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Investigation of Groundwater Contamination from Septic Tank Siting in Umungasi/Abayi, Abia State

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Authors' contributions

This work was carried out in collaboration among all authors. Author KON designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors CLE and IUI managed the analyses of the study. Author KON managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The investigation of groundwater contamination from septic tank siting was done in Umungasi/Abayi, Abia State. The aim of this study was to investigate the effect of siting septic systems on the quality of groundwater in Umungasi, Abayi, Aba. Twenty (20) water samples were randomly collected from boreholes located less than 30 m away from septic systems in Umungasi, Abayi Aba, Nigeria to determine their physico-chemical and heavy metals characteristics. While three (3) water samples at distances ranging from 60 m from the nearest septic system were sampled for analyses as controls. Standard analytical techniques were employed in the investigation. The result showed that most of the physicochemical parameters analysed in the borehole water samples were within the WHO/SON/NAFDAC recommended limits except for pH in BH4 and BH7 which had values of 6.3 respectively and were not within the WHO/SON/NAFDAC standard limit of 6.5-8.5. Some of the heavy metals analysed during the period of study were within the permissible limits except for iron in BH5 (0.443 mg/L), BH7 (0.367 mg/L), BH8 (0.511 mg/L), BH9 (0.31 mg/L), BH15 (0.41 mg/L), BH16 (0.327 mg/L), BH17 (0.337 mg/L) and BH18 (0.315

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mg/L) that were above the permissible limits of WHO standards of 0.3 mg/l. There was no influence of septic tank siting to the boreholes on groundwater quality during the period of study even though the distance of septic tanks from boreholes in the areas investigated did not conform with that recommended by WHO of 30 – 40 m. The contamination is from the general unhygienic condition of the environment.

Keywords: Boreholes; groundwater quality; heavy metals; physicochemical characteristics; septic tank.

1. INTRODUCTION

Water is a natural resource and is vital to sustain life. Accessibility and availability of potable water does not only play a crucial role in various aspects of life such as economic development and social welfare, but also it is an essential element in health. Groundwater is particularly important as it accounts for about 88% of man's safe drinking water [1].

A borehole is a hydraulic structure which when properly designed and constructed, permits the economic withdrawal of water from an aquifer.

One of the common sources of groundwater contamination is septic system and, in many instances, septic tanks and soak-away pits are closer to boreholes than standards prescribed by the [2] safe distance of 30m-40m. Besides, boreholes are drilled to depths shallower than UNICEF standard of 100 m-150 m.

Widespread groundwater contamination has occurred in many rural areas utilizing septic tank systems. This is because of effluent which is discharged onto the subsurface by soakaways as this often percolates into the same aquifer tapped by wells for domestic water supply [2].

It has been estimated that the total volume of waste disposed of via septic tanks is approximately 800 million gallon per year, virtually all of which is disposed in the subsurface [3]. This makes septic tanks the leading contributor to the total volume of waste discharged directly to ground water. Assessment of water is therefore very crucial to safeguard public health and the environment [4].

This study investigated possible groundwater contamination from septic system siting in Umungasi/Abayi Aba, Abia state and the relationship between the distances of the wells to septic tanks.

1.1 Description of Study Area

Aba is a city in the southeast of Nigeria and the commercial center of Abia State. Aba was divided into 2 major local government areas namely, Aba South and Aba North [5]. It has an area of about 5833.77 km^2, which is roughly 9% of Nigeria's land mass. It is bounded in the north by Enugu state, in the south by River state, in the east by Cross River and Akwa Ibom states and in the west by Imo state. The sample area covered to the East 7^{o}180"E -7^{o}22"E and to the North 5°6'.0"N - 5°10'.0"N (Fig. 1).

2. METHODOLOGY

2.1 Collection and Preparation of Samples

Water samples were collected from taps located at distance not more than 50m from septic tanks. The tap was allowed to flow for about 1minute to flush the line of any deposits of debris. In addition, while filling the sample cans, care was taken not to have contact with the tap head to avoid contamination. The sample for physic-chemical parameter was collected into 1liter container with no preservative to maintain the physical properties of analyte. Sample for heavy metals was collected into 120ml container. The sample was fixed with nitric acid of 70% concentration to avoid metal precipitation. Iron, Lead and Manganese are metal of interest, as iron seems regularly present in water. Sample for Biochemical Oxygen Demand (BOD) analysis was collected into a 250 ml amber bottle (airtight) to eliminate oxygen interference and protect light sensitive contents during storage and transport. All containers were sterilized to prevent contamination. Table 1 shows the containers and preservatives for the samples. The samples were properly tagged with sample labels indicating the identity of the sample and loaded into an ice chest for onward movement to the laboratory for analysis.

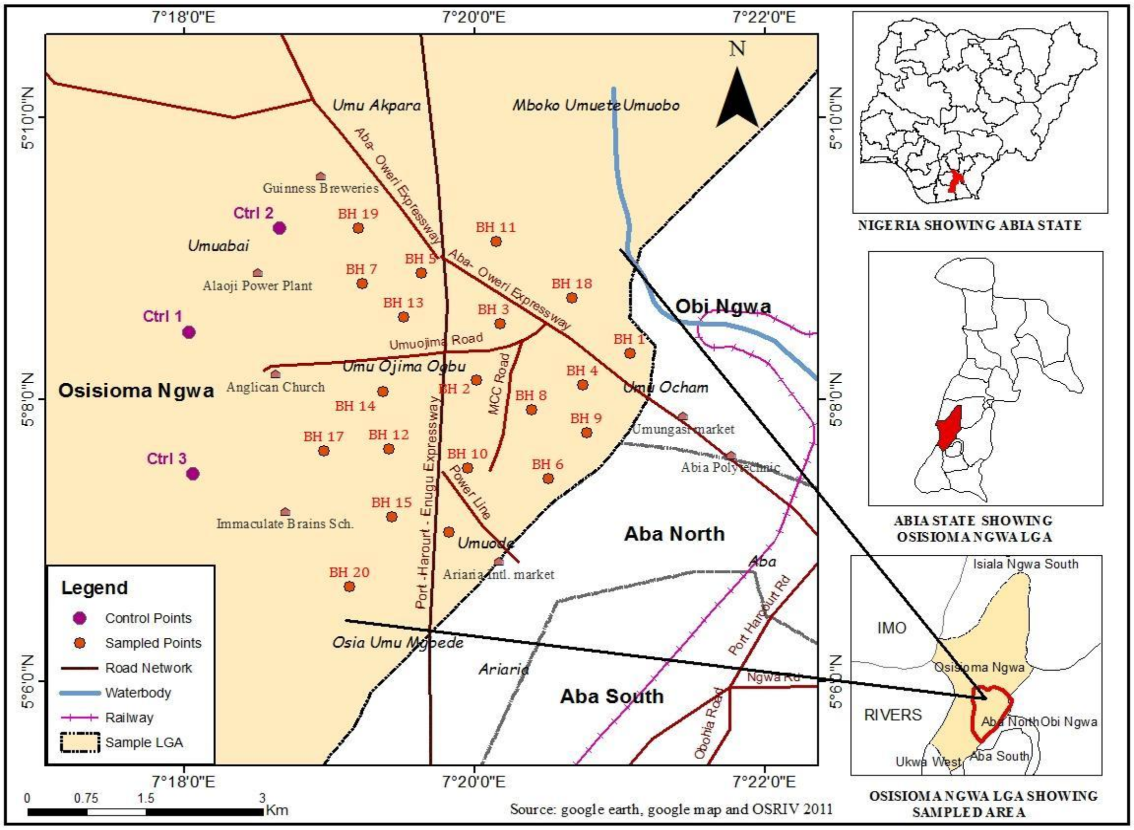

Fig. 1. Map of Aba, showing the study area

2.2 Physico-Chemical Analysis and Heavy Metals

pH was determined with the use of a portable pH meter (Aquariums/pH7). The meter was calibrated prior to use with buffer solutions of pH 7, 4 and 10 of known calibration standard. The probe of the meter was dipped into the sample and values obtained as displayed on the screen of the equipment. The probe was rinsed in distilled water the display mode adjusted for the next parameter.

The determination of temperature was done by an alcohol-in-glass portable thermometer (Extech EC500) dipped into the water samples to obtain the reading in the laboratory. To determine turbidity, the Nephelometric method was used, LaMotte 300wi Tri-Meter [6]; total dissolved solids, by gravimetric method [7]; electrical conductivity was determined using the conductivity meter (Extech EC500), by dipping the probe into the container of the water samples until a stable reading was obtained and recorded; and sulphate by turbidimetric method using barium chloride and concentration reading through UV spectrophotometer (PG Instruments Ltd/T60) [8] and sodium by flame photometry. Heavy metals were determined using an Atomic Absorption Spectrophotometer (AAS) (SenSAA) as described in APHA 3111B. This involved direct Aspiration of the sample into an air/acetylene or nitrous oxide/acetylene flame generated by a hollow cathode lamp at a specific wavelength peculiar only to the metal programmed for analysis. For every metal investigated, standards and blanks were prepared and used for calibration before samples were aspirated and concentrations at specific absorbance displayed on the data system monitor for printing.

2.3 Septic Sewage Disposal Systems Distance Measurement

The distance between each borehole and the septic tank was measured using measuring tape and compared with the WHO [9] recommended minimum distance between boreholes and septic tanks which is set at 30-40m. The average distance of the septic tanks located around a selected borehole was measured and recorded. The most ideal sampling site for the study Borehole (BH1 - BH20 and Control) were selected, where septic tanks and boreholes were located within proximity of ≤30m and 60m from each other and with easy access. The distance of the three control borehole points was measured as well and the average distance nearest to the septic system recorded. Twenty boreholes were identified, and access was granted by the owners for sample collections during the field work. Records were available and permission granted to access boreholes for sampling and observations from the surroundings areas were also noted.

3. RESULTS AND DISCUSSION

The results of the physicochemical characteristics and heavy metals are presented in Table 1 and Table 2.

The temperature values for all the twenty samples of Boreholes and the three controls which ranged from 23 – 25°C satisfied WHO standards of ≤35°C despite the varying distances between septic tanks from the boreholes. This finding is in corroboration with [10] that conducted an investigation on possible groundwater contamination from septic system siting in Port Harcourt, Nigeria and discovered that the temperature of the water which ranged from 26 – 33°C was equally not influenced by the location of the soakaway. The least and highest electrical conductivity were observed in BH3 and BH1 respectively, while for the control it was CONT 2 BH and CONT 1 BH. All the borehole samples satisfied WHO standards of 1200µS/cm. This finding is in agreement with [11] that conducted studies on the effect of septic tank locations on borehole water quality in Port Harcourt, Nigeria and discovered that the conductivity values of all the water samples were below the maximum allowable standard of 1200µS/cm set by the WHO. Electrical conductivity depends on the concentration and degree of dissociation of electrolytes and it gives a good idea of the amount of dissolved material in the water [12]. From Table 1, all the values of Total Dissolved Solids from the sampled boreholes which ranged from 13.0mg/L to 36.0mg/L and 20.0mg/L to 23.6mg/L for the controls were very far below the WHO recommended guideline value of 1000mg/L. The total dissolved solids (TDS) indicate the general nature of salinity of water [12]. Figure 4.1 showed that there was no significant variation in TDS values This is in line with [13] that conducted studies on the effect of distance between septic tank and TDS in which it was concluded that distance between septic tank and borehole had little or no correlation with TDS. Low TDS is said to be a characteristic of hills and upload areas that represent areas of recharge [14]. The turbidity values in Table 1 indicated that all the borehole water samples satisfied the permissible limits set by WHO of ≤5.0NTU. The control Borehole water samples satisfied the permissible limit set by WHO. This finding is in tandem with [10] that conducted an investigation on possible groundwater contamination from septic system siting in Port Harcourt, Nigeria and discovered the boreholes located close to soakaways did not in any way show turbidity values above those located more than 40m from a soakaway.

The result from Table 1 showed that twenty-one borehole water samples satisfied the WHO standards of 6.5-8.5 for pH in water except for BH4 and BH7 whose pH of 6.3 were not within the standard limit. However, the sampled water from umungasi/ Abayi area Aba Abia state had a better pH than those of the borehole water studied in my literature review say that of Port Harcourt Rivers State. This finding is in line with [10] and that of [11], that discovered that the water from the different boreholes in their study were all slightly acidic with slight variations in the pH value. Table 1 also showed that all the B.O.D values of the different boreholes satisfied the WHO standards of 3.0mg/L. This is in line with [11] that discovered that biochemical oxygen demand of the borehole water samples were all within the acceptable range of 3.0mg/L and therefore pose no threat to the water source. It was evident that all borehole water samples were below WHO standards for D.O of 5mg/L. This is in line with [11] that discovered in their study that dissolved oxygen of the borehole water samples were all within the acceptable range of 5.0mg/L. This indicates that the correlations of distance of septic tanks siting from borehole did not have any effect on D.O. Table 1 showed that the different boreholes were within safe limits for WHO standards of 250mg/L. The distance of septic tanks from boreholes did not have any effect on chloride concentration. However, there is no evidence that intake of chloride in large quantity in drinking water can harm humans [15]. Nitrate Concentration was below the WHO standards of 50mg/L. This shows that the distance of septic tanks to boreholes did not have any effect on nitrate concentration.

Table 1. Physico-chemical characteristics of borehole water samples from Umungasi/Abayi area in Aba, Abia State

Sample code	Distance of borehole to septic tank system (m)	Estimated depth of septic tank system (m)	Physical characteristics					Chemical characteristics				
			Temp (°C)	EC (µS/cm)	TDS (mg/L)	Turbidity (NTU)	pH	BOD (mg/L)	DO (mg/L)	Cl^- (mg/L)	NO_3^- (mg/L)	Hardness (mg/L)
WHO	**30-40**		**≤35**	**1200**	**1000**	**≤5.0**	**6.5-8.5**	**3**	**5**	**250**	**50**	**500**
CONTROL 1 BH	60		24	48.2	23.6	4.1	6.6	0.3	4.3	14.46	0.2	20
CONTROL 2 BH	60		24	40.2	20	4.3	6.5	0.6	4.3	12.39	0.1	14
CONTROL 3 BH	60		24	44.2	22.1	4	6.5	0.2	4.4	12.74	0.1	14
BH 1	23.6		24	72	36	3.8	6.5	0.8	4.5	10.65	0.2	12
BH 2	4.85		23	38.5	17.2	4	6.5	1.5	4.3	7.13	0.5	24
BH 3	6.85		25	26.2	13	5.1	6.5	1.4	4.4	7.43	0.3	16
BH 4	10.31		24	44.2	22.1	4.2	6.3	1.3	4.6	8.87	0.3	44
BH 5	12.33	2.5	24	32.3	16.2	4.3	6.5	1.3	4.5	9.53	0.4	16
BH 6	8.21		24	42.5	21.3	5	6.5	1.2	4.5	14.37	0.1	26
BH 7	4.97		24	51	25.6	4.2	6.3	1.6	4.3	14.65	0.2	24
BH 8	6.11		24.	32.4	16.2	4.3	6.8	1.2	4.4	9.35	0.1	18
BH 9	8.25		25	38	19	4.5	6.5	0.9	4.3	10.24	0.1	20
BH 10	12.17		23	38.8	19.4	4.8	6.6	0.9	4.5	10.61	0.2	22
BH 11	5.92		24	28	14	4.5	6.5	1.3	4.3	6.33	0.1	14
BH 12	7.82		24	45.1	22.3	5	6.7	1.2	4.5	10.25	0.2	18
BH 13	6.29		25	30.8	15.4	4.1	6.5	0.9	4.3	7.35	0.4	14
BH 14	11.37		24	30.6	15.3	4.2	6.5	1	4.2	7.35	0.2	16
BH 15	18.92		24	35.1	17.4	5.1	6.5	0.5	4.5	10.32	0.2	24
BH 16	7.86		25	39	19.1	4.2	6.6	1.4	4.3	12.93	0.1	22
BH 17	11.31		24	64.2	32.1	4.5	6.5	0.6	4.4	22.18	0.3	20
BH 18	8.24		24	50	25	4.2	6.8	0.7	4.6	14.35	0.2	14
BH 19	14.57		24	53	27.2	4.8	6.5	0.4	4.6	15.26	0.4	18
BH 20	9.63		24	40.1	19.5	4.5	6.5	0.5	4.5	12.94	0.2	18

KEY: Temp: Temperature; EC: Electrical Conductivity; TDS: Total Dissolved Solids; pH: Pontium Hydrogenium; BOD: Biological Oxygen Demand; DO: Dissolved Oxygen; Cl^-: Chlorides; NO_3^-: Nitrates

Table 2. Heavy metals characteristics from Umungasi/Abayi area in Aba, Abia State

Sample code	Distance of borehole to septic tank system (m)	Estimated depth of septic tank system (m)	Heavy metals characteristics		
			Fe^{+} (mg/L)	Mn^{2+} (mg/L)	Pb (mg/L)
WHO Standards	**30-40**		**0.3**	**0.4**	**0.01**
SON Standards			0.3	0.2	0.01
NAFDAC Standards			0.3	0.2	0.01
CONTROL 1 BH	60		0.154	0.001	0.001
CONTROL 2 BH	60		0.137	0.001	0.001
CONTROL 3 BH	60	2.5	0.182	0.001	0.001
BH 1	23.6		0.214	0.001	0.001
BH 2	4.85		0.112	0.001	0.001
BH 3	6.85		0.115	0.001	0.001
BH 4	10.31		0.186	0.001	0.001
BH 5	12.33		0.443	0.003	0.01
BH 6	8.21		0.251	0.001	0.001
BH 7	4.97		0.367	0.001	0.001
BH 8	6.11		0.511	0.001	0.001
BH 9	8.25		0.31	0.001	0.001
BH 10	12.17		0.241	0.001	0.001
BH 11	5.92		0.111	0.001	0.001
BH 12	7.82		0.172	0.001	0.001
BH 13	6.29		0.283	0.001	0.001
BH 14	11.37		0.193	0.001	0.001
BH 15	18.92		0.41	0.002	0.001
BH 16	7.86		0.327	0.001	0.001
BH 17	11.31		0.337	0.001	0.001
BH 18	8.24		0.315	0.001	0.001
BH 19	14.57		0.218	0.001	0.001
BH 20	11.1		0.246	0.002	0.001

KEY: Fe^{+}: Iron; Mn^{2+}: Manganese; Pb: Lead

Hardness values were within the safe limits of WHO standards of 500mg/L. There was no effect in hardness values as a result of distance of septic tanks from boreholes. Groundwater is normally harder than surface water because of its high solubilizing potentials from rocks containing gypsum, calcite and dolomite [16].

Table 2 showed that BH5 (0.443mg/L), BH7 (0.367mg/L), BH8 (0.511mg/L), BH9 (0.31mg/l), BH15 (0.41mg/L), BH16 (0.327mg/L), BH17 (0.337mg/L) and BH18 (0.315mg/L) were above the permissible limits of WHO standards of 0.3mg/l for iron and this makes them unsatisfactory for human consumption. [17] showed that naturally occurring metals present in the rocks and sediments may be dissolved in the water and later be found in water. Manganese is naturally occurring in many surface water and groundwater sources, particularly in anaerobic or low oxidation conditions. Levels in fresh water typically range from 1 to 200 mg/L, although levels as high as 10 mg/L in acidic groundwater have been reported; higher levels in aerobic waters usually associated with industrial pollution [18]. Manganese is an essential element for humans and other animals and occurs naturally in many food sources. The manganese level in the twenty-three (23) borehole water samples satisfied WHO standards of 0.4mg/L and as such poses no threat upon human consumption. Lead is used in the production of meal products, cables, pipelines, paints and pesticides. There are certain factors that determine the dissolution of lead from the plumbing systems and they include: pH, temperature, water hardness and standing time of the water, with soft, acidic water being the most plumb solvent. Lead targets organs such as kidney and liver and causes adverse health effects [18]. Lead was high at BH5 (0.01mg/L), however, it was just within the safe limit of 0.0.1mg/L for lead while others were constant during the period of study. However, the different boreholes were within the safe limits of WHO standards of 0.01mg/L.

4. CONCLUSION

The study showed that most of the physicochemical parameters analysed in the borehole water samples were within the WHO/SON/NAFDAC recommended limits except for pH in BH4 and BH7 which had values of 6.3 and were not within the WHO/SON/NAFDAC standard limit of 6.5-8.5. The heavy metals analysed during the period of study were within the permissible limits for fifteen borehole water samples with the three control except for iron that had values above the WHO/SON/NAFDAC limits in BH5, BH7, BH8, BH9, BH15, BH16, BH17 and BH18, during the study period.

Finally, there was no influence of septic tank siting to the boreholes on groundwater quality during the period of study. The distance of septic tanks from boreholes in the areas investigated did not conform with that recommended by WHO, however, there was no indications that this contamination is as a result of the fact that the boreholes are closer to septic tank.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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