Research Journal of

Environmental Sciences

ISSN 1819-3412

Academic
Journals Inc.

www.academicjournals.com

Research Journal of Environmental Sciences 5 (6): 603-610, 2011
ISSN 1819-3412 / DOI: 10.3923/rjes.2011.603.610

Bacteriological Quality of Water Stored Exteriorly in Storage Tanks

I.O. Sule, T.O. Agbabiaka and A.V. Akomolafe
Department of Microbiology, University of Ilorin, Ilorin, PMB 1515, Ilorin, Kwara State, Nigeria

Corresponding Author: I.O. Sule, Department of Microbiology, University of Ilorin, Ilorin, PMB 1515, Ilorin, Kwara State, Nigeria

ABSTRACT

This study was conducted to determine the quality of water stored exteriorly in storage tanks. The water samples were obtained from ten different storage tanks at homes in Tanke area, Ilorin. The water samples were investigated for their physicochemical and bacteriological characteristics. The pH, suspended solids, chloride and total hardness were determined using pH meter, loss in weight on drying, argentiometric and complexometric titration, respectively. The viable bacterial, total coliform and faecal coliform counts were determined by standard plate count method, multiple tube fermentation and the use of differential media, respectively. The viable bacterial count ranged from 2.1×10^1 to 1.6×10^3 cfu mL^{-1}. The total coliform and faecal coliform ranged from 0 to 210 cfu 100 mL^{-1} and 0 to 6 cfu mL^{-1}, respectively. The pH of the water samples ranged between 6.53 and 7.45; the suspended solids between 0.5 and 6 mg mL^{-1}, the total hardness between 10 and 55 mg L^{-1} and the residual chlorine contents ranged 0.23 and 0.89 mg L^{-1}. A total of ten bacteria were isolated from the stored water sample collected. The bacterial isolates were: *Bacillus lentus, Bacillus licheniformis, Bacillus circulans, Staphylococcus aureus, Lactobacillus brevis, Streptococcus* sp., *Corynebacterium kutscheri, Micrococcus varians, Pseudomonas aeruginosa* and *Escherichia coli*. This study revealed that the quality of water in a storage tank depends on the source from which it was drawn and the handling of the tank by the users. Recommendations were made that good quality water from borehole or municipal supply should be stored in the storage tank and the users should ensure proper sanitation in order to minimize the rate of contaminations.

Key words: Physicochemical, bacteriological, water quality, reservoirs, residents

INTRODUCTION

Water is a pertinent component of life and its main sources include rain, lakes, wells, streams, springs, ponds, oceans. Though water sources are so numerous on earth, the addition of a key word potability to water on earth reduces to a great extent the amount of acceptable useful water on earth. Thus, on a sanitary point of view for domestic water usage, water can be classified as polluted and unpolluted (Twort *et al*., 2000).

There are three types of water environment and they are atmospheric water, surface water, and underground water (Prescott *et al*., 2007). During rainy seasons, rain water can serve as a good source of water for domestic purpose if properly stored. Thus, potable water can be obtained from the rainfall if properly collected into a well protected storage tank and can be used for domestic purposes in most homes (Mitra and Roy, 2011).

The primary purpose of the guidelines for drinking water is the protection of public health. Water is essential to sustain life and it must be safe, adequately supplied and accessible to all. The WHO guideline states that water intended for drinking must not contain any concentration of a constituent that will or may result in any significant health risk to the consumers over a lifetime of consumption. It also states that *E. coli* or thermotolerant coliform bacteria must not be detectable in any 100 mL sample of water intended for drinking (WHO, 2008). The Nigerian Standard for Drinking Water Quality is also fashioned after the WHO standards.

Humanity is facing water bankruptcy. There is no way of bailing the earth from water scarcity considering it's availability, domestic and industrial use which has been increasing with increase in population growth and the constancy of the earth fresh water (George and Edward, 1985). Also, it is being polluted as a result of human activities thereby reducing the availability of potable water (Cheesbrough, 2004; Adefemi *et al.*, 2008; Fard *et al.*, 2011; Ndimele and Jimoh, 2011). With the present water crisis human in his efforts has devised some means either to treat polluted water into potable water or to store the little available potable water for long or short term usage.

Storage generally reduces the numbers of organisms in water. Several factors affect the microbial flora of stored waters. These are sedimentation; activities of other organisms, light ray, temperature, food supply (Eniola *et al.*, 2007). Orji and Anyaegbunam (2009) harvested and treated flood water to obtain water that was potentially safe for human consumption. Domestic storage of water can be made in a cemented reservoir, plastic tanks, buckets or metal tanks (Eniola *et al.*, 2006). The purity of this water depends on its source, treatments it has received and the storage facilities available (WHO, 2004). This research is justified due to the significant parts played by storage tanks at many homes in Nigeria so as to bridge the gap of intermittent water supply.

This study was aimed to: investigate the bacteriological quality of water stored exteriorly in storage tanks prior to use at homes; determine some physical and chemical characteristics of these stored water samples; determine the sanitary appraisal of the stored water and provide recommendations on how to minimize contaminations of storage tanks.

MATERIALS AND METHODS

Collection of water samples: Water samples from ten storage tanks in some homes located at Tanke area of Ilorin metropolis, Kwara State of Nigeria were aseptically collected as described by APHA (1998). The water samples were collected from October, 2009 to February, 2010 which represents the peak of dry season.

Determination of physicochemical qualities of the stored water samples: The pH of each sample was determined using standard methods (AOAC, 1990) while The amount of suspended solid of each sample was determined as described by AWWA (1990). The chlorine content of the water sample was determined by argentiometric titration (British Pharmacopoeia, 1993).

The total hardness of the water sample was determined using complexometric titration as described by De Zuane (1997).

The sanitary appraisal of the stored water samples were determined with the aid of questionnaire administered to the owners of the storage tanks. The questions raised include: What was the source of water stored in the tanks?; Is the reservoir a plastic or metal material?; Do they avoid opening the reservoir to rain?; if yes, did they allow the roof to be washed by rain water before collection into the tanks?; Is the pipe work on the reservoir not leaking?; is colour of reservoir

not white?; Did they cover the reservoir immediately it is filled?; is the water consumed within 6 days?; Do they wash their reservoir?; If yes, how often?; Do they perform quality analysis on the source of water? (NIS, 2007).

The sanitary risk score was determined by finding the % of sanitary parameters with yes score.

Bacteriological analysis of water samples: The viable bacterial count was determined in duplicate using Standard pour plate method with nutrient agar as the medium of choice (Dubey and Maheshwari, 2005). The faecal coliform count was determined using spread plate technique and Eosin methylene blue agar (Salle, 1973).

Multiple tube fermentation technique was used to determine the total coliform count per 100 mL of the water sample with reference to the Most Probable Number (Pelczar *et al.*, 2005).

Purification and preservation of isolates: The isolates obtained were subculture on nutrient agar until pure culture was obtained. Then, they were stored in the refrigerator at 4°C as stock cultures (Fawole and Oso, 2004).

Characterization and identification of isolates: Pure bacterial isolates were characterized in terms of their colonial morphology, staining reactions and biochemical characteristics. (Buchanan and Gibbons, 1974; Cowan and Steel, 1985).

Statistical analysis: The statistical analysis employed were percentage, mean, range and standard error of mean (Bello and Ajayi, 2000).

RESULTS

The pH of the storage water from the different sources ranged from 6.53-7.45. The minimum and maximum pH values were obtained from the municipal water source at Tanke Iledu and a well at Mark area, respectively. These were within the pH values of 6.5-8.5 allowed (Alan *et al.*, 2000). The level of the suspended solids; total hardness and chlorine content of the stored water ranged from 0.5-6.0, 10-55 and 0.21-0.89 mg L^{-1}, respectively (Table 1). The sanitary appraisal as well as the sanitary risk score of the different stored water was as presented in Table 3. The sanitary risk score for the reservoirs ranged from 25.0-85.7%. This is a measure of the extent to which each

Table 1: Physicochemical qualities of water stored exteriorly in storage tanks

Sample	Source of water in Tank	pH*	Suspended solid (mg mL^{-1})*	Total hardness (mg L^{-1})*	Chorine content (mg L^{-1})*
A	Well at Oke-Odo I	6.95±0.02	6.00±0.33	24±1.16	0.82±0.04
B	Municipal Water, GRA, Tanke	6.70±0.06	1.00±0.06	22±1.53	0.75±0.02
C	Well at Mark area	7.45±0.01	1.50±0.15	35±2.08	0.45±0.02
D	Well at Bekind area	6.99±0.03	2.00±0.15	55±1.53	0.47±0.02
E	Borehole at Mark area	6.84±0.01	2.00±0.06	18±1.53	0.26±0.02
F	Well at Sarab	6.95±0.02	1.25±0.02	30±1.53	0.23±0.02
G	Borehole at Tipper garage	6.60±0.02	0.50±0.02	15±1.00	0.21±0.01
H	Well at Oke-odo II	6.70±0.01	1.00±0.15	18±1.00	0.89±0.03
I	Borehole at Tanke junction	6.55±0.01	0.88±0.06	10±1.53	0.31±0.02
J	Municipal Water supply at Tanke Iledu	6.53±0.01	2.00±0.15	23±0.58	0.67±0.01

* Mean values±Standard error of means

Table 2: Bacteriological counts of water stored exteriorly in storage tanks

Sample	Source of water in storage tank	Bacterial Count (cfu mL^{-1})*	MPN Index of Coliform 100 mL of water*	Faecal Coliform Count (cfu mL^{-1})*
A	Well at Oke-Odo I	100±7.64	23±1.53	0±0.00
B	Municipal Water, GRA, Tanke.	21±0.58	28±1.00	0±0.00
C	Well at Mark area.	580±5.77	150±1.53	2±0.00
D	Well at Bekind area	1500±28.87	210±2.89	6±0.58
E	Borehole at Mark area.	100±2.89	1±0.00	0±0.00
F	Well at Sarab	1600±5.77	210±0.00	0±0.00
G	Borehole at Tipper garage	110±2.89	4±0.58	0±0.00
H	Well at Oke-odo II	502.89	9±0.67	0±0.00
I	Borehole at Tanke junction	25±1.00	0±0.00	0±0.00
J	Municipal Water supply at Tanke Iledu	30±2.89	20±0.58	0±0.00

*Mean values±Standard error of means

Table 3: Sanitary appraisal of water stored exteriorly in storage tanks

		Sanitary appraisal parameters								
Stored water locations	Sources	I	II	III	IV	V	VI	VII	VIII	Sanitaryscore(%)
Oke-odo I	Well	Yes	Yes	Yes	No	No	Yes	No	Yes	62.5
GRA, Tanke	Municipal	No	Yes	Yes	Yes	-	Yes	Yes	No	71.4
Mark area	Well	Yes	Yes	Yes	No	Yes	Yes	No	No	62.5
Bekind area	Well	No	Yes	No	No	No	Yes	No	No	25.0
Mark area	Borehole	Yes	Yes	Yes	Yes	-	Yes	No	No	62.5
Sarab	Well	Yes	Yes	Yes	No	No	Yes	No	No	50.0
Tipper garage	Borehole	Yes	Yes	Yes	Yes	-	Yes	No	No	62.5
Oke-odo II	Well	Yes	Yes	Yes	Yes	-	Yes	No	Yes	85.7
Tanke junction	Borehole	Yes	Yes	Yes	Yes	-	Yes	Yes	No	85.7
Tanke Iledu	Municipal	Yes	Yes	Yes	Yes	-	Yes	No	No	71.4

I: Reservoir pipe not leaking, II: Colour of reservoir not white, III: Reservoir properly covered, IV: Reservoir not opened to rain, V: If IV is yes, roof allowed to wash before collecting rain water, VI: Water consumed within 6 days, VII: Reservoir being washed, VIII: Quality analysis being done on water source; -. Not assessed

reservoir at each resident is prone to the possibility of being contaminated by human and non-human factors.

The viable bacterial count of the stored water ranged from 2.1×10^1 to 1.6×10^3 cfu mL^{-1}. Similarly, the total and faecal coliform counts of the stored water had a range of zero to 210 MPN/ 100 mL and zero to 6 cfu mL, respectively (Table 2).

A total of ten different bacterial species were characterized and identified as: *Bacillus lentus, Bacillus licheniformis, Bacillus circulans, Staphylococcus aureus, Lactobacillus brevis, Streptococcus* sp., *Corynebacterium kutscheri, Micrococcus varians, Pseudomonas aeruginosa* and *Escherichia coli* and their occurrence is shown in Table 4. However, these organisms are not all found in the water sample from the reservoir of each resident. Some of the organisms were not isolated. The least sample had the occurrence of only two of the ten isolates while majority had six isolates present.

Table 4: Occurrence of bacterial isolates in water stored exteriorly in the storage tanks

samples	I	II	III	IV	V	VI	VII	VIII	IX	X
A	+	–	+	–	+	+	–	+	–	–
B	–	+	–	–	+	+	+	–	–	–
C	+	–	+	+	–	–	+	–	+	+
D	–	+	–	+	–	–	–	+	+	+
E	+	+	–	–	+	–	+	–	–	–
F	–	+	+	+	+	–	–	–	+	–
G	+	–	+	–	–	–	+	+	+	–
H	–	+	–	–	+	–	+	–	–	–
J	–	–	+	–	–	+	–	–	–	–
K	–	–	+	–	+	+	+	–	–	–

A: Oke-odo I, B: GRA, Tanke, C: Mark area, D: Bekind area, E: Mark area, F: Sarab, G: Tipper garage, H: Oke-odo II, J: Tanke junction, K: Tanke Iledu, I: *B. lentus*; II: *B. licheniformis*; III: *B. circulans*; IV: *S. aureus*; V: *L. brevis*; VI: *Streptococcus* sp.; VII: *Corynebacterium kutscheri;* VIII: *Micrococcus varians*; IX: *P.aeruginosa*; X: *E.coli*; +, Isolated; –: Not isolated

DISCUSSION

The pH of the water samples ranged between 6.53 and 7.45 which is within the range that bacterial cells proliferate best. It plays an important role in the survival rate of micro-organisms and a neutral pH will support growth of a large number of bacteria (Madigan *et al.*, 2000).

Ninety percent of the stored water sampled can be described as being soft since the level of total hardness fell within the range of 0-49 mg L^{-1} (Hammer and Hammer, 2003). The level of hardness of the stored water sources would depend on the treatment it has received as well as the mineral compositions of the soil where the borehole or well is sited. Hard water not only affects laundry at homes it also causes discolouration of cooking utencils at homes. Although, research had found that a little presence of calcium and magnesium salt in water will help in reducing the incidence of cardiac disease (Mintz *et al.*, 1995).

Only 40% of the stored water sampled had suspended solid within the limit of 0.5-1.0 mg mL^{-1} allowed (WHO, 1994). The high suspended solid level obtained in some of the wells could be due to constantly stirring of the sediments especially if the well water is not only pumped into the storage tank but also being fetched by individuals with buckets.

The chlorine content of the stored water ranged from 0.21-0.89 mg L^{-1}. In a similar study, Al-Safady and Al-Najar (2011) obtained infringement of up to 41.4% to WHO standards in the residual chlorine level of water supply to Gaza Strip. The low level of chlorine in some of the well or borehole also depends on the local geology of the site. However, the reduction in the level of residual chlorine in municipal water sources could also be attributed to depletion along the distribution system before it gets to the consumers' homes (Lechevallier *et al.*, 1996).

Sixty percent of the stored water had bacterial counts within the range of 100 cfu mL^{-1} allowed (Ford, 1999). and these are mostly from the municipal and borehole sources. However, only 40% of the stored water from the wells met up in terms of the bacterial counts and physicochemical quality (Table 1, 2). Orji *et al.* (2006) found that the bacteriological qualities of wells could be improved by storage. The viable bacterial count of the stored water depends on the treatment the water source has undergone, handling of the storage tank and the quality of the stored water source and also that depth could affects the quality of water from wells.

The coliform count of the stored water ranged from zero to 210 MPN index per 100 mL of the water sample. Only 10% of the water sample was devoid of coliform and met up in all the quality

parameters determined and this was obtained from a borehole water source. Faecal coliforms were isolated in 20% of the stored water sources.

The sanitary appraisal (Table 3) also indicated that some of the storage tanks were normally opened to rain or without a cover. Hence, soil particles and dirts could get into the reservoir from the unclean roof as well as from the surrounding. There is correlation between the sanitary risk score of the stored water and their bacteriological qualities (Table 2, 3).

The presence of potential pathogens such as *E. coli, S. aureus, Pseudomonas aeruginosa* etc. in some of the stored water sources is totally uncalled for and it indicated absence of sanitation on the part of the users. The other species of bacterial isolated could be derived from soil especially when strong wind blown off soil particles which might be deposited in the uncovered reservoirs as revealed by the sanitary appraisal (Table 3).

In view of the above findings recommendations were made as follows: that the stored water should be sourced from good quality water sources such as from the municipal water supply and borehole; the source should be analysed from time to time in order to determine if its quality is within the allowed limit; if the water is sourced from well, its depth must be deep; periodic cleaning and disinfection of the storage tanks is highly desirable.

CONCLUSION

It can be concluded from this study that not all the reservoir water samples met up in terms of physicochemical qualities where 90 and 40% of the samples were within the allowed specifications of total hardness and suspended solids. The same applied for the bacteriological parameters where only 10% of the water samples were satisfactory. It evident from this studies that borehole and municipal supplies provide better sources of water for the reservoirs at homes. Furthermore, handling of reservoir is also critical in order to prevent contaminations.

ACKNOWLEDGMENTS

The authors wish to use this medium to acknowledge the residents at Tanke Iledu area, Ilorin, Kwara State of Nigeria for their co-operations in the course of samples collection and administration of the sanitary appraisal of their respective storage tanks.

REFERENCES

AOAC, 1990. Official Methods of Analysis. 15th Edn., Association of Official Analytical Chemists, Washington, DC., USA.

APHA, 1998. Standard Methods for the Examination of Water and Wastewater. 20th Edn., American Public Health Association, Washington, DC., ISBN: 0-309-09122-5.

AWWA, 1990. Water Quality and Treatment. 4th Edn., McGraw Hill, New York.

Adefemi, S.O., S.S. Asaolu and O. Olaofe, 2008. Determinant of heavy metals in Tilapia mossambicus fish, associated water and sediment from Ureje dam in South Western Nigeria. Res. J. Environ. Sci., 2: 151-155.

Al-Safady, M. and H. Al-Najar, 2011. Disinfection process of water supply system in the Gaza strip between real practice and WHO limitations. Res. J. Environ. Sci., 5: 414-423.

Alan, T., D. Ratnayaka and J.B. Malcom, 2000. Water Supply. 5th Edn., IWA Publishing, London.

Bello, R. and O.O.S. Ajayi, 2000. Research Methods and Statistical Analyses. Haytee Press and Publishing Co. Ltd., Ilorin, Nigeria, pp: 131-139.

British Pharmacopoeia, 1993. The British Pharmacopoeia. Vol. 1, HMSO Publication Center, London, pp: 604-605.

Buchanan, R.E. and N.E. Gibbons, 1974. Bergey's Manual of Determinative Bacteriology. 8th Edn., Williams and Wilkins, Baltimore, USA., pp: 1268.

Cheesbrough, M., 2004. District Laboratory Practice in Tropical Countries. Cambridge University Press, Cambridge, UK, pp: 62-70.

Cowan, S.T. and K.J. Steel, 1985. Manual for the Identification of Medical Bacterial. 4th Edn., Cambridge University Press, London, pp: 217.

De Zuane, J., 1997. Maintaining Potability. Handbook of Drinking Water Quality. 2nd Edn., John Wiley and Sons Inc., New York, pp: 478-480.

Dubey, R.C. and D.K. Maheshwari, 2005. Practical Microbiology. 1st Edn., S. Chand and Co. Ltd., New Delhi.

Eniola, K.I.T., A.B. Olayemi, S. Awe, A. Adegoke, L.B. Osanoto, O.O. Abolade and T.M. Kayode-Isota, 2006. Effect of storage on the bacteriological quality of well water. Afr. J. Clin. Exp. Microbiol., 2: 27-32.

Eniola, K.I.T., D.Y. Obafemi, S.F. Awe, I.I. Yusuf, and O.A. Falaiye, 2007. Effects of containers and storage conditions on the bacteriological quality of borehole water. Nigerian J. Microbiol., 21: 1578-1585.

Fard, R.F., G.N. Bidhendi and A.A. Azimi, 2011. Biosorption of nickel from batch reactor using the powder of waste activated sludge. Res. J. Environ. Sci., 5: 461-470.

Fawole, M.O. and B.A. Oso, 2004. Laboratory Manuals of Microbiology. Spectrum Books Ltd., Ibadan, Nigeria, pp: 127.

Ford, T.E., 1999. Microbiological safety of drinking water: United States and global perspective. Environ. Health Perspect., 107: 191-206.

George, T. and D.S. Edward, 1985. Water Quality. Addison-Wesley Publishing Co., New York, pp: 768.

Hammer, M.J. and M. Jr. Hammer, 2003. Water and Wastewater Technology. 4th Edn., Prentice Hall, New Delhi, pp: 536.

Lechevallier, M.W., N.J. Welch and D.B. Smith, 1996. Full-scale studies of factors related to coliform regrowth in drinking water. Applied Environ. Microbial., 62: 2201-2221.

Madigan, M.T., J.M. Martinko and J. Parker, 2000. Brock Biology of Microorganisms. Prentice Hall Press, USA.

Mintz, E.D., E.M. Reiff and R.V. Tauxe, 1995. Safe water treatment and storage in the home a practical new strategy to prevent water borne disease. J. Am. Med. Assoc., 273: 948-953.

Mitra, S. and P. Roy, 2011. BTEX: A serious ground water contaminant. Res. J. Environ. Sci., 5: 394-398.

NIS, 2007. Nigerian standard for drinking water quality. ICS 13.060.20, Approved by Standard Organization of Nigeria (SON)Governing Council, Lagos and Abuja, Nigeria. http://www.unicef.org/nigeria/ng_publications_Nigerian_Standard_for_Drinking_Water_Quality.pdf.

Ndimele, P.E. and A.A. Jimoh, 2011. Water hyacinth {*Eichhornia crassipes* (Mart.) Solms.} in phytoremediation of heavy metal polluted water of Ologe Lagoon, Lagos, Nigeria. Res. J. Environ. Sci., 5: 424-433.

Orji, M.U. and B.C. Anyaegbunam, 2009. Flood water: A veritable source of rural water supply in South Eastern, Nigerian. Nigerian J. Microbiol., 23: 1797-1802.

Orji, M.U., E.E. Ezenwaje and B.C. Anyaegbunam, 2006. Spatial appraisal of shallow well water pollution in Awka, Nigeria. Nig. J. Microbiol., 20: 1389-1394.

Pelczar, M.J., E.C.S. Chan and N.R. Krieg, 2005. Microbiology. 5th Edn., Tata McGraw Hill, New Delhi, pp: 571.

Prescott, L.M., J.P. Harley and A. Klein, 2007. Microbiology of Fresh Water. McGraw Hill, New-York, pp: 669-682.

Salle, A.J., 1973. Bacteriology of Water and Fundamental Principles of Bacteriology. 7th Edn., McGraw Hill Co. Inc., New York, USA., pp: 687-710.

Twort, A.C., D.D. Ratnayaka and M.J. Brandt, 2000. Standards for Physical and Chemical Quality of Water Supply. Arnold and IWA Publishing, London, pp: 240-244.

WHO, 1994. Operation and Maintenance of Urban Water Supply and Sanitation Systems: A Guide for Managers. World Health Organization, Geneva, pp: 102.

WHO, 2004. Guidelines for Drinking Water Quality. 3rd Edn., World Health Organization, Geneva.

WHO, 2008. Water Sanitation and Health (WSH): Guidelines for drinking water quality, 3rd Edn, incorporating the first and second addenda. Vol.1, Recommedations. http://www.who.int/water_sanitation_health/dwq/gdwq3rev/en/.