International Journal of
Strategic Research in Education, Technology and Humanities
p-ISSN: 2465-731X | e-ISSN: 2467-818X
IJSRETH
September, 2020
Vol. 8, No. 1

On the Use of *Kriging* Model Concept to Detect Groundwater Potential Zones in Hilly Dutsin-Ma, Northwestern Nigeria

Kankara, I. A.
Department of Geology,
Federal University Dutsin-Ma

Article DOI:
10.48028/iiprds/ijsreth.v8.i1.04

Keywords:
Geology, Groundwater, *Kriging* Model, Dutsin-Ma, Northwestern Nigeria

Corresponding Author:
Kankara, I. A.

Abstract

In this present study, the geology, relief, spatial variation and challenges of groundwater quality has been carried out, using Kriging Model. The methodology employed was drawn from primary and secondary data sources. Detailed chemical analyses for some of the parameters of the groundwater were done on a total of twenty-one (21) samples of both hand-dug wells and borehole waters collected during the full field investigation. In the laboratory analysis, the AAS and XRF machines were used to analyze eight (8) samples, namely: Temperature, pH, Total Dissolved Solids (TDS), EC, Total Hardness, Lead, Iron, and manganese. The results of the chemical analyses which were akin to groundwater geochemical characterization based on the ranges of parameters shows that the value of pH in the study area ranges from (6.53 to 7.30), The Total Dissolved Solids ranges between (0.00 to 24.00), the EC has concentrations between (0.06 to 22.00) which was also around the permissible units of both SON and WHO. Total Hardness of the samples of the area run from lowest concentrations of (60 to 3915) which does not exceed the SON permissible unit, but exceed the recommended limit of WHO. The corresponding limited ranges of iron and manganese ranges from (0.53 to 15.24 and 0.4 to 3.35), the concentrations of Lead from lowest to highest were (0.74 to 2.31), both of which defy the recommended limits of WHO (0.05) and that of SON (0.01). Based on this, it was concluded that some of the groundwater sources assessed are safe for human consumption. If the practice of consuming groundwater without treatment continues, it may lead to health hazard. ANOVA-F (One Way) was adopted in testing the hypothesis (Calculated F=6.63 while Critical F=2.16). The study recommended that appropriate measures should be taken to bring the higher concentrated parameters to desired levels.

Background to the Study

According to data gathered (RUWASA, 2014; Kankara, 2019) geology and relief nature of Dutsin-Ma environ govern the nature of contamination of the groundwater within the area (Figure 1) Groundwater itself is a product of geological formations. Geology is among the factors that filters fresh groundwater. The natural chemical composition of groundwater is influenced by the type and depth of soils and subsurface geological formations through which groundwater passes. Once polluted, groundwater body could remain so for decades, or even for hundreds of years, because the natural processes of through-flushing are very slow (Skibon, 2005; Asadi and Anji, 2007) Nearly 2.3 billion citizens (one-third of World population) obtain their domestic water directly from groundwater resources (WHO, 2000). The outlook for global overwhelming dependence on groundwater as a major source of domestic, agricultural and industrial water supply means that quality and not only quantity should be given a topmost priority (WHO, 2006)

Aside, GIS can be used as an effective tool for mapping of groundwater quality, determining water availability, preventing flooding, understanding the natural environment, and managing water resources on a local or regional scale (Yammani, 2001). GIS technologies have great potential for use in groundwater hydrology (Maroju, 2007). This section reviews different literature on the status of groundwater quality.

The concept that was used in executing this research is Kriging interpolation method which is largely a reflection of Waldo Tobler's law in geography. Interpolation is the process of using points with known values to estimate values at other unknown points. In GIS, spatial interpolation can be applied to create a raster surface with estimate made for raster cells **(**Nas and Buktav, 2010; Adji and Sejati, 2014**)**. According to Waldo Tobler's law "everything is related to everything else, but near things are more related than distant things. This law is the foundation of the fundamental concepts of spatial dependence and spatial autocorrelation and it supported the regionalized variable theory for Kriging. Distance is the most important variable governing the influence of one entity on another (Ismail and Yola, 2012; Dike, 2013; Mohoid Dhote, 2013).

Kriging is a term coined by G. Matheron in 1963 after the name of D.G. Krige. The concept of Kriging is based on a statistical model of a phenomenon instead of interpolating function. It uses a model for spatial continuity in the interpolation of unknown values based on values at neighboring points (Matos et al, 2002)

Study Area and Relief

Dutsin-Ma is located at the central part of Katsina State and lies between Latitudes $12^0 27'$ 10″ Nand $12^0 27' 16''$ N and longitude and $07^0 29' 56''$ E $07^0 30' 04''$ E (Idris, 2011). It is bounded to the north by Kurfi, some part of Charanchi and Kankia LGA's, Matazu in the south-east, Safana and Dan-musa from west. With an estimated area of 552,323 km^2. The area comprises of Safana, Batsari, Kurfi and Dan-musa LGAs respectively (Figure 2)

The relief consists of low land plains that are undulated. These plains are dotted with granitic rock out-crops known as Inselbergs. There are also low valleys and channels which are wide and full of sand materials. Generally, the soil of the area is the tropical ferruginous red and brown soil of the basement complex (Kankara, 2019)

Materials and Methods

Review of Related Literature

Kriging is a weighted, moving averaging method of interpolation which is derived from regionalized variable theory which assumes that the spatial variation of any geological, soil, or hydrological property, known as a 'regionalized variable' It is statistically homogenous throughout the surface that is, the same pattern of variation can be observed at all locations on the surface. It is based on regionalized variable theory which provides an optimal interpolation estimate for a given coordinate location, as well as variance estimate for the interpolation value. It involves an interactive investigation of the spatial behavior of the phenomenon before generating an output surface **(**Maroju, 2007**).** It assumes that some of the spatial variation observed in natural phenomena can be modeled by random processes with spatial autocorrelation and requires that spatial autocorrelation can be explicitly modeled (Lewis and Foster, 1980). The techniques can be used to describe and establish a model spatial pattern. Which predict values at unmeasured locations and assess the uncertainty associated with predicted value at the unmeasured location (Jeff, 2006; Danhassan and Olashehinde, 2010**)**. Kriging methods depend on mathematical and statistical models; the addition of statistical model includes the probability that separates Kriging methods from the deterministic methods (Kagiso, 2016**)**. Kriging methods rely on the idea of autocorrelation, correlation which is usually thought of as the tendency for two types of variables to be related. Autocorrelation is a function of distance, and this is the defining feature of geostatistics. Kriging can be expressed in the following mathematical formula:

$$Z(s) = \mu (s) + \varepsilon (s)$$

Where, Z(s) is the variable of interest, decomposed into a deterministic trend μ(s) and a random auto correlated errors form. The symbol Ɛ(s) indicates the location, and it can be thought as containing spatial x (longitude) and y (latitude) coordinates. It has two (2) types: The Ordinary Kriging and the Cokriging Model. Ordinary Kriging assumes the model as:

$$\mathbf{Z(s) = \mu + \varepsilon (s)}$$

Where **μ** is an unknown constant

Ordinary Kriging has remarkable flexibility. Thus Ordinary Kriging can be used for data that seems to have a trend (Amadi and Sedghunuz, 2008; Kagiso, 2016). The Cokriging technique uses information for several variable types. The main variable of interest is Z_1 and both autocorrelation for Z_1, and cross-correlations between Z_1 and all other variable types are used to make better predictions. Cokriging requires a lot of information, including estimating the autocorrelation for each variable as well as cross-correlations. Theoretically, when there is no cross-correlation, Cokriging will do the autocorrelation for Z (Hudak and Sammance, 2000; Kagiso, 2016)

Geological and Hydrogeological Context of the Study Area

The geology of Dutsin-Ma region is largely Basement Complex rocks which are predominantly metamorphic (Figure 1) The oldest rocks are the igneous types which later metamorphose into metamorphic rocks as a result of heat and pressure. In some parts of the area, the rocks have changed over time as a result of weathering and erosion effects. The rocks which later leads to the formation of granites hills and inselbergs such as the one found in the center of Dutsin-Ma town (Jidauna et al, 2017; Kankara, 2019). lithologies (rocks) in this area are of two types: the ancient biotite-mica-rich older granites older than 650 million years (commonly called the Pan-African granite suites), and the granite-gniess-migmatite with minor bandings and augen structures in occasional places types. The most notable tectonic igneous reactivation of this suite is attributable to Pan African episode. These Pre-Cambrian crystalline complex rocks cover nearly the area, and even extend to neighboring sheet (Kankara, 2019)

Sub-surface data obtained from wells indicates three types of aquifer zones which are made up of medium to fine grained sand (RUWASA, 2014). The thickness of aquifer zones and the depth at which groundwater for dug well is encountered is 10m- 20m. The thickness of aquifer zones and the depth at which groundwater for borehole is encountered is 45 to 60m. Aquifer zones found within 50m depths have much higher discharge than the deeper aquifers. The discharge of these deep tube wells ranges from 1500 to 3500lp/h and their minimum drawdown is between 6-30m in Dutsin-Ma town.

Figure 1: Geological map of the study area

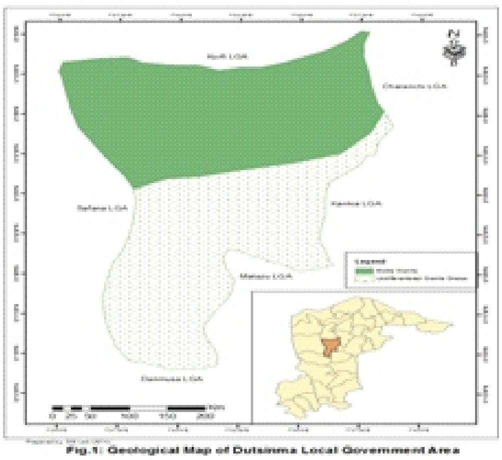
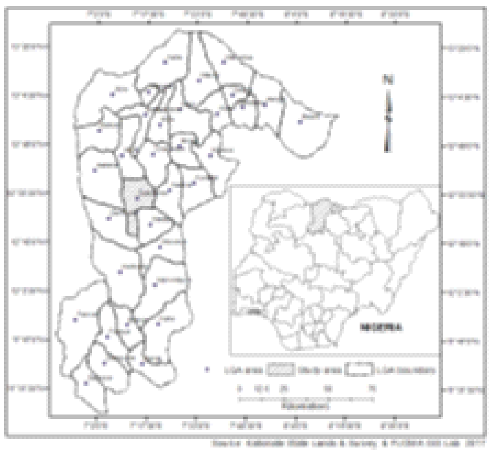


Figure 2: Katsina State showing the study Area



Water table varies between 1.5- 9.17m bgl and is shallow towards SE and SW of Dutsin-Ma town (RUWASA,2014). In the area, ground water occurs in unconfined shallow aquifer and semi-confined to confined aquifer conditions in deeper aquifers. The porosity and permeability of the sedimentary rocks in the hilly areas are partly due to coarser grain size of some rocks, weathering, fracturing and faulting. Ground water occurs in both unconfined and confined conditions; in some places within Dutsin-Ma town ground water occurs at shallow depths both under unconfined and confined conditions (RUWASA, 2014).

Data Collection and Analysis

Field work was divided into Pre-field work which involved reconnaissance survey of the study area to identify different water sources in the town for the selection of the sampling points, and main field work which involved collection of water samples from both hand-dug wells and boreholes (Figure 3; Table 1) Ground throttling method was adopted. The information acquired through this process is aimed at identifying and mapping the different groundwater sources. Global Positioning System (GPS) device was used in picking the coordinate point of the groundwater sources, through which it is used for mapping of the entire sampled area (Figure 3)

In the secondary data, past existing records on water management and consumption were collected. This constituted exposing the water samples for analysis in harmony with standard method for the examination of water and waste water. The bottles were thoroughly rinsed with hydrochloric acid and then washed with tap water in order to render it safe from acid and then washed with distilled water twice. The bottles were filled with groundwater sample leaving only small air gap at the top sealed bottles. Glassware, casserole and pipettes were thoroughly cleaned with tap water and finally with de-ionized distilled water. P^H meter, Conductivity meter, Spectrophotometer, Flame photometer instrument were used to analyze the selected parameters. Parameters analyzed in the laboratory are Iron, Manganese, P^H, Lead, Total Dissolved Solid, electrical conductivity and Hardness. These parameters were tested using standard laboratory techniques. The Laboratory analysis was done in Soil Laboratory of Geography Department, Federal University Dutsin-Ma and Federal Ministry of Agriculture and Rural Development Zaria Kaduna State. The parameters that were assessed in Soil Laboratory, FUD were P^H, Total Dissolved Solid, electrical conductivity and Hardness (see Table 3), and those assessed at Zaria were Iron, Manganese and Lead.

Table 1: Sampling Location for Hand-dug wells and boreholes

S/No	Location	Groundwater Source
1	Primary Health Care Shema	Dug Well
2	Behind Nurril'azim Islamic School Hayin Gada	Dug Well
3	Behind Yarima Primary School	Dug Well
4	Dan-rimi	Dug Well
5	Behind Dutsin-ma LGA H/Quarters	Dug Well
6	Unguwar Yandaka	Dug Well
7	Gangaren Wakaji	Dug Well
8	Yarar Dole	Dug Well
9	Shema Quarters Hayin Gada	Dug Well
10	Unguwar Yamma (Bayan Dutsi)	Dug Well
11	Opposite General Hospital Dutsin-ma	Borehole
12	Dutsin-ma weekly market	Borehole
13	Yandaka Primary School,	Borehole
14	Kadangaru	Borehole
15	IKCOE Dutsin-Ma,	Borehole
16	Low cost	Borehole
17	Unguwar Alkali	Borehole
18	Police Barrack	Borehole
19	Darawa	Borehole
20	FUDMA Take-off Site (Miami)	Borehole
21	Shema Quarters	Borehole

Source: Field Work, (2020)

Table 2: Result of Parameters in the Groundwater Samples

S/n	Parameters	Localities																				
		L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	L13	L14	L15	L16	L17	L18	L19	L20	L21
1.	P^H	6.97	6.56	7.03	6.53	7.02	6.91	6.88	6.57	7.09	6.91	7.01	7.17	7.23	6.58	6.81	6.94	6.88	6.83	6.64	6.72	7.30
2.	TDS	0.00	4.0	0.00	24.00	2.0	0.0	3.00	2.0	2.00	1.00	1.00	0.00	0.00	2.00	2.00	1.00	1.00	0.00	18.00	1.00	2.00
3.	EC(MS/M)	3.40	16.00	1.40	0.06	1.60	4.00	7.60	3.60	0.60	3.20	4.0	2.40	1.20	1.20	0.040	2.00	1.20	0.06	1.00	1.20	22.00
4.	Total hardness (PPM)	260	545	155	3915	160	220	425	295	130	190	125	85	120	2660	180	195	180	95	2500	60	80
5.	Lead (PB)	1.1175	0.2675	0.6725	1.6075	0.885	1.2025	1.0075	1.1675	1.625	0.855	0.605	1.5575	1.43	2.31	0.5825	1.125	0.74	1.8475	2.025	1.7275	0.5775
6.	Iron(FE)	1.8425	1.1925	1.7625	2.62	2.335	2.7925	0.6075	1.1325	0.8225	0.855	1.335	0.545	4.705	1.68	3.4775	2.03	1.065	15.2425	1.25	4.05	0.5275
7.	Manganese	1.85	2.83	3.3475	1.025	1.0025	0.5375	0.6675	0.9775	0.835	0.55	0.705	0.4	0.5225	0.57	0.6125	0.43	0.495	1.19	0.54	0.59	0.34
8	Temperature	20^{0}C	20^{0}C	23^{0}C	25^{0}C	23^0 C	23^{0}C	20^{0}C	25^{0}C	20^0 C	20^0 C	23^0 C	23^0 C	25^0 C	20^0 C	23^{0}C	25^{0}C	23^{0}C	20^{0}C	23^{0}C	23^{0}C	20^{0}C

Table 3: Selected Parameters and Standard for Groundwater

S/NO	PARAMETERS	UNIT	WHO	SON
1	P^H	-	6.5-8.5	6.5-8.5
2	Hardness($caco_3$)	Mg/l	500	150
3	Total Dissolved Solid (TDS)	Mg/l	500	500
4	Electrical Conductivity(EC)	μS/m	500	1000
5	Manganese (Mn^{+2})	Mg/l	0.5	0.2
6	Iron(Fe^{+2})	Mg/l	1.0	0.3
7	Lead (Pb)	Mg/l	0.05	0.01
8	Temperature	^oC	-	Ambient

Source; WHO (2000)/SON (2007)

Presentation of Results

The data collected for the purpose of this study were analyzed based on the parameters selected 2. in this study which are discussed in the subsequent section of the chapter. ***Values of P^H:*** The result of the samples taken from groundwater sources is presented in Table P^H is the measure of the active hydrogen ion (H+) concentration in water, and it represents the relative alkalinity or acidity of water. P^H scale lies between 0 and 14. On a typical p^H scale, the medium is increasingly more acidic from p^H of 0 to 7, more alkaline from p^H of 7 to 14. While P^H of 7, the medium is neutral. Water with acidity less than 6.5 could be considered acidic, soft and corrosive, while water with p^H of more than 7 is alkaline. The p^H helps in the removal of waste product from the body. Water that ranges from 6.5 to 8.5 are good for domestic uses as recommended by the standards set by WHO and Standard Organization of Nigeria (SON). From the field work, Samples collected from groundwater sources has a mean of 6.88 (see figure 4). From the groundwater sources of water sample analyzed, P^H in all the water samples are within the acceptable Standards (WHO and SON)

In comparison to this study, the result found in this study produced contrasting results with those found by Adamu et al (2013) on spatial and source disparities of groundwater quality in Dawakin-Tofa LGA of Kano State. According to the finding of the study, P^h has mean of 6.66 with a range of 6.0 in Jemomi to as much as 7.2 in Dawakin-Tofa town. This variation is observed to be caused by urbanization and complexity of activities (Dawanau). Because with the exception of Jemomi, all the remaining towns and villages level of water acidity was a reflection of the complexity of activities in the areas.

Figure 3: Map showing sampled areas

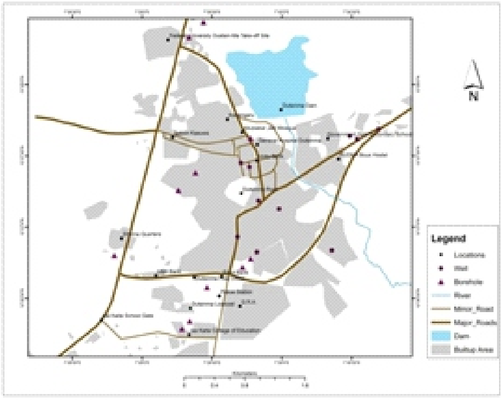
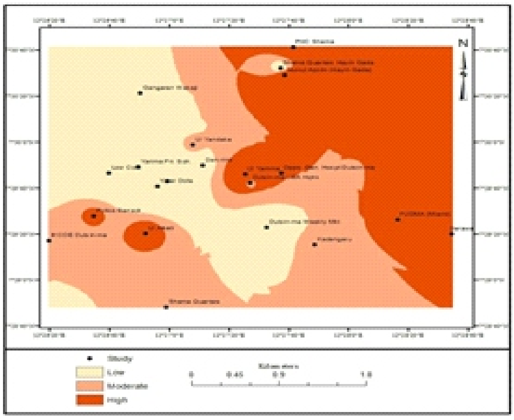


Figure 4: Spatial variation of pH values



Groundwater quality assessment in Southern parts, like the Eti-Osa, Lagos-Nigeria by Adeshina et al, (2018) also reported similar findings. The result of the studies of p^h in groundwater samples ranges from 6.79 to 7.22 with a mean of 7.01 mg/l, indicating a neutral condition. The p^h values are within the prescribed limits of 6.5-8.5 for drinking water standards.

Similar finding to the current study were observed by Yammani (2001) on physicochemical and bacteriological analysis of water quality in drought prone areas of Pune and Satara Districts of Maharashtra in India. The authors recorded optimal p^h for drinking water which ranges between 6.5 to 8.5 (BIS 10500 Desirable limit). The value 7.5 which is average of 6.5 and 8.5 was considered as the best and given an index value of 1. The p^h range was split into two classes where acidic range was generated from 7.5 and below and basic range was developed from 7.5 and above. The BIS drinking water range (6.5–8.5) differs from 7.5 by 1 p^h unit. Therefore, the size of each interval in both groups was considered as 0.2 which was obtained by dividing 1 p^h unit.

Electrical Conductivity: The results obtained for electrical conductivity concentration from the sample collected in Dutsin-Ma town is presented in Table 2. Conductivity of a substance is defined as the ability or power to conduct or transmit heat, electricity, or sound. Its units are siemens per meter (S/m) in water and ionic materials or fluids. A net motion of charged ions can occur; this phenomenon produces an electric current and is called ionic conduction. Pure water is not a good conductor of electricity. Ordinary distilled water in equilibrium with carbon dioxide of the air has a conductivity of about 10 x 10^{-6} W-1*m-1 (20 dS/m). Because the electrical current is transported by the ions in solution, the conductivity increases as the concentration of ions increases. According to World Health Organization (WHO) and Standard Organization of Nigeria (SON) groundwater should have Electrical Conductivity (EC) of 1500 and 1000 S/m concentration. From the groundwater sources of groundwater sample analyzed Electrical Conductivity (EC) has a mean of 3.7. Electrical Conductivity (EC) in all the groundwater samples is below the acceptable Standards (WHO and SON).

Similar finding to the current study were made by Jidauna *et al* (2017) who studied some selected domestic water sources in Dutsin-Ma town Katsina state of Nigeria. The authors observed slightly highest electrical conductivity of 774.50µ/cm which is below what is recommended by the standard (WHO & SON). Dam water in Dutsin-Ma town has the lowest electrical conductivity of 50.25 µ/cm. This means that all the sample sources in Dutsin-Ma town have an electrical conductivity below the acceptable standard (Figure 5).

This confirmed to the study by Idris (2011) on determination of seasonal variability of portable water quality in Dutsin-Ma town Katsina State of Nigeria. Finding of the study reveal that electrical conductivity of the samples were found within the range of (151.00 um/cm to 1100.00 us/cm) in the dry season. Point 7 is having the highest value (1100.00 us/cm). Next to it was point 8 (550.00 us/cm), point 4 (340.00 us/cm), point 6 (185.00 us/cm), point 5 (176.00 us/cm), point 3 (172.00 us/cm), point 1 (156.00 us/cm) and point 2 (151.00 us/cm). The values ranged between (150.00 us/cm) to 1390.00 us/cm) in the rainy season.

In the Weija dam of Ghana, it was observed there were a slightly high conductivity values during the dry season and low values in the wet season. High EC values during dry season are due to evaporation resulting in high concentration of ions. The lower conductivity in the wet season might be due to high rainfall, which reduces the level of dissolved solids by dilution of water in the dam through runoff which increases the volume of water. The concentrations of EC in the Dikgathong Dam were within allowable limits.

Total Dissolve Solids: The concentration of Total Dissolve Solid for the groundwater samples collected in Dutsin-Ma town is presented Table 2. Total dissolved solids are combination of organic salts and little quantity of organic matter that dissolved in water. Total Dissolved Solid in groundwater originates from sewage, industrial waste water, urban run-off, and chemicals used in water treatment processes. Problems associated with high TDS concentration is more of an aesthetic problem rather than a health hazard. An elevated TDS is an indication of elevated levels of ions that are above the primary or secondary drinking water standards. High concentrations of Total Dissolved Solids can as well lower the water quality and cause water balance problems for individual aquatic organisms.

According to World Health Organization (WHO) and Standard Organization of Nigeria (SON) water should have TDS concentration of 500mg/l. From the groundwater sources of water sample analyzed TDS has a mean of 3.14. The concentrations of TDS in all the groundwater samples are below the acceptable Standards (WHO and SON).

Jidauna *et al* (2017) who studied some selected domestic water sources in Dutsin-Ma town Katsina state of Nigeria. Samples tested for borehole has the highest concentration of TDS 474mg/l and dam has the lowest .According to World Health Organization (WHO) and Standard Organization of Nigeria (SON) water should have TDS concentration of

500mg/l. Samples tested for borehole has the highest concentration of TDS 474mg/l and dam has the lowest concentration 56.15mg/l. From the five sources of water sample analyzed, TDS in the water samples are within the acceptable Standards (WHO & SON) (Figure 6). This means that the water from the selected sampled sources can be used for domestic usage.

Figure 5: Spatial variation of EC samples

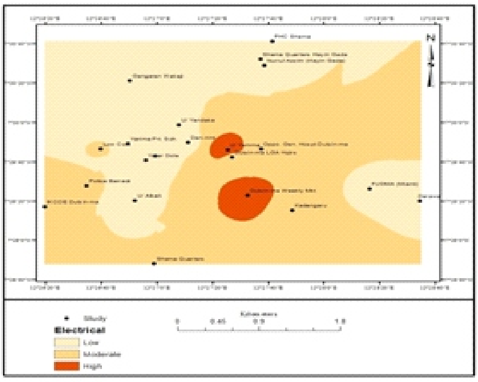
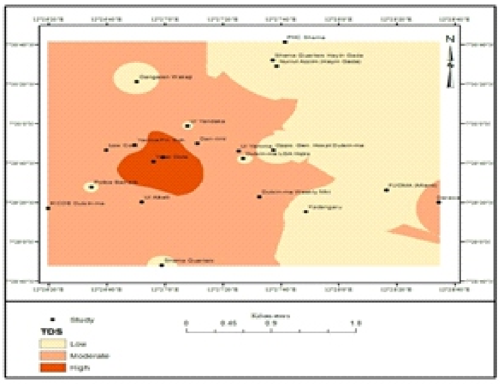


Figure 6: Spatial variation of TDS



Similar results were attained in a study of boreholes by Agbaire et al (2014) in Abraka Nigeria. Finding of the study show that TDS concentrations varied from Ugep area (44.47mg/L) and Anantigha area (157.59 mg/L). The result shows variations of TDS values higher in the wet season (0.39 to 7.11mg/L) compared to the dry season (0.00 to 2.11mg/L). They attributed this to different forms of leachate during the rainy season. The high concentrations in TDS and EC can be attributed to seawater influence, changing seasons and tidal periods. Agbaire et al (2014) found the values in both seasons to be far below the WHO permissible limits. In contrast to this study, results of borehole water quality by Adeshina et al (2008) in Dawakin Tofa Nigeria. Showed that Only Jalli (with above 300) and Tattarawa (with above 400) mg/l recorded total dissolved solid levels close to the maximum accepted limit of 500.

Lead: The concentration of Lead for the groundwater samples collected is presented in Table 2.Lead is a ubiquitous environmental and industrial pollutant that has been detected in every facet of environmental and biological systems. Lead can be found in water pipes, insecticides, lining of equipment where corrosion resistance and pliability are required. In petroleum refining, construction, gun bullets, x-ray and atomic radiation. Reproductive dysfunction by lead has distinct morphological and biochemical features such as disorganized epithelia. Decreased sperm quality and altered sperm morphology. WHO and SON recommend that the concentration of lead in water should be 0.5mg/l and 0.1mg/l. However, the entire groundwater samples collected are above the permissible limit set by WHO and SON.

Similar results were attained in a study of selected domestic water sources in Dutsin-Ma town Katsina state of Nigeria by Jidauna *et al* (2017). From Sample collected, well and tap has the highest concentration of lead with 0.13mg/l which is higher than what is recommended by SON. Thus base on SON standard water from wells and tap should not be used for domestic purpose since they are above the standard. While water from water vendors, borehole and dam has low concentration which is below the limit by WHO and SON (see figure 7).

Similar Finding to the current study was made by Sabrina *et al* (2013) on Assessment of physicochemical drinking water quality in the logon valley (Chad-Cameroon). During the monitoring in the Logon valley, lead concentration did not comply with the WHO standard (0.01 mg/L) in 95% of the sources. In particular, it exceeded this standard in 100% of the piped waters, boreholes and open dug wells. While 25% of the sampled superficial waters had a lead concentration below 0.01 mg/L. A maximum value of 1.5 mg/L was measured in the borehole of Kamargui-Bosgoye, while a minimum value of 0.01 mg/L was measured in the Logon River near Yagoua. In the same way as for Fe and Mn, high concentrations of Pb were also found mostly in boreholes rather than in shallow open wells and in surface waters, so that a correlation with the depth of the water could be possible. Furthermore, high concentrations were measured mainly in zones 2 and 7, as observed for iron and manganese. Most lead in drinking-water arises from plumbing. So it is possible that boreholes and open dug wells with concrete walls were constructed with materials containing this metal. Nevertheless, lead was found also in superficial waters and in simple open dug wells with ground walls; as a consequence, its presence in these source typologies has a different origin. The Logon valley is a rural area with no industrial activities or uncontrolled dumping and therefore such high concentrations of lead could not be possible from such sources. As a consequence, lead in such waters could originate from sources other than human pollution and it could be due to the geology of the sub-soil.

Ruma (2013) in the study Assessment of heavy metal contamination in well drinking water and its effects on human health in Katsina state of Nigeria. The results of analysis gave the concentration of average heavy metals with range of (0.07 – 0.11 mg/l) in both dry and wet season. The mean value of Pb analysed during dry and wet season of this study are above the maximum permissible levels set by the (WHO) standard.

Hardness: The concentration of Hardness for the groundwater samples collected in Dutsin-Ma town is presented Table 2 (Figure 8). Total hardness is the concentration of multivalent metallic cations in a solution. Bicarbonates and carbonates of calcium and magnesium impart temporary hardness. While sulphates, chlorides and other anions produce permanent hardness. Calcium and magnesium salts are largely responsible for the total hardness of water. The sources of calcium and magnesium in natural water are various types of rocks, industrial waste and sewage. According to World Health Organization (WHO) and Standard Organization of Nigeria (SON) groundwater should have Total Hardness concentration of 500mg/l for (WHO) and 150 mg/l for (SON).

The sampling locations that are within the permissible set by (WHO & SON) are unguwar yamma(well) with total hardness of 80ppm,Shema quarters Hayin Gada (AP filling station) with total hardness of 60ppm, Gangaren wakaji (well) with total hardness of

95ppm,Behind Nurrulazim Islamic School Hayin gada (well) with total hardness of 120ppm,Primary Health Care Shema (well) with total hardness of 85ppm,Unguwar Alkali (borehole) with total hardness of 130ppm and police barrack (borehole) with total hardness of 125ppm.

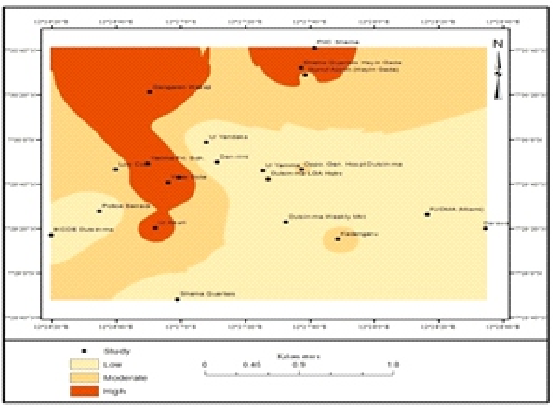


Figure 7: Spatial variation of Lead samples

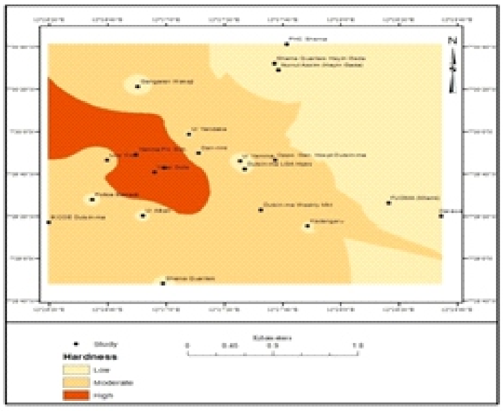


Figure 8: Spatial variation of Hardness

The remaining sampling locations are above the permissible limit set by (WHO & SON). With the worst cases of total hardness in Yandaka primary school (borehole) with total hardness of 3915ppm, followed by behind Yarima primary school (well) with total hardness of 2660ppm and Yarar Dole with total hardness of 2500ppm.

Kagiso (2016) assessed some physicochemical properties of Dikgathong Dam in Botswana. The Author found values of total hardness ranging from 90 mg/l to 114 mg/l with an average of 103.4 mg/l and below 350 mg/l CaCO3 of Environmental Protection Agency Standard. The Dikgathong dam water is classified as moderately soft hardness. The water in the dam can be classified as moderately soft (50 – 110 mg/l) to moderately hard (151 – 250 mg/l) according to the EPA standard. ANOVA showed no significant variation ($p=0.436$) between the total hardness values. High values were observed in February and declined towards April, depicting high values in dry season and low values in wet season.

Similar results were obtained by a research in India on the assessment of physico-chemical parameters for Jia-Bharali River Basin. The reporter observed low total hardness values during wet season and high values during dry season, and linked the pattern to high dilution during wet season. Total hardness is due to the presence of bicarbonate, sulphate, chlorides and nitrates of calcium and magnesium. Total hardness values were within allowable limits in the Dikgathong dam. A similar study was carried out by Danhassan and Olashehinde in Central part of Nigeria, (2010) on Assessment of groundwater quality in Abuja, Nigeria. The result of the studies shows that total hardness varied between 27.21 to 47.02, with a mean of 37.11mg/l, indicating the groundwater quality of the study area is slightly hard.

***Iron*:** The result of Iron concentrations of groundwater sample is presented in table 2 (see Figure 9). WHO and SON recommend that the concentration of iron in groundwater should be 1.0mg/l and 0.3mg/l respectively. However, the entire groundwater samples are above the permissible limit set by WHO and SON.

Similar results were found in a study in in Benue State of Nigeria. Finding of the study shows that more boreholes had iron concentrations are above the WHO permissible limits of 0.03 mg/L during the rainy season. And during the dry season few had concentrations exceeding the permissible limits. Contrasting results about seasonal effect were found by Edet and Worden (2009) on monitoring of physical parameters and evaluation of the chemical composition of river and groundwater in Calabar (Southeastern Nigeria). Finding of the study reveals concentrations of iron ranging from 0.01 to 0.06 during the dry season and 0.01 to 0.04 during the wet season. With a higher concentration during the dry season compared to the wet season. However, the general iron values were similar to the ones in this study.

Manganese: The result of manganese concentrations of groundwater sample is presented in Table 2. WHO and SON recommend that the concentration of manganese in groundwater should be 0.5 and 0.2 mg/l respectively. The sample that is within the permissible limit set by WHO. All samples are above the WHO and SON standard. Figure 10 shows the spatial variation of samples of Manganese across the area. Similar findings to the current study were found by Sabrina*et al* (2013) on Assessment of physical-chemical drinking water quality in the logon valley (Chad-Cameroon). Concerning manganese, 24% of the sampled sources had concentrations exceeding the WHO standard of (0.4 mg/L). The maximum value (1.5 mg/L) was observed in the borehole of Kamargui-Bosgoye (Cameroon). Furthermore, manganese concentrations increased with water depth. Manganese is an essential human micronutrient and most human intake occurs through consumption of various types of food. Inhalation studies linked chronic manganese intake with neurological disorders; however, data on the human health effects of long-term exposure to elevated manganese levels through oral intake (food and water) are still limited.

Figure 9: Spatial variation of Iron

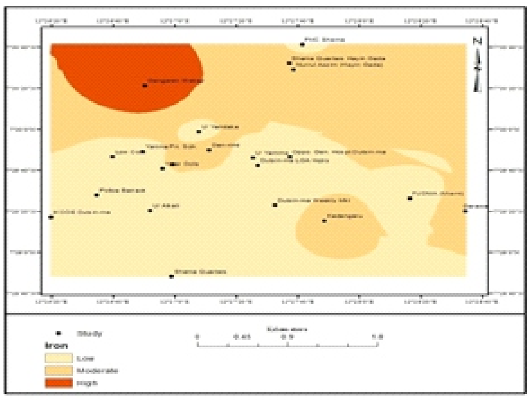
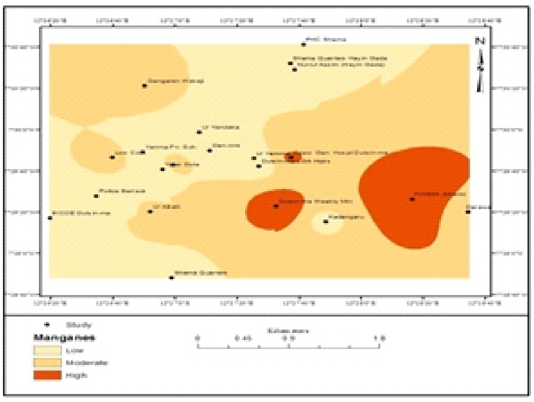


Figure 10: Spatial variation of Manganese



Onspatial and source disparities of groundwater quality in Dawakin-Tofa Local Government Area of Kano State Nigeria, the study found high amount of manganese in Jemomi (0.2) for well and (0.05) for borehole Tumfafi (0.1) for well and (0.15) for borehole. This is believed to be due to the nature of weathered rocks and aquifers in those areas. The areas are dominated by late rites which contains high amount of manganese and iron.

Ruma (2013), in the study Assessment of heavy metal contamination in well drinking water and its effects on human health Katsina state of Nigeria The results of analysis for manganese is 0.05 – 0.16 mg/l (dry season) and 0.03 – 0.11 mg/l (wet season).

Temperature: The Result of Temperature a concentration of groundwater sample is presented in table 2..The reading of Temperature is taking during collection of groundwater samples. According to SON Standard recommend that the concentration of Temperature in groundwater is Ambient. This confirmed to the study by Idris (2011) on determination of seasonal variability of portable water quality in Dutsin-Ma town Katsina State of Nigeria. Findings of the study reveal that, the temperature of water samples analyzed ranged between (20^0c to 24^0c) in the dry season. Sampling point 1 recorded higher value of temperature (31^0c). This was followed by sampling point 6 with (30^0c), point 7 and 8 with (29^0c) and point 2 with the lowest value of (25^0c). In the rainy season, the temperature readings ranged between (24.3^0c to 28.7^0c). Sampling point 8 was found to have the highest value (28.7^0c), point 6 (28.3^0c), point 7 (27^0c), point 3 (26.3^0c), point 4 and 5 (26^0c), point 1 (25^0c) and point 2 with lowest temperature of (24.3^0c). The values of temperature were found to be higher in the rainy season across all the sampling point.

Discussions

Fundamental to the study of groundwater in any place is the geology - the main controlling factor in groundwater hydrology. The nature and the properties of the rock, aquifer, specific yield and retention, the chemistry of water are governed by the geology of the environment. The quality of groundwater is a function of natural processes as well as anthropogenic activities, and that the type, extent and duration of anthropogenic activities on groundwater quality are controlled by the geochemical and physical processes and the hydrological condition present.

Migration of dangerous contaminants and agrochemicals through the vadose zone is a possible pollution pathway for vulnerable drinking water resources. Geology can dispose water and human wastes very effectively. Leachate contains dissolved organic substances, chemically reduced inorganic substances like Ammonia, Iron, and Manganese which vary according to the hydrology of the site and the chemical and physical conditions within the site. The migration of contaminants is controlled by advection in the fracture. Exchange between the fracture and matrix, sorption and molecular diffusion in the low permeability matrix, organic content, saturation level of groundwater, p^H, grain size porous matrix, iso-electric point of virus, colloids and bacteria in groundwater aquifers impact contaminant migration rates by either facilitation if they have a smaller retardation factor. The aquifer is eventually recharged by the influent seepage of surface water, so that some proportion of the pump from the groundwater from the surface source.

Conclusion

The data obtained from this research and its comparison with WHO/SON standard revealed that some of the groundwater sources in Dutsin-Ma town were found to be safe for human consumption because the parameters are below the portability limits of WHO/SON standard, they are: P^h, Total Dissolve Solid and Electrical Conductivity.

The P^H in the study area ranges from (6.53 to 7.30), the Total Dissolved Solids ranges between (0.00 to 24.00), and the Electrical Conductivity has concentrations between (0.06 to 22.00), both of which were around the permissible units of both SON and WHO. The Total Hardness of the samples of the area run from lowest concentrations of (60 to 545) which does not exceed the SON permissible unit, but slightly exceed the recommended limit of WHO.

The concentration of Lead from lowest to highest was(0.74 to 2.31), which defy the recommended limits of WHO (0.05) and that of SON (0.01) that tries to improve on purity levels respectively. The corresponding concentration levels or limited ranges of iron and manganese ranges from (0.53 to 15.24). (0.4 to 3.35) respectively, both of them exceed the normal recommended units of WHO and SON. It can also be concluded that concentration of heavy metals clearly shows there is serious risk because they are above the limit set by WHO/SON. if the practice of consuming groundwater without treatment continues in the following areas:' Yandaka Primary School (Borehole), Yarima Primary School (well) and Yarar Dole with TDS of 3915ppm,2660ppm and 2500ppm respectively, it may lead to health hazard on the part of consumers both in the short and long terms There is therefore the need to continually monitoring, controlling and taking necessary policy decisions so as to limit and ultimately prevent these avoidable problems.

Recommendations

1. Local communities, groundwater management committees, together with health personnel should monitor anthropogenic activities near the groundwater sources and carry out sanitary inspections so that hygiene and sanitation is maintained around the groundwater sources.
2. Strict laws should be enforced by the government because people are not following the safe distance between groundwater and potential sources of groundwater pollution setback distance of 30m for soak-ways and 500m distance for dumpsite from hand dug wells which should be more than sufficient to reduce the rate of pollution.
3. Public Health and Environmental officers should be given a mandate to inspect and checkwells to ensure they are safe for drinking and free from all forms of pollution. Polluted wells should be sealed. There is the need for formation of groundwater management committees and training of local Borehole technicians in case of breakdown.

4. Boreholes should be drilled by considering UNICEF standard of 100m-150m shallower depths. There should be protection of groundwater sources so that indiscriminate dumping of wastes into water sources should be prevented and hand dug well should have protective covers and sanitary environment kept free of stagnant waters and animal/human defecation. Sanitary landfills and waste disposal sites to be properly designed and constructed.

References

Adamu, G. K., Kankara, A. I. & Tukur, R. (2013). Groundwater quality assessment in the Basement complex areas of Kano State Nigeria, Paper published in the *American Journal of Engineering Research (AJER)* New Delhi India. II, (7).

Adelana, S. M., Abiye, T. A., Nkhuwa, D.C., Tindinugaya, C., & Oga, M. S. (2008*). Urban ground water management and protection in Sub-Saharan Africa in: Adelana, S. M. and MacDonald, A.M Applied groundwater studies in Afric*a, International Association of Hydrogeologists, selected papers.

Adji, T. N., & Sejati, S. P. (2014). Identification of groundwater potential zones within an Area with various Geomorphological units by using several field parameters and a GIS approach in Kulon Progo Regency, Java, Indonesia, *Arab Journal of Geosciences*. Retrieved from http://link.springer.com/article/10.1007/s12517-012-0779-z. Accessed *15/04/2019.*

Agbaire, P.O., Akporido, S.O. & Akporhonor, E. E. (2014). Water quality index assessment of borehole water in hostels in one of the higher institutions in Delta State, Nigeria, *Research Journal of Chemical Sciences 4 (7), 77-81.*

Ahmadi, S. H., & Sedghamiz, A. (2008). Application and evaluation of kriging and cokriging methods on groundwater depth mapping, *Environmental Monitoring and Assessment*, 138, pp. 357-368

Asadi, S. S. & Anji, M. (2007). Remote sensing and GIS techniques for evaluation of groundwater
quality in municipal corporation of Hyderabad, *Journal of Applied Sciences and Environmental Management,* 13 (1), 55-57. New Delhi India.

Dike, M., (2013). Selected physico-chemical parameters to determine the water quality of River Jakara in Kano, *International Journal of Innovative Research in Science, Engineering and Technology* 2, Edition, London.

Dan-Hassan, M. A. & Olasehinde, P. I. (2010). *Seasonal variations in physico-chemical properties of groundwater from central part of the Federal Capital Territory, Abuja,* Nigeria. Proceedings, Annual Conference of the Nigerian Association of Hydrogeologists on Water Resources Development and Climate Change.

Edet, A. & Worden, R. (2009). *Monitoring of physical parameters and evaluation of the chemical composition of river and groundwater in Calabar (Southeastern Nigeria*).

Hudak, P. F., & Sanmanee, D. (2000). Regional trends in nitrate content of Texas groundwater, *Journal of Hydrology (Amsterdam)*, 228.

Idris, S. (2011). *Evaluation of portable water quality in Dutsinma Metropolis Katsina State*, Unpublished Msc Thesis, Department of Geography, Bayero University Kano, Nigeria.

Jidauna, G. G., Barde, S. R., Ndabula, C., Oche, C. Y., & Dabi, D. D. (2017).Water quality assessment of selected domestic water resources in Dutsinma Town, Katsina State, *Science World Journal*, 12 (4) Retrieved from www.ScienceWorldjournal.org. Accessed 12/01/2019.

Lewis, W. J., &. Foster, S. D. (1980). *The risk of groundwater pollution by on-site sanitation in developing countries: A literature review*, International Reference Centre for Wastes Disposal.

Jeff, D. (2006). *Forum for groundwater and Geomorphological units by using several field parameters and GIS approach in Kulon Progo regency*, Retrieved from htt://www.waternet.co.za/groundwater/Accessed 17/04/2019.

Kankara, I. A. (2019). *The Geology of Dutsin-Ma Region: A geographical compendium of GEO 105: local field course manual*, Dept. of Geography, Federal University Dutsin-Ma.

Kagiso, M. (2016). *Integration of physicochemical assessment of water quality with Remote sensing techniques for the Dikgathong Dam in Botswana*, Unpublished Msc Thesis. Department of civil engineering, University of Zimbabwe.

Matos, B. A., Pacheco, A., Bastianon, D. & Batello, E. (2002). *Hydrogeological characterization of the unconfined aquifer in the Vila Nova Cachoeirinha cemetery, São Paulo municipality]. In XII Congresso Brasileiro de Águas Subterrâneas.* [XII Brazilian Congress on Groundwater], ABAS, São Paulo.

Maroju, S., (2007). *Evaluation of five GIS based interpolation techniques for estimating the radon concentration for unmeasured Zip Codes in the State of Ohio,* Master's Thesis, The University of Toledo.

Mohod, C. V., & Dhote, J. (2013). Review of heavy metals in drinking water and their effect on Human health, *International Journal of Innovative Research in Science, Engineering and Technology,* 2 (1)

Nas, B., & Berktay, A. (2010). Groundwater quality mapping in urban groundwater using, GIS *Environmental Monitoring and Assessment*, 1 (60), pp. 215-227.

Ruma, M. M. (2013). *An assessment of heavy metal concentration in well drinking water and Its effect on human health in urban Katsina, Katsina State*, Paper Presented at the 57th Annual Conference of the Association of Nigerian Geographers, Lagos University Yaba.

Rural Water Supply and Sanitation Agency, Katsina State (RUWASA, 2014). Survey *of Groundwater in Dutsin-Ma Town*, Katsina State.

Sabrina, S., Daniela, P., Joseph, M., Sieliechi, D. & Martin B. N. (2013). Assessment of physical chemical drinking water quality in the logone valley (Chad-Cameroon), *Journal of Sustainability*.

Skubon, B. A. (2005). Groundwater quality and GIS investigation of a shallow sand aquifer, opening region, *Journal of Geology Society of America, 37 (5) p.94*.

WHO & UNICEF (2000). *Global water supply and sanitation assessment 2000 Report*. WHO, Geneva and UNICEF, New York, Retrieved from http://www.unicef.org/infobycountry/ghana_statistics.html/.

WHO & UNICEF (2006). *Meeting the MDG drinking water and sanitation: Target the urban and rural challenge of the decade*, World Health Organization and UNICEF, Geneva, Switzerland.

Yammani, S. (2001). Groundwater quality suitable zones identification: Application of GIS, Chittoor Area, Andhra Pradesh, India. *Environmental Geology*, 201-210. New York: Oxford University Press.