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ANALYSIS OF THE IMPACT OF ANTHROPOGENIC ACTIVITIES ON GROUNDWATER QUALITY IN GREATER JOS URBAN AREA, PLATEAU STATE, NIGERIA

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ABSTRACT

The Greater Jos Urban Area has witnessed increase in human activities coupled with the shallow aquifers of a well mineralized geology. These have created a vulnerability situation that is deteriorating the quality of groundwater in Jos urban area. This groundwater quality is not envisaged along with the pace of rapid urban development and groundwater quality governance is either weak or not existing in the metropolis. The aim of this study is to examine the human influence and factors responsible for the variation of groundwater quality. This was carried out to develop ways of ensuring the sustainability of groundwater quality in the area.106 well water levels were measured to determine human influence and 72 samples tested for various parameters including pH, total dissolved solids (TDS), K, HCO_3, Fe, Na, Ca, Mg, Cl, NO_3, SO_4, Cd, Pb, F, feacal coliforms and hardness following the United States Environmental Protection Agency (USEPA) standard procedures. The findings of the study indicated that Nitrates, feacal coliform, lead and cadmium had high values around the city center of Bukuru and Jos in the study area of the metropolis exceeding the SON (2015) standard for drinking water at certain points within the area. The factor analysis results indicated that the geology is controlling the quality of the groundwater and that human activities measured closely after the geology in ratio of one (1) part to four (4) respectively. The implication of this is that human activities chiefly due to poor sanitation, lack of development planning with cognizance to groundwater resources and weak groundwater quality governance were influencing the quality of the groundwater in the area. The study concluded that a framework for the Greater Jos Urban area to address urban groundwater quality governance should be developed along with proper land use planning to curb this menace. This would conceptualize how development can be planned alongside with the groundwater quality in the metropolis to achieve the sustainable management of groundwater resources in the study area.

Keywords: Anthropogenic Activities, Ground water, Jos Urban Area, Lead, Nitrates, Water Quality,

INTRODUCTION

Groundwater quality is influenced by the natural environment (geological formation) and anthropogenic activities, such as, changes in land use, urbanization, intensive irrigated agriculture, mining activities or disposal of untreated sewage in river, lack of rational management. (Beka, 2019; Devic, Djordjevic and Sakan, 2014; Mohamed and Elmahdy, 2015; Khatri and Tyagi, 2015). These two groups of generalized impacts are spatial in nature. The rock types and human activities all occur in space with varying impact on groundwater quality. Spatial patterns or variations in the quality characteristics of these groundwater resources would begin to emanate as groundwater comes under these influences owing purely from the spatial spread of these impacts. The pattern of the impacts would then need to be studied in terms of their attributes or the processes underlying these patterns, then described to understand, expressed, and exploited in the order or structure inherent in these geographically distributed phenomena (Haining, 2003; Buyong, 2007; Wolf and Murray, 2017).

A good insight into spatial patterns like these allows for understanding of how these geographic phenomena distribute and how they can be compared with others. The ability to describe spatial processes enables the determination of the underlying environmental or cultural factors that are changing the patterns. Once the changes are not desirable, ways to correct the problems could be determined (Lee and Wong, 2001). This puts a heavy premium on the need to understand environmental problems that are spatial in nature and have public health concerns, such as the one posited here; specifically, the deterioration of groundwater quality in scenarios that is local and spatial. The anthropogenic and natural influences do not act alone as they have a formidable ally helping to strew these potential pollutants far and near. The water itself under gravity would flow from a higher gradient to a lower one, transporting these substances from both point and diffuse sources is essentially what is known as groundwater flow (Stuurman and Griffioen, 2003).

Increasing urbanization and rapid urban population growth as well as an attendant growth in human activities are changing the landscape of the Greater Jos urban area Metropolis putting a high demand for land and water to cater for the economic and social needs of the teeming population of this city. The ineffectiveness of the Municipal water supply has encouraged development of groundwater as a freshwater resource. In addition, the increase in human activities like residential settlements, agricultural and commercial, transportation and industrial activities plus the shallow aquifers of a well-mineralized geology in the study area has created a vulnerability situation that is deteriorating the quality of groundwater. This is exacerbated by the fact that groundwater quality is not planned along with this pace of rapid urban development and groundwater quality governance is either weak or not existing in the metropolis (Wapwera, Mallo and Jiriko, 2015). Most scholars concerned with water quality issues in the area have mostly dwelt on specific water bodies, areas and surface water resources associated with particular areas like (Vivan, Aliand Adamu, 2014; Jiya and Musa, 2012; Garba et al 2019) only studied Lamingo dam. Population explosion over time within Jos metropolis has led to serious human activities and the spike in generation of different types and volume of wastes that end up in the aquifers thereby polluting the entire system (Ali, 2018). This study therefore, seeks to establish the effects of human activities on the ground water resources of the entire area.

MATERIALS AND METHODS

Study Area

The study area is the Greater Jos metropolis, the capital of the State. It is bounded by the latitudes N 9º 45′and N 10º 00′and longitudes E 8º 55′and E 9º 00′ (figures 1). The study area covers: (a) Jos North and Jos

South Local Government Areas and (b) Parts of Jos East, Bassa, Riyom and BarkinLadi Local Government Areas (Figure 1). The total area covers approximately 1,362 square kilometres, made up of scattered inselbergs, settlements, numerous streams and burrow pits or mining ponds that are interspersed by expansive relatively flat and undulating land (Fola Consult, 2009). This area is largely covered by the topographical sheet Naraguta NE 168. It is bounded by Bauchi plains to the North, Barkin-ladi (Jos South) in the south, Bassa Local Government in the west and Jos East Local Government.

Geology of the Study Area

The rocks in the study area are largely made up (3) group of rocks namely (i). Precambrian rocks >500MA, crystalline basement rocks, migmatites, gneisses, older granites which are the intrusive older granites of Pan –African Orogeny Ring Complexes in the Younger Granite. This complex underlies about half of the entire State and in some places has been intruded by Precambrian to the late Paleozoic Pan-African granite (Older Granite), diorite, charnockite. (ii). The Jurassic age (Younger Granites, 140-190MA) which are Intrusive into these Basement Complex rocks are the Jurassic and orogenic alkali Younger Granites. (iii). The Tertiary and Quaternary rocks which are mostly basalts (Opara, 2015) (figure 2). In association with the Younger Granites are volcanic rocks such as basalts and rhyolites that overlie or cross-cut this formation of the Basement rocks. These volcanic rocks are believed to have been formed during the early Cenozoic (Tertiary) “Older Basalts” and Quaternary “Newer Basalts” (Macleod and Berridge, 1971). The sequence of magmatic activity for this complex can be divided into three (3) namely, the central granite cycle, early granite cycle and the volcanic cycle (Obaje, 2009).

The geology of the Greater Jos metropolis is essentially a hard rock terrain being underlain by Basement Complex rocks compose of granitic and migmatitic gneisses and granites. The older and younger granites are poor aquifers, therefore, the overburden, which is mostly a thin layer of lateritic material and other weathered materials from these rocks are where the groundwater potential lies. These rocks are heavily mineralized and could influence water quality especially minerals like fluorite a common mineral found in the Jos granite, fluorite is an abundant accessory and shows the same tendency to associate with the large biotite flakes. Columbite, Zircon, monazite and ilmenite are the remaining accessories. The N’gell granite, which is one of the younger granite rocks has been known to be a major source of the alluvial deposit of tin and columbite (Obaje, 2009; Adelana, 2008).

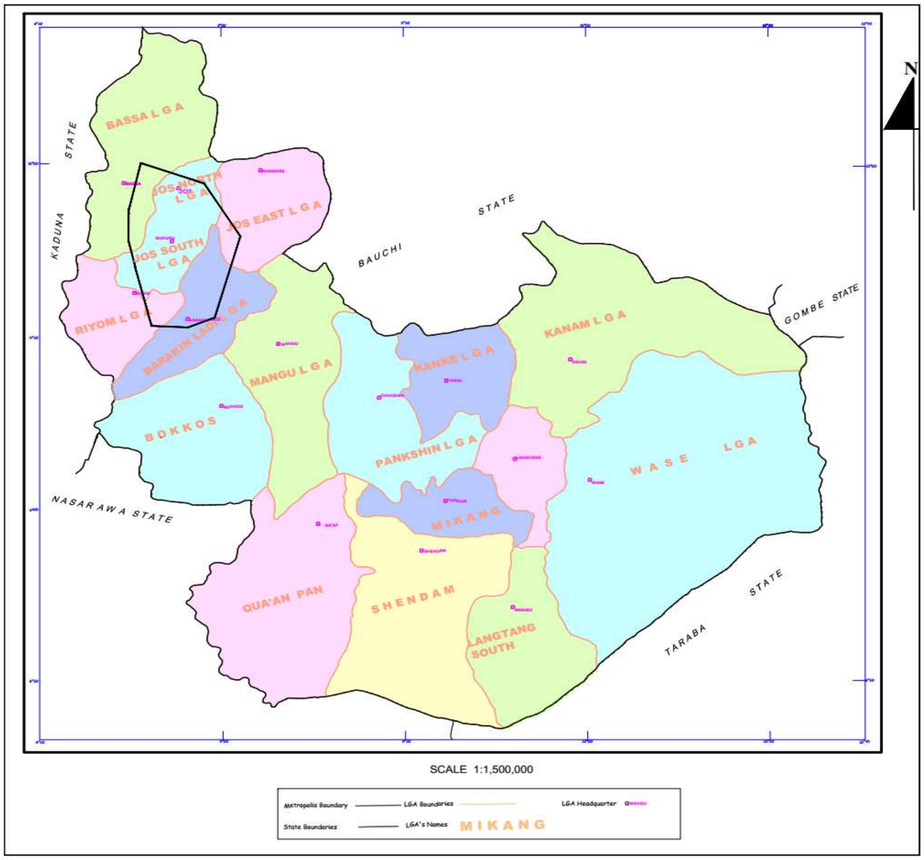

Figure 1: Plateau State showing the Greater Jos Urban Area Metropolis
Source: GIS Unit, Department of Geography and Planning, University of Jos, 2019. Drainage Pattern

The study area has generally a radial pattern of drainage but major river systems have mainly the dendritic pattern. The Jos Plateau is copiously drained by streams which are largely head-waters and tributaries of larger river systems (Bingel, 1978; Eziashi, 1995; Ndace and Danladi, 2012). Some of these river systems include the Wase, Shemankar, Dep-Ankwe, Mada, Lere-Gongola and The Delimi –Bunga. The Delimi –Bunga river system is captured mostly in the study area. It is north-east of the study area, the head-water of the Delimi-Bunga water system takes its rise some 13km south-east of Jos, and then north-east towards Lake Chad. Its major tributary, the Tilden Fulani, rises from the shere Hills, and flows through the Neil's valley before joining it about 20km beyond the plateau edge. Also, North West of the study area is the Rukuba tributaries of the Kaduna River system. This flows over the Crystalline Basement Aplo-pegmatitic rock type in the study area to the Jurassic N'gell rock type. The streams along the southern part of the study area are linked to other river systems controlling the southern part of Jos-Plateau.

Climatic Characteristics

The Greater Jos urban area metropolis fall within the Aw climatic type known as the tropical savannah with dry winter, it is a climatic sub-region in the koppens climate classification. This region experiences weather conditions that are warmer during the rainy season (April-October) and much colder weather during the winter or hammattan period (December-February) (Nyong, et al 2008 and Ali, 2018). Generally, altitude and its position control the climate of Jos-Plateau across the seasonal migration of the Inter-Tropical Convergence Zone (ITCZ). Altitude lowers the temperatures and induces rainfall of the orographic type, the lowest temperature occurs around December and January, when the cold, dry Harmattan wind from the Sahara Desert dominates the climactic scene (Vgen and Gumbricht, 2012). In March and April, as the ITCZ approaches from the south, the north – easterly airflow weakens and both temperature and humidity start to increase (Ariyo, 2000).

The mean annual temperature of the area ranges between 20^{o}C and 26^{o}C, which are influenced by relief, rainfall and cloud cover at different periods and seasons of the year. The Greater Jos metropolis has wet and dry seasons with precipitation ranging from 70cm to 100cm during the climax of the rainy season for 8 to 9 months normally from mid-march to October. The dry season takes the remaining 3 to 4 months from mid-November to mid-March (Ali, 2018). The long wet season means groundwater is recharged for longer period, so groundwater dependent residents only struggle for 3 to 4 for water in areas with thin aquifers that will not hold water through these periods.

Population of the Study Area

The 2006 national census placed the population of Plateau state at 3,206,531 and was projected to grow to about 4,000,000 in 2016. The population of Jos city is put at 736,016. The population density in the seventeen (17) Local Governments that make up the state varies with most of the highest in three of the local governments in study area (i.e. Jos North, Jos south and Jos East LGAs). These three have a combine population density of 391 persons per sq.km to become the most densely populated parts of Plateau State (National Population Commission, 1991, 2006). The high concentration of people in Jos North, Jos South and Jos East LGAs can be attributed to the attraction of mining, industrial and commercial activities, which are concentrated in and around Jos, also the attraction to the seat of government being the state capital (Vivan, Ali, Kwesaba and Sahabo, 2015). These densely populated areas will have higher anthropogenic impact on groundwater resources.

The mostly densely populated areas are the most economically vibrant areas, prior to the new Master plan, the capital of the state and therefore the city centre was Jos North LGA but developments had overtime spilled to areas of Bukuru which is in Jos South thereby expanding the city centre. The main economic and source of livelihood for the populace use to be agriculture but with the rapid rate of urban growth and new urban development taking place, the status of farming as a major source of employment and livelihood has declined with commercial and service activities gaining more prominence. The main activities that generate employment in area are: civil service, trade and commerce, agriculture especially growing fruits and vegetables, poultry farming, manufacturing and construction.

Nature, Sources and Types of Data

Essentially two types of maps were consulted as aforementioned. These are the topographical map and the geological map of the Greater Jos Metropolis. Various GIS and cartographic software like ArcGIS 10, Automap and Surfer 12 were used to digitize these maps; these computer programmes were employed because they have specific and different capabilities. The geological map was digitized (computer traced) using ArcGIS 10.3.1 Software from the geological Survey of Nigeria map and the locations of the samples were plotted in the same program at 1: 250,000 scale. The Automap was however used for the topographical map to digitize its contours and other features at 1: 50,000 ArcGIS 10.3.1was used for kriging to illustrate the behaviour of any important parameter in the study area spatially. The satellite image was obtained from the National Centre for Remote Sensing and it was used to define area covered by various land uses in the study area. The image characteristics are given in Table 1. The technique was used to achieve the data requirement of collecting the spatial extent of land uses within the metropolis. This is because the physical expressions and patterns of urban development on landscapes can be detected, mapped, and analyzed using remote sensing and GIS with image processing and classification (Barnes et al. 2001 and Feng, 2009).

Table 1: Satellite image characteristics

Satellite	Bands(nm)	Spatial Resolution (at nadir-m)	Swath width (Km)	Orbital Altitude (Km)	Year of Acquisition
Quick Bird	445-900 (pan)	0.61	16.5	450	2017
	450-520 (blue)				
	520-600 (green)	2.44			
	630-690 (red)				
	760-900 (NIR)				

Source: National Centre for Remote Sensing, 2018

The satellite image was re-projected to the appropriate coordinate system and UTM zone (zone 32) of the study area. Shape files were created for the built- up areas, roads, and strategic locations such as round-about and junctions, these to represent the point, line and polygon layers in the Arc Catalog environment. The layers were then exported to ArcMap environment and thereby digitized as independent thematic layers using the on-screen method of digitizing.

Four kinds of field operations were undertaken in collecting the relevant data for the determination of spatial variation of groundwater quality in the study area.

i. Collection of GPS locations of wells, which were plotted in a geo-referenced geological map of the study area to show the position of these samples.
ii. Testing of field parameters such as pH, EC and temperature using the HANNA instruments pH meter, model HI98129
iii. Collection of water samples for determining physical, chemical and biological parameters of quality in the laboratory.

iv. Measurement of groundwater level readings to determine the direction of flow

Proposed well location areas were located in the field and wells within that vicinity were sought after. GPS coordinate of the well were taken and recorded before the sampler is lowered into the well to obtain the sample, after which bottled for the laboratory (see 3.6.3). Some parts of the water sampled was poured into a testing dish to test the field parameters. The water level meter was then subsequently lowered and readings of the levels were measured and recorded as well.

The Garmin GPSmap 76Cx GPS was used to obtain the global positioning satellite coordinate for every sample location. This it is a pocket size hand-held equipment powered by 3volts lithium-ion batteries with an LED display and buttons for Power, paging, zooming and menu. This is a stainless steel heavy open ended cylindrical equipment with a hook at the top of the equipment to tie a rope so the equipment can be lowered into a well or borehole. The inner part has a stopper at the lower end that depresses when on contact with water when lowered to take in water and shuts when been pulled up to retain the sample. The upper end also has a stopper that does the reverse to only pour in the sampling bottles Wagtech projects mini water level meter model 102m is the technology for one-off measurements of head is the most common tool for measuring depth to water is a "dipper". For instance, a graduated tape attached to a probe, in which a simple electrical circuit is completed when it comes into contact with water. With the circuit complete, the user of the dipper is alerted by the sound of a buzzer and/or the illumination of a bulb. The dipper tape is simply lowered down the borehole until a signal is detected and the depth to water recorded to the nearest centimetre.

The HANNA instruments PH meter, model HI 98129 was used to test the samples for pH and EC. This pocket-sized combo meter gives four readings namely: pH, EC (conductivity), TDS (total dissolved solids), and temperature, all in a rugged, waterproof meter. Reads full scale pH 0.00 - 14.00 (accuracy ±0.01, resolution 0.01), EC from 0 - 3,999 µS (accuracy ±2% full scale, resolution 1 µS), TDS from 0 - 2000 ppm (accuracy ±2% full scale, resolution 1 ppm) and temperature in Celsius or Fahrenheit.

Methods of water level measurement and sample collection

Water levels were measured from 106 wells using a water level dip meter, where the dipper tape is simply lowered down the borehole until a signal is detected and the depth to water recorded to the nearest centimetre. The measurement of head at a specific point in an aquifer requires also the measurement of the depth to water in a borehole or well, and then convert this value into an elevation (relative to sea level), which is done by subtracting the depth to water from the surveyed elevation of the point at the well head from which depth was measured. Some precautions were taken during these measurements. 144 water samples were collected from 72 sample locations using the 75 cl plastic bottle. These bottles were rinsed with ionized water before the collection of the samples. A Cooler with ice packs was used to store the samples before taken to the laboratory within the same day. This is to avoid a rise in temperature. This would cause excessive growth or death of bacteria and thus a wrong result. These water samples were conveyed to the laboratory for determination of the required data on water quality.

Hach conductivity meter, wagtech/palintest photometers, palintest turbidity meter, palintest PH meter, Hanna PH meter, filter membrane apparatus, wagtech Arsenator meter, titration apparatus, DR 2000 Spectrophotometer, Atomic absorption spectrometer. Spectrophotometeris a laboratory instrument with a four-digit liquid crystal display and provides three operator selectable readout modes of absorbance, percent transmittance or concentration. It was used for testing many parameters such as Alkalinity, Aluminum, Ammonia, Cadmium, Chloride, Copper, Fluoride and many others, in each case different parameters required different reagents to be used in testing.The samples collected were analyzed at the UNDP assisted Bauchi State water and sanitation Agency Laboratory (RUWASSA), to test for the physical, chemical parameters and biological indicators. The backup laboratory was the Bauchi State Gubi Dam Laboratory and ATBU chemistry laboratory, Bauchi, Nigeria.

In selecting the parameters to be tested three categories were considered along the U.S. Environmental Protection Agency, (2003) recommendations for a comprehensive ground-water quality assessment programme. These are:

(a) Constituents that need to be monitored for protection of beneficial uses, especially drinking-water supply.
(b) Constituents that provide information on the sources of water and sources of contamination; these constituents can be used for understanding the natural and human factors that affect water quality. The Major dissolved constituents of Ca, Mg, Na, K, Cl, SO_4, F, CO_3, and HCO^-_3 ions are mostly of the concentration controlled by both hydrogeological and geological factors (Blanchette, Lefebvre, Nastev and Cloutier, 2010). Also some minor dissolved constituents were selected based on the land uses (NO_3, Fe, Mn, PO_4^{2-}).
(c) These are constituents that are presently unregulated but that are of potential concern; these “emerging contaminants” include pharmaceuticals and personal care products.

Therefore, a total of 25 parameters were selected for laboratory testing namely: Aluminium, Cadmium, Lead, Copper, Temperature, pH , Turbidity, EC, TDS, TotalIron, Total Hardness, Total alkalinity, Calcium, Magnesium, Zinc, Nitrate, Potassium, Sulphate, Chloride, Arsenic, Bicarbonate, Phosphate, Sodium, Fluoride, faecal coliform.

Selection of Biological Parameters

Sources of water are hand-dug wells from shallow aquifers, which are sometimes situated near sewage and septic tanks, open defecation and indiscriminate dumping of refuse necessitates the need for biological test to examine how these poor sanitation practice and other human activities impact on our ground water, therefore, Coliforms were tested and counted.

Laboratory Testing

The samples were analyzed in accordance “standard methods for the examination of water and waste water American Public Health Association (APHA 1985)”. The Total Hardness (TH) and calcium (Ca) of water was analyzed volumetrically by ethylene diamine tetra acetic acid (EDTA, 0.01M) titration method using 5ml of 20% triethanolamine and calgon.Ca Hardness =titre × 1000/volume of sample, then multiply the answer with 0.4 for ca-ion. The magnesium (Mg) concentration were calculated by subtracting concentration of

Ca from total concentration of Ca and Mg. Concentration of chloride (Cl) was determined by Argentometric method by titrating against Silver nitrate solution ($AgNO_3$, 0.014M). SPADNS calorimetric method was used to measure the concentration of fluoride. Sulfates would be measured by turbidimetric method as $BaSO_4$ while phosphates were determined by stannous chloride method.

Nitrate (NO_3^-) concentration was measured using UV-visible spectrophotometer at a wavelength of 220-275nm to overcome interferences by dissolved organic matter, which also absorbs at 220nm whereas NO_3^- values were accordingly corrected by subtracting twice the reading at 270nm from 220nm reading. Using the following procedure; a blank tube was filled with sample water only to the 10 ml mark. 1ml of the sample was added into the 20ml nitratest tube using a syringe (found inside the nitratest pack) and fill to the 20 ml mark with deionised water. One level spoonful of nitratest powder was then added and one nitratest tablet, but not crushed.

The screw cap was replaced and tube shaken vigorously for one minute. The tube was then allowed to stand for about one minute then gently inverted three or four times before allowing it to stand until the supernatant (solution above) is as clear as the deionised water. The screw cap was then removed and wiped around the top of the tube with a clean tissue. Then carefully the clear solution was poured into a 10ml sample tube, filling to the 10ml mark. One nitricol tablet was added but crushed and mixed to dissolve, mixture was allowed to stand for 10 minutes to allow full colour development. The blank tube was subsequently then placed in the cell holder and 'phot 63' selected for results in nitrate as mg/L NO_3, the 'OK' was pressed on the photometer for the screen to display the reading. The photometer reading was then multiplied by 20 (e.g photometer reading 0.62mg/L, the result was then 0.62 x20 = 12.4mg/L NO_3).

Concentrations of iron (Fe), sodium (Na) and Potassium (K) were measured using Flame Atomic Absorption Spectrophotometer (FAAS) Model 240 FS AA with single Element Ultra AA Hollow Cathode Lamps. The standard for Fe was prepared from stock solutions of the Fe. The concentration of all the major ions (Cations and anions) and metals were measured using standard reference solutions of analytical grade. Double distilled water was used for preparing the solutions and blanks throughout the analysis.

Biological test was done using the biological parameters involving faecal coliform was tested using the ELE International paqualab system for biological investigation this is a multi-purpose water testing unit. The procedure for the membrane filtration used to count the coliforms was a known volume of the water sample was measured. Then it is filtered through the Membrane Filter Paper (MFP) placed on the M FU. The MFP was then removed after filtration and placed on the petri-dish saturated with media to incubate for 18-24 hours at 37 or 440C.The result was then read by removing the petri-dish after incubation and placed on a flat surface in good natural light, avoiding direct sunlight. The lids were removed and the yellow colonies counted with lens as the various cases necessitated. Clear, red or any other colour colonies were not counted. The results were then expressed as colony forming units per unit volume (cfu/100ml).

RESULTS

From Figure 2, the levels of concentration of parameters like Nitrate, Lead, Cadmium and Feacal coliform in groundwater within the study area were used to investigate human influence on the groundwater quality. Also, the percentage of the explained variance of the factors observed from the factor analysis is used here to quantify the level of human influence.

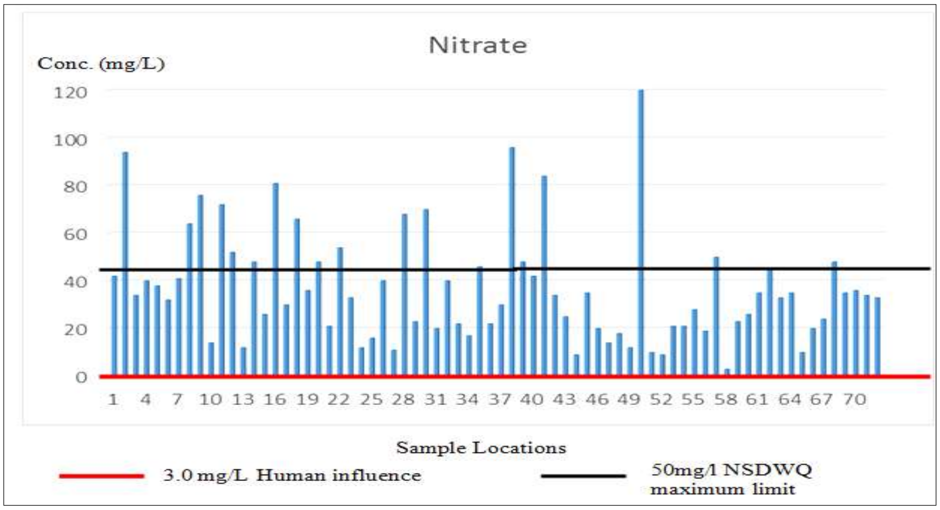

Figure 2: Nitrate threshold to indicate influence by human activities
Source: Field work, 2019

Feacal Coliform

Gray, (1994) observes that there several reasons why a specific individual isolation and identification of pathogenic organisms is impracticable or not objective, these include: the fact that it is time consuming and that it is misleading as each species can tolerate different environmental conditions. This has led to development and the use of indicator organism to determine the likelihood of contamination by faeces. The most widely used forms of indicators are the non-pathogenic bacteria, in particular coliforms, faecal streptococci and sulphate-reducing clostridia. *Escherichia coli* (feacal coliforms as seen in Figure 3) can survive for several weeks under ideal conditions and are far more easily detected than the other indicator bacteria. Because of this it is the most widely used test organism, although others are often used to confirm faecal contamination if *E. coli* is not detected. The EC directive specifies that total and faecal coliforms are to be measured by way of a count, It also set that safe water must be free from and faecal coliform *(Escherichia coli)* and has about 3×10^{-2}mg/l of total coliform.

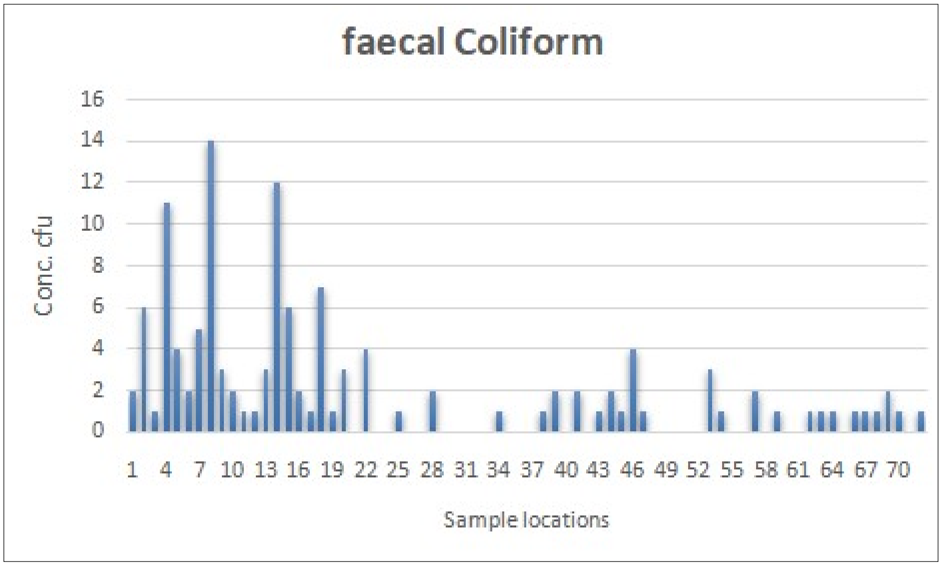

Figure 3: Feacal coliforms concentrations in the Greater Jos Urban Area.
Source: Field Survey, 2019

Lead and Cadmium

Lead and Cadmium are very toxic to humans and other organisms and because their effect can be long lasting and so bear a certain level of concern and hence discussed together. The results show that more than 50% of the concentration of lead in the study area exceeded the Nigerian Standard for drinking water quality Maximum permissible limit (figure 4). The bar chart on cadmium shows that 27% exceed the Nigerian Standard for drinking water quality Maximum permissible limit of 0.03mg/L (Figure 5). Lead and Cadmium have many anthropogenic sources, some of which are industrial application, including the manufacture of batteries, industrial waste, mining and mineral processing facilities that are so pervasive within the area. The distribution in the environment is an indicator of overall human impacts to the environment.

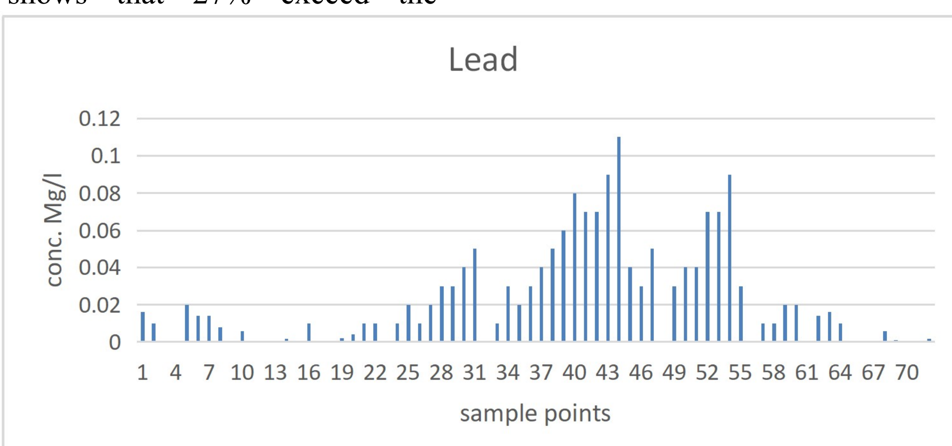

Figure 4: Lead concentration in the Greater Jos Urban Area.
Source: Field Survey, 2019

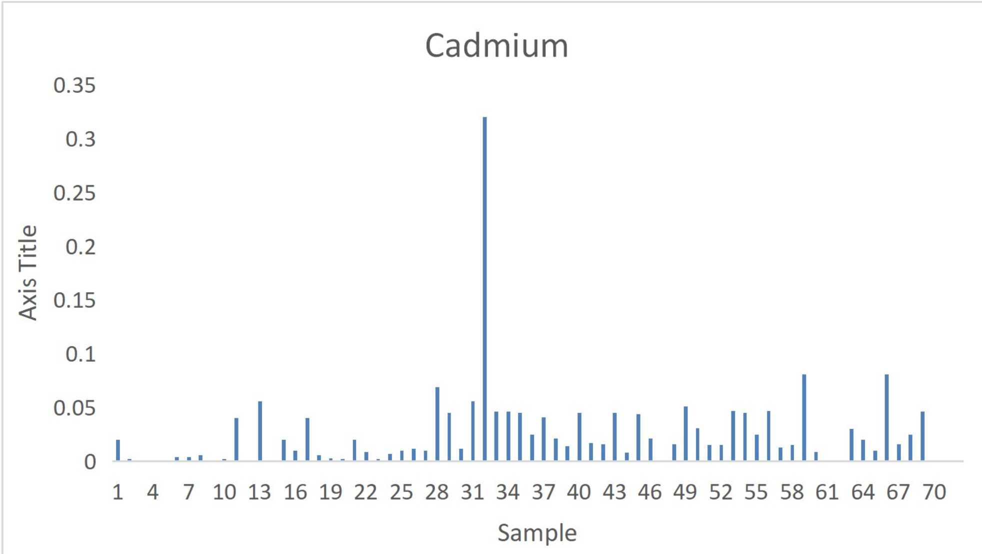

Figure 5: Cadmium concentration in the Greater Jos Urban Area.
Source: Field Survey, 2019

Percentages of Explained Variance

The Table 2 shows all the factors extractable from the analysis along with their eigenvalues, the percent of variance attributable to each factor, and the cumulative variance of the factor and the previous factors. Three factors were extracted based on the cut off eigenvalues of greater than 1.5. The first factor accounts for 43.315% of the variance, the second 9.563% and the third 7.263 %, the three factors account for 60.14 % of the total variance in the data. Not all the remaining factors are significant since they do not explain much variance and were not worth including in the final model.

DISCUSSION

All sampled points indicated elevated levels of nitrate (above the red line). The red line placed at 3 indicates that all points are showing evidence of contamination by human activities according to Madison and brunett, (1985), 3.1 to 10 mg/l - may indicate elevated concentrations resulting from human activities (Figure 4). Therefore, all the points have been influenced by human activities. However, only about 10% of the sample points presented levels above Nigerian Standard for drinking water quality maximum permissible limit of 50mg/l. The Nitrate elevated values where noticed to be predominant on the Jurassic Younger granite rock type which happens to be the largest rock type with the most built up areas. This leads to the deduction that the high nitrate values could result from sewage, pit latrines and refuse dumps.

High nitrate concentrations in drinking water are associated with the development of methaemoglobinaemia in infants. This is a situation where nitrate is reduced to nitrite as nitrate itself does not cause this disorder. The nitrite combines with haemoglobin in red blood cells to form methaemoglobin, which is unable to carry oxygen and so reduces oxygen uptake in the lungs. Normal methaemoglobin level in blood is between 0.5 and 2.0%. As methaemoglobin does not carry oxygen, excess levels lead to tissue anoxia (i.e. oxygen deprivation). It is only when the methaemoglobin concentration in the blood exceeds 10% that the skin takes on a blue tinge in infants, the disorder known as methaemoglobinaemia or blue-baby syndrome. The progressive symptoms resulting from oxygen deprivation are stupor, coma and eventual death. Death ensues when 45-65% of the haemoglobin has been converted. However, the disorder can be readily treated using an intravenous injection of methylene blue, which results in rapid recovery (World Health Organization, 1984). Although methaemoglobinaemia is well recognized and is unlikely to be a problem in areas with adequate medical facilities, it may be more important in the developing areas where such facilities are lacking.

All the health considerations relating to nitrate are related to its conversion to nitrite. In the gastrointestinal tract, nitrite reacts with certain compounds in food under acidic conditions to produce *N*-nitroso compounds with amines and amides. Many of these compounds are known carcinogens. Although there is no epidemiological evidence to link nitrate directly with cancer in humans, increased concentrations of nitrite and N-nitroso compounds have been detected in people who secrete inadequate amounts of gastric acid, a group known to be particularly at risk from gastric cancer. (Gray, 1994, Forman *et al.*, 1985).

Table 2: Total variance explained for the extracted components.

	Initial Eigen values			Extraction Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	9.529	43.315	43.315	9.529	43.315	43.315
2	2.104	9.563	52.878	2.104	9.563	52.878
3	1.598	7.263	60.14	1.598	7.263	60.14
4	1.396	6.347	66.487			
5	1.123	5.104	71.591			
6	1.031	4.686	76.277			
7	0.972	4.419	80.696			
8	0.751	3.412	84.108			
9	0.652	2.964	87.072			
10	0.584	2.652	89.724			
11	0.51	2.319	92.043			
12	0.455	2.069	94.112			
13	0.36	1.636	95.748			
14	0.252	1.146	96.894			
15	0.229	1.039	97.933			
16	0.194	0.88	98.813			
17	0.115	0.524	99.337			
18	0.101	0.46	99.797			
19	0.034	0.153	99.949			
20	0.011	0.048	99.997			
21	0	0.002	99.999			
22	0	0.001	100			

Extraction Method: Principal Component Analysis. Source: Field Survey, 2019

Our data shows about 63 % of contamination in the total number of wells, (Flanagan (1988) summarized the interpretation of coliform results as follows: where *E. coli* are present in large numbers the interference is that heavy, recent pollution by human or animal wastes has occurred and this can be observed in samples: S2, S7, S8, S4, S14,S15, S18, and S20. If the *E. coli* numbers are low it is inferred that pollution from the same source(s) is either recent or less severe, this is observed in samples: S1, S3, S6, S10, S11, S12, S16, S17, S19, S25, S28, S34. If coliforms not including E. coli are observed the indication is that either the pollution is recent and non-feacal in origin or of remote, origin such that the intestinal coliforms have not survived (figure 5). This is observed only in sample S21, S23,S24,S26,S27,S29,S30, S31, S32, S33, S35, S36, S37, S40, S42, S48, S49, S50, S51, S55, S56, S58, S60, S61. The remaining samples showed no evidence of contamination.

There is need for caution in the above interpretation as noted by Gray, (1994) that in tropical regions E. coli in particular is known to multiply in warm waters and there is increasing evidence that E. coli able to reproduce in enriched waters generally, indicating an increased health risk. The obvious pathogenic contamination of these shallow wells is a strong case for bad sanitation practices. These wells easily get contaminated within the metropolis because of their proximity to sewage, septic tanks and the ubiquitous problem of open defecation (ODF). There are several effects that specific pathogens would have on human health, but since the laboratory standards today use normal intestinal organisms rather than the pathogens themselves for monitoring and assessing microbial safety of water supplies our discussion here would center on feacal pollution *(Escherichia coli)*. There are 14 distinct serotypes of Escherichia coli which cause gastroenteritis in humans and animals, being especially serious in newborn infants and children under five years of age. This disease does not cause fever but profuse watery diarrhea with little mucous, nausea and dehydration. Enteropathogenic *E. coli* is commonly isolated from sewage but represents less than 1% of the total coliforms present in polluted waters. However, only 100 organisms are required to cause illness.

CONCLUSION

The study has shown that Nitrates, faecal coliform, lead and Cadmium had high values around the centre of the study area of the metropolis exceeding the SON (2015) standard for drinking water. The Factor analysis indicated that the geology is controlling the quality of the groundwater in the metropolis but also reveals that human activities measures closely after the geology by a proportion of 4 to 1 respectively. The implication of this is that human activities due to poor sanitation and poor planning alongside groundwater resources are impacting on the groundwater quality of the area.

Recommendations

Areas around Du and Shen close to the Yakubu Gowon Dam should restrict human activities that have polluting potentials. Also, areas like Rantya, Shere hills, Furaka, Zarazon, Vom and Gyero should be cautiously assessed to prevent movement of polluting substances from a higher groundwater level to recharge areas. The Government should as a matter of urgency develop policies to address Nitrate, Lead and cadmium as seen in the city centre. Open defecation and borehole or well construction standards should also be urgently enforced to arrest the cases of rising pollution of groundwater sources from seepages. The state government should consider the development of central sewage system for densely populated areas other than on-site waste management systems like soak-away and latrines so as to control the contribution of nitrates and sometimes faecal coliforms to groundwater in the event of a poorly constructed soak away. A standard for the construction of soak-away should equally be developed for suburban areas that would be well regulated and monitored for deterioration by the relevant authorities.

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