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Characterization of Pathogenic Bacteria Associated with Contamination of Domestic Water in Owerri Area

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ABSTRACT

This study examined characterization of bacteria pathogens associated with domestic water contamination in Owerri area. Ten samples of water were collected from various sources of water in Owerri and were bacteriologically analyzed. Using the Pour-plate method on nutrient agar, MacConkey, and Salmonella-Shigella agar and the Most Probable Number technique, the total heterotrophic count and the most probable number index of coliform using double and single strength MacConkey broth as well as confirmed and completed test were determined. Result was presented in mean ± standard deviation, and Log_{10}cfu/ml. The total heterotrophic count ranges from 7.8 ± 1.06 x 10^5cfu/ml to 6.1 ± 0.21 x 10^5cfu/ml, total coliform count ranges from 4.0 ± 1.41 x 10^4 cfu/ml to 1.5 ± 0.0 x 10^4cfu/ml. The Log_{10}cfu/ml for heterotrophic count ranges from 8.7 Log_{10}cfu/ml to 5.79 Log_{10}cfu/ml, total coliform ranges 3.6 Log_{10}cfu/ml to 1.9 Log_{10}cfu/ml. Student t - test was used in comparing the mean between total heterotrophic count and total coliform count. The result revealed that there is a significant difference between the mean P > 0.005. *Escherichia coli*, *Klebsiella* species, *Staphylococcus aureus*, *Pseudomonas* species, *Salmonella* species and *Enterobacter* species were the organisms identified. Water is indispensable for human health and wellbeing. Portable water is an essential amenity that will aid eradication of water-borne diseases as well as improve the environmental sanitation. There should be enlightenment programs for the communities and other concerned populace in order to educate them on the dangers of such water sources serving for drinking or utilization for other domestic activities

KEYWORDS: Domestic water, contamination, pathogen, health.

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1.0. INTRODUCTION

In developing countries of the world, the main sources of domestic water are either open waters also known as surface waters such as rivers, streams and lakes or closed water supply system like tap and ground water as in borehole waters. Surface water has its unique natural sources of contaminants such as animal wastes and dead animal. Most microbial risks are associated with consumption of water contaminated with animal or human faeces. Waste water discharges into freshwater and costal seawaters are the main source of faecal pathogens contamination. Some studies on effect or impact of abattoir effluents into surface waters have shown that such water bodies are grossly contaminated as a result of the constituents of the effluent discharge into them [1, 2, 3]. The contaminated water bodies constitute significant environmental and health hazards as reported by Osibanjo and Adie [4] and Emeh *et al.*, [3]. Some other pollution sources of rivers in Owerri and its environs include activities of cattle-rearing, sand dredging operations, cassava processing industries, motor servicing workshops, as well as effluents from hospitals and paramedical establishments [3]. According to Ikem *et al.* [5] and Ejiogu *et al*. [6], dumping of waste in open sites is subjected to infiltration of accumulated organic and inorganic substances at the bottom of the dump sites as water percolates through the waste. Consequently, the contaminated water seeps through the soil into ground water. Boreholes dug close to specific tanks can also be contaminated by same process making it unfit for domestic use [7].

WHO, [8] recorded that water-borne diseases are prominent in the developing countries and affect the populace of which greater percentage at risk are mostly children. As a matter of fact, water-borne diseases infect millions in developing countries and more than 1.5million children die each year

from diarrheal diseases due to use of contaminated water [9]. Related studies are also stated that 3.4million people of which 1.4million are children die each year due to water related diseases [10, 11]. However, WHO [12] opined that mortality of water associated diseases exceeds 5million people per year which more than 50% are due to intestinal infection especially due to cholera outbreaks.

Contamination of domestic water by pathogenic microorganisms is a serious global concern. Acute diarrheal diseases as a result of pathogenic microorganism are major public health problem in African and Asian continents associated with developing countries where people with poorest hygienic facilities and very low financial resources are mostly affected. However, microbial waterborne diseases are also recorded in developed countries. World Health Organization [11] reported that in the USA, it has been estimated that about 560,000 people suffer from waterborne diseases each year. Acute microbial diseases such as cholera, salmonellosis, shigellosis, typhoid fever, campylobacteriosis, and other gastroenteritis caused by bacteria, viruses and protozoa are major public health problems in developing nations of the world. Some of the bacterial pathogens that has been incriminated with water pollution include; *Vibrio* species, *Salmonella* species, *Shigella* species, pathogenic *Escherichia coli* strains, *Helicobacter pylori*, *Campylobacter jejuni*, *Aeromonas hydrophyla*, *Proteus* species and *Staphylococcus aureus* [13, 14, 15, 16, 17, 18, 11, 3].

According to Schnabel [19], diarrhoeal illness can have a significant impact on the economy and cause long term damage to the development of a country due to related costs and burden as a result of financial pressures for treatment and medication assistance as well as physical deterioration of the patients and absence from work. Improving water quality is one of the United Nations eight Millennium Developmental Goals (MDGs) targeted at having safe water by 50% by 2015 [12]. Drinking water can be graded into four categories depending on the Most Probable Number (MPN) value. Water with MPN of zero is excellent; MPN of 1-3 is satisfactory; while MPN of 4-10 is suspicious and MPN above 10 is unsatisfactory. Any water with MPN greater than 3 is not suitable for drinking water [11, 20].

Water for domestic use (drinking, cooking, bathing, recreation etc.) should be free from microbes that might be detrimental to human health. These bacterial pathogens from domestic water pose high risk of infectious diseases and are hazardous to the population when consumed or used untreated. It is absolutely necessary therefore that water for human drinking and other domestic use is free from any microorganism that its presence and number will constitute harm. Hence this work is aimed at characterizing the bacterial pathogens associated with domestic water contamination in Owerri as to know the health implication with such contamination. The findings of this research will enable policy makers to see the need for improvement of access to safe domestic water which will have positive significance to human health within the population.

2.0. MATERIALS AND METHODS

Brief Description of Study Area

Owerri, the study area is the capital city of Imo State, Nigeria and consists of three local government areas namely; Owerri Municipal, Owerri North and Owerri West. The city is approximately 100 square kilometers in area and lies between Latitude 5.4^{o}N and Longitude 7.03^{o}E with an estimated population of 401,873 according to 2006 census [21]. Owerri is bordered by Otamiri River to the East and Nworie River to the South [22]. These water bodies are used for domestic activities including drinking, cooking, washing, processing of food such as cassava; swimming and other recreational purposes. Apart from domestic use, they also serve local industrial needs as well as sites for abattoir effluent discharge [3]. For instance, the Otamiri River was the major source of water for Owerri Municipal public water supply before the inception of boreholes. Owerri is majorly an urban setting where different higher education institutions and high density centers of relaxation are situated.

Sample Collection

Samples of Borehole water and Tap borne water were aseptically collected in triplicates from each of the three local government areas (Owerri Municipal, Owerri North and Owerri West). The Borehole and Tap water were allowed to flow for two minutes before samples were collected using sterile sample bottles.

The sampling method used for the rivers water collection was the grab method as described by Nafarnda *et al.*, [1] using wide mouthed 500ml sterilized Pyrex glass bottles with tight screw dust proof stoppers; a top space of about 2.5cm was left as the bottles were filled. The river water samples were collected in triplicates from different sampling points; downstream, middle stream and upstream. The samples were labeled appropriately and transported without delay in icepacks to the Microbiology laboratory of Imo State University Owerri, for immediate analysis.

Bacteriological Analysis

The media used in this study which include; MacConkey broth, MacConkey agar, Nutrient agar, Salmonella-Shigella agar (SSA), Simmons citrate agar, Triple Sugar Iron Agar (TSIA) and Eosin-Methylene Blue (EMB) agar were prepared according to manufacturer's instructions. For enumeration of total aerobic heterotrophic bacteria, an aliquot (0.1ml) of ten-fold serial dilution of each of the samples were introduced into corresponding labeled sterile duplicate plates. Then freshly prepared agars of Nutrient, MacConkey and Salmonella-Shigella were aseptically poured and carefully agitated for proper mixing and allowed to solidify. Thereafter the plates were incubated at 37^{o}C for 24hours. The plates that yielded bacterial growth within 30-300 colonies were counted and the average of each sample growth was recorded as the THC of the sample [23].

The enumeration of the faecal coliform was carried out by one-step tube Most Probable Number (MPN) technique using MacConkey broth containing bromocresol purple indicator and inverted Durham's tube. 10ml, 1ml and 0.1ml aliquot of each water sample were added to single or double strength medium appropriately and incubated at 44ºC for 24hours. The tubes recorded as positive showed growth and gas production after 24hours incubation. The positive tubes were subjected to confirmed coliform test by further culturing them on Eosin Methylene Blue (EMB) agar plates [24] which appeared as small metallic sheen colonies. Thereafter subjected to completed test [16]. The positive results were counted and the number determined in MPN 100ml by using statistical MPN tables.

Identification of Isolates

The bacteria isolated from each of the water samples were screened and their morphological, physiological and biochemical properties were used as to identify them [23, 24, 25].

3.0. RESULTS

Table 1 shows the mean ± standard deviation of total heterotrophic bacteria count (THBC) and total coliform count (TCC) of the water samples. The THBC of the surface waters ranged from 6.6 x 10^5cfu/ml to 8.7 x 10^5cfu/ml while that of the borehole water samples ranged from mean value of 6.8 x 10^5cfu/ml to 7.1 x 10^5cfu/ml; whereas the tap water had mean value ranging from 6.1 x 10^5cfu/ml to 7.5 x 10^5cfu/ml. The result of the total coliform count unraveled that the river water samples had mean values ranging from 1.5 x 10^3cfu/ml to 3.5 x 10^3cfu/ml; the borehole water TCC ranged from 1.7 x 10^3cfu/ml to 4.0 x 10^3cfu/ml and the tap water samples had mean TCC ranging from 0 to 3.0 x 10^3cfu/ml.

Figure 1 is a Bar chart representing the mean distribution of both heterotrophic bacteria count and total coliform count recorded from the domestic water sources.

Table 2 revealed the Log_{10}cfu/ml of the water samples THBC and TCC which ranged from 5.82 Log_{10}cfu/ml for Oramiri-Ukwa to 7.0 Log_{10}cfu/ml for Otamiri River. That of Boreholes ranged from 5.83Log_{10}cfu/ml for Borehole 3 to 5.85Log_{10}cfu/ml for Borehole 2. Whereas Tap water1 had the highest THBC of 5.88Log_{10}cfu/ml while Tap water2 and 3 had same 5.79Log_{10}cfu/ml. the total Log_{10}cfu/ml of TCC of the water samples showed that Oramiri-Ukwa had the highest, 3.54Log_{10}cfu/ml followed by Otamiri, 3.39Log_{10}cfu/ml; Okitankwo, 3.27Log_{10}cfu/ml; Nworie River, 3.17Log_{10}cfu/ml for the surface water samples. While for the borehole waters, 3.60Log_{10}cfu/ml was recorded for borehole 1; 3.34Log_{10}cfu/ml for borehole 2 and 3.3Log_{10}cfu/ml for borehole 3. However, the tap water samples 3 and 2 had the highest Log_{10}cfu/ml of 5.79; while sample 1 had 3.47Log_{10}cfu/ml.

Figure 2 shows the Bar chart distribution for Log_{10}cfu/ml of total heterotrophic bacteria count and total coliform count.

Table 3 and Table 4 revealed the most probable number test result for surface water samples (A- D) and that of samples from borehole and tap water (E - J) respectively. All the samples (A - D) sources were contaminated whereas table 4 showed that borehole samples showed positive confirmatory test while tap waters were negative. Only borehole 1 water sample showed positive completed test whereas others were negative indicating absence of *Escherichia coli*.

Table 5 revealed the identity of the isolates based on their colonial, cellular, morphological and biochemical characteristics. Whereas table 6 unraveled specific sources of bacterial isolates from the water samples. From the results, t-test shows that there is a significant difference i.e. P>0.005.

Table 1: Mean ± Standard deviation of THBC and TCC

Samples	THBC x 10^5cfu/ml	TCC x 10^3cfu/ml
Nworie	7.8 ± 1.6	1.5 ± 0.0
Otamiri	7.0 ± 1.41	2.5 ± 0.70
Okitankwo	8.7 ± 0.70	1.9 ± 0.07
Oramiri-Ukwa	6.6 ± 0.35	3.5 ± 0.70
Borehole 1	6.9 ± 0.21	4.0 ± 1.41
Borehole 2	7.1 ± 0.28	2.2 ± 0.49
Borehole 3	6.8 ± 1.06	1.7 ± 0.26
Tap water 1	7.5 ± 0.21	3.0 ± 1.41
Tap water 2	6.2 ± 0.84	-
Tap water 3	6.1 ± 0.21	-

Key: THBC = Total Heterotrophic Bacterial Count
TCC = Total Coliform Count

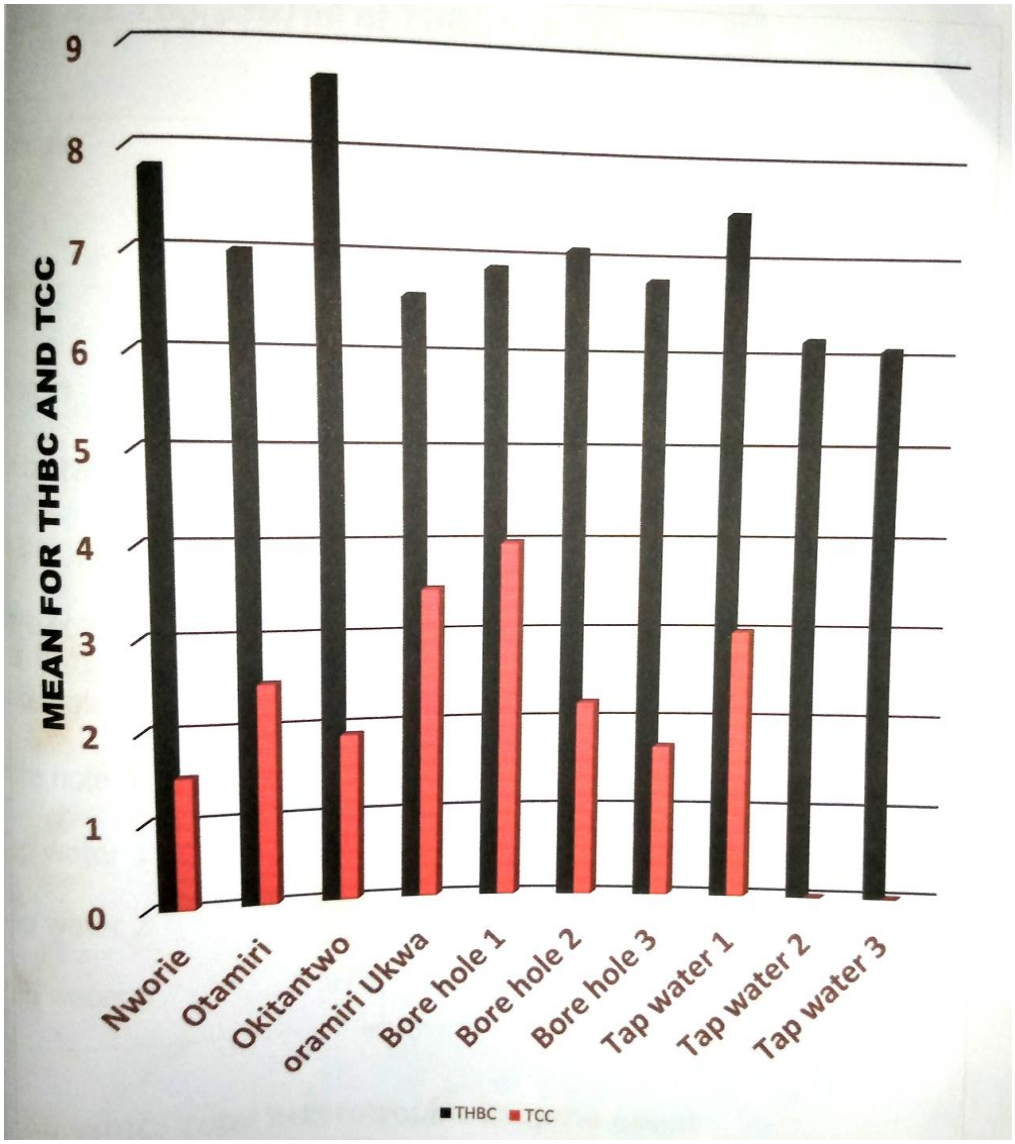

Figure 1: Bar chart distribution of mean for THBC and TCC for Various Water Sources

Table 2: Log_{10}cfu/ml of THBC and TCC

Samples	THBC Log_{10}cfu/ml	TCC Log_{10}cfu/ml
Nworie	5.89	3.17
Otamiri	7.0	3.39
Okitankwo	8.7	1.9
Oramiri Ukwa	5.82	3.54
Borehole 1	5.84	3.60
Borehole 2	5.85	3.34
Borehole 3	5.83	3.23
Tap water 1	5.88	3.47
Tap water 2	5.79	-
Tap water 3	5.79	-

Key: THBC = Total Heterotrophic Bacterial Count; TCC = Total coliform count; cfu = colony forming unit; mi = milliliter

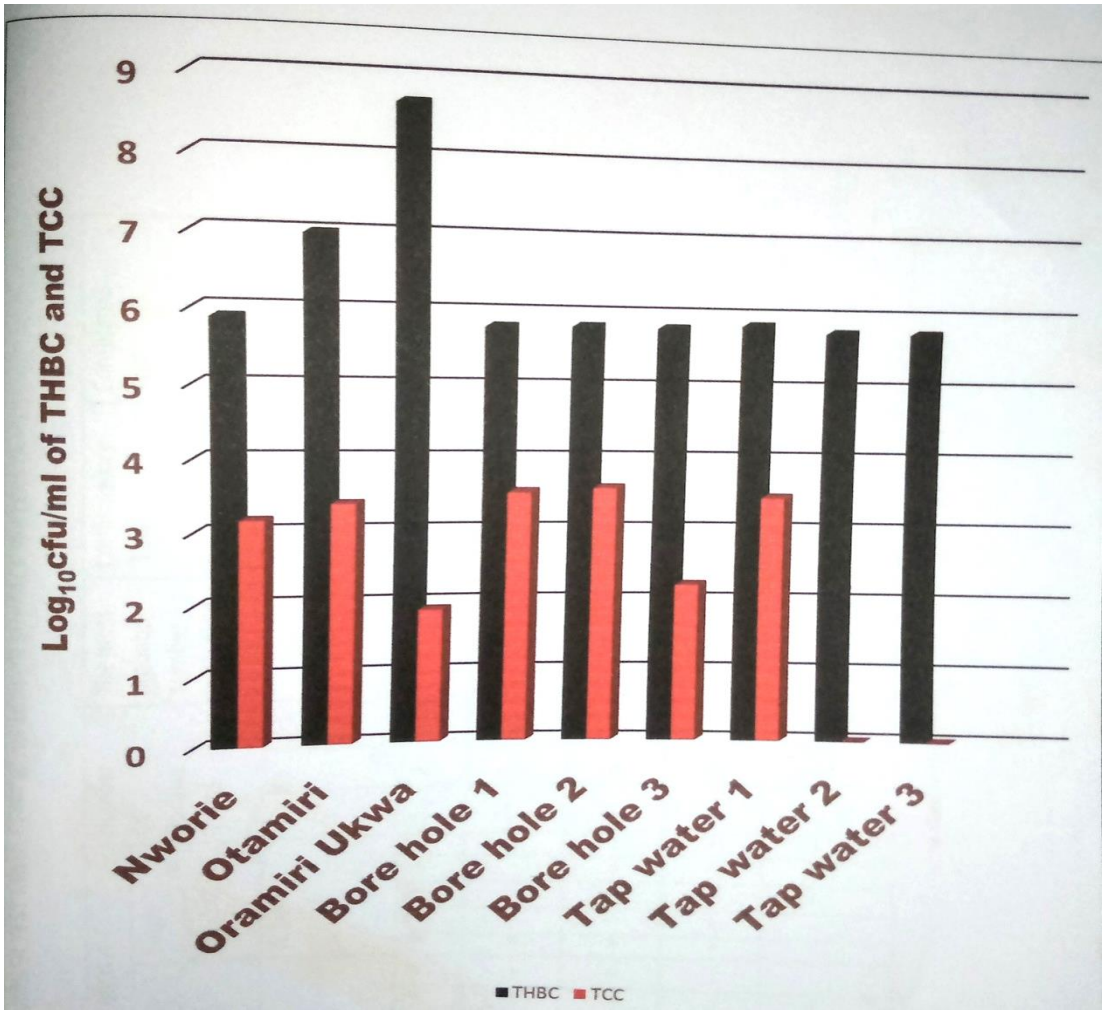

Figure 2: Bar chart distribution of Log_{10}cfu/ml of THBC and TCC

Table 3: The Most Probable Number Test Result for Surface Water Samples (A - D)

Media	**MACCONKEY BROTH**															**Number of Positive Tubes**			**The Most Probable Number index/100ml**			**Confirmatory Test**	**Completed Test**
Strength	**Double Strength**										**Single**												
Quantity of water innoculated	10ml					1ml					0.1ml					10	1	0.1					
Number of tubes	1				5	1	2	3	4	5	1	2	3	4	5	5	5	5					
A Nworie River	+	+	+	+	+	+	+	+	+	+	+	-	-	-	+	5	5	2	5	5	0	+	+
B Otamiri River	+	+	+	+	+	+	-	+	+	+	+	+	+	+	-	5	4	4	3	5	0	+	+
C Okitankwo River	+	+	+	+	+	+	+	+	-	-	+	+	+	+	+	5	3	5	2	5	0	+	+
D Oramiri-Ukwa River	+	+	+	+	+	+	-	-	+	-	-	-	+	+	+	5	2	3	1	2	0	+	+

Key: + = Present/Positive; - = Absent/ Negative

Table 4: The Most Probable Number Test Result for Borehole and Tap Water Samples (E - J)

Media	MACCONKEY BROTH											Number of Positive Tubes			The Most Probable Number index/100ml	Confirmatory Test	Completed Test
Strength	Double Strength						Single Strength										
Quantity of water innoculated	50ml	10ml					1ml					50	10	1			
Number of tubes	1	1	2	3	4	5	1	2	3	4	5	1	5	5			
E Borehole 1	+	+	+	+	+	+	-	-	+	+	-	1	5	2	50	+	+
F Borehole 2	+	+	+	+	+	+	+	-	-	-	-	1	5	1	35	+	-
G Borehole 3	+	+	+	+	+	-	+	+	-	-	-	1	4	2	20	+	-
H Tap water 1	+	+	+	+	-	-	-	-	-	-	-	1	3	0	8	-	-
I Tap water 2	+	+	-	-	-	-	+	+	-	-	-	1	1	2	7	-	-
J Tap water 3	+	-	-	-	-	-	+	+	-	-	-	1	0	2	4	-	-

Key: + = Present/Positive; - = Absent/ Negative

Table 5: Colonial, Morphology and Biochemical Characteristics of the Bacterial Isolates

Isolates Number	Colonial Appearance			Cell Morphology			Gram Reaction	Motility	Coagulase	Catalase	Oxidase	Indole	Methyl Red	Citrate	Voges Proskauer	Glucose	Lactose	Manitol	Sucrose	Possible Isolates
	Colour	Shape	Elevation	Rod	Cocci	Arrangement														
1	C	R	Ra	+	-	Single	-	+	-	+	-	+	+	-	-	A/G	A/G	A	-	*Escherichia coli*
2	Y	Ci	Co	-	+	Clusters	+	-	+	+	-	-	+	-	+	A/G	A/G	A/G	A/G	*Staphylococcus aureus*
3	C	Ci	F	+	-	Single	-	-	-	+	-	-	-	+	+	A/G	A	A	A	*Klebsiella* species
4	Cb	Ci	Ra	+	-	Single	-	+	-	+	+	+	+	+	-	A/G	-	A/G	A	*Salmonella* species
5	G	Ir	F	+	-	Chain	-	+	-	+	+	-	-	+	-	A	-	-	-	*Pseudomonas* species
6	C	Ci	F	+	-	Chain	-	+	-	-	-	-	-	+	+	A/G	A	A	A	*Enterobacter* species

Key: C = Cream; Y = Yellow; G = Green; Cb = Courlorless with black center; R = Round; Ci = Circular; Ir = Irregular; Ra = Raised; Co = Convex; F = Flat; + = Positive; - = Negative; A/G = Acid and Gas production; A= Acid production

Table 6: Bacterial Isolates from Specific Sources of the Samples

S/NO.	Isolates	Nworie River	Otamiri River	Okitankwo River	Oramiri-Ukwa River	Borehole 1	Borehole 2	Borehole 3	Tap water 1	Tap water 2	Tap water 3
1	*Escherichia coli*	+	+	+	+	-	-	-	-	-	-
2	*Klebsiella* species	+	+	+	-	+	-	-	-	-	-
3	*Staphylococcus aureus*	+	+	+	+	+	+	+	+	+	+
4	*Salmonella* species	+	+	+	+	-	-	-	-	-	-
5	*Pseudomonas* species	+	+	+	+	-	-	-	+	-	-
6	*Enterobacter* species	+	+	+	-	+	-	-	-	-	-

Key: + = Present/Positive; - = Absent/ Negative

4.0. DISCUSSION

The result of this study (Table 1 and Figure 1), revealed that the heterotrophic bacteria count of all the samples were generally high exceeding the standard permissible limit of 1.0 x 10^2cfu/ml for drinking water [20, 12, 26, 27]. The resulting high heterotrophic counts may be attributed to runoffs, sewage from abattoir, agricultural wastes which are high in organic matter and nutrients [28, 29, 30, 31, 3]. The World Health Organization and UNICEF reported that 68% of the global population had no access to improved sanitation facilities. This implies that about 2.4billion of the global population do not have improved sanitation and 15% do not have any form of sanitation thereby practicing open defecation [32]. The findings of this study is in agreement with certain similar studies by Ibe and Okplenye and [33], Uzoigwe and Agwa, [34] who stated that the sources of heterotrophic bacteria in water are human and animal wastes. In addition, Taiwo *et al.* [31] and Emeh *et al.* [3] reported that abattoir effluent is the major contributor of microbial contaminants to rivers into which the effluents discharge. Whereas the borehole that are situated close to dumpsites are contaminated due to seepage of contaminated water into the water level of underground water [35, 34, 29, 33, 36, 37].

The higher number of bacterial count recorded in river water samples (Table 1, Figure 2, Table 2 and Figure 2) could also be as a result of increased surface area which exposes the water to contaminants as well as human activities such as swimming, dipping of dirty hands, legs and cans into the river while fetching water. The absence of coliform in tap water samples 1 and 2 is a clear indication that the tap waters received some level of treatment and complied with the World Health Organization standard of water for human use. The presence of bacteria such as *Salmonella* species, *Escherichia coli, Pseudomonas* species, *Staphylococcus* species, *Enterobacter* species and *Klebsiella* species (Tables 5 and 6) from the various sources of water in Owerri area is of public health significance in terms of human use and other activities [12, 20, 38, 39, 40, 3, 26]. It is a known fact that *Escherichia coli* being an indicator organism signifies fecal contamination of any water source in which it is found. In addition, the presence of *Klebsiella* species, *Enterobacter* species and *Salmonella* species belonging to the family of Enterobacteriaceae is a strong indication that the water sources from which they were isolated have fecal matter pollution. Sewage containing human excreta is the worst material that pollutes water.

Some of these isolated bacteria cause diseases, for example, enteropathogenic *Escherichia coli* and Salmonella species cause acute enteritis [27, 41]; *Salmonella typhi* causes typhoid fever [42]. *Staphylococcus aureus* is a common human microflora but its ability to penetrate the tissue, multiply and spread can result to boils, skin sepsis, enteric infections, septicaemia, endocarditis, osteomyelitis and pneumonia [10, 43].

There can be no life on earth without water. In fact, the human body is composed of 70% water. However, that same water can cause harm to the body if not purified. From the results of the Most Probable Number for surface water, borehole and tap water samples (Table 3 and Table 4), the domestic water are unfit for drinking unless special treatment is administered as stated by WHO [8]. Water is an indispensable amenity; therefore, the provision of portable water will enhance the eradication of water-borne diseases from the population concerned.

CONCLUSION

The domestic water sources especially those from surface water investigated in this study contain some pathogenic bacteria contaminants, thus making them unfit for human consumption if not adequately treated. The water from these sources should undergo a number of treatments to make them potable as exemplified by World Health Organization water treatment. Portable water is an essential amenity that will aid reduction of water-borne diseases as well as improve the

environmental sanitation. Therefore, there should be enlightenment programs for the communities and other populace in order to educate them on the dangers of such water sources serving for drinking or utilized for other domestic activities.

REFERENCES

I. Nafarnda WD, Ajayi IE, Shawulu JC, Kawe MS, Omeiza GK, Sani NA, Tags SZ. Bacteriological Quality of Abattoir Effluents Discharged into Water Bodies in Abuja, Nigeria. International Scholarly Research Network (ISRN) Veterinary Science, 2012; 1–5.

II. Ogunnusi TA, Dahunsi OV. Isolation and Identification of Microorganisms from Abattoir Effluents from Oyo, Oyo state, Nigeria. Asian Journal of Applied Sciences. 2014; **2**(2): 218–222.

III. Emeh AA, Anyanwu GO, Ibeh IJ, Emeh TC, Odaghara CJ, Nwaehiri UL. Assessment of the impact of Egbu abattoir effluent on the microbiological properties of Otamiri river. International Journal of Scientific and Research Publication. 2020; **10**(5): 61-70.

IV. Osibanjo O, Adie GU. Impact of effluent from Bodija abattoir on the physico- chemical parameters of Oshunkaye stream in Ibadan City, Nigeria. African Journal of Biotechnology. 2017; **6**(15): 1806–1811.

V. Ikem A, Osibanjo O, Sridhar MKC, Sobande A. Evaluation of groundwater quality characteristics near two waste sites in Ibadan and Lagos Nigeria. Water, Air and Soil pollution. Kluwer Academic Publishers, the Netherlands. 2002; 140: 307-333.

VI. Ejiogu CC, Okpara CB, Opara KD, Onyeocha IO, Azubuike C, Emeh AA. Effects of solid waste disposal on the physicochemical properties of borehole water along FUTO road, Eziobodo, Owerri-West, Nigeria. Current Journal of Applied Science and Technology. 2018; 26(1):1-7.

VII. Aderemi AO, Oriaku AV, Adewumi GA, Otitoloju AA. Assessment of groundwater contamination by leachate near a municipal solid waste landfill. African Journal of Environmental Science and Technology. 2011; 5: 933-940.

VIII. World Health Organization (WHO). Burden of disease and cost effectiveness estimates. 2014.

IX. Fenwick A. Waterborne infectious diseases – Could they be consigned to history? International Journal of Science. 2006; **313**:1077-1081.

X. World Health Organization (WHO) (2004). Pathogenic Mycobacteria in water: A guide to public health consequences, monitoring and management, Pedley, S., Bartram, J., Rees, G., Dufour, A., Cotruvo, J., Eds.; IWA Publishing: London, UK, 2004.

XI. World Health Organization (WHO). Enterohaemorrhagic Escherichia coli (EHEC). Fact sheet No.125; Available online: http://www.who.int/mediacentre/factsheet/fs125/en/ Accessed 4 September 2010.

XII. World Health Organization (WHO). Guidelines to drinking water quality criteria, Geneva. 4th edition incorporating 1st, 2nd and 3rd Addenda. 2011; 1:13-33.

XIII. Le Minor LE. The genus *Salmonella*. In The Prokaryotes: An evolving Electronic Resource for the Microbiological Community, electronic release 3.14. 3rd edition, Dworkin, M., Falkow, S., Rosenberg, E. Editors. Spriger-Verlag, New York, NY, USA. 2003.

XIV. Scheutz F, Strckbine NA, Brenner DJ, Krieg NR, Staley JT. Genus *Escherichia*. In Bergey's Manual of Systematic Bacteriology, Springer: New York, NY, USA. 2005.

XV. Popoff MY, Le Minor LE. Genus *Salmonella*. In Bergey's Manual of Systematic Bacteriology, 2nd edition, Brener, D.J., Krieg, N.R.and Staley, J.T. Editors. Springer: New York, NY, USA. 2005.

XVI. Dike-Ndudim JN, Udebuani AC, Ogbulie JN. Bacteria of public health significance isolated from surface water in Imo State. International Journal for Environmental Health and Human Development. 2007; **8**(1): 24-34.

XVII. Yunus M. Risk areas and neighborhood-level risk factors for *Shigella dysenteriae* 1 and *Shigella flexneri*. Heath Place. 2008; **14**: 96-105.

XVIII. Todar, K. (2009). *Vibrio cholerae* and Asiatic cholera. In Todar's online Textbook of Bacteriology, Available online: http://www.textbookofbacteriology.net/cholera.html 2009.

XIX. Schnabel B. Drastic Consequences of Diarrhoeal Disease. 2009; 16 – 25.

XX. World Health Organization (WHO). Guidelines to drinking water quality, Incorporating 1st and 2nd Addenda, WHO; Geneva, Switzerland. 2008.

XXI. Federal Republic of Nigeria Official Gazette. Legal notice on the publication of the details of the breakdown of the National and State provisional totals 2006 census. 2007.

XXII. Acholonu ADW. Water quality studies of Nworie River in Owerri, Nigeria. Mississipi Academy of Sciences. 2008.

XXIII. Cheessbrough M. District laboratory practices in tropical countries, 2nd edition. Cambridge University Press. 2006.

XXIV. Rompre A, Servais P, Baudart J. Detection and enumeration of coliforms in drinking water: current methods and emerging approaches. Journal of Microbiological Methods. 2002; 49:31-54.

XXV. Biradar N, Ambarish SS, Bellad AS, Jayarama R, Ravi N, Shivaraj N, Sadashiv SOCU. Assessment of physico-chemical and microbiological parameters of Kotur Lake. International Journal of Current Microbiology and Applied Sciences. 2014; 3(2), 88–96.

XXVI. Titilawo Y, Nwakpa F, Bankole S, Nworie O, Okoro C, Titilawo M, Olaitan J. Quality audit of drinking water sources in Ikwo rural setting of Ebonyi state, South-Eastern Nigeria. International Journal of Energy and Water Resources. 2020; **4**: 321-334.

XXVII. Abhirosh C, Sherin V, Thomas AP, Hatha AAM, and Mazumder A. Potential public health significance of faecal contamination and multidrug-resistant *Escherichia coli* and *Salmonella* serotypes in a lake in India. Public Health. 2011; 125: 377-379.

XXVIII. Ichor T, Umeh EU, Duru EE. Microbial contamination of surface water sources in rural areas of Guma Local Government Area of Benue state, Nigeria. Journal of Medical Sciences and Public Health. 2014; **2**(2): 43-51.

XXIX. Gerba CP, Smith JE. Sources of pathogenic microorganisms and their fate during land application of wastes. Journal of Environmental Quality. 2005; **34**: 42-48.

XXX. Omari S, Yeboah-Manu D. The study of bacterial contamination of drinking water sources: A case study of Mpraeso, Ghana. Internet Journal of Microbiology. 2012; **10**(1): 6-11.

XXXI. Taiwo AG, Adewunmi AR, Ajayi JO, Oseni OA, Lanre-Lyanda YA. Physicochemical and microbial analysis of the impact of abattoir effluents on Ogun River Course. International Journal of Chem. Tech Research. 2014; **6**: 3083-3090.

XXXII. WHO and UNICEF. Progress on drinking water and sanitation: 2015 update and MDG assessment. 2015.

XXXIII. Ibe SN, Okplenye JI. Bacteriological analysis of borehole water in Uli, Nigeria. African Journal of Applied Zoology and Environmental Biology. 2005; **7**: 116-119.

XXXIV. Uzoigwe CI, Agwa OK. Microbiological quality of water collected from boreholes near refuse dumpsites in Port-Harcourt, Rivers state, Nigeria. Journal of Biotechnology. 2012; **11**(13): 3135-3139.

XXXV. Palamuleni L, Akoth M. Physicochemical and microbial analysis of selected borehole water in Mahikeng, South Africa. International journal of Environmental Research and Public Health. 2015; **12**: 8619-8630.

XXXVI. Obi CN, Okocha CO. Microbiological and physicochemical analysis of selected borehole waters in World Bank Housing Estate, Umuahia, Abia state, Nigeria. Journal of Engineering and Applied Science. 2007; **2**(5): 920-929.

XXXVII. Ngele SO, Itumoh EJ, Onwa NC, Alobu F. Quality assessment of selected groundwater samples in Amike-Aba, Abakaliki, Ebonyi state, Nigeria. Canadian Journal of Pure and Applied Science. 2014; **8**(1): 2801-2805.

XXXVIII. Chigor VN, Umoh VJ, Okuofu CA, Ameh JB, Igbinose EO, Okoh AI. Water quality assessment: Surface water sources used for drinking and irrigation in Zaria, Nigeria are a public health hazard. Environmental Monitoring and Assessment. 2012; 184: 3389-3400.

XXXIX. Dami A, Ayuba HK, Amukali O. Physiochemical and bacteriological analysis of the surface water used for domestic purposes in Okpai and Beneku, Delta state, Nigeria. Global Journal of Human Social Science Geography and Environmental Geosciences. 2012; **12**(3): 31-36.

XL. Daso AP, Osibanjo O. Water quality issues in developing countries – A case study of Ibadan Metropolis, Nigeria. Water quality monitory and assessment. In Tech. ISBN 978-953-51-0486-5.Retrieved from https://www.intechopen.com/books/water-quality-monitoring-and-assessment/water-quality-issues-in-developing-countries-a-case-study-of-ibadan metropolis-nigeria. 2012.

XLI. Osiriska A, Korzeniewska E, Harnisz M, Niestepski S. The prevalence and characterization of antibiotic-resistant and virulent *Escherichia coli* strains in the municipal waste water system and their environmental fate. Science of the Total Environment. 2017; **577**: 367-375.

XLII. Muoghalu L, Omoch V. Environmental health hazard resulting from Awka abattoir. Journal of Environmental Studies. 2000; **21**(1): 72–73.

XLIII. Emeh AA, Nwagwu FN. Foundations of Medical Microbiology. Amandu & Sons (Nig.) Limited, Owerri, Nigeria. 2019.