



Vulnerability of Groundwater Quality to Septic Systems in Calabar Municipality, Nigeria.

by

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Abstract

The physicochemical and bacteriological parameters of groundwater quality were examined between the wet season months of May, June and July in Calabar Municipality to investigate the effect of leaky septic systems on groundwater quality in the study area. A total of sixty (60) water samples were collected from the sampling locations of five boreholes (CMBH1, CMBH2, CMBH3, CMBH4 and CMBH5) once a week for a period of three (3) months in prewashed 2-litre plastic containers which were rinsed thoroughly with the sample to avoid contaminations and analysed in the laboratory to ascertain the concentration of the monitored parameters using Standard methods. The results of the concentrations of the sampled. The levels of pH, turbidity, EC, TH, Nitrate, Manganese, Iron, Sulphate, TDS and Copper were within the permissible limits given by NSDWQ while the concentrations of TCC, FCC, Total Chlorine, Nickel and Chromium were above the maximum permissible limits given by NSDWQ and the proximity of 7m and 15m between boreholes and septic systems, therefore poses a serious environmental concern as these concentrations may hamper the health status of unsuspecting users of these boreholes. The study showed that high microbial loads in the sampled boreholes indicate that the water sources are polluted and not safe for drinking. The study recommended that septic systems and boreholes should be located 30 m apart as recommended by WHO to avoid massive contamination. The construction processes of septic systems should be monitored by professionals and standards strictly adhered to.

Key words: Vulnerability, septic systems, groundwater, boreholes, contamination.

1. Introduction

Water has a unique place in nature amongst other natural resources, like ore minerals, fuels, forests, and live-stock. No country can survive in the absence of water. The World Health Organization (WHO) noted that majority of people in urban centres of developing countries do not have access to potable water, which is considered a basic necessity in developed countries. Interestingly, water can be put to various uses, due to its unique properties, such as domestic, industrial, commercial, agricultural, hydroelectric power generation etc. Domestically, water has been subjected to many uses, which include, drinking, cooking, washing, bathing, cleaning etc. The luxuries of domestic uses of water have become a necessity to people in their homes (Abrashinsky, 2004).

However, having abundant water resources does not necessarily mean that human water needs are satisfied or the quality standard of such water is met every day (Rajindra, 2000). On the verge of each use of water and the exploitation of land and water resources, various forms of pollution as a result of anthropogenic activities contribute to the degradation of the environmental quality (Udiba et al, 2012). Generally, water use is limited by its quality status which makes it unsuitable or unhealthy for a particular purpose. The quality status of water to a greater extent depends on its physical, chemical and bacteriological composition; thus, a clear understanding of the bacteriological and physicochemical characteristics of the water will enhance the detection of future deviation in water quality (Eze and Abua, 2003; Abua and Ajake, 2014).

Human and animal faecal wastes are believed to be the primary source of pathogenic microbial pollution of both surface and groundwater. It has been observed that bacteria are the most diverse microbes within this group with respect to their ability to infiltrate through the different layers of the soil. Many water-borne diseases such as typhoid, dysentery, diarrhea and cholera are caused as a result of bacterial contamination. FAO (1979) in Abdel-Lah (2001), revealed that the threat posed by the transmission of pathogenic bacterial organisms to public health as a result of the contamination of groundwater by septic systems has been reported throughout the world. In the same vein, domestic septic system effluent typically contains about 3×10^7 coliform bacteria/100 ml as well as numerous human viral infections up to 1×10^7 virus/litre (DeBorde et al, 1998; Abdel-Lah and Shamrukh, 2001).

Eni, Obiefuna, Oko and Ekwok (2011) reiterated that groundwater plays a fundamental but often unappreciable role in the socio-economic wellbeing of both urban and rural dwellers. Although, there are no comprehensive statistics on the proportion of urban and rural water supply derived from groundwater. In their opinion, Foster et al. (1998) estimated that more than 1 billion urban dwellers in Asia and 150 million in South America probably depend directly on groundwater in order to meet their daily water needs. In addition, schools, residence, worship centres, businesses and offices depend hugely on groundwater for their water use as well as on septic systems for their sewage and wastewater disposals (Kuttab, 1993).

1.1 Statement of the problem

It has been observed that all volumes of liquid portion of sewage effluent leave the septic system and percolate into underlying aquifer. This issue has often been neglected by hydrologists, environmentalists and the general public especially in developing countries and Calabar Municipality in particular, but this form of pollution represents the largest source of microbial contamination to groundwater. In other words, most often, unskilled labourers are contracted to carry out the construction of such septic systems due to cheaper costs. The construction processes are often rushed with substandard materials and the methods employed in their construction makes it possible for such microbial contamination to leach easily into the underlying aquifer as a result of constant failures of the system, thereby causing groundwater contamination especially during the wet season. This agrees with the study of Sincero and Sincero (2006) who posited that septic tanks have been found to fail leading to profuse leakages which in turn degrades the environment.

Landlords also resort to the drilling of boreholes in order to tap groundwater without proper consideration of feasible geotechnical surveys and the proximity between boreholes and septic systems (Fubara-Manuel and Jumbo, 2014). Groundwater can be contaminated by different means, but close proximity (< 30 m) of septic systems to boreholes is the commonest cause of contamination especially when there is failure of such systems and presence of cracks or fissures in the adjoining geological formation (Onunkwo and Uzoije, 2011). This study however assessed the effect of leaky septic systems to boreholes; the study intends to investigate the proximity of boreholes to soak-away (septic system) and create awareness on the menace of leaky septic systems pollution on boreholes.

1.2 Objectives

It is upon these submissions and background that this study:

1. examined the vulnerability of groundwater quality status to leaky septic systems
2. assessed the proximity between septic systems and boreholes in Calabar Municipality, Nigeria.
3. make possible suggestions to observed problems based on findings.

2.0 Literature Review

Researches on the impact of septic systems on groundwater quality have been examined by various scholars among whom Abdel-Lah (2001) who investigated the impact of septic system on groundwater quality in a Nile Valley Village, Egypt; DeBorde et al. (1998) who examined virus occurrence and transport in a school septic system in an unconfined aquifer and Fubara-Manuel and Jumbo (2014) who assessed the effect of septic tank locations on borehole water quality in Port Harcourt, Nigeria. Also Onunkwo and Uzoije (2011) on exploratory survey of geochemical aspects of underground water in Ehime Mbano Area SE Nigeria as well as Eruola et al. (2013) who examined the effect of sewage intrusion from septic tanks into the consumable hand dug wells in Lagos State, Nigeria.

3.0 Materials and Methods

3.1 Materials

3.1.1 Study Area

Calabar Municipality lies between longitudes 08°50' and 08°35'E and latitudes 04°40' and 05°05'N of the equator (see Figure 1), it has a landmass of 142 km². It is a settlement built on a highland between two adjacent river valleys. It is bounded to the east by the Great Kwa River which flows into the Cross River estuary and by the Calabar River to the west (Efiog, 2011; Obianuju and Efiog, 2015). Calabar Municipality is bordered to the north by Odukpani Local Government Area (LGA), to the south by Calabar South and the mangrove swamp forest. The city is fast developing to the east towards Akpabuyo LGA and northwards towards Odukpani LGA.

Calabar Municipality is located in the tropical rainforest region of West Africa. The rainfall is characterized by double maxima, which starts from April and ends in October, reaching its climax in the months of July and September and with a short break during the month of August (known also as the August break). The lowest temperature is around 17°C and rises to about 27°C. The relative humidity of Calabar Municipality is usually between 80 per cent and 100 per cent (Nigerian Meteorological Agency, 2014). The area has an undulating topography which rises and falls gradually. The relief can be described as a lowland or plain. The area has a

2014 projected total population of 230,008 with an annual growth rate of 2.8 per cent; the projection was based on the 2006 census (National Population Commission, 2006).

Geologically, the area is made up of Tertiary to Recent continental fluvial sands and clays known as the coastal plain sands. This formation is characterized by alternating sequence of loose gravel, sand, silt, clay, lignite and alluvium (Short et al, 1967; Obianuju et al., 2015). It is underlain mostly by rocks of the cretaceous Calabar flank and Precambrian Oban massif. The coastal plain sand (Benin formation) is by far the most prolific aquifer in the area (Obianuju et al., 2015).

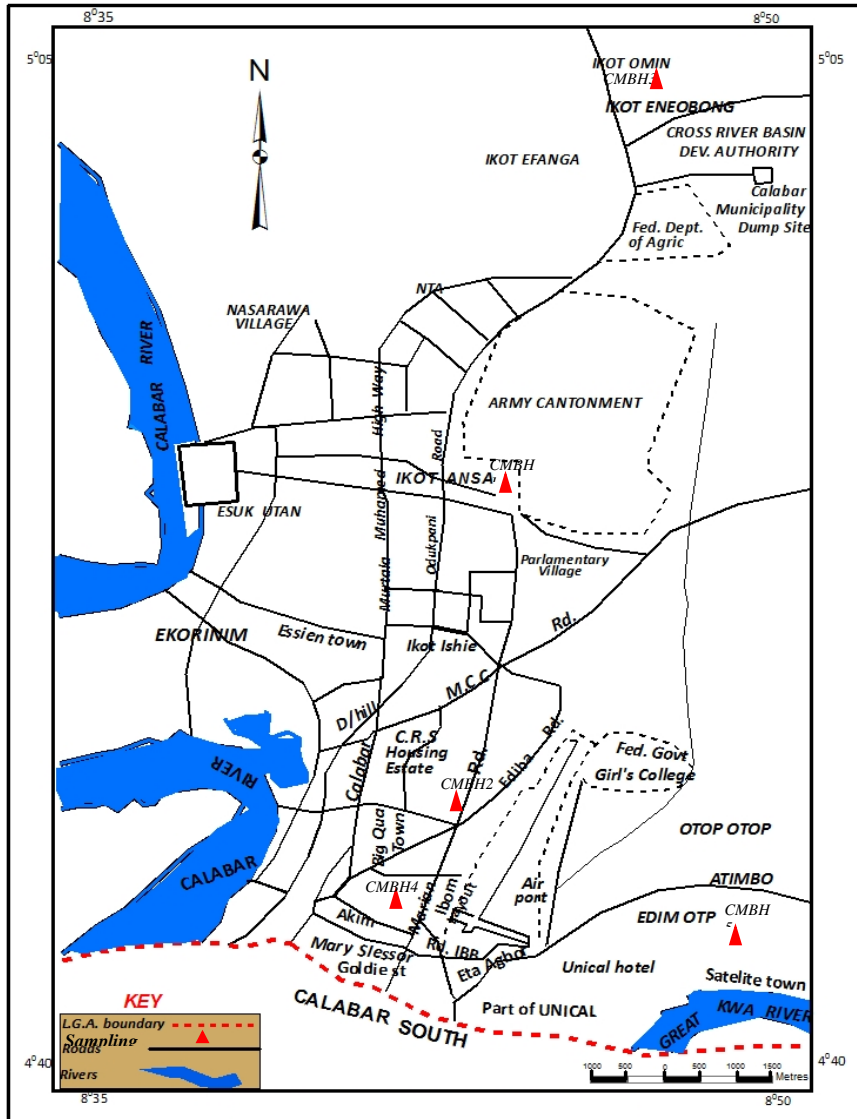


Figure 1: Map of Calabar Municipality showing sampling points

3.2 Methods

3.2.1 Design of the study

Groundwater samples were collected in the rainy season months of May, June and July of 2015. The procedure for data collection started with a reconnaissance survey of the area. This enabled functional boreholes to be identified. A functional borehole is conceptualized as one that is frequently in use with level of patronage

(use) greater than 50 persons per day (Afangideh *et al.*, 2011; Njar *et al.*, 2012). Through this approach, five (5) functional boreholes (CMBH1, CMBH2, CMBH3, CMBH4 and CMBH5), and located < 30 metres to septic systems were selected adopting the purposive sampling technique in the study area. The geo-references of the sampled locations are presented on Table 1. A total of sixty (60) water samples were collected from the functional boreholes once a week for a period of 3 months in prewashed 2-litre plastic containers and rinsed thoroughly with the sample to avoid external contaminants. The parameters studied include; temperature, pH, turbidity, conductivity, dissolved oxygen (DO), total hardness, alkalinity, nitrate, manganese, iron, sulphate, potassium, total dissolved solids (TDS), total suspended solids (TSS), phosphates, zinc, nickel, copper, aluminum, Chromium, salinity, total and fecal coliform counts. After the collection of samples, the samples were transported to the laboratory for analysis in a cooler and preserved at 4⁰C. The proximity between the septic system and boreholes were measured with the aid of a measuring tape.

3.2.2 Sources of data and laboratory analysis

Data for this research were collected from primary sources. The primary sources of data were derived from direct field measurements (*in-situ* measurements), surveys and collection of water samples for laboratory analysis by the author.

Temperature was determined with the aid of the mercury-in-glass thermometer *in situ*. pH was determined with the F10-pH meter model by inserting the probe inside the container for some minutes until the reading became stable. Electrical conductivity concentration was determined by the use of conductivity meter (Model RS-42R); the gravimetric method was used in determining TDS. Total Alkalinity was determined by Acid-Base titration method, while total hardness was determined by the EDTA titration method. Spectrophotometer model DR 2010 was used to determine the concentration of the following parameters by entering their respective program and wavelength numbers: TSS, Turbidity, manganese, iron, potassium, total suspended solids (TSS), zinc, nickel, copper, Chromium.

Chlorine was determined by the Amperometric method using the ChemScan A-2000 analyzer in the presence of potassium iodide. Sulphate and phosphate were analysed using modular iron chromatograph (Metrohm, Switzerland) having a metrohm IC-709 programmable pump, metrohm IC-733 suppressor module and 9, metrohm IC-733 conductivity detector. Total and faecal coliform counts were

analysed using presumptive count (technique). DO was analysed digitally by inserting the probe into the container containing the sample with the aid of the Jenway model 9071 water proof meter. Salinity was determined by using hand-held Refractometer (Model RHS 10ATC).

3.2.3 Data Presentation

The results obtained from the sampled parameters are presented as descriptive statistics in table 1 showing mean, range, standard deviation and standard error (see Table 3) in order to give meaning to the data obtained.

Table 1: Geo-references of the sampled locations/proximity between borehole and septic system

S/No	Borehole Sample location	Easting	Northing	Proximity between borehole and septic system (metres)
1	CMBH1 (Ikot Ansa)	8.313445	4.960766	10
2	CMBH2 (Marian Road)	8.321659	4.946591	15
3	CMBH3 (Ikot Omin)	8.320134	4.960044	12
4	CMBH4 (Big Qua)	8.323282	4.949014	7
5	CMBH5 (Edim Otop)	8.313654	4.934504	14

Table 2: The analytical results of water samples at different boreholes sites and the NSDWQ (2007) standards

S/ No	Parameter (Unit)	CMB H1	CMB H2	CMB H3	CMB H4	CMB H5	NSDWQ (2007)
1	Temperature (°C)	28.6	28.5	27.6	24.8	27.8	Ambient
2	pH	7.42	7.56	7.47	7.04	6.91	6.5-8.5
3	Turbidity (NTU)	0.69	0.529	0.365	0.164	0.581	5
4	Conductivity (μ S/cm)	66.8	66.3	66.9	65.3	67.2	500
5	DO (mg/l)	33	34	32	33	31	-
6	Total Hardness (mg/l)	34.2	34.6	34.2	34.3	34	150
7	Alkalinity (mg/l)	8.11	8.13	8.12	8.01	8.14	-
8	Nitrate (mg/l)	1.8	2.4	1.6	1.8	2.1	50
9	Chlorine (mg/l)	1.7	1.4	1.2	1.7	1.6	0.5
10	Manganese (mg/l)	0.03	0.04	0.047	0.02	0.042	0.05
11	Iron (mg/l)	0.07	0.03	0.05	0.03	0.07	0.3
12	Sulphate (mg/l)	16	18	17	18	17	100
13	Potassium (mg/l)	4.1	4	4.2	4.9	5.2	-
14	TDS (mg/l)	40.08	39.78	40.11	49.2	41.09	1000
15	TSS (mg/l)	ND	ND	ND	ND	ND	0.1
16	Nickel (mg/l)	0.044	0.03	0.035	0.048	0.029	0.02
17	Zinc (mg/l)	0.12	0.14	0.17	0.15	0.14	-
18	Chromium (mg/l)	0.001	0.004	0.006	0.001	0.006	0.05
19	Copper (mg/l)	0.12	0.08	0.08	0.14	0.16	1
20	Salinity (ppt)	0	0	0	0	0	0.05
21	Total coliform (cfu/100ml)	5	12	9	11	17	0
22	Fecal coliform count (cfu/100ml)	13	8	7	14	6	0

Nigerian Standard for Drinking Water Quality, NSDWQ (2007); ND=Not Detected .

Table 3: Descriptive statistics summary of the bacteriological and physicochemical parameters of water sample from the sampled boreholes

Parameter (Unit)	Min. Value	Max. Value	Mean	Range	Standard Dev.	S _E
Temperature (°C)	24.8	28.6	27.46	3.8	1.54854771	0.692532
pH	6.91	7.56	7.28	0.65	0.28661821	0.12818
Turbidity (NTU)	0.164	0.69	0.4658	0.526	0.20541105	0.091863
Conductivity (μS/cm)	65.3	67.2	66.5	1.9	0.74498322	0.333167
DO (mg/l)	31	34	32.6	3	1.14017543	0.509902
Total Hardness (mg/l)	34	34.6	34.26	0.6	0.21908902	0.09798
Alkalinity (mg/l)	8.01	8.14	8.102	0.13	0.05263079	0.023537
Nitrate (mg/l)	1.6	2.4	1.94	0.8	0.31304952	0.14
Chlorine (mg/l)	1.2	1.7	1.52	0.5	0.21679483	0.096954
Manganese (mg/l)	0.02	0.047	0.0358	0.027	0.01077961	0.004821
Iron (mg/l)	0.03	0.07	0.05	0.04	0.02	0.008944
Sulphate (mg/l)	16	18	17.2	2	0.83666003	0.374166
Potassium (mg/l)	4	5.2	4.48	1.2	0.53572381	0.239583
TDS (mg/l)	39.78	49.2	42.052	9.42	4.02621038	1.800576
TSS (mg/l)	0	0	0	0	0	0
Nickel (mg/l)	0.029	0.048	0.0372	0.019	0.00846759	0.003787
Zinc (mg/l)	0.12	0.17	0.144	0.05	0.0181659	0.008124
Chromium (mg/l)	0.001	0.006	0.0036	0.005	0.00250998	0.001122
Copper (mg/l)	0.08	0.16	0.116	0.08	0.03577709	0.016
Salinity (ppt)	0	0	0	0	0	0
Total coliform count (cfu/100ml)	5	17	10.8	12	4.38178046	1.959592
Fecal coliform count (cfu/100ml)	6	14	9.6	8	3.64691651	1.630951

S_E= Standard Error

4.0 Results/Findings

The results of bacteriological and physicochemical parameters analysed during the wet season months of May, June and July of 2015, are presented in Table 2, while the summary of statistical description of the data are presented in Table 3.

Tables 2 and 3 revealed that, temperature of the samples ranged from 24.80 – 28.60 (27.46±0.69°C); pH ranged from 6.91 – 7.56 (7.28±0.13); Turbidity varied between 0.169 – 0.69 (0.47±0.09 NTU), conductivity was within the range of 65.3 – 67.2 (66.5±0.33uS/cm). DO ranged between 31 – 34 (34.26±0.51 mg/l); Total

hardness on the other hand varied between 34 -34.6 (34.26 ± 0.09 mg/l) across the sampled boreholes; Alkalinity varied from 8.01 – 8.14 (8.102 ± 0.02 mg/l); Nitrate varied between 1.6 -2.4 (1.94 ± 0.14 mg/l); Chlorine ranged from 1.2 – 1.7 (1.52 ± 0.09 mg/l); Manganese was in the range between 0.02 -0.047 (0.036 ± 0.005 mg/l); similarly, Iron varied between 0.03 – 0.07 (0.05 ± 0.009 mg/l); Sulphate varied from 16 -18 (17.2 ± 0.37 mg/l).

In the same vein, Potassium varied between 4 -5.2 (0.24 mg/l); TDS ranged from 39.78 – 49.2 (42.05 ± 1.80 mg/l); TSS and Salinity were however not detected throughout the period of this study. Nickel ranged between 0.029 – 0.048 (0.037 ± 0.004 mg/l); Chromium varied between 0.001 – 0.006 (0.0036 ± 0.001 mg/l); Copper ranged between 0.08 - 0.16 (0.116 ± 0.016 mg/l); Total coliform count (TCC) ranged between 5 – 17 (10.8 ± 1.96 cfu/100ml) and Fecal coliform count (FCC) varied between 6 – 14 (9.6 ± 1.63 cfu/100ml).

Temperature recorded the highest value of 28.6°C at CMBH1. Higher temperatures especially during the wet season as recorded throughout the study period thus indicate that there is a significant impact of leaky septic systems on groundwater quality. This study is in line with the study of Eni et al. (2011) in terms of the degree of temperature in groundwater around Calabar. The pH had the lowest value of 6.91 at CMHB 5 indicating slight acidity; the low pH value could be attributed to dilution of ionic concentration by rain water of low pH which infiltrated into the borehole (Akpan, 2002). The pH of rain can be as low as 5.6 due to dissolved carbon (IV) oxide. The pH however was within the recommended limit provided by the NSDWQ (2007). Turbidity recorded the lowest value of 0.164 NTU at CMHB4 and highest value of 0.69 NTU at CMBH1. Turbidity is a measure of water clarity, that is to say, how much the materials suspended in water decreases the passage of light through the water, it also affect the colour of the water.

Akeredolu (1991) reported that, the higher the turbidity, the cloudier the water appears. If water becomes too turbid, it loses the ability to support a wide variety of plants and other aquatic organisms. It is caused by suspended and fine insoluble particles and colloidal impurities like clay, silt, algae and microbes. The conductivity values recorded across the five sampled boreholes were far lesser than the recommended limit of 500 mg/l as given by NSDWQ (2007). Similarly, Dissolved Oxygen (DO) had a low value of 31 mg/l at CMBH5, there was however no significant difference in DO across the sampled boreholes. The results for the concentrations of Total hardness, Alkalinity, Nitrate, Manganese, Iron, Sulphate,

Potassium and TDS showed that these parameters were within the maximum values recommended by NSDWQ (2007).

More so, TSS and Salinity were not detected throughout the study; absence of salinity in the samples indicated that there was no salt water intrusion as at the time the study was carried out. Chlorine had the highest value of 1.7 mg/l at CMBH1 and CMBH4 respectively and low value of 1.2 mg/l at CMBH3 but these values all exceeded the safe limits given by NSDWQ (2007). Nickel recorded a high value of 0.048 mg/l at CMBH4 and a low value of 0.029 mg/l at CMBH5; the values throughout the study were above the standard limits of 0.02 mg/l. Chromium and Copper values were all within the recommended limits given by the NSDWQ (2007).

Total coliform count of 17 cfu/100ml was recorded at CMBH5 due to its close proximity to the location of the septic system and a value of 5 cfu/100ml was recorded at CMBH1. Also, Fecal coliform count values of 14 and 6 cfu/100ml were recorded at CMBH4 and CMBH5 respectively. Total fecal coliform counts throughout the study area far exceeded the safe limits of 0 cfu/100ml given by NSDWQ (2007), indicating the presence of high microbial loads in the water samples which in turn shows that the water is contaminated. It has been argued that especially in the case of heavy downpour, the heavy metals and microbial loads of infiltrating waters may suddenly increase and reach groundwater quickly (Kistemann et al, 2001).

Similarly, the minimum distance between boreholes and septic systems as recommended by WHO (2010) should be 30m, this study showed that all the sampled boreholes were sited very close to septic systems, as the proximity between boreholes and septic systems ranged between 7m to 15m (see table 1) which violated the recommended standard given by WHO (2010). This according to Fubara-Manuel et al. (2014) is ascribed to the maximization of space for the construction of the main building, leaving smaller spaces for boreholes and septic system constructions at very close proximity. In this study, it was discovered that Chlorine, Total and faecal coliforms were highly susceptible, this is because their mean values were higher than the maximum limits issued by NSDWQ (2007).

The spatial variation of results from one borehole to another in the study area could be attributed to the depth, topography variation, permeability and infiltration rate of the boreholes. Even if the boreholes were located in the same study area, these factors are very key parameters that impact water quality in boreholes. It is

important to note that this work limited its scope to the proximity of boreholes to septic systems and water quality therein.

5. Conclusion and Recommendations

It is indeed true that natural conditions as well as anthropogenic activities in any environment significantly contribute to the contamination of that environment which in turn affects human health. However, this study examines the effect of leaky septic systems on groundwater. The results obtained from the study shows that the water is polluted possibly from the impact of leaky septic systems which suggest a possible risk to the population of the study area given the toxicity of these heavy metals, the high microbial loads and the fact that in the study area, ground water is the main source of water supply. In the same vein, based on the results presented. Tables 2 and 3, there is however, a strong indication of the impact of leaky septic systems on groundwater quality status with high mean values of 10.8 ± 1.96 and 9.6 ± 1.63 cfu/100ml for total and fecal coliform counts respectively, which far exceeded NSDWQ (2007) recommended limit of zero (0)/100ml of total fecal coliform counts for drinking water. The proximity of the sampled boreholes to septic systems in the areas examined did not conform to the recommendation given by WHO.

It was recommended from this study that septic systems should be located far from boreholes sites (30m apart as recommended by WHO) to avoid massive contamination. Secondly, the construction processes of septic systems should be monitored by professionals and standards strictly adhered to. There should be constant evacuation of sewage effluents (at least once in three years) from septic systems by the municipal waste management agencies or private individuals charged with the responsibilities to maintaining safety precautionary measures.

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