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Original Research Article

Physicochemical and Bacteriological Analysis of Selected Borehole Water Close to Septic Tanks in Edo State, Nigeria

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ABSTRACT

Groundwater from boreholes is particularly vulnerable to pollution, especially from septic tank effluents. This study was carried to assess the physicochemical and bacteriological qualities of borehole water close to septic tanks in Edo State, Nigeria. Groundwater samples were collected from twelve (12) residential boreholes in Ovia North East (Iguosa, Isihor), Egor (Federal Government Girls College (FGGC) road, Technical College road) and Oredo (Olague, Uzagbe) Local Government Areas of Edo State for three months, with distances ranging from 5.2 to 15 m from the septic tanks. The University of Benin Water board served as the control station. Standard procedures for analysis of the determination of the physicochemical and bacteriological properties of the water samples were employed. Questionnaire analyses from the study revealed high dependence on groundwater from boreholes with low awareness of the effects of proximity of boreholes to septic tanks. Results showed that the physicochemical parameters were within acceptable limits except for total suspended solids, turbidity, ammonium and biological oxygen demand (BOD) which were above recommended limits. Results also showed that the proximity of boreholes to septic tanks may suggest a high tendency for groundwater contamination. Total coliform count in all the stations, Escherichia coli and Enterococcus faecalis in Isihor were above threshold levels. The presence of E. coli and E. faecalis in the borehole water samples and the levels of total coliform bacteria above threshold values indicate that the assessed borehole water sources close to septic tanks are not potable; thus, raising serious public health concerns.

1. INTRODUCTION

Groundwater serves as the major source for drinking water in developing countries like Nigeria, as it provides a reasonable constant supply of potable water (Howard, 1997; Asiwaju-Bello *et al.*, 2020). Groundwater is extensively utilized in Nigeria in both rural and urban areas with about 60% of the nation's population obtaining portable drinking water from groundwater sources (Omole, 2013). This high demand is attributed to the inability of the government to meet the ever-increasing water demand as a result of inadequate and dilapidated infrastructure (Omole, 2013). Most people, therefore resort to groundwater sources such as boreholes, which is usually drilled into the aquifer for the abstraction of groundwater. Consequently, there is an increase in borehole drilling for the abstraction of groundwater especially in new residential areas (Omole, 2013; Akinlalu and Afolabi, 2018).

There are however potential problems associated with boreholes as possible sources of portable groundwater (Chimphamba and Phiri, 2014). The vulnerability of borehole water to contamination is of serious public health concern and currently a growing global water quality issue (Odey *et al.,* 2017*;* Taonameso *et al.,* 2019). The unavailability of infrastructure to obtain portable water and the absence of central wastewater treatment systems in most areas has compelled many households to drill boreholes to obtain portable groundwater and install septic tanks to dispose of wastewater (Adelekan, 2010; Omole, 2013; Fubara-Manuel and Jumbo, 2014). However, most of these households do not take cognizance of the distance of the boreholes from septic tanks. The stipulated distance of 30 m upslope between the water source and the septic tank most times is disregarded, consequently resulting in groundwater contamination in some of these boreholes (Takal and Quaye-Ballard, 2018). Borehole contamination from leaking septic is the most common cause of borehole water pollution and it is most times associated with the close proximity of septic tanks to boreholes/groundwater especially where the adjoining geological formation is fissured (Fubara-Manuel and Jumbo, 2014). Sewage stored in septic tanks may contaminate groundwater sources like boreholes as the effluents from the septic contains high levels of bacteria and nutrients capable of contaminating groundwater (Takal and Quaye-Ballard, 2018).

Borehole water pollution as a result of the close proximity of boreholes to septic tanks have been reported (Adetunji and Odetokun, 2011; Fubara-Manuel and Jumbo, 2014; Banda *et al*., 2014; Chimphamba and Phiri, 2014; Palamuleni and Akoth, 2015; Eze and Eze, 2015; Oluwasola *et al.,* 2017*,* Mlipano *et al*., 2018; Takal and Quaye-Ballard, 2018; Ekhosuehi *et al.,* 2018). However, only scanty data exist on the effect of the close proximity of boreholes to septic tanks on borehole water quality in Benin City, Nigeria. It is therefore against this background that the physicochemical and bacteriological qualities of borehole water close to septic tanks in Edo State, Nigeria were assessed to determine the safety of drinking water from boreholes close to septic tanks.

2. MATERIALS AND METHODS

2.1. Study Area

Analysis of groundwater from boreholes was carried out in three Local Government Areas (LGA) in Edo State (Ovia North East, Egor, and Oredo) (Figure 1). In Ovia North East LGA, two (2) sampling stations comprising of four (4) residential boreholes were sampled (Iguosa (House 1: Latitude 6.43131 N and Longitude 5.59806 E; House 2: Latitude 6.43219 N and Longitude 5.59806 E) and Isihor (House 3: Latitude 6.41113 N and Longitude 5.61000 E; House 4: Latitude 6.41306 N and Longitude 5.60917 E). In Egor LGA, two (2) sampling stations comprising of four (4) residential boreholes were sampled (Federal Government College Road (FGGC) (House 5: Latitude 6.38563 N and Longitude 5.61731 E; House 6: Latitude 6.38566 N and Longitude 5.61724 E) and Technical College road (House 7: Latitude 6.3851 N and Longitude 5.61782 E; House 8: Latitude 6.38594 N and Longitude 5.61621 E). In Oredo LGA, two (2) sampling stations comprising of four (4) residential boreholes were sampled (Olague (House 9: Latitude 6.33786 N and Longitude 5.61731 E; House 10: Latitude 6.33928 N and Longitude 5.61725 E) and Uzagbe (House 11: Latitude 6.33685 N and Longitude 5.61949 E; House 12: Latitude 6.3379 N and Longitude 5.61898 E).

A total of twelve (12) private residential boreholes (four (4) boreholes from each local government area, with composite sampling, carried out for houses in the same location) were used for the study.

The stations were selected because water from boreholes is the major source of water for drinking in these areas and boreholes especially privately owned boreholes are fast becoming ubiquitous in these areas (Agheyisi, 2007). University of Benin Water board (Latitude 6.40697 N and Longitude 5.61009 E) served as the control station.

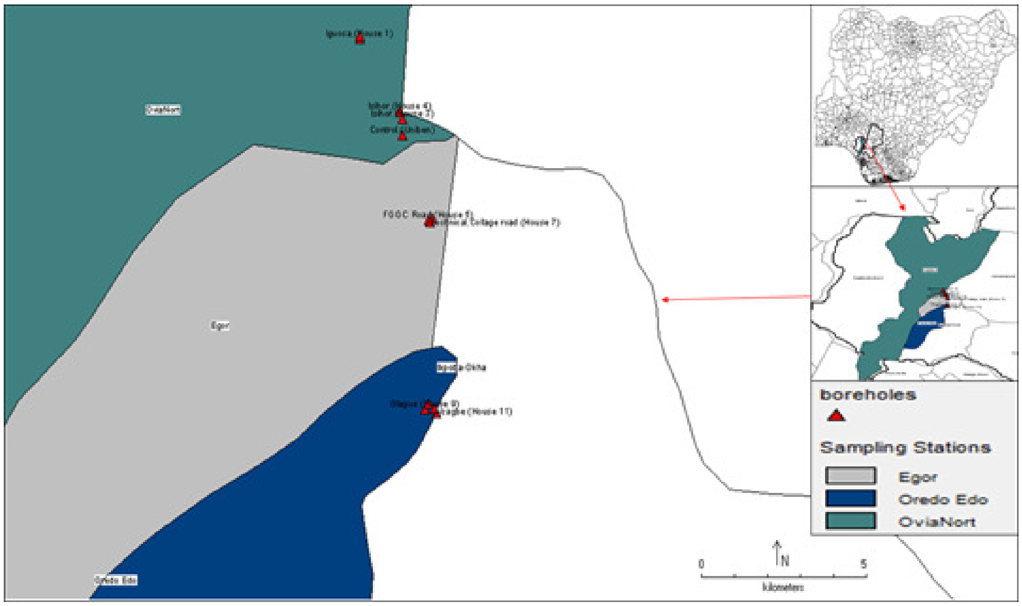
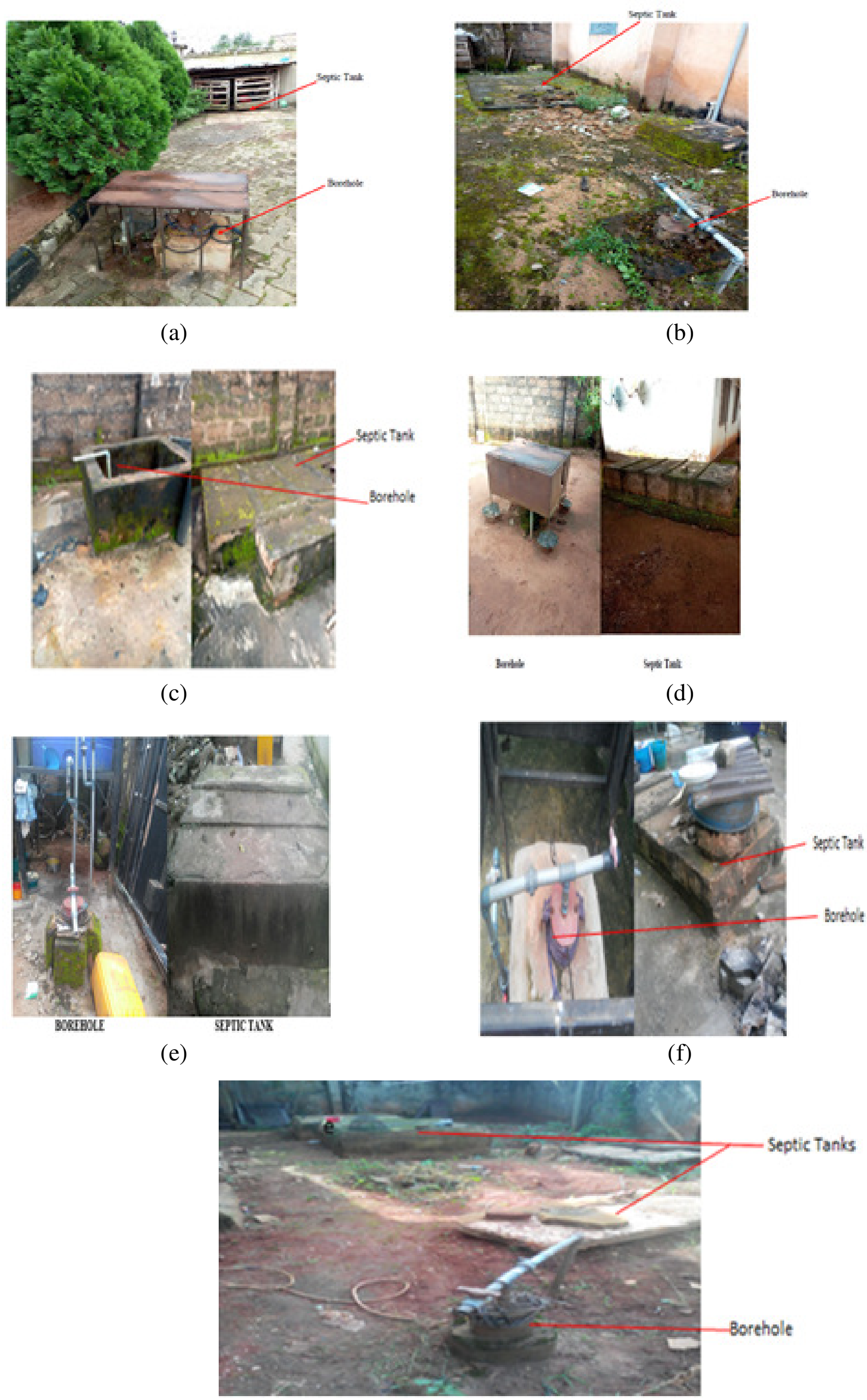


Figure 1: Study area showing sampling stations and residential boreholes sampled

The distances of these boreholes to the septic system ranged from 5.2 to 15 m (Figures 2 a to g). The University of Benin Water board which served as the control station had a distance of over 30 meters (> 30 m) between the water source and septic tank.



(g)

Figure 2(a-g): Boreholes assessed close to septic tanks

2.2. Questionnaire Survey

Qualitative analysis was carried out using questionnaires. The questionnaires were completed by members of the twelve (12) households with the assessed boreholes and also people around the study location to get relevant information for the study. A sample of the questionnaire is presented in Figure 3. The questionnaire was used to assess the usage and quality of the borehole water. A range of characteristics relating to the borehole water was documented and it include the amount of water consumed per day, usage of the borehole water, treatment and method of treatment of the borehole water, awareness of the distance of borehole to septic tank when building or renting their apartments, and awareness of the effect of the close proximity of borehole to the septic tank on the borehole water quality. This qualitative survey was used to assess awareness and health risk factors relating to borehole water usage in the study area.

QUESTIONER FOR BOREHOLE WATER QUALITY ASSESSMENT

Q1. Would you agree to participate in the interview?
1. Yes
2. No

Respondent:
Name...
Address
....
....
....
Phone ....

Q2. Your gender:
1. Male
2. Female

1. Uses of Water

Q3. Is the Borehole water your main source of drinking water for members of your household?
1. Yes
2. No

Q4. Does your household use other sources of water for drinking?
1. Yes, Please State____________________
2. No

Q5. Please tick other uses of the Borehole water
1. Drinking
2. Cooking
3. Washing clothes
4. House cleaning
5. Bathing/washing your bodies
6. Domestic agriculture
7. Other (write down.................)

Q6. How much of water do you drink per day?
1. 0.5 - 1 Litres
2. 1 - 1.5 Litres
3. 1.5 - 2 Litres
4. 2 - 3 Litres
5. More than 3Litres

2. Drinking water treatment

Q7. Has your household ever treated the water to make it safer to drink?
1. Yes
2. No

Q8. What do your household do to make the water safer to drink? (You can tick more than one option)
1) Boil the water
2) Add bleach/chlorine
3) Sieve it through cloth
4) Water filter (ceramic, sand, composite, etc.)
5) Let it stand and settle
6) Other (please write down....................)
7) Don't know

3. Awareness

Q9. Are you confident that the drinking water from your borehole is suitable for drinking?
1. Yes
2. No

Q10. Have you analysed your Borehole drinking water quality in a laboratory?
1. Yes
2. No

Q11. Do you know that close proximity of septic tanks to boreholes could be a source of pollution to your drinking water?
1. Yes
2. No

Q11. Do you know that faecal matter and other contaminants like pathogenic bacteria can drain from septic systems to contaminate your borehole water?
1. Yes
2. No

Q11. Did you take cognizance of the distance of your borehole from the septic tanks when building or when looking for accommodation?
1. Yes
2. No

Conclusion

I have better understanding of the effects of close proximity of septic tanks to boreholes to my drinking water
1. Yes
2. No

I would ensure adequate treatment of my water before drinking
1. Yes
2. No

Figure 3: Questionnaire for borehole water quality assessment survey

2.3. Collection of Borehole Water Samples and Borehole-Septic tank Measurements

Water samples were collected randomly for three months (April to June 2018) from twelve (12) residential borehole sources with distances ranging from 5.2 to 15 m from the septic system. These distances of borehole groundwater sources from septic tanks were all less than the WHO (WHO, 2006a) standard safe distances of 30 meters between septic tanks and any drinking water source. The University of Benin Water board served as the control station as this station had no septic tank close to the water source.

Water samples were collected directly from the borehole outlet and not from taps to avoid other possible sources of contamination. Samples were collected in clean and sterile glass sampling bottles, while samples for biological oxygen demand (BOD) and dissolved oxygen (DO) analysis were collected in amber bottles. Samples for dissolved oxygen analysis were mixed with 1 ml each of Winkler's solutions A and B. Each sample was well labeled according to respective stations then stored in ice-packed containers and transported immediately to the laboratory for analysis. Distance between each borehole and septic tank was measured with a surveyor's measuring tape.

2.4. Borehole Water Quality Assessment

2.4.1. Physicochemical assessment

Methods used in the determination of the physicochemical parameters (pH, conductivity, total suspended solids (TSS), turbidity, alkalinity, chloride, phosphate, sulphate, nitrate, ammonium, dissolved oxygen, biological oxygen demand) of water samples was based on standard methods described by the American Public Health Association (APHA, 2005). The pH, conductivity, turbidity and salinity of the water samples was determined in-situ using the Hanna meters (Hi-1922 model). Chloride was determined by the Argentometric titration method while total suspended solids were measured determined gravimetrically (APHA, 2005). Dissolved oxygen was determined by Winkler's method while for BOD, samples were incubated at 20 °C for five days while for BOD, samples were incubated at 20 °C for five days followed by the determination of the dissolved oxygen concentration at day 0 and day 5 (APHA, 2005).

2.4.2. Bacteriological assessment

Total coliform counts, *Escherichia coli* and *Enterococcus faecalis* were assessed. The total coliform count was carried out by the most probable number (MPN) technique using Mac-Conkey broth in multiple tubes and incubating at 37 °C for 24 hours (MacFadding, 2000). The total plate count technique was used to estimate the number of viable colonies of bacteria present in the samples. For Isolation of pure culture, 0.02 ml of samples were dispensed into MarCartney bottles containing nutrient broth and left in the incubator for 24 hours. After 24 hours, mixed bacterial colonies were observed from the nutrient broth. With the aid of a sterilized wire loop, the suspects were subcultured into petri dishes containing solidified MacConkey agar and the organisms were streaked on the agar plates several times and then incubated in an inverted position for 24 hours (USEPA, 2003).

2.5. Statistical Analysis

Data were analyzed using Microsoft® Excel version 2013 (Microsoft, Redmond, WA, USA). Basic statistical analysis to characterize the stations in terms of physicochemical and bacteriological parameters was carried out. Descriptive statistics were used to express the mean, percentage, standard deviation, standard error of the assessed parameters. Mean, standard deviations and standard error were calculated from the results of the analysis of two samples per sampling location (composite sampling was carried out for houses in the same location). One-way analysis of variance (ANOVA) was used to test for significant differences in spatial and temporal variations in the assessed physicochemical and bacteriological parameters. P-values of less than 0.05 were considered statistically significant. The correlation coefficient was carried out to determine the relationship between physicochemical parameters/bacteria load and the distance of the Boreholes to Septic Systems across the stations. The assessed water quality results were compared with the Nigerian Standards for Drinking Water Quality (NSDWQ, 2007) and the World Health Organisation (WHO, 2006b) drinking water standards.

3. RESULTS AND DISCUSSION

3.1. Qualitative Assessment of Borehole Water

The result and summary of information collected from questionnaires administered to respondents within the study area for qualitative assessment of the study are presented in Figures 4a to 4e. Questionnaire analyses from the study revealed that 87% of respondents use the borehole water as their main source of drinking water while 63% have never treated their borehole water to make it safer to drink. Majority (87%) of the respondents have never tested their borehole water in a laboratory and 62% do not know proximity of septic tanks to boreholes as a source of pollution to their drinking water. 63% of the respondents did not take cognizance of the distance of borehole from septic tanks when building or looking for accommodation. Results of the study, therefore, indicate that residents of the communities assessed depend heavily on groundwater from boreholes which agrees with previous reports that borehole water serves as the *main source* of drinking water for the local population of Nigeria (Ibe and Okplenye, 2005; Akpoveta *et al.,* 2011). Results of the qualitative assessment also showed a low level of awareness on the siting of boreholes close to septic tanks (Figure 4a to 4c) and the need for the borehole water test in the laboratory. Although 38% of the people are aware of the effects of the close proximity of boreholes to septic tanks, they have no alternative because of the inability of government to provide potable water and central wastewater or sewage treatment system. People are therefore compelled to install septic tanks and boreholes in the little space available to them.

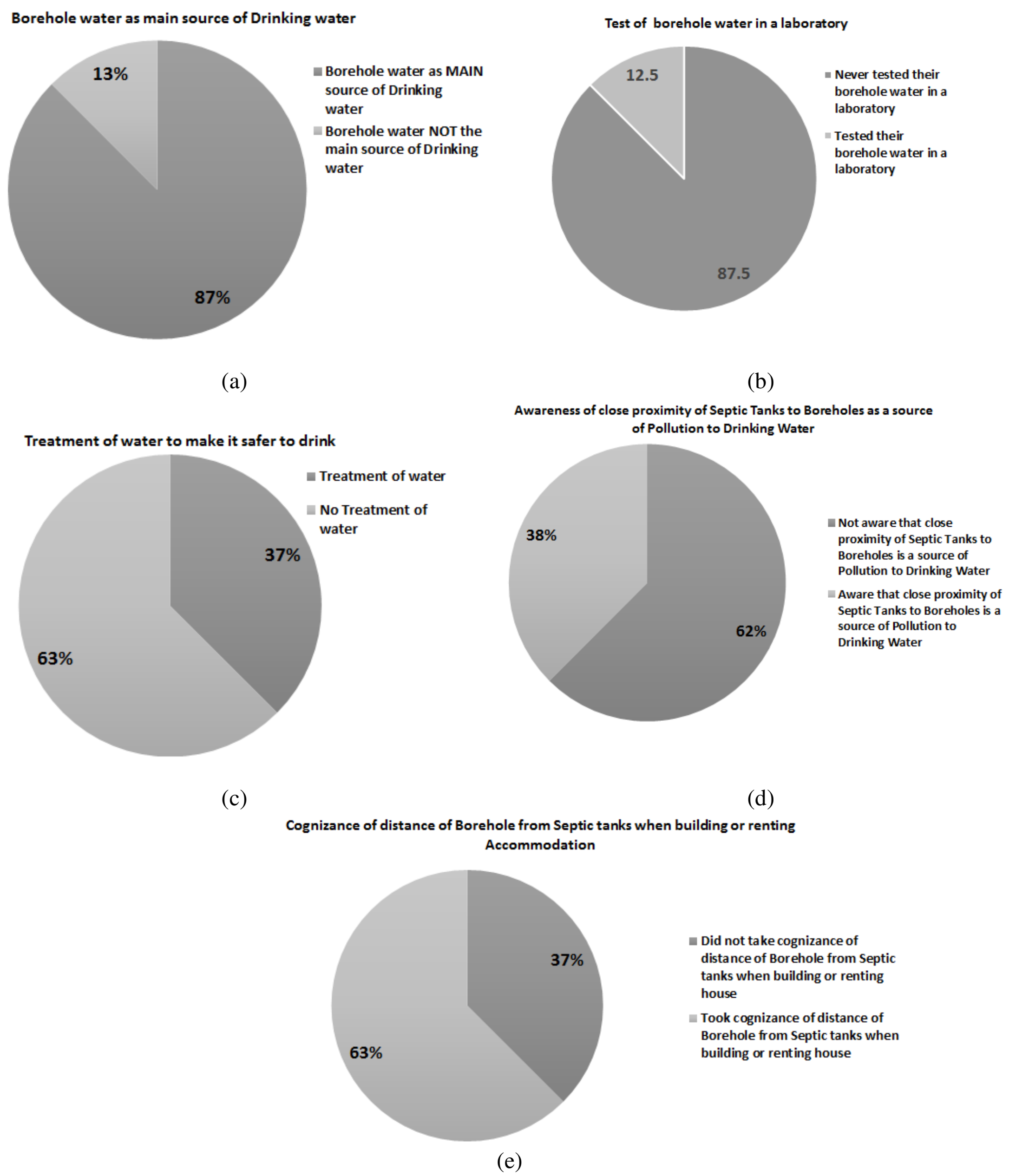


Figure 4(a-e): Qualitative assessment of borehole water

3.2. Physical-chemical Analyses of Water from Boreholes

Table 1 shows the results of the physicochemical analyses of groundwater from boreholes in selected areas in Edo State. Generally, most of the physicochemical parameters in the boreholes sampled were within the WHO and NSDWQ water standards for drinking water. However, pH values in all the stations assessed including the control had slight variations with values below those recommended by WHO and NSDWQ (Table 1) indicating that the water was slightly acidic. The slight variation in pH values between the control and sampling areas as well as the acidic nature of the assessed water samples might be attributed to the general local geology and environmental condition of the sampling areas and also to the nature of the underlying rocks (Pritchard *et al.,* 2010; Kanyerere *et al.,* 2012). Low pH values of water sources in developing countries have been reported (Pritchard *et al.,* 2010; Kanyerere et *al.,* 2012; Fubara-Manuel and Jumbo, 2014; Eze and Eze, 2015; Shigut *et al.,* 2017) and results are similar to those obtained in this study. However, only water with pH values below 4 has been reported to irritate due to the corrosive effect (Sabrina *et al.,* 2013). Higher values of (6.0-7.97) for pH in groundwater have been recorded for groundwater (Palamuleni and Akoth 2015; Garba *et al.,* 2016; Nwugha *et al*., 2016).

Turbidity level in borehole water from FGGC road and total suspended solids in borehole water samples from Iguosa, FGGC road, Technical College road and Uzagbe were above the recommended limits. The turbidity values indicate the presence of organic and/or inorganic constituents in the water samples. Consumption of water with high turbidity may have negative impacts on consumers and could result in health risk, as excessive turbidity can reduce the efficiency of disinfectants on kill pathogenic microorganisms in water (Singh *et al.,* 2013*;* Tiwari and Singh 2014). Total suspended solids of water are usually particles found in the water larger than 2 microns (2µm). Suspended matter in wastewater especially domestic wastewater is largely organic (Aniyikaiye, 2019) and these tend to degrade drinking water quality (Ogbeibu and Anagboso, 2004; Oboh and Agbala, 2017). TSS ranged from 0.0 to 3.83 mg/L across the stations. The values recorded fall within the WHO limit of 3 mg/L, but FGGC and Technical exceeded the NSDWQ limit of 0.1 mg/L for suspended solids in drinking water. Nwugha *et al.* (2016) reported lower values (0.03-0.2 mg/L) for suspended solids in groundwater samples. High TSS values in water can be attributed to higher concentrations of organic (bacteria, nutrients, pesticides) and inorganic (metals) particles in the water (Murphy, 2017; Musa *et al.,* 2018; Aniyikaiye *et al.,* 2019). This corroborates findings from this study as results showed a significantly strong positive correlation ($p<0.05$. $r=0.88$) between the total coliform bacteria counts and TSS concentrations in borehole water samples from all the stations except borehole water samples from Olague.

Phosphate is one of the principal nutrients that limit productivity (Ekeh and Sikoki, 2003). It occurs in groundwater as a result of domestic sewage, detergents and agricultural effluents (Ekeh and Sikoki, 2003). Phosphate values observed in this study were within the WHO and NSDWQ limit of 0.2 mg/L and 5 mg/L respectively for phosphate in drinking water except for Iguosa. Although the concentration of phosphate was low, it has been reported that a low phosphate value of 0.01 mg/L in groundwater could promote the growth of algae (Adekunle *et al.*, 2007). Fubara-Manuel and Jumbo (2014) reported values of less than 0.05 mg/L for phosphate in groundwater in Port-Harcourt, Nigeria. Ibiang *et al.* (2016) recorded higher values of (4.02-6.30mg/L). Biological oxygen demand (BOD) concentrations from borehole water from Iguosa and dissolved oxygen (DO) in water samples from Isihor were above WHO and NSDWQ limits. High BOD is an indication of poor water quality and may also indicate faecal contamination (Dangi *et al.,* 2017). BOD is a direct measurement of oxygen requirement and an indirect measurement of biodegradable organic wastes in water. The values recorded in this study were above those previously reported (Fubara-Manuel and Jumbo, 2014; Mlipano *et al.* 2018.

Ammonium concentration ranged from 2.37 to 4.77 mg/L across the sampled stations. Ammonium concentrations in all the assessed stations including the control station were all above the WHO and NSDWQ recommended limits. High concentration of ammonium in groundwater, although not directly harmful to human health, is often an indication of groundwater being influence by anthropogenic activities, such as spreading fertilizers of manure or leaking sewage water (Perovic *et al.*, 2020). Septic systems and wastewater can be important point sources for releasing contaminated water containing high levels of ammonium (Perovic *et al.*, 2020). Fubara-Manuel and Jumbo (2014) recorded lower ammonium values of between <0.05 to 1.4 mg/L in a groundwater quality assessment in Port-Harcourt, Nigeria.

3.3. Bacteriological Analyses of Water from Boreholes

Bacteria count is an important water quality parameter especially drinking water (João and Cabral, 2010; Fubara-Manuel and Jumbo, 2014). Mean concentrations of total coliform counts ranged from 43.33 cfu/100 ml to 17900.17 cfu/100 ml l (Table 1). Coliform organisms present in drinking water are used as indicators of water pollution (Ray and Hill, 1978; Gruber *et al.,* 2014). The presence of high concentrations of coliforms in the borehole water from the sampling stations compared to the control, therefore, indicates faecal contamination (Haruna *et al.,* 2005) which could result in waterborne diseases such as hepatitis, typhoid fever, dysentery, etc when this water is taken into the body as drinking water (Lawson, 2011). All the water samples from the boreholes were above the WHO and NSDWQ water standards for drinking water which calls for serious health concern.

Table 1: Physicochemical analyses of groundwater (Mean ± SD) from boreholes in selected areas in Edo State

Parameters	Control (UNIBEN)	Sampling Stations						Water Quality Standard	
		Ovia North East		Egor		Oredo			
		Iguosa	Isihor	FGGC Road	Technical College road	Olague	Uzagbe	WHO	NSDWQ
Distance (m)	>30	*5.20±0.99	*13.65±7.71	*14.75±4.74	*5.98±1.52	*15.00±7.07	*10.00±00	30	30
pH	5.43±0.47	5.75±0.10	5.12±0.20	4.77±0.10	4.75±0.18	4.97±0.35	5.22±5.22	6.5-9.5	6.5-8.5
Conductivity (µS/cm)	26.67±11.55	24.17±8.04	11.67±2.89	43.33±2.89	20.00±0.00	211.67±7.64	158.33±158.33	1200.00	1000.00
Turbidity (NTU)	0.00±0.00	0.33±0.58	0.00±0.00	*6.67±4.25	2.33±3.21	0.50±0.87	2.50±2.50	5.00	5.00
Total suspended solids (mg/L)	0.00±0.00	*0.17±0.29	0.00±0.00	*3.83±5.01	*1.00±1.73	0.00±0.00	*2.50±2.50	3.00	0.10
Alkalinity (mg/L)	6.00±2.00	8.37±5.20	4.67±0.58	4.00±1.00	3.33±3.06	6.33±1.53	8.67±8.67	100.00	-
Chloride (mg/L)	10.59±6.11	8.26±7.31	12.94±2.04	16.47±4.08	11.75±5.37	60.01±7.06	49.42±49.42	250.00	250.00
Phosphate (mg/L)	0.09±0.03	*1.09±1.65	0.12±0.05	0.15±0.05	0.12±0.02	*0.29±0.04	*0.26±0.26	0.20	5.00
Sulphate (mg/L)	1.33±0.58	1.82±0.74	1.83±0.76	3.50±2.29	3.83±3.01	8.33±3.25	7.17±7.17	250.00	100.00
Nitrate (mg/L)	2.48±1.51	2.73±0.59	2.90±0.79	2.86±0.40	2.28±0.55	2.52±0.39	1.95±1.95	45.00	50.00
Ammonium (mg/L)	*3.03±1.85	*4.77±2.84	*3.53±0.97	*3.49±0.48	*2.75±0.62	*3.07±0.48	*2.37±2.37	1.50	-
Dissolved Oxygen (mg/L)	7.30±0.44	5.37±2.76	*8.05±1.00	5.88±1.00	5.62±0.38	7.20±1.08	7.12±7.12	-	7.50
BOD (mg/L)	2.93±2.03	*51.63±85.19	3.13±0.96	2.45±2.21	2.50±1.43	3.15±0.65	3.57±3.57	6.00	0.05
Total coliform (cfu/ml)	0.00±0.00	*1198.33±1993.87	*17900.17±28233.38	*3003.33±3133.21	*4408.33±6165.04	*1435.00±172.99	*1788.33±1788.33	10	10
Escherichia coli (cfu/100 ml)	0.00±0.00	0.00±0.00	*16.67±28.87	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0	0
Enterococcus faecalis (cfu/100 ml)	0.00±0.00	0.00±0.00	1.77±3.06	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0	0

* Above Threshold level; WHO: World Health Organization (WHO, 2006); NSDWQ: Nigerian Standard for Drinking Water Quality (NSDWQ, 2007)

Since total coliform count serves as a secondary indicator of water contamination (Ashbolt *et al.,* 1997), *E. coli* and *E. faecalis* bacteria in the borehole water samples were assessed as indicators of contamination by human or animal faecal matter (Gearheart, 1999; Dangi *et al.,* 2017). Results showed that borehole water samples from Isihor were more contaminated with *E. coli* and *E. faecalis* than the other boreholes although results were not statistically significant ($p>0.05$). *E. coli* and *E. faecalis* counts in Isihor were above WHO and NSDWQ thresholds. The presence of *E. coli* and *E. faecalis* in the borehole water samples raises serious public health concerns as their presence in the water samples renders the water unsafe for drinking. For water to be potable, it should contain no indicator organisms of faecal contamination (WHO, 2010; USEPA, 2009). Consequently, the presence of *E. coli* and *E. faecalis* bacteria in the borehole water samples from Isihor may indicate recent microbial activity (WHO, 2011; Okoro *et al.,* 2017). These results agree with previous studies of varying levels of faecal coliforms concentrations reported in borehole water close to septic tanks (Hanchar, 1991; Fubara-Manuel and Jumbo, 2014; Palamuleni and Akoth, 2015; Ibiang *et al*., 2016; Yaw, 2016; Farouq *et al*., 2018).

3.4. The Effect of Distance from Septic Tank to Boreholes on Physicochemical Parameters of the Water

For the assessed physicochemical parameters results showed significant differences ($p<0.05$) in pH, total suspended solids, turbidity, alkalinity, phosphate, sulphate, nitrate and ammonium concentrations of the borehole water samples close to septic tanks compared to the control except for conductivity, chloride, DO and BOD (Figure 5), However, no significant differences ($p>0.05$) were observed in all the physicochemical parameters between the six sampling areas (Iguosa, Isihor, FGGC Road, Technical road, Olague, and Uzagbe). Figure 5 illustrates the relationship between the concentrations of the physicochemical parameters in the water with the respective distances from septic tanks. Results indicate significantly higher values in parameters from borehole water close to septic tanks compared to the control although, the correlations between the assessed physicochemical parameters and the distances of the septic tanks from the boreholes were quite negligible ($r<0.5$).

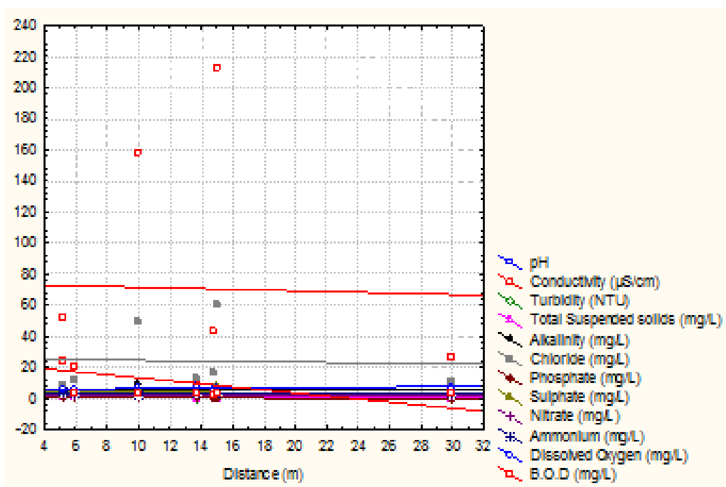


Figure 5: Effect of distance between borehole and septic tank in relation to the assessed physicochemical parameters

Fubara-Manuel and Jumbo (2014) and Mlipano 2016 reported no significant effect of the distance of boreholes from the septic tanks on pH. Fubara-Manuel and Jumbo (2014) however stated that boreholes, where the adjoining geological formation is fissured, may have variation in pH with distance from the septic tanks. The significant differences ($p<0.05$) in pH, total suspended solids, turbidity, alkalinity, phosphate, sulphate, nitrate and ammonium concentrations of the borehole water samples close to septic tanks compared to the control may be as a result of fissures in the adjoining geological formation. The weak correlation observed in this study between the assessed physicochemical parameters and the distances of the septic tanks from the boreholes could be attributed to the fact that several other factors apart from the distances of the boreholes to septic tanks could indeed affect the quality of groundwater from boreholes (Banda *et al.,* 2014;

Taonameso *et al.,* 2019), However, most boreholes may become highly polluted through continuous leaching or seepage from surrounding septic tanks (WHO 2006, Ibiang *et al.,* 2006; Ekhosuehi *et al.,* 2018).

Similarly, for the bacteriological parameters, total coliform count, *Escherichia coli,* and *Enterococcus faecalis* also showed significant differences ($p<0.05$) in the borehole water samples close to septic tanks compared to the control and no significant differences ($p>0.05$) were observed in these parameters between the six sampling areas. Furthermore, the correlations between the assessed bacteriological parameters and the distances of the septic tanks from the boreholes were also negligible ($r<0.5$), however, results indicate significantly higher bacteria load in borehole water close to septic tanks compared to the control (Figure 6).

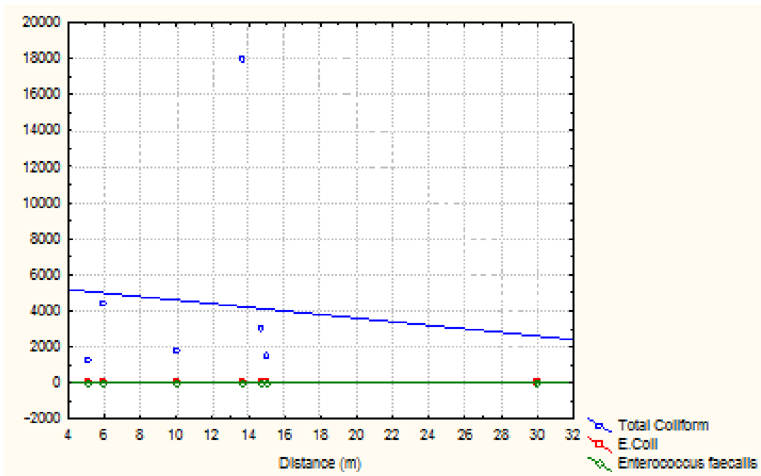


Figure 6: Effect of distance between borehole and septic tank in relation to the assessed bacteriological parameters

Takal and Quaye-Ballard 2018 reported that the distance between borehole and septic tank had no effect on the levels of *E. coli* in the wells/boreholes from Ashanti Region in Ghana, but noticed high levels for non-faecal coliform counts in well/boreholes are closer to the septic tank. Adetunji and Odetokun *et al.* (2011), Palamuleri and Akoth, (2015), Oluwasola *et al.* (2017) reported high coliform count and *Escherichia coli* counts in boreholes and water wells close to septic tanks and this agrees with findings from this study. There is, therefore, a high tendency for contamination when boreholes are sited close to septic tanks.

4. CONCLUSION

The study has revealed that groundwater from boreholes close to septic tanks in Edo State is vulnerable to physicochemical as well as bacteriological pollution. Results for total suspended solids, turbidity, ammonium and BOD were above recommended limits while the total coliform count in all the stations, *Escherichia coli* and *Enterococcus faecalis* in Isihor were also above threshold levels. The study clearly showed the non-compliance of most of the boreholes with the recommended minimum effective distance of 30 meters of septic tanks to drinking water sources and that the proximity of boreholes to septic tanks may suggest a higher tendency for groundwater contamination. Testing and monitoring of borehole water quality close to septic tanks are therefore imperative to prevent imminent health risks of borehole water pollution.

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6. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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