academicJournals

Vol. 8(21), pp. 2137-2143, 21 May, 2014
DOI: 10.5897/AJMR12.749
Article Number: 13532A945001
ISSN 1996-0808
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http://www.academicjournals.org/AJMR

African Journal of Microbiology Research

Full Length Research Paper

Assessment of chemical and bacteriological quality of pipe-borne water from various locations in Delta State University, Abraka, Nigeria

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Received 21 March, 2012; Accepted 28 April, 2014

Eighteen samples, consisting of six samples each, from three different locations that were 250, 500 and 750 away from the drinking water source in Delta State University, Abraka Campus, were collected and analyzed for their microbial and chemical quality using standard methods. Total viable counts were carried out using the pour plate method, while the most probable number was determined with the multiple tube fermentation technique. The total viable counts increased with distance away from the water source and were high for all the water samples, exceeding the 2.0 Log_{10}cfu/ml set limit for drinking water. The isolated organisms were *Micrococcus* sp., *Chromobacterium* sp., *Streptococcus* sp., *Pseudomonas aeruginosa* and *Staphylocosus aureus*. Chemical parameters analyzed were pH, chloride, alkalinity, carbon-dioxide, calcium, magnesium, zinc, iron, copper, potassium, total hardness, total dissolved solids, total suspended solids and total solids. The results obtained from each parameter were compared with the quality standard for drinking water laid down by the World Health Organisation and Federal Environmental Protection Agency (FEPA), Nigeria. The analyses revealed that there were increases in some of the parameters with distance away from the water source while some of the parameters studied were within the approved standard, others were above or below. It is thus imperative for our drinking water to be properly treated prior to consumption.

Key words: Water, microbial, chemical, parameters, standards.

INTRODUCTION

Water supply is the general process required for the provision of water from public water system to individual buildings and subsequent distribution of such water to various parts of such buildings. The water from public supply system to buildings is supplied through pipes. The strength of the pipes, water carrying capacity, life and

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durability of pipes, joining process, maintenance and repairs affect the quality of water being supplied. Piped water remains susceptible to biological and/or chemical contamination. Portable water supply system requires not only pipes, but many fittings and valves which add considerably to their functionality (Roberge, 1999).

Drinking water system thus provides habitat for microorganisms which are sustained by organic and inorganic nutrients present on the surface of the pipes or in the conveyed water. Maintaining the distribution system will require maintenance and survey procedures to prevent contamination and also remove and prevent the accumulation of internal deposits (Sobsey, 1989).

The safety of drinking water therefore depends on a number of factors which include quality and source of water, effectiveness of treatment and integrity of the distribution system that transfer the water to containers. The traditional approach to varying the bacteriological and chemical safety of piped water supply has relied on sampling strategies based on the end product, that is, tap water (WHO, 2003; Craun et al., 1997).

The objectives of this study, therefore, are to determine the bacteriological, and ascertain the chemical quality of piped water distribution system and suggest ways to reduce corrosion and increase portability of water for human consumption.

MATERIALS AND METHODS

Six samples from each of the three different locations (designated A - C, and were 250, 500 and 750 m away from the borehole), were collected with 500 ml sterile conical flasks, corked with cotton wool wrapped with aluminium foil and were transported immediately to the laboratory for analyses.

Identification of bacterial isolates

The identification of the sample microorganisms were based on cultural, morphological and biochemical characteristics according to the schemes of Cowan and Steel (1974), Buchanan and Gibbons (1974) and MacFaddin (1980). The result of each test was observed and recorded.

Bacteriological analysis

The total aerobic count (TAC) was carried out as described by Anon (1994). The sample water was serially diluted with distilled water after which 0.1 ml aliquots of 10^{-1} and 10^{-3} dilutions, respectively were dispensed into separate Petri dishes. Molten plate count agar cooled to 450°C was dispensed into each plate and incubated for 48 h at 37°C. The growths were observed and counted.

Estimation of coliforms

Coliforms were estimated using the five tube most probable number (MPN) technique. The lauryl sulphate broth used has high nutrient quality and the presence of phosphate buffer in this medium enhances rapid growth and increased gas production of slowly lactose fermenting coliform bacteria. It also inhibits the growth of undesired bacteria. The numbers of positive tubes were compared with MPN index table. Aliquots of the water samples were also incubated on centrinide agar which is selective for *Pseudomonas* sp. and also violet red bile which is a selective medium for *Escherichia coli.* Degradation of lactose to acid is indicated by the pH indicator, neutral red, which changes to red, and also by precipitation of bile acids. The appearance of the colonies on the plates is red, surrounded by reddish precipitation zones.

Chemical analyses

Determination of carbon-dioxide

Twenty millilitres (20 ml) of water sample was dispensed into a sample vial using a sterile syringe and two drops of phenolphthalein indicator was added. The content of the vial was mixed thoroughly after which it was titrated with carbon dioxide reagent B (0.02 N sodium hydroxide solution) until a pink colour was observed. The test result was read directly from the scale on the titrator barrel and recorded.

Determination of chloride

Ten millilitres (10 ml) of water sample was dispensed into the sample vial and three drops of chloride A reagent (5% potassium chromate) was added as indicator and mixed thoroughly. The mixture was titrated with chloride turned to a faint permanent brick-red colour. The result was read directly from the scale of the titration barrel and recorded.

Determination of alkalinity

Five millilitres (5 ml) of the water sample was pipette into the sample vail and a tablet of BCG-MR indicator (Bromocresol green-methyl red) was added and allowed to dissolve. The green colour was titrated with alkalinity reagent B (0.1%) sulphuric acid0 until solution turned purple. A post end colour was red. The result was read and recorded.

Determination of total hardness

Three millilitres (3 ml) of the water sample was dispensed into the vial using a syringe. The vial was inserted into the spectrophotometer chamber and scanned blank after which it was removed from the chamber and the sample transferred into Ca hardness UDV (unit dose vial). The vial was mixed vigorously for about 10 s and inserted into the chamber. The sample was scanned and results were recorded in mg/L.

Calcium hardness

Calcium hardness was recorded as one third of the total hardness in milligram per litre.

Magnesium hardness

Magnesium hardness was recorded as two third of the total hardness in milligram per litre.

Determination of electrical conductivity

Electrical conductivity was determined using a conductivity meter. The probe was dipped into a beaker containing the sample until a stable reading was obtained and recorded in µs/cm.

Determination of pH

The pH of the water samples were determined using the Hanner microprocessor pH meter standardized with a buffer solution of 4 to 9. The results were obtained using a stable reading.

Determination of zinc

Ten millilitres (10 ml) of the water sample was dispensed into a clean tube with the help of a syringe. The sample was scanned black after which 0.1 g of sodium ascorbate and 0.5 g of zinc buffer powder were added and mixed thoroughly for 1 min. Three drops of 10% sodium cynate, 1 ml of zinc indicator solution (5.0 ml zinc indicator solution and 17.8 ml methyl alcohol) and four drops of formaldehyde solution (37%) were added, capped and mixed thoroughly. The vial was inserted into the Smart spectrophotometer and readings were recorded in mg/L.

Determination of copper

The vial was rinsed with water sample after which 3 ml of the sample was dispensed into the vial with the help of a sterile syringe and was capped, its content mixed thoroughly and allowed to stand for 5 min. This was followed by further mixing to re-suspend the settled precipitate after which it was immediately inserted into the spectrophotometer chamber and scanned. The results were recorded in mg/L.

Determination of cadmium

The tube was rinsed with sample water after which 10 ml of sample was dispensed into it and scanned blank. The tube was removed from the chamber and 1.0 ml buffered ammonia reagent, two drops of 10% sodium citrate, 0.5 ml of PAN indicator, and 0.5 ml of stabilizing reagent were added, capped and mixed thoroughly. The tube was inserted into the chamber and its content scanned.

Determination of iron

The tube was rinsed with the sample water and filled to 10 ml line of the vial and scanned blank. With the help of a syringe, 0.5 ml of iron reagent 2 powder was added and mixed thoroughly for 30 s. The solution was allowed to stand for 30 s for maximum colour development after which the sample vial was inserted into the spectrophotometer chamber and scanned. Results were read and recorded in mg/L.

Determination of total dissolved solids

The electrode of the Hanna's instrument (Model TDS 1) was rinsed with distilled water after which it was dipped back into the water sample in a clean beaker. The total dissolved solids were read by slightly sliding the knob on top of the instrument. The result was read and recorded.

Determination of total solids

A clean, dry and flat silica disc was weighted (W1) and 50 ml of the water sample was dispensed into it. The content of the disc was evaporated in a water bath. With the help of a forceps, the disc was transferred into an oven set at 105°C for 3 h after which it was removed, left to cool and re-weighed. The process was repeated till a constant weight was obtained (W2). Total solid (mg/L) = (W2-W1) 20,000 mg/L.

Determination of total suspended solids

The difference between the total solids and total dissolved solids is equal to the total suspended solids.

SS = TS - DS mg/L

RESULTS AND DISCUSSION

The organisms isolated from the water samples presented in Table 1 were *Micrococcus* sp.*, Chromobacterium* sp.*, Streptococcus* sp.*, Pseudomonas aeruginosa* and *Staphylocosus aureus.* These are reported water resident organisms (Benka-Coker and Olimani, 1995; Edema et al., 2006; Ukpong, 2008). Some of the organisms are reported causal agents of some water-borne diseases. Thus, their presence in water could pose some effects on human health.

The results obtained in the analyses of the water samples as presented in Table 2 shows that the mean values of carbon-dioxide in the water samples, which ranged from 11 - 23 ppm, were not within the World Health Organization approved standard of 50 ppm. Hung and Hsu (2004) reported that carbon-dioxide quickly combines with water form carbonic acid, a weak acid. Thus the presence of carbon-dioxide in water may have negative effects depending on the water pH. If the water has a high pH value, the carbonic acid will act to neutralize it, but if the water is acidic, the carbonic acid will act o neutralize it, but if the water is acidic, the carbonic acid will make it even more acidic.

The mean values of chloride content, that ranged from 8.17 to 12.5 ppm, was below the 200 ppm maximum range for standard water, and so, has no adverse health impact when present in water for consumption and other domestic uses.

The mean values of alkalinity of the water samples, which ranged from 10.67 to 16 ppm, was below the set standard of 100 ppm which would have no adverse effect on human health while the mean values of pH, which ranged from 5.38 to 6.32, were below the acceptable limit of 6.5-8.5. This calls for the treatment of such water necessary prior to consumption in order to avoid the associated adverse health implications.

The mean values of electrical conductivity of the water samples, that ranged from 10.32 to 31.82 µs/cm, was

Table 1. Identification of bacterial isolates.

	A	B	C	D	E
Shape	Cocci in clusters	Rod	Cocci in chains	Rod	Cocci in clusters
Gram reaction	+	-	+	-	+
Aerobic growth	+	+	+	+	+
Anaerobic growth	-	+	+	-	+
Endospore production	-	-	-	-	-
Motility test	-	+	-	+	-
Catalase test	+	+	-	+	+
Oxidase test	+	+	-	+	-
Glucose fermentation	-	+	+	-	+
Organism identified	*Micrococcus* sp	*Chromobacterium* sp.	*Streptococcus* sp.	*Pseudomonas aeruginosa*	*Staphylococcus* sp.

Table 2. Average values of water parameters of samples.

Parameter	A (250 m)	B (500 m)	C (750 m)	Set standards
CO_2	8.83	11.00	23.00	50 ppm
Cl (ppm)	10.67	12.50	8.17	200
Alk (ppm)	12.00	16.00	10.67	100
Cond (µs/cm)	10.38	31.82	12.42	1000
pH	5.85	6.32	5.38	6.5 - 6.8
Hardness (ppm)	21.83	27.83	21.00	100
TDS (ppm)	0.57	1.92	0.80	-
TSS (ppm)	0.22	0.50	0.16	-
TS (ppm)	0.79	2.42	0.96	500
Mn (ppm)	14.55	17.55	14.00	30
Ca (ppm)	7.25	8.77	7.00	75
Zn (ppm)	0.09	0.10	0.18	5.0
Cu (ppm)	0.23	0.27	2.25	1.0*
K (ppm)	0.24	0.63	0.63	10.00
Cd (ppm)	0.09	0.07	0.23	0.003*
Fe (ppm)	3.63	1.38	1.66	0.30*
Total aerobic counts	2.35	2.67	3.56	-
Coliforms (cfu/ml)	0.33	2.33	1.33	0.00*

* = Above set limits.

within the acceptable limit of 10.00 µs/cm set by the World Health Organisation and Nigeria for drinking water.

range of 500 ppm. Storey and Ashbolt (2003b) reported that solids can either be suspended or dissolved solids and together are referred to as total solids. Solids in water samples can vary significantly with season and rainfall. Events and abnormal changes in the amount and type of solids, whether total or dissolved can provide information on the pollution level of the water. Solids can also affect the taste and appearance of the drinking water.

The showed that the mean values of total solids present in the water samples were within the acceptable

The mean values of zinc concentration, which ranged from 0.09 to 0.18 ppm, were within the set limit of 5 ppm. While the copper concentration of the samples from locations A (0.23 ppm) and B (0.27ppm) were within set limits, water samples from Location C (2.25 ppm) was above the acceptable limit of 1.0 ppm.

The mean values of value for potassium concentration, which ranged from 0.24 to 0.63 ppm, were within the acceptable standard of 1.0 ppm. However, the mean

values of values for cadmium (0.09 – 0.23 ppm) and iron (1.38 – 3.63 ppm) were above the set limits of 0.003 and 0.30 ppm, respectively. Florea and Busselberg (2006) and Hung and Hsu (2004) reported that some trace elements are potentially toxic. Zinc and copper are essential elements for the maintenance of the body's metabolic activities but copper contaminated water could pose health hazards such as abdominal pains, nausea, vomiting, diarrhoea, headache and dizziness as reported by Chinwe et al. (2010). Copper poisoning principally influences formation of liver cirrhosis known as non-India childhood cirrhosis (WHO, 2003). Jerup (2003) reported that some trace elements are potentially toxic because they act on the cell membrane or interfere with the cytoplasmic or nuclear functions when they enter into the cell, hence their entry into the human body could result in malfunctioning of the body systems. Therefore copper, zinc, cadmium and other trace metals have adverse effects in humans if present in water samples in very high concentration. Cadmium, for instance, derives its toxicological properties from its similarity with zinc, an essential micronutrient in humans. Cadmium is bio-persistent and once absorbed by humans, remains resident for many years, although it is eventually excreted.

The mean values of total aerobic counts (2.35 – 3.56Log_{10}cfu/ml) of the water samples were high. According to the World Health Organization (2003) report, a high aerobic count does not itself present a risk to human water supply system. A particular feature of the *Pseudomonas aeruginosa* is its ability to grow in low nutrient water. Warburton (1992) reported that the *Pseudomonas* strains present in water usually do not have the same genetic pattern as those in clinical cases during gastrointestinal infections. Though, Allen et al. (2000) reported that water for human consumption is required to be free from any bacteria that may pose a health risk, the presence of *Pseudomonas* in these water samples may not pose adverse health hazard due to their genetic constitution.

The presence of biofilms in the drinking water distribution system may play a role in the presence of potential pathogens in drinking water pipes. This contamination can occur due to defective joints, back siphonage, rusted pipelines crossing over the sewage pipes and low/high pressure in the pipelines. For water to be wholesome, it should not present a risk of infection or contain unacceptable contamination of chemicals hazardous to health and should be aesthetically be acceptable to consumers.

The mean values of coliform counts (0.33 - 2.33log_{10}cfu/ml) were higher than the set standard of 0.0. This could have been due to mixing-up of water and sewage where the water pipes are broken. Being indicator organisms of faecal contamination and the causal organisms of many water-borne diseases, it is therefore pertinent to treat the water with physical and/or chemical methods prior to use for domestic uses. The university community draws her drinking water from these locations and this could lead to outbreak of water-borne infections if treatment options are not employed.

The Pearson moment correlation coefficients presented in Table 3 revealed strong correlations between the tested parameters. CO_2 was strongly correlated to Zn, Co, K, Cd and TAC; Cl was strongly correlated to alkalinity, conductivity, pH, Mn, Co, hardness, TDS, TSS and TS; Alkalinity was strongly correlated to pH, Mn, Ca, hardness, TDS, TSS, TS, Cl and coliform counts; conductivity was strongly correlated to Cl, alkalinity, Mn, Ca, hardness, TDS, TSS, TS and K; pH was strongly correlated to Cl, alkalinity, conductivity, Mn, Co, hardness, TDS, TSS and TS; Mn was strongly correlated to Cl, alkalinity, conductivity, pH, hardness, TDS, TSS, TS and coliform counts; Ca was strongly correlated to Cl, alkalinity, conductivity, pH, Mn, TDS, TSS. TS and coliform counts; Hardness was strongly correlated to Cl, alkalinity, conductivity, pH, Mn, Ca, TDS, TSS, TS and coliform counts; TDS, TSS and TS were strongly correlated to Cl, alkalinity, conductivity, pH, Mn, Ca, hardness and coliform counts; TDS was strongly correlated to TSS and TS; Zn was strongly correlated to CO_2, K and total aerobic counts; Cu was strongly correlated to CO_2, K, Cd and total aerobic counts; K was strongly correlated to CO_2, conductivity, TDS, TS, Zn, Cu, total aerobic counts and coliform counts; Cd was strongly correlated to CO_2, Cu and total aerobic counts; Fe was not correlated to all parameters; TAC was strongly correlated to CO_2, Zn, Cu, K and Cd while CC was strongly correlated to alkalinity, Mn, Ca, hardness, TDS, TSS and TS and K.

Student t-test at 95% confidence level revealed that there was a statistically significant difference between the values in the locations. The parameters increased with distance away from the water source (borehole).

Conclusion

The need for suitable water for human consumption can never be overemphasized. The water parameters were found to vary with distance away from the water source. There is need to maintain water quality during transport either by chemical and/or physical treatments to avert water related diseases which are harmful to the health of man.

Conflict of Interests

The author(s) have not declared any conflict of interests.

Table 3. Pearson moment correlation coefficient for the tested parameters.

Parameter	CO_2	Cl (ppm)	Alk (ppm)	Cond (µs/cm)	pH	Mn (ppm)	Ca (ppm)	Hardness (ppm)	TDS (ppm)
CO_2	1								
Cl (ppm)	-0.83802	1							
Alk (ppm)	-0.58349	0.932098	1						
Cond (µs/cm)	-0.29041	0.765485	0.94657	1					
pH	-0.78615	0.996033	0.96063	0.819704	1				
Mn (ppm)	-0.50154	0.89235	0.995237	0.9735	0.928971	1			
Ca (ppm)	-0.48976	0.886146	0.993823	0.976512	0.923865	0.999908	1		
Hardness (ppm)	-0.47286	0.877048	0.9915	0.980484	0.916316	0.999461	0.999814	1	
TDS (ppm)	-0.21925	0.716095	0.920292	0.997292	0.775364	0.954047	0.958023	0.963372	1
TSS (ppm)	-0.52015	0.90191	0.997114	0.968322	0.936766	0.999766	0.99938	0.998516	0.947337
TS (ppm)	-0.28207	0.759858	0.943728	0.999962	0.81469	0.971473	0.9746	0.978736	0.997895
Zn (ppm)	0.999155	-0.85974	-0.61637	-0.32949	-0.81088	-0.53667	-0.52518	-0.50868	-0.25916
Cu (ppm)	0.992157	-0.89965	-0.68043	-0.40774	-0.85724	-0.60575	-0.5949	-0.5793	-0.33949
K (ppm)	0.618038	-0.08898	0.27783	0.572787	5.25E-16	0.370151	0.382718	0.400456	0.631515
Cd (ppm)	0.967003	-0.94938	-0.77114	-0.52461	-0.91766	-0.7054	-0.69572	-0.68174	-0.46058
Fe (ppm)	-0.52424	-0.02532	-0.38569	-0.66263	-0.11417	-0.47379	-0.48569	-0.50245	-0.71591
Total aerobic counts	0.993349	-0.76962	-0.48609	-0.17829	-0.70976	-0.39859	-0.38611	-0.36826	-0.10545
Coliforms (cfu/ml)	0.142162	0.420956	0.720923	0.9059	0.5	0.785046	0.793376	0.804963	0.93459

Table 3. contd.

Parameter	TSS (ppm)	TS (ppm)	Zn (ppm)	Cu (ppm)	K (ppm)	Cd (ppm)	Fe (ppm)	Total aerobic counts	Coliforms (cfu/ml)
TSS (ppm)	1	1							
TS (ppm)	0.966112	0.966112	1						
Zn (ppm)	-0.55481	-0.55481	-0.32126	1					
Cu (ppm)	-0.62283	-0.62283	-0.39978	0.996456	1				
K (ppm)	0.349957	0.349957	0.579897	0.585206	0.514923	1			
Cd (ppm)	-0.72058	-0.72058	-0.51718	0.976656	0.991264	0.39736	1		
Fe (ppm)	-0.45462	-0.45462	-0.66912	-0.4888	-0.41368	-0.99346	-0.28999	1	
Total aerobic counts	-0.41835	-0.41835	-0.16972	0.987777	0.971165	0.704449	0.931235	-0.61881	1
Coliforms (cfu/ml)	0.771454	0.771454	0.909551	0.101361	0.017318	0.866025	-0.11471	-0.91745	0.255193

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