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The Effect of Distances between Soakaway and Borehole on Groundwater Quality in Calabar, South-South, Nigeria

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Abstract— *The main objective of these study was to investigate the effect of sitting bore (drinking water source), and soakaway system within the same area in close proximity (distance) to each other on the quality of the ground water. To achieve the purpose of this study, a Null and Alternate Hypothesis were formulated to guide the research process: The hypothesis was tested at 0.05 level of significance with relative degree of freedom, whereby all p- values less than 0.05 was considered statistically significant, thereby rejecting the null hypothesis, while those greater than the p- value as non-significant. Therefore, sitting borehole close to any pollution source (soakaway) was very detrimental to the quality of the ground water.*

Keywords— *Soakaway, total coliform count, faecal coliform, dissolved oxygen, temperature.*

I. Introduction

Water is one of the earth's most important, renewable and widely distributed resources of which about 97.2% constitutes ground water (Rajesh et al, 2012). Groundwater is generally considered to be least polluted compared to other inland water resources. Due to rapid growth of population, industrialization, and urbanization, there have been intense human activities and interference into nature leading to an over-exploitation and severe pollution stress on natural water bodies.

According to Gideon et al, (2004), on-site wastewater (water collected from indoor flush toilets, bathrooms, laundries and kitchen etc. via septic tanks/soakaway) treatment systems are point sources of pollution; therefore, they are expected to exert greatest impact on groundwater sources in their vicinity. This study was carried out in Calabar south local government area of Cross River State, Nigeria. Calabar Metropolis lies between latitudes 04 45' 30" North and 05 08'30" North of the Equator and longitudes 8 11' 21" and 8 30'00" East of the Meridian**.** The town is flanked on its eastern and western borders by two large perennial streams namely: the Great Kwa River and the Calabar River respectively. The city lies in a peninsular between the two rivers, 56km up the Calabar River away from the sea. Calabar has been described as an inter-fluvial settlement Ugbong, (2000). According to WHO (2003) recommended standard, the effective distance between septic tank and any drinking water source is estimated to be a minimum of 30m and above. The scope of this research work is limited to the use of simple multiple regression model analysis to show the effect of the distance of sitting soakaway pits from borehole on the water quality.

Aims and Objectives

The specific objectives are:
1.0 To investigate the physio-chemical and bacteriological quality of the ground water sample obtained from boreholes within the study area.
2.0 To measure the level of contamination in ground water that soakaway contributes to the water table within the study area.
3.0 To investigate the impact of the distance of constructed soakaway on borehole water quality.
4.0 To recommend an alternative or protective measure to avoid the intake of contaminated and untreated water within the study area.

Significance of Study

The purpose of this study was to assess the effect of siting boreholes and septic tanks/soakaway in the same area on groundwater quality in calabar south local government area of south-south region of Nigeria. As noted by Agunwamba (2008), human activities on the environment often results to pollution and degradation, which are detrimental to health.
The increased and continuous growths of the population within this area has led to the congestion of building without appropriate spacing, with majority of the households utilizing the services of septic/soakaway system for on-site waste treatment/disposal and boreholes as one of their major source for domestic water supply.

Majority of the water users, borehole owners and operators are ignorant of the implication of constructing a soakaway system for liquid and solid waste disposal in close proximity to a borehole water source. This research will serve as an eye opener.

Limitation of the Study

In the event of conducting this research work, there some constraints.
- Inability to sample for a one year period to obtain results based on seasonal variations due to the high cost involved in running laboratory analysis on the water samples.
- Difficulty in obtaining complete data for the research work due to the inability of borehole owners to provide some relevant borehole data such as the borehole depth. The

researchers were not allowed to collect samples from some black spot locations by residence

Research Hypothesis

The purpose of this study was to assess the effect of sitting boreholes and septic tanks/soakaway in the same area on groundwater quality in Calabar south local government area. This is the area where septic tank system is one of the major means of treating and disposing of wastewater and boreholes are also operated as a source for drinking water. The null hypothesis and the alternative hypothesis were:

Ho: There is no association between sitting boreholes and septic tanks/soakaway in the same area and quality of groundwater in Calabar south.

H1: There is association between sitting boreholes and septic tanks/soakaway in the same area and quality of groundwater in Calabar south.

II. Materials and Methodology

This was a cross-sectional study with respondent selected from fixed points in time around Calabar south. The map of Calabar south was used to distribute the sampling locations around the study area. Sampling points were selected based on borehole usage and the arrangement of soak away systems and other point sources of contamination around the study location in relation to the borehole position. Five sampling locations were randomly selected within the study area and there include Efioawan, Target, Edgerly, Goldie and Atamanu.

Questioners were designed and distributed to respondents around the study location in other to get relevant information for the study. During the study, only Four (4) soak-away distances were considered from each location

III. Data Collection

Information regarding the age of septic/soakaway and boreholes was collected from homes and the general public utility company. Records of the soak away distance from relative bore holes were measured in the field with a measuring line tape of 50meters and the corresponding distances of all the septic system was recorded as shown in table I

Also the information regarding the household numbers and septic system usage was also collected

TABLE I. Relative distance of soakaway pit from selected boreholes.

Sampling Location	Soakaway one (1)	Soakaway two (2)	Soakaway three (3)	Soakaway four (4)
TARGET	8.5m	13.6m	8.7m	11.3m
GOLDIE	10.0m	18.3m	15.6m	21.4m
EFFIO ANWAN	10.4m	10.9m	11.7m	14.4m
EDGERLEY	7.8m	8.9m	11.3m	17.0m
ATAMUNU	14.5m	15.2m	16.0m	19.4m

Source: Field data.

Laboratory analysis of water is established in other to ascertain the quality of the water sample. The water samples obtained from the five locations, were taken to the Cross River state water board authority laboratory for the physico-chemical and bacteriological analysis which involves tests for determining the physical, chemical, and bacteriological impurities present in water samples.

Bacteriological analysis (total coliform and faecal coliform): The method employed for this analysis is the membrane filtration method. All the glass, waves and the media used were sterilized in an autoclave at 121^0c for 15 minutes. The media used (Endo agar and MF-c agar base), were prepared according to the manufacturers instruction before sterilization

Data analysis method: Microsoft Excel computer package 2013 version was used for both data entry and analysis. Multiple regression model was employed to determine if there was a relationship between the bacteriological quality of borehole water and the distance of soakaway from the water source. P-values of less than 0.05 were considered statistically significant in other to reject the null hypothesis.

An empirical model was generated to determine the relationship between the bacteriological quality of water and the distances between soak away and borehole water source. From the model, the dependent variable (Y variable) was taken as the fecal coliform, while the independent variables (X variables) includes distances from borehole to soak away, Total coliform count (TCC), total dissolved solid (TDS), and Nitrate. All of which are product of human waste. From the general linear regression equation written as;

$$Y = a + bX + e \quad (1)$$

Where

Y = dependent variable, a = constant, b = Slope

X = independent variable, e = error term.

For this study, the model sample is given as:

$$Y_{fcc} = 0.121X_{dist} + 0.487X_{tcc} - 0.509X_{tds} + 2.806X_N + 0.554 \quad (2)$$

Where:

Y_{fcc} = faecal coli form; that is the dependent variable.

$\beta_{1,2,3,4}$ are coefficients of the independent (x) variables which represents the slopes of the regression line. While β0 is the error term.

X_{dist} = variable 1, representing the distances between soak away and bore hole.

X_{tds} = variable 3, representing the total dissolved solid obtained from the sample result.

X_N = variable 4, representing the level of Nitrate (NO2) present in the sample. The area of each soakaway was calculated using the principle of the area of each soakaway was calculated using the principle of Thiessen's mean method in AUTOCAD2012 version, and then the area of each soakaway influence was divided by the total area surrounding the selected boreholes. The corresponding result obtained for each soakaway was then multiplied with the laboratory analysis result per parameter been studied for each soakaway to borehole.

Data generated from this computation was then used to develop the empirical model as shown in equation (5), to test for the relationship between the bacteriological quality of borehole water and its relative distance to soakaway point.

Fraction of soak away contribution Where:

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$$SK_n = \frac{A}{A_{total}} \quad (3)$$

SK_n = fraction of the soakaway contribution to the water quality.

n = 1,2,3,4

A= area of each soak away influence

A_{total} = total area surrounding the bore hole

Actual contribution=(3)*(actual lab result of the parameter) --(4)

$$(A_{total} = A_1 + A_2 + A_3 + A_4)$$

IV. Results and Discussions

The main indicator used for these studies to ascertain the bacteriological quality was the faecal coliform count per100ml of the groundwater sample.Water samples which had a coliform count of zero was considered to be satisfactory, while those containing coliform count greater than zero was considered unsatisfactory based on the WHO and NSDWQ (2008) standards set for drinking water quality.For the regression analysis, a significance level of 0.05 was used for the regression.

UNOBJ = Unobjectable, BDL =below detection level, CFU = Colony forming unit, TSS =Total suspended solid, TDS = Total dissolve solid, DO = Dissolved oxygen, NSDWQ = Nigeria standard for drinking water quality, (2008).

Table II shows the result for all the physio-chemical and bacteriological quality of the water samples collected and analysed from all the locations.

TABLE II. Laboratory result analysis for the different sampling locations.

Parameter/ Unit	EffioAnwan	Target	Goldie	Edgerley	Atamunu	NSDWQ
Appearance	Clear	Clear	Clear	Clear	Clear	Clear
Odour	UOBJ	UOBJ	UOBJ	UOBJ	UOBJ	UOBJ
Taste	UOBJ	UOBJ	UOBJ	UOBJ	UOBJ	UOBJ
Colour (HU)	5.0	5.0	5.0	5.0	5.0	5.0
Temperature (^{0}C)	29.0	28.9	29.0	28.6	30.0	Ambient
pH	4.03	3.89	3.60	3.61	4.06	6.5- 8.5
Turbidity (NTU)	0.926	1.44	1.22	1.08	1.14	5.0
Conductivity (µs/cm)	93.3	30.1	55.6	54.5	36.6	1000
TDS (mg/l)	55.98	18.06	33.36	32.7	21.96	500
TSS (mg/l)	0.00	0.00	0.00	0.00	0.00	0.1
DO (mg/l)	8	6.6	10.6	7.8	4.0	-
Zinc (mg/l)	0.26	0.13	0.18	0.35	0.17	5.0
Iron (mg/l)	0.23	0.10	0.15	0.10	0.07	0.30
Copper (mg/l)	0.17	0.09	0.11	0.24	0.05	1.0
Nitrite (mg/l) NO2	0.02	0.05	0.06	0.03	0.10	0.1
Nitrate (mg/l) NO3	9.20	6.00	8.20	10.0	7.00	10
Alkalinity (mg/l)	6.51	6.40	6.11	6.12	6.55	-
Calcium (mg/l)	5.60	4.20	6.0	5.0	4.13	10
Magnesium (mg/l)	9.22	10.5	8.50	7.30	7.22	20
Total hardness (mg/l)	14.82	14.70	14.10	12.30	11.35	100
Chromium (mg/l)	0.00	0.00	0.00	0.00	0.00	0.01
Lead (mg/l)	BDL	BDL	BDL	BDL	BDL	0.001
Phosphate (mg/l)	6.30	5.13	4.02	5.00	4.80	100
Sulphate (mg/l)	3.11	4.05	3.55	3.01	2.65	100
Fluoride	0.60	0.40	0.51	0.40	0.57	1.5
Total coliform count (cfu/100ml)	45	68	25	65	15	0
Fecal coliform count (cfu/100ml)	21	37	12	41	8	0

TABLE III. Result for the bacteriological quality of borehole water.

Parameters/location	Target	Effioanwan	Goldie	Edgerley	Atamunu	NSDWQ
Total coliform count (cfu/100ml)	68	45	25	65	15	0
Faecal coliform count (cfu/100ml)	37	21	12	41	8	0

Based on the bacteriological quality result of the water samples extracted from table II above and presented below in table III, it shows that all the water samples collected from all the locations and tested for, are contaminated, having traces of total and faecal coliform counts greater than zero as against the WHO (2003), and NSDWQ (2006) standards for drinking water quality.

Hence, all the water samples were unsatisfactory, showing higher responses at two locations, Target and Edgerley, which recorded readings of 37cfu/100ml and 41cfu/100ml.Field data from table IV shows that no borehole meets the recommended minimum effective distance of 30m WHO (2006) for constructing soakaway from any drinking water source.

TABLE IV. Borehole distance measured from relative soakaway.

Soakaway distance(m) to Sampling Locations	Soakaway one (1)	Soakaway two (2)	Soakaway three (3)	Soakaway four (4)
TARGET	8.5m	13.6m	8.7m	11.3m
GOLDIE	10.0m	18.3m	15.6m	21.4m
EFFIO ANWAN	10.4m	10.9m	11.7m	14.4m
EDGERLEY	7.8m	8.9m	11.3m	17.0m
ATAMUNU	14.5m	15.2m	16.0m	19.4m

Source: Field data.

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TABLE V. Data fromThiessen's mean method computation analysis.

TARGET				Computed Parameters Result			
Soakaway positions	**Distance (m)**	**Calculated Area (m^2)**	**Fraction (A/Atotal)**	**FCC**	**TCC**	**TDS**	**N03**
SK 1	8.5	35.8	0.1703	6.30	11.58	3.08	1.02
SK 2	13.6	81.1	0.3858	14.28	26.23	6.97	2.32
SK 3	8.7	31.7	0.1508	5.58	10.25	2.72	0.91
SK4	11.3	61.6	0.2932	10.85	19.94	5.31	1.76
GOLDIE							
SK 1	10.0	43.1	0.0822	0.99	2.76	2.74	0.67
SK 2	18.3	149.7	0.2854	3.42	7.14	9.52	2.34
SK 3	15.6	110.1	0.2099	2.52	5.25	7.00	1.72
SK4	21.4	221.7	0.4226	5.07	10.57	14.11	3.47
EFFIO ANWAN							
SK 1	10.4	48.0	0.1925	4.04	10.78	10.78	1.77
SK 2	10.9	57.8	0.2318	4.87	12.98	12.98	2.13
SK 3	11.7	56.9	0.2281	4.79	12.76	12.77	2.19
SK4	14.4	86.7	0.3476	7.30	19.46	19.46	3.20
EDGERLEY							
SK 1	7.8	28.2	0.1217	4.99	7.91	3.98	1.22
SK 2	8.9	28.4	0.1225	5.02	7.96	4.01	1.23
SK 3	11.3	59.7	0.2576	10.56	16.74	8.42	2.58
SK4	17.0	115.5	0.4983	20.43	32.39	16.29	4.98
ATAMUNU							
SK 1	14.5	101.5	0.1999	1.60	2.99	4.39	1.39
SK 2	15.2	109.5	0.2157	1.73	3.24	4.73	1.51
SK 3	16.0	115.4	0.2273	1.82	3.41	4.99	1.59
SK4	19.4	181.3	0.3571	2.86	5.36	7.84	2.50

The model developed records a good multiple regression coefficient of 0.998 and an R-squared value of 0.995 confidence level. This implies that the model is good and can be used to explain over 99 percent of the variables. Table V shows that all the **p**-values of the variables are less than the $\alpha =$0.05 and hence are all statistically significant in the prediction of the response Variable 1 (distances), recorded a **p – value** of 0.0023 < 0.05 indicating that it is highly significant in explaining the relationship between the distance of soakaway to drinking water source and the bacteriological quality of the groundwater. Comparing the **calculated't'**with the **critical 't'** from the standard table, it shows that the calculated '**t'** for variable 1(distance) recorded a higher value of 3.647, than the critical '**t**' 2.132 at 0.05 significance level. This implies that distance is statistically significant with regards to the prediction of the impact of faecal coliform in the borehole.

From the empirical model developed for these studies given below to determine this relationship,

$$Y_{fcc} = 0.121X_{dist} + 0.487X_{tcc} - 0.509X_{tds} + 2.806X_{N} + 0.554 \quad (5)$$

V. CONCLUSION

Due to the close arrangement of building structures, small plots sizes within the study area, with over 85 percent of the households, utilizes septic tank and soak away system as a major means for on-site waste water treatment and disposal, while the other 15 percent employ other methods such as aqua privies.

Also due to the unstable and unreliable supply of water by the state utility company to the growing population, hence the residents resort to sourcing for an alternative means of drinking water such as drilling of borehole and hand dug wells within and around compounds utilizing soakaway systems for waste disposal and thereby operating soakaway system in close proximity to the drinking water source.

The model analysis used in this study shows all p-values lower than the significance level of 0.05 implying, all are statistically significant in predicting the response variables, and a multiple regression coefficient of 0.998. Therefore, sitting borehole close to any pollution source (soakaway) is very detrimental to the quality of the ground water resources

TABLE V. Regression analysis for the bacteriological quality of borehole water in relation to soak away distance:

Summary output

REGRESSION STATISTICS	
Multiple R	0.99782387
R Square	0.995652485
Adjusted R Square	0.994493147
Standard Error	0.362528518
Observations	20

Anova

	df	**SS**	**MS**	**F**	**Significance F**
Regression	4	451.4838911	112.8171	858.8116286	1.63892E-12
Residual	15	1.97140389	0.131427		
Total	19	453.455295			

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	Coefficient	Standard Error	t Stat	p-Value	Lower95%	Upper95%	Lower95%
Intercept	0.54352238	0.362090519	1.501095	0.154086004	-0.228245435	1.31530991	-0.228245435
X variable 1	-0.121310583	0.033258403	-3.64752	0.002381937	-0.192199192	-0.050421975	-0.192199192
X variable 2	0.48695073	0.020852071	23.35263	3.3046E-13	0.442505592	0.531395869	0.442505592
X variable 3	-0.508934091	0.03336986	-15.2513	1.53506E-10	-0.58006034	-0.437807841	-0.58006034
X variable 4	2.806653142	0.258157531	10.87186	1.64582E-80	2.256403391	3.356902894	2.256403391

VI. Recommendations

Based on this research work, the following recommendations were made.

Government should improve the general public water supply to these areas in order to reduce the over dependent on borehole water source.

Proper geological and environmental studies should be carried by qualified personnel before carrying out any project involving ground water exploration such as borehole drilling. Government should put in place a legislation which would be responsible for supervising borehole construction and issuance of permits and penalising offenders.

The state government should fund further studies on the ground water quality control and other factors that may lead to water contamination within the study area and beyond.

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