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Groundwater Quality Assessment of Kano Metropolis using Water Quality Index and Geospatial Techniques

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***Abstract* – The study involved groundwater quality assessment of Kano metropolis using water quality index and geospatial techniques. Samples were collected from four individual boreholes within each of the eight local government areas that constitute Kano metropolis (Dala, Fagge, Gwale, Municipal, Nassarawa, Tarauni, Kumbotso and Ungogo). Physicochemical parameters were analyzed for pH, total hardness, magnesium, chlorides, sulphate, sodium, zinc, and iron using standard methods. The study's findings were compared to the World Health Organization's (WHO) and Nigerian Drinking Water Quality Standards (NSDWQ). Water Quality Index (WQI) was also calculated using an arithmetic model to measure the overall potability of water quality, and WQI was mapped using a Geographic Information System (GIS) for the entire Kano metropolis. The study's findings revealed that the majority of these physicochemical parameters in the metropolis' groundwater are within WHO and NSDWQ permissible limits, with the exception of pH and Iron, which have values outside the permissible limits in a few areas. Based on its spatial distribution of WQI within the metropolis, the study also revealed a poor to very poor WQI rating. These areas are characterized by high population density and a small number of industrial sites that pollute the environment. The findings suggest that groundwater from the study area should be treated before consumption, and that appropriate management practices should be developed to protect groundwater resources from anthropogenic activities within Kano metropolis.**

Keywords: Physicochemical, Water quality index (WQI), Spatial Distribution, Groundwater Quality, Geographic Information System (GIS).

INTRODUCTION

Worldwide, the stress on the freshwater resources from surface and groundwater sources is ever increasing due to population growth and rapid industrialization. Natural occurring groundwater is typical of high quality, but it can deteriorate due to insufficient source protection and poor resource management. Its contamination may be due to improper dwelling of well and waste disposal (Allamin *et al.*, 2015; Shawai *et al.*, 2019). The demand for groundwater supply for drinking, domestic, agricultural, and industrial use has been steadily increasing. It is still the largest available source of freshwater, making it an essential component of the water supply chain (Ibrahim, 2019). Due to the natural environmental processes and anthropogenic activities, groundwater quality is a major concern for users and stakeholders in many geographical areas. Groundwater pollution, in general, not only reduces water quality but also jeopardizes socioeconomic activities and the public health of any nation. The quality of geochemical processes, recharge water, surface water, and precipitation influence groundwater quality: (Olatunji, Odediran, Obaro and Olasehinde, 2015; Patel and Vadodaria, 2015).

The occurrence of organic and inorganic compounds that are either suspended or dissolved in water determines the physicochemical parameters useful for assessing water quality. While some of the compounds are toxic to the ecosystem, others serve as nutrients for aquatic organisms, and some contribute to the aesthetics of the water body (Rao and Nageswararao, 2013). Monitoring and evaluating groundwater quality are crucial components in effective water resource management. The traditional groundwater quality assessment method compares individual parameter concentration from generally acceptable standard guidelines data and water samples with parameter concentration values that exceed their limit values are expected to have health implications (Dede, Telci and Aral, 2013). This approach delivers vague information on overall quality but doesn't provide any information on overall quality temporal and spatial scales. Furthermore, interpreting the results of this approach is not always simple. In most cases, when some of the many parameters used to describe the water quality status of a water body are within the guideline limits but others are not, the overall quality of the water is ambiguous. As a result, contemporary approaches such as water quality indices and geospatial techniques are recommended (Ibrahim, 2019; Balogun *et al.*, 2020).

The Water Quality Index is a technique that provides the composite influence of individual water quality parameters on an area's overall water quality. It is calculated in terms of human consumption and accurately depicts the overall quality of water for public consumption or any other intended use. It is simple and straightforward for stakeholders to understand the quality and potential uses of any water body (Ambiga and Annadurai, 2013**).** Geographic Information System is also an effective tool for developing solutions for water resources quality problems by mapping groundwater quality, understanding the natural environment and assessing groundwater vulnerability to pollution. it is a tool that provides a simple, stable, and visual display of measurement and also communicates water quality information to policymakers and other stakeholders. As a result, it has become a significant parameter for groundwater quality assessment and management (Chauhan, Pawar and Lone, 2010; Singha *et al.*, 2015).

In Nigeria, the government's inability to consistently provide adequate potable water for the growing population has significantly contributed to the proliferation of groundwater resources. The population growth is characterized by high population concentration, increasing industrial, commercial and agricultural activities, environmental degradation, and indiscriminate disposal of all types of wastes, is perceived to pose serious pollution threats, with all of the associated health hazards on groundwater quality, particularly in urban areas (Balogun *et al.*, 2020). As a result, the high reliance on untreated groundwater extracted from shallow and deep wells has resulted in the innate proliferation of diseases and other health-related issues. The need for safe water for humanity, as well as the prevention of water-borne diseases and the protection of human health, led to the establishment of a water quality index for most bodies of water used for human consumption.

Severe potable water scarcity has been one of the major problems the population within Kano metropolis had to contend with, and very few areas within the metropolis could boast of access to potable water supply from the waterboard. This has forced the city's population to rely solely on groundwater exploration for municipal, industrial, and agricultural purposes. Because groundwater is a primary source of water supply in Kano, there is a constant need to evaluate its quality for domestic use. Several researchers, including Saeed and Mahmoud (2014), Abdulbaki *et al.*, (2014), Nahannu, *et al.*, (2017), Shawai *et al*., (2017), Bataiya *et al.*, (2017), Boyi *et al.*, (2017), Shawai *et al.*, (2018), Nahannu *et al*., (2018), Balogun *et al.*, (2020) all carried out groundwater quality in various parts of Kano Metropolis. Literatures reviewed indicate that no study was have been conducted in the study area on groundwater quality to look at Water Quality Index (WQI) and depict the results on maps to determine the spatial variation of WQI within the study area. Consequently, this research will dwell on deploying WQI and Geographic Information System (GIS) in assessing groundwater quality within the study area by determining the level of concentration of few physicochemical parameters, compare the level of concentrations with the acceptable standards, assessment of the water quality using water quality index and spatial mapping of WQI for the study area.

MATERIALS AND METHODS

Study Area

Kano Metropolis encompasses six (6) Local Government Areas which includes Dala, Fagge, Gwale, Municipal, Nassarawa, Tarauni, Kumbotso and Ungogo. The metropolis covers about 499 square kilometres at an altitude of 472 meters above sea level and lies between latitude 11^0 05' N to 12^0 07' N and longitude 8^0 23' E to 8^0 47' E. Kano Metropolis is bounded to the north-east by Minjibir LGA and the east by Gezawa LGA, and to the south-east by Dawakin Kudu LGA and to the west by Madobi and Tofa LGAs (See Figure 1). Kano metropolis is Nigeria's second-largest commercial centre after Lagos, and the largest urban centre in Hausa land, with phenomenal growth. It is also the most influential commercial town in the Sudan region, with a long-standing sedentary population in an organized emirate (Boyi *et al*., 2017). Its population in 2006 was estimated 2,163,225 in the city and 2,828,861 in the metropolis (NPC, 2007). In 2020, the population was projected to be around 4,103,000. It is also one of the most densely populated cosmopolitan cities with diverse ethnic groups (Boyi *et al*., 2017). The majority of the study area is dominated by residential landuse. Commercial, agricultural, institutional, industrial, and educational activities are all part of the study area. Dakata, Sharada, and Bompai served as industrial layouts, with industries such as steel rolling, packaging, beverages, rice processing, and so on. Commercial activity can be found throughout the city, with several major markets including Sabon-Gari, Kantin-Kwari, Singer market, Dawanau market, and Yankaba market. Kano metropolis is supported by Precambrian basement complex rock composed of amorphous ingenious and metamorphic rock. The soil is tropical ferruginous, and the natural belongs to that of vegetation is Sudan Savannah. The climate is tropical wet and dry, with the wet season lasting 4.5 months between May and September (Olofin and Tanko, 2002).

Sample Collection and Laboratory Analysis

Water samples were collected from four individual boreholes within each of the eight local government areas that constitute Kano metropolis such as Dala, Fagge, Gwale, Municipal, Nassarawa, Tarauni, Kumbotso and Ungogo respectively, at the peak of the wet season. The details of the samples are presented in Table 2. The samples were collected in clean 1litre plastic bottles that were rinsed twice using distilled water before sampling. The pH for the samples was immediately measured and recorded after collection in-situ while the other physicochemical parameters were measured in the laboratory using standard procedures and precautions as shown in Table 1. Each sample was levelled and transported to the laboratory for the analysis of total hardness, magnesium, chlorides, sulphate, sodium, zinc, and iron which are carried out following the standard methods.

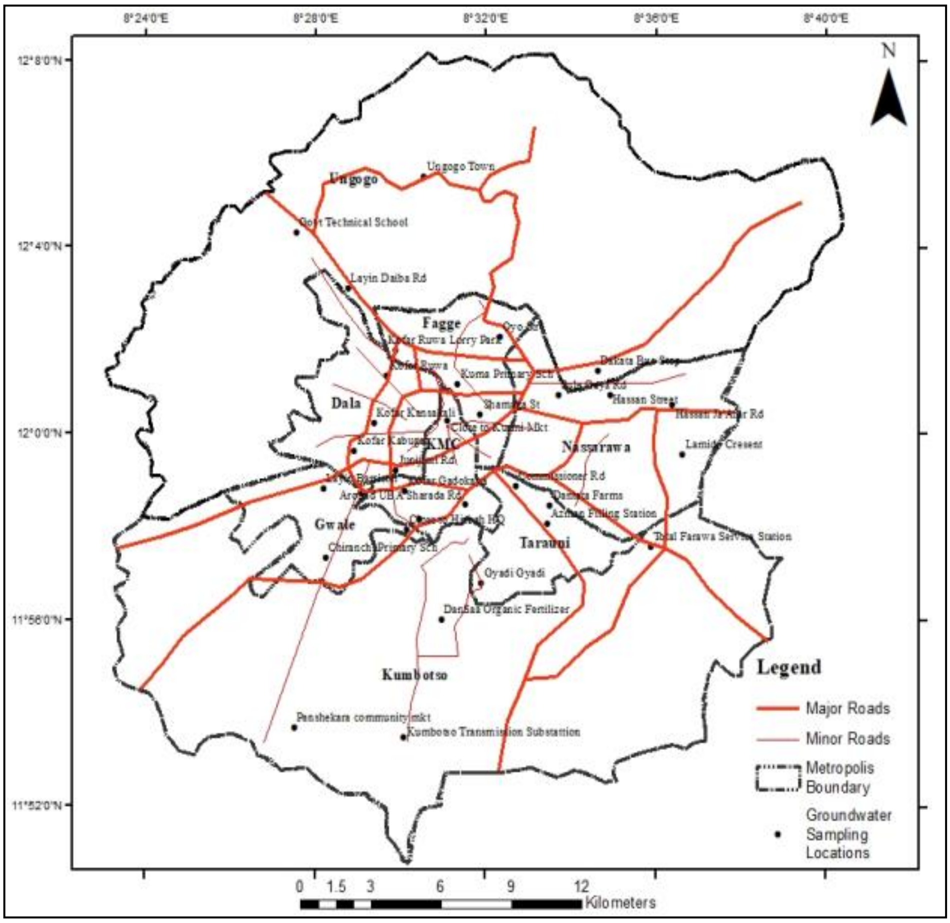

Figure 1. Location of Kano Metropolis

Source: Adapted from the Administrative Map of Kano State, Nigeria

Table 1: Methods Adopted for Physicochemical Test

No.	Physicochemical Parameters	Method of Analysis
1	pH	Digital pH meter (APHA, 1992)
2	Total Hardness	EDTA-Titrimetry (APHA, 1992)
3	Magnesium	Spectrophotometry (APHA, 1992)
4	Chlorides	Mohr'sTitrimetry (APHA, 1992)
5	Sulphate	Turbidimetric Method (APHA-AWWA-WEF, 1998)
6	Sodium	Flame Photometric (APHA, 1992)
7	Lead	Spectrophotometry (APHA, 1992)
8	Iron (Fe)	Spectrophotometry (APHA, 1992)

Table 2: Ground Water Sample Locations

S/N	Sample Locations	LGA	Northing	Easting	S/N	Sample Locations	LGA	Northing	Easting
1	Close to Annur Plaza	KMC	1321432.80	446034.20	17	Layin Barrister	Gwale	1325241.17	446693.92
2	Around UBA Sharada Road	KMC	1322032.53	445333.00	18	Close to Hisbah HQ	Gwale	1324908.86	448342.69
3	Kofar Gadokaya	KMC	1321559.68	443711.88	19	Around Kano State Polytechnic	Gwale	1325088.31	445240.14
4	Close to Kurmi Market	KMC	1323688.38	446753.76	20	Chiranchi Primary School	Gwale	1325879.53	447276.39
5	Junijimi Road	Dala	1328369.63	446270.47	21	Dantata Farms	Tarauni	1324214.71	452381.60
6	Kofar Ruwa	Dala	1328885.71	444996.92	22	Azman Filling Station	Tarauni	1323396.35	451932.07
7	Kofar Kansakali	Dala	1327007.55	444468.00	23	Commissioner Road	Tarauni	1324970.38	450827.72
8	Kofar Kabuga	Dala	1326204.18	448111.52	24	Gyadi Gyadi	Tarauni	1321095.48	446616.88
9	Oyo Street	Fagge	1329068.88	451629.07	25	Panshekara Community Market	Kumbotso	1314949.21	441091.69

10	Kofar Ruwa Lorry Park	Fagge	1329868.80	445410.30	26	DanSaa Organic Fertilizer	Kumbotso	1319255.98	447357.56
11	Kurna Primary School	Fagge	1328535.71	448033.91	27	Kumbotso Transmission Substation	Kumbotso	1314572.87	445726.59
12	Shamaga Street	Fagge	1327360.32	449007.04	28	Total Farawa Service Station	Kumbotso	1322309.24	455819.22
13	Lamido Cresent	Nassarawa	1325653.43	452411.86	29	Ungogo Town	Ungogo	1335325.99	449659.68
14	Sule Gaya Road	Nassarawa	1328536.95	452619.13	30	Dakata Bus Stop	Ungogo	1329057.37	454023.17
15	Hassan Street	Nassarawa	1328717.99	454534.81	31	Layin Daiba Rd	Ungogo	1332003.86	442848.09
16	Hassan Ja'Afar Road	Nassarawa	1327725.62	457170.93	32	Govt Technical School	Ungogo	1334512.25	441182.39

Source: Field Survey

Water Quality Index Analysis

The WQI is an effective tool for communicating water quality to the general public, policymakers and stakeholders. It is an unambiguous tool that enables the integration of the water parameters which are deemed important to the quality of the water accordingly and reflects the combined impact of various water quality parameters on overall water quality. In this study, the WQI is calculated using the weighted arithmetic index method in assessing groundwater quality for each of the Local Government Area within Kano Metropolis. Once the WQI scores were determined, they were compared to a scale (Table 2) to establish how healthy the water is in the various Local Government Areas that comprise the Metropolis (Brown *et al.*, 1970).

The WQI is given as:

$$WQI = \left(\sum_{I=1}^{i=n} W_i\, q_i\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ (1)$$

Where;
WQI = Water Quality Index
q_i = Quality Rating Scale
W_i = Relative weight as inverse proportional to the quality standards

$$q_i = 100\left(\frac{v_i - v_{io}}{s_i - v_{io}}\right) \quad \ldots\ldots\ldots\ldots\ (2)$$

Where;
v_i = estimated value of the ith parameter
v_{io} = ideal value of the ith parameter
s_i = standard permissible value of the ith parameter
In most cases, $v_{io} = 0$ except for pH which has a $v_{io} = 7$

$$W_i = k/s_i \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (3)$$

$$\text{Where } k = \frac{1}{\sum_{i=1}^{n} \frac{1}{s_i}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ (4)$$

Table 3. Water Quality Rating Based on Arithmetic Method

Water Quality Index Level	Rating of Water Quality/ Grade
0-25	Excellent water quality/ A
25-50	Good water quality/ B
51-75	Poor water quality/ C
76-100	Very poor water quality/ D
>100	Unsuitable for drinking/ E

Source: (Oni and Fasakin, 2016; WHO. 2018).

Geospatial Analysis

Geospatial analysis was carried out with the aid of spatial maps, field data and WQI values derived from laboratory results. Using the spatial and geostatistical analyst extensions modules in the ArcGIS (version 10.5) environment, the spatial distribution of the groundwater WQI for the study area was determined. The inverse distance weighted (IDW) raster interpolation model was used to define the locational distribution of various groundwater quality. The various sampling station locations were compiled in an excel spreadsheet and saved in comma-separated value format (.csv) before being imported into GIS software via point layer (ESRI, 2015). The database file holds values for all WQI for each sample point and was assigned a unique code all saved in the point attribute table. The geodatabase was then used to create spatial distribution maps for the water quality index. Figure 2 shows a schematic diagram of the methodology for the study.

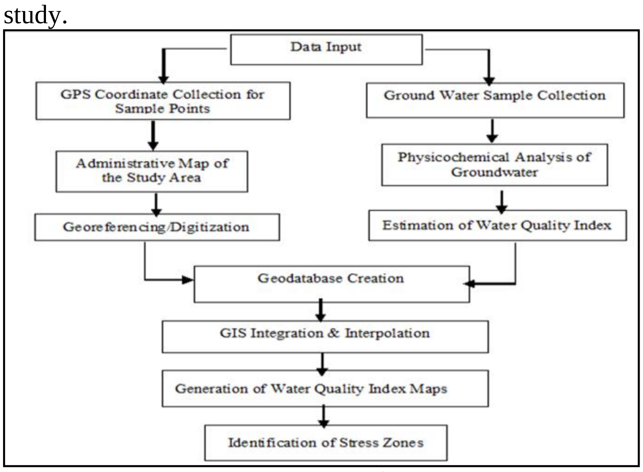

Figure 2: Schematic Diagram of the Methodology

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RESULTS AND DISCUSSION

The groundwater quality for the LGAs that constitute Kano metropolis (Dala, Fagge, Gwale, Municipal, Nassarawa, Tarauni, Kumbotso and Ungogo) was measured to determine the physicochemical parameters (pH, Total Hardness, Magnesium, Chlorides, Sulphate, Sodium, Zinc, and Iron) at 32 different sample locations within the study area. A detailed report of the test result is shown in Table 2 and mean variations are depicted graphically in Figures 3 to 10 for each parameter. While Water Quality Index (WQI) values are presented in Table 5 and spatial mapping of WQI is shown in Figure 11.

Table 4: Results of the Physicochemical Analysis Compared with WHO and NSDQW Standard Values

S/No.	pH	Total Hardness	Magnesium	Chlorides	Sulphate	Sodium	Zinc	Iron
BWS1	6.52	220.50	24.30	70.20	2.10	13.40	0.23	0.35
BWS2	6.41	100.20	23.00	56.00	1.52	18.00	0.16	0.32
BWS3	7.05	20.00	16.20	20.00	0.80	5.20	0.11	0.18
BWS4	7.08	20.00	11.50	19.00	0.64	10.00	0.10	0.19
BWS5	6.60	50.50	10.51	26.30	0.02	10.21	0.15	0.25
BWS6	6.90	50.30	9.50	34.21	0.10	9.03	0.11	0.21
BWS7	6.82	60.20	9.00	25.22	0.06	7.10	0.20	0.24
BWS8	7.02	50.10	10.00	23.20	0.27	8.51	0.11	0.22
BWS9	6.50	120.00	22.30	65.30	1.60	20.00	0.22	0.29
BWS10	6.53	80.20	16.60	19.20	0.09	26.10	0.21	0.32
BWS11	6.62	40.50	8.40	26.00	0.10	10.00	0.15	0.18
BWS12	7.00	70.30	10.00	26.40	0.32	18.20	0.13	0.27
BWS13	6.61	62.50	12.90	20.40	0.21	11.60	0.14	0.26
BWS14	6.50	200.00	29.00	60.03	2.06	29.02	0.33	0.36
BWS15	6.51	170.40	18.30	53.00	0.28	27.20	0.32	0.33
BWS16	6.73	180.00	20.06	76.00	1.61	20.03	0.14	0.29
BWS17	6.80	90.00	16.40	26.30	0.10	8.23	0.11	0.19
BWS18	6.62	110.30	23.00	62.20	0.31	29.10	0.16	0.32
BWS19	7.02	70.40	10.30	24.01	0.06	7.00	0.13	0.18
BWS20	6.50	50.20	12.40	20.20	0.52	10.05	0.11	0.19
BWS21	6.66	68.50	14.79	28.65	0.03	5.24	0.12	0.22
BWS22	7.02	56.80	10.02	25.00	0.52	8.70	0.22	0.18
BWS23	6.80	52.30	9.61	28.50	0.33	7.04	0.21	0.17
BWS24	7.00	79.00	10.10	19.91	0.07	10.06	0.16	0.21
BWS25	6.22	165.00	27.02	60.30	1.92	28.20	0.16	0.39
BWS26	6.40	50.00	20.60	22.40	0.42	24.30	0.15	0.36
BWS27	6.72	55.00	16.64	25.80	0.72	19.00	0.12	0.29
BWS28	6.61	72.49	11.83	26.66	0.09	6.80	0.14	0.21
BWS29	6.74	82.41	15.18	28.50	0.17	12.20	0.15	0.20
BWS30	6.41	80.30	21.02	34.40	0.72	16.50	0.12	0.19
BWS31	6.51	52.40	12.06	26.40	0.13	6.40	0.12	0.16
BWS32	6.70	85.90	11.44	20.72	0.20	10.00	0.12	0.17
WHO	**6.5-8.5**	**500**	**150**	**250**	**250**	**200**	**3.00**	**0.30**
NSDQW	**6.5-8.5**	**150**	**0.20**	**250**	**100**	**200**	**3.00**	**0.30**

BWS: Borehole Water Sample, World Health Organization (WHO), Nigerian Standard for Drinking Water Quality (**NSDQW**)
All parameters are in mg/l respectively.

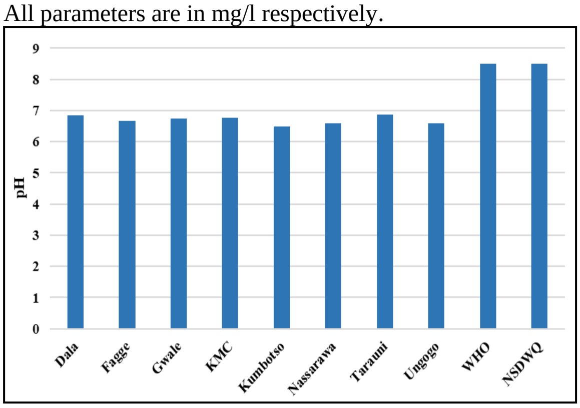

Figure 3: Mean Variation in pH for Kano Metropolis

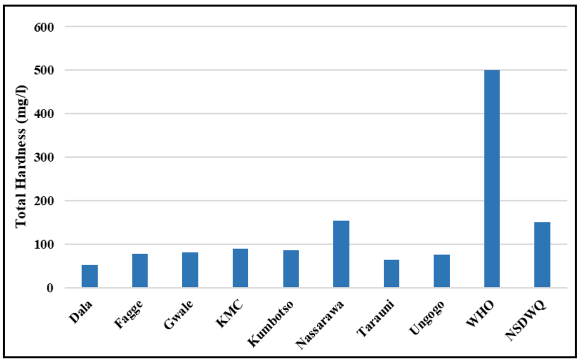

Figure 4: Mean Variation in Total Hardness for Kano Metropolis

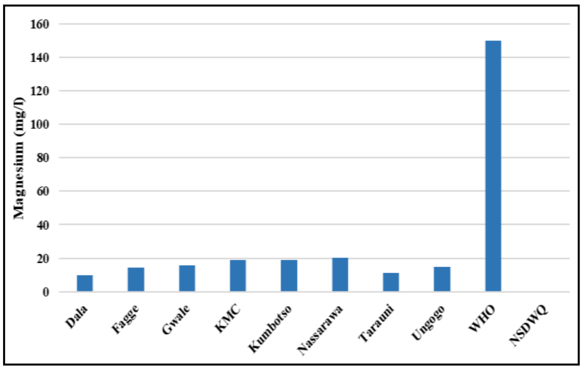

Figure 5: Mean Variation in Magnesium for Kano Metropolis

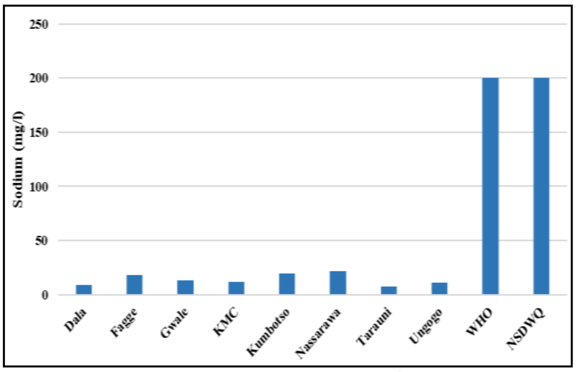

Figure 8: Mean Variation in Sodium for Kano Metropolis

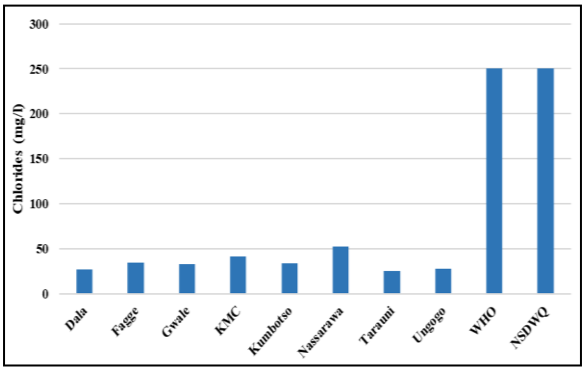

Figure 6: Mean Variation in Chlorides for Kano Metropolis

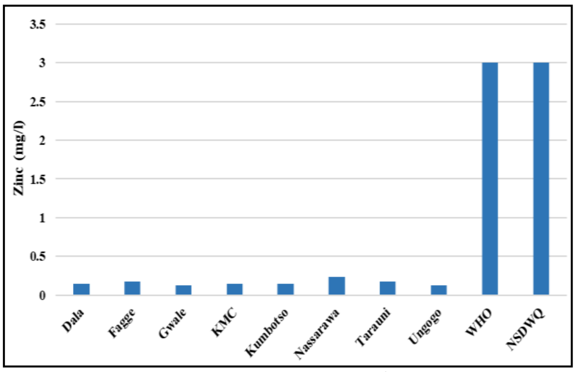

Figure 9: Mean Variation in Zinc for Kano Metropolis

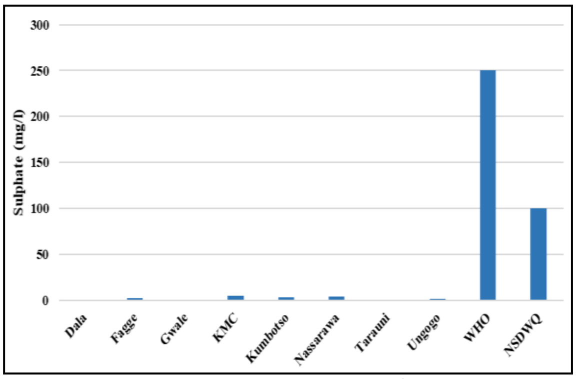

Figure 7: Mean Variation in Sulphate for Kano Metropolis

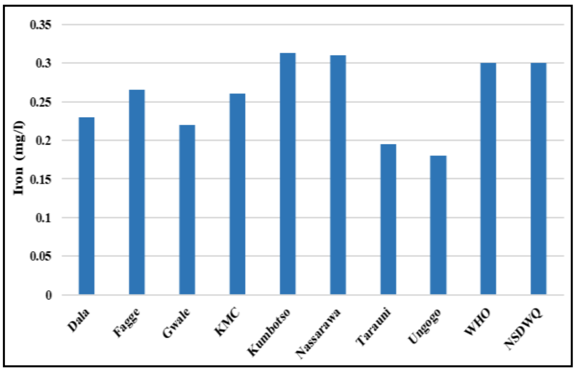

Figure 10: Mean Variation in Iron for Kano Metropolis

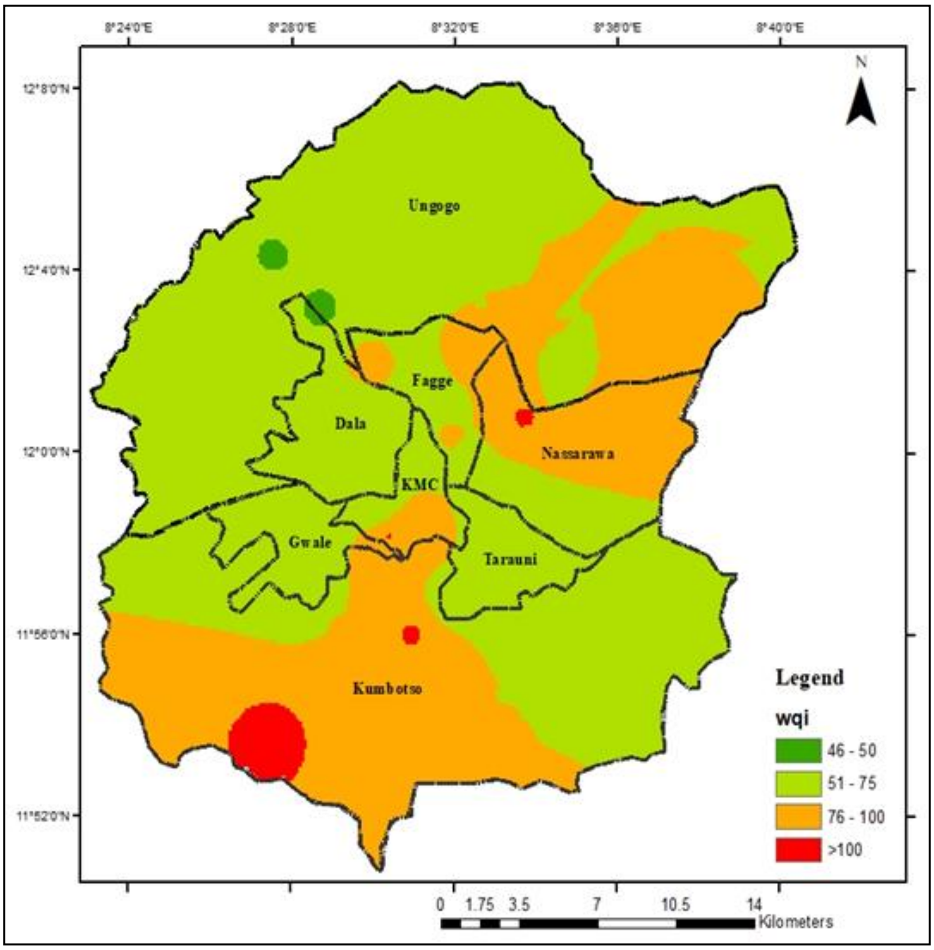

Figure 11: Spatial Distribution of Water Quality Index within Kano Metropolis

Table 5: Results of Water Quality Index Analysis

Sample Points	LGA	WQI	Water Quality Rating	Sample Points	LGA	WQI	Water Quality Rating
BWS1	KMC	101	Unsuitable for drinking	BWS17	Gwale	55	Poor water quality
BWS2	KMC	92	Very poor water quality	BWS18	Gwale	92	Very poor water quality
BWS3	KMC	53	Poor water quality	BWS19	Gwale	53	Poor water quality
BWS4	KMC	56	Poor water quality	BWS20	Gwale	55	Poor water quality
BWS5	Dala	73	Poor water quality	BWS21	Tarauni	64	Poor water quality
BWS6	Dala	61	Poor water quality	BWS22	Tarauni	53	Poor water quality
BWS7	Dala	70	Poor water quality	BWS23	Tarauni	50	Good water quality
BWS8	Dala	65	Poor water quality	BWS24	Tarauni	62	Poor water quality
BWS9	Fagge	83	Very poor water quality	BWS25	Kumbotso	112	Unsuitable for drinking
BWS10	Fagge	92	Very poor water quality	BWS26	Kumbotso	103	Unsuitable for drinking
BWS11	Fagge	52	Poor water quality	BWS27	Kumbotso	84	Very poor water quality
BWS12	Fagge	79	Very poor water quality	BWS28	Kumbotso	60	Poor water quality
BWS13	Nassarawa	76	Very poor water quality	BWS29	Ungogo	58	Poor water quality
BWS14	Nassarawa	104	Unsuitable for drinking	BWS30	Ungogo	54	Poor water quality
BWS15	Nassarawa	96	Very poor water quality	BWS31	Ungogo	46	Good water quality
BWS16	Nassarawa	85	Very poor water quality	BWS32	Ungogo	49	Good water quality

BWS: Borehole Water Sample

The pH of a solution generally indicates its acidity or alkalinity and typically doesn't have a direct impact on the consumers' health. The data from the study revealed that the pH value ranges from a minimum of 6.22 in BWS25 around Panshekara community market in kumbotso LGA to a maximum of 7.08 in BWS4 close to Kurmi market in Kano Municipal. Also, it shows that the pH values of all samples did not exceed the permissible limit (6.5-8.5) of WHO and NSDWQ. The pH values from the samples collected were slightly acidic in nature. The mean variation of pH is shown in (Figure 3).

The hardness of groundwater could be due to the occurrence of alkaline earth metals calcium carbonates and bicarbonates of magnesium, chlorides and sulphates of calcium and magnesium. The groundwater samples from the sampled locations range from a minimum of 20 mg/L in BWS3 around Kofar Gadokaya and BWS4 Close to Kurmi market to a maximum of 220.5 mg/L in BWS1 close to Annur Plaza. Result also revealed all sample points are within WHO permissible limits (500 mg/L). while BWS25 around Panshekara community market, BWS15 along Hassan Street, BWS16 around Hassan Ja'Afar Rd, BWS14 around Sule Gaya Rd and BWS1 close to Annur Plaza have their concentrations above the NSDWQ permissible limit (150 mg/L). The mean variation in values of Total Hardness is shown in (Figure 4).

The magnesium values range from a minimum of 8.4 mg/L in BWS11 around Kurna primary school in Fagge LGA to a maximum of 29 mg/L in BWS14 around Sule Gaya road in Nassarawa. Also, it shows that all samples did not exceed the permissible limit (150mg/L) of WHO. In contrast to NSDWQ, all samples are seen to exceed the maximum permissible limit of 0.2mg/L. The mean variation of Magnesium is shown in (Figure 5).

Chlorides are found in almost all natural waters. Water with a higher value has a salty taste, making it unfit for human consumption (Hassan et al., 2017). The result from the study revealed that chloride concentrations range from a minimum of 19mg/L in BWS4 close to Kurmi market in Kano Municipal to a maximum of 76mg/L in BWS16 around Hassan Ja'Afar road in Nassarawa LGA. Also, the levels of chlorides from all samples collected are within the WHO and NSDWQ permissible limit (250mg/L). The mean variation of Chlorides is shown in (Figure 6).

The source of sulphate in groundwater is majorly geological formations or anthropogenic activities. Sulphates exist in combination with magnesium or sodium in natural waters and varies in concentrations according to the nature of the terrain. It causes laxative effect when consumed in excess (Chindo et al., 2013). The result revealed that the concentration of sulphate within the study area ranges from a minimum of 0.02 mg/L in BWS5 around Junijimi road in Dala LGA to a maximum of 2.1mg/L in BWS1 close to Annur Plaza in Kano Municipal. Also, the concentrations of sulphate from all sample points are within the WHO and NSDWQ permissible limit (250mg/L and 100mg/L respectively). The mean variation of Sulphate is shown in (Figure 7).

The study result revealed the concentration of sodium which range from a minimum of 5.2mg/L in BWS3 around Kofar Gadokaya in Kano Municpal to a maximum of 29.1mg/L in BWS18 close to Hisbah HQ in Gwale LGA. Also, all samples have sodium concentrations within the WHO and NSDWQ permissible limit (200mg/L). The mean variation of Sodium is shown in (Figure 8).

Zinc occurs in small amounts in almost all igneous rocks within the crust and released into groundwater sources. There are also man-made releases of Zinc into the groundwater due to the anthropogenic activities of man within the environment. Zinc concentrations ranged from 0.1 mg/L in BWS4 near Kurmi market in Kano Municipal to 0.33 mg/L in BWS14 near Sule Gaya road in Nassarawa LGA. In addition, all samples have zinc concentrations that are less than 3 mg/L, which is within the WHO and NSDWQ permissible limit. The mean variation of Zinc is shown in (Figure 9).

Natural weathering of iron-bearing minerals and rocks is the most common source of iron in groundwater, but other sources include industrial effluent, sewage, and landfill leachates. Within the study area, iron concentrations ranged from 0.16 mg/L in BWS31 near Layin Daiba road in Ungogo LGA to 0.39 mg/L in BWS25 near Panshekara community market in Kumbotso LGA. Furthermore, the majority of the samples have iron concentrations below the 0.3 mg/L WHO and NSDWQ permissible limit. But BWS2 around UBA Sharada road, BWS1 close to Annur Plaza in Kano Municipal, BWS18 close to Hisbah HQ in Gwale LGA, BWS10 around Kofar Ruwa Lorry Park in Fagge LGA, BWS15 around Hassan Street, BWS14 around Sule Gaya road in Nassarawa LGA, and BWS26 around DanSaa Organic Fertilizer and BWS25 around Panshekara community market in Kumbotso LGA, all have concentrations slightly above the WHO and NSDWQ permissible limit 0.3mg/L. Iron must be removed to avoid rusting in distribution pipes and home plumbing systems. The mean variation of Iron is shown in (Figure 10).

Water Quality Index (WQI)

WQI measures the quality of water by deriving a single value that reflects the overall state of groundwater quality for human consumption. The result from Table 5 indicated that BWS31 and BWS32 in Ungogo, and BWS23 in Tarauni have good water quality index (WQI) rating, followed by BWS3 and BWS4 in Kano Municipal, BWS17, BWS19 and BWS20 in Gwale LGA, BWS29 and BWS30 in Ungogo LGA, BWS28 in Kumbotso LGA, BWS21 BWS22 and BWS24 in Tarauni LGA, BWS5 BWS6 BWS7 BWS8 in Dala LGA, and BWS11 in Fagge LGA all have poor water quality index (WQI) rating. Also, a very poor water quality index rating was found in BWS9 BWS10 and BWS12 in Fagge LGA, BWS13, BWS15 and BWS16 in Nassarawa LGA, BWS2 in Kano Municipal, BWS18 in Gwale LGA and BWS27 in Kumbotso LGA. While BWS25 and BWS26 in Kumbotso LGA, BWS1 in Kano Municipal, and BWS14 in Nassarawa LGA have water quality index (WQI) rating which indicates that the groundwater is Unsuitable for drinking.

The overall view of WQI of the present study area shows higher WQI values. The main reasons for this may be due to the presence of industrial activities, misused drainages, poorly sighted dumpsites and open dumping of solid wastes. The spatial distribution of WQI within Kano metropolis is shown in (Figure 11).

CONCLUSION

The goal of this study was to use a water quality index and geospatial techniques to assess groundwater

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quality in Kano. Water Quality Index (WQI), a simple way to understand overall water quality potability, was calculated after the levels of physicochemical parameters were determined. The Geographic Information System (GIS), which is an effective tool for spatial analysis and interpretation of groundwater quality, was used to map WQI for the entire Kano metropolis. The study's findings revealed that the majority of these physicochemical parameters in the metropolis' groundwater sources are within WHO and NSDWQ permissible limits, with the exception of pH and Iron, which have values outside the permissible limits in a few areas. The study also revealed majorly a poor to very poor WQI rating based on its spatial distribution within the metropolis. These areas are characterized by high population concentration and some few industrial sites generating wastes and cocktails of pollutants into the environment. The findings suggest that groundwater from the study area should be treated before utilization. Also, sustainable management practices should be developed to protect groundwater resources from environmental pollution within Kano metropolis by public enlightenment on the need to treat groundwater before consumption and carrying out regular monitoring of groundwater resources.

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