IMPACT OF ANTHROPOGENIC ACTIVITIES ON THE QUALITY OF SHALLOW GROUNDWATER OF THE CHAD BASIN IN MAIDUGURI, NIGERIA

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ABSTRACT: *This study examined the effects of anthropogenic activities on the quality of shallow groundwater of the Chad Basin in Maiduguri, Nigeria by analyzing samples from 46 boreholes with a range of 40 m – 115 m, and an average depth of 60.54 m. The result of the analysis showed groundwater to be polluted in many boreholes. The pollution results from increased anthropogenic activities such as waste disposal, pit latrines and agricultural activities. About 22% of the sampled boreholes complied with the separation distances stipulated by the Federal Ministry of Water Resources and the Environmental Protection Agency leaving a whopping 78% in contravention of the minimum separation distance. Major point pollution sources identified include soakaways, pit latrines, solid and liquid wastes, plant and animal waste products and mechanical workshops. Turbidity, total dissolved solids (TDS), Fe, Cr, Cu, Mn and PO_4 are physicochemical parameters found to have exceeded the standard set by the Nigerian Standard for Drinking Water Quality. Seven wells had exceeded turbidity and TDS standards, 11 and 34 wells had exceeded the standards for Fe, Mn and PO_4, and Cr and Cu respectively. Densely populated parts of the city have high TDS and turbidity values. To improve groundwater quality in the study area, the paper suggests enforcement of the minimum standard spacing for boreholes and pit latrines. Also, it suggests environmental education that will make the public to be aware of the necessity of ensuring environmental health which will ensure quality of groundwater and proper disposal of solid wastes.*

KEYWORDS: Anthropogenic Activities, Quality of Shallow, Groundwater, Chad Basin,

INTRODUCTION

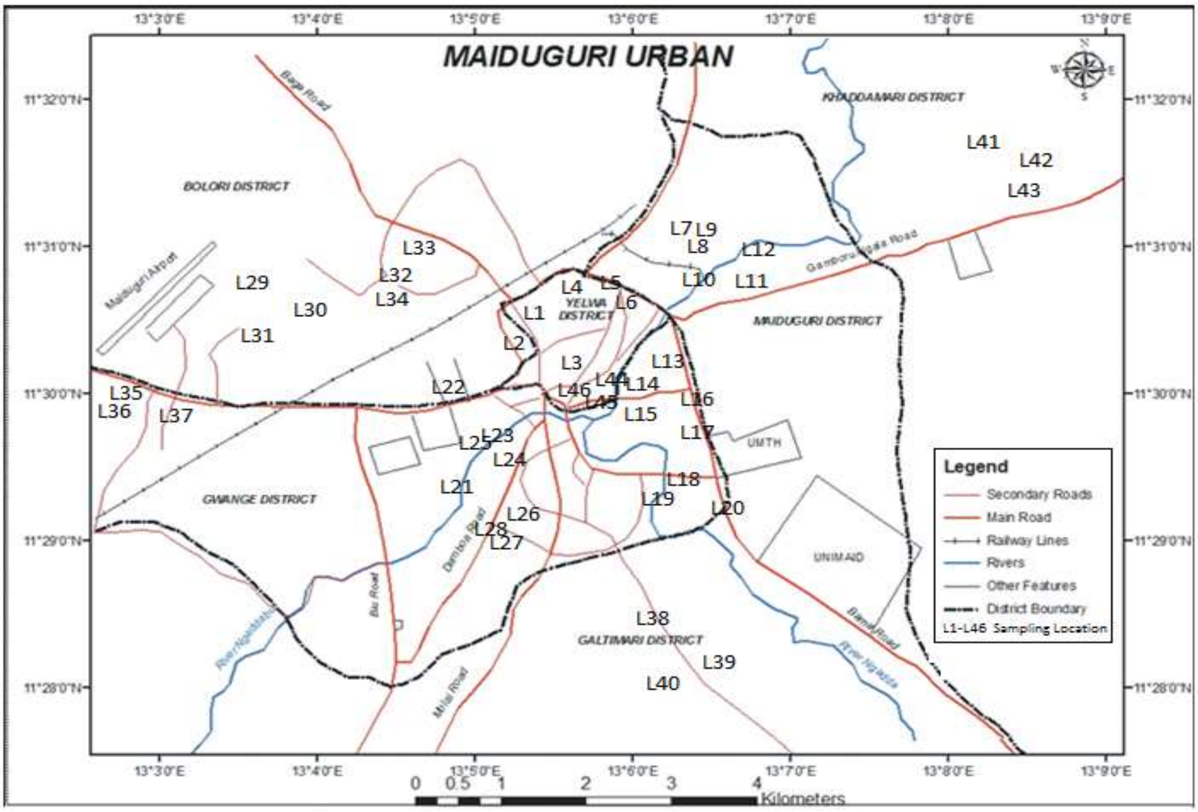
Groundwater is an important part of the global freshwater supply because it provides much of the public and domestic water supply, supports agricultural and industrial activities globally. The usefulness of groundwater to humans depends on its physical, chemical and biological status, thus assessment of groundwater quality is important for socioeconomic development. Groundwater is the primary and reliable source of potable water in most parts of Nigeria. However, the reliability of this precious and vital resource is under increasing threats from surface anthropogenic activities related to uncontrolled urbanization, incessant waste disposal and poor land use management (Galadima *et al*, 2011). Urban population in Nigeria is growing rapidly, for example the total population of the country rose from 45.2 million in 1960 and was projected to rise to about 168 million in 2013 (NPC, 2006). Most of the people are concentrated in urban areas where there is limited access to water, and environmental health and sanitation are often compromised. Wastes generated in urban areas are often disposed of in open spaces. Often, public places such as roads serve as dumps. These wastes, over a period of time and under the influence of climatic conditions, could infiltrate down and pollute underlying

ISSN: 2052-6377(Print), ISSN: 2052-6385(Online)

groundwater. In Maiduguri, uncontrolled urbanization has resulted in increased anthropogenic activities including uncontrolled or improper waste disposal, proliferation of pit latrines and agricultural activities (Bakari, 2014). These are affecting aquifers on which the city's water supply depends to a large extent (Mohammed 2015). Mohammed (2015) also observed that the contamination from the seepage that contaminates groundwater sources poses threats to humans. This study seeks to investigate the impact of human activities on the quality of groundwater in Maiduguri, Nigeria. Specific objectives include determination of the depths of boreholes and their association or relationship with groundwater pollution, and assessment of the major point pollution sources. Other objectives include determination of the level of compliance with the separation distance of boreholes and other structures as stipulated by the Federal Environmental Protection Agency (FEPA).

Location of the study Area

Maiduguri urban with a land mass of 137,356 sq km is located between latitudes 11°46´18"N -11°53´21"N and longitudes 13°02´23"E - 13°14´19"E (Google Earth, 2014). Figure 1 show the study area which lies within the Chad Basin, which is formed as a result of down-warping during the Pleistocene period (Miller *et al*, 1968). The study area has a population of 749 123 (National Population Commission, 2006).



Source: Modified from Google Earth, 2014.

Figure 1: Study Area with Locations of Sampled Boreholes.

Climate and Relief

The climatic regime of the area consists of a long dry season (October to May) and a shorter rainy season (June to September). The rainfall pattern in the area generally shows spatial and

ISSN: 2052-6377(Print), ISSN: 2052-6385(Online)

temporal variability and has been characterized by single maximum, with a peak around August. The rainfall records at the Maiduguri station for the period of 1980 to 2005 show that the average rainfall is over 600mm. In the dry period, the temperature over the area may go up to 48°C. During harmattan it may be as low as 15°C. Humidity is generally low, except during the brief rainy season. The potential evapotranspiration is high over the area with an estimated annual average of about 2,300mm (Goni, 2006).

The topography of Maiduguri is made up of undulating plains of the Chad formation that lies at a mean level of 320m above sea level with gradual sloping towards the Lake Chad at 282m above sea level. Equally, the landforms can be classified into plains and ridges comprising palaeo-lacustrian and flood plain with undulating terrain of about 320m above sea level drained by River Ngadda in to the Ngadda delta popularly called the "Jere-Bowl" (Nyanganji, 1996).

Hydrogeology

The Basement Complex, Bima Sandstone, Kerri Kerri and Chad Formations are the main sources of groundwater supply in the Nigerian sector of the Chad Basin. The Chad Formation becomes the most important hydrogeologic unit and underlies the entire study area. It comprises of thick clays, bearing little or no groundwater, but generally includes three distinct sandy horizons constituting three separate aquifer systems. These aquifers were assigned names of Upper, Middle and Lower aquifers by Barber and Jones (1960). However, in some places in the study area, the Chad Formation is overlain by fine sand and silty sediments of recent deposits and is mainly of Aeolian origin. The Lower sandy part of the recent deposits was assigned to the upper aquifer (Dar Al Handasah, 1981). The Lower aquifer is confined and its thickness varies but reaches up to 90m (Dar Al Handasah, 1981). The depth to its top is from 450m in Maiduguri. It consists of fine to coarse grained sands and gravels. Exploitation of this aquifer is inhibited by cost. However, it is being exploited by considerable number of boreholes around Maiduguri (Oteze and Fayose, 1988). The Middle zone aquifer appears to underlie the entire study area and extends up to the Republics of Niger, Chad and Cameroon (Dar Al Handasah, 1981). It is separated from the Upper aquifer by some thick argillaceous layer of about 150m thick (Goni *et al*., 2000). The aquifer consists of sands, sandy clays and clays with extremely variable proportion in different sections. The sand varies from fine grained to very coarse grained, with little gravel, feldspar grains, iron ore and mica present along with fragments of granite, but quartz grains form the bulk of the arenaceous materials (Goni *et al*., 2000). The Upper aquifer extends across the entire study area and it is under unconfined to semi-confined conditions. It is composed of sands and gravels units laid down during recent times since Lake Chad commenced its current phase of major regression in volume (Dar Al Handasah, 1981). Around Maiduguri, Beacon Service and Consulint International Ltd (1979) sub-divided the Upper aquifer into three sub-units; A, B, C and termed it as Upper aquifer system.

Soil and vegetation

The soil of Maiduguri urban environment is part of the brown and reddish brown hydromorphic alluvial soil of the entire Borno region. In consonance with soil and climate of the area, the vegetation is similar to Sahel savanna, surrounded by shrubby vegetation interspersed with tall trees woodland (Waziri 2009).

ISSN: 2052-6377(Print), ISSN: 2052-6385(Online)

METHODOLOGY

Groundwater samples were collected from forty six (46) boreholes within Maiduguri Metropolis and analyzed to reveal their physical and chemical characteristics. Purposive sampling was employed for obtaining data in the study area. This sampling technique was employed to sample some specifically targeted boreholes in areas with characteristics such as high population density and proximity to some activities perceived to pollute groundwater. Based on the aim of this study, which is to understand the quality of groundwater especially its physicochemical properties as it relates to depth, population density and activities perceived to cause groundwater pollution, five samples each from Maduganari and Gwange representing densely populated areas of Maiduguri were collected and analyzed while three samples each from Monday Market, Gamboru Market, Abattoir, Majema, Arinmari, Coca Cola Company and 555 Housing Estate representing areas with high anthropogenic activities perceived to be source of groundwater pollution were collected and analyzed respectively. Also, three samples each from Polo, New G.R.A, Damboa Road, Pompomari and 777 housing estate representing sparsely populated areas of Maiduguri were collected and analyzed. Prior to collection of the water samples, the 750ml plastic containers that were used for collection and storage of samples for the physicochemical analysis were washed with de-ionized water, and then three times with the sample water in order to avoid any contamination. Then, the water samples were collected from the boreholes after 5 to 10 minutes of pumping to ensure that the samples were true representatives of the aquifer. Field parameters such as pH, electric conductivity (EC), total dissolved solids (TDS) and temperature were measured in the field due to their unstable nature. The pH, EC and temperature of the water were measured with a portable digital HANNA conductivity meter (Model H1 98129). TDS and salinity were measured with salinity meter (Model EC400 EX Stilk II). The water samples were analyzed for Ca, Mg, Na, K, F, Fe, Mn, Cr and Cu using Atomic Absorption Spectrometer (Analyst 400). SO_4, NO_3, and PO_4 were analyzed using UV/VIS Spectrometer (Lamder 35) and Cl, CO_3, HCO_3 using titrimetric method according to APHA (1998).

Results and Discussion

The minimum depth of boreholes sampled is 40m while the deepest is 115m with an average depth of 60.54m (Table 1). This revealed that most of the sampled boreholes are tapping the upper aquifer which according Odihi (1988), Goni (2000) and Mohammed (2015), is shallow and unconfined. The average distance of boreholes to the possible points of pollution sources was 8.80 m while the minimum and maximum distances were 3 m and 36 m. Approximately 22% of the sampled boreholes complied with the separation distances stipulated by the Federal Ministry of Water Resources and the Environmental Protection Agency leaving a whopping 78% in contravention of the minimum separation distances as shown in Table 2. Major point pollution sources identified in this study include soakaways, pit latrines, solid and liquid wastes, plant and animal waste products and Mechanical workshops as Table 1.

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Table 1: Locations, depths of boreholes, distance and possible sources of point pollution

Sample ID	Location	Coordinate	Elevation (m)	Depth of boreholes (m)	Distance to possible source(s) of pollution (m)	Point pollution source(s)
L1	Shehuri South	11°50.822'N 13°09.608'E	329	40	4	Soakaway
L2	Shehuri South	11°50.703'N 13°09.627'E	333	68	7	Soakaway, Gutter
L3	Alajiri Arinmari	11°50.663'N 13°09.555'E	329	48	4	Soakaway, Gutter, Dying pits
L4	Majema	11°50.940'N 13°09.220'E	327	64	8	Gutter, Tannery
L5	Masallacin Mallam	11°59.663'N 13°09.645'E	332	46	6	Solid waste, Gutter
L6	Sabon number	11°59.565'N 13°09.745'E	334	63	10	
L7	Abattoir	11°51.485'N 11°10.679'E	326	43	Within the abattoir	Animal waste
L8	Abattoir	11°51.573'N 13°10.698'E	324	64	Within the abattoir	Animal waste
L9	Abattoir	11°51.538'N 13°10.557'E	344	83	Within the abattoir	Animal waste
L10	Gamboru Market	11°51.119'N 13°10.459'E	326	78	Within Gamboru market	Waste from plants, metals etc
L11	Custom Bridge	11°51.006'N 13°10.321'E	321	45	4	River Ngadda
L12	Gamboru Market gidanwanka	11°51.208'N 13°10.353'E	325	52	10	Solid waste disposal site
L13	Gwange Sudan Street	11°50.792'N 13°10.200'E	324	47	36	River Ngadda

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L14	Gwange 2 Primary School	11°50.472'N 13°10.287'E	321	84	3	Soakaway, Pit latrine
L15	Gwange Zuwa Dawuri	11°50.109'N 13°10.425'E	327	54	9	Car wash
L16	Layin Bola	11°49.950'N 13°10.431'E	327	51	4	Soakaway, Pit latrine
L17	Layin Mata	11°50.286'N 13°10.101'E	324	62	6	Solid waste disposal site
118	New GRA	11°49.500'N 13°10.300'E	335	46	15	Soakaway
L19	New GRA	11°48.540'N 13°10.231'E	327	67	5	Soakaway
L20	New GRA	11°48.370'N 13°10.470'E	386	48	18	*
L21	Maduganari NUT	11°49.738'N 13°08.153'E	332	43	36	Solid waste disposal site, soakaway
L22	Madaganari behind mobile barrack	11°49.526'N 13°07.592'E	333	61	4	Pit latrine, Soakaway
L23	Maduganari bus stop	11°49.526'N 13°07.791'E	337	48	7	Solid waste disposal site, River Ngadda
L24	Maduganari	11°49.588'N 13°07.608'E	331	53	10	Solid waste disposal site, Mechanic W/Shops and farm lands
L25	Maduganari bypass	11°49.740'N 13°08.165'E	336	62	19	Pit latrine
L26	Damboa Road off primary sch.	11°48.303'N 13°08.101'E	332	42	4	Soakaway, Pit latrine
L27	Behind NNPC depot	11°48.340'N 13° 07.732'E	334	63	6	Soakaway, Pit latrines
L28	Damboa road Bulama's residence	11 °48.307'N 13°07.625'E	333	48	12	Garden

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L29	Coca Cola	11°52.200'N 13° 06.101'E	337	56	9	Farm land
L30	Coca Cola	11° 52.260'N 13°06.433'E	328	69	16	Soakaway
L31	Coca Cola	11°52.860'N 13°06.234'E	333	115	25	Waste water
L32	Pompomari Gujba str	11°51.334'N 13°07.137'E	332	*	11	Poultry farm
L33	Pompomari	11 °51.260'N 13°06.985'E	336	103	13	Soakaway, Gutter
L34	Pompomari	11°51.492'N 13°06.847'E	335	*	*	*
L35	House No. 379 777 housing estate	11°50.323'N 13°03.758'E	331	63	*	*
L36	777 housing estate	11°50.507'N 13°03.727'E	340	78	10	Solid waste
L37	777 housing estate	11°50.843'N 13°03.648'E	333	57	8	Soakaway/ drainage
L38	Filin Polo	11°80.368'N 13°14.5368'E	368	80	12	Mechanical workshop
L39	Polo, Town engineer estate	11°80.130'N 13°14.859'E	354	53	19	Farmland, poultry farm and feeds factory
L40	Triple A primary and Nursery Sch.	11°80.375'N 13°13.943'E	329	64	*	*
L41	505 central mosque	11°80.297'N 13°12.083'E	319	93	12	Pit latrines
L42	505 Housing estate	11°51.294'N 13°12.197'E	316	52	2	Farm lands
L43	505 Off first gate	11°51.309'N 13°12.236'E	312	46	6	Farmlands/ soakaway

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L44	Monday Market	11°49.396’N 13°09.151’E	360	61	Within the Market	Solid/Liquid Waste
L45	Monday Market	11°49.286’N 13°09.333’E	382	98	Within the Market	Solid/Liquid Waste
L46	Monday Market	11°50.428’N 13°09.181’E	362	68	16	Solid/LiquidoWaste

*not measured/identified

Table 2: Separation Distances Stipulated by the Federal Ministry of Water Resources under the Water Resources Act 101 and the Federal Environmental Protection Agency Act-Retained as Cap 131.

Sources of Potential Contamination	Types of Well	Minimum Distance from well
Septic tank, Concrete Vault privy, Sewer drain	Drilled Well Dug Well	15m 30m
Seepage (leaching pit), Filter bed, Soil absorption field, Earth pit Privy or similar disposal unit	Drilled Well Dug Well	15m 30m
Right of way of any highway or Public road	Any types	10m
Septic tank or Soak away	Drilled Well Dug Well	15m 30m
Solid/Liquid disposal field	Drilled Well Dug Well	23m 30m

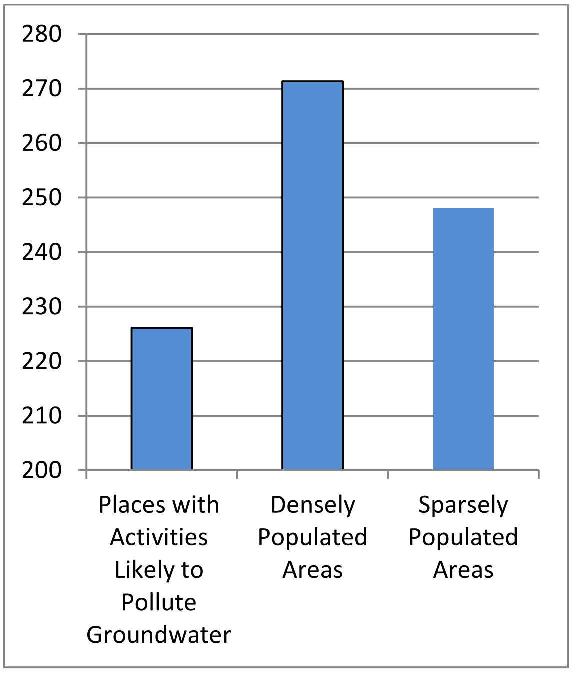
Source: Nigerian Standard for Drinking Water Quality 2007.

Relationship between Pollutants and sampling sites

The analysis of physical and chemical parameters of groundwater in the study area indicates that turbidity, TDS, Fe, Cr, Cu, Mn and PO_4 are above the set standard by Nigeria Standard for Drinking Water Quality (NSDWQ) (see Appendix 1). Places in the city that are densely populated had high TDS values compared to the sparsely populated areas and places with activities likely to pollute groundwater as shown on Figure 2a). Turbidity was also higher in densely populated areas followed by the places that have activities with high groundwater pollution potentials. Sparsely populated areas had the lowest values (Figure 2b). Iron (Fe) concentrations were higher in sparsely populated places followed by places with activities likely to pollute groundwater. Densely populated areas had the least concentration of Fe (Figure 2c). This suggests that the elevated Fe concentrations in the study area could either be as a result of iron leaching from refuse, sewage and iron related industries which are all factors that can influence the concentration of iron in groundwater. Manganese (Mn) which according to (Hem, 1985) has a similar geochemistry with iron is also having higher concentrations in the sparsely populated areas followed by the places with activities likely to pollute groundwater

ISSN: 2052-6377(Print), ISSN: 2052-6385(Online)

and then densely populated areas of the city as shown in (Figure 2d). The heavy metals Chromium (Cr) and Cupper (Cu) concentrations were higher in places with activities likely to pollute groundwater followed by densely populated areas with sparsely populated areas of the city having less Cr and Cu concentrations (Figures 2e and 2f). Also, Phosphate PO_4 concentration levels were higher in places with activities likely to pollute groundwater followed by densely populated areas with the least concentration values occurring in the sparsely populated areas of the city (Figure 2g).



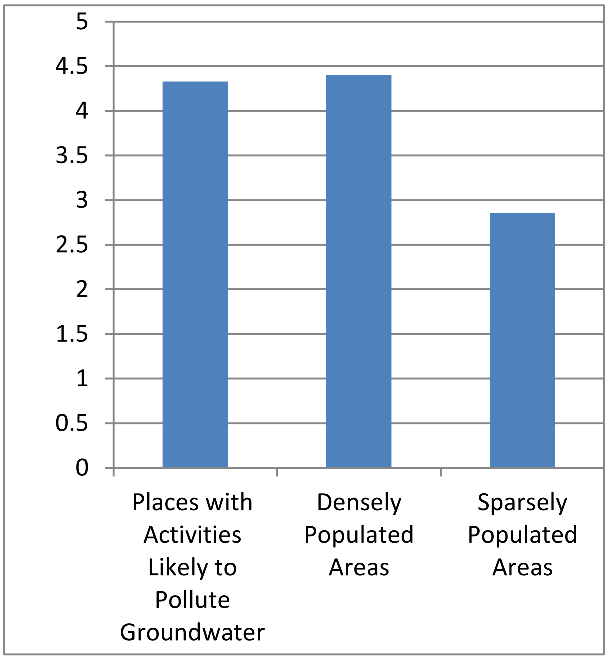
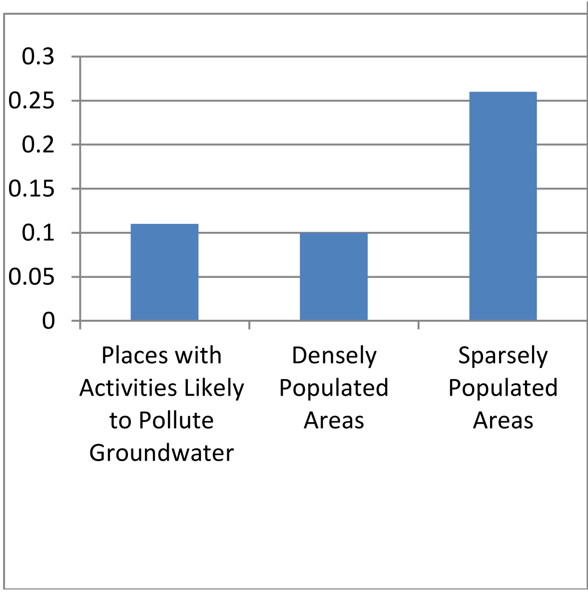


Figure 2a Average TDS concentrations concentrations at the sample sites.

Figure 2b: Average Turbidity at the samples sites.



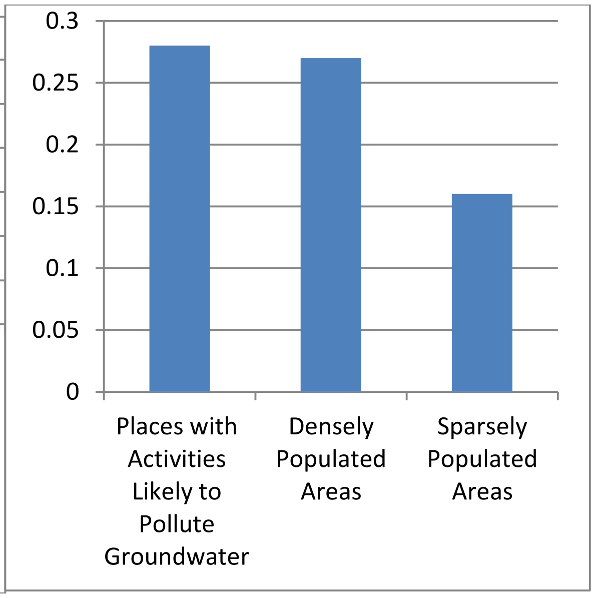


Figure 2c Average Fe concentrations concentration at the sample sites

Figure 2d : Average Cr sample sites

ISSN: 2052-6377(Print), ISSN: 2052-6385(Online)

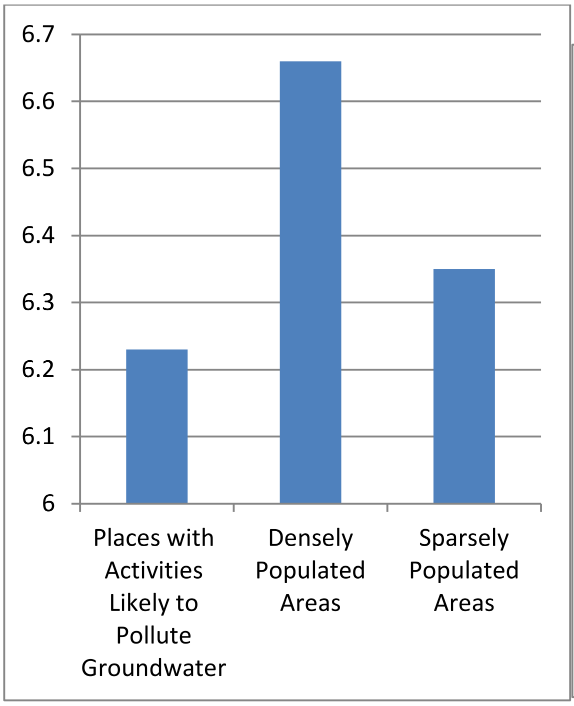


Figure 2e Average Cu concentration at he sample sites

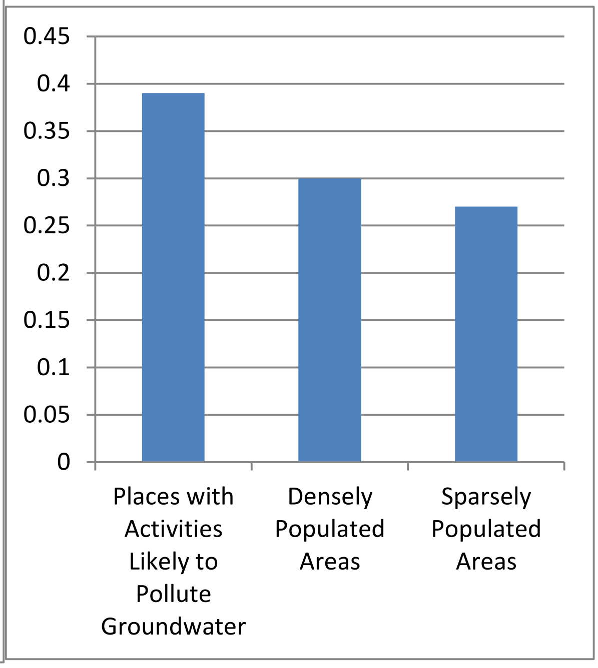


Figure 2f: Average PO_4 concentration at the sample sites

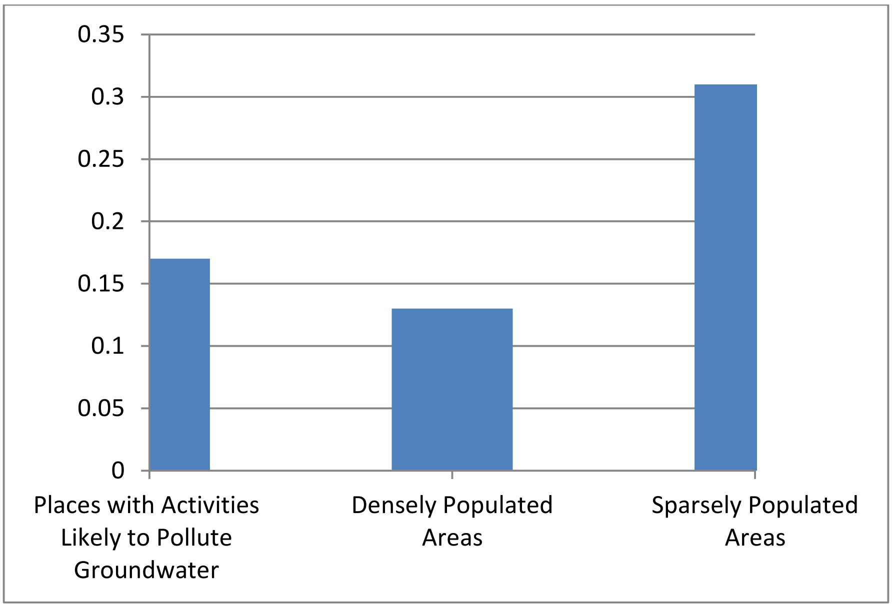


Figure 2g Average Mn concentration at the sample sites

Relationship between Depth of Boreholes and the Concentration of Pollutants

Depths of boreholes seem not to have a strong relationship with concentration of the pollutants. This could be attributed to the wide variations in the sources of pollution as stated above.

ISSN: 2052-6377(Print), ISSN: 2052-6385(Online)

Figures 3, 4, 5, 6, and 7 show the relationship between some of the identified pollutants and depth of boreholes.

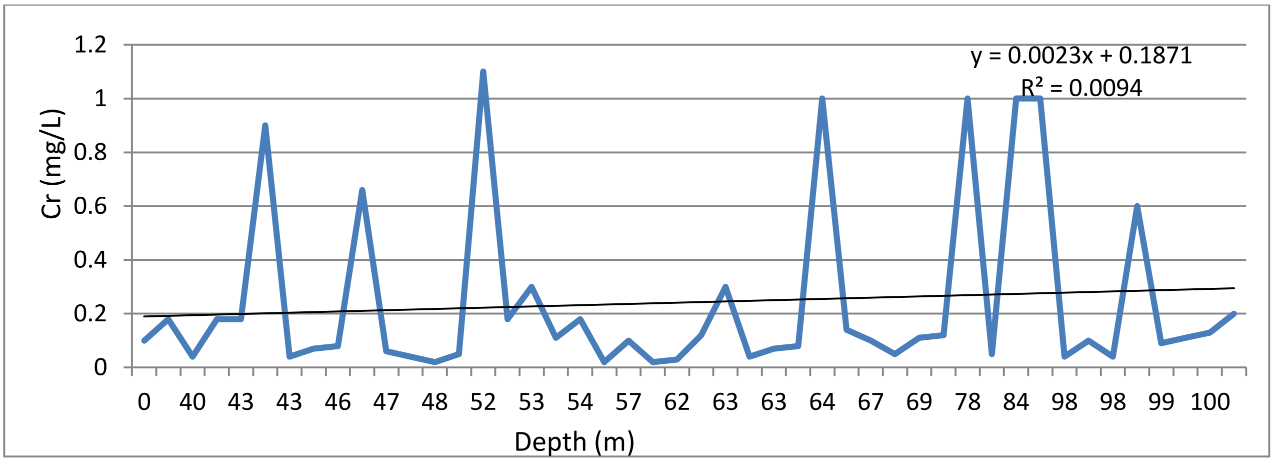


Figure 3 Relationship between depth(m) and Chromium (mg/L) in the groundwater samples.

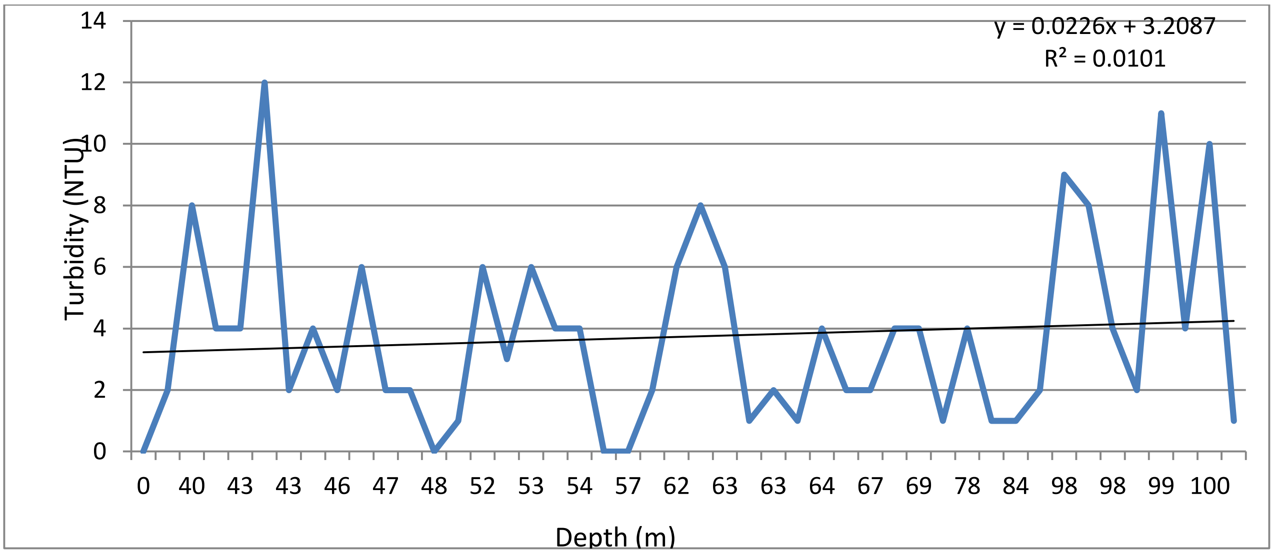


Figure 4 Relationship between depth(m) and turbidity (NTU) in the groundwater samples.

ISSN: 2052-6377(Print), ISSN: 2052-6385(Online)

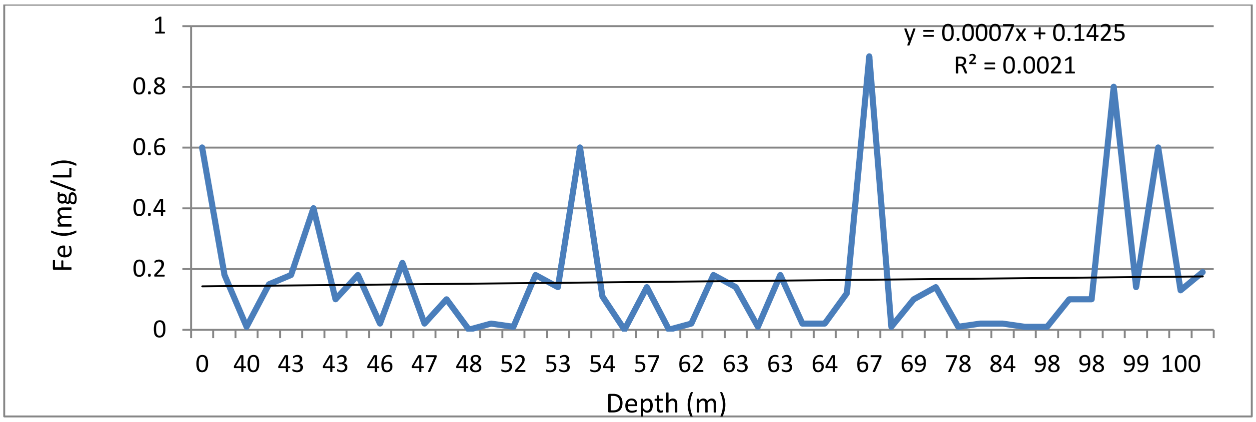


Figure 5 Relationship between depth(m) and Fe (mg/L) in the groundwater samples.

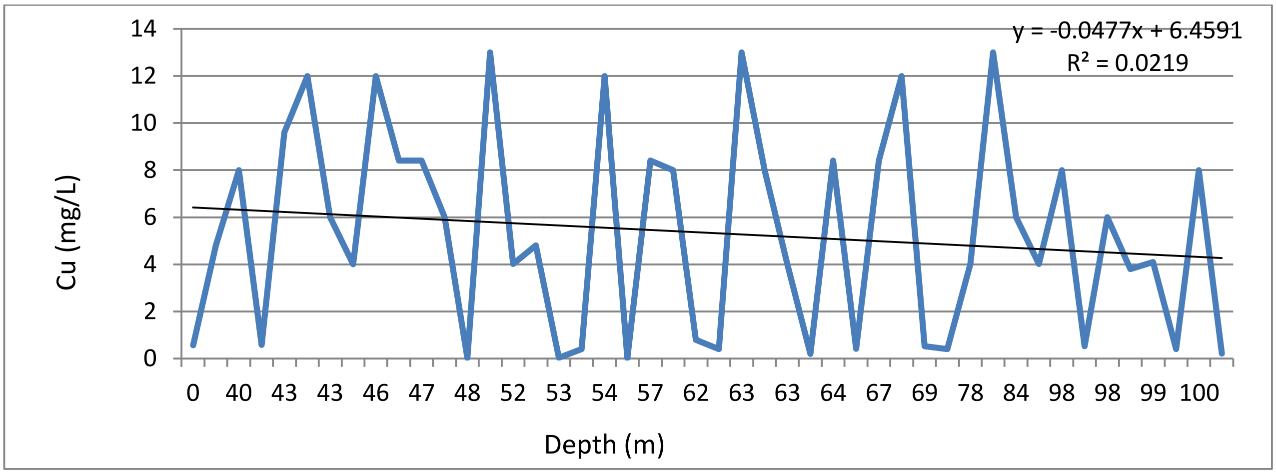


Figure 6 Relationship between depth (m) and Cu (mg/L) in the groundwater samples.

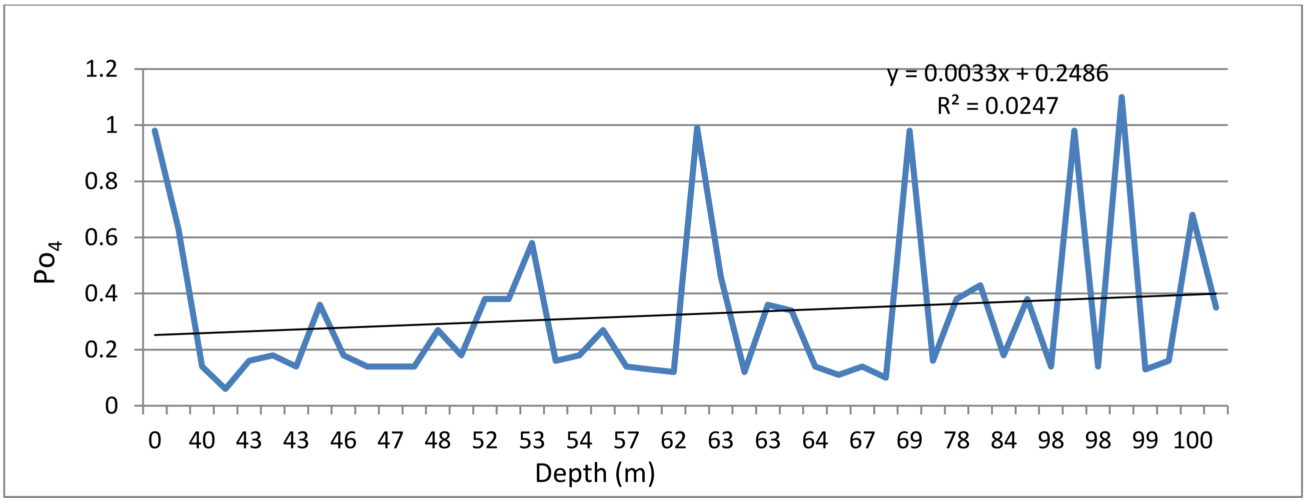


Figure 7 Relationship between depth (m) and PO_4 (mg/L) in the groundwater samples.

ISSN: 2052-6377(Print), ISSN: 2052-6385(Online)

SUMMARY AND CONCLUSION

The study examined the impact of anthropogenic activities on the quality of shallow boreholes in Maiduguri. The study revealed that the factors compromising groundwater quality in the area are many. They include non-adherence to distance specifications between boreholes and possible point pollution sources, unsustainable solid and liquid waste management, use of pit latrines and soakaways. It is recommended that quantifying the domestic sewage that enters into the different water bodies located in the city by government will help in planning effective sewage treatment plant and minimizing groundwater pollution by sewage. Also hygienically approved and scientifically feasible technologies for waste disposal (both solid and liquid) should be explored and adopted by the Borno State Environmental Protection Agency to check the possibilities of indiscriminate land-dumping of waste. Also, the agency should ensure that appropriate spacing of boreholes according to the standard specification by relevant ministries to protect the boreholes from potential contaminant sources e.g. septic tank, effluent disposal areas should be strictly or observed or enforced.

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International Journal of Physical and Human Geography
Vol.4, No.2, pp.11-26, June 2018
Published by European Centre for Research Training and Development UK (www.eajournals.org)

APPENDIX 1:

Results of Physicochemical Analysis

Sample ID	TDS(mg/l)	Turbidity NTU	PO_4	Fe	Mn	Cr	Cu
L1	209.00	8.00	0.14	0.01	0.02	0.04	8.00
L2	221.00	4.00	0.10	0.01	0.02	0.05	12.00
L3	208.00	2.00	0.12	0.02	0.01	0.04	8.30
L4	101.00	1.00	0.34	0.02	0.30	0.08	0.20
L5	114.00	2.00	0.18	0.02	0.03	0.08	12.00
L6	168.00	6.00	0.46	0.14	0.04	0.30	13.00
L7	87.00	4.00	0.16	0.18	0.03	0.18	9.60
L8	367.00	4.00	0.14	0.02	0.04	1.00	8.40
L9	206.00	1.00	0.43	0.02	0.03	0.05	13.00
L10	125.00	1.00	0.16	0.14	0.06	0.12	0.40
L11	131.00	4.00	0.36	0.18	0.02	0.07	4.00
L12	394.00	6.00	0.38	0.01	0.06	1.10	4.01
L13	260.00	2.00	0.14	0.02	0.02	0.06	8.40
L14	111.00	1.00	0.18	0.02	0.03	1.00	6.00
L15	392.00	4.00	0.18	0.11	0.01	0.18	12.00
L16	151.00	1.00	0.45	0.02	0.03	0.05	13.00
L17	943.00	6.00	0.12	0.02	0.02	0.03	0.80
118	943.00	11.00	0.13	0.14	0.21	0.09	4.10
L19	192.00	4.00	0.14	0.90	0.30	0.10	8.40
L20	181.00	4.00	0.16	0.60	0.13	0.11	0.40
L21	181.00	12.00	0.18	0.40	0.26	0.90	12.00
L22	58.00	2.00	0.13	0.00	0.03	0.02	8.00
L23	142.00	2.00	0.14	0.10	0.02	0.04	6.00
L24	402.00	6.00	0.58	0.14	0.60	0.30	0.03
L25	73.00	8.00	0.99	0.18	0.30	0.12	0.40
L26	360.00	4.00	0.06	0.15	2.20	0.18	0.57
L27	181.00	1.00	0.12	0.01	0.02	0.04	8.00
L28	58.00	0.00	0.27	0.00	0.00	0.02	0.02
L29	94.00	0.00	0.27	0.00	0.01	0.02	0.01
L30	169.00	4.00	0.98	0.10	0.80	0.11	0.52
L31	640.00	6.00	1.10	0.80	0.60	0.60	3.80
L32	65.00	0.00	0.98	0.60	0.40	0.10	0.56
L33	122.00	4.00	0.14	0.10	0.02	0.04	6.00
L34	104.00	2.00	0.63	0.18	0.03	0.18	4.80
L35	185.00	2.00	0.36	0.18	0.02	0.07	4.00
L36	325.00	4.00	0.38	0.01	0.06	1.00	4.01
L37	39.00	0.00	0.14	0.14	0.21	0.10	8.40
L38	59.00	1.00	0.35	0.19	0.30	0.20	0.21
L39	824.00	4.00	0.16	0.60	0.13	0.11	0.40
L40	84.00	2.00	0.11	0.14	0.63	0.12	0.41
L41	209.00	2.00	0.38	0.01	0.06	1.00	4.01
L42	109.00	3.00	0.68	0.18	0.03	0.18	4.80
L43	224.00	6.00	0.14	0.22	0.02	0.66	8.40

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L44	208.00	10.00	0.68	0.13	0.61	0.13	8.00
L45	620.00	9.00	0.14	0.01	0.02	0.04	8.00
L46	145.00	8.00	0.98	0.10	0.80	0.10	0.52
Maximum	943.00	12.00	0.34	0.16	0.21	0.24	5.39
Minimum	39.00	0.00	1.10	0.90	2.20	1.10	13.00
Average	257.39	3.80	0.06	0.00	0.00	0.02	0.01
NSDWQ	500	5	0.4	0.3	0.2	0.05	1

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