World Wide Journal of Multidisciplinary Research and Development

WWJMRD 2020; 6(5): 51-58
www.wwjmrd.com
International Journal
Peer Reviewed Journal
Refereed Journal
Indexed Journal
Impact Factor MJIF: 4.25
E-ISSN: 2454-6615

Spatial Distribution of Groundwater Quality Using GIS in Kano Metropolis, Kano State, Nigeria.

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Abstract
Assessing spatial distribution of groundwater quality in Kano Metropolis was carried out using GIS. Thirty-two water samples were collected from the eight LGAs that constitutes Kano metropolis and four sample points were randomly selected from each. Spatial interpolation and mapping were deployed. The results revealed that total hardness, calcium, magnesium, chlorides, sulphates and sodium from the groundwater within the study area falls within the permissible limits. Also, most of the sample sites around the industrial areas within the metropolis such as parts of Kano Municipal, Fagge, Nassarawa, Gwale, Kumbotso and Ungogo LGAs showed higher physicochemical concentrations and are slightly acidic. The results suggest that the groundwater from the highly populated areas and areas close to the industrial sites needs some form of treatment before consumption and it indicates the need to develop suitable management practices to protect groundwater resources from effluents and discharges of industries in Kano metropolis.

Keywords: Physicochemical, Spatial Distribution, Groundwater Quality, Geographic Information System, Interpolation, Kano metropolis

Introduction

Water is one of the most important natural resources in the world [1]. Without it, life cannot exist. Unlike any other raw materials, there is no substitute for water. Water plays a vital role in the development of a community since a reliable supply of water is an essential prerequisite for the establishment of a permanent community. It supports all forms of life and creates jobs and wealth in the water sector, tourism, recreation and fisheries [2].

Groundwater represents an important source of drinking water and constitutes the largest source of deep and shallow wells [3]. Water from shallow and deep wells are often of better quality than surface open water sources, if the soil is fine-grained and its bedrocks do not have cracks, crevices, and bedding plants, which permit the free passage of polluted water [4, 5]. The availability and purity of groundwater are affected by location, construction, and operation of the wells [6]. It is often assumed that natural, uncontaminated water from deep wells is clean and healthy, and this is usually true with regards to bacteriological composition [7]. However, the aquifer and groundwater are under intense threats from both natural and anthropogenic sources such as urbanization, infiltration from dumpsites and effects of various land use configurations [8, 9, 10]. The pollutant that infiltrate from dumpsite has once been described as the worst threats to groundwater quality [11, 12, 13].

In Nigeria, the rate of urbanization characterized by high population concentration, increasing industrial and agricultural activities coupled with environmental pollution/degradation and indiscriminate disposal of all kinds of wastes are perceived to pose serious pollution threats with all its concomitant health hazards on groundwater quality especially in urban areas [14, 15, 16, 17]. This concern has attracted overwhelming attention of researchers in different parts of Nigeria urban areas. This borders on the fact that the public or municipal water supply is inaccessible to a large proportion of urban dwellers, and even where is available the supply is highly inadequate, unreliable and irregular. Consequently, there is high dependency on untreated groundwater abstracted through hand dug wells and borehole systems [18, 19]. The inability of the Government to persistently provide adequate potable water for the growing population has tremendously contributed to the proliferation of other water sources in Nigeria which could be unfit for human consumption [20]. Such suspected water sources cannot be used without caution for human drinking purposes due to the inherent health risks [21, 22, 23]. The drinking qualities of groundwater are largely dependent on the concentration of biological, chemical, and physical contaminants as much as environmental and human activities in such respects [24].

The need for safe water for mankind and to prevent water borne diseases, in order to safeguard human health led to the determination of the water quality of most water bodies for human use. The quality of water is the degree of its potability and is determined by the amount and level of physicochemical, microbial and heavy metals found in it. Water for domestic purposes should be free from all these substances in order for it to be potable for human use vis-à-vis, prevent water borne diseases. Assessment of quality of groundwater and spatial distribution mapping for various pollutants utilizing GIS technology and the resulted information on quality of water could be useful for policy makers to take remedial measures [25, 26, 27]. GIS can be a powerful tool for developing solutions for water resources problems to assess water quality and understanding the natural environment. There is need to have an up-to-date groundwater quality status maps for the groundwater sources being exploited by the masses, this will create a consciousness for a need to treat water to ensure healthy living. Hence, this study is aimed at assessing spatial distribution of groundwater quality in Kano Metropolis, Kano State using Geographic Information System.

The study area, Kano metropolis lies between latitude 11^0 05' N to 12^0 07' N and longitude 8^0 23' E to 8^0 47' E and altitude 472 meters above sea level. Kano Metropolis bordered by Minjibir LGA on the North-East and Gezawa LGA to the East, while Dawakin Kudu LGA to the South-East, Madobi and Tofa LGAs to the South-West. Kano metropolis is the second largest industrial and commercial Centre in Nigeria after Lagos and it is experience rapid population growth rate, the population of metropolis at (year 2000) is 1.6million [28]. In 2003 the population raised to 2.3 million (approximately) and in 2006 to 2.8million. The area covers almost 499 square kilometers. With a population density of about 1000 inhabitants per km2 within the Kano closed-settled zone compared to the national average of 267 inhabitants per km2. It is also one of the most crowded cities and has a large migrant worker population which is on the increase at the rate of 30 to 40 per cent per annum. It has also through time become a cosmopolitan city with all the ethnic groups across the city [29].

Kano Metropolis comprises the six core urban local government (Dala, Fagge, Gwale, Kano Municipal, Nassarawa and Tarauni) and two peri-urban local governments (Kumbotso and Ungogo) figure 1. Residential uses dominate most part of the study area, however other land uses such as commercial, institutional, and educational are all located within areas. Dakata, Sharada and Bompai functioned as industrial layout. Industries such as steel rolling, packaging, beverages processing etc. are found in this area. Commercial activities happened to be growing very fast in the area. There are many big and international markets such as Sabon-Gari, Kantin-Kwari, Singer market, Dawanau and Yankaba markets in the area [30].

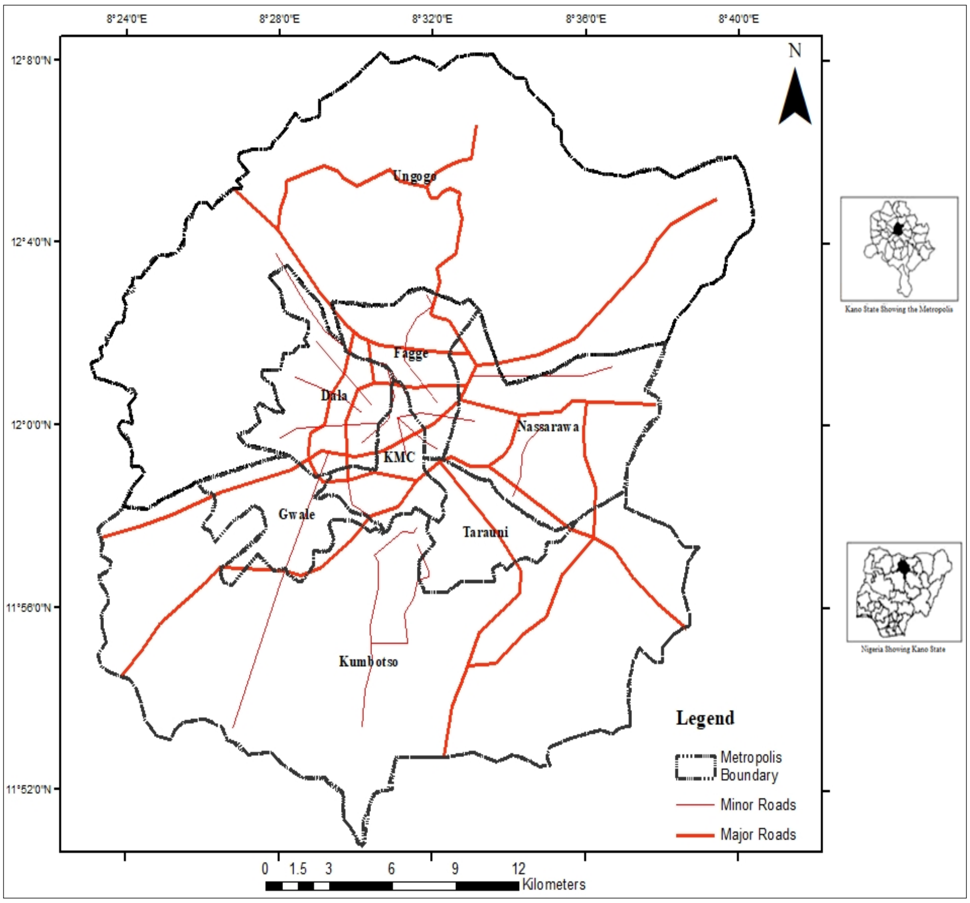

Fig. 1: Location of Kano Metropolis
Source: Adapted from the Administrative Map of Kano State, Nigeria

2. Materials and Methods

2.2 Sampling

Groundwater samples were collected from predetermined boreholes during the dry season in 2019. A total of thirty two (32) water samples were collected from the eight local government areas that constitutes Kano metropolis. Four (4) sample points were randomly selected from each of the Local Government areas which forms the metropolis. The selected sampling locations are shown in table 1 and figure 3. Pre-cleaned polypropylene bottles were used to collect water samples for chemical analysis and were kept in a cool box from collection point to the laboratory [31]. These samples were analyzed for different physicochemical parameters (pH, total hardness, calcium, magnesium, chlorides, sulphate and sodium) following standard methods [32]. The GPS coordinates of the locations were recorded by GPS (Hand-held GamineTrex 30 GPS receiver).

2.3 GIS Analysis

Model Inverse distance weighted (IDW) raster interpolation technique of spatial analyst module in ArcGIS (version 10.5) software was used to delineate the locational distribution of various ground water pollutants. The different locations of the sampling stations compiled in excel spread sheet saved in comma-separated value format (.csv) were imported into GIS software through point layer. Each sample point was assigned by a unique code and stored in the point attribute table. The database file contains values of all chemical parameters in separate columns along with a sample code for each sampling station. The geodatabase was used to generate the spatial distribution maps for the selected water quality parameters namely pH, total hardness, calcium, magnesium, chlorides, sulphate, and sodium. A schematic diagram of the methodology is shown in figure 2.

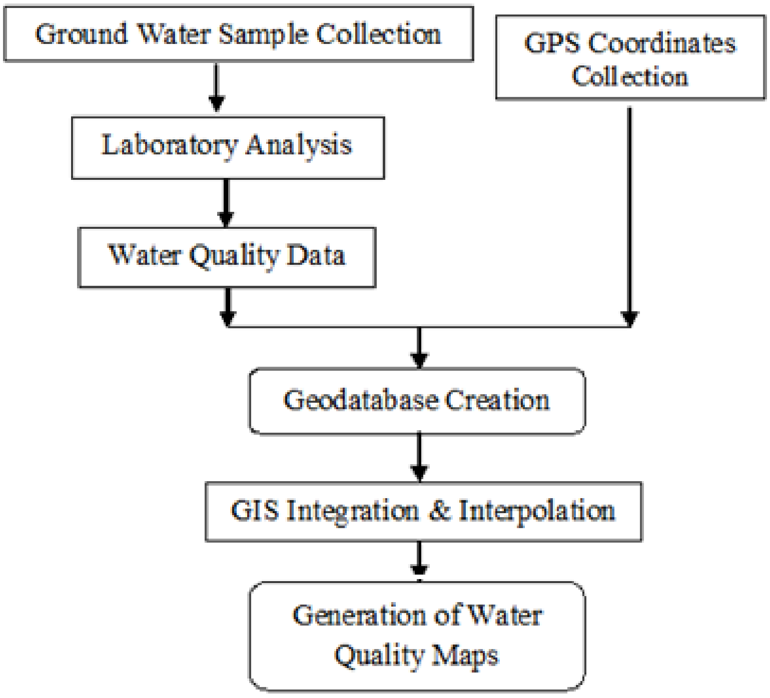

Fig. 2: Schematic Diagram of the Methodology

Table 1: Ground Water Sample Locations

S/N	Sample Locations	LGA	Northing	Easting
1	Close to Annur Plaza	KMC	1321432.80	446034.20
2	Around UBA Sharada Road	KMC	1322032.53	445333.00
3	Kofar Gadokaya	KMC	1321559.68	443711.88
4	Close to Kurmi Market	KMC	1323688.38	446753.76
5	Junijimi Road	Dala	1328369.63	446270.47
6	Kofar Ruwa	Dala	1328885.71	444996.92
7	Kofar Kansakali	Dala	1327007.55	444468.00
8	Kofar Kabuga	Dala	1326204.18	448111.52
9	Oyo Street	Fagge	1329068.88	451629.07
10	Kofar Ruwa Lorry Park	Fagge	1329868.80	445410.30
11	Kurna Primary School	Fagge	1328535.71	448033.91
12	Shamaga Street	Fagge	1327360.32	449007.04
13	Lamido Cresent	Nassarawa	1325653.43	452411.86
14	Sule Gaya Road	Nassarawa	1328536.95	452619.13
15	Hassan Street	Nassarawa	1328717.99	454534.81
16	Hassan Ja'Afar Road	Nassarawa	1327725.62	457170.93
17	Layin Barrister	Gwale	1325241.17	446693.92
18	Close to Hisbah HQ	Gwale	1324908.86	448342.69
19	Around Kano State Polytechnic	Gwale	1325088.31	445240.14

20	Chiranchi Primary School	Gwale	1325879.53	447276.39
21	Dantata Farms	Tarauni	1324214.71	452381.60
22	Azman Filling Station	Tarauni	1323396.35	451932.07
23	Commissioner Road	Tarauni	1324970.38	450827.72
24	Gyadi Gyadi	Tarauni	1321095.48	446616.88
25	Panshekara Community Market	Kumbotso	1314949.21	441091.69
26	DanSaa Organic Fertilizer	Kumbotso	1319255.98	447357.56
27	Kumbotso Transmission Substation	Kumbotso	1314572.87	445726.59
28	Total Farawa Service Station	Kumbotso	1322309.24	455819.22
29	Ungogo Town	Ungogo	1335325.99	449659.68
30	Dakata Bus Stop	Ungogo	1329057.37	454023.17
31	Layin Daiba Road	Ungogo	1332003.86	442848.09
32	Govt. Technical School	Ungogo	1334512.25	441182.39

Source: Field Survey

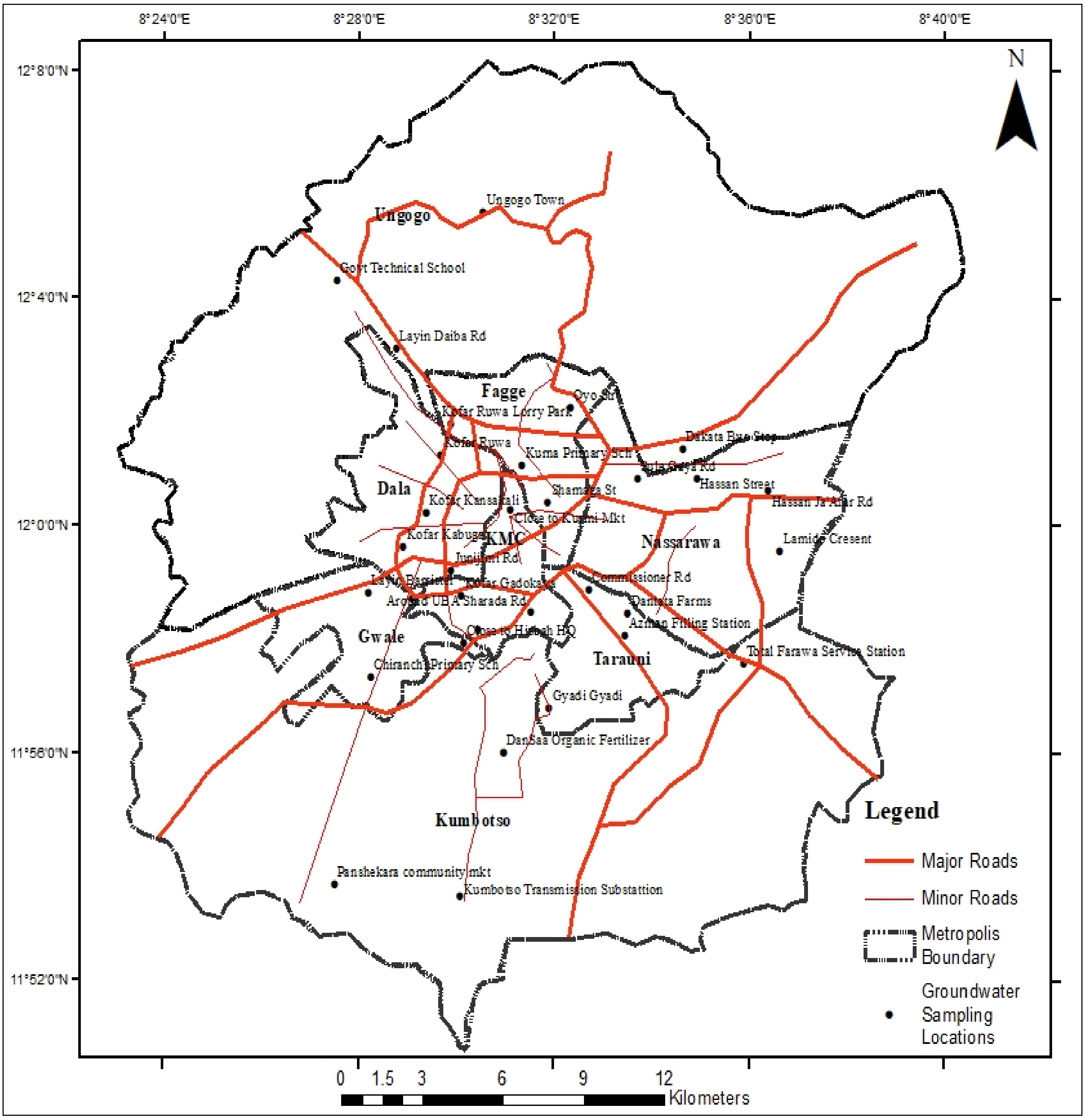

Fig. 3: Kano Metropolis Showing Sample Locations

4.0 Results and Discussion

4.1 Results

The results obtained from the physicochemical analysis are presented in table 2 and figures 4 to 10 for the various sampling locations that constitutes the metropolis which will be compare to World Health Organization 2011 standard guidelines. The figures in this section depicts the spatial distribution of each physicochemical water quality parameter as it varies across Kano metropolis.

Table 2: Maximum and Minimum Values of Groundwater Quality in the Study Area

Location		pH	Total hardness (mg/l)	Calcium (mg/l)	Magnesium (mg/l)	Chlorides (mg/l)	Sulphate (mg/l)	Sodium (mg/l)
KMC	Min	6.15	20.00	12.50	11.50	19.00	0.64	5.20
	Max	7.08	220.50	25.50	24.30	70.20	2.10	18.00
Dala	Min	6.60	50.10	8.00	9.00	23.20	0.02	7.10
	Max	7.02	60.20	16.50	10.51	34.21	0.27	10.21
Fagge	Min	6.00	40.50	8.20	8.40	19.20	0.09	10.00
	Max	7.00	120.00	23.20	22.30	65.30	1.60	26.10
Nassarawa	Min	5.96	62.50	9.20	12.90	20.40	0.21	11.60
	Max	6.73	200.00	25.00	29.00	76.00	2.06	29.02
Gwale	Min	6.02	50.20	11.24	10.3.0	20.20	0.06	7.00
	Max	7.02	110.30	20.50	23.00	62.20	0.52	29.10
Tarauni	Min	6.66	52.30	9.02	9.61	19.91	0.03	5.24
	Max	7.02	79.00	12.80	14.79	28.65	0.52	10.06
Kumbotso	Min	5.95	50.00	10.05	11.83	22.40	0.09	6.80
	Max	6.72	165.00	20.40	27.02	60.30	1.92	28.20
Ungogo	Min	6.00	52.40	10.33	11.44	20.72	0.13	6.40
	Max	6.74	85.90	17.41	21.02	34.40	0.72	16.50
WHO (2011)		8.50-6.50	500	NA	150	250	250	50

Source: Laboratory Analysis
NA - Not Available

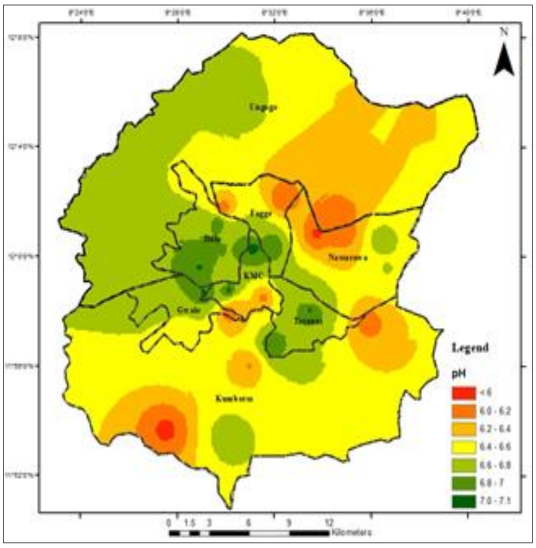

Fig. 4: Spatial distribution of pH in Kano Metropolis

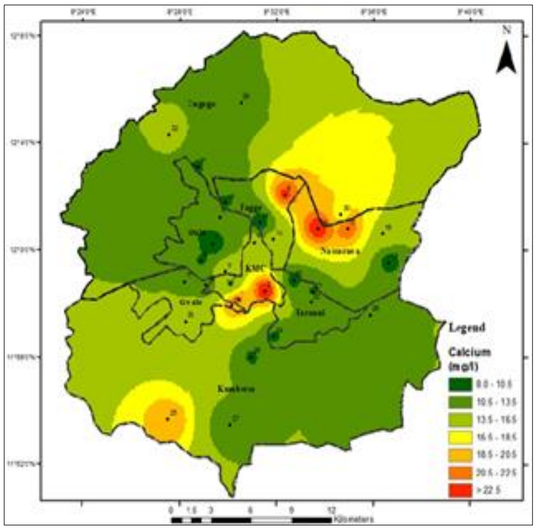

Fig. 6: Spatial distribution of calcium in Kano Metropolis

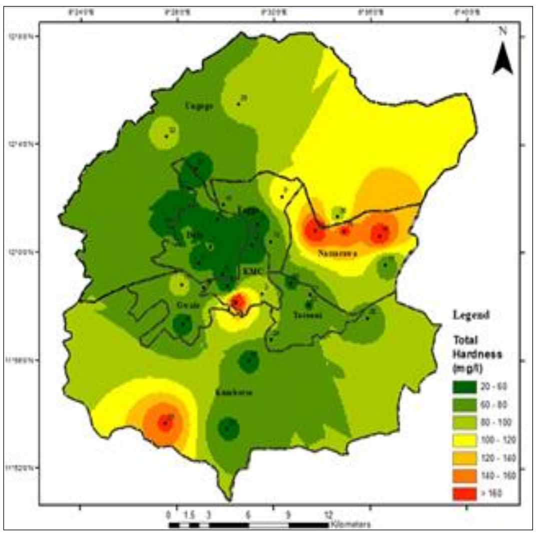

Fig. 5: Spatial distribution of Total hardness in Kano Metropolis

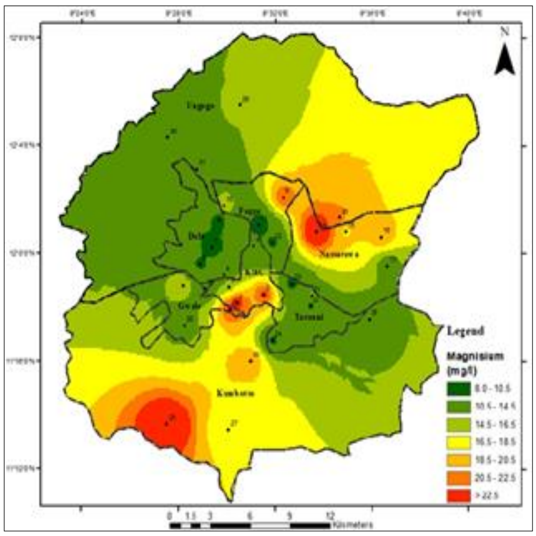

Fig. 7: Spatial distribution of magnesium in Kano Metropolis

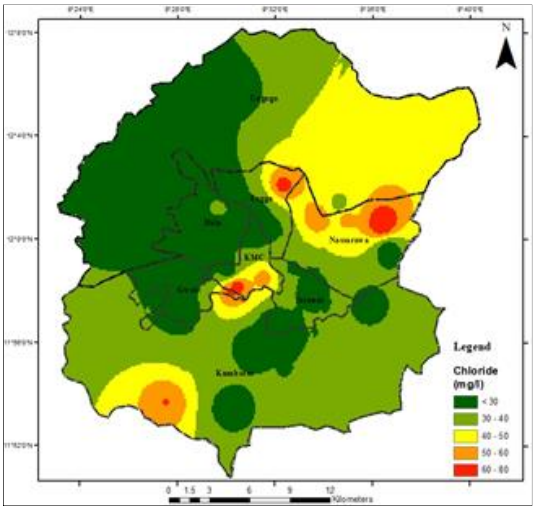

Fig. 8: Spatial distribution of sodium in Kano Metropolis

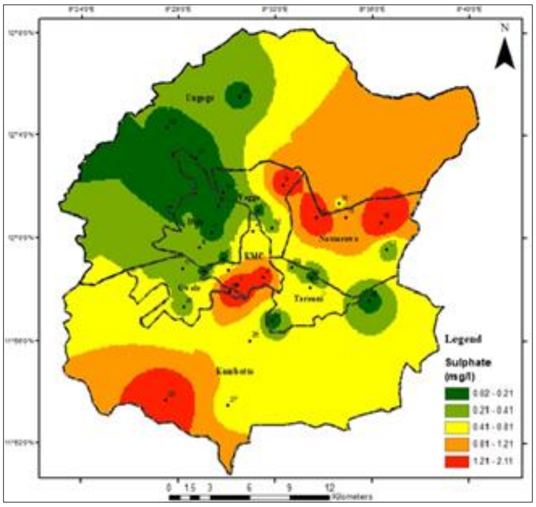

Fig. 9: Spatial distribution of sodium in Kano Metropolis

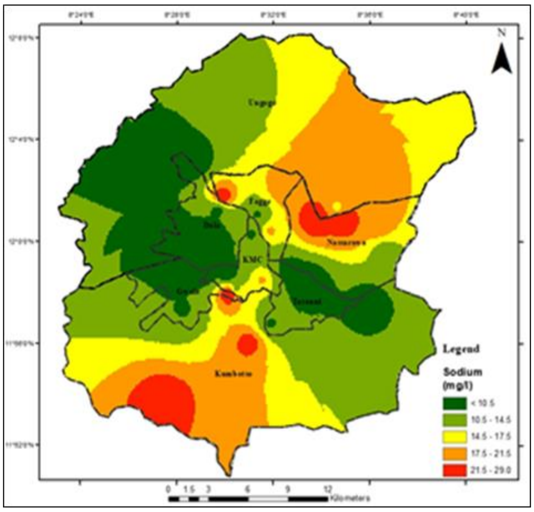

Fig. 10: Spatial distribution of sodium in Kano Metropolis

4.2 Discussion

The pH is one of the most vital operational water quality parameters with the maximum and minimum permissible limit for in drinking water as given by WHO as 6.50 to 8.50. The value of pH in groundwater data collected varied from a minimum of 5.95 in borehole 25 (Panshekara community market Kumbotso) to maximum of 7.08 in borehole 4 (Close to Kurmi market Kano Municipal). Results from the analysis indicate that most sites close to industrial areas within the metropolis have pH less than 6.5 which may cause tuberculation in water supply systems. This shows that ground water around the industrial areas are slightly acidic such as parts of Kano Municipal, Fagge, Nassarawa, Gwale, Kumbotso and Ungogo LGAs. Spatial distribution of pH concentrations are shown in figure 4. Past studies had equally revealed the acidic nature of groundwater in northeastern and western part of Nigeria [33, 34, 35].

Hardness in water is caused due to the presence of carbonates and bicarbonates of calcium and magnesium, chlorides, nitrates and sulphates of calcium and magnesium. The concentration of total hardness in groundwater data collected varies from 20.00 mg/l to 220.50 mg/l and are within the desirable limits of WHO (500 mg/l). The maximum concentration was recorded in borehole 1 around Annur plaza in Kano municipal. Spatial distribution of total hardness in groundwater is shown in (figure 5).

Most geological material aquifers are composed of calcium. The value for calcium concentration in groundwater within the metropolis ranges from 8.00 mg/l to 25.50 mg/l similar to the study of [36]**.** The maximum concentration of calcium was recorded around UBA area borehole 2 in Sharada Kano Municipal. WHO permissible limit are not available for calcium. The spatial distribution of calcium in groundwater (figure 6) varies across the metropolis with higher concentrations spotted around industrial areas.

Magnesium concentration in ground water within the metropolis ranges from a minimum of 8.40 mg/l to a maximum of 29.00 mg/l in borehole 14 around Sule Gaya road Nassarawa. The result also indicated that the concentration of magnesium from the different sample points were within the WHO permissible limit of 150mg/l. The spatial distribution of magnesium in groundwater varies across the metropolis (figure 7), with higher concentrations around industrial and highly populated areas.

In all types of natural waters the amount of chloride present is in varying concentration. The chloride content in groundwater may be attributed to the presence of soluble chloride from rocks and saline intrusion. The chloride concentration in the study area ranges from 19.00 mg/l to 76.00 mg/l lower than the WHO permissible limit of 250 mg/l. the maximum concentration of chloride was recorded in borehole 16 around Hassan Ja'Afar road Nassarawa. The spatial variation of chlorides in groundwater across the metropolis is shown in (figure 8). Areas showing higher concentrations of chlorides could be due to sewage mixing and increased temperature and evapo- transpiration of water.

Ions of sulphte are present in groundwater and are in soluble form naturally. The sulphate concentrations in the study area varies from 0.02 mg/l to 2.10 mg/l where the maximum concentration was recorded in borehole 1 close to Annur Plaza Kano Municipal. It was observed that the concentration of sulphate falls within WHO permissible limit of 250mg/l. The presence of sulphate in groundwater (figure 9) showed spatial variation across the metropolis.

Higher concentrations of sodium found in groundwater are within areas where discharge of effluents such as domestic and industrial are eminent. In general sodium salts are not actually toxic substances to humans because of the

efficiency with which kidneys excrete sodium [37]. The sodium concentration in the study area ranges from a minimum of 5.20 mg/l to maximum of 29.10mg/l around Hisbah headquarters in Gwale LGA and falls within the WHO permissible limit of 50mg/l similar to the study of [36] who's results for sodium were within permissible limits in Kano. Also, (figure 10) depicts a spatial variation in sodium groundwater concentrations across the metropolis.
Results from the study in general revealed that total hardness, calcium, magnesium, chlorides, sulphates and sodium from the groundwater within the metropolis falls within the permissible limits of WHO standards. This is agreement with the study of [37] who carried out an assessment of physicochemical qualities of water sources in Kano metropolis, also in agreement with the study of [18].

5.0 Conclusion

Groundwater quality is dependent on the type of the pollutant and nature of mineral found at specific sample site. Geographic Information System (GIS) was an effective tool for spatial analysis and interpretation of the groundwater quality. The study has demonstrated the application of GIS technology combined with analysis in evaluation and mapping of groundwater quality in Kano Metropolis. Results from the study revealed that most of these physicochemical parameters from the groundwater within the metropolis falls within the permissible limits of WHO standards. Also, most sample sites around the industrial areas within the metropolis showed higher physicochemical concentrations and are slightly acidic such as parts of Kano Municipal, Fagge, Nassarawa, Gwale, Kumbotso and Ungogo LGAs having high population and producing pollutants to the environment.
Regardless of physicochemical concentration been within WHO permissible limits, long term consumption could accumulate in the body thereby negatively impact the health of the population. Thus, GIS spatial distribution maps gave better visual understanding to the present groundwater quality status within the metropolis. The results suggest that the groundwater from the highly populated areas and areas close to the industrial sites needs some form of treatment before consumption and it indicates the need to develop suitable management practices to protect the ground water resources from effluents and discharges of industries in Kano metropolis.

6.0 References

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