HYDROGEOPHYSICAL AND HYDROGEOCHEMICAL STUDY OF GROUNDWATER WITHIN RIDO COMMUNITY AREA IN KADUNA NORTHCENTRAL NIGERIA.

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ABSTRACT

In this study, Very Low Frequency Electromagnetic Field (VLF-EM) method has been integrated with hydrogeochemical method to characterise the aquifers in the study area and also to determine the extent of groundwater pollution in the region. For the VLF-EM, a total of 12 traverses were established in the W–E directions, with traverse lengths of 200 m (although one of the traverses was 360m) with regular station intervals of 20 m. A total of 128 station positions were occupied for VLF-EM profiling using the Scintrex-EM equipment. And for the Hydrogeochemical analyses, 12 water points (boreholes and wells) were sampled for physiochemical analyses. Ultimately, the Inphase, Quadrature, Fraser Filter profiles and the Karous Hjelt pseudo sections from the VLF-EM survey of the area revealed high groundwater potential in the area. The VLF-EM interpretation also shows that the soil and groundwater at shallow depth in some part of the area have been polluted. This is in line with the results from the physicochemical analysis which revealed that the soil and groundwater quality in the region have been affected by oil spillage and improper disposal of untreated effluents from petroleum products. Finally, from the results of Geophysical and Water Quality Analyses, the following recommendations are suggested among other things; a total overhaul of environmental procedures of the refinery in Rido should be embarked upon. Also, there should be a clean-up and remediation of the Rido ecosystem, plus a welfare/rehabilitation project of the host community-Bioremediation and Phyto-remediation should be employed.

KEYWORDS: *VLF-EM, Quadrature, Fraser Filter, Karous Hjelt Filter, Physicochemical Analyses, Rido*

1.0 INTRODUCTION

The history of petroleum exploration, exploitation, refining and marketing in Nigeria is a long, complex and painful one in terms of soil and groundwater pollution, which has resulted to multiple environmental and health problems. In present scenario, due to industrialization and increased population, drains in Nigeria carry the industrial and municipal effluents that ultimately carry the polluted water to the canals and rivers. The discharge of industrial effluents into water bodies is one of the main causes of environmental pollution and degradation in many cities in Nigeria, like other developing countries. This is because many of these industries lack liquid and solid waste regulations and proper disposal facilities. These wastes may be infectious, toxic or radioactive (WHO, 2004). Particularly, the activities of the industries have led to the release of heavy metals into the environment. And unlike the organic pollutants that are biodegradable, heavy ions are not easily degradable, thus making them a source of great concern. Through food chain, the heavy metals eventually accumulate in living organisms.

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Kaduna Refinery and Petro chemical Company refines crude oil by distillation process which involves the separation of crude oil into different hydrocarbon groups. The crude oil is subjected to various treatment and separation processes in order to remove undesirable constituents and improve on the product quality. According to Amadi et al (2014) the following heavy metals, Cd, Cr, Cu, Fe, Pb, Ni, Mo and Zn are utilized for blending of petroleum. Some of these heavy metals constitute the components of effluents dispersed off into surrounding streams, rivers and soils. The effluents leach into sub surface and may contaminate shallow aquifers.

Now, Residents of Kaduna South Local Government Area (where the study area is located) rely heavily on groundwater for domestic use, where over 80% of the populace in the local government area use tube wells or boreholes as water sources. Even in areas where pipe borne water is accessible, wells are used as a complimentary source. The scientific or technological control of these water sources by relevant Authority has been scarce, and this has led to a situation where water for domestic purpose, especially drinking water is not tested or treated and the resulting effect of this is outbreak of cholera and typhoid in the third quarter of year 2012 in Kaduna South Local Government area. Also the untreated industrial and municipal wastes in the area have created multiple environmental hazards for mankind, irrigation, drinking water and sustenance of aquatic life. The drainage water contains heavy metals in addition to biological contaminations. This water pollution will affect food in addition to groundwater contamination when used to irrigate crops and poses great risks to public health in the region

1.2 Location and Physiography

The area of study is located in Kaduna State. The area is Rido community which hosts the Kaduna Refinery and Petrochemical Company (KRPC) in Chikun LGA. The location map of the study area is shown in Figure 1. Kaduna state is located in the southern end of the high plains of northern Nigeria and bounded by latitude $9^{0}\,0'\,3''$ and $11^{0}\,3'\,2''$ N and longitude $6^{0}\,0'\,5''$ and $8^{0}\,4'\,0''$ E. The location of the VLF-EM profiles in the study area is given in Figure 2.

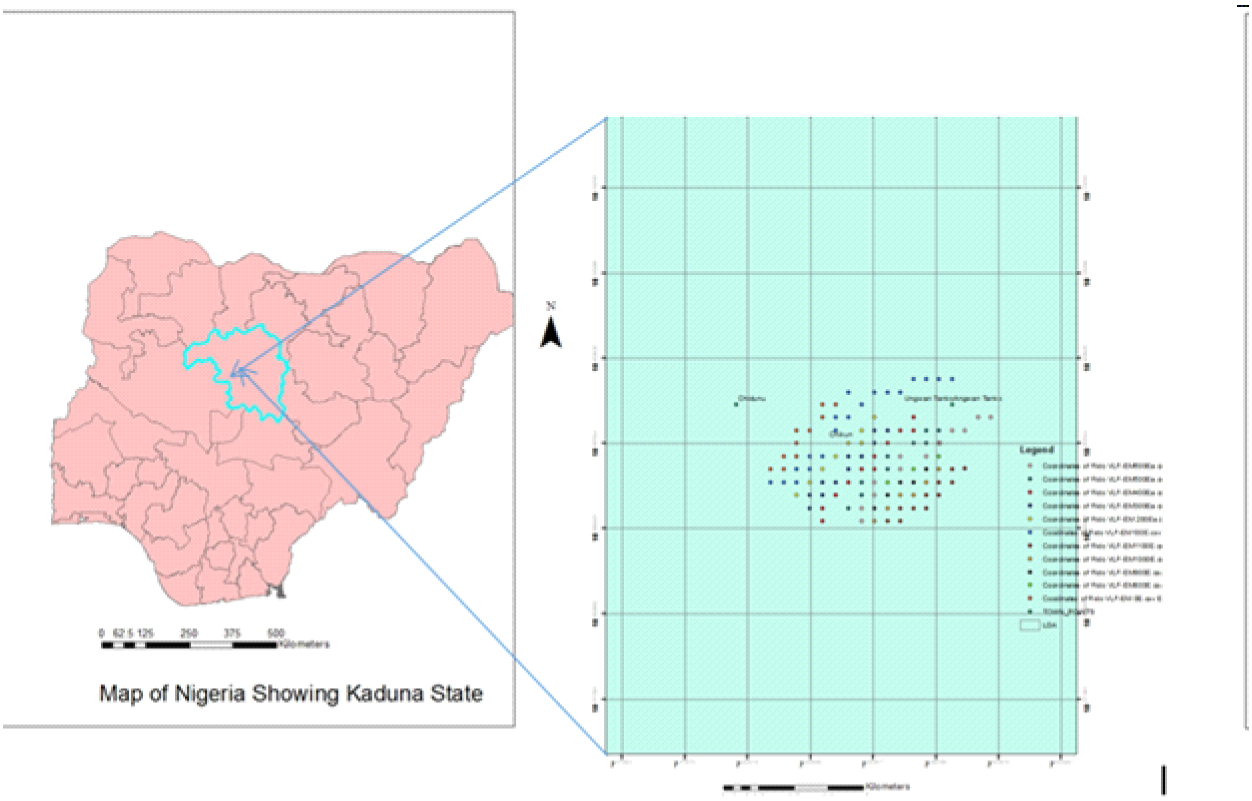

Figure 1 Map of Nigeria Showing Rido in Kaduna State with the VLF-EM Profile Points

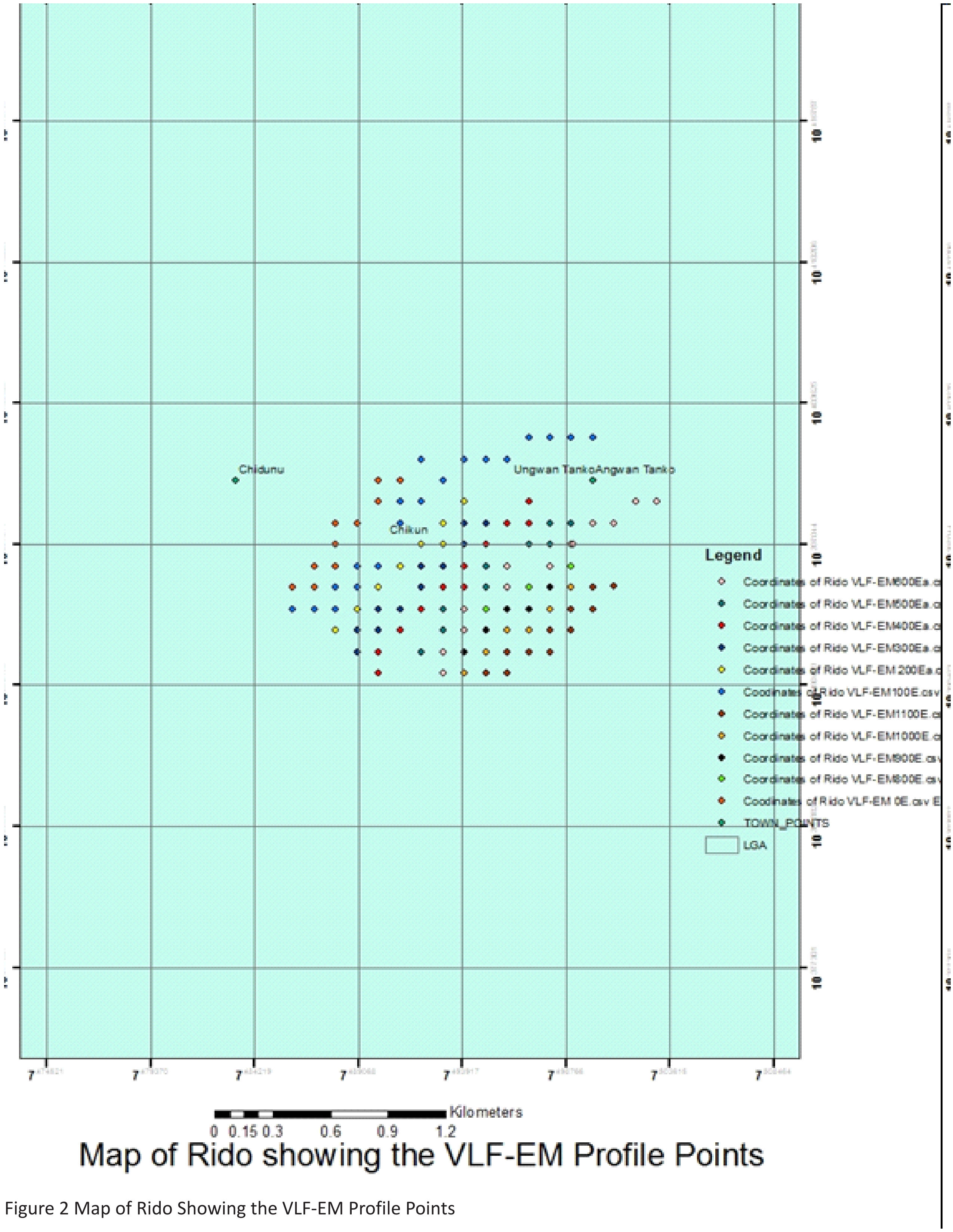

Figure 2 Map of Rido Showing the VLF-EM Profile Points

1.3 BASIC PRINCIPLES

1.3.1 Very Low Frequency Electromagnetic Method (VLF-EM)

The VLF method is an inductive exploration technique that is primarily used to map shallow subsurface structural features in which the primary EM wave induces current flow (Singha, 1990; Kaikkonnen, 1997). In principle, it utilises transmitters' wave source. The EM waves propagating into the ground from the source (Hp) induce electric currents in any subsurface conductor in their path. The induced current produces a secondary EM field (Hs). The vector sum of the primary field (Hp) and secondary field (Hs) produces the elliptically polarised field over time. These elliptically polarised fields consist of two components of the same frequency, but of different amplitudes and out of phase with each other. The amplitude of the component that is in phase with the primary field Hp is the tilt angle, which is the inclination of the major axis of the polarisation ellipse from the horizontal axis while the component that is out of phase with the primary field is the ellipticity. Ellipticity (e) is the ratio of the minor axis to the major axis of the polarisation ellipse (Okpoli and Tijani, 2016).

The VLF-EM technique makes use of remote radio transmitters operating in the bandwidth 15- 30 KHz, i.e. it uses very low frequency (Ogilvy et al, 1991). A worldwide network of high power VLF stations are available and are planned such that at least two stations can be detected anywhere on the earth surface (Telford et al, 1990). The signals from these stations can penetrate deep into the ground. And when they encounter large water bearing fractured zones in bedrock for example, they give rise to secondary radio waves which cause a disturbance or an anomaly in the electromagnetic field. In the presence of a conductor, the VLF is elliptically polarized. The method detects and measures tilt angle ? of the major axis of the polarization ellipse and its ellipticity (e) which is the ratio of the major to minor axis. It should be noted that,

Real (%) = 100 ? , where ? is in radians

Imaginary (%) = 100 tan ?

1.3.2 Hydrogeochemical Analysis

In groundwater quality study, there are 2 major types of analyses, viz chemical and bacterial. The measurements are usually carried out in group of determinands that together provide a good indication of specific aspects of the groundwater quality. Six commonly used analytical suites from which one can select those that are appropriate to one's study. These suites are (1) Field Parameters- Temperature ph, Eh, DO, EC and Alkanity (2) Major ions- Ca^{2+} mg^{2+}, Na^{+}, K^{+}, HCO^{2-}, Cal $^{-}$,SO_4^{2-}, NH_3^{-}, No_2 (3) Minor ions- Al^{3+}, Cd, Hg, As, I, Mo, Be, Cr N, Pb, Can, Sir, B, Cu, Br, L, Zn, Fe, Sib (4) Organic- TOC, COD, BOD, aromatic hydrocarbon, halogenated hydrocarbon, thematic chlorophenols. (5) Pesticides- Atrazine, Simazine, Mecocrop, et Isoproher, triallate etc. (6) Total coliform, faecal coliform, etc.

Note: Field measurement are additional to laboratory suites – suites 2 – 6 require laboratory measurements (Gilli et al, 2013)

2.0 CLIMATE, VEGETATION AND GEOMORPHOLOGY

Kaduna State lies within the Sudan Savanna, and consists of two seasons: dry and rainy, typical of a tropical continental climate. The average temperature and rainfall in the area are 38.2^0 and 1530mm respectively. The vegetation is characterized by grassland, with scattered trees and woody shrubs. The soils are reddish brown, typical of ferruginous soils. Rivers Kaduna and Romi and their tributaries are the major drainage features in the area. The tributaries generally are seasonal, as they dry up completely during the dry season. The drainage pattern is mostly dendritic which indicates absence of structural control over drainage lines.

3.0 GEOLOGY AND HYDROGEOLOGY

The study area consists mainly of the Migmatite- Gneiss Complex which consists of migmatite, biotites and granitic gneiss. The Migmatite-Gneiss Complex represents reactivated metasedments which are characterized by a variety of structures and textures. The Pan-African event (600±150M.a) was the latest reactivation that affected the whole region (Fitches et al, 1985), and it caused regional metamorphism and deformation which imposed a generally N-S foliation trend and brought about the emplacement of granitoids. The major rock type in the area of study comprises of Migmatite-Gneiss Complex that underlain most of the area. The metasedimentary series consists of undifferentiated schist, including gneiss, fine grained flaggy quartzite and pegmatites. These are metamorphosed sedimentary and metavolcanic rocks. The area is capped by laterites. The laterites are sometimes highly consolidated especially at the surface and weathered into lateritic nodules mixed with silty and sandy clays.

The Storativity and hydraulic conductivity of groundwater flow systems in the crystalline basement areas as in the area of study depend on the extent of development of secondary structural features such as the weathered overburden and fractures. These fractures tend to close with depth due to increasing weight of the overburden. In these areas groundwater therefore occurs either in the weathered mantle or fractured systems of the unweathered or partly weathered bedrock or both as these two aquifer types mostly interconnected in places culminating in groundwater basins. Due to differential weathering, these groundwater basins are often localized in such a way that it becomes desirable for a geophysical investigation to be carried out prior to drilling to locate them as accurately as possible to avoid abortive wells.

4.0 METHODOLOGY

4. 1 Very Low Frequency – Electromagnetic Method

4.1.1 Field Procedures

The Very Low Frequency EM method was used. The equipment was adjusted to get a good signal minimum for each station reading and the values of inphase, quadrature, tilt angle and total field were recorded for each station in a tabular form. Readings were taken at intervals (e.g. 20m interval) and this was best done by facing the west. A total of 12 traverses were established in the W–E directions, with traverse lengths of 200 m (although one of the traverses was 360m) with regular station intervals of 20 m. A total of 128 station positions were occupied for VLF-EM profiling using the Scintrex-EM equipment. VLF-EM equipment detects the ratio in percentage between the vertical and horizontal components of the EM signal. The primary field is horizontal.

4.1.2 Interpretation Procedures of VLF-EM Method

4.1.2.1 The KHFFILT program

This was used to interpret the VLF-EM data and it includes performing Fraser and Karous-Hjelt filtering on the data. In VLF method two orthogonal components of the magnetic field are measured, and normally the tilt angle, α, and ellipticity, e, of the vertical magnetic polarization ellipse are derived. Real (in-phase) and Imaginary (quadrature) components, however, are traditionally used in KHFFILT program. These components are based on the tilt angle and ellipticity as: Re= tan(α).100 % and In= e.100 %. From this one is able to get the following: Raw Real and Imaginary profiles, Fraser Filtered profiles and Karous Hjelt Psedosections (Karous and Hjelt, 983).

4.1.2.2 Data presentation

The raw real and imaginary components of the VLF-EM anomalies were plotted on the same axes using the Microsoft Excel and are presented as profiles. This double plot of the real and imaginary components enable qualitative identification of the top of linear features, i.e., points where they have opposite signs may indicate presence of a conductor. Also the plot of the filtered real component against distance is considered and the points of coincidence of crossovers of raw real and positive peaks of the filtered real also indicate the presence of a conductor

The VLF-EM raw real data were converted to the pseudo-section using the K–H filter. Visual inspection of this section allows the determination of depth of occurrence, width and dip of the body. The pseudo-section is a measure of the conductivity of the subsurface as a function of depth. The conductivity is shown as colour codes, with conductivity increasing from left to right (i.e. from negative to positive). Different features of varying degrees of conductivity trending in different directions were delineated on the section

4.2 Hydrogeochemical Analysis

The physico-chemical and microbial parameters were determined according to procedures outlined in the standard method for the examination of water and waste water (APHA, 1988). . The samples were collected in clean plastic bottles, with the sampling tools washed and dried before every sample was taken. The parameters that were analysed are those believed to have effects on water quality and referred to by WHO 2004. These parameters are electrical conductivity, suspended solids, dissolved solids, Ph, Dissolved Oxygen, Bio-chemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), oil and grease. Also, heavy metals like arsenic, barium, cadmium, chromium, lead, mercury, iron, selenium and silver were tested for Collection of water samples were done in the morning. These samples were collected using the grab method which means that samples are collected into clean 1.1 litre plastic bottles and are stored in ice box of 4^0C and then taken to the laboratory within 24hous for analysis. To collect, water samples, the pre-cleaned plastic bottles was lowered into the bottom of the water body, about 30cm deep and allowed to overflow before withdrawing.

5.0 RESULTS AND DISCUSSION

5.1 Very Low Frequency Electromagnetic (VLF-EM) Method of Rido Community

5.1.1 Data Presentation

The Interpretation of the VLF-EM survey carried out at Rido Community is presented as follow: Figures 3 to 5 show samples of the curves of the raw, Fraser Filter and Karous Hjelt Psedosections of the inphase data, while Figures 6 to 8 show samples of the curves of the raw, Fraser Filter and Karous Hjelt Pseudo section of the Quadrature data. And Figure 9 shows a sample of the double plot of the raw Inphase and the raw Quadrature values against Distance.

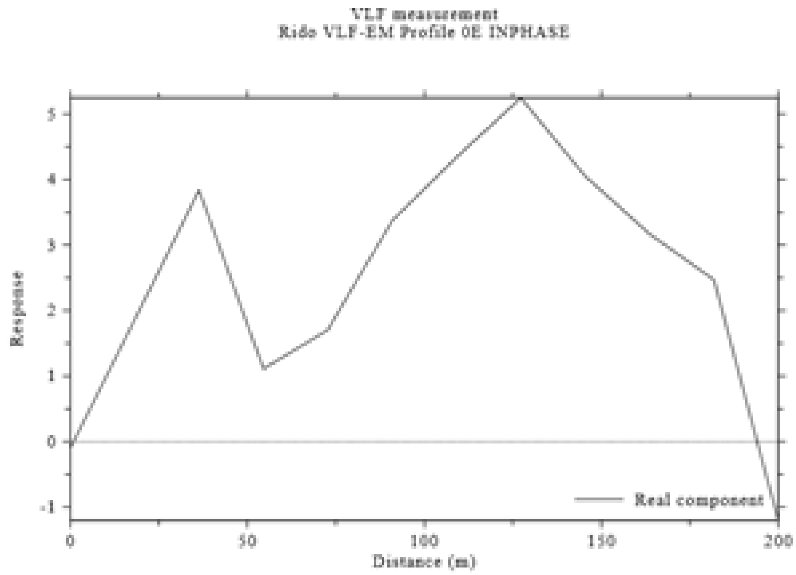

Figure 3 Rido VLF-EM Profile 0E Inphase

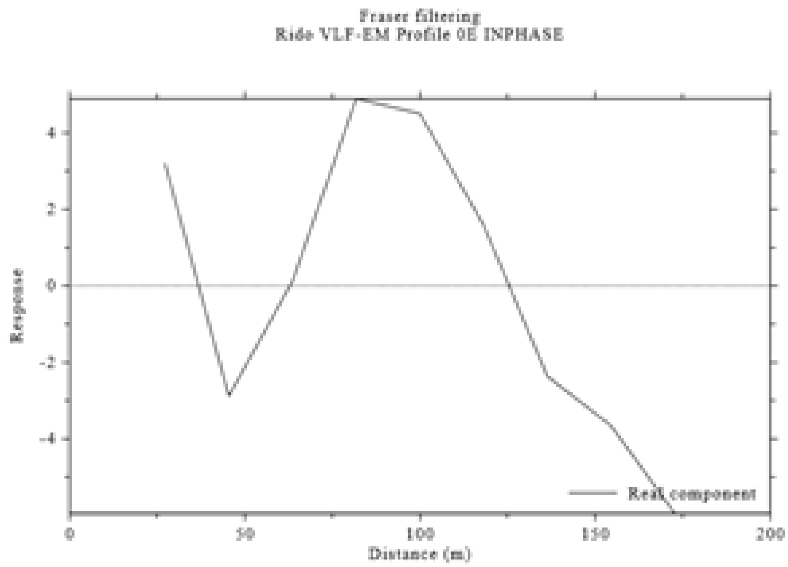

Figure 4 Rido VLF-EM Profile 0E Inphase-Fraser Filtered

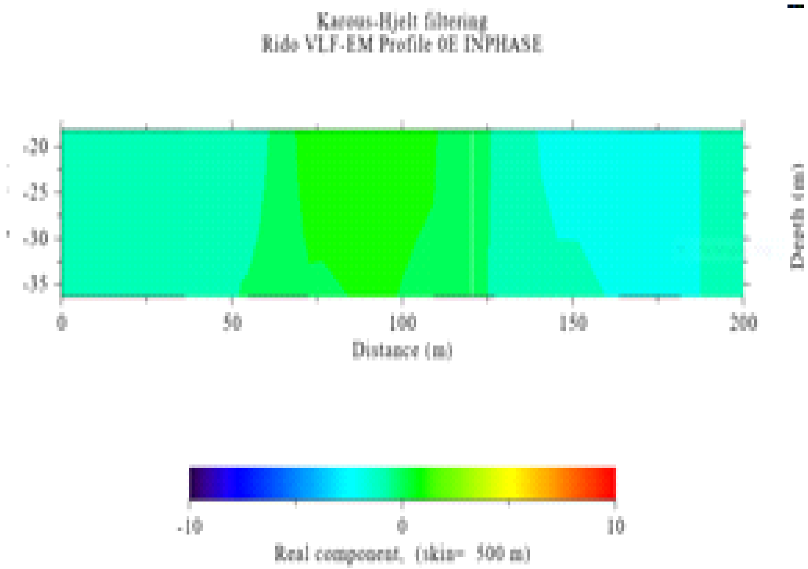

Figure 5 Rido VLF-EM Profile 0E Inphase- Karous- Hjelt Filtered

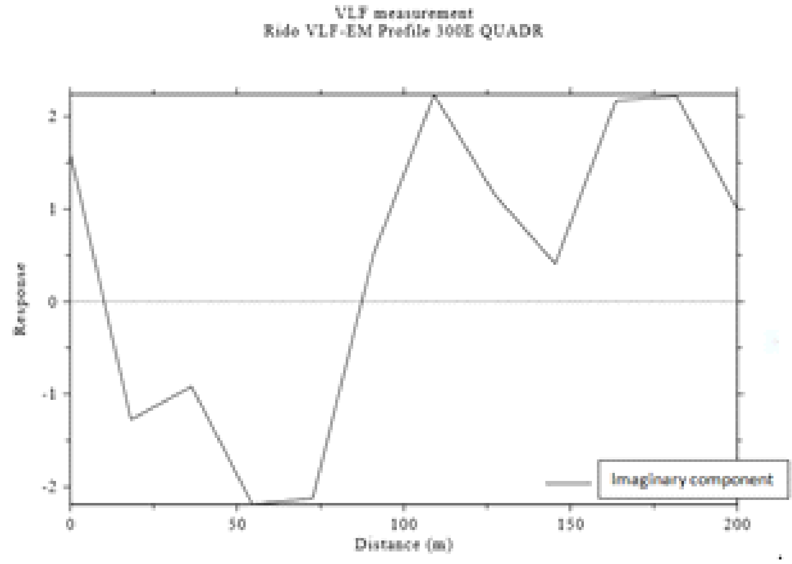

Figure 6 Rido VLF Profile 300E Quadrature

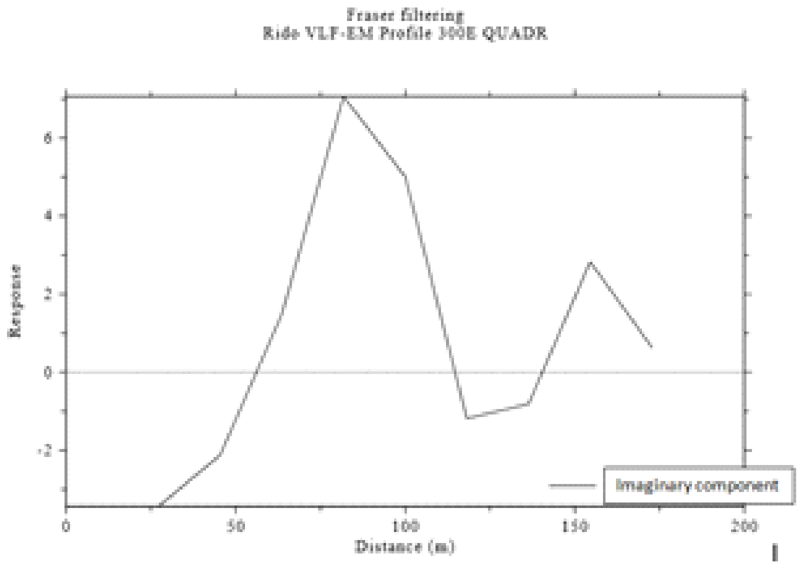

Figure 7 Rido VLF-EM Profile 300E Quadrature-Fraser Filtered

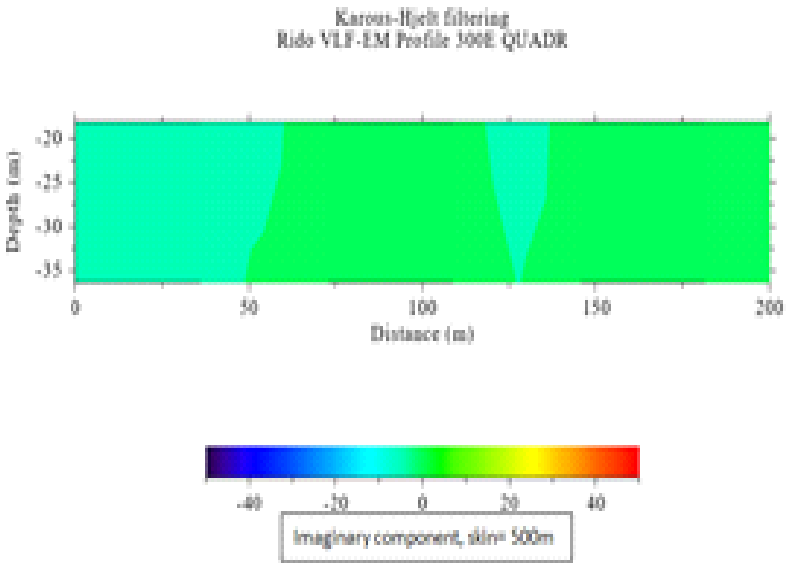

Figure 8 Rido VLF-EM Profile 300E Quadrature- Karous- Hjelt Filtered

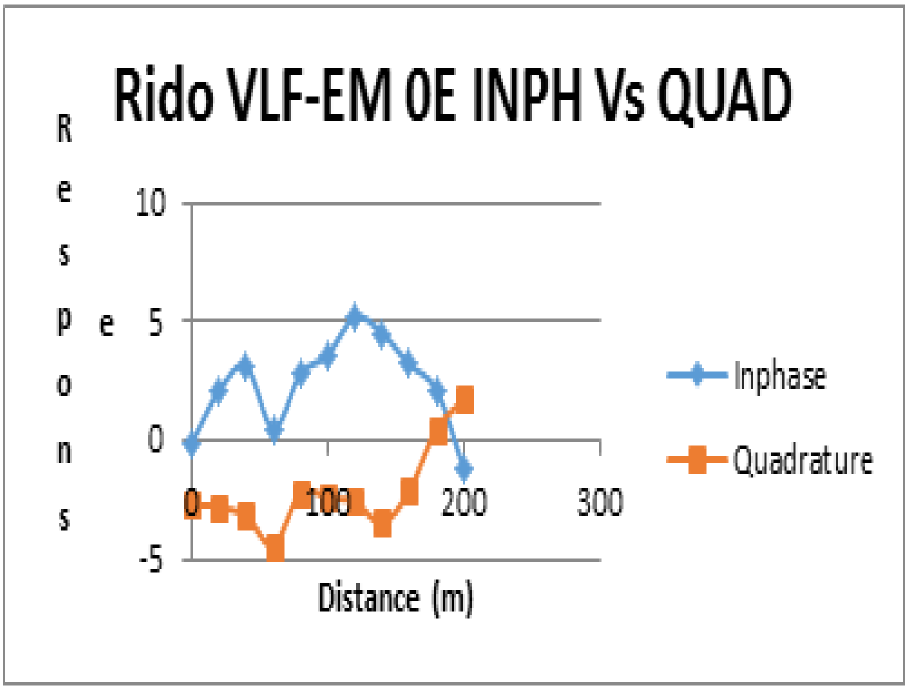

Figure 9 Plot of Inphase and Quadrature Vs Distance for Profile 0E

5.1.2 Data Interpretation

Table 1 shows the interpretation of the VLF-EM profiles, sections and curves

Note: CB-Conductive Body, SCB- Slightly Conductive Body, HCB- Highly conductive body, HRB- Highly Resistive Body

Table 1 Interpretation of the VLF-EM Profiles, Sections and Curves

Traverse Number	Distance Range of opposite sign of Inphase and Quadrature (m)	Crossover point (m)	Point of Fraser Filter Peak (m)	Sign of Fraser Filter Peak	Karous Hjelt Anomaly distance range (m)	Karous Hjelt Anomaly depth range (m)	Current Density of Anomaly	Remarks*
VLF-EM 0E	25-200	195	175	-ve	137-187	20-35	-ve Low	SCB
		-	50	-ve	0-60		-ve Low	SCB
			80	+ve	70-110		+ve Low	SCB
VLF-EM 100E	0-50	-	-	-	0-40		+ve Low	SCB
	25-62	65	70	-ve	70-75	20-30	-ve very Low	
							+ve Very High	HRB
	150-180	140	150	+ve	120-142	30-60	+ve Very High	
								HCB
	-	-	130	-ve	100-105	20-35	+ve high	
								HCB
							-ve Very High	
	-	210	225	+ve	213-280	20-35		CB
	-	310	310	-ve	300-350	20-45		
								HRB
VLF-EM 200E	10-30	10	-	-	0-30	20-35	-ve Low	SCB
		40	45	-ve	30-55	20-27	+ve low	SCB
					62-80	20-30	+ve Very High	
							-ve Low	HCB
	100-120	100	100	-	82-115	20-35		SCB
							+ve Very High	
	120-155	-	-	-	125-130	20-25	+ve High	
								HCB
				-	118-180	20-35		CB

VLF-EM 300E	0-13 85-145	- - - - - -	- 40 80 120 135 150	- -ve +ve -ve +ve +ve	0-25 30-60 75-100 110-118 120-135 140-187	20-35 20-35 20-30 20-27 20-35 20-37	+ve Low -ve Low +ve Very High -ve Low +ve High +ve Very High	SCB SCB HCB SCB CB HCB
VLF-EM 400E	20-90 90-130 140-165	- 90 130 -	- 95 135 -	- +ve -ve	0-75 85-100 125-135 120-188	20-35 20-30 20-30 20-35	+ve Low +ve Very High -ve Very High -ve Low	SCB HCB HRB SCB
VLF-EM 500E	30-39 140-200	- 25 100 148	- - 62 100 -	- - +ve -ve -	28-62 25-28 50-80 80-120 125-200	20-35 20-30 20-35 20-35 20-35	+ve Very High +ve Low +ve High -ve Very Low +ve Low	HCB SCB CB HRB SCB
VLF-EM 600E	10-25 50-70 110-138	25 - 70 135 -	- 40 70 130	- -ve -ve	15-20 50-60 62-85 87-120 125-168	20-35 20-22 20-32 20-35 20-35	+ve High +ve High -ve Very High +ve Low to Very High -ve Very High	CB CB HRB SCB to HCB HRB
VLF-EM 700E	90-110 115-125 115-140	90 140	80 125 30	-ve +ve +ve	83-90 115-125 105-150 110-125 15-35	20-30 20-27 20-35 20-27 20-35	-ve Very High +ve High +ve Low +ve High +ve High	HRB CB SCB CB CB
VLF-EM 800E	55-85 90-125	60 - 115	55 80 100	+ve -ve +ve	20-62 70-80 80-200 37-50	20-35 0-30 20-30 20-25 with a thin extension runs to 35m	+ve High -ve Low +ve Low +ve Very High	CB SCB SCB HCB
VLF-EM 900E	100-130	40 70 - 160	40 78 100 160	+ve +ve -ve -ve	37-60 68-80 100-115 125-130 140-149	20-35 20-30 20-27 20-22 20-35	+ve Low +ve Very High -ve Low +ve High -ve Low	SCB HCB SCB CB SCB

VLF-EM 1000	-	0	-	-	0-12	20-40	+ve Low	SCB
	20-60	-	25	-ve	12-50	20-40	+ve High	CB
		60	50	+ve	48-62	20-40	+ve Low	SCB
	60-140		115	-ve	62-130	20-40	+ve Low	SCB
	190-200	160	150	-ve	130-175	20-40	+ve Low	SCB
VLF-EM 1100					35-50	20-22 with a thin extension runs to 35m	+ve High	CB
						20-35		
						20-32		
	120-150	90	100	-ve	125-135		+ve Low	SCB
					135-170	20-22	+ve high	CB
					80-105		-ve Very High	HRB
						20-35	+ve Very High	
	160-180	150	150	+ve	140-155		+ve Very high	HCB
					172-188			HCB

5.1.2.1 Deductions from interpreted VLF-EM Data Interpretation

Four interpretation techniques were employed. These are (1) When the values of Inphase and Quadrature are plotted against distance, then it will be seen that the arithmetic signs of the inphase and quadrature components are different across a good conductor and are the same across a poor conductor (2) As the instrument passes perpendicularly over a vertical target the vector orientation changes from a maximum on one side to a minimum on the other side. The point at which the reading changes from positive to negative is termed the 'cross-over' point and lies directly above the conductor, therefore from the Inphase against Distance plot, the crossover points on each profile are determined and (3) The Fraser Filter was applied to the real component VLF data to transform the data set to the filtered real VLF data (Fraser, 1969). The filtered real transform every genuine crossover or inflection points of the real anomaly to positive peaks while reverse cross over become negative peaks (4) The Karous-Hjelt filter computes the approximate subsurface current density giving rise to a given profile of data, and the values are relative across the profile. The output of the Karous-Hjelt filter is relative current density versus surface position at a chosen depth. Lower values of relative current density correspond to higher values of resistivity. The input of Karous Hjelt filter is the Fraser filter. The results got from all these are harmonized to get the best picture of the subsurface in the area of study. Interpretations were done normally by considering the high amplitude signal, which is diagnostic of weathered or fractured zones (Oluwafemi, 2012). Using Table 2, the interpretation of each profile is described as follow:

Profile VLF-EM 0E

Points diagnostic of conductive zones are found at horizontal distance between 70 and 110m with depth ranging from less than 20m to greater than 35m. This zone has a positive but low current density value which makes the zone a weak conductor, and therefore not an encouraging groundwater potential zone.

Profile VLF-EM 100E

Points diagnostic of conductive zones are found between (a) 100 and 105m with depth ranging from less than 20m to 35m (b) 120 and 142m with depth ranging from 30m to greater than 60m indicating a deep-seated fracture domain containing groundwater that is shielded from pollution (c) 213 and 280m with depth ranging from less than 20 to 22m. The conductors in (a) and (b) may contain water which is probably contaminated at shallow depth and may extend to the surface. However, highly resistive bodies are found between 70 and 75m and between 300 and 350m.

Profile 200E

Points diagnostic of conductive zones are found between (a) 62 and 80m with depth ranging from less than 20m to 30m and may be indicative of an aquifer which may contain water that is contaminated at shallow depth (b) 125 and 130m with depth ranging from less than 20m to 27m and is considered to be moderately conductive.

Profile 300E

Points diagnostic of conductive zones are found between (a) 75 and 100m with depth ranging from less than 20m to 30m indicative of an aquiferous zone, in addition there is a tiny zone around 80m and of less than 20m depth that is extremely conductive and may be indicative of contaminated water zone (b) 140 and 187m with depth ranging from less than 20 to greater than 35m

Profile 400E

Points diagnostic of conductive zones are found between (a) 85 and 100 with depth ranging from less than 20m to 30m. This may indicate an aquiferous zone. Moreover, there is tiny region of higher resistivity between 89 and 92 at a depth less than 22m and probably extend to the surface that may contain contaminated water. A high resistivity structure is found between 125 and 135m from a depth of 20 to 30m.

Profile 500E

Points diagnostic of conductive zones are found between 30 and 62m with depth ranging from less than 20 to 35m. The current density is very high to extremely high. This complex situation is a pointer to the presence of many sources which may mean that the water here is therefore contaminated. However, there is a highly resistive structure found between 80 and 120m at a depth ranging from less than 20m to greater than 35m.

Profile 600E

Points diagnostic of conductive zones are found between (a) 10 and 25m at a depth ranging from less than 20m to greater than 35m. This is a slightly conductive body (b) 50 and 60m with a depth ranging from less than 20m to 21m, this is also a slightly conductive body and is suspected to extend to the surface and probably contains contaminated water (c) 87 and 120m with a depth ranging from less than 20m to greater than 35m. This structure is slightly conductive to highly conductive. This complexity indicates many sources, more so that the highly conductive component found between 100 and 110m with depth ranging from less than 20m to 22m may indicate contamination of the aquifer at shallow depths. There are also notable highly resistive zones recognized between (a) 60 and 85m with depth ranging from less than 20 to 35m (b) 125 and 168 with depth ranging from less than 20m to greater than 35m.

Profile 700E

Points diagnostic of conductive zones are found between 15 and 35m with depth ranging from less than 20m to greater than 35m. This is a slightly conductive body that may have little groundwater exploration potential (b) 110 and 125m with depth ranging from less than 20m to greater than 35m. This structure is also slightly conductive. Also, a resistive body of note is found between 83 and 90m

Profile 800E

Points diagnostic of conductive zones are found between (a) 20 and 62m with depth ranging from less than 20m to greater than 35m which can be considered to be slightly conductive, although there is a higher conductive zone between 37 and 50m with depth ranging from 20 to 25m with a thin extension that runs to a depth of greater than 35m. This is indicative of a fracture zone with the water at shallow depths probably contaminated.

Profile 900E
Points diagnostic of conductive zones are found between 68 and 80 with depth ranging from less than 20m to 30m. It is a conductive zone that indicates an aquifer.

Profile 1000E
Points diagnostic of conductive zones are found between 12 and 50m with depth ranging from less than 20m to greater than 40m. This may be indicative of an aquiferous zone

Profile 1100E
Points diagnostic of conductive zones are found between (a) 35 and 50m with depth ranging from less than 20m to greater than 35m and with a thin extension that runs to a depth of greater than 35m. This is indicative of an aquiferous zone that contains water that is contaminated, especially at shallow depths (b) 140 and 155m with depth ranging from less than 20m to 22m. This is also a highly conductive body and is suspected to be an aquifer connected to the surface and probably contains contaminated water (c) 170 and 188m with depth ranging from less than 20m to greater than 35m, this is indicative of an aquiferous zone. There is also a highly resistive zone of note found between 80 and 105m with depth ranging from less than 20m and 32m.

5.2 Hydro Geochemistry of Rido

The Table 2 below shows the results of physico-chemical and heavy metal analyses conducted in Rido community.

5.2.1 Deductions

Table 3 shows the results of fieldwork and laboratory analysis conducted for Rido community. It was revealed that the heavy metals have higher values than the standard values of WHO and NSDWQ values at some points. The metals are; Iron, Zinc, Copper, Lead, Chromium, calcium and Manganese. The high values of these metals are due to improper disposal of untreated effluents from petroleum product leading to the enrichment with the heavy metals. Also, part of the heavy metal enriched the groundwater through bedrock dissolution processes. The pH range 4.3-6.8 indicates slight acidity which may be attributed to the impact of the effluent on the soil and groundwater system in the area. The result of the microbial analysis revealed the presence of total coliform bacteria in the hand-dug well water from the area. Their presence is an indication that the groundwater is contaminated with animal/human excreta. During the sampling, it was observed that some un-ringed and uncovered hand-dug wells were sited very close to soakaways/ latrine in the area and this proximity may have led to the bacteriological contamination. The remaining physical parameters had their concentration within the permissible limits. The use by the host communities of groundwater from shallow hand-dug wells should be discouraged and alternative source of groundwater should be provided for the inhabitants. Deep sited boreholes should be sunk to replace the existing shallow hand-dug wells in the area. Effluents and waste-water from the refinery and petrochemical should be treated before disposing into the nearby farmlands or surface water. Bioremediations and phytoremediation should be employed in the cleaning up of contaminated sites.

Table 2 Physico-Chemical and Heavy Metals Analysis at Rido Community

N0	Parameter	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	WHO	NSDWQ
1	Appearance	Clear	Clear	Clear	clear	clear	Clear	Clear	Clear	Clear	Clear	Brown	Cloudy	Clear	Clear
2	Ph	4.3	4.8	5.6	5.2	6.0	6.3	5.1	4.2	5.1	4.8	6.1	6.8	6.5-8.5	6.5-8.5
3	Colour	15	20	15	20	15	20	20	15	10	15	50	70		
4	Temperature	24.1	24.3	24.1	25.6	25.3	24.2	25.5	24.5	24.1	24.2	23.5	23.8		
5	Electrical Conductivity	360	125.9	431	41.2	101.2	76	119.2	95	180.2	108.3	33.7	26.1	1000	1000
6	TDS	180	62.8	217	20.4	51.1	102	59.6	38.9	90.1	63.6	16.7	12.9	500	500
7	Turbidity	12.1	2.2	2.6	0.5	0.2	4.3	3.7	2.5	34.1	3.5	164.5	1.0	5.0	5.0
8	Hardness	96	50	96	8.0	25	34	33	17	22	40	50	38	500	150
9	Alkalinity	16	7.0	14	2.0	1.0	1.5	2.0	10	21.0	6.0	31	33		
10	Salinity	48.25	30.92	75.47	96.94	26.79	52.13	35.89	80.4	195.89	90.4	35.05	25.99		
11	Faecal Coliform	TNTC	TNTC	0	160	TNTC	TNTC	0	0	250	TNTC	200	TNTC		
12	Total Coliform	TNTC	TNTC	0	TNTC	TNTC	TNTC	0	0	TNTC	TNTC	TNTC	TNTC	10	10
13	Copper	0.3	0.2	1.04	1.5	0.96	0.89	1.07	1.21	1.09	0.782	1.2	1.5	1.0	
14	Iron	0.53	0.10	0.65	0.41	0.08	0.0	0.20	0.3	0.0	0.0	1.6	0.0	0.03	0.3
15	Zinc	0.2	0.12	0.14	0.13	0.19	0.24	0.35	0.5	0.32	0.24	5.6	6.0	4.0	

16	Potassium	30.6	32.43	34.10	32.0	35	33.8	36.2	37.8	32.1	30.1	40.2	38.3	15	
17	Sodium	43.50	43.2	50.0	42.8	41.8	47.2	41.0	43.9	51.9	60.3	65.1	87.2	200	
18	Calcium	53.14	52.18	60.3	56.7	74.2	86.1	60.7	78.3	90.12	98.33	70.5	900.6	75	-
19	Magnesium	62.5	61.97	70.5	64.34	78.11	68.23	92.26	85.33	75.92	64.3	125	128.8	150	-
20	Lead	0.29	0.27	1.06	1.30	0.92	1.10	1.23	0.87	1.04	0.221	1.221	0.99	1.05	
21	Chromium	4.35	6.1	5.6	4.2	3.7	5.01	3.8	0.97	4.75	5.22	5.18	4.91	? 5.0	
22	Manganese	0.788	0.92	0.51	0.81	0.67	0.84	0.78	0.92	1.05	1.02	0.8	0.89	? 0.8	
23	Nitrate	16	6	1.02	3.70	19	10	4.2	7.3	19	4.4	3.70	24	10	50
24	Sulphate	0.0	18	2	4.0	0	7	0.0	5.1	3.0	0.0	44	66	250	100
25	Carbonate	26.89	27.41	23.7	38.3	35.8	36.9	38.2	40.3	41.9	50.7	45.2	23.9	250	-
26	Bicarbonate	57.3	57.9	51.3	82.9	67..9	85.9	78.3	50.1	55.2	44.0	70.3	67.3	250	-
27	Chloride	29.24	18.74	45.4	2.0	16.24	25.0	21.74	15.759	18..72	19.4	21.24	15.75	600	

6.0 CONCLUSION AND RECOMMENDATION

In this study, geophysical methods have been integrated with hydrogeochemical methods to determine the extent of groundwater pollution in the regions.

Firstly, the Inphase, Quadrature, Fraser Filter profiles and the Karous Hjelt pseudo sections from the VLF-EM survey of Rido community have revealed high groundwater potential in the area.. The VLF-EM interpretation also shows that the soil and groundwater at shallow depth in some part of the area have been polluted. This is in line with the results from the physicochemical analysis carried out in the region which revealed that the soil and groundwater quality in the region have been affected by oil spillage and improper disposal of untreated effluents from petroleum products. The following recommendations are suggested:

(a) A total overhaul of environmental procedures of the refinery in Rido should be embarked upon.
(b) Rehabilitation and cleaning of effluents and wastewater retention pond should be pursued, so that effluent water can be properly treated before discharging to nearby farmlands or surface waters.
(c) KEPA and NESREA should ensure compliance with standard for drinking water quality guidelines
(d) Deep sited boreholes should be sunk to replace existing shallow hand-dug wells in the area

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