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DEVELPOMENT OF A GROUNDWATER QUALITY MAP OF ILESA WEST LOCAL GOVERNMENT AREA, OSUN STATE NIGERIA- A GIS APPROACH

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ABSTRACT

The spatial distribution of the physico-chemical groundwater quality was assessed with a view to generating a groundwater quality map for Ilesa West local government area (LGA) Well points were selected using stratified random sampling to represent all the 10 wards of the LGA. Water samples were collected from 69 points for a period of one year covering the rainy and dry seasons. The samples were analyzed in the laboratory for pH, electrical conductivity (EC), temperature, total dissolved solids (TDS), chloride, sulphate, nitrate, sodium, potassium (K), calcium, magnesium, hardness, alkalinity and bicarbonate using standard methods. The ground water quality map was developed using the raster calculator, interpolation technique and water quality index in Arc GIS 10.1 software. Generally, the concentrations of the parameters were within the maximum permissible limits except for pH, TDS, EC and K. The map revealed that the groundwater resources belong to the good water quality based on World Health Organisation (WHO) and Nigeria Industrial Standard (NIS) rating scale except for the South East region that was poor in quality rating. The groundwater in the study area is generally acidic and soft. The study concluded that the effect of human activity and landuse may have greatly influenced the concentration of some parameters thus a further study on effect of land use and routine monitoring of the sources were recommended.

Keywords: Ilesa West, Groundwater quality, GIS ,WQI, Water quality map.

1.0 INTRODUCTION

Groundwater plays a fundamental but often unappreciated role in the economic and social well-being of most urban areas. It provides potable water and has proved to be the most reliable resource for meeting urban needs. Over 2 billion people rely on groundwater as the only source of drinking water (Sampat, 2000) and this has raised some concern and a pressing need for groundwater quality and monitoring network to investigate baseline characteristics and trends in Nigeria (Adelana *et al.*, 2011). For any town or city, a groundwater quality map is important as a precautionary indication of potential environmental and health problems and to evaluate the safety of drinking water. Studies have shown that Nigeria urban groundwater quality is influenced by the rate of urbanization, bacteriological pollution, geology, and geochemistry of the environment, industrialization, landfill/dumpsite leachates, heavy metals and seasons (Ocheri *et al*., 2014). Ocheri *et al*.(2014) found that 80% of wells had nitrate concentrations above the WHO allowable limit for drinking water in wet season. Wongdem *et al*. (2001) reported 4 mg/L as against 1.5mg/L specified limits of fluoride in groundwater in Langtang town, Nigeria. Adelana (2006) reported that nitrate, the most pervasive contaminant has been found at levels in excess of drinking water standards in many regions in Nigeria. A survey conducted by Yusuf *et al*. (2012), reported that most chemicals analyzed were within the permissible limits but magnesium contents were above the permissible level in boreholes in Ilesa and Osogbo. Odebunmi *et al*. (2014) reported that exceptions were observed in Pb, Hg, As and Cd which were found to be a little above the set standard in Ilesa and concluded that the users of the untreated sources of water from the study area may suffer from several heavy metal-induced toxicity symptoms. Tijani *et al*. (2014) concluded that the water in Ilesa is neutral to slight alkaline and Ogunlesi *et al.* (2004) linked the diarrhea reported in Ilesa with poor quality of drinking water of the children. Ayoade and Ibitoye (2012) reported that coliform bacteria occur in high numbers in wells and boreholes in Ilesa. The best way to manage groundwater optimally and sustainably is when the quantity and quality are properly assessed (Kharad *et al*., 1999). The overall goal of a groundwater quality assessment programme is to obtain a comprehensive picture of the spatial distribution of groundwater quality and of the changes that occur, either naturally or under the influence of man (Wilkinson and Edworthy, 1981). A lot of mathematical means have been created to simplify the assessment of groundwater; Water Quality Index (WQI) is a rating that is used to reflect the composite influence that the different water quality parameters have on the overall water quality. The use of Geographical Information System (GIS) technology has greatly simplified the assessment of groundwater. Geo-statistics is a collection of methods that allows estimation of values for locations where no samples have been taken and also to assess the uncertainty of these estimates. Inverse distance weighting (IDW) is one of the method used for multivariate interpolation and it calculate values of unknown points in any study area with values available at known points. In interpolation with IDW method, a weight is attributed to the point to be measured. The amount of this weight is dependent on the distance of the point to another unknown point. ((Burrough and McDonnell, 1998).

Studies in Nigeria on groundwater quality assessment abound in literatures such as Odebunmi *et al*. (2014), Tijani *et al*. (2014), Ufoegbune *et al*.(2009), Aladejana and Talabi (2013), Talabi and Tijani (2011), Obada and Oladejo (2013), Talabi and Ogundana (2014), Agbede and Ojelabi (2017) and it was concluded that there were problems with groundwater in the towns of Nigeria hence the need for monitoring. Non-availability of pipe borne water has forced Ilesa community to resort to the exclusive use of groundwater. There has been indiscriminate sinking of wells by individuals and local authorities and some of the wells are not fit for drinking as residents are not comfortable with the taste. Past studies showed that many of the wells in the Ilesa town have failed at least one drinking water standards but it cannot be linked with the study area hence monitoring the resources has been difficult. Groundwater quality map has not been developed and spatial distribution was not reported, hence this study.

2.0 DESCRIPTION OF THE STUDY AREA

The study area (Figure 1) is Ilesa West Local Government Area (LGA) in Osun State, Nigeria which was carved out of the then Ilesa Local Government Area in 1996. Geographically, it is located within coordinates 07^0 36’ N and 004^0 40’E and 07^0 42’N and 004^0 46’E and has a total area of 63 km^2. Typical of a tropical region, it has two dominant seasons; a rainy season which is usually between May and October and a dry season from November to April and because of these, two periods of high temperatures were recorded annually. The first period is usually in March to April and the second is in November and December. The average daily temperature could vary between 20°C and 35°C (for a very hot day). Geologically, the LGA is characterized with biotite-gneisis schist and amphibolites complex (Malomo *et al.*, 1990). The LGA headquarter is located in Omi-Aladiye along Osogbo Road and it has 10 wards.

3.0 MATERIALS AND METHODS

The administrative and Google map of the study area were used to identify the various streets. A field study was then conducted to obtain the GPS points of the different groundwater resources. These points were imported into a gridded map using Arc GIS 10.1. The well points that fell within the built up and the centers of the grids were selected for the survey. A total number of 69 points were finally used as sampling points and their point features were made the spatial data used to develop the location study area map (Figure 2). From these wells, groundwater samples were collected and analysed for physico- chemical parameters in laboratories at Obafemi Awolowo University. The water quality data obtained formed the non-spatial database. These were stored in excel format and linked with the spatial data. A method of inverse distance weighting was used for spatial interpolation and the raster calculator of ArcGIS 10.1 was used to perform the water quality index (WQI) analysis to generate the water quality maps. For computation, 11 parameters were selected; pH, TDS, chloride, nitrate, sulphate, bicarbonate, calcium, magnesium, sodium, potassium and total Hardness (TH). They were assigned a weight (w) according to their relative importance in the overall quality of water for drinking purposes. WQI was computed by adopting the formula proposed by Vasanthavigar *et al.* (2010) and Tiwari *et al*. (2014). Parameters such as TDS, sodium, chloride, nitrate and sulphate were assigned a maximum weight of 5 because they are cations and anions that are important in the chemistry of water quality. Parameters; pH, calcium, magnesium, potassium and TH were assigned weights between 2 and 5 in the order of their importance in water quality determination and Bicarbonate was given the minimum weight of 1. The relative weight (W_i) was computed from Eq. (1):

$$Wi = \frac{wi}{\sum_1^n wi} \qquad 1$$

Where w_i is the weight of each parameter and n is the number of parameters. The calculated relative weight (W_i) values of each parameter are given in Table 1. A quality rating scale (q_i) for each parameter was assigned by dividing its concentration in each water sample by its respective standard according to the guidelines in the NIS(2007) and WHO (2008). The result was multiplied by 100 in Eq. (2)

$$qi = \frac{Ci}{Si} x100 \qquad 2$$

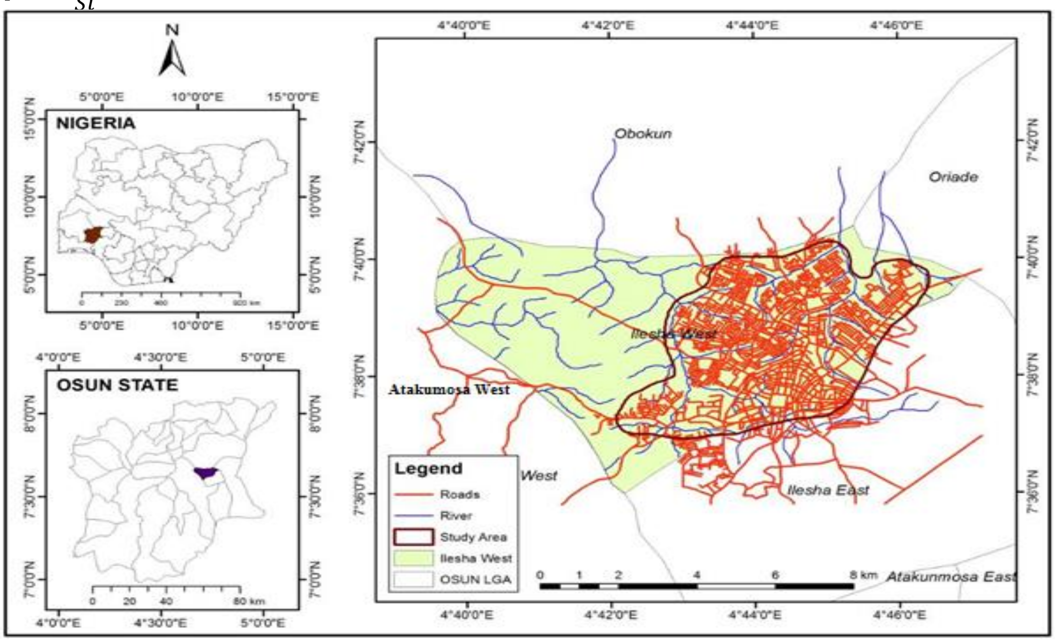


Figure 1: Study area map

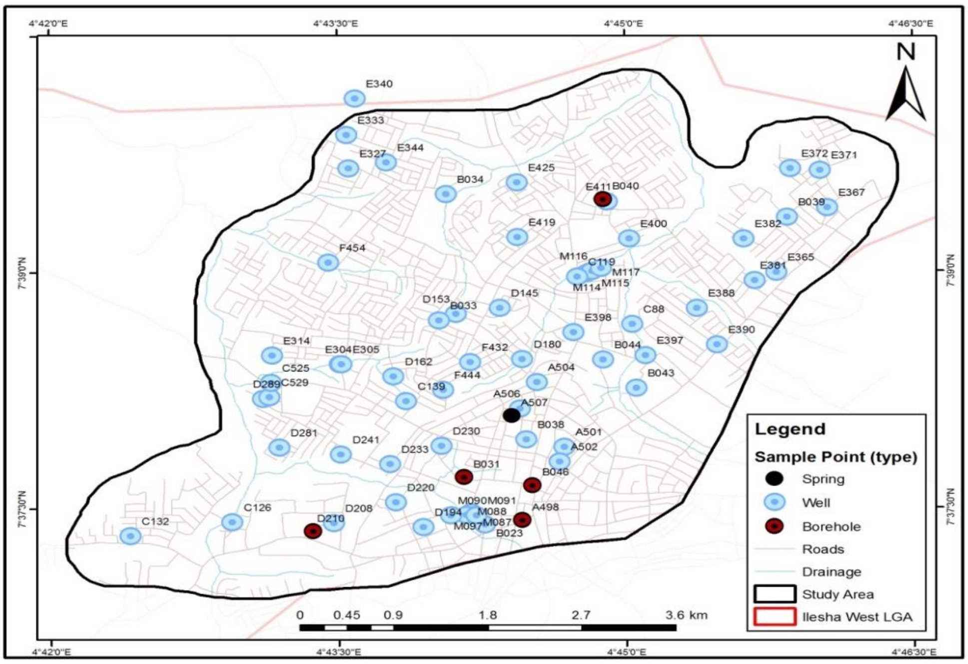


Figure 2: Sample points on study area map

Table 1: Relative weights of chemical parameters in WQI calculation

Chemical Parameters	Standards (NIS/WHO)	Weight (w_i)	Relative Weight (W_i)
pH (no unit)	8.5	4	0.1
TDS (mg/L)	500	5	0.125
Chloride (mg/L)	250	5	0.125
Nitrate (mg/L)	45	5	0.125
Sulphate (mg/L)	200	5	0.125
Bicarbonate (mg/L)	200	1	0.025
Calcium (mg/L)	75	3	0.075
Magnesium (mg/L)	30	3	0.075
Sodium (mg/L)	50	5	0.125
Potassium (mg/L)	100	2	0.05
Total Hardness (mg/L)$CaCO_3$	300	2	0.05

Source: Adapted from Vasanthavigar *et al.* (2010); Tiwari *et al.* (2014) and Tiwari *et al.* (2015).

where C_i is the concentration of each chemical parameter in each water sample in mg/L. This was calculated from the raster calculator of the ArcGIS tool. S_i is the WHO standards for each chemical parameter in mg/L.

For computing the WQI, the S_i was first determined for each chemical parameter (Eq. 3) which was then used to determine the WQI in Eq. (4). The WQI rating is presented in Table 2

$$Si = Wi\ x\ qi \qquad 3$$

$$WQI = \sum Si \qquad 4$$

where the S_i is the sub-index of ith parameter, q_i is the rating based on the concentration of ith parameter and n is the number of parameters.

4.0 RESULTS AND DISCUSSION

4.1 Physico-Chemical Results

The descriptive statistics of the physico-chemical parameters are presented in Table 3. Most of the parameters were within the WHO/NIS acceptable limits except for pH TDS, EC and K. The groundwater in the study area was generally soft based on Sawyer and McCarty (1967) classification and the nitrate level signal an anthropogenic interference based on Madison and Brunnet (1994) recommendation. The spatial map for the different parameters revealed that higher concentrations were concentrated in the South-East region but the concentrations were not health threatening.

4.2 pH, TDS, EC and K

The pH showed similar pattern for all the sampling periods; pH values were within the acidic range (4.1-7.4) except for the South East region of the area that the groundwater had pH within the WHO range (6.5-8.5). The values of the pH obtained agreed with the results of Malomo *et al.* (1990) and Ayoade and Ibitayo (2012) for Ilesa environs. The acidity in this area may be due to natural acidification which is possible in areas with weathering-resistant soils and rocks and where the climate is humid. Acidification can also come from the precipitation, which in its natural state has a pH value around 5.6 owing to the content of

Table 2: Classification of WQI range and category of water

WQI Range	Category of Water
< 40	Excellent Water
40 – 80	Good water
81 – 160	Poor water
161 – 240	Very poor water
> 240	Unfit for Domestic Usage

Source: Adapted from Tiwari *et al.*(2015)

Table 3.Descriptive statistics of physic- chemical parameters

Parameters	Mean	Min	Max	Std .Error	Skewness	Kurtosis
pH (no unit)	5.63	4.1	7.4	0.04	-0.01614	-0.7604
WT(^{0}c)	27.9	16.7	34.0	0.07	-1.35	13.37
TDS (mg/L)	175.24	8.40	1022.00	10.21	1.71	2.18
EC (µS/cm)	282.57	12.34	1625.00	17.09	1.85	3.19
Cl (mg/L)	29.90	1.40	212.70	1.933	2.28	7.16
SO_4 (mg/L)	11.41	1.28	33.76	0.45	3.92	37.88
NO_3 (mg/L)	1.42	0.07	24.22	0.09	4.77	45.19
Ca (mg/L)	18.36	1.66	132.29	1.01	2.02	4.03
Mg (mg/L)	1.83	0.00	7.35	0.09	1.79	4.01
TH(mg/L)	54.37	6.50	330.15	2.54	1.85	3.40
Alkalinity (mg/L)	46.53	4.00	260.00	2.54	2.02	3.24
HCO3 (mg/L)	55.83	4.80	312.00	3.05	2.02	3.24
Na (mg/L)	23.19	0.98	107.50	1.19	1.46	1.51
K (mg/L)	16.33	0.02	176.01	1.39	2.27	5.31

WT- water temperature; TH- total hardness

carbonic acid in the atmosphere and natural emissions of sulphur from the land and the sea. When there is release of chemical gases, e.g. sulphur-dioxide, nitrogen dioxide, carbon monoxide and carbon dioxide from bush burning, combustion (organic and inorganic), vehicular emission and industrial wastes, it could generate acidic rains and the water, which can infiltrate into the ground can lower the pH of the water. The groundwater pH in the study area followed a definite trend (acidic). There were no known health effects of pH but are known to cause bitter metallic taste (Nathanson, 2000). When pH value is less than 6.5, it can cause corrosion and the subsequent release of metals such as Pb, Zn, and Cu from pipes and plumbing fixtures into water; these substances can be toxic to humans (Lehr *et al.,* 1980). Acidity in groundwater has been reported in literatures such as Ufoegbunne *et al*. (2009), Ayodele (2012), Atarhe and Egbuna (2013) and Agbede and Ojelabi (2017).

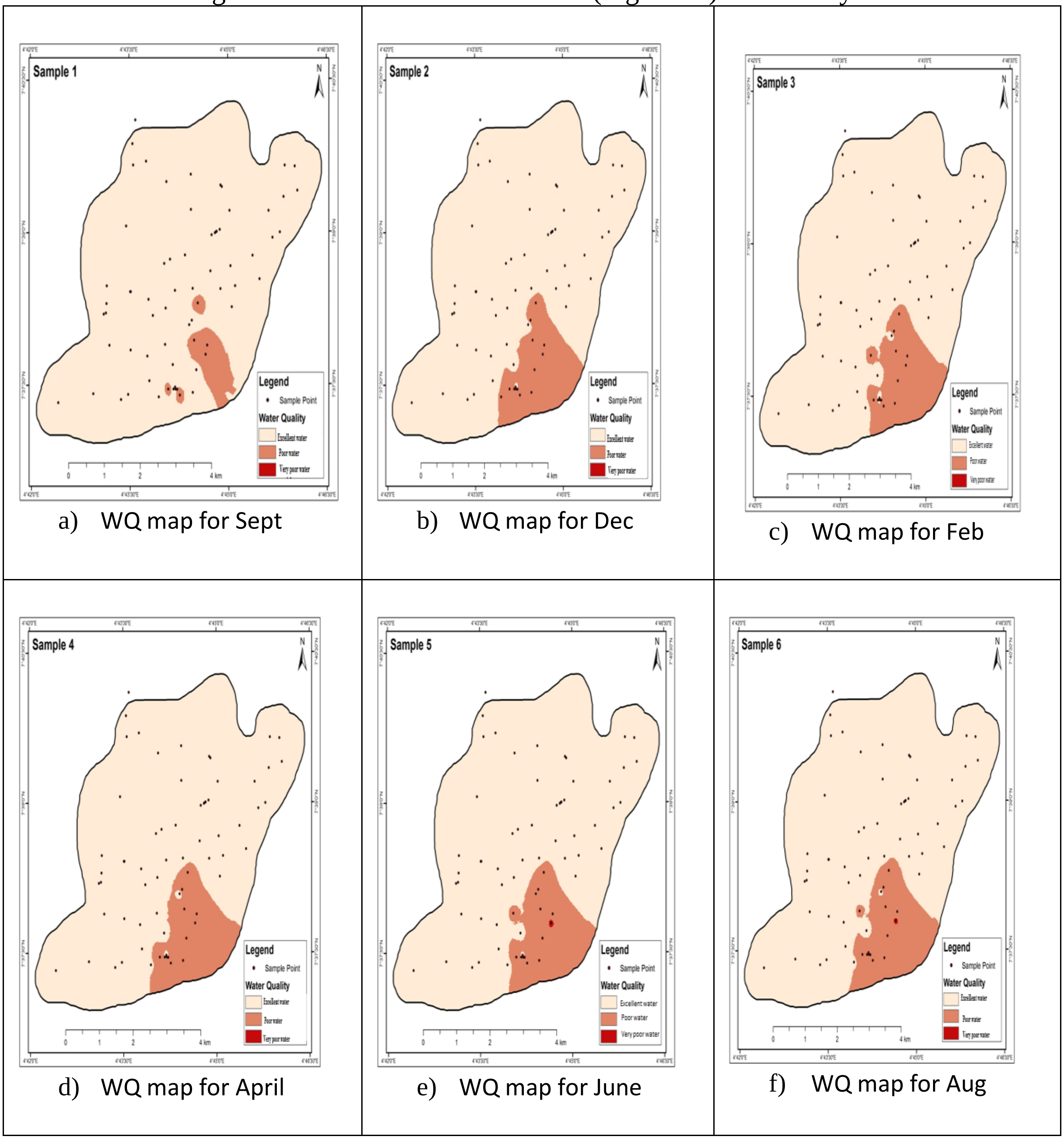
The spatial distribution of TDS displayed that higher values of TDS were concentrated in the South East region of the study area. Recommended values for TDS is 500 mg/L and Hem (1998) classified water as fresh if it has a TDS of <1000 mg/L while TDS between 1000-3000 mg/L is classified as slightly alkaline. This was true when compared to the spatial variation of the pH in the South East region. Some of the constituents that may dissolve in groundwater as it moves down include sodium, potassium, calcium, magnesium, silica, bicarbonate, sulphate, chloride, and nitrate (Panno and Hackely, 2010). These constituents come from the dissolution of rocks such as limestone. Considering the pH in the study area, anthropogenic influence could not be ruled out. Higher values of TDS decrease the palatability of water and may also cause gastrointestinal irritation and laxative effects in humans.. Craun *et al*. (1975) reported that increased TDS concentrations in drinking water can cause cancer, coronary heart disease, and cardiovascular disease. Higher values are indicators of corrosivity (related to lead levels in water) and it can damage plumbing and limit the effectiveness of soaps and detergents (Nathanson, 2000).

The mean EC values for the water sources were generally low but the maximum value (1625 µS/cm) was higher than 1000 µS/cm recommended. The values of EC for the study area showed a constant trend for the period of assessment but there were wide disparity among the locations. Most times, EC and TDS are basic indicators of the total mineral contents of water and may be related to problems such as excessive hardness, corrosive characteristics or other mineral contamination (Anilkumar *et al.*, 2015). The effects of high EC may include disturbances of salt and water balance and high salt concentrations in water. Some of the adverse health effects of high salt concentrations include heart problem, high blood pressure and renal disease (Department of Water Affairs (DWAF), 1998). The spatial distribution of EC showed a direct reflection of the TDS maps. Spatially, the South East region of the study area had concentration of potassium that was high. Although potassium is a relatively abundant element, its concentration in natural fresh water is usually less than 20 mg/L (Ufoegbune, *et al.,* 2007). Potassium salts are widely used in industry and in fertilizers for agriculture. The high concentration in the South East region suggested an anthropogenic influence.

Generally, the study area was characterized with soft water and the trend agreed with most literatures on the combination of parameters with high concentration; when the EC and TDS are high, they indicate the total mineral contents of the water and may be related to problems such as excessive hardness, corrosive characteristics or other mineral contamination (Anilkumar *et al.*, 2015). Water softer than 30 –50 mg/L tend to be corrosive and should be examined for plumbo-solvency (Adewoyin *et al.*, 2013). Soft waters with hardness less than 100 mg/L are more corrosive for water pipes because of their low buffer capacity and this is also true for low pH values. The results obtained in this study indicated that majority of the wells in the LGA have low pH and with soft water dominating in the area; there should be a concern in terms of lead pipes and dissolution of heavy metals. The presence or absence of the hardness minerals in drinking water is not known to pose a health risk to users. The concentration of nitrate is well below WHO permissible levels but the range signal possible human influences when compared with Madison and Brunnet (1984) thus a routine monitoring is necessary to follow-up the source.

4.3 Water quality map

The water quality map revealed that water in the study area was excellent in water quality category (Figure 3) except the samples from the South East region that fell under poor water category. The only physical feature in this area was a dumpsite although the place was highly populated and it is the commercial centre of the study area. In addition to the above, there were no good sanitary systems in the South East region and the groundwater levels were closer to the surface. The high distribution of excellent water (Figure 3a) in the rainy months



a) WQ map for Sept
b) WQ map for Dec
c) WQ map for Feb
d) WQ map for April
e) WQ map for June
f) WQ map for Aug

Figure 3: Water Quality (WQ) maps for the study area

of September might be due to dilution of the concentration of the parameters. The existence of poor water in June and August (Figure 3e and 3f) explained the seasonal variation of the water quality in the study area. Rainy season starts in May and this might have introduced pollutants in June and August.

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5.0 CONCLUSION AND RECOMMENDATION

The groundwater quality map of Ilesa West LGA revealed that the water was generally good based on WQI rating. However, the poor water quality in the South East region for all the sampling period signaled an anthropogenic influence around the area. The pH was consistently low, thus a routing monitoring is recommended for heavy metal dissolution and the effect of land –use on the quality should be assessed

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