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GIS-Based Underground Water Quality Risk Mapping of Kaltungo L.G.A, Gombe State, Nigeria

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Abstract

The research aimed at identification and risk mapping of the concentration of physiochemical properties of some metal ions in the underground water in Kaltungo LGA of Gombe State with the aid of Geospatial Techniques. Water samples used comprises of all of the 40 wells and boreholes were sampled and two control points and out of that, wells constitute about 25 and 15 boreholes respectively. Also, ten metals ions which includes; Alkalinity of the water, B.O.D, C.O.D, D.O, Chloride, Electric Conductivity, Fluoride,Nitrate, phosphate, Sulphate, T.Hard, were selected and analyzed in laboratory. DEM, Curvature, Watershed, Aspect, Slope and Hillshed were also used. The methods employed were both Laboratory and Geospatial techniques. The result obtained from the lab was compared with WHO standards, imported in to ArcGIS 10.3 environment and interpolated and subsequent analysis were done using kringing methods and query. Based on the query from the geodatabase of the underground water, it was found that 60% out of the metal ions used in this study were not in conformity with the WHO standards for drinking water. Amongst these metals are; Electric Conductivity, Fluoride, Nitrate, Sulphate, T.Hard and T.Hard. It was also found that 97.5% of the wells and boreholes have higher concentration of Fluoride, 85% Sulphate, 75% Electric Conductivity and 55% Nitrate while 32.5% and 30% have lower concentration of T.Hard and Turbidity respectively. Again reveal that those metals with higher concentrations of physiochemical properties are found to be within lower elevation, moderately water table due to down slope movement of water.

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Moreover, it was revealed that due to the convex profile curvature and watershed nature of the study area physiochemical of the water was accelerating to the lower slope towards the Northeast and Eastern part of the study area. Furthermore, it was found from the risk map that the vulnerability underground water risk area was the Northeast, central and Eastern part of Kaltungo. It was recommended that GIS techniques should be of paramount used in examine water related issues so as the results will served as a basis for decision support for WHO and others related organizations.

Keywords: Physiochemical Parameters; Underground Water (wells and boreholes); Drinking Water; Geodatabas; Risk Zone; GIS.

1. Introduction

According to [1,2], Groundwater is one of the most significant natural sources and can be used as an alternative to surface water for drinking, irrigation and industry usage. Poor drinking water quality, high cost of water purification, human health problems, and loss of water supply are attributable to groundwater contamination. The monitoring of the chemical, physical and biological conditions of groundwater is considered to be critical for the planning strategy for the protection of groundwater quality [2]. The number of patient seriously affected by arsenic from drinking water has now risen to thousands and possesses a great risk to human health. Risk analysis is the process of quantifying the probability of a harmful effect to individuals or populations from certain geological, physical or anthropogenic activities. Risk assessment examines the potential human health challenge due to exposure to toxic contaminants in various environmental media. Its purpose is to estimate the severity or magnitude of risk to human health posed by exposure to an environmental hazard [3,4]. Control of water-related health risks requires a view that links water management and sanitation to public health in development projects [5,6,7]. It was noted that improvements in the quantity of water use have an impact on the water washed diseases, and diseases which mainly spread when not enough water is available to maintain a good hygiene [8,9]. Chemical contamination of groundwater is one of the most serious pollution problems, particularly in arid and semi-arid areas where typically there is a deficiency in water resources. Chemical pollutions and waste water pollutions in river and GW are not normally identified until some illness has affected the local population [10]. Geostatistics is a spatial statistical technique that can be used to assess and represent the distribution of concentration over space and time [11]. This technique predicts the estimated values based on the relationship between the sample points and estimates the uncertainty of that prediction [11,12,13]. GIS have been used increasingly in environmental epidemiology and are an extremely useful tool to determine spatial variability and relationships between environmental factors and health-outcomes provided that exposure routes are established [14]. Risk assessment GIS have been developed previously for physiochemical parameters in Durango, Mexico where concentrations determined in tap water were used to categorise the city into zones of low to high risk. It is against this background this research aimed at identification and risk mapping of the concentration of physiochemical properties of some metal ions in the underground water in Kaltungo LGA of Gombe State with the aid of Geospatial Techniques. The aim was achieved through the following objectives:

i. Examine the level of physicochemical parameters of the underground water (Borehole and Wells) and create a geodatabase in Kaltungo L.G.A.

ii. Evaluate the spatial distribution of the Parameters in Kaltungo L.G.A.
iii. Identify and map the underground water quality risk zones in Kaltungo L.G.A.

2. The Study Area

2.1 Description of the Study Area

Kaltungo LGA lies between latitude $9^0$48'00N to $9^0$50'38N and longitudes $11^0$16'00E to $11^0$19'45'E. It's a Local Government Area of Gombe state which lies at the central position of North-eastern part of Nigeria. The study area forms part of the Gongola arm of the Benue Trough. The area has a mean maximum temperature of 31^0C and average annual rainfall of 1550.7mm, with a topography range from 402 meters to 702 meters above mean sea level among which characterise the famous Tangale peak [15].

3. Materials and Methods

About 40 Water samples were collected from open wells and boreholes from different sites in the study area during in May, 2013. Wells constitute about 25 and 15 boreholes respectively. The locations of the sites were obtained by using hand-held Global Positioning System (GPS) receiver. Samples were collected in clean plastic containers and labelled. The containers were thoroughly rinsed with the ground water to be sampled. In the case of bore wells and hand pumps, the samples were collected after pumping for few minutes. The water level and depth of the wells for each sampling locations were also recorded. Preservation and transportation of the water samples to the laboratory followed standard methods. The physical and chemical parameters of the samples were analysed in the laboratory following standard methods (Table. 1). The parameters analysed saw in the table below. The result obtained from the lab was compared with WHO standards to examine the suitability for drinking purpose.

Table 1: Analytical Methods and Equipments Used

S/No	Parameter	Method	Equipment
1	Temp. ^oC	Thermocouples	A thermometer
2	pH	Electrometric	pH meter
3	Electrical Conductivity (µS/cm)	Electrometric	Conductivity meter
4	Turbidity (NTU)	Nephelometric	Nephelometer
5	Alkalinity(mg/l)	Dilution method	volumetric pipette
6	Total Hardness (mg/l)	Rude Home Soap Test	Flame atomic absorption spectrophotometry
7	Dissolved Oxygen (mg/l)	Amperometric	Barometers
8	Chemical Oxygen Demannand (mg/l)	Colorimetric	Colorimeter
9	Biological Oxygen Demannand (mg/l)	Ion chromatography	Ion Chromatograph
10	Sulphate (mg/l)	Ion chromatography	Ion Chromatograph
11	Fluoride mg/l)	ion selective electrode (APHA, 2012)	spectrophotometry
12	Nitrate (mg/l)	Ion chromatography	Ion Chromatograph
13	Chloride (mg/l)	flame photometry	flame photometry
14	phosphate (mg/l)	Colorimetric	Lachat Instruments

Spatial interpolation techniques such as IDW were used for predicting spatial distribution of ground water quality parameters as show on Table 1. The IDW interpolation for each parameter was calculated using ArcGIS 10.3.

4. Results and Discussions

4.1 Results

4.1.1 Examine the level of physicochemical parameters of the underground water (Borehole and Wells) and create a geodatabase

About 14 of the physicochemical parameters of the underground water (Borehole and Wells) were tested in the laboratory. After the test, the results for each of the element were compared with the WHO standard for drinking water and the result shows that out of the 14 elements that were examine, is only five (5) of them (Sulphate, Fluoride, Nitrate, Electric Conductivity and T. Hard) that were not in conformity with the WHO requirements for drinking water as shows from Figure 1 to Figure 5 respectively.

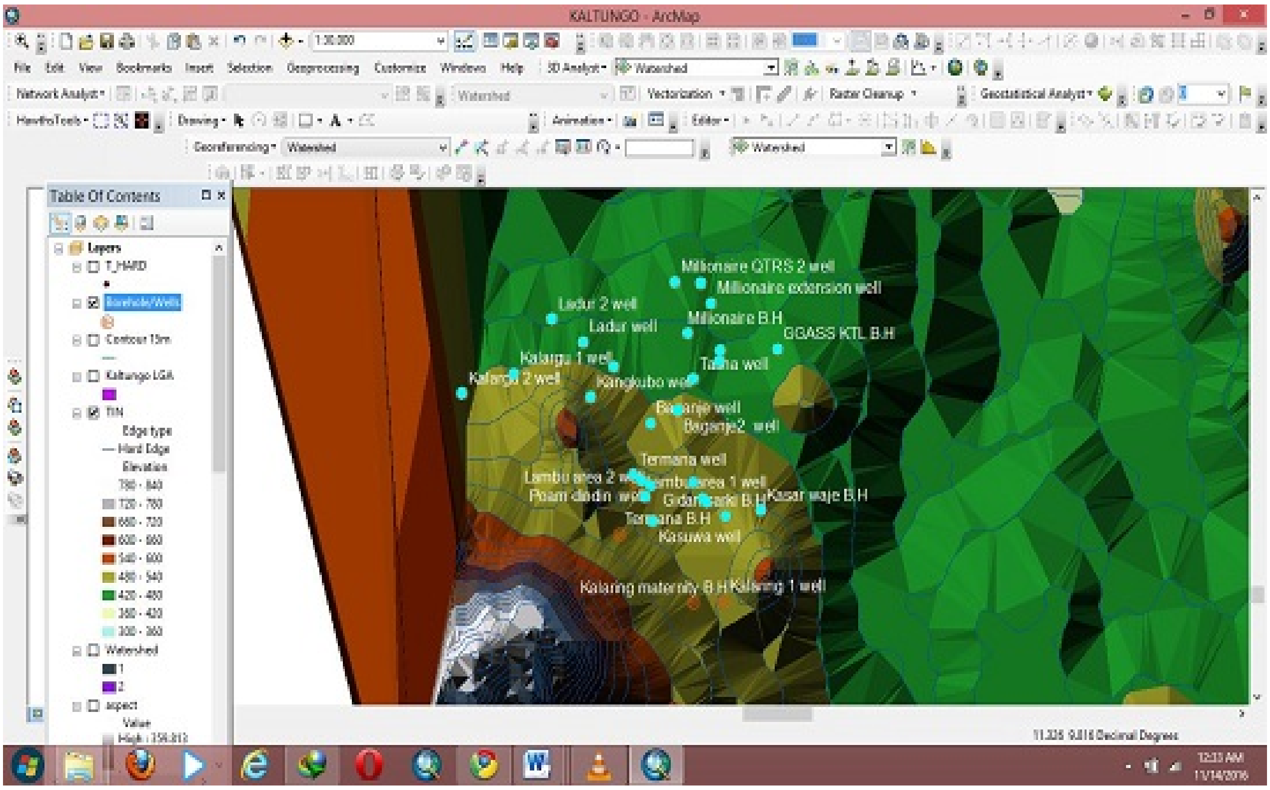

Figure 1: Spatial Distribution of Sulphate

Source: Author Analysis 2016

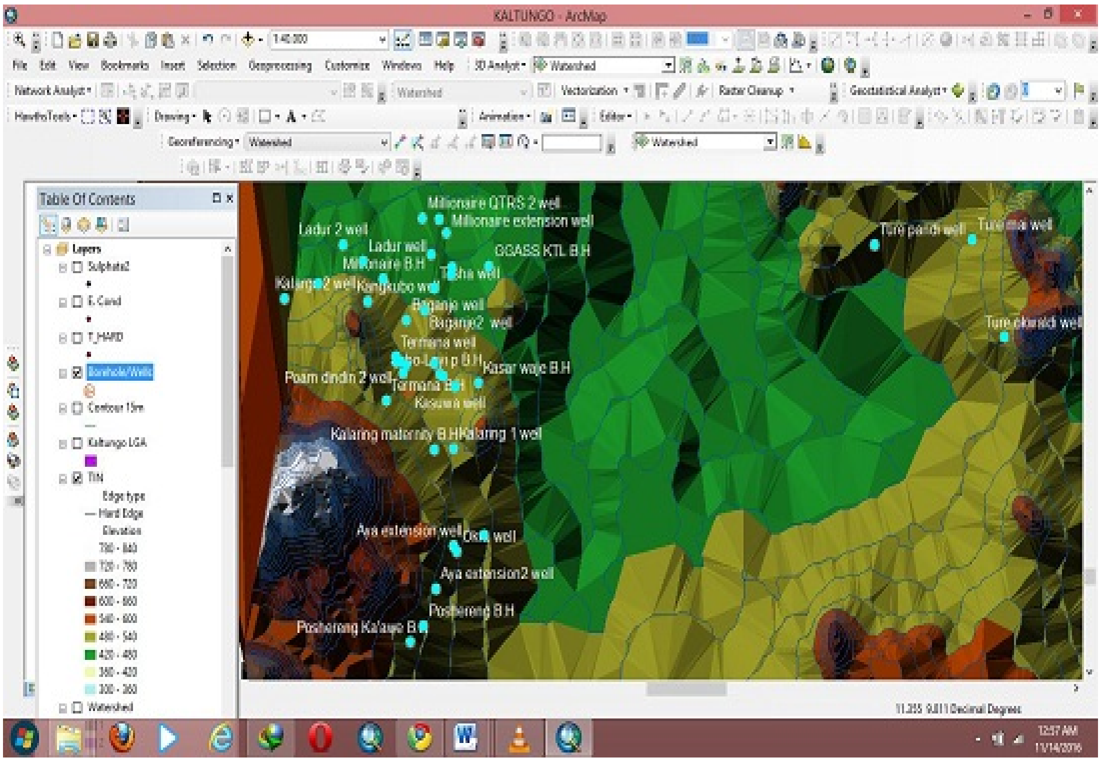

Figure 2: Spatial Distribution of Fluoride

Source: Author Analysis 2016

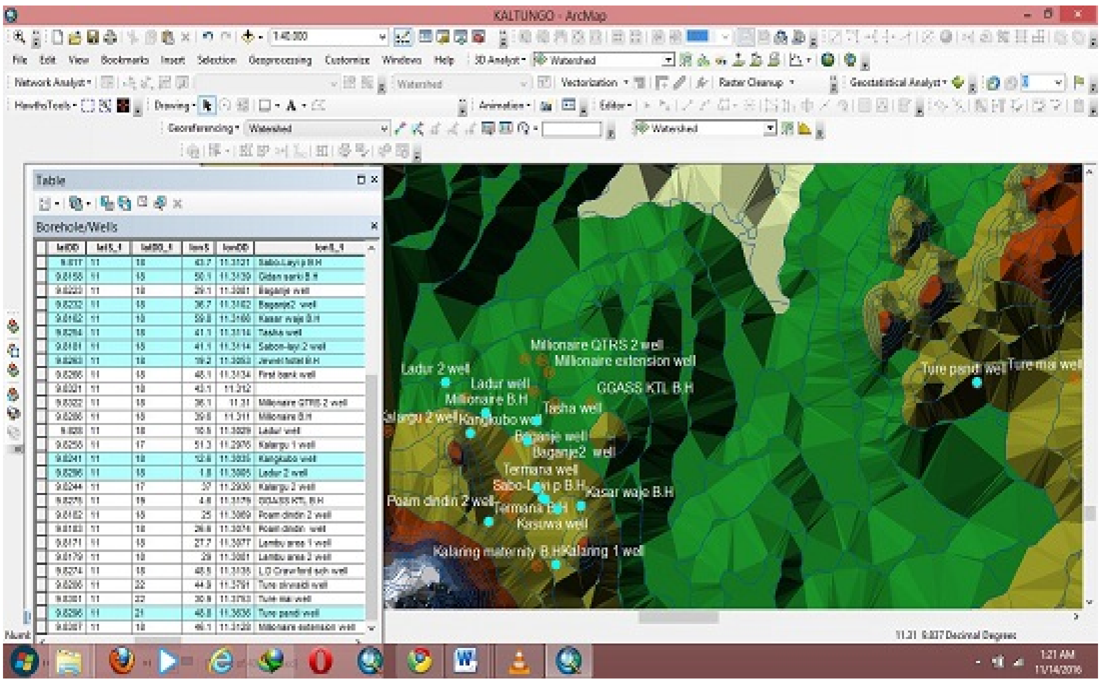

Figure 3: Spatial Distribution of Nitrate

Source: Author Analysis 2016

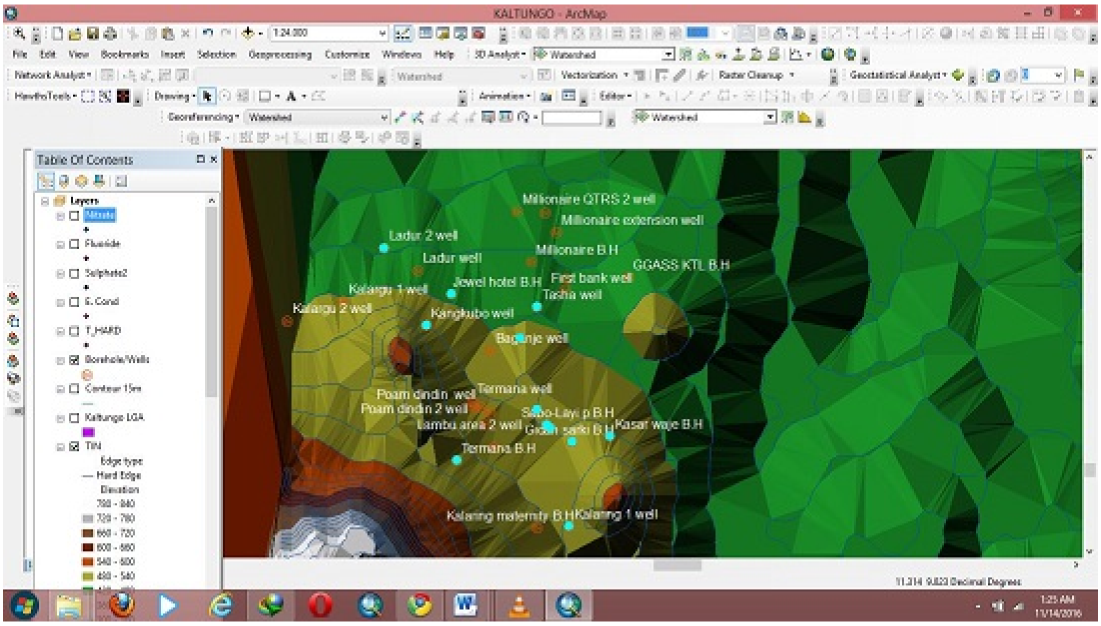

Figure 4: Spatial Distribution of Nitrate

Source: Author Analysis 2016

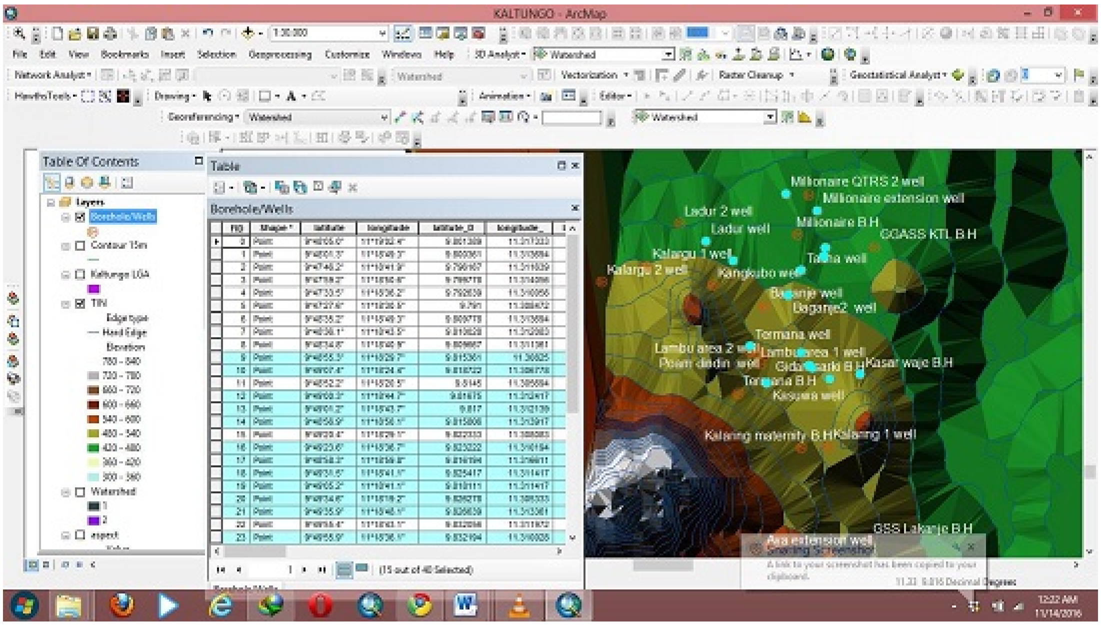

Figure 5: Spatial Distribution of Total Hardness

Source: Author Analysis 2016

4.1.2 Evaluate the spatial distribution of the Parameters

The results obtained from the analysis of physiochemical parameters, queries and campaiared with WHO stard were evalauate using interpolation by Inverse Density Weighted method (IDW) to show the concentrations of the parametrs in the underground water of the study area and the results is shows from Figure 4.6 to Figure 4.10 respectively. These analysis were done in order to show the level of concentrations of those parameter inr reelat underground water so as to served as a decision support tools for health workers and undergroung water related research as the case maybe for proper plans and managements. The level of concentration were mainly in to two groups (high and low) but the symbology (using graduate colour) of the map determine the concentrations of the parametes as shown from Figure 6 to Figure 10.

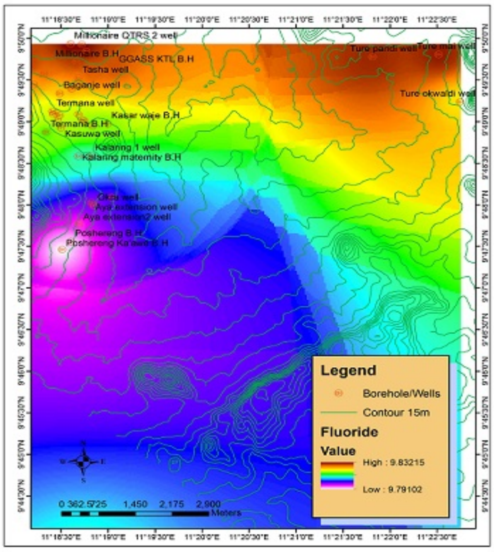

Figure 6: Fluoride Concentrations in the Ground water

Source: Author Analysis 2016

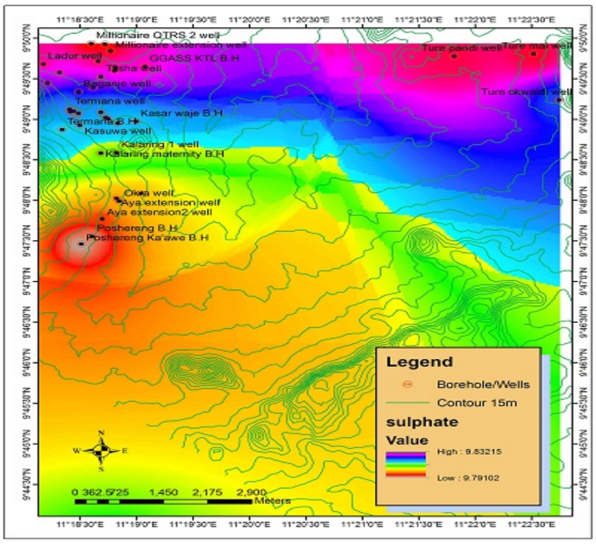

Figure 7: Sulphate Concentrations in the Ground Water

Source: Author Analysis 2016

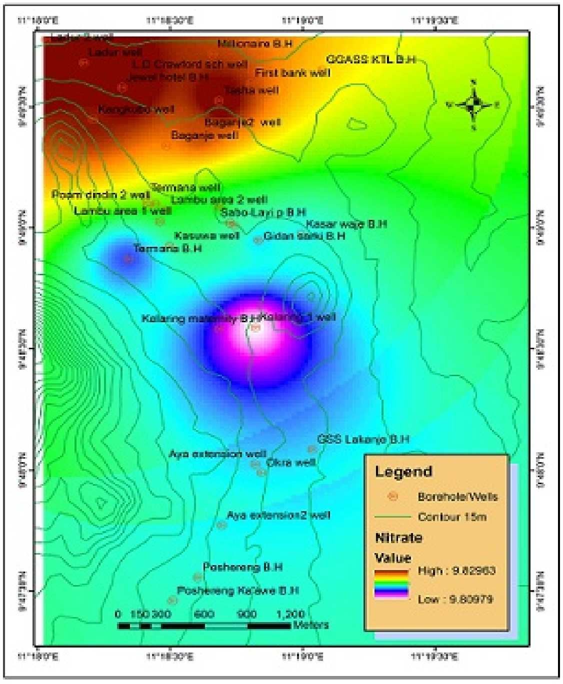

Figure 8: Nitrate Concentrations in the Ground Water

Source: Author Analysis 2016

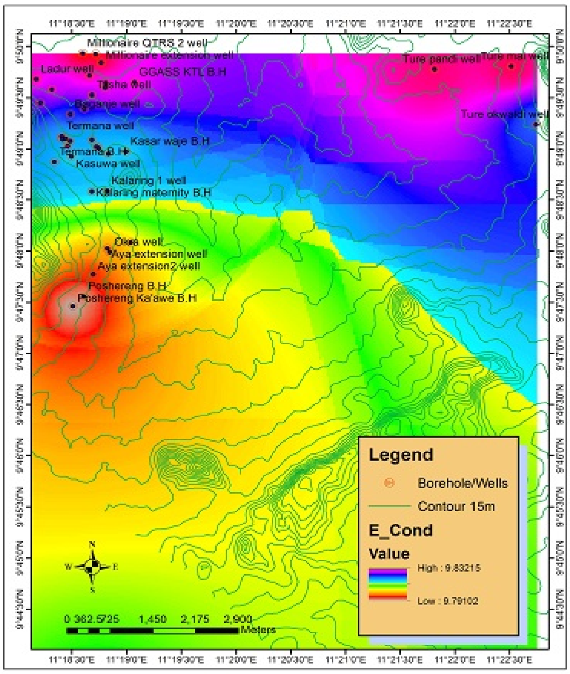

Figure 9: Electric Conduc.Concentrations in the Ground Water

Source: Author Analysis 2016

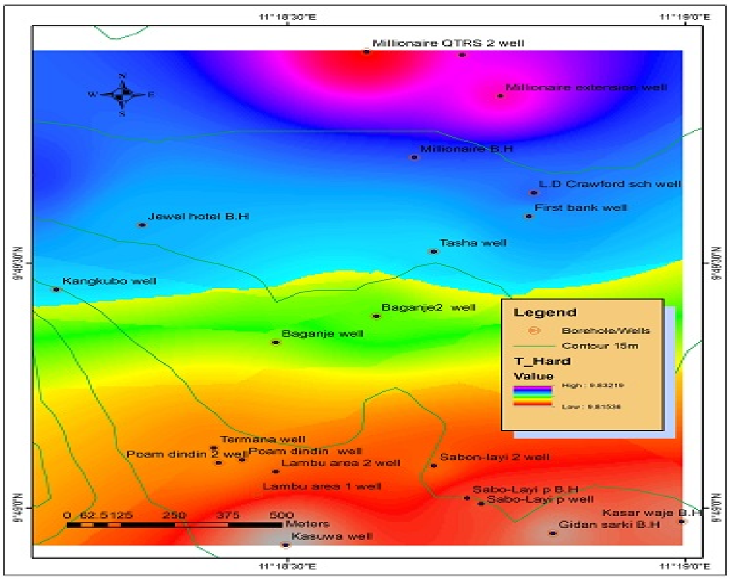

Figure 10: T. Hard Concentrations in the Underground Water

Source: Author Analysis 2016

4.1.3 Identify and map the underground water risk zones

The locations of the physiochemical parameters that was not in conformity with WHO standards is shown on Figure 11using a layer overlay in order to identify all of the five at a glance for visual interpretations. Furthermore, the final output of this research work which is the underground water risk zone Map is show in Figure 12.

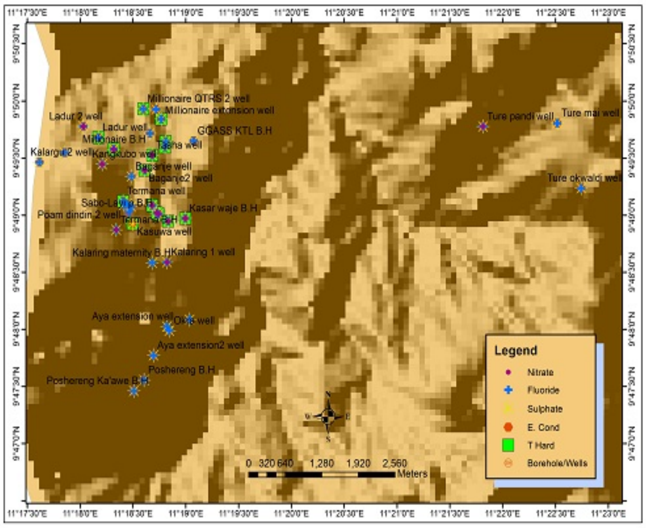

Figure 11: Overlay Location of Elements that are not Confirmity with WHO Standard

Source: Author Analysis 2016

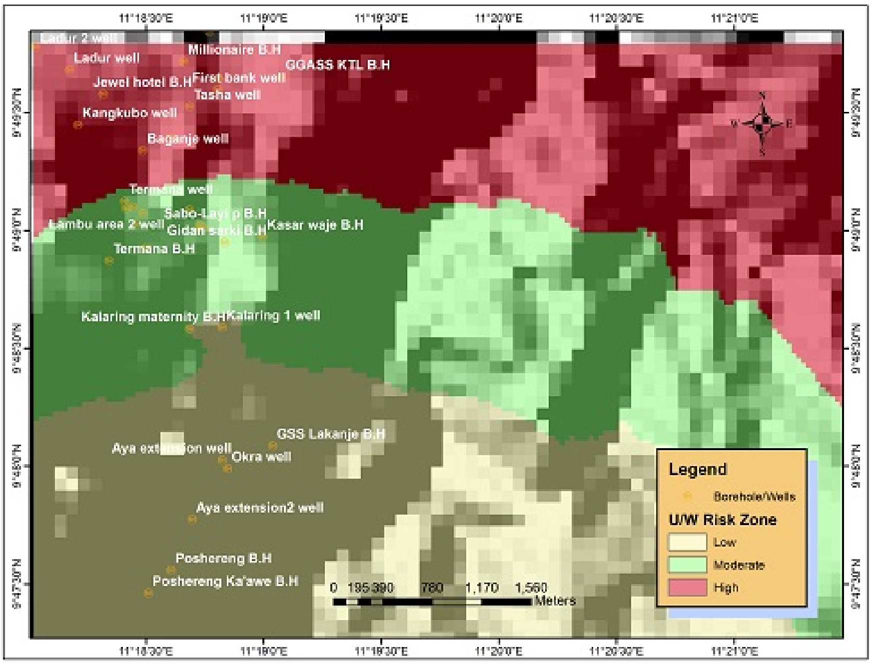

Figure 12: Underground Water Risk Zone Map

Source: Author Analysis 2016

5. Discussion of Results

From Figure 1 to Figure 5, queries were made on the geodatebase of the underground water (borehole and wells) but only the results of those physiochemical parameters that that are has heigher values than the given stadards of [16] WHO 2011 for the chemicals concentration that were selected and show saperately on the map.

From Figure 1, it was found that out of the 40 sampled points, about 85% % has Sulphate that were not comfirmed with the WHO 2011 standards of drinking water. Also found that those areas that has heigh values were located at the heart of the local government area headquater's (central part as shown on Figure 1). The places that were confiremed with the requeired standards are; Poshereng Ka'awe BH, Poshereng BH, Ture Pandi well, Ture Mai well and Ture Okwadi well and were happen to be located at the outskirth of the LGA. Figure 2: , it was found that about 97.5% has Fluoride whereas only Termana Borehole is confirmed with the requred standards. Moreover, about 55% of Nitrate confirmed with the required standard by WHO while 45% of did not and all the locations were ramdomly distributed as show on 3. and Figure 4 respectively.

Furthermore, the result of Figure 5 shows that only 32.5% of the T. Hard were confirmed with the standard whereas 67.5% were not. Majority of the 67.5% were located at the lower slope. Again, it was found that 85% concentration of Electric Conductivity were not confirmed with the standards whereas only 15% (6 of the Boreholes and wells) were within the required standard amongs which includes; Poam Dindin 2 well, GSS Lakanje BH, Aya estension well, Tamana BH, Kalarin 1 well, and Kalarin Matanity BH. This further reveals that their is presence of ionic solutes in the study area as supported by [17] which stated that the electrical conductivity of polluted waters is due to the presence of ionic solutes in the water.

From Figure 6 is was revealed that the concentration of Fluoride in the underground water was towards the northern part of the study area especially around Millionaire Quarters well, Millionaire BH, Tasha well, Turi pandi and Ture mai well amongs others whereas Poshereng BH and Poshereng Ka'awe BH has low concentration of Fluoride (from the western part of the study area). The higher concentration of the fluoride towards the northanpart were due to the flow direction of water in the study area from as the result of downward movement of water from the uplands and the results uptaine from the watershed, hillhed and slope angel of the study area. these result is also the same with the findings on Electric Conductivity Concentrations in the Underground Water as shown on Figure 9. Excessive intake of fluoride causes dental and skeletal fluorosis, which is a chronic disease manifested by mottling teeth in mild cases, softening of bones, and neurological damage in severe cases [18].

Also found from Figure 7 that there high concentration of **S**ulphate in the Underground Water (borehole and wells) towards the northern part of the study area especially around Millionaire BH, Tasha well, Ladur well, Ture pandi and Ture mai well amongs others whereas Poshereng BH and Poshereng Ka'awe BH also has low concentration of Fluoride with Termana well, Kasuwa well and Kasar waje BH amongs others with moderate concentration of Sulphate. These were as the result of the nature of the tophography and the nature of the underground water movemement (direction of water flow in the study area). This high concentration of sulphate in water can cause malfunctioning of alimentary canal [19].

However, the result of Nitrate Concentrations in the Underground Water in Figure 4.8 revealeds that there is a heigher level of Nitrate in Ladur well, Ladur 2 well, Millionaire BH, Jewel hotel BH, L.D Crowford schoo, well, first bank well, and Baganje 2 well as well while there is lower concentration of the Nitrate in the central part of the study area (Kalaring Maternity BH and Kalaring 1 well) which was also attributed due to the anthropogenic activities and topography of the study area as well. The result is due to anthropogenic activities in the study area as affiremed by [16].

Meanwhile the results of Figure 10 on T. Hard Concentrations in the Underground Water differ significantly from the other findings of this research. It revealeds that the heigher concentration was at Millionaire Quarters 2 well followed by Millionaire extension well with lowerconcentration towards the northern part of the study area. The high concentration of Total Hardness in water may have some effect in reducing certain types of heart diseases and thus softening water may have a detrimental health effect. Also, some softening processes increase sodium content of the water and this can be undesirable for some heart and kidney complaints in the study area as supported by [20]. From these it was discovered that the central part of the study area has lower concentration of the physiochemical parameters and this could be attributed as the result of the topography of the area which are the major determonant of ungerground water movement and may lead to the tranosrtation and deposions of chemicals concentration in the undergrown water respectively.

Figure 11 show the result of overlay Location of physiochemical parameters that are not Confirmity with WHO Standard. Iw was revealed from Figure 11 that all the five parameres were found to be located within northwester part of the study area with two of them (fluoride and Sulphate) from northeast and southwest respectively.

Finally, Figure 12 show the result of the underground water risk zone Map. The final output map is categories in to three, namely; the high zone which is more vonourable, moderste zone which moderately vonourable and the lower zone which is less vonourable to the risks.

The areas that were found within the high zones are; Millionaire Quarters well, Millionaire BH, Tasha well, Turi pandi and Ture mai well, Jewel hotel BH, First bank well, Tasha well, Kangkubo well and Bagange well. Moderate risk zone are; Termana well, Lambu area 2 well, Sabonlayi P BH, Kalaring Maternity BH, Kalaring 1 well, Gidan sarki BHand Kasar waje BH. lowe zone; Aya extension well, GSS Lakanje BH, Okra well, Poshereng BH and Poshereng Ka'awe BH. These findings justify the concentration of the physiochemical parameters in the underground water in Kaltungo LGA, Gombe State, Nigeria.

6. Conclusions

The GIS-Based studies carried out in the study area distinctly revealed its effectiveness on groundwater risk mapping. Physiochemical parameters of the underground water (well and boreholes) sample analysis shows increased concentration of Fluoride, Sulphate, Nitrate, Turbidity and electrical conductivity, which indicates anthropogenic and topography factors are influencing underground water in Northeast and Eastern part of the study area. Hence analysis of underground water risk mapping with Geospatial technologies can provide appropriate platform for convergent analysis of large volume of physiochemical parameters data and also serves as decision support making tool for underground water risk mapping.

7. Recommendations

Based on the outcome of the research, the following recommendations were made:

i. There is the need for the Gombe State Government to checkmate the underground water risk zone of Kaltungo LGA especially the northern and central part of the area so as to provide solution to the underground water contamination with fluorid, sulphate and nitrate among other factors as revealed by this research finding. So as to reduces the cases of dental fluorosis due to the use of water contamination with fluoride as reported from by other researches in the area.
ii. It was recommended that GIS techniques should be of paramount used in examine water related issues so as the results will served as a basis for decision support for WHO and others related organizations.
iii. There is also the needs to carry out such research in the other parts of the the Gombe state so as to provides a lasting solution to the underground water risk.

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