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Original Research Article

Bacteriological qualities of sources of domestic water supply and prevalence of typhoid fever in some communities of Enugu State, Southeast, Nigeria: a cross-sectional study

Emmanuel I. Umegbolu[1]*, Moses E. Offor[2]

[1]District Hospital, Awgu, Enugu State, Nigeria
[2]Department of Microbiology, Nnamdi Azikiwe University, Awka, Nigeria

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***Correspondence:**
Dr. Emmanuel I. Umegbolu,
E-mail: cumegbolu7@gmail.com

ABSTRACT

Background: From the public health point of view, the microbiological properties of domestic water supply are the most important parameters of domestic water supply because of the propensity for microbial water-related diseases. In Enugu State, statistics have shown that reported cases of waterborne diseases (including typhoid fever) have been on the increase since 2003. The aim of the study was to determine the bacteriological qualities of domestic water supply and prevalence of typhoid fever in five communities of Enugu State in connection with the rising incidence of typhoid fever in the state.
Methods: This was a cross-sectional study of sources of domestic water supply and prevalence of typhoid fever in five rural communities of Ezeagu Local Government Area. 297 copies of structured questionnaire, 10 grab water samples analysed using the membrane filtration method and 227 blood samples collected for Widal test were used to generate the data for the study, analysed as frequency distributions, t-test of means difference and Pearson product moment correlations using MaxStat (version 3.60) statistical software.
Results: 2 (40%) of the 5 communities complied with the WHO standard for faecal coliform counts. Prevalence of typhoid fever was high in all the communities (71.4%-100%). Only faecal coliform counts correlated positively and strongly (r=0.69) with prevalence of typhoid fever.
Conclusions: Since faecal coliform counts correlated positively and strongly (r=0.69) with prevalence of typhoid fever, improving the bacteriological qualities of domestic water supply may help to reduce the prevalence of typhoid fever.

Keywords: Bacteriological, Domestic, Water, Prevalence, Typhoid, Communities

INTRODUCTION

Water is a colourless, odourless and tasteless liquid at room temperature and is the only substance that exists naturally on Earth in all three physical states of matter-gas, liquid and solid.[1] Although about 70% or two-thirds of the Earth's surface is covered by water, less than 1% of the water is readily available for drinking.[1] Domestic water supply is defined as water used for all domestic purposes (consumption, bathing and food preparation).[2,3] According to WHO, sources of domestic water supply are categorized into improved (which are protected from outside contamination, in particular faecal matter) and unimproved (that are not adequately protected from outside contamination) types.[4] However, the chemical, physical and biological characteristics of water will determine its intended use.[5]

From the public health point of view, the microbiological properties of domestic water supply, usually determined by the types and number of microorganisms present in the water, are the most important parameters of domestic water supply because of the propensity for microbial water-related diseases. A major public health implication of domestic water supply is the risk of outbreak of water-related diseases resulting from the consumption of water of poor microbiological quality. Because of the number and variety of microorganisms that live and thrive in water, it is not practical, nor necessary to monitor all waterborne pathogens during domestic water quality monitoring. It is also complex, expensive, and time consuming. That is why the use of reference pathogens representing different groups of microorganisms such as bacteria (e.g. *Vibrio*, *Campylobacter*, *E. Coli* O157, *Salmonella* and *Shigella*), viruses (e.g. rotaviruses, enteroviruses) and protozoa *(e.g. Cryptosporidium*, *Balantidium)*, comes in handy. In essence, the most commonly used indicator organisms for monitoring the bacteriological quality of domestic water supply include *E. coli*, coliform organisms and faecal streptococci. A major source of *E. coli* in drinking water is human excreta.[6] This is why the presence of *E. coli* in drinking water usually indicates recent faecal contamination of any origin.

Analyses of the bacteriological parameters, which form an integral part of the microbiological parameters of sources of domestic water supply, are usually concerned only with the detection of the bacterial contaminants of these sources, ignoring the other components of the water microbiology. In these analyses, the use of faecal coliforms as indicator organisms simplifies the analytical process. Therefore, using the number of faecal coliforms (bacterial contaminants) found per 100 mls of water as a parameter, water qualities have been graded as "reasonable quality" (1-10), "polluted" (10-100), "very polluted" (100-1000) and "grossly polluted" (1000+).[7]

In Enugu State, studies have shown that most sources of domestic water supply were contaminated, especially with microbial contaminants.[8-15] Causes of contamination of these domestic water sources include domestic, agricultural, natural and industrial activities. Consumption of water contaminated with microorganisms has been implicated as an aetiological factor in the causation of microbial water-related diseases. A convenient way of classifying these diseases is one that is based on their routes of transmission, which makes it possible to institute the types of intervention that are likely to be effective in reducing their incidence.[16] Accordingly, water-related diseases are classified into water-borne diseases (caused by the ingestion of faecally contaminated water e.g. cholera, typhoid fever, shigellosis, hepatitis A and amoebic dysentery), water-washed (water-hygiene) diseases (occurring due to lack of adequate water supply for washing, bathing and cleaning), water-based diseases (caused by organisms that spend parts of their life cycles in different habitats) and vector-borne diseases (caused by bites from insects that breed in water such as mosquitoes, tsetse fly, black fly).[4]

Among the waterborne diseases, infectious diarrhoea has been identified as the major health threat posed by drinking unsafe water. Globally, it has been reported to be the leading cause of mortality in children under five and, is estimated to cause about 1.5 million deaths annually.[3,17] Studies have shown that the incidence of diarrheoa can be reduced by around 44% by improving the quantity of water actually consumed, while improving source water quality can reduce it by 21%.[17]

In developing countries, paucity of infrastructure for effective treatment and distribution of water accounts for the high morbidity and mortality associated with waterborne diseases.[18]

In Africa, waterborne diseases are among the major causes of morbidity and mortality. It is estimated that around half of all patients occupying hospital beds in Africa suffer from waterborne illnesses due to lack of clean water and sanitation.[19] It has also been estimated that in Africa, every child has five episodes of diarrhoea every year and that 800,000 children die each year from diarrhoea and dehydration.[20]

In Nigeria, diarrhoeal diseases rank second among the causes of infant mortality and the third main cause of under-five mortality.[21] Studies have shown that the prevalence of diarrhoeal diseases is higher in the rural, than urban areas, and in the northern zones, than in the south of the country because, the provision of adequate potable water and sanitation is worse in the rural than urban areas; and the northern zones of the country are worse off in provision of infrastructure for adequate domestic water supply and sanitation than any other zone.[21]

In Enugu State, statistics have shown that reported cases of waterborne diseases, including typhoid fever, have been on the increase since 2003.[22] As evidence, in 2003, there were 3 reported cases of cholera, 1,537 of typhoid fever and 2,260 of bloody diarrhoea in Enugu State. Two years on, in 2005, cholera cases had risen to 5755, typhoid fever to 45,211 and malaria to 60,997.[22] Between 2006 and 2014, official statistics on the prevalence of waterborne diseases in Enugu state apparently are missing. However, from three government hospitals in Enugu State, available records show that diagnosed cases of typhoid fever in 2013 and 2014 were 1 200 and 1 392 respectively, indicating a rising trend.

The aim of this study is therefore, to determine the bacteriological qualities of domestic water supply and prevalence of typhoid fever in the five communities of Enugu State, to see to what extent the bacteriological qualities of the sources of domestic water supply had contributed to the rising incidence of typhoid fever (since

2003) in the state, since the bacteriological (microbiological) qualities of domestic water supply, among other factors, are largely responsible for the development of microbial water-related diseases, including typhoid fever.

METHODS

This was a cross-sectional study of sources of domestic water supply and prevalence of typhoid fever in five rural communities of Ezeagu Local Government Area of Enugu State.

According to the National Population Commission (NPC), Enugu state has a population of 3,267,837, and Ezeagu Local Government Area (LGA) 170,603.[23] Applying the Taro-Yamane formula, a sample size of 395 households was obtained from this population. However, only representatives of 297 households who reside permanently in these communities that were available at the time of the study were included in the study. Indigenes of the communities who reside outside the communities but were also present at the time of the study were excluded.

For the sampling, multistage sampling technique was used. Through balloting, Enugu West Senatorial District (out of 3), Ezeagu LGA (out of 17) and the five communities of the LGA (out of 23), namely Umusuru, Afor-Ugwu, Iwollo, Obinofia-Ndiagu and Mkpagu, were rando mly selected.

Copies of structured questionnaire were administered to 297 representatives of the various households in the five communities. With the assistance of local contact persons, sampling points of sources of domestic water supply were identified. Using 1.5 liters capacity plastic bottles, grab samples were collected from two of the most commonly used water sources in the selected communities, strictly observing the guidelines for water sampling as outlined by.[24] Collected water samples were sent to the laboratory in ice in a sealed container ('cooler') within 2 hours of collection. In all, 10 water samples were collected from the following sources: rainwater A and B in Umusuru, borehole water and spring water from *Iruala* spring in Afor-ugwu, well water and borehole water in Iwollo, tap water from taps A and B in Obinofia-ndiagu; and spring water from *Mkpuchi* spring and river water from *Oji-River* in Mkpagu. The principal method used for isolation of indicator organisms from the water samples was the membrane-filtration (MF) according to.[24]

For the Widal test, 227 blood samples were collected from the respondents who gave their consents (one sample per respondent). The one-off Widal test was a screening test to determine the prevalence of typhoid fever using the test titre. Blood samples were collected by applying a tourniquet on the lower one-third of the forearm, or on the mid-upper arm to occlude the veins, after which the venepuncture site (the dorsum of the hand or antecubital fossa) was cleaned with a swab soaked in methylated spirit. With a sterile 5 ml syringe, the selected vein was punctured and about 3 ml of venous blood withdrawn. The blood samples were then transferred into sterile specimen bottles placed in test tube racks and allowed to stand to enable the serum separate from the cells. After collecting the blood, pressure was then applied to the venepuncture site and the arm slightly raised for about a minute to stop the bleeding from the puncture site. The syringes and used swabs were discarded in the waste bin.

Using an adaptation of the slide test by Cruickshank, a drop of the patient's serum to be tested was pipetted on each of the eight reaction circles, after which one drop each of 'O' (typhi, paratyphi A, B, C) and 'H' (typhi, paratyphi A, B, C) antigens was also added to the eight reaction circles. The contents of each circle was mixed with separate mixing sticks and then the slide gently rocked back and forth while observing for agglutination macroscopically within one – two minutes. A titre of 1: 80 or more was considered clinically significant.[25]

A pilot study was done in two communities (Ihuezi and Adu-Achi) in May 2014 to test the questionnaire. Data were collected over a period of 20 weeks (from July to November 2014). The data so generated were analyzed as frequency distributions, t-test of means difference and Pearson product moment correlations using MaxStat (version 3.60) statistical software. Respondents' demographics, sources of domestic water supply, total coliform and faecal coliform counts, and prevalence of typhoid fever were analysed as frequency distributions, while the difference between total coliform and faecal coliform counts was analysed as t-test. The correlations between total and faecal coliform counts and the prevalence of typhoid fever were analysed as Pearson product moment correlations.

RESULTS

297 copies of the questionnaire were administered to respondents made up of 131 (44.2%) males and 166 (55.8%) females in the five communities. Of the 297 who filled the questionnaire, a sample of blood was collected from each of the 227 (76.4%) respondents who gave their consents (227 samples). 10 water samples were collected from the sources of domestic water supply in the selected communities.

Table 1: Distribution of respondents by sex.

Total	Male	Female
297	131 (44.2%)	166 (55.8%)

Table 1 shows the distribution of respondents in the five communities. From the distribution, it is seen that of the 297 respondents, 131 (44.2%) were males, while 166 (55.8%) were females.

The distribution of respondents by communities is shown in Table 2. The table shows that the respondents are not uniformly distributed in the five communities. Obinofia-ndiagu had the largest number of respondents with 126 (42.4%), followed by Mkpagu with 66 (22.2%), Iwollo with 54 (18.2%), Afor-ugwu with 27 (9.1%) and Umusuru with 24 (8.1%).

Table 2: Distribution of respondents by communities.

Community	Number of respondents
UMUSURU	24 (8.1%)
AFOR-UGWU	27 (9.1%)
IWOLLO	54 (18.2%)
OBINOFIA-NDIAGU	126 (42.4%)
MKPAGU	66 (22.2%)

Table 3: Sources of domestic water supply in Enugu state.

Community	Sources of domestic water supply	No. of improved	No. of unimproved
UMUSURU	*Rainwater	1	0
AFOR-UGWU	*Public boreholes, ^{0}unprotected spring, *rainwater	2	1
IWOLLO	*Public borehole, *protected private wells, * rainwater	3	0
OBINOFIA-NDIAGU	*Public taps, *private taps	2	0
MKPAGU	^{0}Unprotected spring, ^{0}stream	0	2
Total		8(72.7%)	3(27.3%)

Key: * indicates an improved source of domestic water supply, ^{0} indicates unimproved source of domestic water supply.

Table 4: Total coliform counts of sources of domestic water supply in Enugu State (no. of samples = 10).

Parameter	Mean total coliform count (cfu/100 ml)
UMUSURU	5
AFOR-UGWU	8
IWOLLO	6
OBINOFIA-NDIAGU	6
MKPAGU	3
Mean	5.6
WHO (2011)	0
SON (2007)	< 10

Key: cfu = colony forming unit.

Table 5: Faecal coliform counts of sources of domestic water supply in Enugu State (No. of samples = 10).

Parameter:	Mean Faecal coliform count (cfu/100 ml)
UMUSURU	0.5
AFOR-UGWU	0.5
IWOLLO	0
OBINOFIA-NDIAGU	0
MKPAGU	3.5
Mean	0.90
WHO (2011)	0
SON (2007)	0

Table 3 shows sources of domestic water supply designated as improved and unimproved types. From the table it is seen that 8 (72.7%) of the 11 different sources of domestic water supply were of the improved type, while 3 (27.3%) were of the unimproved type. Iwollo had more of the improved type than any other community (3), followed by Obinofia-ndiagu (2) and Afor-ugwu (2). Mkpagu had no improved source of domestic water supply.

Total coliform counts of the sources of domestic water supply are shown in Table 4. From the table it is seen that Afor-ugwu had the highest count with 8 cfu/100 ml, followed by Iwollo and Obinofia-ndiagu, each with 6 cfu/100 ml and Umusuru with 5 cfu/100 ml. The lowest count was detected in Mkpagu which had 3 cfu/100 ml. Mean total coliform count in all the samples was 5.6 cfu/100 ml.

Table 6: Total and faecal coliform counts of sources of domestic water supply in Enugu State (no. of samples = 10).

Parameter: count (cfu/100 ml)	Mean Total coliform count (cfu/100 ml)	Mean Faecal coliform
UMUSURU	5	0.5
AFOR-UGWU	8	0.5
IWOLLO	6	0
OBINOFIA-NDIAGU	6	0
MKPAGU	3	3.5
Mean	5.60	0.90
t		4.491
p-value		0.0020
WHO (2011)	0	0
SON (2007)	< 10	0

Table 5 shows the faecal coliform counts in the five communities. Mkpagu with 3.5 cfu/100 ml had the highest count, while Umusuru and Afor-ugwu each had 0.5 cfu/100 ml. In the samples from Iwollo and Obinofia-ndiagu, no faecal coliform was detected (0 cfu/100 ml). Mean faecal coliform count of all the samples from the five communities was 0.90 cfu/100 ml.

Table 7: Prevalence of typhoid fever in Enugu state using Widal test titre as indicator (no. of samples = 227).

Community	Widal test titre		
	Significant	Non-significant	% Positive
UMUSURU	22	2	91.7
AFOR-UGWU	15	2	88.2
IWOLLO	28	3	90.3
OBINOFIA-NDIAGU	85	34	71.4
MKPAGU	30	0	100
Mean	36.0	8.20	88.3

Table 6 shows the comparison between total coliform and faecal coliform counts. The table shows that Mkpagu with the lowest total coliform count of 3 cfu/100 ml, had the highest faecal coliform count with 3.5 cfu/100 ml. Afor-ugwu with total coliform count of 8 cfu/100 ml and Umusuru with total coliform count of 5 cfu/100 ml both had faecal coliform counts of 0.5 cfu/100 ml. Both Iwollo and Obinofia-ndiagu which had total coliform counts of 6cfu/100 ml each also had faecal coliform counts of 0 cfu/100 ml each. Between total coliform counts and faecal coliform counts of the samples from the five communities, the means difference was significant (p=0.0020).

Prevalence of typhoid fever is shown in Table 7. From the table, it is seen that Mkapgu had the highest prevalence with 100%, followed by Umusuru with 91.7%, Iwollo with 90.3%, and Afor-ugwu with 88.2%. The lowest prevalence was at Obinofia-ndiagu with 71.4%. Mean prevalence of typhoid fever in the five communities was 88.3%.

Table 8: Relationship between total coliform count of domestic water supply and prevalence of typhoid fever in Enugu state.

Parameters	Mean total coliform count (cfu/100 ml)	Prevalence of TF (in %)
UMUSURU	5	91.7
AFOR-UGWU	8	88.2
IWOLLO	6	90.3
OBINOFIA-NDIAGU	6	71.4
MKPAGU	3	100
Mean	5.60	88.3
R		-0.51
p		0.38
WHO (2011)	0	
SON (2007)	< 10	

Key: TF = typhoid fever.

Table 9: Relationship between faecal coliform count of domestic water supply and prevalence of typhoid fever in Enugu state.

Parameters:	Mean Faecal coliform count (cfu/100 ml)	Prevalence of TF (in %)
UMUSURU	0.5	91.7
AFOR-UGWU	0.5	88.2
IWOLLO	0	90.3
OBINOFIA-NDIAGU	0	71.4
MKPAGU	3.5	100
Mean	0.90	88.3
R		0.69
P		0.20
WHO (2011)	0	
SON (2007)	0	

Table 8 shows the relationship between total coliform counts and prevalence of typhoid fever. From the table it is seen that whereas Mkpagu which had the lowest total coliform count of 3 cfu/100 ml, had the highest prevalence of typhoid fever (100%), while Afor-ugwu with the highest total coliform count of 8 cfu/100 ml had a prevalence of 88.2%. Iwollo and Obinofia-ndiagu with total coliform counts of 6 cfu/100 ml each, had prevalence of 90.3% and 71.4% respectively. Umusuru with total coliform counts of 5cfu/100 ml had a prevalence of 91.7%. Pearson product moment correlation between total coliform counts and prevalence of typhoid fever in the five communities was strong and negative (r= -0.51), but not significant (p = 0.38).

The relationship between faecal coliform counts and prevalence of typhoid fever is shown in Table 9. The table shows that Mkapgu with the highest faecal coliform count of 3.5 cfu/100 ml also had the highest prevalence of 100%. Umusuru and Afor-ugwu both with faecal coliform counts of 0.5 cfu/100 ml each had prevalence of 91.7% and 88.2% respectively. Iwollo and Obinofia-ndiagu with faecal coliform counts of 0 cfu/100 ml each had prevalence of 90.3% and 71.4% respectively. Pearson product moment correlation between faecal coliform counts and prevalence of typhoid fever in the five communities was strong and positive (r = 0.69), but not significant (p = 0.20).

DISCUSSION

Water used for all domestic purposes is defined as domestic water supply.[2,3] In categorizing sources of domestic water supply, the WHO classifies them into improved (protected from outside contamination) and unimproved (not protected from outside contamination) types.[4] The study has demonstrated that about 73% of the sources of domestic water supply in the five communities were of the improved type, which include rainwater, boreholes, protected wells and taps. The remaining 23% of the sources which were of the unimproved type include unprotected springs and stream. The ability of microorganisms to thrive in water in great numbers gives rise to the microbiological properties of water, i.e., the microbiological qualities of sources of domestic water supply are usually determined by the type and number of microorganisms present in them. To investigate the bacteriological parameters of a given source of domestic water supply, indicator organisms are usually employed. The most commonly recommended indicator organism of faecal contamination is *E. coli* (thermotolerant coliforms), while total coliforms and heterotrophic plate counts can be used for operational monitoring. E. coli or thermotolerant coliform bacteria must not be detectable in any 100 ml sample of domestic water supply.[4]

The present study has demonstrated that none of the samples from the sources of domestic water supply in the five communities complied with the WHO guidelines value for total coliform in drinking water as all the samples had total coliform counts ranging from 3-8 cfu/ 100 ml.[4] The study has also demonstrated that improved sources of domestic water supply do not always provide safe drinking water, for although about 73% of the samples from sources in the study area were of the improved type, none of them complied with the WHO guidelines value for total coliform count. This finding is in line with the position that improved sources of domestic water supply do not always guarantee safety of supply as reported earlier on by.[26] However, in faecal coliform counts, samples from two (Iwollo and Obiofia-ndaigu) of the five communities complied with the WHO guidelines value with counts of 0 cfu/100 ml.[4] Between the total and faecal coliform counts of the samples from the five communities, there was a significant difference (p=0.0020).

Microbial contamination of sources of domestic water supply usually gives rise to the development of microbial water-related diseases. The indicator for measuring the number of cases of a disease present in a community at any given time is the prevalence. Thus, the prevalence of a disease is defined as the number of cases of the disease that are present in a particular population at a given time. Generally, the prevalence of typhoid fever was high in all the five communities, with the highest prevalence (100%) found in Mkpagu. This finding is in line with what had already been shown by the NBS statistics indicating a rising trend in the reported cases of typhoid fever and other water-related diseases between 2003 and 2005 in the state.[22] The finding of a 100% prevalence of typhoid fever in Mpkagu could mean that there is an endemicity of typhoid fever in this community, although this appears not to have been reported anywhere in literature before. Between faecal coliform counts and prevalence of typhoid fever, the correlation was strong and positive (r=0.69), although not significant (p=0.20). This correlation could also explain why the prevalence of typhoid fever was highest in Mkpagu, which also had the highest faecal coliform count of 3.5 cfu/100 ml.

The reported rising incidence and prevalence of typhoid fever in Enugu State, since 2003 may be attributed to sources of domestic water supply with poor bacteriological (microbiological) qualities as this study has found that 3 (60%) of the 5 communities studied, did not have sources of domestic water supply which complied with the WHO guidelines value for drinking water in faecal coliform counts, indicating recent faecal contamination.[4] And typhoid fever is known to be transmitted by the feco-oral route through contaminated water, food, among other vehicles, hence the reported rise in its incidence and prevalence. Also in total coliform counts, none of the samples from the communities complied with the WHO standard. However, poor bacteriological qualities of sources of domestic water supply in the five communities as identified by this study might not be the only factor responsible for the rise in the prevalence of typhoid fever in the state after all, as methods of storage and treatment of domestic water supply as well as access to improved sanitation are also factors that could affect the incidence and prevalence of waterborne diseases (including typhoid fever) in any given community.

Limitations of the study

1. The Widal test employed in this study was a one-off screening test which is not diagnostic of typhoid fever. For diagnosis of typhoid fever, a rising titre between two samples from a patient taken at least one week apart from the second week of the illness has to be demonstrated.
2. The uneven distribution of respondents in the five selected communities could have affected some of the data, however only the available and consenting representatives of the households that make up these communities could be recruited into the study.

CONCLUSION

Three (60%) out of the five selected rural communities of Ezeagu LGA of Enugu State had bacteriological qualities of sources of their domestic water supply which did not comply with the WHO guidelines values for drinking water in faecal coliform counts. Faecal coliform counts correlated positively and strongly with prevalence of typhoid fever (r=0.69) in these communities, which was why Mkapgu with the highest faecal coliform counts (3.5 cfu/100 ml) also had the highest prevalence of typhoid fever (100%). This finding suggests that this community (Mkapgu) might be endemic for typhoid fever. Therefore to reduce the prevalence of typhoid fever in the five selected communities in particular, and Enugu State in general, there is need to, among other things, improve on the bacteriological qualities of sources of their domestic water supply.

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