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Quality Assessment of Surface and Groundwater Sources in Lugbe, Abuja, North-Central Nigeria

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Abstract
Lugbe is one of the satellite towns in Abuja, the Federal Capital Territory of Nigeria. It is situated between latitudes 08°55´N to 09°00´N and longitudes 07°19´E to 07°26´E covering an area of about 50 km^2. The area is underlain by crystalline rocks of Precambrian age mainly the older granite and the Migmatite-gneiss. Groundwater and surface water samples were collected and analyzed for their physical, chemical and microbial parameters. Results of the analyses indicate that the physical parameters falls within the acceptable limit except pH which ranged from 5.8 and 6.9 indicating slightly acidic environment. Concentrations of the chemical parameters analyzed are within the permissible limits except copper and lead whose concentration in few locations where found to be higher than the WHO and NSDWQ recommended limits for safe drinking water. The water is poor bacteriologically as total coliform and E.coli were determined in both the surface and groundwater samples which is an indication of faecal contamination. The dominant water type from Piper diagram and Schoeller plot is Ca-Mg-Cl-SO_4. Due the poor quality of surface and groundwater sources in Lugbe, treatment of the water before domestic usage is recommended. The observed anomalies in the water sources are finger-prints of anthropogenic contamination due to upsurge in population and urbanization without proper sanitary measures as well as rock-water interaction mechanism.
Keyword: Quality Assessment, Surface water, Groundwater, Lugbe, Abuja, North-Central Nigeria

1. Introduction

The quality of water is the determinant of its suitability for any use as irrigational, industrial or domestic. Water is importance to life, without it life cannot go on. Due to the intimate relationship between water and life, water can be said to be woven into fabric of all cultures, religious societies in myriad ways (Amadi *et al*., 2014). It is a common knowledge that water covers a little above two-thirds of the surface of the earth but World Health Organization (WHO, 2010) argued that it is not just enough to have water in large quantities, the quality of water should also be adequate for healthy living. Therefore it is very imperative to pay particular attention in the provision and proper management of groundwater resources in places like Africa that consists of mainly developing countries with and characterized by poor sanitary conditions which are capable of contaminating both the surface and groundwater regimes. (Amadi *et al*., 2013). These are areas with such challenges as high evaporation rates, relative scarcity of water resources and degradation in water quality. No doubt with increase in population in these areas, there would be high level of anticipated future demand (Offodile, 2002; Amadi *et al*., 2015).

The practice of disposing both liquid wastes and solid wastes generated from cities and suburbs an on the surface or at shallow depths has a very harmful effect on the quality of groundwater (Nwankwoala *et al*., 2014). The impact of urban population distribution on underground water quality in the sub-Saharan Africa is well reported in the works of Uma and Oteze (1999). Faecal coliform are indicators of anthropogenic contamination affecting the quality of waters to be used for drinking purposes (Olasehinde *et al*., 1998). Bacteriologically polluted water is potentially dangerous to health because of possible outbreaks of typhoid, dysentery or cholera epidemics (Aminu and Amadi, 2014; Akoteyon and Soladoye, 2011; Dan-Hassan *et al.,* 2012).

The quality of groundwater is in most cases, determined by its chemistry and this may be changed by geology or human activities. Improper waste management system which is common in most developing countries like Nigeria has greatly affected both the groundwater resources both in quantity and quality. Every effort should be made to safeguard the quality of groundwater because one cannot restore the quality of a contaminated groundwater by removing the pollutants from source (Ramakrishnaiah *et al*., 2009). It is not good for man to negatively affect the source of water through his activities on the surface of the earth in order to guarantee the availability of groundwater to meet our water needs both now and in future (Sarukkalige, 2009). Human activities on the environment bring disorder on the supply of water, quality and creates unhealthy environment for man. (Okoro *et al*., 2009). Tay and Kortatsi (2008) drew attention on the human need for groundwater in the world and the implication on human health if contaminated. The quality of groundwater is mainly controlled by the range and type of human influence as well as geochemical, physical and biological processes occurring in the ground (Zaporozec, 1981; Carter *et al*., 1987). It therefore becomes imperative to regularly monitor the quality of the water and device ways to perfect it (Yisa and Jimoh, 2010).

The search for greener pasture in the Federal Capital Territory has attracted professionals of different kinds as well as artisans and this has contributed to the creation of slums in and around the study area. There is no public water supply in Lugbe thus the inhabitants rely on utilizing groundwater sources through construction of hand-dug wells, boreholes and rainwater harvesting in some cases.

Nevertheless, a primary consequence of rapid population explosion and steady rise in agricultural and industrial activities in an area are the degradation of the environment but especially groundwater quality. The sub-urban town of Lugbe and the nearby settlements have the problem of inadequate waste management system, with mostly little or no planned development in the area, poorly constructed septic tanks and pit latrines in some places. The waste generated includes domestic, agricultural and industrial types which decay soon afterwards and the leachates infiltrate into the ground which eventually pollute the groundwater.

The search for greener pasture in the Federal Capital Territory has made it difficult to control the influx of both skilled and unskilled people which has led to the creation of slums in and around the study area. There are mostly unplanned developments in the area, no drainage system, unplanned septic tanks and unlined pit latrine in some places. Also indiscriminate and open defecation in nearby undeveloped bushes are still in practice, inadequate waste management system, leakage from septic tanks, heaps of refuse dumps and metal scraps constitute nuisance in the study area. This lack of proper sanitation results to surface and groundwater pollution. The present work is aimed at evaluating the extent of contamination arising from various unregulated human activities in the area.

2. Materials and Methods

2.1 Description and Physiography of the Area

Lugbe is one of the satellite towns in Abuja, the Federal Capital Territory of Nigeria. It is situated between latitudes 08º55´N to 09º00´N of the Equator and longitudes 07º19´E to 07º26´E of the Greenwich Meridian (Figure 1). The topography of the study area is varied with the highest elevations found in the northeast where the plain is at elevation of about 460m above sea level. The lowest part of the area is the southern part (Sabon-Lugbe) where the elevation is 345m above sea level. The relative humility varies in the study area due to seasonal variations. The average relative humility for dry and rainy seasons in the area is 37% and 87.5% respectively. The area records its highest temperature of about 34°C during the dry season, which occurs from November to March. During the rainy season April to October, the maximum temperature drops to about 24°C due to the dense cloud cover (McCurry, 1985). The annual total rainfall is in the range of 1100mm to 1600mm (Ajibade, 1980). Two major types of vegetation, namely, forest and savanna, are found within Abuja. The forest is predominantly of woody plants, in which grasses are virtually absent.

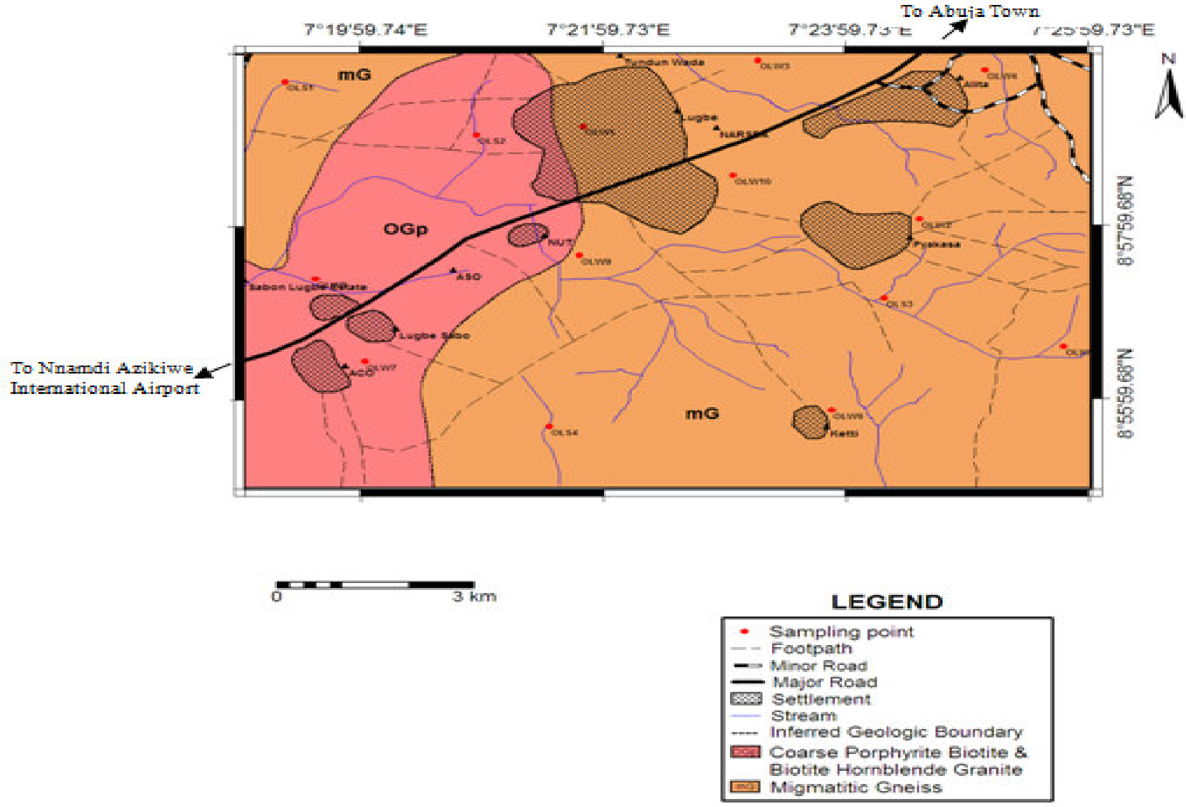

Figure 1: Geological map of the Lugbe and Environs

2.2 Geology and Hydrogeology of the Area

The study area is underlain by crystalline rocks comprising of older granite (Plate 1) and the Migmatite-gneiss (Plate 2). Hydrogeologically, two types of aquifers are recognized in the area. These are the regolith or weathered zone aquifer and the fractured zone aquifer. In the study area the rocks are weathered into reddish micaceous sandy-clay to clay materials capped by laterites at varying depths. In the study area groundwater is found mainly in variable weathered/ transition zone and in fractures, joints and cracks of various crystalline rocks. The local water table depth is controlled by textural and compositional changes within the regolith vertical profile and the bedrock topography.

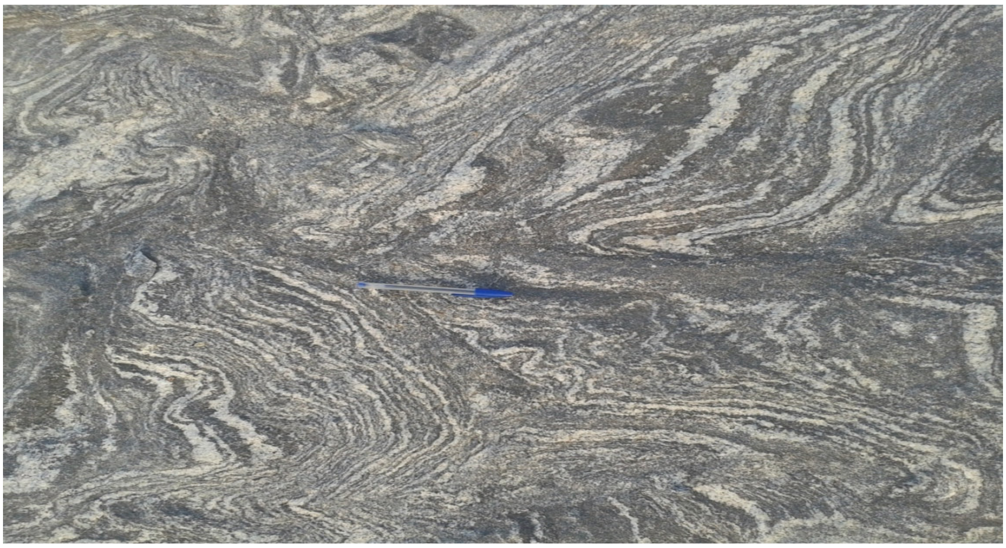

Plate 1: Gneiss outcrop showing mineral alignment at Pyakasa, Lugbe, Abuja
Latitude: 08º57′49.7″N and Longitude: 07º24′23.3″E

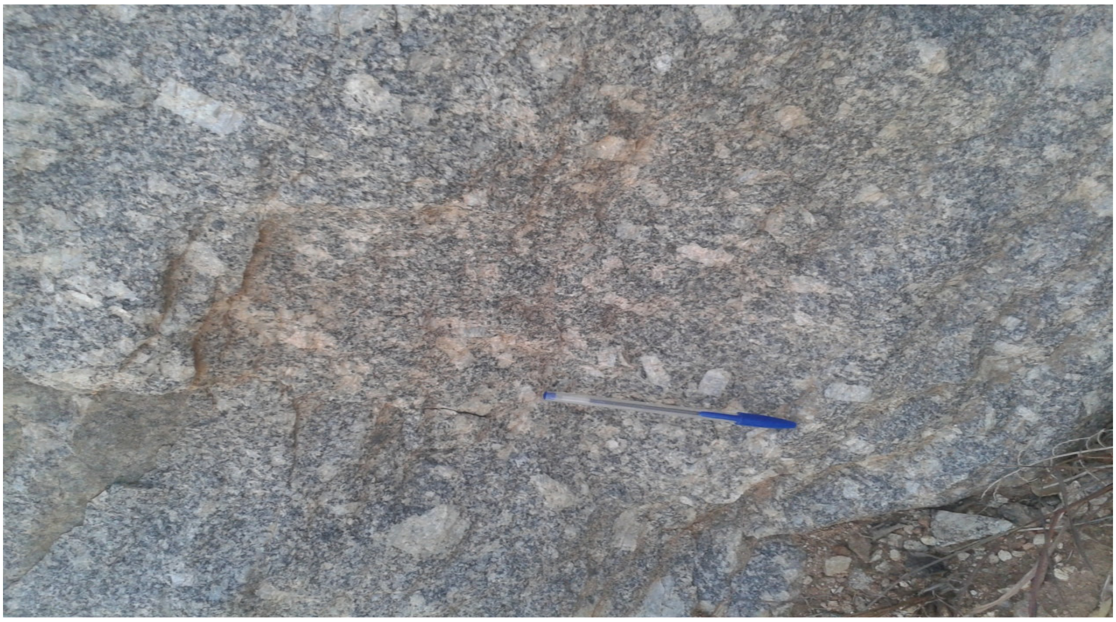

Plate 2: Medium-grained granite at Lugbe, Abuja with visible quartz and feldspar minerals
Latitude: 08º57′52.7″N and 07º20′55.1″E

3. Results and Discussion

The pH values ranged from 5.68 to 6.29 with a mean value of 5.94 for the surface waters and 5.88 to 6.9 with an average value of 6.27 for the well water samples. This implies that the groundwater samples have relatively higher pH values compared to those of surface water samples and that both the groundwater and surface water samples have pH values that fall within the WHO and NSDWQ guidelines for drinking water of 6.5 and 6.5-8.5 respectively (Figure 2). The combination of rainwater during precipitation with carbon-dioxide in the atmosphere to form a weak acid (carbonic acids) may have been responsible for the slight acidic nature of the water The pH concentration map of Lugbe area is shown in figure 2.

Total dissolved solids (TDS) concentrations ranged from 138mg/l to 257mg/l with a mean value of 209.8mg/l for the groundwater samples, while the corresponding electrical conductivity (EC) values ranged from 201µS/cm to 377µS/cm with a mean value of 302µS/cm. However, TDS and EC values for the stream water samples ranged from 550mg/l to 859mg/l (avg. 745.8mg/l) and 769 - 1353µS/cm (avg. 1099.2µS/cm) respectively. This revealed that all the TDS concentrations (Figure 3) and EC values of the groundwater samples are within the WHO and NSDWQ limits of 500mg/l and 1000µS/cm respectively. Meanwhile, all the TDS and EC values of the surface water samples recorded values that are above these limits except two locations that had EC values of 956µS/cm and 769µS/cm respectively. Total hardness (TH) values of the well water samples ranged from 20mg/l to 150mg/l with an average value of 68.3mg/l while the surface water samples had values that ranged from 14mg/l to 162mg/l (avg. 100.8mg/l). This showed that both categories of samples had total hardness values that conform to the WHO and NSDWQ limits of 200mg/l and 150mg/l respectively except samples S4 & S5 that recorded TH values of 162mg/l and 160mg/l respectively. The ions dissolved in water makes it conductive.

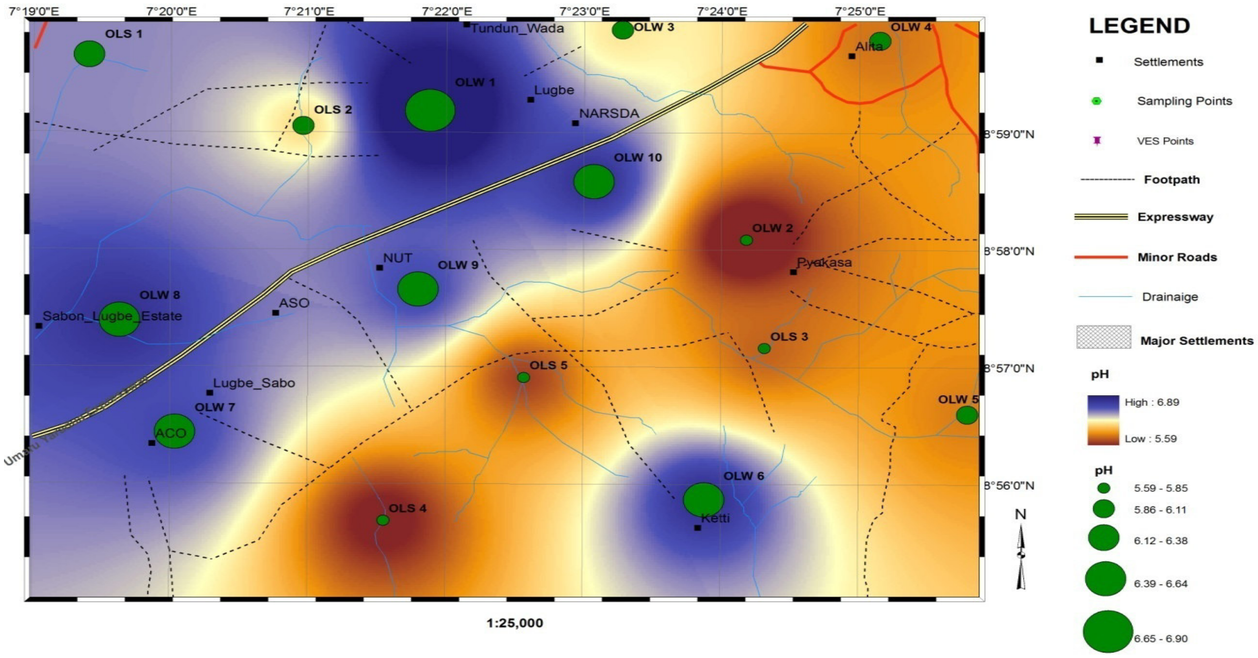

Figure 2: pH distribution map of water samples in Lugbe and environs

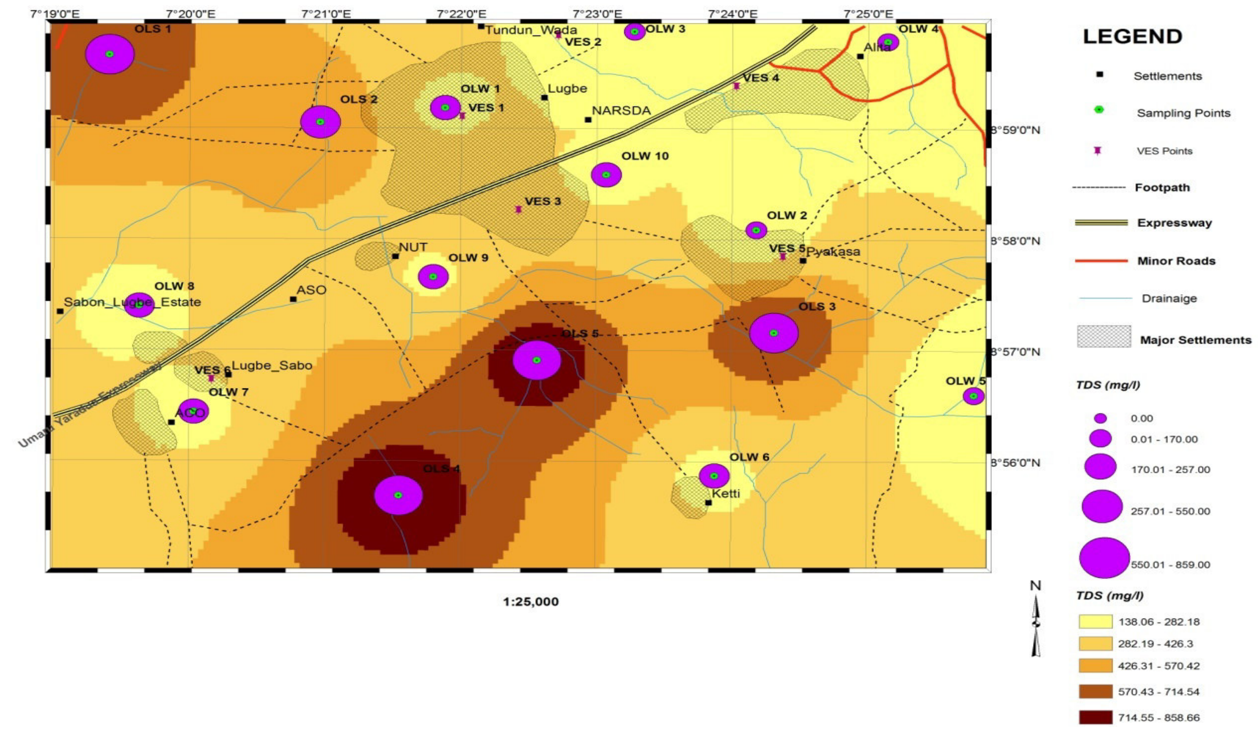

Figure 3: TDS concentration map of Lugbe and environs

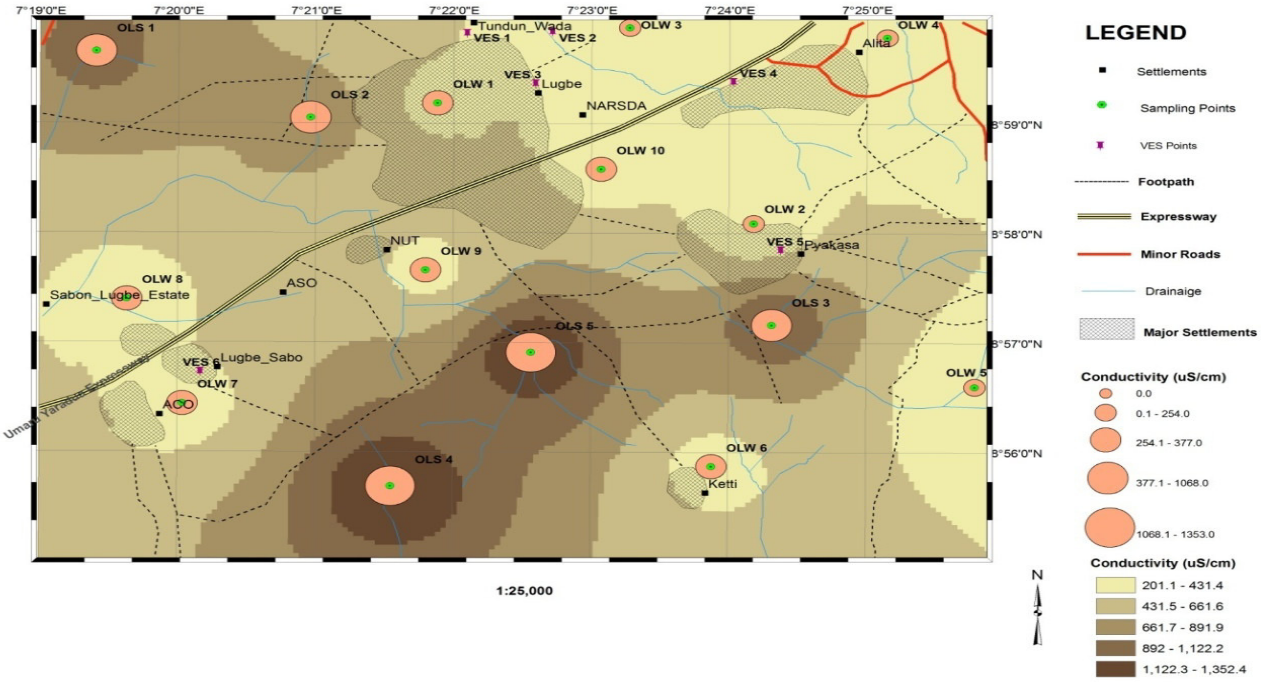

Figure 4: Conductivity map of Lugbe and environs

The turbidity values of the groundwater samples ranged from 0.78 to 58.19NTU with an average value of 10.92NTU while the surface water samples had turbidity values that ranged from 1.31 to 5.87NTU (avg. 2.45NTU). Although the turbidity values of the surface water samples are higher than those of the well water samples, all the samples obtained within the study area had turbidity values that exceeded the WHO maximum permissible limit of 0.5NTU in drinking water. The combined concentrations of sodium and potassium in both the groundwater and surface water samples analyzed ranged from 3.8 to 8.0mg/l (avg. 6.14mg/l) and 7.8 to 12.4mg/l (avg. 10.2) respectively. The occurrence of potassium in groundwater is attributed to the weathering of potassium feldspars while the occurrence of sodium in groundwater is through the release of soluble products during the weathering of plagioclase feldspar (Amadi *et al.,* 2014). Nonetheless, both the sodium and potassium concentrations in both categories of water samples fall within the WHO and NSDWQ permissible limits of 200mg/l and 10mg/l respectively in drinking water. The groundwater and surface water samples analyzed had calcium concentrations that ranged from 8.1 to 60.2 mg/l with an average concentration of 27.29mg/l and 18 to 63.3mg/l (avg. 42.46mg/l) respectively; and magnesium concentrations that ranged from 2.9 to 21.0mg/l with an average concentration of 9.72mg/l and 5.3 to 23.18mg/l (avg. 15.17mg/l) respectively. It should be observed that in both categories of samples, the concentrations of calcium and magnesium (alkaline earth metals) fall within the WHO permissible limits of 200mg/l and 50mg/l respectively. The concentrations of bicarbonate in the groundwater and surface water samples ranged from 16.2 to 121mg/l with an average value of 42.51mg/l and 14 to 128mg/l (avg. 58.2mg/l) respectively. Bicarbonate usually contributes to the alkalinity of the water and its source may be attributed to the CO_2-charged precipitation recharging the study area. All the values obtained fall within the WHO permissible limit of 1000mg/l in drinking water. The concentrations of carbonate in the groundwater and surface water samples ranged from 12.9 to 90.2mg/l with an average value of 35.21mg/l and 24 to 96mg/l (avg. 62.6mg/l) respectively. These concentrations are also within the WHO (2010) and NSDWQ (2007) limit of 100mg/l.

The concentrations of chloride in the samples analyzed ranged from 61 to 101.2mg/l with a mean value of 69.62mg/l (for the groundwater samples) and from 158 to 299mg/l (avg. 227.4mg/l) for the surface water samples (Figure 5). These concentrations all fall within the WHO and NSDWQ permissible limits of 250mg/l and 240mg/l respectively except samples S4 & S5 that recorded chloride concentrations of 294mg/l and 299mg/l respectively. The concentrations of sulphate in the groundwater and surface water samples ranged from 55 to 75.8mg/l with an average value of 61.1mg/l and from 55 to 60mg/l (avg. 56.6mg/l) respectively (Figure 6). These concentrations are also within the WHO and NSDWQ limit of 100mg/l. The samples had nitrate concentrations that ranged from 20 to 50mg/l with an average value of 36.4mg/l (for the groundwater samples) and from 57.3 to 124.8mg/l (avg. 83.6mg/l) for the surface water samples (Figure 7). The groundwater values all fall within the WHO and NSDWQ permissible limits of 50mg/l while, all the surface water samples recorded nitrate concentrations that exceeded this limit. The presence of nitrate in water is an indication of contamination through anthropogenic activities especially waste effluents from households. However, the concentrations of phosphate in both the groundwater and surface water samples analyzed ranged from 0 to 0.95mg/l with a mean value of 0.46mg/l and from 0 to 0.45mg/l (avg. 0.16mg/l) respectively.

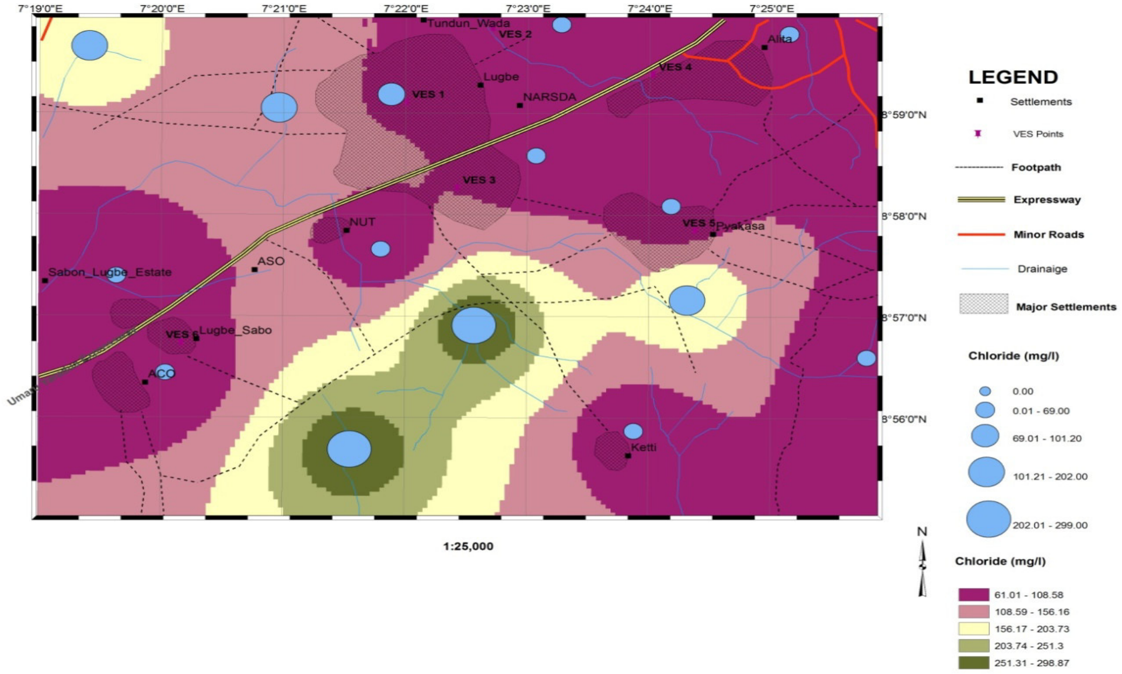

Figure 5: Chloride concentration map of Lugbe and environs

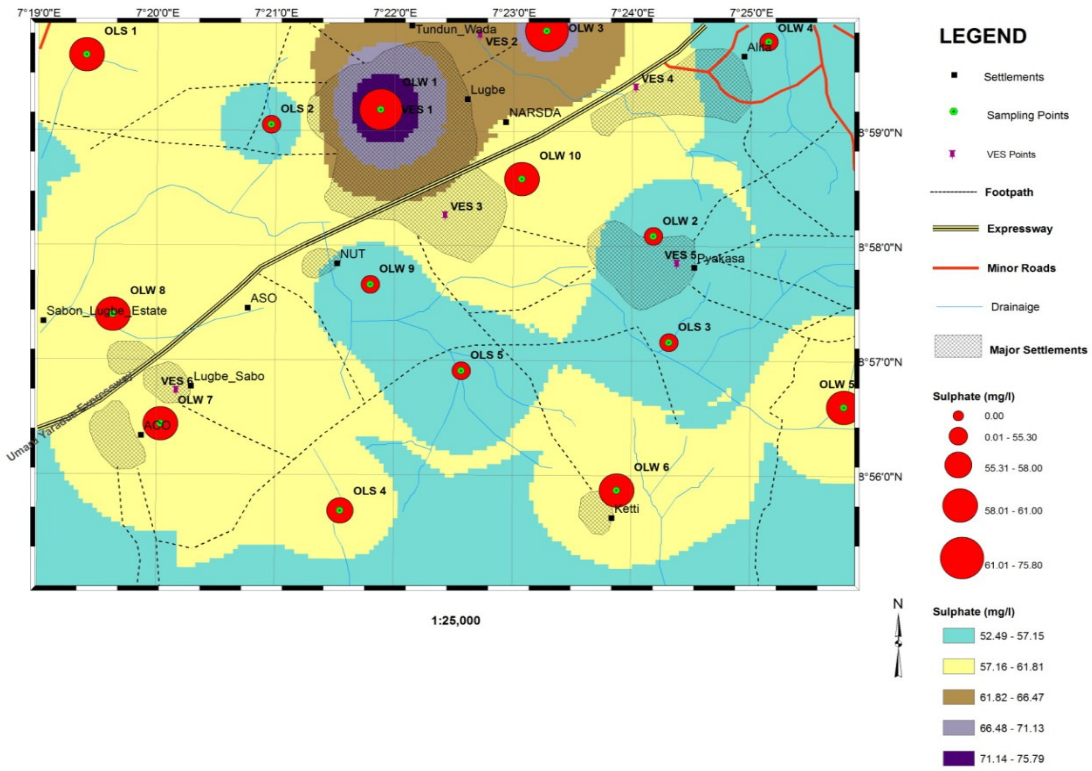

Figure 6: Sulphate concentration map of Lugbe and environs

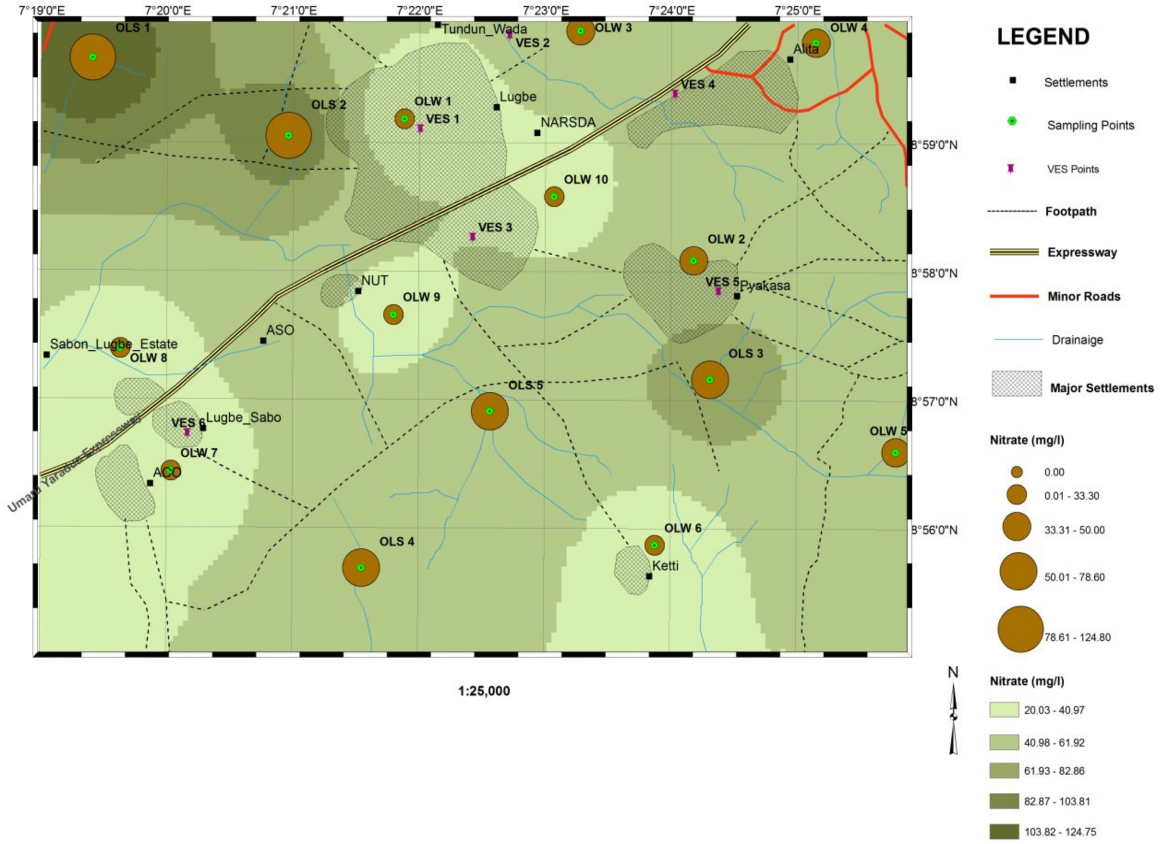

Figure 7: Nitrate concentration map of Lugbe and environs

3.1 Hydrochemical Facies

The classification of the water samples to determine the relative abundance of the major cations and anions was done using the Piper diagram (Figure 8) and Schoeller plot (Figure 9) respectively. The Piper trilinear method was devised by Piper (1944) to outline certain fundamental principles in a graphic procedure, which appears to be an effective tool in separating analytical data with respect to sources of the dissolved constituents in water. The concentration of 8 major ions (Na^+, K^+, Mg^{2+}, Ca^{2+}, Cl^-, CO_3^{2-}, HCO_3^- and SO_4^{2-}) are represented on a trilinear diagram by grouping the (K^+ and Na^+) and the (CO_3^{2-} with HCO_3), thus reducing the number of parameters for plotting. On the Piper diagram, the relative percentages of the cations and anions are plotted in the lower triangles and the resulting two points are extended into the central field to represent the total ion concentration. The Piper diagram was used to classify the hydrochemical facie of the water samples according to their dominant ions. The plot clearly revealed that the dominant hydrochemical facies in the area is Ca-Mg-Cl-SO_4 water type. These dominant water types are indicative of the fact that the wells from which the water samples were from the regolith zone. This condition as well as short residence time of groundwater greatly reduces the effect of the subsurface geology on the groundwater chemistry.

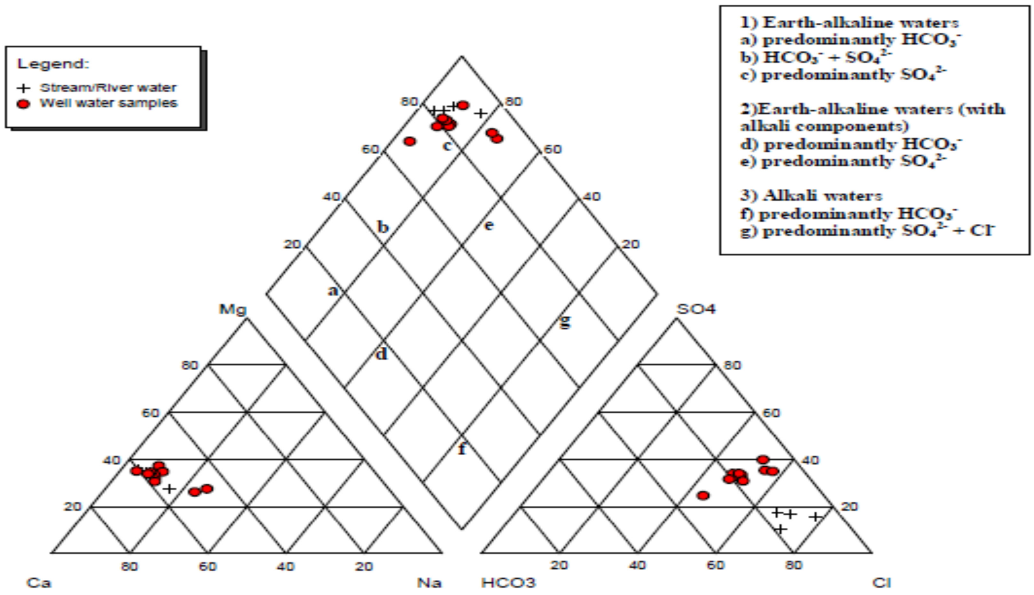

Figure 4.8: Piper's trilinear diagram of Lugbe and environs

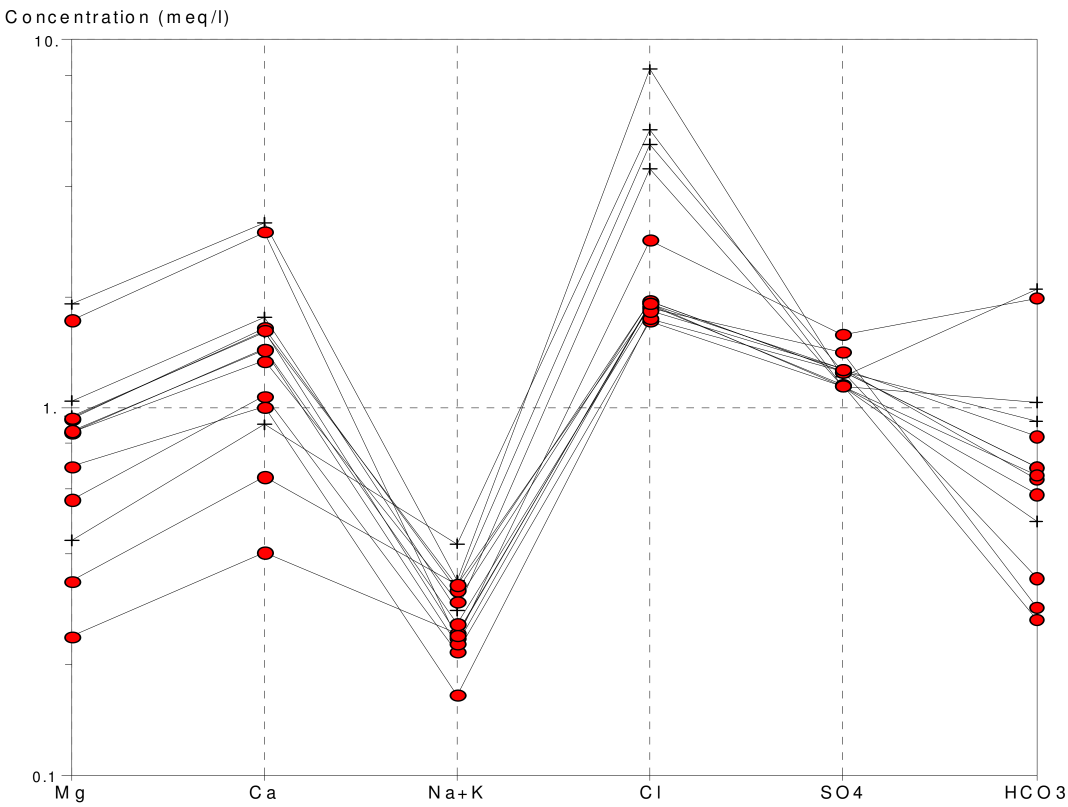

Figure 4.9: Schoeller plot of the major cations and anions in Ligbe and environs

Zinc concentrations in both the groundwater and surface water samples ranged from 0 to 1.2mg/l with average value 0.4mg/l and from 0 to 2mg/l (avg. 0.8mg/l) respectively. Both sources recorded zinc concentration that fall within WHO and NSDWQ maximum permissible limit of 3.0mg/l for drinking water. Zinc helps in healing of wounds. Concentrations of iron in both the groundwater and surface water samples ranged from 0.1mg/l to 5.5 mg/l with mean value of 1.7mg/l and from 0.25 to 1.8mg/l (avg. 0.66mg/l) respectively (Figure 10).

Iron occurs naturally as a mineral from sediment and rocks, discharging of waste effluents on land and corroding metal are the main source of iron in groundwater. High concentrations of iron generally causes bitter and astringent taste in water and make it unfit for drinking. It can also colour clothes, plumbing fixtures and cause scalding which encrusts pipes (Amadi *et al.,* 2015). The total coliform counts in both the groundwater and surface water samples ranged from 0 to 400 CFU/100ml with a mean value of 170CFU/100ml and from 0 to 300 CFU/100ml (avg. 120CFU/100ml) respectively. This is an indication of faecal contamination and poor sanitation. The concentrations of lead in both the groundwater and surface water samples ranged from 0 to 0.15mg/l with mean value of 0.14mg/l and from 0 to 0.23mg/l (avg. 0.09mg/l) respectively.

The major source of lead contamination in the area could be from gasoline and plumbing. It affects red blood cell chemistry; delays normal physical and mental development in babies and young children. Lead causes slight deficits in hearing and learning in children. Concentrations of manganese in both the groundwater and surface water samples ranged from 0 to 0.5mg/l with average value of 0.2mg/l and from 0 to 1mg/l (avg. 0.2mg/l) respectively Manganese occurs naturally as a mineral from sediment and rocks, and industrial waste. The presence of manganese above permissible limits of drinking water often imparts alien taste to water. It also has adverse effects on domestic uses and water supply structures. Concentrations of copper in both the groundwater and surface water samples ranged from 0 to 0.12mg/l with average value of 0.07mg/l and from 0 to 0.06mg/l (avg. 0.05mg/l) respectively.

The source of copper that enhance the concentration in groundwater in the area includes domestic effluents, paints and pesticides. It also enters the environment through mineral leaching. Excess copper in the body can cause stomach and intestinal distress, liver and kidney damage, anemia in high doses. It imparts an adverse taste and significant staining to clothes and fixtures. Copper is an essential trace element but toxic to plants and algae at moderate levels. The concentration of some of these metals in groundwater slightly above their permissible values may be attributed to rock-water interaction and bedrock dissolution/weathering processes as well as anthropogenic means.

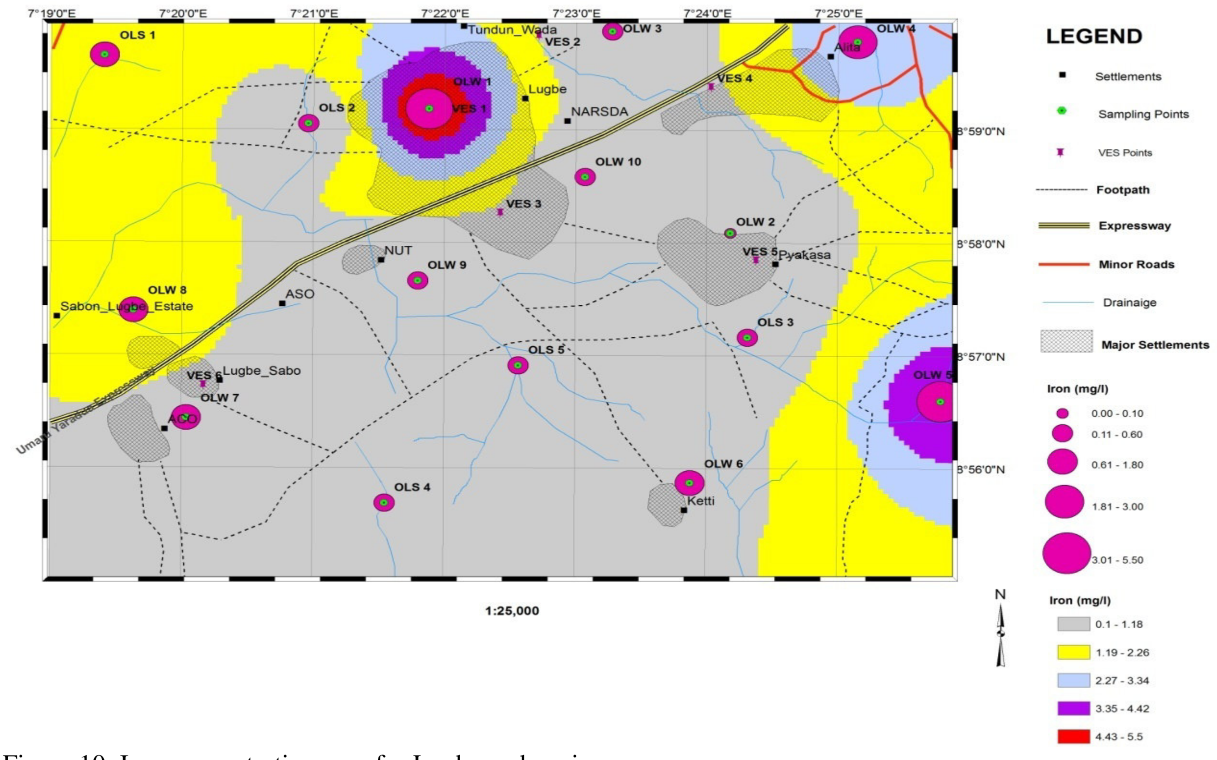

Figure 10: Iron concentration map for Lugbe and environs

4. Conclusion and Recommendations

Quality assessment of groundwater sources in Lugbe has been studied. The study area is underlain by crystalline rocks that is overlain by regolith or weathered zone which serve as aquifer. Most of the hand-dug wells in Lugbe area are from the shallow regolith aquifer. This can be attributed to weathering/dissolution of host-rock as well as anthropogenic interference. The concentration of Total coliform and E.coli were higher in most of the locations. Their presence in water is an indication of contamination arising from human/animal feaces. There is an urgent need for a public health education and sensitization aimed at improved household and community sanitation in Lugbe. Sanitation inspectors should be recruited to enforce sanitation laws.

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