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Bacteriological Characterization of Drinking Water Boreholes Sited in Residential Areas: A Study of Water Quality in Afikpo and Unwana Towns of Ebonyi State Nigeria

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ABSTRACT: Access to safe drinking water sources curtails the spread of water borne diseases. Bacteriological characterization can provide data for safe management of drinking water sources. Water boreholes sited in residential areas are prone to bacteriological contamination because of anthropogenic activities in the site environment. However, most bacteriological characterization studies on water boreholes have not generated data on the site environment. Therefore, this study undertakes bacteriological water quality and site environment analyses to characterize water boreholes in residential areas of Afikpo and Unwana Towns of Ebonyi State, Nigeria. Thirty five water samples were taken from seven major water boreholes. The samples were analysed for colonies of microorganisms, coliform organisms, and E-coli, using agar plate count method, multi-tube fermentation technique, and Endo- agar plate count enumeration method, respectively. Colonies of microorganisms were detected in all the samples (mean: 65cfu/ml); coliform Organism in 31 samples (mean: 26 cfu/100ml), and E-coli in 28 samples (mean: 5cfu/100ml). These results did not meet the safe drinking water limits set by the World Health Organization and the Nigerian Standards for Drinking Water Quality. The site environment was evaluated using a semi-quantitative matrix. Six of the seven borehole site environments have medium to high "likelihoods" of bacteriological water contamination. The study found a strong link between bacteriological water quality and the site environment. The findings demonstrate that bacteriological characterization based on water quality and site environment can provide reliable data for monitoring drinking water boreholes in residential areas, for protecting public health.

KEY WORDS: Bacteriological; Contamination; Environment; Likelihood; Public Health

I.INTRODUCTION

Water is a prime necessity of life. Good quality water precedes good quality life. Bad quality drinking water causes ill health, spreads diseases most of which have a major impact at increasing infant and child mortality. The provision of public portable water has been a major tool for elimination or reduction of many waterborne diseases in developed countries such as United States, United Kingdom and Japan (Water Quality and Health Council ,2019; Smith et al , 2006; Japan International Cooperation Agency, 2017;). However, access to clean drinking water remains a pressing global challenge.

According to the World Health Organization [WHO], (2019) about 2.2 billion people globally are still not provided with safely managed drinking-water services, to the extent that, at least 2 billion people obtain drinking water from faecally contaminated sources. Many governments in the developing countries are still unable to meet drinking water needs of many of their citizens (United Nations Children's Fund [UNICEF] and WHO, 2019). Due to the scarcity public drinking water supplies, many people in water scarce countries are constrained to obtaining drinking water through self-help or private efforts, consisting of abstracting water from any readily available or affordable source such as rain water, surface water, springs, water wells or water boreholes. Where public drinking water supplies systems exist, they are usually managed through organized and structured systems, for example source-to- tap

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municipal supplies or isolated improved supplies such as protected springs and wells. Public drinking water systems typically include some kind of water treatment or source water protection. However private water supplies systems are often not safely managed; water source protection, facility maintenance, water treatment, and drinking water quality management are usually neglected in private drinking water supply arrangements.

In Sub-Saharan Africa and South-East Asia regions of the world there is acute public drinking water shortages (Hunter, et al, 2010).Many people in these countries obtain water from private water supply arrangements that are not safely managed. It may not be therefore be surprising that countries in Sub-Saharan Africa and South-East Asia do also experience high prevalence of water borne diseases such as diarrhea (UNICEF, 2O19) and typhoid fever (WHO, 2018). Nevertheless, advice or enlightenment based on good analysis of water sources can help individuals to properly manage their water supplies in a way to avoid or minimize water contamination and reduce water borne disease prevalence.

The Nigeria government is currently unable to meet the increasing drinking water needs of citizens (The Guardian Editorial Board, 2009, International Atomic Energy Agency [IAEA], 2009). In response, many citizens resort to sinking of water boreholes at their homes so as to provide drinking water for their families. This practice is gaining much prominence in Nigerian drinking water supplies. According to Kumolu (2012), since all levels of government in Nigeria have failed to provide adequate safe drinking water supply to its citizens, many Nigerian property owners consider water boreholes as a necessary alternative source to potable water. Unfortunately the sinking and operation of water boreholes in Nigeria are still largely unregulated. There are, however, some concerns about the water quality especially the public health effect of water contamination. Some argue that reliance on boreholes for potable water portents danger for Nigerians because boreholes can easily be contaminated by microorganisms, leaky hazardous substances, and heavy metals. The fears are not unfounded because despite increasing number of water boreholes in Nigeria, incidences of waterborne diseases, such as typhoid fever and diarrhea, are still high in the country.

Many water quality studies of drinking water boreholes have been carried out in Nigeria. The studies tried to determine the nature and the quantity of contaminants in the studied drinking water boreholes (Osiemo, et al, 2019; Okoye, et al, 2016; Okereke, et al, 2014). However, these studies did not evaluate the associated environmental risk factors which contribute to contamination of drinking water boreholes. Nonetheless, the current study attempts to close this gap. In addition to determining the bacteriological water quality parameters, this study seeks to evaluate the environmental factors within the site environment which likely contribute to bacteriological contamination of drinking water boreholes. The study also intends to characterize water boreholes sited in the residential areas of Afikpo and Unwana Towns of Ebonyi State Nigeria, based on water quality and site environment parameters. It develops a semi-quantitative methodology for determining the likelihoods of bacteriological contamination of borehole water supplies which may come from the borehole site environment. This study further assesses the relationship between bacteriological water quality parameters and borehole site bacteriological environment.

Figure 2.1: Photograph of water borehole dispensing point with a child collecting water (Outside the fence of a residential compound)

Figure 2.2: Photograph of the wellhead (Inside the compound)

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II MATERIALS AND METHODS

A. The Study Area

The study area consists of the communities in Afikpo and Unwana Towns in Ebonyi State Nigeria. Afikpo and Unwana are the two most populous towns of Afikpo North Local Government Area of Ebonyi State in South Eastern Nigeria. Afikpo is located on a map in latitude 5.8895 ° N, longitude 7.9538 ° E, while Unwana can be found in latitude 5.8660° N, longitude 7.9457° E. Afikpo is the administrative headquarters of the Local Government while Unwana is home to Akanu Ibiam Federal Polytechnic Unwana. The Study area comprises of over 70% of the Local Government Population put at 156,611 people by 2016 Census (National Bureau of Statistics, 2013). Private water boreholes sited in residences are the major source of drinking water in the study area. The study was based on seven major communities: Amaizu, Amuro, Mgbom, Ngodo, Ndibe, Akanu Ibiam Federal Polytechnic Unwana and Unwana Community. The water boreholes selected are those that supply water to the owners" households and also sell water to other families in the neighbourhood. Figure 2.1 shows a photograph of water dispensing arrangement of one the studied boreholes in a residential area, while figure 2.2 is a photograph of the well (borehole) head of the same borehole. The arrangements are typical of water boreholes sited in residential areas in Nigeria.

B. Sample Collection

Water samples were collected from seven drinking water-boreholes sited at residential areas (or living compounds) spread across communities in Afikpo and Unwana Towns of Afikpo North Local Government Area in Ebonyi State, Nigeria. The boreholes selected were those that serve both compounds occupants and consumers/customers in the neighbourhood. Water samples were collected at points of delivery to consumers. Clinical hand gloves were worn during sample collection. The samples were collected in clean sterilized bottles which have stoppers. Each bottle was rinsed 3 times with water from a selected sampling water-borehole dispensing point before a sample was collected, and subsequently labelled, indicating the source, date, and time of collection. The samples were stored in a clean ice chest containing ice-packs and water to ensure rapid cooling. The samples were transferred to the laboratory for analysis within 24 hours for bacteriological examination. Each water-borehole was sampled once weekly for five consecutive weeks.

C. Bacteriological Investigation of Water Samples

Bacteriological investigation focused on indicator organisms, namely the colonies of microorganisms, coliform organisms and E-coli. Colonies of microorganisms in water samples were determined using the agar plate count method. A nutrient agar media was prepared according to manufacturer's instruction. Each water sample was serially diluted with distilled water. An empty petri-dish was inoculated with 1ml of each diluted sample. The prepared nutrient agar was raised to a temperature of about 45 OC in a water bath. Then 10ml of the sterile nutrient agar was added under flame to each petri-dish containing specific dilution of the water sample. The contents were mixed thoroughly by gently rotating the dish and ensuring that the medium covered the plate evenly. The agar was allowed to completely solidify without disturbance in about 10 minutes. The dish was sealed and placed in an inverted position inside an incubator at 37 OC for 48 hours. Colonies of microorganisms were indicated in the dishes by white spots which were enumerated using a colony counter (Bichi & Amatobi, 2013).

Coliform organisms were determined using the multi-tube fermentation technique (American Public Health Association. [APHA],1999; Punmia, Jain & Jain, 1995).The presence of E-Coli in the water samples was determined by subjecting a portion of every sub-culture tube that tested positive for coliform, during the presumption test to Endo-agar plate count enumeration method (Bichi & Amatobi, 2013).

D. Semi-quantitative Assessment of Borehole Site Environment.

The site bacteriological environment elements of the studied boreholes consist of well heads, septic tanks, landfills/refuse dumps, animal farmyard refuse, runoff accumulation, water storage devices , water distribution pipes and manual handling of water. In this study the "likelihoods" that borehole water could be contaminated by the site environment elements were assessed using a semi- quantitative matrix developed in this study (Table 2.1). The elements assessed are those that are common to most residential areas in the study area. The elements include:

1. Distance of well head from septic tank:
2. Well head protection

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3. Manual handling /poor hygiene at water dispensing points (through valves, funnels, pipes)
4. Accumulation of runoff after rains within less than 15m radius of the wellhead position
5. Existence of landfills/animal farm in the vicinity of the premises
6. Storage tank protection system

Based on the existing practices surrounding these elements *vis-à-vis* international best practices and expert opinions, each of environment element situations was categorized as good, poor or bad. The international best practices were obtained from literature : United States Environmental Protection Agency[US EPA] ,(2002) - for septic tank, landfill, animal farm ; University of Georgia, (2017); EPA (Ireland),(2013) - for wellhead protection; Agensi, et al,(2019) - for manual handling/hygiene; Khan and AlMadani, (2017) - for storage tank maintenance; University of Nebraska–Lincoln , (2019) - for accumulation of runoff. Opinions of experts in public health, microbiology and water resources engineering were also obtained concerning the likelihood of water contamination from the environment elements.

Table 2.1: Semi-Quantitative Matrix for Determining the Likelihood of a Water Borehole Bacteriological Contamination

	Borehole Label:	**Practices Level (Likelihood to Bacteriological Contamination)**					
S/no	Environment Element	Level 1- Good(Score)	Level 2 -Poor (Score)	Level 3 Bad (score)	Weigthts	Level Score	Likelihood Scores (Level Score X Weight)
1	Distance of well head from septic tank	Above 15 m(0 .25)	12 to 15 m (0.5)	Less than 12 m (0.75)			
2	Well head protection	Concrete apron cast around top of the borehole; head protected from human and animal access (0.25)	Concrete apron cast around top of the borehole but head is not protected from human and animal access (0.5)	No concrete apron cast around top of the borehole and head is not protected from human and animal access (0.75)			
3	Manual handling of water at dispensing points (through valves, funnels, pipes)	Restricted (0.25)	Partially restriced(0.5)	Not restricted (0.75)			
4	Accumulation of run off within 12m radi of the wellhead position afer rains	No accummulation (0.25)	Intermittent accummulation (0.5)	Regular accummulation (0.75)			
5	Existence of landfils/animal farm in the vicinity of the premises	Above 15 m(0 .25)	12 to 15 m (0.5)	Less than 12 m (0.75)			
6	Storage devices protection	Covered and no leaks(0.25)	Covered but there are leaks (0.5)	Not covered or there are leaks (0.75)			
					Total Likelihood Score		L(β)

The likelihood of contamination was obtained by assigning probabilities to bacteriological contamination of boreholes due to site environment: 0.25 for good environment, 0.5 for poor environment and 0.75 for bad environment. To account for the relative significance of the environment factors, weights were assigned to the scores based on expert's opinion. The weights sum to one. The total likelihood (probability) of contaminations was obtained by the linear pool aggregation (Robert & Robert, 1999), using:

$$L(\beta) = \sum_{i=1}^{n} w_i L_i\,(\beta) \qquad (2.1)$$

where $L(\beta)$ is the combined likelihood of bacteriological contamination of a borehole from environment elements, n is the number of environmental elements, $L_i(\beta)$ represents the $i's$ probability distribution for unknown β, and the weights w_i are non negative numbers and sum to one.

The likelihood of bacteriological contamination of water borehole based on the site environment elements was characterized using a schedule developed in this study, as shown in figure 2.2 below:

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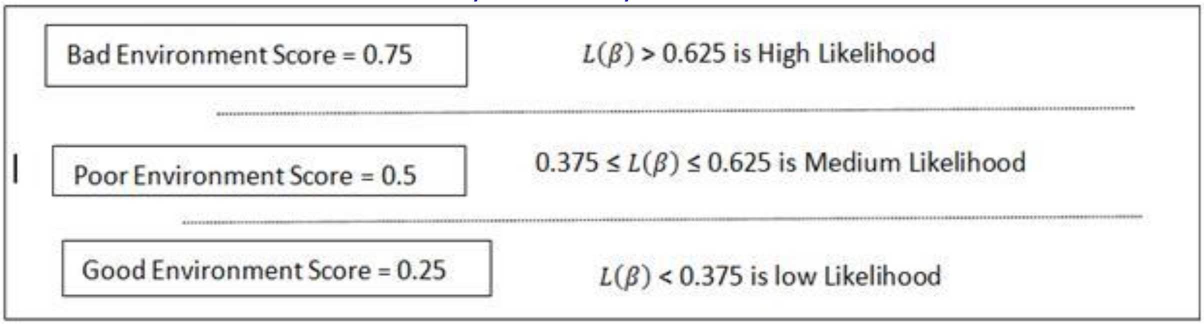

Figure 2.2: Likelihood Characterization Schedule.

Chi-square distribution was used to assess the relationship between bacteriological water quality parameters and borehole site bacteriological environment. Thus null hypotheses were stated as follows:
H_o1: The number of Colonies of microorganisms in water supplies from boreholes sited in residential areas is not related to the characteristics of the resident environment.
H_o2: The number of Coliform organisms in water supplies from boreholes sited in residential areas is not related to the characteristics of the resident environment.
H_o3: The number of E-coli in water supplies from boreholes sited in residential areas is not related to the characteristics of the resident environment.

III. RESULTS AND DISCUSSION

A. Results of Bacteriological Analysis of Water from Boreholes Sited at Residential Areas

Table 3.1 is a summary of the results of bacteriological investigation of water samples collected from boreholes sited in residential areas at Afikpo and Unwana Towns of Afikpo North Local Government Area of Ebonyi State Nigeria. Figures 3.1, 3.2, and 3.3 show the variations in the colonies of microorganisms, coliform organisms, and E-coli, respectively.

Table 3.1: Summary (Mean) Result of Bacteriological Water Investigation of Water Samples Collected from Drinking Water Boreholes Sited in Residential Areas of Afikpo and Unwana Towns in Ebonyi State of Nigeria

		SAMPLED BOREHOLE LABELS										
S/No	Parameters	A	B	C	D	E	F	G	Mean	Standard deviation	WHO limits	NSDWQ limits
1	Colonies of microorganisms grown on Nurient Agar at *37 degrees Celcius for 48 hours(cfu/ml)*	65	76	109	32	56	45	69	65	25	10	10
2	MPN of coliform organism per 100ml of water sample (cfu/100ml)	21	36	55	8	9	28	23	26	16	0	0
3	MPN of E-coli organism per 100ml of water sample (cfu/100ml)	4	4	8	0	3	7	6	5	3	0	0

Source: Field Survey

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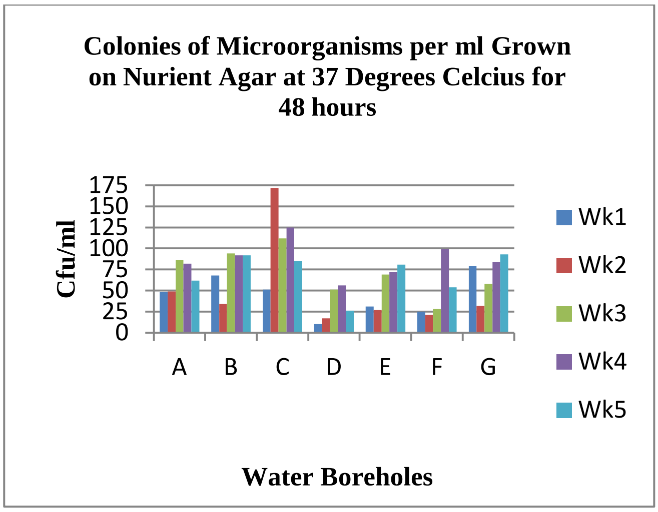

Figure 3.1 Variation in Colonies of Microorganisms

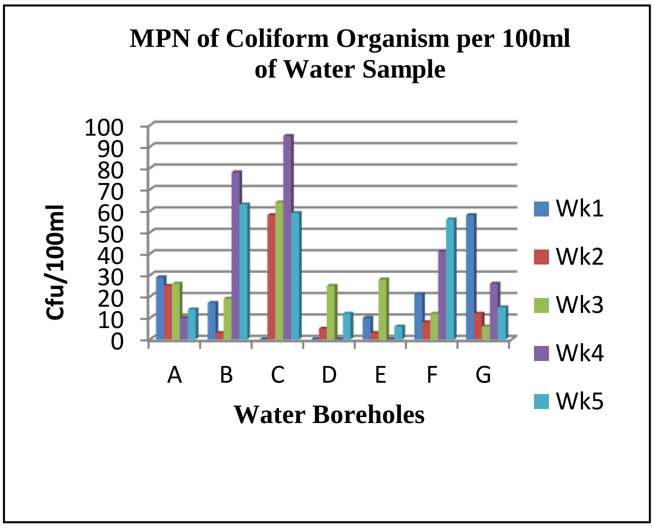

Figure 3.2 Variation in Coliform Organisms

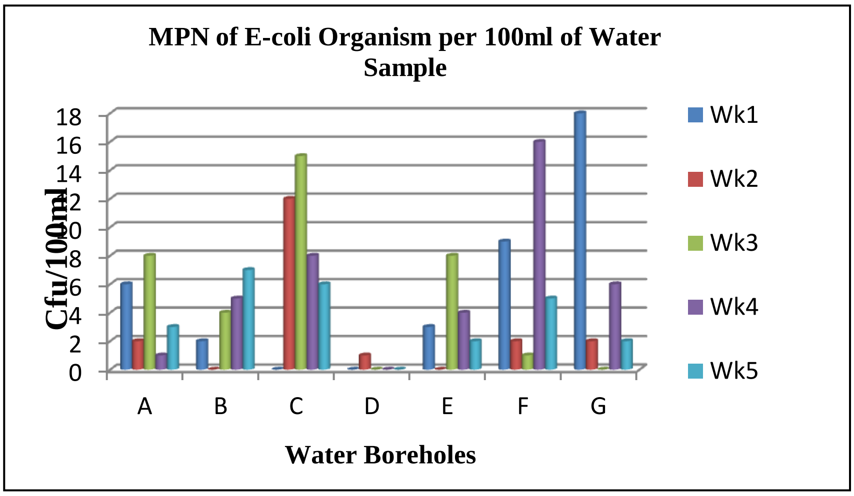

Figure 3.3 Variations in E-coli Organisms

From the results of the bacteriological investigation, 100% of the samples tested positive to colonies of microorganisms with a mean of 65cfu/ml; about 88% of samples tested positive to coliform organisms with a mean of 26cfu/100ml, and 80% of the samples tested positive to E-coli with a mean of 5cfu/100ml. The results also show that water from only one borehole met the safe drinking water limits set by the Nigerian Standards for Drinking Water Quality (2007) and the World Health Organization (2004) which were 10cfu/ml, 0cfu/100ml, and 0cfu/100ml, for colonies of microorganisms, coliform organisms and E-coli respectively. The presence of E-coli is an indication of recent faecal contamination. The poor environment of most of the borehole sites (lack of proper installation, maintenance, water treatment and good hygiene) may have increased the chances of water contamination. Bad bacteriological water borehole site environments are not uncommon in Nigeria or in any other country where the operation of drinking water borehole is not regulated, supervised or monitored. The result agrees with the findings of similar studies in Nigeria such as Onuorah, et al (2019); Aina, et al (2012); Ibe and Okpelemye (2005); among others. Feacal contamination of borehole water has also been identified from studies in other countries such as South Africa (Palamuleni and Akoth, 2015), India (Mukhopadhyay, et al, 2012), and Ghana (Odonkor and Addo, 2013).

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B. Results of Semi-quantitative Assessments of Borehole Site Environments.

Table 3.2 is the result of semi-quantitative assessments of residences in relation to the sampled borehole sites.

Table 3.2 Characterization of the Likelihood of Borehole Site Environment to Contaminate Water Supply

Boreholes	Likelihood scores	Environment Likelihood to Contaminate Water
A	0.6000	Medium
B	0.6000	Medium
C	0.6625	High
D	0.3250	low
E	0.6375	High
F	0.7500	High
G	0.7250	High

Source: Field Survey

About 57% of the boreholes sited in the residential areas seem to have high likelihood of being contaminated by activities going on in the environment. And 28% of the boreholes have medium likelihood. This poor environmental performance can be linked to improper management of most drinking water boreholes in Nigeria. It is fact that in Nigeria, the sinking and operation of drinking water boreholes at homes is simply an “owner’s affair.” Issues pertaining to proper installation, maintenance and good water quality are often neglected, albeit ignorantly.

C. Test of Hypotheses

For the test of hypotheses a Chi-square (X 2) analysis was used at a confidence interval, $\alpha = 0.05$. The data for the test are the loads of microbial organisms detected in water samples from all the boreholes under different likelihoods of bacteriological contamination.

a). Test of Hypothesis one (H01): The number of Colonies of microorganisms in water supplies from boreholes sited in residential areas is not related to the characteristics of the resident environment. Table 3.3 is the Chi-square (X2) analysis table used to test hypothesis one.

Table 3.3 Chi-square (X2) Analysis Table for Test of Hypothesis One

Bore Hole Environment	Colonies of Microorganisms Detected in Water Samples					
(Likelihood of Contamination)	WK1	WK2	WK3	WK4	WK5	TOTAL
High Likelihood	186	252	267	380	313	1398
Medium Likelihood	116	83	180	174	154	707
Low Likelihood	10	17	51	56	26	160
Total	312	352	498	610	493	2265
Observed Frequency (FO)	Expected Freuency (FE)	FO-FE	$(FO-FE)^2$	$(FO-FE)^2/FE$		
186	192.57	-6.57	43.19	0.22		
252	217.26	34.74	1206.80	5.55		
267	307.37	-40.37	1630.13	5.30		
380	376.50	3.50	12.23	0.03		
313	304.29	8.71	75.89	0.25		
116	97.39	18.61	346.40	3.56		
83	109.87	-26.87	722.20	6.57		
180	155.45	24.55	602.88	3.88		
174	190.41	-16.41	269.16	1.41		
154	153.89	0.11	0.01	0.00		
10	22.04	-12.04	144.96	6.58		
17	24.87	-7.87	61.86	2.49		
51	35.18	15.82	250.31	7.12		
56	43.09	12.91	166.65	3.87		
26	34.83	-8.83	77.89	2.24		
			Calculated X^2	49.07		
			Tabulated $X^2\alpha,v$ $:\alpha = 0.05, v = 8$	15.51		

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Since calculated X2 value is greater than the tabulated X2 value, the null hypothesis is rejected. Hence it is concluded that the number of Colonies of microorganisms in water supplies from boreholes sited in residential areas at Afikpo and Unwana towns is related to the characteristics of the resident environment.

b). Test of Hypothesis Two (H02): The number of Coliform organisms in water supplies from boreholes sited in residences is not related to the characteristics of the resident environment. Table 3.4 is the Chi-square (X2) analysis table used to test hypothesis two.

Table 3.4 Chi-square (X2) Analysis Table for Test of Hypothesis Two

Bore Hole Environment	Coliform Organisms Detected in Water Samples					
(Likelihood of Contamination)	WK1	WK2	WK3	WK4	WK5	TOTAL
High Likelihood	89	81	110	162	136	578
Medium Likelihood	46	28	45	88	77	284
Low Likelihood	0	5	25	0	12	42
Total	135	114	180	250	225	904
Observed Frequency (FO)	Expected Freuency (FE)	FO-FE	$(FO-FE)^2$	$(FO-FE)^2/FE$		
89	86.32	2.68	7.20	0.08		
81	72.89	8.11	65.78	0.90		
110	115.09	-5.09	25.89	0.22		
162	159.85	2.15	4.64	0.03		
136	143.86	-7.86	61.79	0.43		
46	42.41	3.59	12.88	0.30		
28	35.81	-7.81	61.06	1.70		
45	56.55	-11.55	133.37	2.36		
88	78.54	9.46	89.49	1.14		
77	70.69	6.31	39.87	0.56		
0	6.27	-6.27	39.34	6.27		
5	5.30	-0.30	0.09	0.02		
25	8.36	16.64	276.80	33.10		
0	11.62	-11.62	134.91	11.62		
12	10.45	1.55	2.39	0.23		
			Calculated X^2	58.97		
			Tabulated $X^2\alpha,\nu$:$\alpha = 0.05$, $\nu = 8$	15.51		

The calculated X2 value is greater than the tabulated X2 value; so the null hypothesis is rejected. Thus, it is concluded that of Coliform Organisms in the water supplies from boreholes sited in residential areas at Afikpo and Unwana towns is related to the characteristics of the resident environment.

c). Test of Hypothesis Three (H03): The number of E-coli organisms in water supplies from boreholes sited in residences is not related to the characteristics of the resident environment. Table 3.5 is the Chi-square (X2) analysis table used to test hypothesis three.

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Table 3.5 Chi-square (X2) Analysis Table for Test of Hypothesis Three

Bore Hole Environment (Likelihood of Contamination)	No of E-Coli Organisms Detected in Water Samples					
	WK1	WK2	WK3	WK4	WK5	TOTAL
High Likelihood	30	16	24	34	15	119
Medium Likelihood	8	2	12	6	10	38
Low Likelihood	0	1	0	0	0	1
Total	38	19	36	40	25	158
Observed Frequency (FO)	Expected Freuency (FE)	FO-FE	$(FO-FE)^2$	$(FO-FE)^2/FE$		
30	28.62	1.38	1.90	0.07		
16	14.31	1.69	2.86	0.20		
24	27.11	-3.11	9.70	0.36		
34	30.13	3.87	15.00	0.50		
15	18.83	-3.83	14.66	0.78		
8	9.14	-1.14	1.30	0.14		
2	4.57	-2.57	6.60	1.44		
12	8.66	3.34	11.17	1.29		
6	9.62	-3.62	13.11	1.36		
10	6.01	3.99	15.90	2.64		
0	0.24	-0.24	0.06	0.24		
1	0.12	0.88	0.77	6.44		
0	0.23	-0.23	0.05	0.23		
0	0.25	-0.25	0.06	0.25		
0	0.16	-0.16	0.03	0.16		
			Calculated X^2	16.10		
			Tabulated $X^2\alpha,\nu$ $:\alpha = 0.05, \nu = 8$	15.51		

For the test of hypothesis three the calculated X2 value is greater than the tabulated X2 value; the null hypothesis is therefore rejected. Hence it is concluded that of E-Coli Organisms in the water supplies from boreholes sited in residential areas at Afikpo and Unwana towns is related to the characteristics of the resident environment

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d). Bacteriological Characterization of the Studied Water Boreholes Based on Laboratory Investigation of Water Samples and Semi-Quantitative Site Environment Analysis

A summary (average) of the bacteriological characterization of the water samples is shown in Table 3.6.

Table 3.6: Bacteriological Characterization of Water Boreholes Sited in Residential Areas of Afikpo and Unwana Towns of Ebonyi State Nigeria.

Boreholes	Colonies of Mmicrorganisms(Cfu/ml)	Coliform Organisms (Cfu/ml)	E-Coli Organisms (Cfu/100ml)	Likelihood scores	Environment Likelihood to Contaminate Water
A	65	21	4	0.6000	Medium
B	76	36	4	0.6000	Medium
C	109	55	8	0.6625	High
D	32	8	0	0.3250	low
E	56	9	3	0.6375	High
F	45	28	7	0.7500	High
G	69	23	6	0.7250	High
WHO (2004) Limits	10	0	0		
NSDWQ(2007) Limits		0	0		

The bacteriological characterization table indicates that poor environment is linked to the contamination of water supplies from drinking water boreholes in residential areas of Unwana and Afikpo Towns of Ebonyi State, in Nigeria.

IV. CONCLUSION AND RECOMMENDATIONS

The Study has assessed the bacteriological water quality and the bacteriological environment of major drinking water boreholes sited in residential areas of Afikpo and Unwana Towns of Ebonyi State in South Eastern Nigeria. Water from the studied boreholes did not meet the safe drinking water limits set by Nigerian Standards for Drinking Water Quality and the World Health Organization. Feacal contamination of water supplies is a big issue as 80% of the studied boreholes in residential areas were faecally contaminated. This reaffirms other findings which suggest that faecal contamination is a major issue of drinking water boreholes in Nigeria. Nwandkor and Obeagu (2015) found 58% of boreholes in Umuahia Metropolis to be faeceally contaminated. In same vein, Uzoigwe and Agwa (2012) found 100% of six sampled boreholes in Port Harcourt Nigeria to contain faecal coliform.
Most of the drinking water boreholes operate under poor sanitary and poor hygienic environments that are likely to contaminate water supplies. The sites of most water boreholes in the residential areas did not consider the location of septic tanks, or latrines, as possible sources of water contamination. The study found a strong association between the bacteriological water quality of drinking water boreholes sited in residential areas and the characteristics of the site Environment. The characterization provides a base data for monitoring drinking water boreholes, and protecting public health.
The Following are the recommendations:

1. Water boreholes, especially in residential areas must be sited at safe distances from pollutant sources (at least 15m from septic tanks, refuse dumps and farm yards). It should not only be a matter of space, as it is currently the case.
2. Water from boreholes sited in Afikpo and Unwana towns must always be boiled before direct consumption. This will reduce the high prevalence of typhoid fever and other water borne diseases in the area.
3. Drinking water borehole operators should be encouraged to undertake periodic assessments of the water quality and the borehole environment in order to envisage and avoid water contamination.

In order to safeguard the health of citizens, public health authorities and government agencies in Nigeria should begin to regulate the operation of water boreholes and to monitor borehole water quality

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