Investigation of Bacteriological Water Qualities of the River Surface and the River Bank of Iyere Unwana River, at Efe Amaekwu Village, Unwana, in Ebonyi State, Nigeria

Amatobi, D. A.[1]; Adenaike, A. O.; and Okeke, E. C.

Department of Civil Engineering, Akanu Ibiam Federal Polytechnic Unwana, Ebonyi State Nigeria
[1]**Corresponding** author: amatobiada@gmail.com

Abstract

This study investigates the bacteriological water quality of Iyere Unwana River at Efe Amaekwu Village, Unwana in Ebonyi State, Nigeria. The bacteriological water quality parameters were determined for two pairs of water samples collected at the river surface and at the river bank sampling points. Samples were collected every fortnight from October 2018 to July 2019. Each pair of the sample was analysed in the laboratory for the determination of the colonies of microorganisms, total coliform and E-Coli. For water samples collected from the river surface, the mean result values are 9.86 X 10^5 cfu/ml, 92cfu/100ml and 6cfu/100ml, for colonies of microorganisms, total coliform and E-Coli, respectively. For the river bank samples, the respective values are 7.67 X 10^5 cfu/ml, 64cfu/100ml and 3cfu/100ml. The study concludes that the bacteriological water quality of Iyere Unwana River at Amaekwu Village, at both the river surface and the river bank, exceeds the safe limits set by the World Health Organization (WHO) and the Nigerian Standard for Drinking Water Quality (NSDWQ). The off-limit microbial load at the river surface is not being reduced to safe levels as it flows to, or accumulates in the bank. The study recommends that the Amaekwu Village and other rural/ poor communities should be sensitized to always boil water obtained from rivers, streams or ponds before drinking, washing of plates and hands, and washing of fruits and vegetables meant to be eaten raw.

Keywords: Drinking Water, Quality, Bacteriological, River Bank, River Surface, Public Health

{**Citation**: Amatobi, D. A.; Adenaike, A. O.; and Okeke, E. C. Investigation of bacteriological water qualities of the river surface and the river bank of Iyere Unwana River, at Efe Amaekwu Village, Unwana, in Ebonyi State, Nigeria. American Journal of Research Communication, 2019, 7(10): 1-11} www.usa-journals.com, ISSN: 2325-4076.

1.0 Introduction

Water is a fundamental necessity of life. As the Pontifical Council for Justice and Peace **(2003**) puts it, "water plays a central and critical role in all aspects of life – in the national environment, in our economies, in food security, in production, in politics." Access to good quality drinking water is of vital importance for mankind because water quality has a direct link with the general wellbeing and welfare of people (United Nations Educational Scientific and Cultural Organization [UNESCO], 2019; UN-Water, 2011). Intake of clean drinking water is an essential daily need for a healthy body function. Adequate good quality water, or portable water, is also required for life supporting activities such as cooking, sanitation, personal hygiene, agriculture, industry, and recreational activities. However poor quality water is unsafe for human consumption because it can cause adverse health consequences, or lead to spread of waterborne diseases. In regions, nations and communities of the world where there are shortages of good quality drinking water, many people, especially the poor, tend to abstract water for domestic uses from unsafe water sources which consist of the unimproved and the surface water sources. According to the World Health Organization [WHO], (2019a), in the year 2017, 435 million people obtained water from unimproved sources and 144 million people from surface water sources.

Unimproved sources include unprotected well and springs while surface water sources includes rivers, streams, canals and ponds. Like many other sub-Saharan African countries, Nigeria still suffers acute portable water shortages (Council on Foreign Relations, 2018). As depicted in table 1 below many Nigerians depend on poor quality drinking water. Twenty-two per cent of Nigerians obtain their drinking water from unimproved and surface water sources (United Nations Children Fund [UNICEF] &WHO , 2019). Unimproved and surface water sources usually offer unrestricted access to pathogenic microorganisms such as pathogenic bacteria, viruses, protozoa and helminthes. The presences of any of these harmful organisms in a drinking water is an indication that the water is of poor bacteriological quality and unsafe for human consumption. Many members of these pathogens can live and breed in the intestinal tracks of humans and warm blooded animals, and can be present in faeces. Thus the unimproved and surface water sources can easily become tools for the spread of waterborne diseases, especially in situations where human and animal faeces can easily enter water bodies used as drinking water sources. This circumstance may not be farfetched in Nigeria, where there is lack of portable water facilitates, inadequate sanitation and poor hygiene, and also where there exists improper dumping of refuse and the practice of open defecation.

Consumption of drinking water that is contaminated by pathogens is linked to prevalence of waterborne diseases which results in the loss of thousands of lives, globally, every year. According to the WHO (2018) estimate, contaminated drinking-water causes more than 500,000 diarrhea global deaths annually. Access to poor quality drinking water also increases the risk of other diseases like cholera, typhoid fever and dysentery. The health risks and disease burden associated with unsafe drinking water is high among children below five years of age, in low income countries (WHO, 2019b). An analysis of table 1 below suggests that access to unimproved and surface water sources is positively correlated with diarrhea deaths of children under five years of age. This can support an assertion that provision of adequate good quality drinking water is requisite for reducing under-five mortality. In fact, UNICEF Nigeria (2019) estimates that poor access to adequate water, sanitation and hygiene is associated with as high as

seventy-three per cent of the diarrhea and enteric disease burden in Nigeria, with poorer children being the most affected.

The quality of drinking water is typically a reflection of the sources of the water. Improved water sources such as pipe borne water, protected boreholes, wells and springs, properly harvested rainwater, and packaged or bottled water are usually the sources of good quality drinking water. However unimproved sources such as unprotected boreholes, unprotected wells and springs, improperly harvested rain water, and surface water are sources of poor quality water. A major issue with unimproved and surface drinking water sources is the absence of proper water treatment and prevention of water contamination. Human and animal faecal materials easily enter the surface water through intake of runoff which usually carry improperly disposed wastes and sewage, and through open defecation, and direct dumping of wastes into water bodies. However, due to poor access to clean water supplies, especially in the rural areas in Nigeria many people still depend on surface water for their domestic and drinking water needs.

Table 1.Sub- Saharan Countries Status on Unsafe Water Access and Underfive Diarrhea Deaths

S/No	Country	Population, 2017 (million)	Unimproved Water Sources	Surface Water Sources	Unimproved Plus Surface Water Sources	% UnderFive Deaths Due to Diarrhoea (2016)*
1	Angola	29.7	19	15	34	13
2	Benin	11.2	20	4	24	11
3	Botswana	2.3	2	1	3	4
4	Burkina Faso	19.2	23	1	24	9
5	Burundi	10.9	15	5	20	10
6	Cameroon	24	16	7	23	10
7	Cape Verde	0.55	4	< 1	5	5
8	Central African Republic	4.6	27	7	34	11
9	Chad	14.9	39	6	45	14
10	Comoros	0.8	8	<1	9	9
11	Congo	5.2	10	6	16	7
12	Côte d'Ivoire	24.3	15	6	21	9
13	Democratic Republic of the Congo	81.3	36	9	45	11
14	Djibouti	0.96	7	2	9	8
15	Equatorial Guinea	1.3	26	6	32	6
16	Ethiopia	105	22	9	31	8
17	Gabon	2	3	3	6	6
18	Ghana	28.8	4	6	10	6
19	Guinea	12.7	9	11	20	8
20	Guinea-Bissau	1.8	26	1	27	9
21	Kenya	49.7	12	20	32	7
22	Lesotho	2.2	14	7	21	8
24	Liberia	4.7	6	13	19	8
25	Madagascar	25.6	22	13	35	9
26	Malawi	18.6	9	2	11	7
27	Mali	18.5	15	2	17	9
28	Mauritania	4.4	16	<1	17	10
29	Mauritius	1.2	1	<1	2	2
30	Mozambique	29.7	16	13	29	7
31	Namibia	2.5	4	6	10	7
32	Niger	21.5	18	24	42	9
33	Nigeria	190.9	15	7	22	10
34	Rwanda	12.2	14	6	20	7
35	Sao Tome and Principe	0.2	1	3	4	8
36	Senegal	15.8	16	<1	17	8
37	Seychelles	0.095	1	4	5	1
38	Sierra Leone	7.6	16	14	30	9
39	Somali	14.7	14	3	17	13
40	South Africa	56.7	2	3	5	8
41	South Sudan	12.6	17	9	26	9
42	Sudan	40.5	4	9	13	9
43	Tanzania	57.3	18	14	32	9
44	The Gambia	2.1	13	<1	14	9
45	Togo	7.8	16	13	29	7
46	Uganda	42.8	12	7	19	8

Source: UNICEF and WHO (2019); * Data published by UNICEF (2018)

Correlation coefficients: Correlation Values: Unimproved Vs Underfive deaths = 0.65; Surface water Vs Underfive Deaths=0.18; Unimproved Plus Surface water Vs UnderFive Deaths = 0.59.

Fetching water from the banks of rivers, streams, and ponds is an old practice in Nigeria, a practice that is still common among the rural and the urban poor. Across Nigeria, it is not uncommon to find villagers and households collecting water for domestic uses by a river bank, usually at a pool behind some grasses or shrubs. The River bank may be an accessible point for collecting water from a flowing river. Secondly, because of natural filtration by grasses and shrubs along the edge of the river, water at the bank may be of clearer colour than that from the main river surface.

However, water from the bank of surface water of poor bacteriological quality may seem physically better, in terms of colour odor or test, yet, such water will most likely not be safe from pathogenic microorganisms since the same water body feeds its banks. Thus using surface water as a source of drinking water can pose a significant risk to public health, because consumption of contaminated water can easily initiate and spread waterborne diseases on an individual or even a population.
Nevertheless, investigation of the water quality of surface waters serving as sources of drinking water in Nigeria has not been given adequate attention by public health authorities and researchers; perhaps because they are usually patronized by the poor, mostly in rural areas. It is therefore important for public health authorities, water quality experts and researches in Nigeria to begin to pay greater attention to the unimproved and surface drinking water sources in order to determine the level of contamination and to advise people on dangers of poor water quality and on possible minimum water treatment to make the water safe for consumption. Emphasis needs to be placed on the very spots where individuals collect surface water for domestic uses.

One of the rural areas in Nigeria where many people depend on surface water for their daily needs of domestic and drinking water is Efe Amaekwu Village, a rural community at Unwana, Afikpo North Local Government Area, Ebonyi State, South Eastern Nigeria . Efe Amaekwu Village does not have a functional public potable water supply. So many members of the village community obtain water for their daily domestic uses from Iyere Unwana River bank. Many typically use the river water for personal hygiene, cooking of food, washing of plates, washing of fruits and vegetables, and for drinking. There is a danger that water from Iyere Unwana River at Efe Amaekwu Village may not be safe for direct human consumption because the water quality has not been determined. Therefore, there is an urgent need to investigate the quality of Iyere Unwana River at Efe Amaekwu Village in order to determine the bacteriological water quality, and for an objective enlightenment of the community members on the dangers of any inherent pathogenic contaminants, including the appropriate measures that may be taken to purify the river water before consumption.
This study therefore aims to investigate the bacteriological water quality of Iyere Unwana River at Efe Amaekwu Village, at both the river surface and the river bank access point, where villagers abstract water for domestic uses. The findings of the study will provide relevant data for households, public health authorities and relevant stakeholders; for enlightenment, for proper water use and treatment measures, and for reducing the spread of waterborne diseases, and for improving public health.. The specific objectives of the study include the following:

i. Determine bacteriological quality of Iyere Unwana River from main surface at Efe Amaekwu Village
ii. Determine bacteriological quality of Iyere Unwana River from its bank at Efe Amaekwu Village where villagers abstract water for domestic uses.
iii. Compare the water quality obtained from i. and ii above with limits set by the World Health Organization and the Nigerian Standard for drinking water quality.
iv. Examine the relationship between the bacteriological water quality parameters of samples from the Iyere Unwana River surface at Efe Amaekwu Village and samples from Iyere Unwana river bank at the same village.

2.0 Materials and Methods

2.1 Study Area

The study area consists of the environment and a section of Iyere Unwana River located at Efe Amaekwu Village in Unwana community of Afikpo North Local Government Area of Ebonyi State Nigeria. Efe Amaekwu Village comprises of two of the 131 polling units in Afikpo North Local government area. Efe Amaekwu Village has a population of about 2392 inhabitants, extrapolating from the average population of residents within each polling unit community in the Afikpo North Local Government Area of Ebonyi State Nigeria (National Bureau of Statistics, 2013). The major occupation of the inhabitants of Efe Amaekwu Village is farming, but a few civil servants and staff and students of Akanu Ibiam Federal Polytechnic Unwana also reside in the community. Iyere Unwana River is one of the reliable sources of drinking water for the village community. Water from the river is used by the community for different purposes such as cooking, drinking, personal hygiene, agriculture, etc. However the water from the river is usually not treated before use. In addition there is high prevalence of gatro-intestinal waterborne diseases in the area. Therefore, an investigation of the bacteriological water quality of the Iyere Unwana River can be seen as a good proactive measure that can provide data for right decisions and actions towards reducing waterborne diseases and protecting public health in Efe Amaekwu Village.

2.2 Sample Collection

Iyere Unwana River water samples were collected fortnightly, at two sampling points, A and B, between October, 2018 and July, 2019. The samples were collected from each of the two points in less than 30 minutes time interval on each sampling day. The sampling point "A" (called surface sampling point) is a point on the mainstream of the flowing river, and sampling point "B"(called river bank sampling point) is a point by the river bank where the villagers fetch water for daily domestic uses. Thus two sets of samples were collected on each sampling day, for 22 sampling days making a total of 44 samples.

During each sampling, clinical hand gloves were worn to avoid hand contact with the water samples. The water samples were collected into clean sterile polypropylene bottles with screw caps, numbered A1 to A22 and B1 to B22, with the letter A representing the river surface and the letter B representing the river bank respectively. At the point of sample collection, the cap of the sampling bottle was removed; the bottom portion of the bottle was grasped with the fingers and the mouth of the bottle was plunged down into the water body to avoid letting in any floating scum. The bottle was tipped slightly upwards to allow exit of air, the bottle was filled with water, leaving a small space of about 8-12mm. Then screw cap was firmly replaced on the bottle and labeled with full details of time and date of collection. The sample was transferred to the laboratory and analyzed within 24 hours.

2.3 Bacteriological Investigation of Water Samples

The bacteriological investigation of Iyere Unwana River water samples focused on laboratory analyses for the colonies of micro-organisms, coliform organisms and E-coli. It was determined for each of 44 water samples, the colonies forming units of microorganisms per mililitre (cfu/ml) after 48 hours, which grew on Nutrient Agar at 37 ^{o}C, the most probable number (MPN) of coliform organisms per mililitre of water samples (cfu/100ml) and the MPN of E-coli in cfu/100ml.The laboratory analysis of

Iyere Unwana water samples followed standard water testing procedures as itemized in Bichi and Amatobi (2013),

2.4 Data Analysis

Descriptive statistics was used in the data analysis. Tables, charts, mean, standard deviation and computations were done with the aid of Microsoft Excel 2007 software. Peasrson's Product Moment Correlation Coefficient was used to examine the relationship between the bacteriological water quality parameters of samples from the Iyere Unwana River surface and samples from Iyere Unwana river bank at the same village.

3.0 Results and Discussion

3.1 Results

The results of the laboratory analyses are presented in tables 3.1 – 3.2 below. Table 3.1 shows the result of bacteriological water quality (colonies of microorganisms, total coliform and E-coli) obtained from water samples collected from Iyeri Unwana River surface (main stream) at Efe Amaekwu Village. Table 3.2 is the result for same quality parameters but for samples collected from the River bank, at a point where villagers abstract water for domestic uses. Figures 3.1 -3.3 below are correlation curves used to examine the relationship between bacteriological water quality parameters at two sets of sampling points.

3.2 Discussion of Results

Tables 3.1 and 3.2 indicate that, on the average, all the water samples taken from the Iyere Unwan river main stream and the river bank both contain microbial contaminants beyond the safe drinking water limits set by the WHO (2004) and NSDWQ (2007). Samples from the main surface of the river contain the highest contamination: with 100% of samples above limits for colonies of microorganisms (mean is 9.86 X 10^5 cfu/ml and Std dev of 4.2 X 10^5 cfu/ml); with 100% of samples also above limits for total coliform (mean is 92cfu/100ml and Std dev of 14 cfu/100ml); and with 100% of samples equally above limits for E-coli (mean is 6cfu/100ml and Std dev of 1cfu/100ml). For samples taken from Iyere Unwana River bank: 100% of samples were above limits for colonies of microorganisms (with mean of 7.67 X 10^5 cfu/ml and Std dev of 2.86 X 10^5 cfu/ml); 100% of samples were above limits for total coliform organisms (mean of 64cfu/100ml and Std dev of 17cfu/100ml); and about 91% of the samples were above limits for E-coli (mean is 3cfu/100ml and Std dev of 1cfu/100ml).

Table 3.1Results of Samples from Iyere Unwana River Surface (main stream), at Efe Amaekwu Village

		Iyere Unwana River Surface Water Sample (A) Parameters		
	Sampling Days	SAMPLE A Colonies of microorganisms (cfu/ml)	SAMPLE A Total coliform (cfu/100ml)	SAMPLE A E-coli (cfu/100ml)
1	6-Oct-2018	900000	89	5
2	20-Oct-2018	840000	78	9
3	3-Nov-2018	660000	79	8
4	17-Nov-2018	570000	86	4
5	1-Dec-2018	630000	76	6
6	15-Dec-2018	480000	74	7
7	29-Dec-2018	540000	72	6
8	12-Jan-2019	510000	76	7
9	26-Jan-2019	730000	89	5
10	9-Feb-2019	770000	77	6
11	23-Feb-2019	810000	79	7
12	9-Mar-2019	720000	95	7
13	23-Mar-2019	630000	98	6
14	6-Apr-2019	1140000	110	7
15	20-Apr-2019	1110000	101	6
16	4-May-2019	1170000	98	5
17	18-May-2019	1455000	120	7
18	1-Jun-2019	1470000	101	6
19	15-Jun-2019	1530000	101	6
20	29-Jun-2019	1500000	104	8
21	13-Jul-2019	1680000	105	7
22	27-Jul-2019	1842000	107	7
	Mean	985773	92	6
	Standard Deviation	423063	14	1
	WHO(2004) STANDARD	10	0	0
	NSDWQ(2007) STANDARDS	10	0	0

Source: Field Survey

Table 3.2 Results of Water Samples from Iyere Unwana River bank

		Iyere Unwana River Bank Water Sample (B) Parameters		
S/No	Sampling Days	SAMPLE B Colonies of microorganisms (cfu/ml)	SAMPLE B Total coliform (cfu/100ml)	SAMPLE B E-coli (cfu/100ml)
1	6-Oct-2018	561000	34	3
2	20-Oct-2018	396000	37	4
3	3-Nov-2018	495000	41	3
4	17-Nov-2018	396000	49	2
5	1-Dec-2018	462000	59	0
6	15-Dec-2018	363000	44	5
7	29-Dec-2018	462000	48	2
8	12-Jan-2019	428000	67	3
9	26-Jan-2019	725000	51	1
10	9-Feb-2019	785000	62	4
11	23-Feb-2019	857000	89	2
12	9-Mar-2019	659000	72	4
13	23-Mar-2019	725000	69	3
14	6-Apr-2019	923000	53	0
15	20-Apr-2019	1056000	61	4
16	4-May-2019	957000	85	3
17	18-May-2019	1056000	87	3
18	1-Jun-2019	1089000	85	3
19	15-Jun-2019	1155000	78	2
20	29-Jun-2019	1006700	76	5
21	13-Jul-2019	1188000	81	3
22	27-Jul-2019	1122000	71	4
	Mean	766668	64	3
	WHO(2004) STANDARD	10	0	0
	NSDWQ(2007) STANDARDS	10	0	0

Source: Field Survey

The results indicate high microbial loads, in terms of Colonies of microorganisms, total coliform and E-coli. These results may not be unexpected since surface water is not usually protected from pollution /contamination by the immediate environment. Onyemaechi and Ejikeme (2018) found a range of 3.1×10^4 cfu/ml to 7.1×10^6 cfu/ml for total heterotrophic bacterial counts from stream water samples at Uzuakoli in Abia State of Nigeria. The presence of E-coli indicates fresh fecal contamination and this may primarily be due to lack of proper sanitation facilities like pit latrines and water flush systems; a situation which encourages the practice of open defecation at Efe Amaekwu Village and its environs.

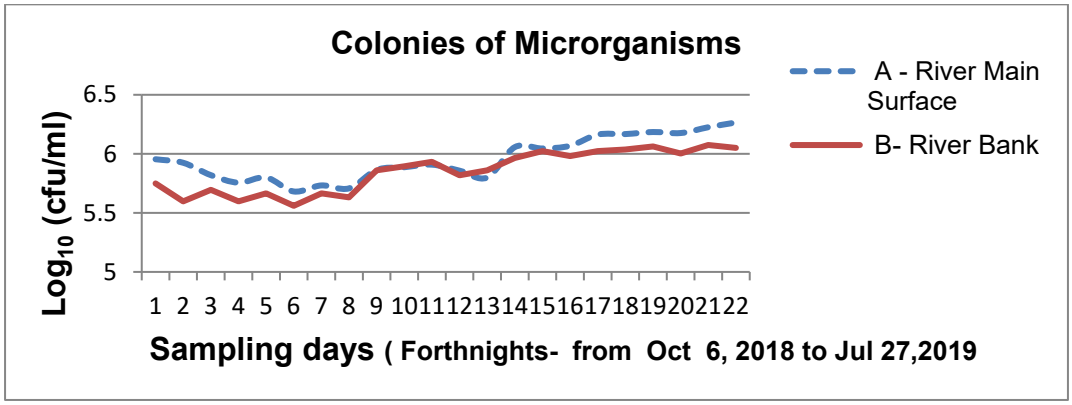

Figure 3.1 Colonies of microorganisms detected in water samples at Iyere Unwana River Main surface and River Bank.

Source: Field Survey, Correlation Coefficient (River Main Surfaces Vs River Bank), r = 0.88

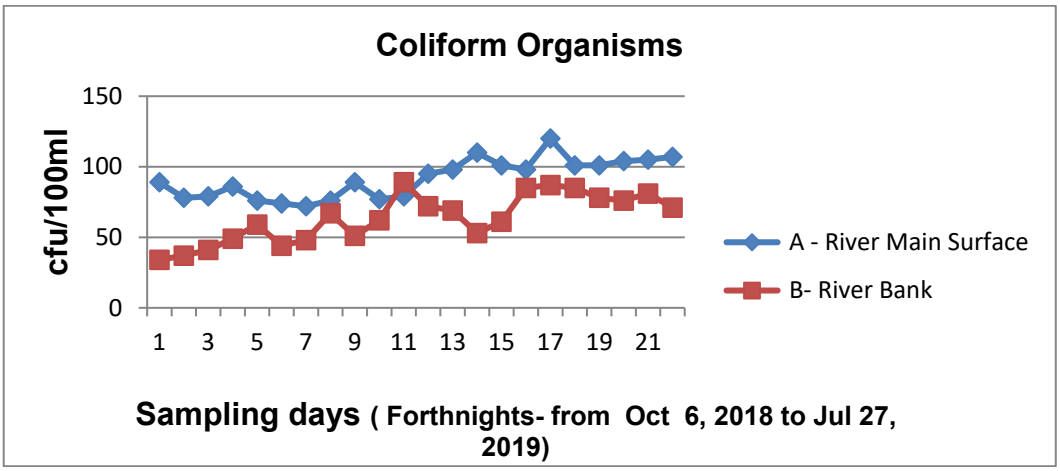

Figure 3.2 Coliform organisms detected in water samples at Iyere Unwana River Main surface and River Bank.

Source: Field Survey, Correlation Coefficient (River Main Surfaces Vs River Bank), r = 0.54

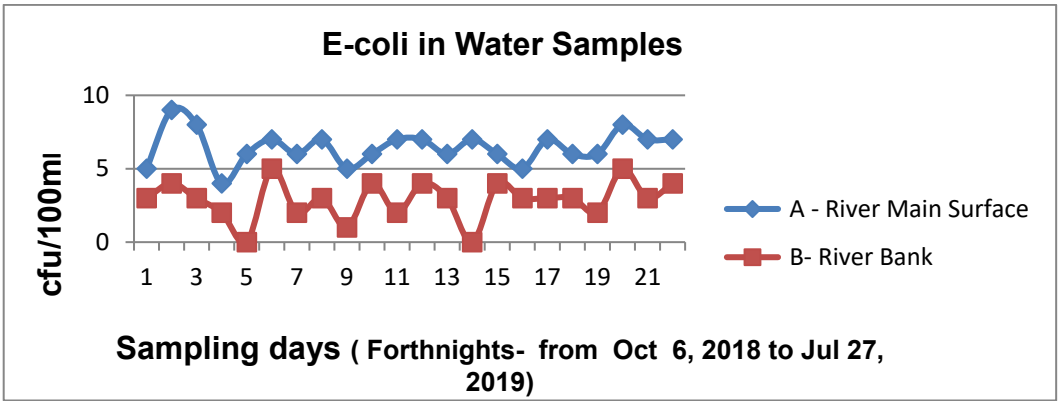

Figure 3.3 E-coli detected in water samples at Iyere Unwana River Main surface and River Bank.

Source: Field Survey, Correlation Coefficient (River Main Surfaces Vs River Bank), r = 0.38

Figures 3.1 to 3.3 above are pairs of curves comparing the bacteriological water quality for water samples collected from Iyeri Unwana River surface (main stream) at Efe Amaekwu Village and the samples collected from the Iyeri Unwana River bank, the domestic water collection point, at the same village. The curves in the figures, 3.1-3.3 represent water quality parameters in terms of the colonies of microorganisms, coliform organisms and E-coli, respectively. A measure of the relationship between quality parameters at the two sampling points (A and B) as calculated using the Pearson's product moment correlation coefficients, r, are: 0.88 for colonies of microorganisms-indicating a high positive relationship; 0.54 for coliform organisms-indicating a moderate positive relationship; and 0.38 for E-coli- indicating low positive relationship. The result indicates that the bacteriological water quality at the river surface can influence the bacteriological quality parameters at its bank.

4.0 Conclusion and Recommendations

The Study has determined bacteriological water quality of Iyere Unwana River at Efe Amaekwu Village, at both the river main surface and the river bank. The bacteriological water quality parameters examined at both the river surface and the river bank are above the drinking water quality limits set by the WHO and the Nigerian Standard for Drinking Water Quality. Therefore water from Iyere Unwana River, within the river surface or its banks at Amaekwu Village, are not safe for direct human consumption. Even though filtration by grasses/shrubs or some other natural processes could be responsible for reduction of microbial loads at the river bank, such processes have not been able to reduce the loads to such levels as to make the water at river bank to be safe for human consumption without treatment.

The following are the recommendations:

1. There is a need for health authorities and other informed stake holders to sensitize Amaekwu villagers and other rural communities to appreciate the fact that water collected from banks of surface water bodies such as rivers, streams and ponds may contain harmful microorganisms and should therefore be boiled before drinking, washing of plates and hands, and washing of fruits and vegetables meant to be eaten raw.

2. It is also important for all levels of government, Non Governmental Organizations (NGOs) and capable individuals to assist the people of Amaekwu Village and the entire Unwana Community with the provision of portable water sources such as water boreholes and water treatment units. This can be done along with the education of community members on basic hygiene practices, good sanitation and proper disposal of refuse.

References

Bichi, M.H. & Amatobi, D.A. (2013). Assessment of the quality of water supplied by water vendors to households in Sabon-Gari Area of Kano, Northern Nigeria. *International Journal of Engineering and Science*, 2(7), 09-17.

Council on Foreign Relations. (2018). *Water Stress in Sub-Saharan Africa*. Retrieved from:https://www.cfr.org/backgrounder/water-stress-sub-saharan-africa.

National Bureau of Statistics. (2013). Annual Abstract of Statistics, 2011. Retrieved from http://istmat.info/files/uploads/53129/annual_abstract_of_statistics_2011.pdf

NSDWQ (2007) Nigerian Standard for Drinking Water Quality. Standard Organization of Nigeria.

Abuja, Wuse. Onyemaechi, O. & Ejikeme, N. (2018) Microbiological evaluation of drinking water supplies in Uzuakoli, Bende L.G.A. of Abia State, Nigeria. *Advances in Applied Science Research*, 9(2), 69-74.

The Pontifical Council for Justice and Peace. (2003). *Water, an essential element for life*. Retrieved from: https://zenit.org/articles/water-an-essential-element-for-life/

United Nations Children Fund. (2018). *Diarrhoeal disease*. Data by county. Retrieved from: https://data.unicef.org/topic/child-health/diarrhoeal-disease/#

United Nations Children Fund Nigeria. (2019). *Water, sanitation and hygiene*. Retrieved from: https://www.unicef.org/nigeria/water-sanitation-and-hygiene.

United Nations Children Fund and World Health Organization. (2019). *Progress on household drinking water, sanitation and hygiene.*2000-2017: Special focus on inequalities, New York, USA, Cecilia Silva Venturini.

United Nations Educational Scientific and Cultural Organization. (2019). *Leaving no one behind – The 2019 UN World Water Development Report*. World Water Assessment Programme (UNESCO WWAP). Retrieved from: http://www.unesco.org/new/en/natural-sciences/environment/water/wwap/

UN-Water.(2011). *Water quality*. Retrieved from: www.unwater.org/app/uploads/2017/05/waterquality_policybrief.pdf

World Health Organization. (2019 a). *Drinking-wate*. Retrieved from: https://www.who.int/news-room/fact-sheets/detail/drinking-water
World Health Organization. (2019b). *Water sanitation hygiene*. Retrieve from: *https://www.who.int/water_sanitation_health/diseases-risks/en/*

World Health Organization. (2018). *Unsafe drinking-water, sanitation and waste management.* Retrieved from: *http://www.who.int/sustainable development/cities/health-risks/water-sanitation/en*

World Health Organization (2004). Guidelines for drinking water quality. (vol 1 3rd ed). Geneva, WHO.