Modelling Groundwater Quality Potential in GIS Environment Within Bayero University Kano New Campus and Environs

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Abstract

This paper describes an important contribution towards understanding ground water quality using GIS application. One of the objectives of the study is to assess water quality status in Bayero University Kano and environs. Secondly, an attempt to determine the spatial distribution of ground water quality parameters which shows or identifies areas with the best quality drinking water within the study area. The method adopted combination of water quality index (WQI) and Geographical Information System (GIS) application to achieve the set objectives. Maps showing spatial distribution of water quality parameters such as SO_4, TDS, pH, Na, HCO_3, Ca, Mg, Fe, CO_3, NO_3 and Total hardness were analysed using a simple kriging method in ArcGIS 10.8.2 environment. Water quality assessment falls within “Good”, “Poor” and “Very Poor” quality for drinking categories. The results indicates that, there is a variation in terms of water quality for drinking using WHO and NESREA water quality standards in the areas sampled. This paper provides the fact that, WQI and GIS application provides a comprehensive result which shows areas with higher and lower drinking water quality. This approach will help decision makers plan a better approach in operation and maintenance of groundwater resources.

Keywords: *Simple kriging, parameters, GIS application, Water Quality Index*

INTRODUCTION

One of the basic human needs for survival on earth is water. Water is colourless, odourless compound used for drinking and other human needs such as cooking and washing. Water accessibility and availability optimally is very crucial in human life to avoid any future problems regarding its qualitative and quantitative availability. Nature blessed mankind with water from many sources such as Rain water harvesting, ground water resources and surface water from rivers lakes and Dams and it is vital for the sustenance and maintenance of life. Generally, water accessibility and management have more problem than availability and sustainability. Abdulhamid (2010) argued that available water resources is fundamental to human development, and monitoring its state of pollution is fundamental requirement for management in Northern Nigeria. The interpretation of remote sensing data in conjunction with conventional data and sufficient ground truth information makes it possible to identify and outline various ground features.

Groundwater contamination due to vigorous human activities has resulted to many problems in the last decade (Umar et al. 2019). The problems of Groundwater contamination are enormous in many regions, especially in arid and semi-arid areas. Groundwater quantity and quality depends on type of groundwater recharge through atmospheric precipitation, inland surface water, and on sub-surface geochemical processes. Water resources suffer from various forms of pollution. If water pollution continues to increase, it will lead to bioaccumulation and in turn affect human health if consumed untreated. There are 88 developing countries that cover 40% of the world's population. Water shortage is a serious hindrance to development due to its social and economic effects.

Increase of world population has contributed to increase in demand for fresh water for consumption and other human activities. Water pollution resulting from anthropogenic sources has adverse effects on humans. In some cases, the effects might not cause immediate damage to our health but can cause damage after a long-term exposure. Different forms of pollutants affect the health of humans in different ways. These include Heavy metals from sewage or from different industrial processes that can accumulate in groundwater or nearby lakes and rivers. These are toxic, they can slow development; result in birth defects and some are carcinogenic in nature.

The quality of groundwater has particularly received immense attention since water of high quality is required for domestic, Industrial, and Agricultural use. Until recently, groundwater assessment has been based on laboratory investigations, but the advent of satellite remote sensing and Geographic Information System (GIS) has made it very easy to integrate various databases. GIS is a powerful tool for developing solutions for water resources problems and management, assessing water quality, preventing flooding, determining water availability, understanding the natural environment and for managing water resources on a local or regional scale. In urban Kano, groundwater resources are not only the most important resources for drinking purposes, but they are also used extensively to satisfy agricultural, domestic, and industrial water demands. In addition, a decrease in drinking water quality has been reported in many cases followed by groundwater pollution.

Water Quality Index (WQI) using several water quality parameters provides a single number that expresses the overall water quality at a certain location and time. One of the objectives of WQI is to turn complex water quality data into information that is understandable and usable by the public. Several indices have been developed to summarize water quality data in an easily expressible and easily understood format. The WQI which was first developed by Horton in the early 1970s is basically a mathematical means of calculating a single value from multiple test results. The index result represents the level of water quality in each water body, such as underground, lake, river, or stream. After Horton, several workers all over the world developed WQI based on rating of different water quality parameters. Basically, a WQI attempts to provide a mechanism for presenting a cumulatively derived, numerical expression defining a certain level of water quality (Sadat-Noori, Ebrahimi, & Liaghat, 2013).

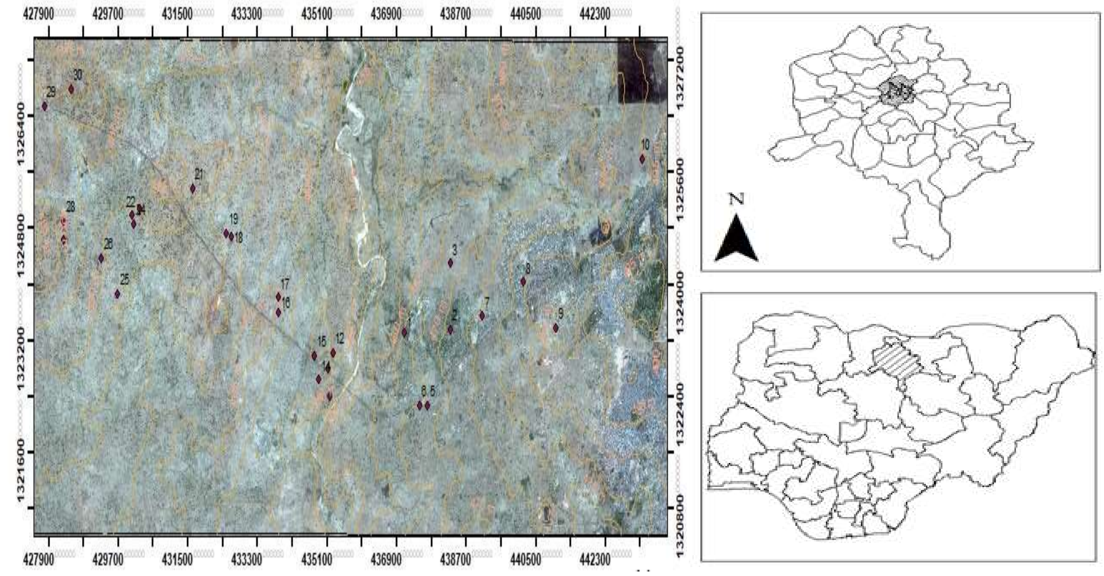

Figure 1: Map of the study area

Analysis using Water Quality Index (WQI) provides a comprehensive presentation of results of a study of water body where it summarizes the result by assigning one value or concept of a parameter analysed. Water quality status assessment can be defined as the evaluation of physical, chemical, and biological state of the water in relation with the natural state, anthropogenic effects, and future uses. The indices are very useful to transmit information concerning water quality to the authorities concerned as well as the public. WQI gives an idea of the evolutionary tendency of water quality over a period of time. A single WQI value makes information more easily and rapidly understood than a long list of numerical values for a large variety of parameters. The water quality can be assessed using physical, chemical, and biological parameters, the harmful limits of those for human health being established at international or national scale (WHO, NESREA). The most convenient way to express the quality of water resources for consumption is the Water Quality Index (WQI), using the water quality data being very useful for the modification of the policies. Water quality index reduces the number of parameters used in monitoring water quality to a simple expression to facilitate interpretation of the data, allowing public access to water quality data (Mădălina and Gabriela, 2009).

Additionally, WQI also facilitates comparison between different sampling sites and events. Inadequate management of water resources as directly or indirectly resulted in the degradation of hydrological environment. Therefore, a continuous periodical monitoring of water quality is necessary so that appropriate steps may be taken for water resource management practices. The present study is to serve as a baseline study since there is no literature regarding the water quality index in this region before now (Sadat-Noori, Ebrahimi, & Liaghat, 2013).

MATERIALS AND METHODS

Study area

The study area covers the entire Bayero University Kano (BUK) new campus in Ungogo Local GA; Langel, Janguza and Tudun Malumai wards in Tofa LGA located in the western part of Kano State, Northwestern Nigeria. It has an estimated land area of about 20 km² with an estimated population of about 100,000 (NPC, 2006). It lies between Latitude 11°57'26"N to 11°59'12"N and Longitude 8°23'26" E to 8°25'52"E. Figures 1 and 2. The climate of Kano is characterized by both annual and seasonal variabilities. Wet years and dry years may record between 850 and 750mm (Ibrahim, 2018). Temperatures are high throughout the year; the mean maximum temperature is 34ºC and the mean minimum temperature is 19ºC. The average rainfall is between 750mm to 850mm, and August is the wettest month of the year. The movement of the tropical maritime air masses from the Southwest to the North determines the weather of the area during the wet season. (Auwal and Kwaya 2022).

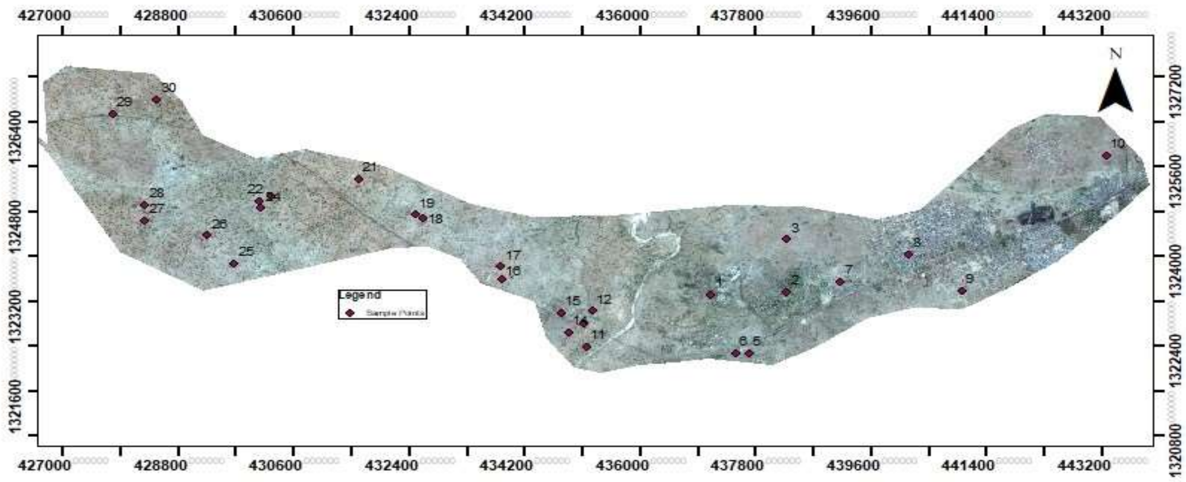

Figure 2: The location of the observation wells

Groundwater table elevation, depth, and flow

The study area falls within the crystalline Basement complex rock of Nigeria. The fractures in the rocks determine their hydrogeological properties and this depends on their texture and mineralogy. The type of aquifer in the study area is fractured basement. The weathered materials overlying the crystalline rocks and are largely covered by a thin layer of superficial material consisting mainly of gravels and silty materials. The fractures of the underlying rock in the study area are mainly due to jointing and shearing probably associated with the Pan African orogeny. The granitic basement aquifer with deeply weathered rocks beneath and fractured rocks with hydraulic conductivity yielded appreciable amount of water in the study area. The depth to water table of hand-dug wells in the study area ranges from 4.1m to 7.2m with an average of 5.1m, while the average depth of the wells is 8.8m. The depth to water table of boreholes ranges from 25.1m to 28.2m with an average of 27.0m, while the average depth of the boreholes is 30.8m (Auwal and Kwaya 2022).

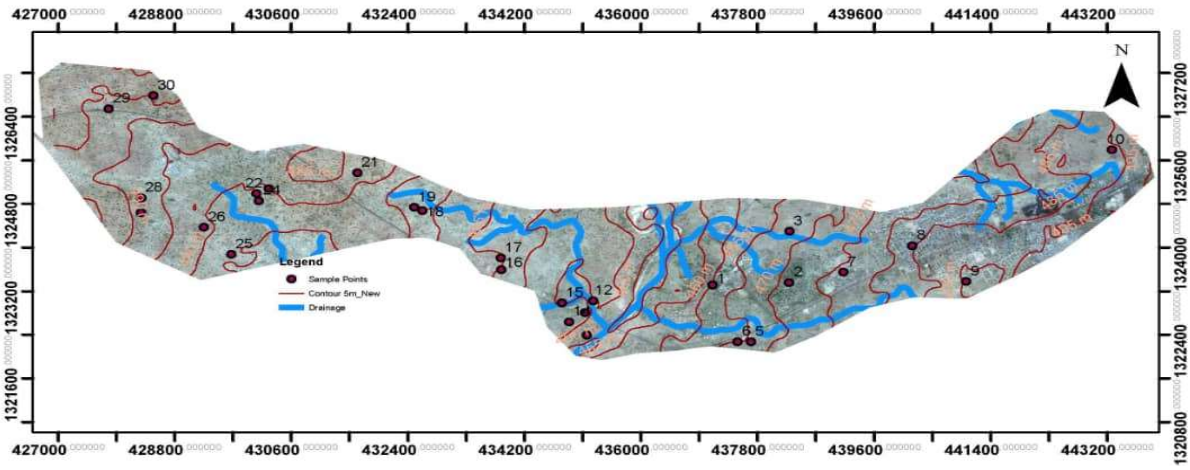

Figure 3: Sample points, elevation, and drainage flow

Water Quality Index method

In this method, the weightage for various water quality parameters is assumed to be inversely proportional to the recommended standards for the corresponding parameters.

The calculation procedure is at three (3) stages. The first stage involves assigning each of the nine water quality parameters (pH, TDS, SO4, HCO3, Ca, Mg, Na, and K) a weight (wi) using both WHO and NESREA standards. Each weight is scaled based on their perceived effects on human health (Table 2). The maximum weight of 5 has been assigned to parameters such as total dissolved solids, and sulphate due to their major importance in water quality assessment (Srinivasamoorthy et al. 2008). Other parameters such as calcium, magnesium, sodium, and potassium were assigned a weight between 1 and 5 depending on their importance in the overall quality of water for drinking purposes (Ketata-Rokbani et al. 2011).

The second stage is to calculate relative weight (**Wi**) of each parameter using Eq. (1):

$$W_i = \frac{w_i}{\sum_{i=1}^{n} w_i} \tag{1}$$

Where **wi** is the weight of each parameter using national and international standards, **n** is the number of parameters and **Wi** is the relative weight. The weight (**wi**), the calculated relative weight (**Wi**) values, and the WHO and NESREA standards for each parameter are given in Table 1. In the third stage, a quality rating scale (**qi**) is calculated for each parameter using Eq. (2):

$$q_i = \frac{C_i}{S_i} \times 100 \tag{2}$$

Where **qi** is the water quality ranking, **Ci** is the concentration of each chemical parameter in each water sample in milligrams per litre and **Si** is the WHO and NESREA standard for each chemical parameter in milligrams per litre (Table 2). For computing the **WQI**, the **Si** is first determined for each chemical parameter using Eq. (3), which is then used to determine the **WQI** according to Eq. (4):

$$\mathrm{SI}_i = W_i \times q_i \tag{3}$$

$$\mathrm{WQI} = \sum \mathrm{SI}_i \tag{4}$$

Where **Si** is the sub-index of ith parameter, qi is the rating based on concentration of ith parameter and n is the number of parameters. Computed **WQI** values are usually classified into five categories (Table 3): excellent, good, poor, very poor, and unsuitable for human consumption (Sahu and Sikdar 2008). The calculation procedure of **WQI** is described in detail by many authors (Pradhan et al. 2001; Dwivedi and Patha 2007; Asadi et al. 2007; Saeedi et al. 2010; Yidana and Yidana 2010).

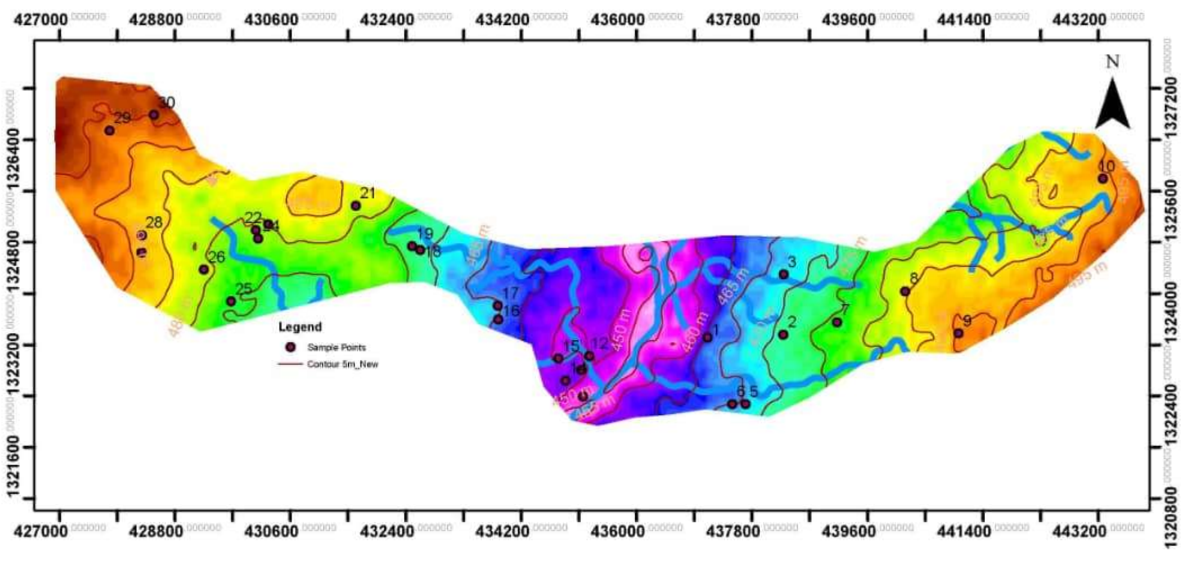

Figure 4: Digital elevation model (DEM) of the study area

Table 1: Site sampled Profile.

Profile number	2	7	8	11	13	14	19	22	26	28	30
Depth											
8	47	140	34	56	62	265	114	62	448	231	63
10	42	111	49	41	75	147	89	52	260	55	96
15	28	59	47	46	63	187	79	51	248	49	91
20	48	33	39	49	54	72	70	59	130	47	92
25	38	30	36	58	58	63	60	67	123	48	98
32	24	42	27	57	59	58	64	74	166	49	93
40	25	59	31	69	63	57	67	91	145	45	113
60	40	48	41	74	72	57	75	92	175	43	128
80	39	54	52	79	74	60	79	122	178	62	124
100	43	67	58	83	76	83	88	151	180	67	131

GIS application

A Geographical Information System (GIS) is a system for capturing, storing, analysing, and managing spatially referenced data and associated attributes. GIS is an efficient tool to capture, store, manipulate, manage, and analyses various types of geographical data and represent graphical view for easy understanding. ArcGIS software has several inbuilt tools which include many operations such as interpolation techniques, network analysis and spatial analysis. GIS software's are widely used for modeling and simulation using data processing and various mathematical functions. In a more generic sense, GIS is a software tool that allows users to create interactive map queries, analyse the spatial information, edit data, produce maps, and present the results of all these operations. GIS technology is becoming essential tool to combine various maps and remote sensing information to generate various models, which are used in real time GIS environment. The study is carried out with the help of high-resolution satellite imagery, ArcGIS 10.8.1 and Global mapper 23. The coordinates of each sample point were captured using a handheld GPS and digital elevation model (DEM), Fig 4 was downloaded using Global mapper Pro. Map of BUK and environs was digitized from a satellite imagery which served as a base Map using UTM coordinate system and entered in GIS environment. Fig 3 and 4, Spatial Analyst, in Arc catalogue in ArcGIS 10.8.1, was used to analyse spatio-temporal behaviour of the groundwater quality parameters. The various thematic layers on water quality parameters were prepared using a spatial interpolation technique through kriging. This contouring method has been used in the present study to delineate the locational distribution of water pollutants or constituents. Kriging technique is an exact interpolation estimator used to find the best linear unbiased estimate. The best linear unbiased estimator must have minimum variance of estimation error.

Table 2: Water Quality weight

Water Parameter	WHO/NESREA standard	Weight (wi)	Relative weight (Wi)
SO	250	5	0.179
Na	200	4	0.143
HCO	120	1	0.036
Ca	75	3	0.107
pH	8.5	3	0.103
TDS	500	5	0.179
Mg	50	3	0.107
Fe	0.3	2	0.033
CO3	100	2	0.033
NO3	45	5	0.267
Hardness	200-600	1	0.067
		39	1.433

Adopted from WHO and NESREA

Table 3: Water Quality index range

WQI range	Type of water
<50	Excellent water
50–100.1	Good water
100–200.1	Poor water
200–300.1	Very poor water
>300	Water unsuitable for drinking purpose

Adopted from (Sadat-Noori, Ebrahimi, & Liaghat, 2013)

RESULTS AND DISCUSSION

In this paper, eleven (11) groundwater quality parameters, pH, TDS, SO_4, Na, HCO_3, Ca, Mg, Fe, CO_3, NO_3, and Hardness were analysed based on their statistical measures such as minimum, maximum, mean, and standard deviation. Findings are presented in Table 4 and the created spatial distribution of their quality maps also presented. TDS are compounds of inorganic salts (principally calcium, magnesium, potassium, sodium, bicarbonates, and sulphates), and of small amounts of organic matter that are dissolved in water. Concentrations of TDS in water vary considerably in different geological regions owing to differences in the solubility of minerals (WHO 2004).

Total dissolved solid (TDS) in the study area varies between 64.25 and 1667.81 milligrams per litre with an average of 1,092.23 mg/l (Table 4). The permissible limit suggested by WHO and NESREA for TDS is 500 mg/l, therefore, both desirable, permissible, and not permissible regions are seen in the study area (Fig. 14). However, the distribution of TDS is uneven, the concentration of TDS in the east and center is higher than that in other parts and the concentration of TDS gradually decreases from east to west.

Water hardness is primarily caused by the presence of cations such as calcium and magnesium; and of anions such as carbonate, bicarbonate, chloride, and sulphate (Ravikumar et al. 2010). According to the grading standards of Total Hardness (TH) as well as calcium carbonate ($CaCO_3$) can cause groundwater to be classified divided into soft water (TH\150 mg/l), moderately hard water (150\TH\300 mg/l), hard water (300\TH\ 450 mg/l), extremely hard water (TH 450 mg/l). In the study area, TH varies between 518.4 and 755.2 mg/l (Table 5). Near 75 % of the sample locations are placed in the hard water classification, which shows the deteriorating groundwater quality conditions for drinking propose and this is due to large human activities. The TH shows a similar characteristic to TDS (Fig. 11). The lowest concentration of sodium (193.37 mg/l) was observed in sample area located close to the agricultural area i.e., at the western part of the study area. While high concentration was found within the high-density residential areas i.e., eastern part of the study area and this may be due to contamination from a septic system, sewage and runoff that can leach and enter the groundwater. The pH Value is one of the most important operational water qualities. The acidity and alkalinity of groundwater are described by the pH of groundwater and, pH mostly controls the quantity and chemical structure of several organic and inorganic matters dissolved in groundwater. This parameter varies between 8.32 and 8.62 with a mean of 8.49 (Table 4).

According to the distribution map (Fig. 13), Electrical Conductivity of water is a direct function of its total dissolved salts. Hence it is an index to represent the total concentration of soluble salts in water. In the study area, the electrical conductivity of the groundwater samples varied between 46.75-2463.23 and the mean of 861.05µS/cm.
The taste threshold concentration of sodium in water depends on the associated anion and the temperature of the solution. At room temperature (26ºC to 28ºC), the average taste threshold for sodium is about 200 mg/l. High sodium values are observed in the eastern parts of the study area, (Fig. 7). The sodium values range from 35.85 to 193.37 mg/l with mean of 98.58 mg/l (Table 5). The desirable limits fall within the threshold for the calcium ion is in the range of 100–300 mg/l, depending on the associated anion, and the taste threshold for magnesium is probably lower than that for calcium (WHO 2004). The maximum calcium and magnesium concentrations are 96.19 and 22.57 mg/l, respectively. Figures 5 and 6 illustrate the spatial distribution of calcium and magnesium concentrations, respectively. As is seen in Fig. 14, most of the samples show a calcium amount that is within permissible limit with a few belonging to non permissible limit. The high total concentrations of Ca and Mg are important factors, which increase the hardness of waters.

Table 4: Physical Water Quality

Parameter	Unit	Maximum	Minimum	Mean	Standard Deviation
Temperature	^0C	28.91	26.71	27.7	0.52
Electrical Conductivity	Us/cm	2463.23	46.75	861.05	618.49
Turbidity	NTU	19.69	4.31	7.44	1.4
pH	mg/l	8.62	8.32	8.49	6.08
Total Dissolved Solid	mg/l	1667.81	646.25	1092.23	237.38

Table 5: Chemical Water Quality

Parameter	Unit	Maximum	Minimum	Mean	Standard Deviation
Total Hardness	mg/l	755.2	518.4	657.6	56.02
CO32	mg/l	719.29	14.22	241.12	203.5
HCO3	mg/l	727.35	239.62	394.94	51.36
NO3	mg/l	91.62	37.09	55.24	15.19
Na	mg/l	193.37	35.85	98.58	47.27
Mg	mg/l	22.57	7.91	16.17	2.96
Ca	mg/l	96.19	16.14	55.97	20.35
Fe	mg/l	1.67	1.13	1.46	0.12

In addition, in presenting the analyses of groundwater quality parameters of BUK and environs, correlations between various parameters were calculated which are presented in Table 66.Based on these correlations, almost all constituents are positively related to one another. EC parameter has high correlation with sodium (Na) and Ca in the cation and anion, respectively. In addition, similar results for TDS are observed. It also showed that pH has high correlation with calcium (Ca). SAR parameter also has a high correlation with sodium (Na) in cations, but in the anions highest correlation amount is seen for SO_4. It is noticed that the highest correlation is among TDS and Na, Ca, and Mg. This demonstrates that these four constituents are the main contributors to TDS amount in the aquifer and they indicate the majority of salts in the groundwater. High correlation between Na, and Mg also demonstrates this fact.

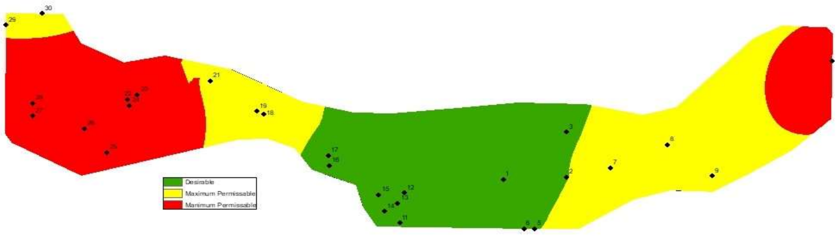

Figure 5: Spatial distribution of water Ca (mg/l)

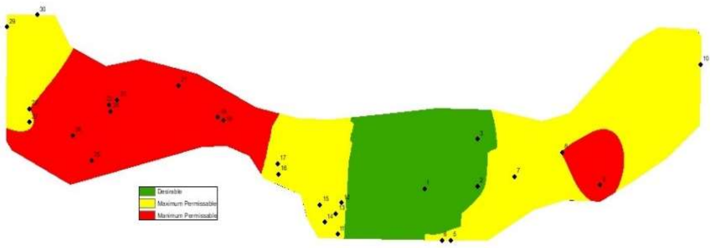

Figure 6: Spatial distribution of water Mg (mg/l)

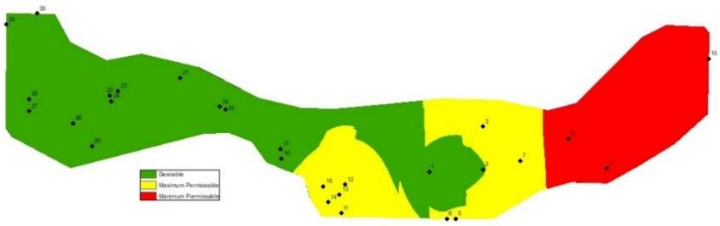

Figure 7: Spatial distribution of Water Na (mg/l)

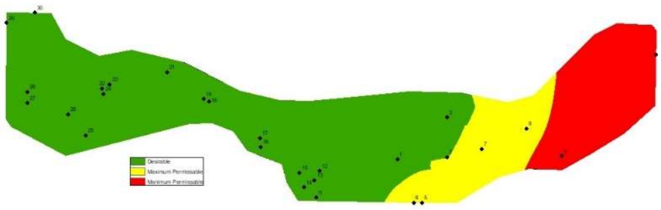

Figure 8: Spatial distribution of water NO3 (mg/l)

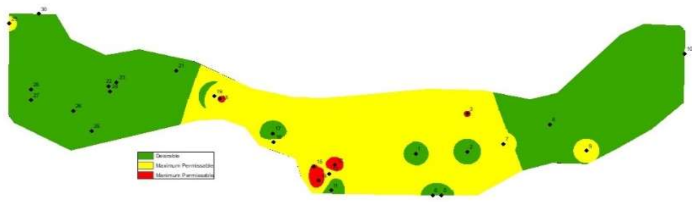

Figure 9: Spatial distribution of water HCO3 (mg/l)

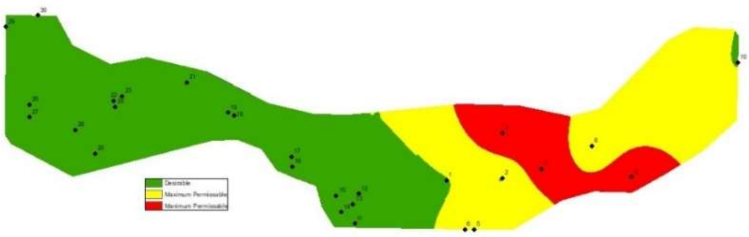

Figure 10: Spatial distribution of water CO3- (mg/l)

Figure 11: Spatial distribution of water Total Hardness (mg/l)

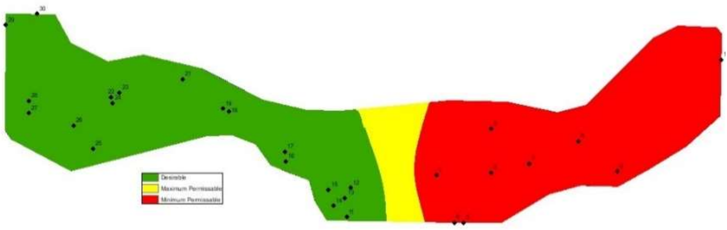

Figure 12: Spatial distribution of water SO4- (mg/l)

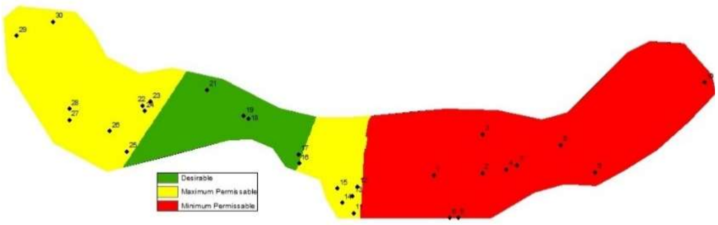

Figure 13: Spatial distribution of water pH

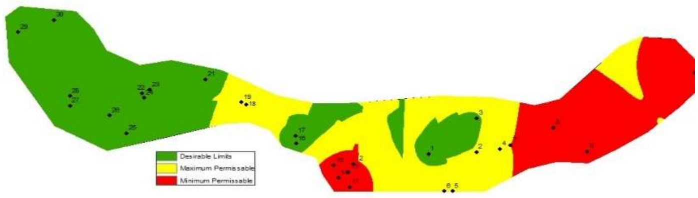

Figure 14: Spatial distribution of water TDS (PPM)

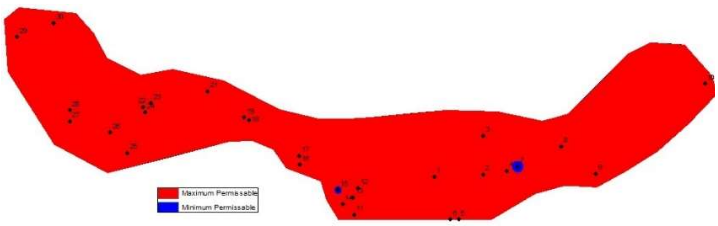

Figure 15: Spatial distribution of water Turbidity (NTU)

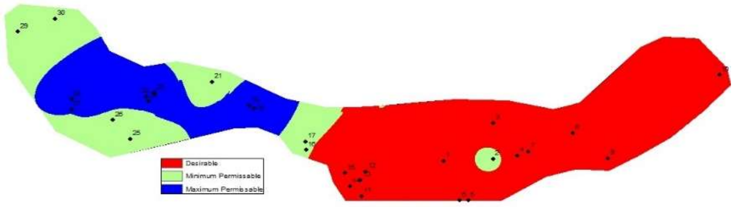

Figure 16: Spatial distribution of water Electrical Conductivity (µS)

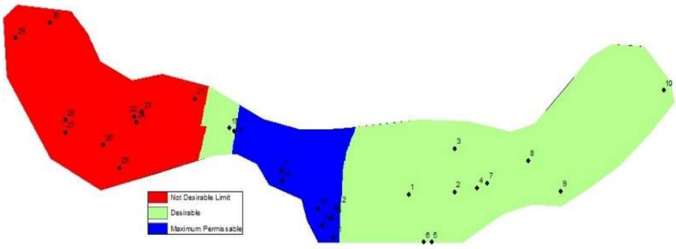

Figure 17: Spatial distribution of water Temperature (^{O}C)

Table 6: Correlation matrix between groundwater Chemical parameters of BUK and Environs

	Fe	*Ca*	*Mg*	*Na*	*NO3*	*HCO3*	*CO32*	*T Hardness*	*SO4*
Fe	1								
Ca	0.28	1							
Mg	0.01	0.67	1						
Na	0.02	0.26	0.57	1					
NO3	-0.04	0.36	0.35	0.34	1				
HCO3	-0.14	0.08	0.24	0.54	-0.17	1			
CO3	0.27	0.07	-0.03	0.29	0.48	0.04	1		
T. Hardness	0.09	0.80	0.87	0.51	0.35	0.37	0.10	1	
SO4	0.35	0.05	0.03	0.28	0.46	-0.15	0.87	0.08	1

Table 7: Correlation matrix between groundwater Physical parameters of BUK and Environs

	PH	*TDS (PPM)*	*Turbidity (NTU)*	*Conductivity (µS)*	*Temperature (^{O}C)*
pH	1				
TDS(PPM)	-0.53	1			
Turbidity (NTU)	-0.10	0.22	1		
Conductivity(µs)	-0.16	0.00	-0.17	1	
Temperature (^{O}C)	-0.41	0.31	0.14	-0.12	1

Table 8: Groundwater classification based on WQI.

S/No	Location	X	Y	WQI	Classification
BUK1	Boys hostel	11.97003	8.42233	102.76	Poor water
BUK2	BUK staff quarters mosque	11.97050	8.43319	206.48	Very poor water
BUK3	Geology dept	11.97900	8.43319	110.02	Poor water
BUK4	BUK staff quarters	11.96475	9.41714	97.26	Good water
BUK5	Dan bare	11.96067	8.42778	142.95	Poor water
BUK6	Hawan dawaki	11.96067	8.42592	96.32	Good water
BUK7	Rimin gata	11.97222	8.44086	215.54	Very poor water
BUK8	Rijiya zaki	11.97664	8.45064	269.60	Very poor water
BUK9	Dorayi babba	11.97072	8.45831	223.31	Very poor water
BUK10	Tudun yola	11.99261	8.47889	201.14	Very poor water
BUK11	Langyal hayingada	11.96169	8.40456	200.76	Very poor water
BUK12	Langyal kazitu	11.96742	8.40539	222.06	Very poor water
BUK13	Langyal baki filing station	11.96542	8.40422	210.90	Very poor water
BUK14	Janguza tudun malamai	11.96392	8.40197	184.63	Poor water
BUK15	Kasuwa janguza	11.96703	8.40094	176.92	Poor water
BUK16	Tashar kadiri 1	11.97253	8.39239	92.95	Good water
BUK17	Tashar kadiri 2	11.97450	8.39228	84.46	Good water
BUK18	Kwanar muhuwa 1	11.98233	8.38114	178.42	Poor water
BUK19	Kwanar muhuwa 2	11.98286	8.37997	126.84	Poor water
BUK20	Kwanar mahuwa 3	12.14731	8.38144	103.45	Poor water
BUK21	Jamaar zailani	11.98858	8.37189	170.68	Poor water
BUK22	Lambu kahutara 1	11.98508	8.35758	198.95	Poor water
BUK23	Lambu kahutara 2	11.98592	8.35933	147.95	Poor water
BUK24	Lambu kahutara 3	11.98392	8.35794	93.23	Good water
BUK25	Sabon garin unguwar rimi 1	11.97500	8.35406	154.74	Poor water
BUK26	Sabon garin Unguwar Rimi 2	11.97950	8.35019	114.26	Poor water
BUK27	Unguwar rimi 1	11.98189	8.34125	112.50	Poor water
BUK28	Unguwar rimi 2	11.98433	8.34125	112.70	Poor water
BUK29	Dan suduu nguwar dawa	11.99911	8.33661	95.13	Good water
BUK30	Lambu	12.00133	8.34294	99.64	Good water

Water Quality Index map

Water quality index is calculated to determine the suitability of any source of water for drinking purpose. Water quality index calculated values for each sample are shown in Table 8. According to the results in Table 8, only WQI values for 15 samples are placed in ‘‘Very good and good water’ ’classification and the rest of the locations fall below the range of being good water. This means that near 50 % of the samples are not in good conditions and are unsuitable for drinking purposes. Figure 18 illustrates the spatial distribution WQI map. The WQI map indicates that the safest zone is in the western part of the study area, where nearly all WQI values of the samples are in excellent class for drinking consume.

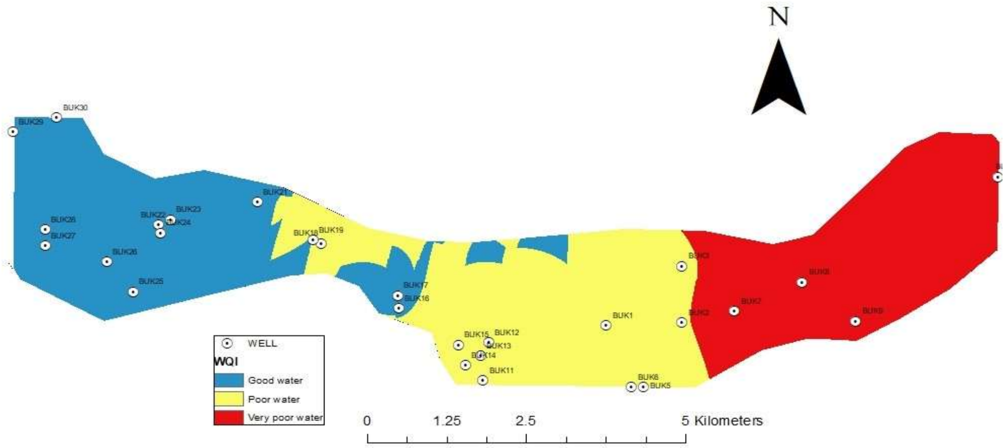

Figure 18: Water quality index map

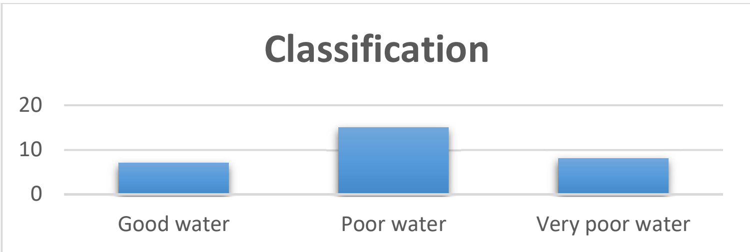

Figure 19: Classification of Water quality index

Correlation of water table depth and land use with water quality

An assessment was carried out to find out the existing correlation among water quality, water table depth and Land use. It can be concluded that as the groundwater level increases, water quality will have better conditions. Moreover, Shallow water tables pose a greater chance for the contaminant to reach the groundwater as opposed to deep water tables. To investigate the correlation of groundwater depth with water quality more accurately, chloride concentration of four wells with different groundwater depths (shallow, medium, deep, and very deep) were analysed.

Table 9: Correlation of Groundwater quality parameters

Physicochemical parameters	B coefficient	Standard error	Standardized beta	Rank	Þ value
PH	1.2118	0.0000	0.0073	XI	0.001*
TDS(PPM)	0.0358	0.0000	0.5325	I	0.001*
Turbidity (NTU)	0.0000	0.0000	0.0000	XII	0.000**
Conductivity(µS)	0.0000	0.0000	0.0000	XII	0.000**
Temperature (^{O}C)	0.0000	0.0000	0.0000	XII	0.000**
Fe (mg/l)	11.0000	0.0000	0.0964	VII	0.001*
Ca (mg/l)	0.1427	0.0000	0.1449	IV	0.001*
Mg (mg/l)	0.2140	0.0000	0.0592	IX	0.001*
Na (mg/l)	0.0715	0.0000	0.0972	VI	0.001*
NO_3-(mg/l)	0.5933	0.0000	0.2485	III	0.001*
HCO_3-(mg/l)	0.0217	0.0000	0.0685	VIII	0.001*
CO_3- (mg/l)	0.0330	0.0000	0.1257	V	0.001*
T. Hardness (mg/l)	0.0335	0.0000	0.2664	II	0.001*
SO_4- (mg/l)	0.0716	0.0000	0.0272	X	0.001*

* Highly significant ** Insignificant

Statistical analysis

Statistical analysis was carried using SPSS 25 software to determine the parameters contributing to the water quality indices. Multiple regression analysis using standardization of the coefficient was done to find out which of the independent variables (quality parameters) had a greater effect on the dependent variable (Water Quality Index). B coefficient shows the coefficient in the model to predict the water quality. Standard Error demonstrates the standard error of beta coefficient, which is the standardized beta weight of each independent variable. The focus is on this, because the aim here is to evaluate the influence of predictors on water quality rather than to predict the water quality. The multiple regression analysis results are presented in Table 9. It can be noticed that all parameters are statistically significant (0.001) in contribution to the water quality index. However, Calcium and Magnesium had the most influence due to having the highest standardized beta-coefficient. The ranking based on the standardized beta-coefficient is demonstrated in Table 9. It can be mentioned that Total Dissolved Solids and total hardness are very important indicators in determining groundwater quality. Therefore, preparing accurate, detailed, and representative data about these parameters can surely improve the outcome of the model. Moreover, these three methods (WQI, Spatial interpolation and statistical analysis) can be applied to save time, money and energy in regular checkups and have acceptable results.

CONCLUSION

In this study, an attempt has been made to investigate groundwater quality status by the combined use of the Water Quality Index, statistical analysis and GIS applied on a set of firsthand information. GIS had a major role in the process and is considered an effective tool. With the use of GIS software various maps showing spatial distribution of various water quality parameters were prepared and analysed. Spatial distribution maps were used to confine the locational distribution of water pollutants and assisted in indicating groundwater contamination control and remedial measures in a comprehensive way. The WQI spatial distribution map clearly shows best sites for drinking water in the area. Water quality indices are used to provide valuable tools for decision makers to be able to understand the status of the water quality in a water source and to have the opportunity to make adequate decisions for better use in future.

Monitoring pollution patterns and its trends with respect to urbanization is an important task for achieving sustainable management of groundwater. An integrated GIS study proves to be an essential tool to evaluate and quantify the impacts of land use on groundwater quality. This research and its results have shown the potentials of combining the use of GIS and WQI in providing a valuable tool for managers to monitor and assess groundwater quality. This can be used to make necessary decisions in aquifer management for groundwater use. Moreover, a set of new groundwater data were presented. The overall results show that groundwater quality suitable for drinking purposes decreases from west to east of the study area. It is recommended that future studies should focus on chlorinated solvents, PCBs, perchlorate, pesticides, and heavy metals and investigate other common contaminants. Finally, it is suggested a comprehensive sewerage system for safe disposal of wastes should be developed to safeguard groundwater quality in the study area.

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