical Research*, Spe. Rep. No. 44.

[34] American society for testing and materials (1982). Standard methods for acidity or alkalinity of water. Publ.D1067-70 (reapproved 1977), *American soc. Testing and materials Philadelphia.Pa*.

[35] APHA (1992). American public health association, Standard Method of the Examination of Water and Wastewater.18th edition, Washington D. C, 1992.

[36] WHO (2006). Guidelines for drinking-water quality, First Addendum to 3rd ed. Recommendations, *World Health Organization, Geneva*.1:185-186.

[37] USEPA (1976). United States Environmental Protection Agency. National Interim primary Drinking Water Regulations, 4o CFR 141, *Environmental reporter* 132, 1-107.

[38] NSDWQ (2007). Nigerian Standard for Drinking Water Quality. Nigeria Industrial Standard, Approve by Standard Organization of Nigeria Governing Council. ICS 13.060.20: 15 – 19.

[39] McCurry P. (1976). The geology of PreCambrian to lower Palaeozoic rocks of Northern Nigeria – A review: In Kogbe, C.A. (Ed.) Geology of Nigeria – Elizabethan. Published Co. Lagos: Pp 436.

[40] Fatoba J.O., Sanuade O.A., Hammed O.S. and Igboama W.W. (2017). The use of multivariate statistical analysis in the assessment of groundwater hydrochemistry in some parts of southwestern Nigeria. Arab. J. Geosci., 10: 328. https://doi.org/10.1007/s12517-017-3125-7.

[41] Tiwari R.N., Shankar M., Prabhat P. (2013). Study of major and trace elements in groundwater of Birsinghpur Area, Satna District Madhya Pradesh, India. Academic Journals, 5(7): 380 – 386.

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