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Effects of Septic Tank Proximity to Boreholes on groundwater contamination at Igwuruta, Rivers State, Nigeria

J.N. Ugbebor[1] and U.B. Ntesat[2]
[1]Department of Civil and Environmental Engineering, University of Port Harcourt, Nigeria.
[2]Department of Agricultural and Environmental Engineering, Rivers State University, Nkpolu-Oroworukwo, Port Harcourt, Nigeria.

Abstract

The study aims to assess the effects of pollutant infiltration from septic tank on groundwater contamination. Water and effluent samples were collected from the surrounding boreholes and cesspools in selected residents in Igwuruta communities. Physical and biochemical analysis using standard techniques and protocols were employed. The results indicated that the pH of Borehole A, B and C were 4.52, 4.36 and 6.79 respectively. Boreholes A and B were acid indicating acidity when compared with the permissible drinking water standards from WHO (2017) with benchmarks of 6.5-8.5, respectively. This must have been influenced by the cesspools proximity to the Borehole water source. Fe, Zn and Pb from Boreholes were 0.75, 0.88, 0.39; 6.23,6.89 4.78; and 0.08, 0.06, ND for boreholes A, B and C, respectively were high when compared with WHO standards of 0.3, 3.0 and 0.01 for Fe, Zn and Pb respectively. PO_4, SO_4 *and* NO_3 *were 101, 119, 0.05; 367,398,245.5; and 9.28, 11.6, 10 for boreholes A, B and C respectively when compared with permissible standard of 0.1, 250 and 5.0 respectively. The Total Coliform bacteria (TCB) and Faecal Coliform Bacteria (FCB) were* $3x10^2$; 2×10^2 *and 0 respectively. Only C corresponds with WHO permissible standards of zero (0) for TCB and FCB. The WQI of sampled boreholes A, B and C respectively, demonstrated contaminated boreholes as a result of possible influence of septic sewage percolation into groundwater. The study recommended minimum distance of 30m upstream from the septic tanks when drilling a borehole to avoid any contaminants infiltration.*

***Keyword**: Effluent, Cesspools, contamination, coli form bacteria, sewage percolation.*

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I. Introduction

Natural groundwater in most part of the world is uncontaminated. Studies today have shown that there is possibility of contamination of ground water through anthropogenic activities. These have resulted in changes in the physical and biochemical characteristics of ground water making it difficult to meet the needs of the intended users. The typical sources of wastewater entering septic tanks include black water from toilets (approximately 38%), grey waters from laundry (25%), baths (22%) and kitchen sinks (15%) (Rotaru & Raileanu, 2008). A standards septic tank is so designed to manage sewage inhabiting bacteria, viruses, nitrate, inorganic and other organic compounds (IETC, 2000; Rotaru & Raileanu, 2008; Fouche et al., 2019). The danger to the immediate surrounding is the infiltration of the untreated sewage to the soil or surface water flood or leaching.

Underground water contamination can be caused by several sewage effluents that by-pass the earth's geological filter and other adsorption processes. Sewage or domestic effluents are of great concern to public health when untreated and their leachability remains unchecked by relevant agencies. For instance, effluents from conventional septic tanks have been known to record certain mind troubling amounts of biological contaminants (THB, FCB, TCB, COD and BOD) (Ugbebor & Ntesat, 2019). Heavy metals that are often found in wastewater include but not limited to Cu, Cd, Cr, Hg, Fe, Zn, Mo, V, Mn and Bo (Oyem et al., 2020). Individual household sewage disposal systems often referred to as septic tank, soakaway, cesspool, sewerage were the most community based domestic wastewater disposal methods especially in underdeveloped and developing countries. (Whithers et al., 2014; Schaider et al., 2017; Connelly et al., 2019). Domestic sewage that is discharged into septic tank has been reported to negatively influence organic and inorganic contamination of groundwater (Emongor et al., 2005; Fubara-Manuel & Jumbo, 2014; Eze & Eze, 2015; Bouderbala, 2019). In the course of this study laboratory analysis bothering on certain physicochemical and biological properties through systematic water samples collection from selected boreholes and effluents from septic tanks were investigated. To ascertain the quality of groundwater from contaminable point sources like septic tank effluents, water quality assessment was carried out as a tool for the monitoring of the composite water parameters along with other standard variations. Results from this study will be used to corroborate the water quality classification as per weighted arithmetic water quality index as indicate in Table 1.

Table 1: Water quality classification as per weighted arithmetic water quality index

WQI values	Rating of water quality	Borehole	WQI values	Grade
0-25	Excellent			A
26-50	Good			B
51-75	Poor			C
76-100	very poor			D
Above 100	Not potable for drinking	A,B & C	2097778, 2437768&2268070	E

Source: Researchgate.net, Ugbebor and Ntesat (2019b);

1.1 Study Area

The study area (see Figure1) covered the three existing borehole waters and their surrounding effluents from the septic tanks at Igwuruta communities in Ikwerre Local Government Area, River State, Nigeria. The study area has a varying estimated water table depth (WTD) of 30-35m as already determined with a water level meter by Ugbebor and Ntesat (2019). Although following several researches, it has been established that water table elevations fluctuate during the wet and dry seasons (Bouderbala, 2019). Certain descriptions with respect to this location/site have been described in a recent work (Ugbebor & Ntesat, 2019b).

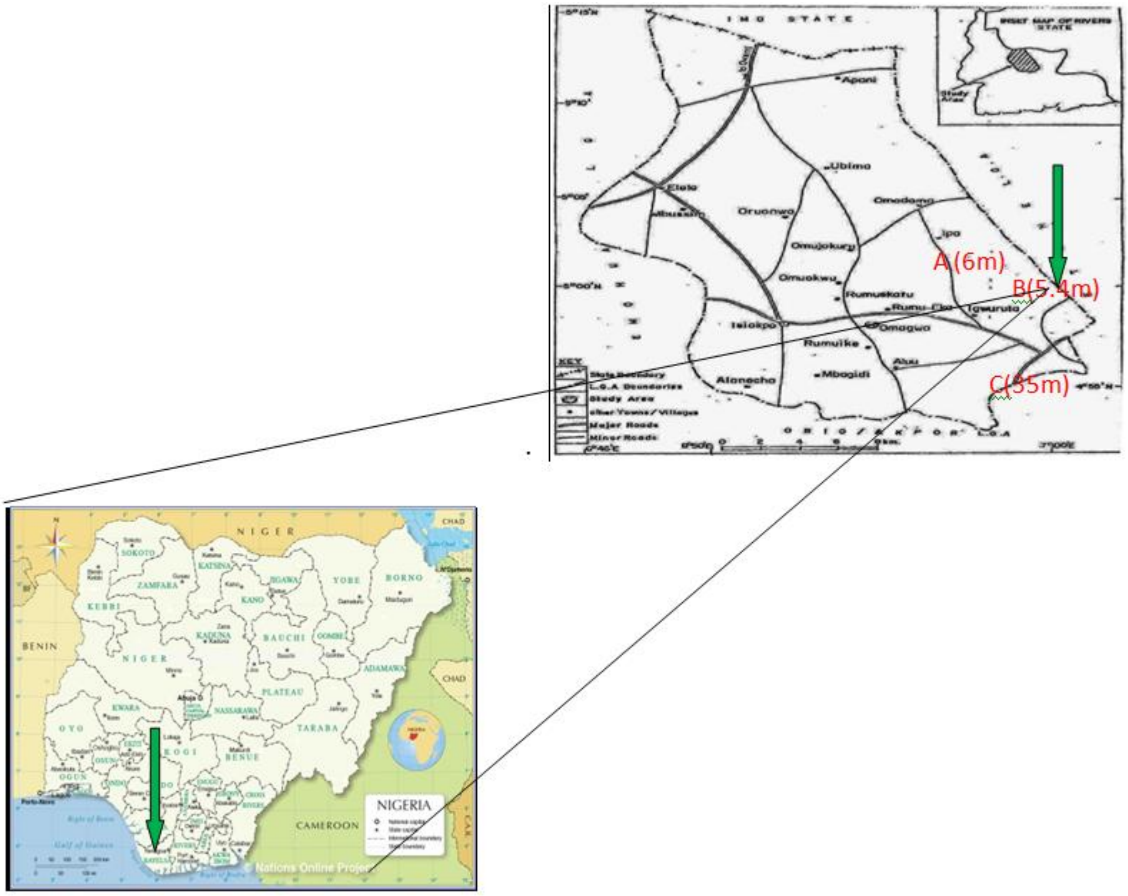

Figure 1: Map of Igwuruta and the sampling points with respect to their distances

II. Materials and Methods

The water and wastewater samples were collected from three (3) selected boreholes
(that the sump pump was allowed to run for 5 minutes before the water was collected directly from the pumping lines as against collecting from the overhead tanks) and each cesspools closer to the boreholes at (6m, 5.4m and 35m) wells were sampled during dry season (December, 2021). The water and wastewater samples were

collected from selected boreholes and wastewater cesspools (see Fig. 1). The samples were collected with sample bottles and stored in chest-cooler and transported for laboratory analysis after *insitu* characterization of pH. Sample collection followed standard protocols of two different samples from individual wells; one set sample properly labeled for physicochemical analyses while the other sample for microbiological characterization. The concentrations of specific physicochemical and microbiological properties (pH, EC, DO, BOD, COD, Nitrate, THB, and Total hardness) from the water and wastewater samples were determined following standard protocols as recommended in HACH 8051 and APHA 3111B.

Taste, smell, colour and Odour were done using an electronic tongue (organoleptic analysis). Spread plate technique with Nutrient Agar was employed for THB while the most probable number (MPN) techniques using Mac-Conkey broth in tubes and incubating at 37^{o}C for 24 hours was also employed for the evaluation of total coliform (TC) and faecal coliform (FC). These procedures were in line with the works of Ugbebor and Ntesat (2019b) and in accordance to standard protocols.

2.1 Water Quality Index

In order to evaluate the true nature of individual sampling borehole water, the water quality index was determined. This was expressed using the water quality rating as per weighted arithmetic water quality index as stated in the works of Ugbebor and Ntesat (2019b) and the results of Nwaogazie et al. (2018) using equations 1-3:

$$WQI = \sum \frac{WiQi}{Wi} \qquad 1$$

Where; WQI= water quality index; Wi is the unit weight for each water quality parameter, Qi is the quality rating scale for each parameter and was estimated using the equation below:

$$Qi = \left(\frac{Ci - Co}{Si - Co}\right) x100 \qquad 2$$

$$Wi = \frac{1}{Si} \qquad 3$$

Where: Ci=Cai and Cbi represents the concentration of the nth parameter in the analyzed borehole water. Co represents the ideal model value of analyzed water parameter of the control borehole water from a close oil and gas company facility (1500m) away from the septic tank site. Si represents the allowable standard value of nth parameter in line with WHO (2017) water quality standards.

III. Results

Table 2: Physical and Biochemical Analysis of Borehole water and Septic tanks wastes along their distances

Parameter	**Sludge**	**Wastewater**	**Borehole A (6m)**	**Borehole B (5.4m)**	**Borehole C (35m)**	**WHO 2017**
pH	7.06	7.13	4.52	4.36	6.89	6.5-8.5
EC (µs/Cm)	3277.2	3896	1390	1367	1056	1000
DO (mg/l)	2.9	2.1	4.51	4.62	4.18	2-5
BOD (mg/l)	255.5	145.5	3.4	2.44	2.78	4
COD (mg/l)	896	32	14	16	9.45	NA
PO_4 (mg/l)	396	289	101	119	0.05	0.1
SO_4 (mg/l)	585	478	367	398	245.2	250
NO_3 (mg/l)	14.5	4.44	9.28	11.6	10	50
Pb (mg/l)	3.56	2.98	0.08	0.06	ND	0.01
Cr (mg/l)	0.31	0.46	0.01	0.02	0.01	0.05
Cu (mg/l)	1.1	0.67	0.96	0.78	0.01	2.0
Fe (mg/l)	6.89	3.56	0.75	0.88	0.39	0.3
Zn (mg/l)	15.46	13.57	6.23	6.89	4.78	3.0
THB (cfu/ml)	$3.5x10^{6}$	$9.9x10^{4}$	$4.0x10^{2}$	$2.0x10^{2}$	42	100
TCB (MPN/100ml)	$5.2x10^{6}$	$3.2x10^{5}$	$3.0x10^{2}$	$2.0x10^{2}$	0	0
FCB (MPN/100ml)	$5.0x10^{4}$	$4.8x10^{4}$	$1.5x10^{2}$	$1.67x10^{2}$	0	0
Odour	yes	yes	clear	clear	clear	clear
Taste	-	-	Nil	Nil	Nil	Inoffensive
Temperature ^{o}C	35.6	32.1	27.3	27.6	25.5	25

ND-not detected, NA-not available

The results of the study sludge, wastewater, and boreholes were presented in the Table 1 and compared with WHO (2017) permissible benchmarks. The Figures 1-3 and Tables 2, 3 and 4 were used to indicate the graphical representation of the results, Pearson's correlation coefficient and the water quality index of the borehole water.

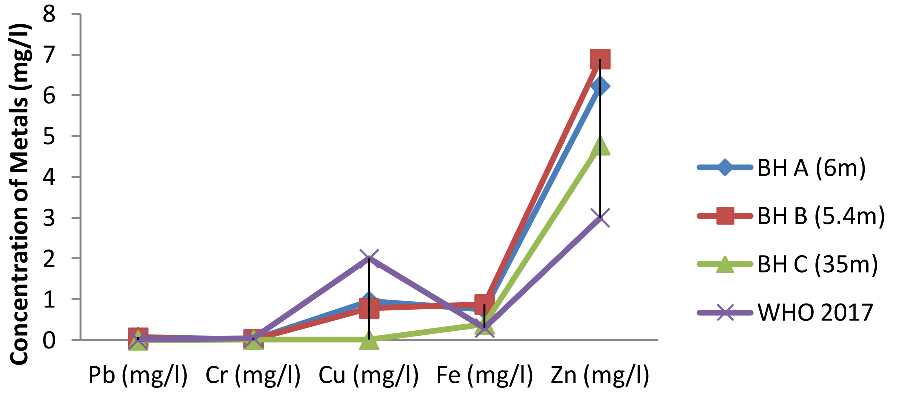

Figure 2: Concentrations of Heavy metals in Selected Borehole along measured Distances

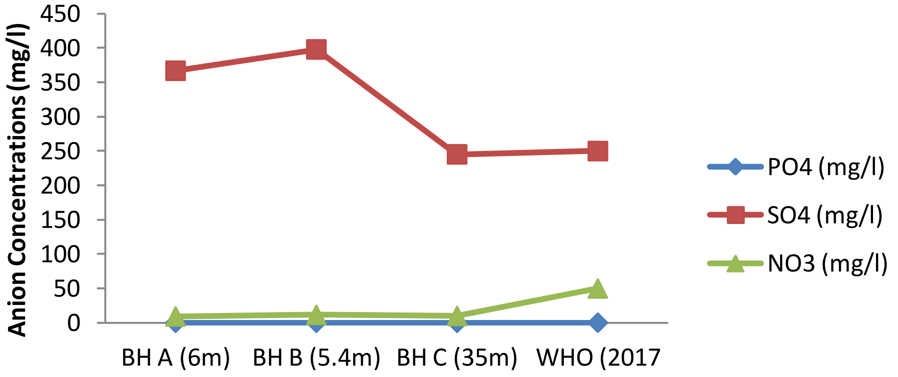

Figure 3: Borehole Water and their distances

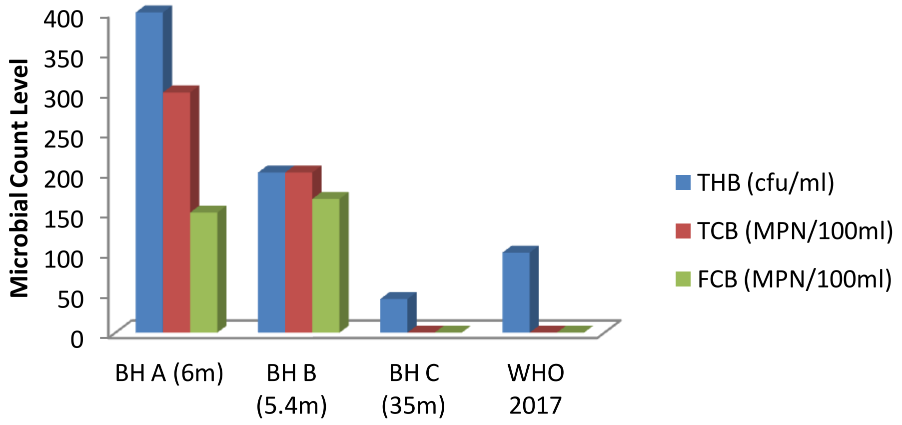

Figure 4: Borehole water Microbial Concentration along distances

Table 3: Summary of computed WQI values for Sampling Location A

Parameters	BHA	BHC	Si	$W_i = \frac{1}{S_i}$	$Q_i = \left(\frac{C_i - C_o}{S_i - C_o}\right)x100$	W_iQ_i
pH	4.52	6.89	6.5	0.15	607.69	91.15
EC (µs/Cm)	1390	1056	1000	0.001	-596.43	-0.6
DO (mg/l)	4.51	4.18	5	0.2	40.24	8.05
BOD (mg/l)	3.4	2.78	4	0.25	51	12.75
COD (mg/l)	14	9.45	0	0	-48.15	0
PO_4 (mg/l)	101	0.05	0.1	10	201,900	2,019,000
SO_4 (mg/l)	367	245.2	250	0.004	2,537.50	10.15
NO_3 (mg/l)	9.28	10	50	0.02	-1.8	-0.04
Pb (mg/l)	0.08	0	0.01	100	800	80,000
Cr (mg/l)	0.01	0.01	0.05	20	0	0
Cu (mg/l)	0.96	0.01	2	0.5	47.74	23.87
Fe (mg/l)	0.75	0.39	0.3	3.33	-400	-1332
Zn (mg/l)	6.23	4.78	3	0.33	-81.46	-26.88
THB (cfu/ml)	400	42	100	0.01	617.24	6.17
TCB (MPN/100ml)	300	0	0	0	0	0
FCB (MPN/100ml)	150	0	0	0	0	0
Temperature ^oC	27.3	25.5	25	0.04	-360	-14.4
Total				**134.835**		**2097778**

Table 4: Summary of computed WQI values for Sampling Location B

Parameters	BHB	BHC	Si	$W_i = \frac{1}{S_i}$	$Q_i = \left(\frac{C_i - C_o}{S_i - C_o}\right)x100$	W_iQ_i
pH	4.36	6.89	6.5	0.15	648.72	97.31
EC (µs/Cm)	1367	1056	1000	0.001	555.36	0.56
DO (mg/l)	4.62	4.18	5	0.2	53.66	10.73
BOD (mg/l)	2.44	2.78	4	0.25	-27.87	-6.97
COD (mg/l)	16	9.45	0	0	-69.31	0
PO_4 (mg/l)	119	0.05	0.1	10	237,900	2,379,000
SO_4 (mg/l)	398	245.2	250	0.004	3,183.33	12.73
NO_3 (mg/l)	11.6	10	50	0.02	4	0.08
Pb (mg/l)	0.06	0	0.01	100	600	60,000
Cr (mg/l)	0.02	0.01	0.05	20	25	500
Cu (mg/l)	0.78	0.01	2	0.5	38.69	19.35
Fe (mg/l)	0.88	0.39	0.3	3.33	-544.4	-1812.86
Zn (mg/l)	6.89	4.78	3	0.33	-118.54	-39.19
THB (cfu/ml)	200	42	100	0.01	272.41	2.72
TCB (MPN/100ml)	200	0	0	0	0	0
FCB (MPN/100ml)	167	0	0	0	0	0
Temperature ^oC	27.6	25.5	25	0.04	-420	-16.8
Total				**134.835**		**2437768**

Table 5: Summary of computed WQI values for Sampling Location C

Parameters	Ci=BHA+BHB	BHC	Si	$W_i = \frac{1}{S_i}$	$Q_i = \left(\frac{C_i - C_o}{S_i - C_o}\right)x100$	W_iQ_i
pH	4.44	6.89	6.5	0.15	628.21	94.23
EC (µs/Cm)	1378.5	1056	1000	0.001	-575.89	-0.58

DO (mg/l)	4.57	4.18	5	0.2	47.56	9.51
BOD (mg/l)	2.92	2.78	4	0.25	11.48	2.87
COD (mg/l)	15	9.45	0	0	-58.73	0
PO_4 (mg/l)	110	0.05	0.1	10	219,900	2,199,000
SO_4 (mg/l)	382.5	245.2	250	0.004	2860.42	11.44
NO_3 (mg/l)	10.44	10	50	0.02	1.1	0.022
Pb (mg/l)	0.07	0	0.01	100	700	70,000
Cr (mg/l)	0.02	0.01	0.05	20	25	500
Cu (mg/l)	0.87	0.01	2	0.5	43.22	21.61
Fe (mg/l)	0.82	0.39	0.3	3.33	-477.78	-1591.01
Zn (mg/l)	6.56	4.78	3	0.33	-100	33
THB (cfu/ml)	300	42	100	0.01	444.83	4.45
TCB (MPN/100ml)	250	0	0	0	0	0
FCB (MPN/100ml)	158.5	0	0	0	0	0
Temperature °C	27.45	25.5	25	0.04	-390	-15.6
Total				**134.835**		**2268070**

Table 6: Pearson correlation coefficients among all parameters in selected boreholes

	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*
1. pH	1.00															
2. EC (µs/Cm)	-0.97	1.00														
3. DO (mg/l)	-0.08	-0.16	1.00													
4. BOD (mg/l)	0.33	-0.45	0.66	1.00												
5. COD (mg/l)	-0.77	0.88	-0.56	-0.78	1.00											
6. PO4 (mg/l)	-0.99	0.98	-0.03	-0.46	0.84	1.00										
7. SO4 (mg/l)	-0.99	0.97	0.00	-0.46	0.83	1.00	1.00									
8. NO3 (mg/l)	0.46	-0.66	0.84	0.79	-0.91	-0.56	-0.53	1.00								
9. Pb (mg/l)	-0.97	0.96	0.04	-0.19	0.73	0.94	0.93	-0.48	1.00							
10. Cr (mg/l)	0.34	-0.56	0.90	0.68	-0.82	-0.43	-0.40	0.98	-0.40	1.00						
11. Cu (mg/l)	-0.02	-0.20	0.97	0.80	-0.63	-0.10	-0.08	0.86	0.03	0.88	1.00					
12. Fe (mg/l)	-0.96	0.97	-0.15	-0.59	0.90	0.99	0.99	-0.65	0.89	-0.52	-0.24	1.00				
13. Zn (mg/l)	-0.84	0.93	-0.43	-0.74	0.99	0.91	0.90	-0.85	0.79	-0.74	-0.52	0.95	1.00			
14. THB (cfu/ml)	-0.83	0.84	0.04	0.07	0.56	0.78	0.75	-0.38	0.94	-0.37	0.12	0.70	0.61	1.00		
15. TCB (MPN/100ml)	-0.94	0.97	-0.08	-0.22	0.77	0.92	0.91	-0.56	0.99	-0.50	-0.07	0.88	0.82	0.95	1.00	
FCB (MPN/100ml)	-0.99	0.99	-0.03	-0.44	0.84	1.00	1.00	-0.56	0.95	-0.44	-0.10	0.98	0.90	0.80	0.94	1.00
16. Temp. °C	-0.96	0.99	-0.19	-0.55	0.91	0.99	0.98	-0.68	0.92	-0.57	-0.26	1.00	0.96	0.75	0.92	0.99	1.00

3.1 Discussion of Findings

Table 1 shows that the pH of Borehole water A and B were slightly acidic with values of 4.52 (Borehole A) and 4.36 (Borehole B) which expressly negate the permissible drinking water standards from WHO (2017) with benchmarks of 6.5-8.5, respectively. This observable trend illustrated the acidic condition of the groundwater and possible influence of the cesspools proximity to the underground water sources by vertical transport of contaminants through the overburden soil. This account corroborated with the works of Ugbebor and Ntesat (2019) that worked and obtained similar result (5.81) in the study area though with closer proximity to a dumpsites. This low pH also confirms the work of Fubara-Manuel and Jumbo (2014) who established similar low pH of 4.4 in a similar research and stated that it may be as a result of high organic and inorganic matter.. However, borehole C which served as the control, recorded a balanced pH of 6.89 which meets the permissible benchmarks. The observation may be as a result of the nature of treatment carried out by the facility proponents on their borehole before being used for consumption.

Table 1 shows the ranges of EC in Borehole A (1390µs/Cm) and Borehole B (1367µs/Cm), which exceeded the permissible limits of (WHO, 2017) of 1000 µs/Cm allowable in drinking water. These recorded increased values may have been attributed to the geological weathering conditions and also the unaccounted human activities within and around the domestic facilities. Bouderbala (2019) recorded greater EC values (2627µs/Cm) around septic tank effluents on groundwater quality. According to the researchers, such high thresholds though generally not a health risk but can be a precursor to other physicochemical characteristics such as sulphate, phosphate, nitrate, etc. as higher amounts will lead to higher EC trends (https://sensorex.com). The temperature values of borehole water samples were higher than the permissible limits of the WHO (2017). The temperature of the selected borehole water samples (27.1^{o}C and 27.6^{o}C for Borehole A and B) were slightly above the permissible limits of WHO (2017) of 25^{o}C except for Borehole C (control) that recorded 25.5^{o}C and maybe said to be within the safety zone for a permissible drinking water range. These temperature ranges were equivalent to Omowumi (2018) experiment which recorded 26.2^{o}C and 27.3^{o}C conducted on septic tanks effluent migration to groundwater. This increase in temperature may be responsible for the growth of heterotrophic bacteria counts like-wise the other microbiological activities. Findings from Pelczar et al. (2005) stated that temperature influence on any water body has the tendency to increase the rate of proliferation of microbial population.

Figure 2 shows borehole A (6m) and borehole B (5.4m) had Pb values of 0.08 and 0.06mg/l, respectively higher than the permissible limits of 0.01(mg/l). Meanwhile, there was no detection of Pb in borehole C (Control). Cu exhibited a unique value both in the septic tank and groundwater samples which may be attributed to the level of exposure of Cu to unsanitary activity and geological formations and this account corroborates the works of Kalagbor et al. (2019). Zn and Fe were relatively very high both in septic tank and groundwater levels which may be evidence of water contact with septic tank wastewater compositions (Zhang et al. 2019). It is relatively clear that the consequence from increased Zn and Fe may lead to goiter in adults, precipitation challenges, bad taste as recorded in Borehole B, blue baby syndrome and memory loss. Similar accounts were recorded in the works of Omowumi (2019) that recorded increase in the thresholds of Fe, Pb, Mn, Zn and Cr values as above the acceptable limits of standard agencies (WHO, 2017).

Figure 3 shows the concentrations of $PO_{4,}$ SO_4 and NO_3 and according to literature, the higher thresholds of orthophosphate, sulphate and other anions can result to health risks such as gastro-intestinal disorder. These higher anions observations may be an outcome of the influence from the intrusion from the septic tank contaminant percolations into groundwater. The study corroborates with the accounts from other researchers such as Chibuogwe and Eze (2015) and others who worked on the interference of septic tank contaminations.

Figure 4 shows that boreholes with closer distances from septic tanks have greater propensity to carry more microbial strains as seen in the amount of total coliform and faecal coliform bacteria counts with borehole A recording 300MPN/100ml and 150MPN/100ml; borehole B with 200MPN/100ml and 167MPN/100ml, respectively. This accounts corroborated with the works of Eze and Eze (2015) who investigated a similar septic tank influence on groundwater quality although miles away from Igwuruta and discovered high thresholds of total coliform bacteria counts and faecal coliform bacteria counts of 110-170MPN/100ml and 14-42MPN/100ml, respectively for all borehole water samples in proximity of 3 to 26m. These thresholds were far away from the permissible limits of the WHO (2017) that established a zero tolerance levels for total and faecal coliform bacteria counts considering the health risk.. This presence and thresholds of bacteriological counts makes these boreholes unsafe for drinking water and also confirm the accounts of Bouderbala (2019) recorded 14-34MPN/100ml for total coliform and 10-24 MPN/100ml for feacal coliform on septic tank effluent on groundwater quality and therefore not safe for drinking purposes. Omowumi (2018) further exposed the trends of bacteriological contamination of groundwater given the results from borehole wells that recorded 290 and 170MPN/100ml of total coliform and faecal coliform respectively. The presence of faecal coliform in water bodies is an indication of faecal contamination and this may expose the population around such location to disease causing pathogens such as bacteria, viruses and parasites.

Table 3-6 show the computed water quality indices for each of the sampled locations. The implication of the analysis indicated that all the borehole water ater A, and B apart from C are suggested to be influenced by the proximity of septic tank intrusion. Therefore, from these indices it is obvious that the water quality from these borehole waters is rated not potable for drinking purpose (Grade E). The study agreed with the study from Kachroud et al. (2013).

Table 6 shows the Pearson's correlation coefficient of all parameters indices with respect to the borehole conditions. Virtually the parameters were highly significant and positively correlated.

IV. Conclusion

As a way to improve the quality of drinking water within and around the study locations, studies have established that the location of drilled borehole should be minimum of 30m away from septic tanks and with the understanding of the groundwater direction (Ogbozie & Toko, 2020). Consequently, adverse effects of certain metals such as Zn, Pb and Fe can result in objectionable tastes, precipitate and corrosion of drinking water equipment. The health implications include goiter in adults, intestinal disorder, blue baby syndrome in children and neurological problem.

V. **Recommendation:**

The paper recommends minimum borehole depth of 50m and surface distance from septic tank of 30m. Study showed that many compounds do not have the land space of 30m upstream between septic tank and borehole. Therefore, the researcher advised that for borehole water to be potable it should be treated by chlorination or other treatment method suitable for public health.

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