www.iiste.org

Geology and Groundwater Quality Assessment of IDO/OSI Area, Southwestern Nigeria

Olusiji Samuel Ayodele
Geology Department Ekiti State university, P.M.B 5363, Ado-Ekiti Nigeria
*riksam2002@yahoo.com, riksam2002@gmail.com

Abstract
Detailed geological mapping of Ido area was conducted with a view to establishing the lithologic units and compiling a working geological map of the area. Also, water quality assessment, entailing the bacteriological and physico-chemical analyses, of water samples from 20 hand dug wells within the study area was carried out. The geological studies confirmed the area to be a part of the Nigerian Basement Complex with lithologic units such as migmatites, gneisses, charnockites and granites underlining it. The results of bacteriological analysis revealed that the hand dug wells are contaminated with faecal coliform and E-coli. The value ranges from 4-13 cfu/100ml which is beyond WHO recommended standard for drinking water. The results of physical parameters revealed that the water samples are colourless and odourless, with average temperature of 26.05^0 C. The pH value ranges from 5 – 7.3, which was interpreted to be slightly acidic to neutral. The results of chemical analysis give values of cations and anions in the water samples as follows (Ca^{2+} 2.83 mg/l), Mg^{2+} (26.99mg/l) , Fe^{2+} (8.48mg/l) SO_4^{2-} (16.24mg/l) Na^+ (8.5 cfu/100ml) Cl^- (1.655mg/l), andNO_3^- (0.026mg/l) .Other parameters determined include total hardness (33.8mg/l), calcium hardness (11.7mg/l), magnesium hardness (13.52mg/l), electrical conductivity (257.6us/cm), turbidity (2.7NTU), total dissolved solids (45.5mg/l). A comparison of the rock chemistry to the chemical parameters of the water showed moderate influence of bedrock on the chemistry of the water. In general, the parameters are within the limit recommended by WHO. Nevertheless, because of the bacteriological contamination, it is advised that all hand dug wells in the area should be cased and fitted with necessary filter and screens, or covered at all times, boiled or chlorinated to ensure safe consumption.

Keywords: Ido, Water quality, Bedrock, Contaminants, Lithologic units

Introduction
The geological mapping exercise carried out in Ido-Ekiti and evirons showed that the area lies within the crystalline rocks of the Nigerian Basement complex and specifically to the Ilesha schist belt. The rock types and the deformation pattern in the area can be related to the Pan– African orogeny (Kennedy, 1965) and this could affect the water retention capacity of the region as the water which does not flow into the streams but percolate into the ground are held by the impermeable rock layers. Therefore, if shallow well water sources are to be estimated accurately, it is important to find out the exact composition of the rock formation, their water retention capacities, physical relationship with groundwater and the bedrock effect on the groundwater. A lot of studies abound in the literature on water quality assessment and development and also on heavy metal pollution on water sources. Such works include Ajibade et. al.,(2008), Bello (2004) , Abimbola et al., (2002), Edet and Offiong (1998b) and Edet and Ntekim (1996). All concluded that there was the need to monitor water quality on regular basis. This is because the increase in concentration of trace elements in potable water, microbial contamination from faecal coliform and E-coli and influence of filths, unguided wastes and sewage disposal will increase the threat to man's health and life. Other literature exists on the development and application of index methods for water quality assessment. Some of these include the work of Joung et al, (1979), Nishidia et al (1982), Tiwary and Mishra (1985), Prasad and Jaiprakas (1999). This study entails geological studies and groundwater quality assessment of Ido area by carrying out detailed geological mapping to ascertain the underlying lithologic units, carry out physico-chemical tests on some hand dug wells in the locality and; to establish whether the water has any relationship with bedrock geochemistry in the area.

Location of the Study Area
The study area is located geographically within the latitudes 70 45' and 70 50'N and longitudes 50 05'E to 50 10'E. The study area is situated in the northwestern part of Ekiti State within the topographical map of Ado Ekiti (N.W sheet 244), on the scale of 1:50,000.
Most of the settlements in the study area are not large in terms of population and can still be classified as towns and villages. Their major and most prominent pattern of settlement is linear along the major roads and nucleated in valleys or plain lands. The major towns in the area include, Ifaki Ekiti, Ido Ekiti, Osi Ekiti , Igbole Ekiti, and Ora Ekiti. Other minor towns include, Aaye Ekiti, Ifisin Ekiti, Orin Ekiti, etc. These settlements are shown on

the map of the study area (Fig.1). Most of the area is fairly accessible as it is connected with network of tarred and unpaved roads. However, some settlements are only connected by footpaths. Farming activities in the area have made accessibility to some outcrops possible.

Topography and Drainage

The landform in this region is generally a combination of highlands and lowlands with the highest peak of 2000m at Orin south of Ido- Ekiti. The variation of relief and gradient over the region strictly dictates the drainage pattern of the study area. Major rivers in the area include, Ero, Ogburugburu, Arototo, Agbara, Okerere and Isepere. The rivers are structurally controlled resulting in the trellis type of drainage pattern. (Fig 2).

Regional Geologic Setting

The study area lies within the Precambrian of southwestern Nigeria, which is a part of the Basement Complex of Nigeria. The study area is mostly underlain by crystalline rocks ranging from Precambrian to Paleozoic. These rocks have been grouped into six lithologic units by Rahaman (1988) as follows:

(i) the migmatite-gneiss-quartzite complex
(ii) the schist belts;
(iii) Charnockites,
(iv) Older granites (Granitoids)
(v) Volcanics, gabbroic and dioritic rocks
(vi) Unmetamorphosed dolerite and syenite dykes

Local Geology

Ido/Osi and its environs lie within the southwestern sector of the reactivated basement complex of Nigeria. The study area comprises dominantly of metamorphic and igneous rocks. The dominating lithologic units include medium-grained migmatite-gneisses (MMG), medium-grained banded gneiss (MBG) medium-grained Granites (MGR), coarse- grained charnockites (CCH) (Fig.3) and are covered generally by lateritic top soils. The rocks mapped in the study area are presumed to have experienced several episodes of deformation which left its imprints on these rocks.

Migmatite Gneisses (Mg)

The migmatite gneisses are the most abundant rock group in the study area and are presumed to be the oldest rocks in the country (Oyawoye, 1970). In the study area, the migmatites form the basement rocks on which all other rocks intruded. This rock displayed alternation of light and dark bands which differ texturally and mineralogically. Structures such as quartz veins, pegmatitic veins, joints, foliations and solution holes were observed on these outcrops. The mineralogy of the rock consists of feldspar, quartz and biotite. This rock group is not porous or permeable and covers most of the mapped areas with exception of Igbole-Ekiti, part of Ora-Ekiti and north of Osi-Ekiti.

Medium Grained Banded Gneiss (MBG)

This is the most abundant rock type in Ido/Osi Ekiti and its environs. They are characterized topographically as plutons, ridges, undulating hills and low lying in other areas. The texture ranges from medium to coarse-grained with colour variations due to alternation of mafic and felsic minerals or as a result of differences in concentration of biotite and feldspars present in the rock. Structures such as foliations, joints, quartz veins and solution holes are common on the outcrop. The outcrop also display folds of different magnitudes and styles indicating different episodes of deformation This rock type covers Ora-Ekiti, north of Osi-Ekiti with the exception of Igbole-Ekiti.

Coarse-Grained Charnockite (CCH)

Charnockites occur as lowlying and undulating outcrops in Igbole-Ekiti area and a small part of Ido. They vary in texture from medium to coarse grained and display greenish to bluish colours. The coarse grained variety is dominant and the rock is generally unfoliated.

The charnockites in Igbole – Ekiti are generally dense with intrusions such as quartz veins and quartzofelspathic veins common on the outcrop. This gneissic nature could be related to the regional effect of the Pan African orogeny as explained by Rahaman (1976, 1988). They are dark green in colour and become lighter towards the surface of the outcrop. Mineralogically, they are composed of feldspar, biotite, quartz. Other assemblages such as hypersthene-zircon assemblages were also observed from the petrographic study of the charnockite samples.

Medium-Grained Granite (MGR)

The medium grained granites occur in Oke osi in Osi-Ekiti. The texture is fine to medium grained with scattered streaks of dark minerals suspected to be hornblende.The granite in Ido is gneissic in nature and it contains structures such as quartz veins, joints, solution holes, fractures. Xenoliths which are inclusions resulting from partial assimilation of the engulfing rocks were observed on the outcrop. Solution holes caused by differential weathering of less resistant minerals are also common. Due to its dense nature, this rock type could serve as an impervious layer in some confined aquifers. The type of granites mapped here are Pan African in age.

Hydrological Setting of the Study Area

The study area is underlain by the crystalline rocks of the Basement Complex of southwestern Nigeria. However, the type of soils observed in the area include top loamy and clay soil, weathered decomposed basement (sandy clay), pure sand, weathered basement unconsolidated and unweathered basement rocks (Fig.4). The water retention capacities of these sequences are generally high and the region enjoys adequate rainfall for most of the year, so when the soil gets saturated at peak periods of rainfall, the rest of the water runs off into nearby rivers and streams. The permeability of the soil sequence is generally high; therefore the shallow wells contain enough water all year round because of constant recharge. When surface run-off passes through marshy lands, the water may acquire a putrid odour. It may be lightly coloured and acidic due to the presence of humic substances. The initial chemical quality of the water could be changed by the interaction with vegetation and impervious surfaces and the changes can be detected by increased concentration of dissolved and suspended material. There is usually a natural filtration of the water and this is carried out by the pure sand and the sandy clay horizons which remove suspended materials and bacteria.

Availability of groundwater in migmatite gneiss complex rocks is dependent either on thick soil overburden of due to fracturing (secondary porosity). The porosity of the Igbole region is very low. As a result of this, before digging a well in the area water retention structures should be put into consideration and sought after. Other geologic structures which can hold water include synclines, faults and fractures. Groundwater exists in geological formations known as aquifer of groundwater reservoirs. A good aquifer must have adequate porosity, permeability and most importantly transmissivity. It should have structural boundaries which will prevent leakage. The top soil (overburden) of the crystalline rocks constitutes the aquifer from which groundwater gets into the hand-dug wells in Ido/Osi and environs.

In some parts of the study area, rocks dominated by unstable ferromagnesian minerals such as charnockite, gneiss and granite tend to weather into clayey soils which have low permeability and porosity. In some areas in which rocks consists mainly of quartz and other stable minerals, rocks such as gneiss and migmatite gneisses disintegrate into a porous and permeable lithology. The weathered zone in the study area possesses a lot of void spaces which enable movement and storage of groundwater. The highest porosity is found in the partly decomposed level below the clay soil mantle of the crystalline rocks such as granite, banded gneiss, charnockite and migmatite gneiss.

Method of Investigation

The method of investigation of this study is divided into two major aspects namely; **FIELD WORK** which involves geologic mapping, collection of rock samples and the **LABORATORY WORK** which also includes water analyses, rock processing, major and trace elements determination. The field mapping aspect entailed detailed study of the outcrops, their distributions and observation of the various structural elements present on them such as folds, faults, joints, factures. Other field activities included taking rock measurements in terms of strikes and dips, determining the orientation of outcrops, determination of the geographical positions of the outcrops using Global Positioning Systems (GPS). Ten localities were covered in the course of this study and twenty rock samples were collected randomly from different outcrops respectively in each location in a systematic manner and were properly labeled to avoid mix up. (Table.2). Also, twenty water samples were collected randomly from different wells in ten locations designated A-J and stored in pre-washed 250ml polythene bottles. Field measurements taken during the study include temperature, pH, conductivity and dissolved oxygen. This was achieved using standard field equipment. The laboratory analyses for cations and anions were determined with the aid of ion chromatography and other standard reagents and indicators. Other parameters determined include total hardness, calcium and magnesium hardness, total dissolved solids. Total digestion of the rock samples were carried out. This method is capable of decomposing metal salts, carbonates, sulphides, silicates, some sulphates and oxides present in the pulverized rock samples. Acids commonly employed include hydrochloric (HCL), Nitric ($HN0_3$) Perchloric ($HCL0_4$) and Hydrofluoric acid (HF) are usually added to the pulverized rock samples to digest them, but certain minerals such as cassiterite and chromite may not go into solution because they are heavy minerals. Minerals such as Zircon, sphene and magnetite may also not be totally dissolved. Therefore, the heavy metals and major elements in the pulverized samples were determined by fusion with a flux such as sodium peroxide (Na_20_2) was employed to analyze the trace elements present in the samples such as Zr, V, Pb, Ba, Cr, Ni and Rb. The procedures for determining the physical parameters such as odour, taste and colour were followed using the human sense organs. The level of microbiological pollution on the water samples was also determined. .The analysis was carried out to determine the degree of biological pollution in the water samples i.e. to determine the number of the bacteria colonies/ coliform present in the samples. 50ml of water sampled were measured. Millipore filter paper was fixed between the upper and lower cup of the Millipore filter instrument. Filter paper was used to retain the bacteria(s) present in the water sampled. Suction pressure was later applied through the lower cup of millipose filter instrument. The filter was removed with sterile forceps and placed upon the agar with a rolling motion to avoid entrapment of air. The plate was incubated for 22 – 24 hours at 35^0c. Colony counts on membrane filter was visible and was determined by vision and with the help of low power binocular wide field dissecting microscope with a light source directed perpendicular on it. Typical coliform colony has a pink to dark – red color with a metallic surface sheen. (Table.1). The counts were computed using membrane filters with 20 – 80 coliform colonies and not more than 200 colony type per membrane by the following equation:

$$\text{Total coliform colonies/100ml} = \frac{\text{coloform colonies counted}}{\text{Ml sample filtered.}}$$

Results

The major elements determined in the rock samples are presented in Table.3. The result showed the dominance of some oxides of elements in the order of SiO2 > Al2O3 > FeO > Na2O > K2O in all the samples analyzed. SiO2 content in all the rocks are very high and are more than 60% in all the locations except in the rock sample at Igbole which is 41.73%, while that of Ido-Ekiti is 73.45%. These values showed that the magma forming the banded-gneiss was highly saturated with silica, and as the magma cools, and the silica content decreases in the magmatic chamber with more of the mafic minerals crystallizing at higher temperature, thereby forming the charnockites at Igbole. The Al2O3 values in the samples range from 10.20% to 16.05% at Igbole and Osi-Ekiti respectively. These could be attributed to the presence of aluminosilicate minerals in the rocks samples such as feldspar , mica and biotite. The FeO content in the samples are also in the range of 2.85% to 22.6%. The charnockites at igbole has high iron content of 22.6% and this could be due to dominance of iron-bearing minerals in the rock samples such as biotite, hornblende and hypersthene, while the iron content in the rocks from other locations are in minimum concentration. The values of Na2O and K2O in the rock samples vary from 2.45%-3.68% and 1.29%-5.17% respectively. These values reveal the presence of feldspars (potassic or plagioclase) in the samples. All other elements determined such as MnO, MgO, CaO and P2O5 occur in trace amounts in the samples and their presence has little or no significance in the geochemical stability of the rocks. The result of the trace elements determined in the rock samples is also presented in Table.4. The results also revealed the presence of Zr, Ba, Rb and Pb as the dominant trace elements and having the highest concentration in the rocks. Zr values range from 112ppm-640ppm. The highest concentration is in the Aaye-Ekiti banded-gneiss, followed by Ido-Ekiti banded gneiss and Ora-Ekiti migmatite-gneiss respectively. The presence of zircon in gneissic rocks indicate the occurrence of certain geological processes in the emplacement of the mineral. Pb, Ba and Rb values showed that these rocks are radioactive in nature. The barium content in the samples range from 351 – 378ppm with an average of 344.1ppm which signifies that the quantity of Barium as a trace element in the samples is very high compared with other trace elements. The Rubidium contents range from 43 – 172ppm with an average value of 133.2ppm. This indicates that Rb content in the rock samples is moderately high. These samples therefore have a high amount of radioactive elements. These can be used in dating the rock based on the decay constant of 87Rb – 87Sr. The vanadium content is high in the migmatite-gneiss at Ora-Ekiti this is also linked with the presence of transition elements in the molten mush that formed the parent rock. It accounts for an average value of 69.6% in the rock samples. The nickel (Ni) values range from 1 – 3ppm with an average value of 1.50ppm. This also indicates traces of transition elements in the molten mush producing the rocks in the locality. The Cr and Ni values in the rock samples are very low compared with other trace elements determined in the rocks.

The results obtained from water analysis using the various chemical parameters are also presented in Table.5. These results were compared with the World Health Organization (1993) standard limits.

Conductivity (µs/cm)

This is measured in µs/cm and range from 68 – 403µs/cm. The WHO desired conductivity is 900µs/cm. When compared generally it is noticed to be of low conductivity, but this does not affect its portability.

Turbidity (NTU)

This is a visual haziness in water caused by the presence of insoluble suspended particles. It is measured by observing the interference to the passage of light through the water sample. The values obtained range from 0 – 11 NTU. Most of the samples do not exceed the desired limit given by the World Health Organization which is 5 NTU, except for samples D and F with 11 and 6 respectively. This renders the two samples not good for consumption. The high turbidity can interfere with disinfectants and cause "piggyback" micro-organisms which are dangerous to human health.

pH

pH values in this study varies from (5.0-7.3). The desired value of the WHO is 7.0 – 8.9. Only samples C and E fall within this limit while the others are not of normal pH but still fall within the maximum permissible limit because the normal pH of raw water varies from 6.5-8.5. Therefore, two of these samples (C and E) are slightly basic while other samples are slightly acidic in nature. The acidity in most wells sampled may be due to the presence of dissolved bicarbonates, hydroxide of calcium, magnesium and sodium which may be as a result of the contaminants.

Acidic waters may favor corrosion of pipes. Basic waters may precipitate calcium carbonate to form scale in pipelines and cooking utensils. Highly acidic water could be hazardous to human health.

Appearance/Colour (Mg/L)

In all samples analyzed, colours were not detected and compared with WHO standard limit, it shows that the water is acceptable for drinking and domestic purpose.

Total Hardness (mg/L)

The total hardness of all the water samples range from 10 – 100mg/L. The accepted value by the World Health Organization is 100mg/L. Therefore, none of the water samples exceed this value and are therefore of desirable hardness.

Total Dissolved Solids (TDS) mg/L

The values of this for all the samples range from 59.6 – 250mg/L. The highest desirable level accepted by the WHO is 500mg/L. Therefore when compared with the standard, none of the samples exceed the limit, so they are accepted and do not contain much dissolved solids.

Calcium Hardness (mg/L)

This is caused by the presence of calcium and magnesium in water. The calcium hardness values for the analyzed samples range from 6 – 87mg/L. The required value by the World Health Organization was not stated but the desirable value should be of moderate levels which are about 50 – 120mg/L, or (3-7 grains per gallon) because water becomes acidic at low hardness levels. Compared with the results obtained in this study, samples A,B,D,F,G,H and J have low levels of calcium hardness while C, E and I have moderate level of calcium hardness. The other samples are not acidic in nature.

Magnesium Hardness (mg/L)

The values for magnesium hardness range from 3 – 26mg/L. The accepted value was also not stated in the World Health Organization standards but value at normal level is 50 – 120mg/l. When compared with this, it is noticed that the magnesium hardness for all the water samples are low.

Ca^{2+} Values (mg/L)

The Ca^{2+} concentration for this study ranges from 2.4 -34.9 mg/l. Though, the World Health Organization standard limit is not stated but National Agency for Food and Drugs Administrative Control (NAFDAC) maximum allowed limits for Ca^{2+} concentration is 75mg/l in portable water. Therefore, the Ca^{2+} concentration in the water samples analyzed are very low compared with NAFDAC desirable limits. Calcium is essential in human diet and are not harmful to human health.

Mg^{2+} Values (mg/L)

The concentration of Mg^{2+} ranges from 0.7 – 6.3 mg/l. The WHO standard for Mg^{2+} concentration is 20mg/L. The Mg^{2+} concentration for all the analyzed samples do not meet up to the stipulated standard. They are therefore not harmful to health.

Some medical experts suggested that high calcium to magnesium ratio may pose health problems. Medical reports indicates that over calciumisation can lead to heart spasm, asthma, arteriosclerosis, headaches, joint problem, hypertension, cataracts, kidney stones and other health problems. Some natural magnesium and calcium controller has been used clinically to successfully treat kidney stones.

Chloride Values (Cl^-) (Mg/l)
The concentration of chlorides in the water samples range from 15 – 49.9mg/L. The chloride standard by WHO is 200-250 mg/L. The water samples do not exceed this limit. High Chloride values are usually not expected in shallow well water. High Chloride concentration may be due to natural mineral deposits, sea water intrusion, industrial effluents or sewage effluent which may have found its way into the well.

Nitrate Concentration (NO_3) (Mg/l)
Nitrate concentration or detected in the water samples range from 0.07 – 4.3mg/L. The highest nitrate concentration allowed by the WHO is 19mg/l. This standard is not exceeded by any of the samples. Nitrate was not detected in samples C and G respectively The World Health Organization desirable nitrate value is 10-15mg/l.All the samples examined fell below WHO standard limit. Nitrate is normally found in hand dug wells at a concentration of 0-10mg/l in the NAFDAC desirable limits. Nitrate at high concentration in drinking water is considered to be dangerous to human health especially to infants. Its concentration in water is also dangerous to aquatic organisms because it encourages the growth of algae which could rapidly use up the dissolved oxygen in the water and as well prevent aeration of the water. High concentration of nitrate could be due to the use of Nitric fertilizers or decomposing materials e.g septic wastes. The low concentration of Nitrate in the water samples is therefore preferred.

Iron Concentration (Fe) (Mg/l)
The highest desirable concentration of Iron in water as required by the WHO is 1mg/L. The concentration of Iron for all the water samples analyzed is below the stipulated limit. This is acceptable for all the samples because Iron should only be present in little concentration in drinking water. The values for the water samples range from 0.01 – 0.06mg/l Iron was not detected in samples F and I representing Orin and Igbole respectively. At any level greater than the minimum concentration allowed in water, Iron gives a bitter astringent taste. Also at this concentration, it imparts a rusty – brown stain to plumbing, laundry, food and appliance.

Sulphate (So_4^{2-}) Concentration (Mg/l)
The sulphate ions present in the water samples tested varies from 7.4-9.8mg/l and are far less than the World Health Organization recommended value of 250mg/L. The highest concentration was found in sample I representing Igbole. High concentration of sulphate in drinking water can form hard scales in boilers and can cause laxative effects in humans. Diarrhoea can be induced at Sulphate levels greater that 500mg/L. Sulphate cannot be readily removed from drinking water except by distillation, reverse osmosis or electrodialysis but these methods are expensive.

Sodium (Na^+) Concentration
The sodium concentration for the water samples are well below the WHO levels of 200mg/l. The concentration ranges from 9.8-32.4mg/l in this study. and this is acceptable because high concentration of sodium in drinking water could be detrimental to hypertensive individuals. The highest concentration of Sodium was found in sample J representing Ifaki with 32.4mg/l. Excessive concentration of the ions may be due to the presence of Sodium carbornate (Na_2CO_3) or Sodium Chloride (NaCl) and can cause heart diseases (Voshoey 1985). Therefore, these shallow well waters are desirable for consumption.

Total Bacterial Count (TBC) CFU/100ml)
The values of the bacterial count in the water samples range from 4 – 13 CFU/100ml. (Table.1).This grossly exceeds the World Health Organization recommended standard of zero and this renders all the well water samples unsafe for drinking. Certain bacterial species particularly E. coli, designated as Coliforms are normal inhabitants of large intestine of human and other animals and are consequently present in faeces. Thus the presence of any of these bacterial species in water is an evidence of faecal pollution. The contamination may arise from sewage effluent, pit latrine or refuse dumps. Bacterial presence in drinking water could result in diseases such as Typhoid, Cholera, Diarrhoea and Dysentery and so on.

Physical and chemical tests coupled with other hydrogeochmical parameters have been used to evaluate the quality of some hand-dug well water in Ido area, southwestern Nigeria. All the water samples were colorless and clear despite the lateritic nature of the overburden materials in the study area. This is an evidence of the good water filtration capability of the topsoil. The pH values for the hand-dug wells range from 5.0 to 7.3 (Table 5). The highest pH value of 7.3 was obtained from Aaye and this was within the WHO suggested limit for pH value. All the water samples within the study area can be interpreted to be slightly acidic to neutral in nature. Total hardness values for the water samples were all within the permissible limits. The calcium hardness and

magnesium hardness values were also of moderate levels. Among the cations analyzed, calcium and magnesium concentrations were low and within permissible limits. All the water samples were contaminated by chloride, sulphide and nitrates at low levels. Their average values were 26.99mg/L, 8.48mg/L and 2.07mg/L respectively.
Statistical analysis of the chemical properties of the water showed the dominance of cations and anions in the area is in the order of $Cl^- > Na^+ > Ca^{2+} > SO_4^{2-} > Mg^{2+} > NO_3^- > Fe^{2+}$ respectively. Also, the chemical characteristics of the water have fairly significant effect on some of the physico-chemical parameters of the water considered such as pH, total dissolved solids. The correlation analysis (Table 6, Figs 5,6 and 7)shows that there is poor and good correlations between pH and total dissolved solids, total dissolved solids and total hardness. Very low and negative correlation occurs between PH and Total hardness (Fig.5). This is an indication of low level of contamination in the study area while the relationship between PH and total dissolved solids (Fig.7) is good and positively correlated. The positive correlation between Total dissolved solids and Total hardness is an indication of high significant level of contamination in the study area (Fig.6). In assessing the quality of the hand dug wells in the area, microbial contamination was considered and the entire water sampled fell below the microbial contamination standard as suggested by W.H.O. The bacteriological analysis revealed that all the hand-dug wells analyzed were contaminated with faecal Coliform. Samples taken from Ora and Ifaki had the highest bacterial values of 12 and 13 respectively. Both samples were taken from wells close to pit latrines and refuse dumps. The values are beyond the World Health Organization (2004) Bacteriological standard for drinking water. The well water in these localities is not recommended as drinking water unless special treatments are adopted. Chemical parameters are plotted against locations on a multiple bar chart with dominant cations (Fig.8a&b) which include: Na^+, Ca^{2+} and Mg^{2+} while the dominant anions include Cl^- , $S0_4^{2-}$ and $N0_3^{2-}$

Conclusion

The geological mapping of the study area provided information on the different lithologies found in the study area, while the geochemical analyses carried out on the rocks provided information on the major and trace elements present in them. Also, the physico-chemical and bacteriological analysis were aimed at determining the effect of the rock chemistry on the hand dug wells, thereby assessing the quality of these wells for human consumption. However, the following conclusions can be made from this study;

(i) The water is slightly acidic to neutral in pH
(ii) Major contaminants of hand dug wells in the study area arose from the closeness of these wells to pit-latrines, filths, refuse dumpsite and the bedrocks
(iii) The wells are unfit for drinking because of the high content of biological pathogens.
(iv) The radioactive elements detected from the rock samples could be pathfinder elements to some radioactive minerals in the study area.
(v) It is also concluded that the quality of water from the shallow wells could be influenced by the chemical constituents of the geologic formations in which it occurs. Also, chemical contaminants such as chlorides, sulphides and nitrates occur in the wells at low levels and finally;
(vi) the chemical quality of the well water is within the acceptable limit of WHO guidelines for domestic and other industrial usues.

In other to maintain good health and to improve the quality of the hand dug wells in Ido/Osi Ekiti and its environs, the following recommendations are made:

(a) Wells should be located up gradients out of pollution source e.g. cemetery, latrine, sewage disposal site, land fill site, etc
(b) Identified wells with high microbial colonies should be treated either by boiling or chlorination to ensure safe consumption and utility.
(c) The hardness in the water should be removed by boiling the water up to 120^oc
(d) The government should provide pipe-borne water in the area to ascertain good water quality in Ido/Osi Ekiti and its environs.
(e) All hand-dug wells should be cased and fitted with necessary filter and screens.
(f) All wells should be covered at all times.
(g) Further studies should be carried out in future on the presence of radioactive elements in the water.

REFERENCES

Abimbola,A.F, Ajibade,O.M; Odewande, A.A; Okunola, W.O; Laniyan, T.A.; Kolawole, T. (2008): Hydrochemical characterization of water resources around the semi-urban area of Ijebu-Igbo southwestern, Nigeria. Journal of water resources vol.20 : 10-15.

Abimbola, A,F., Odukoya, A.M.; Adesanya, O.K.; (2002): The environmental impact assessment of waste disposal site on ground water in Oke Ado and Lagos, southwestern Nigeria. Proceedings 15th Annual conference Nigerian Association of Hydrogeologists Kaduna, Nigeria, 42pp

Edet A.E., and Ntekim E.E.U., (1996): Heavy metal distribution in ground water from Akwa Ibom State, eastern Niger delta- A preliminary pollution assessment. Global Journal of Pure and Applied Sciences 2(1): 67-77.

Edet, A.E. and Offiong O.E., (1998b): Surface water quality evaluation in Odukpani, Calabar flank, Southwestern, Nigeria. Journal of Environmental Geology 36(3/4) : 343-348.

Joung H.M., Miller W.W., Mahammar C.N and Gultjens J.C.A..,(1979): A generalized water quality index based on multivariate factor analysis. Journal Environmental Quality 8: 95-?

Kenedy, W.O., (1965): The structural differentiation of Africa in the Pan-African thermotectonic episode. University of Leeds, Institute of African Geology , 8th Annual Report., pp 48-49.

Nishida N., Miyai M., Tada F, and Suzuki s., (1982): Computation of Index of pollution by heavy metal in river water. Environmental pollution 4: 241-?

Oyawoye, M.O.(1970): The basement complex of Nigeria. In. African geology by Dessauvagie,T.F.J and Whiteman A.J (eds) African geology: University of Ibadan 1970, pp 66-102.

Prasad B. and Bose J.M., 2001: Evaluation of heavy metals in ground water near mining area and development of heavy metal pollution index. Journal Environmental science and Health A 34(1): 91-102.

Rahaman, M.A (1976): Review of the basement geology of southwestern Nigeria In. Geology of southwestern Nigeria In. Geology of Nig (C.A Kogbe ed) Elizabethan publishing Company. Lagos pp41-56

Rahaman,M.A (1988): Recent advances in the study of the basement complex of Nigeria In: Precambrian Geology of Nigeria. Geological Survey of Nigeria, pp11-43.

Voshoey (1985): Water Resources Engineering 3rd edition, Edward Arnold Publisher United Statesof America (USA) pp898-948.

World Health Organization (1993): Guidelines for drinking water quality, volume 1, recommendation, 2nd edition, World Health Organization Geneva.

World Health Organisation (WHO) 2004**:** Guidelines for Drinking Water Quality, International Standards for Drinking Water Vol.1 Geneva W.H.O. Pg. 130.

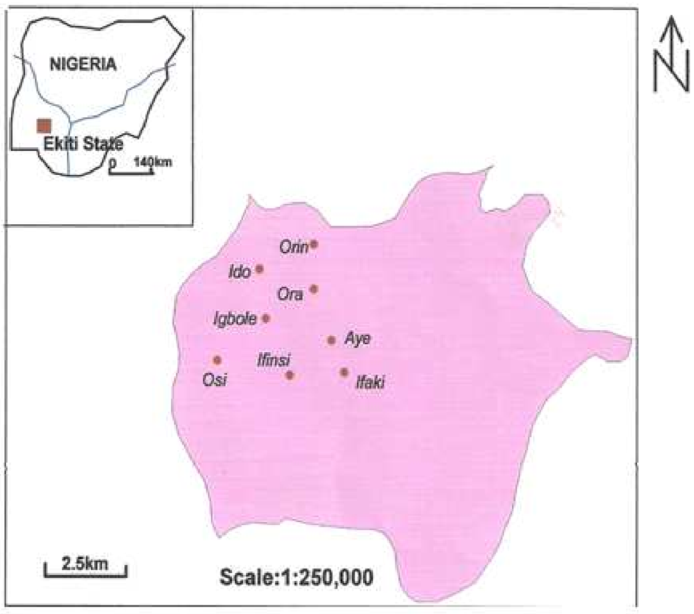

Fig. 1: Map of Ekiti State showing the study area.

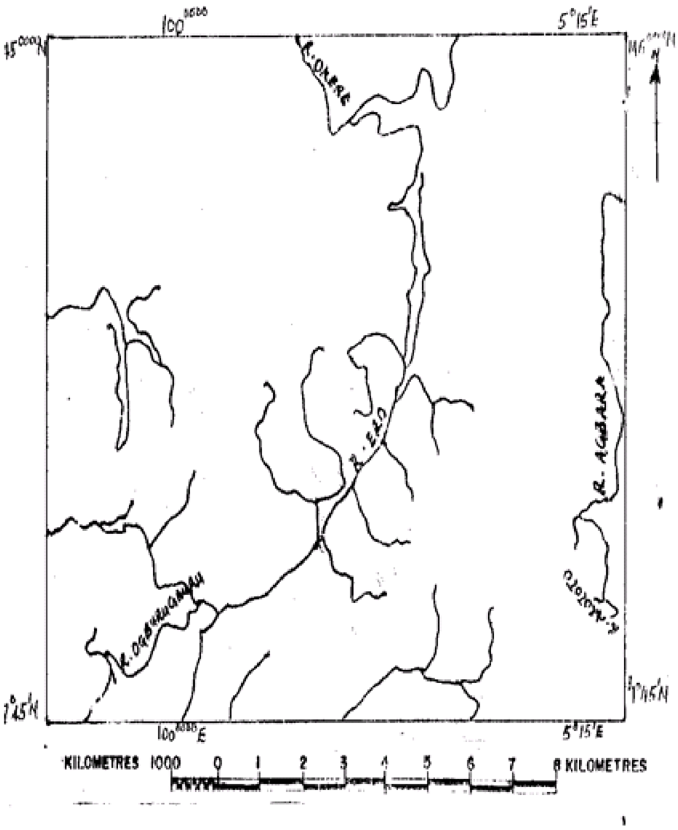

Fig. 2: The drainage map of the study area

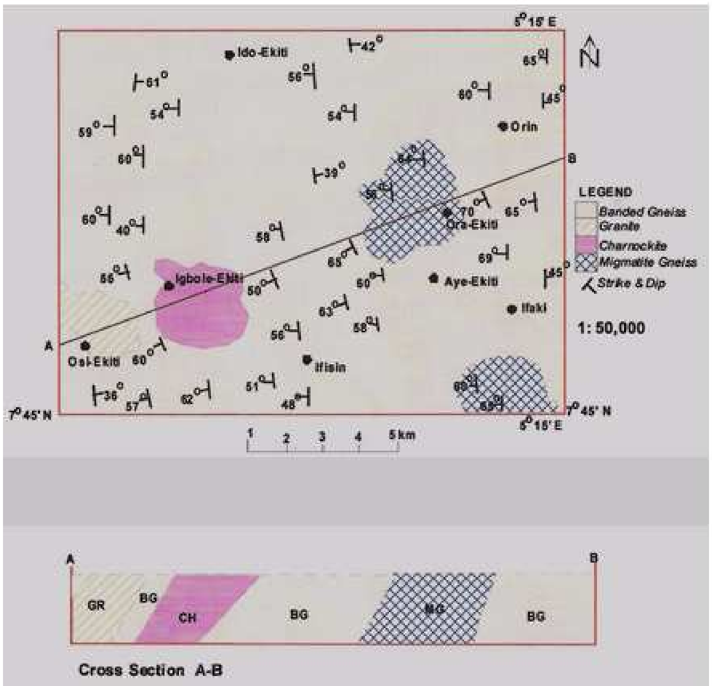

Fig. 3: Geologic Map of Ido Area and Cross Section A-B

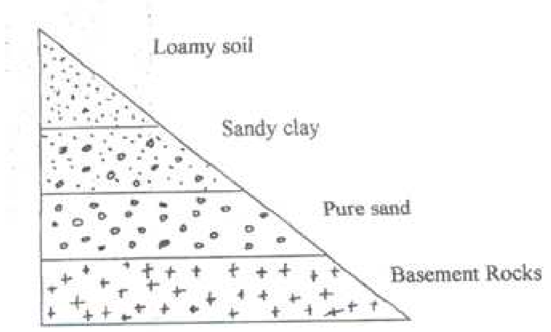

Fig. 4: A generalized soil profile of the study area (not drawn to scale)

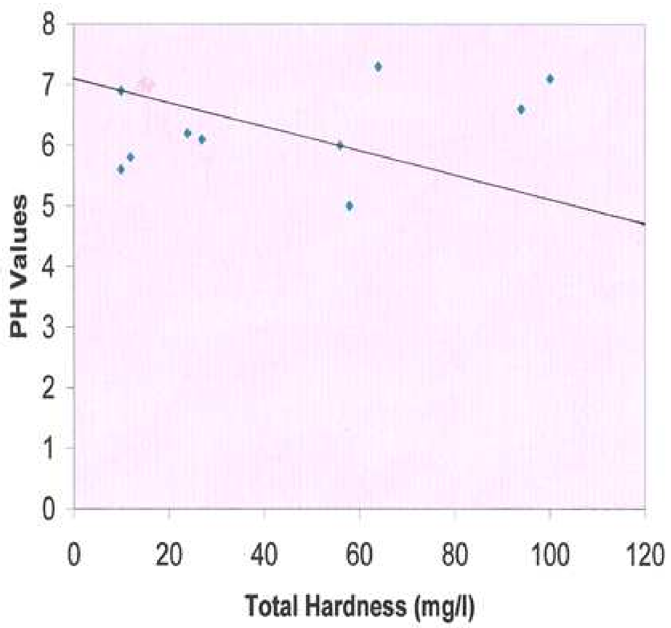

Fig. 5: Graph of PH values against Total hardness.

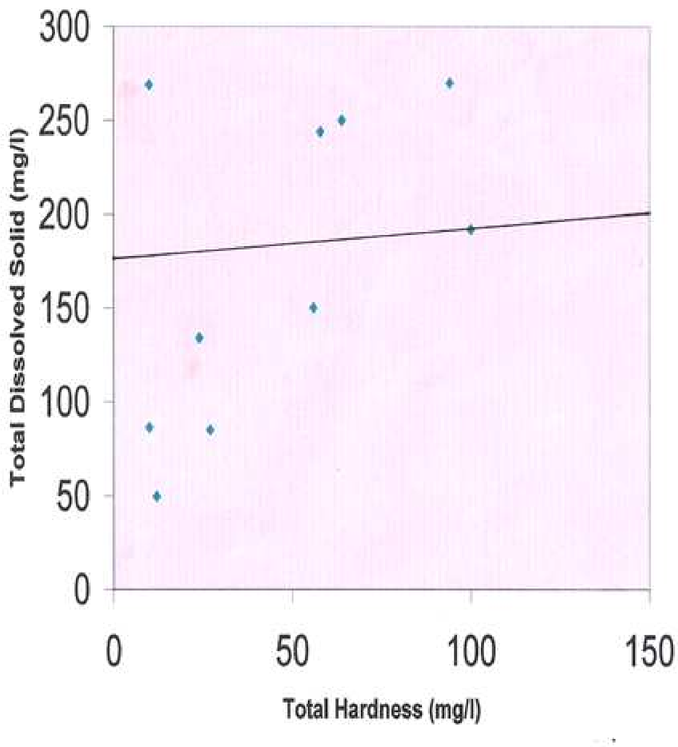

Fig. 6: Graph of Total dissolved solids against Total Hardness

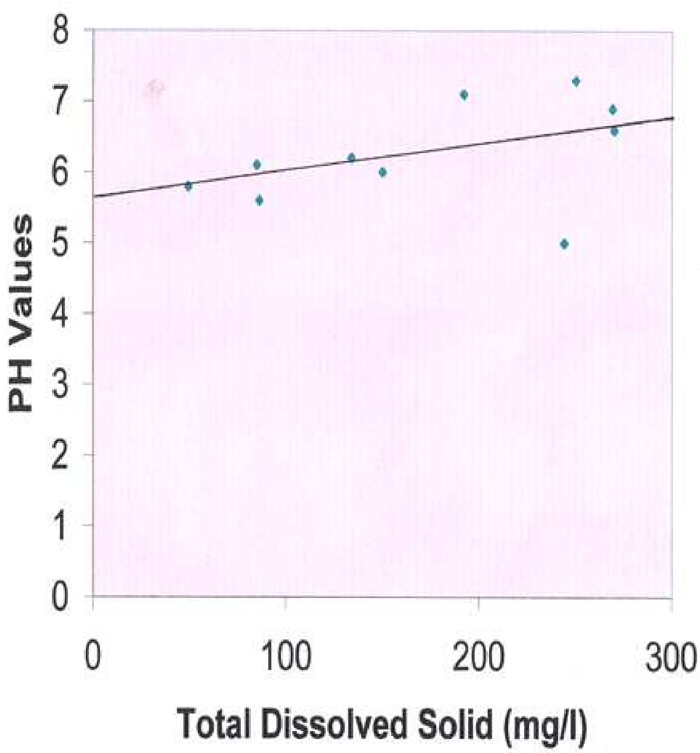

Fig. 7: Graph of PH values Against Total Dissolved Solids

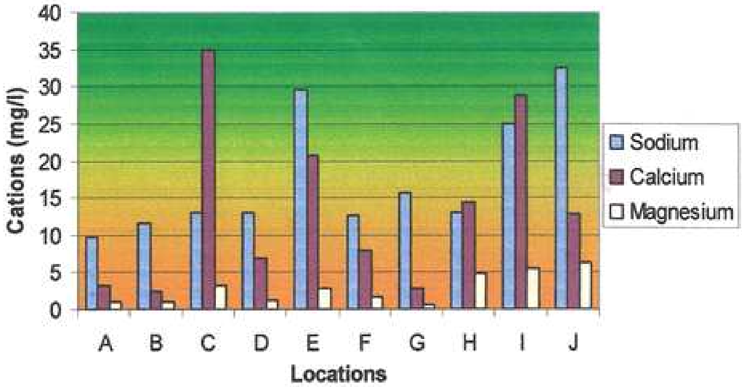

Fig. 8a: Multiple bar chart showing Chemical parameters (Cations) of water samples in each locations.

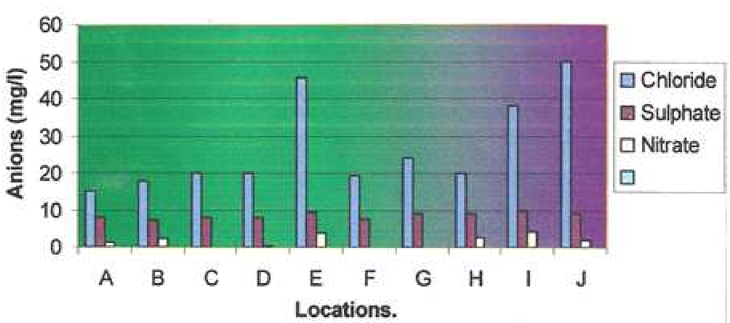

Fig. 8b: A multiple bar chart showing Chemical Parameters (Anions) of water samples in each locations.

TABLE 1: RESULT OF TOTAL BACTERIAL COUNTS FOR WATER SAMPLES

LOCATION		TOTAL BACTERIAL COUNT (CFU/100ml)
A.	IDO	7
B.	ORA	11
C.	IFISIN	6
D.	IDO 2	8
E.	AAYE	4
F.	ORIN	9
G.	ORA	12
H.	OSI	7
I.	IGBOLE	8
J.	IFAKI	13

Table 2: Summary of field data collected during geologic mapping of the study area

Location	Rock Type	Lithology	Geomorphology	Mineralogy	Colour	Texture	Structure	Longitude	Latitude
Along Iworoko / Ifaki Ekiti Road	Metamorphic rock	Migmatite – Gneiss	Well exposed and low lying outcrop	Quartz, feldspar, mica and other ferro magnessian minerals	Light	Medium – Coarse grained	Joints, solution holes	$07^0 47.335^1$ N	$005^0 14.409^1$ E
Along Ifaki/Aye Ekiti Road	Metamorphic rock	Banded Gneiss	Fairly exposed and low lying outcrop	Feldspar, Quartz, Biotite, Hornblende and other Mafic Minerals.	Alternation of mafic and felsic minerals	Medium – Coarse grained	Fractures, exfoliation	$07^0 47.633^1$ N	$005^0 14.531^1$ E
Aye Ekiti	Metamorphic rock	Banded Gneiss	Low lying outcrop and fairly exposed	Quartz, feldspar Mica and other ferro-magnesian minerals	Alternation of light and dark minerals	Medium – Coarse grained	Quartz Veins, crenulation cleavage	$07^0 48.045^1$ N	$005^0 13.130^1$ E
Iloro Ora-Ekiti	Metamorphic rock	Migmatite Gneiss	Hilly and well exposed outcrop	Feldspar, Quartz, Mica, Hornblende and other Mafic Minerals	Light	Medium – Coarse grained	Foliations, quartz veins	$07^0 49.293^1$ N	$005^0 13.133^1$ E
Odo-Ode Ora Ekiti	Metamorphic rock	Migmatite Gneiss	Well exposed and hilly outcrop	Quartz, Feldspar, Mica, Hornblende and other ferro-magnesian minerals.	Light	Medium – Coarse grained	Microfolds, fractures	$07^0 48.996^1$ N	$005^0 13.042^1$ E
Behind Catholic Church Ido Road	Metamorphic rock	Banded Gneiss	It's well exposed and low lying outcrop	Quartz, Feldspar, Biotite, Muscovite and other ferro-magnesian minerals.	Alternation of felsic and mafic mineral	Medium – Coarse grained	Solution Holes, granitic dyke	$07^0 49.984^1$ N	$005^0 14.000^1$ E
Along Igbole Road, Ifisin-Ekiti	Metamorphic rock	Banded Gneiss	Slightly hilly and fairly exposed outcrop	Feldspar, Quartz,, Muscovite, Biotite, Hornblende and other Mafic minerals	Alternation of light and dark minerals	Medium Coarse grained	Fractures, quartzo feldspathic veins	$07^0 47.568^1$ N	$005^0 12.214^1$ E
Igbole Road,	Metamorphic rock	Banded Gneiss	Slightly hilly and fairly	Feldspar, Quartz,,	Alternation of light	Medium	Fractures, quartzo		

Ifisin-Ekiti			exposed outcrop	Muscovite, Biotite, Hornblende and other Mafic minerals	and dark minerals	Coarse grained	feldspathic veins		
Igbole Ekiti	Igneous rock	Charnockite	Slightly hilly and well exposed outcrop	Quartz, Alkali-feldspar, plagioclase, pyroxene, Hornblende, Zircon etc.	Dark grey	Coarse grained	Exfoliation solution holes	$07^{0}47.964^{1}$ N	$005^{0}10.597^{1}$ E
Ekiti Parapo Grammar School	Metamorphic rock	Banded Gneiss	It's well exposed and hilly outcrop	Quartz, Feldspar, Biotite, Muscovite, and other mafic minerals	Alternation of dark and light minerals	Medium Coarse grained	Micro-folds, joint, fractures	$07^{0}51.142^{1}$ N	$005^{0}10.502^{1}$ E
Ido-Ekiti Oke-Osi Ekiti	Igneous rock	Granite	Slightly hilly and exposed outcrop	Quartz, plagioclase orthoclase, Hornblende and other mafic minerals	Light	Fine Medium grained	Fractures	$07^{0}47.029^{1}$ N	$005^{0}09.146^{1}$ E
Along Usi / Ipere Road Ido-Ekiti	Metamorphic rock	Banded Gneiss	Hilly outcrop and well exposed outcrop	Quartz, Feldspar, Mica, and other ferro-magnesian minerals	Alternation of felsic and mafic minerals.	Medium coarse grained		$07^{0}51.572^{1}$ N	$005^{0}10.733^{1}$ E
Along Osi / Epe Road Osi Ekiti	Metamorphic rock	Banded Gneiss	It's well exposed and slightly hilly outcrop	Quartz, Feldspar, Biotite, Muscovite, Hornblende and other ferro-magnesian minerals.	Alternation of light and dark minerals	Medium coarse grained		$07^{0}47163^{1}$ N	$005^{0}09.221^{1}$ E

Table 3: Characteristics Table for Major Elements (%)

	A	B	C	D	E	F	G	H	I	J	Aver
$Si0_2$	73.45	70.80	67.05	62.15	72.45	66.82	69.20	67.20	41.73	71.30	66.21
$Ti0_2$	0.39	0.35	0.45	1.35	0.55	0.53	0.46	0.45	1.80	0.31	0.664
Al_20_3	11.79	13.50	16.03	15.20	13.05	15.58	14.85	16.05	10.20	14.32	14.05
Fe_20_3	4.21	3.27	3.15	7.50	4.40	3.12	3.12	3.17	22.65	2.85	5.744
Mn0	0.04	0.03	0.03	0.08	0.07	0.07	0.06	0.03	0.46	0.05	0.092
Mg0	0.03	0.95	1.55	1.48	0.04	3.8	0.60	1.54	5.25	0.71	1.595
Ca0	1.03	3.45	4.08	3.80	1.58	3.60	1.89	4.08	11.58	1.84	3.693
Na_20	2.45	3.90	4.05	3.00	3.02	3.79	3.64	4.06	1.54	3.68	3.316
K_20	4.22	1.38	1.30	4.33	5.00	3.48	5.17	1.29	1.50	5.07	3.274
P_20_5	0.07	0.06	0.12	0.35	0.08	0.17	0.16	0.12	0.06	0.12	0.131

Key / or Hint

A - Ido-Ekiti (Banded-gneiss)
B - Ora-Ekiti (Migmatite-gneiss)
C - Ifisin-Ekiti (Banded-gneiss)
D - Ido-Ekiti (Banded-gneiss)
E - Aaye-Ekiti(Banded-gneiss)
F - Orin-Ekiti (Banded-gneiss)
G - Ora – Ekiti (Migmatite-gneiss)
H - Osi-Ekiti (Granite)
I - Igbole-Ekiti (Charnockite)
J - Ifaki-Ekiti (Banded-gneiss)

Table 4: Characteristics Table for Trace Element (ppm).

	A	B	C	D	E	F	G	H	I	J	Average
V	1	44	58	64	6	65	252	58	48	100	69.6
Zr	405	165	137	259	640	112	380	137	202	175	261.2
Pb	88	32	30	179	140	122	310	30	42	170	114.3
Ba	354	330	315	359	351	342	335	378	327	350	344.1
Cr	2	1	2	2	1	1	2	1	1	1	1.40
Ni	2	1	1	2	1	1	1	2	3	1	1.50
Rb	165	146	172	162	142	151	148	63	43	140	133.2

Table 5: Physiochemcial and Bacteriological Table for Hand-Dug Well Water Samples.

Parameters	A	B	C	D	E	F	G	H	I	J
Ph	5.8	5.6	7.1	6.2	7.3	6.1	6.9	6.0	6.6	5.0
Temperature	28.3	28.4	29.5	29.1	28.5	29.9	28.3	29.1	29.3	29.1
Conductivity (Ns/Cm)	68	129	286	200	373	127	402	224	403	364
Turbidity (Ntu)	2	1	0	11	4	6	0	2	1	0
Appearance / Colour (Mg/L)	C	C	C	C	C	C	C	C	C	C
Total Dissolved Solid (Mg/L) TDS	49.6	86.4	192	134	250	85.1	269	150.1	270	244
Total Harness (Mg/L)	12	10	100	24	64	27	10	56	94	58
Calcium Hardness (Mg/l)	8	6	87	18	52	20	7	36	72	32
Magnesium Hardness (Mg/l)	4	4	13	6	12	7	3	20	22	26
Ca^{2+} (Mg/l)	3.2	2.4	34.9	7.0	20.8	8.0	2.8	144	28.9	12.8
Ma^{2+} (Mg/l)	1.0	1.0	3.2	1.2	2.9	1.7	0.7	4.9	5.4	6.3
Cl^- (Mg/l)	15	17.9	19.9	19.9	45.7	19.2	24.2	19.9	38.3	49.9
No_2 (Mg/l)	12	2.4	ND	0.48	3.6	0.07	ND	2.8	4.3	1.7
Fe (Mg/l)	0.01	0.04	0.03	0.06	0.01	ND	0.02	0.04	ND	0.05
$S0_4$ (Mg/l)	8.0	7.0	8.0	7.8	9.6	7.4	9.2	9.0	9.8	9.0
Na (Mg/l)	9.8	11.6	12.9	12.9	29.7	12.5	15.7	12.9	24.9	32.4
Total Bacteria count (CFU/100ml)	7	11	6	8	4	9	12	7	8	13

Table 6: CORRELATION COEFFICIENTS FOR THE PHYSIO-CHEMICAL PARAMETERS

PHYSIO-CHEMICAL PARAMETERS	CORRELATION COEFFICIENTS (r)	REMARKS
Between total dissolved solids and PH	0.104	Positively correlated.
Between total hardness and total dissolved solids	0.0081	Positively correlated but low
Between PH and total hardness	-0.032	Negatively correlated