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Physicochemical and microbial analysis of portable water sources in Enugu metropolis

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Water borne diseases and heavy metal poisoning as a result of poor quality of portable water has been of a major public health concern in Nigeria. The quality of portable water in Enugu, a fast growing and population expanding city calls for a general concern. Hence, this study was aimed to ascertain the quality of portable water sources in Enugu metropolis. A total of twelve water samples were randomly collected and analysed for the physicochemical parameters, heavy metals and faecal contaminants. The samples were odourless without colour but a few showed high levels of calcium and magnesium hardness. The total hardness was within the WHO and Nigerian Industrial Standard (NIS) permissible level. The pH was low (2.0 to 6.3) and not within the WHO permissible level (6.5 to 8.5) but the acidity which ranged from 0.1 to 0.6 mg/L was within the acceptable range. Copper, lead and cadmium were present in a few samples but the level was beyond the tolerated limits of NIS and WHO for one sample contaminated with lead (0.29 mg/L) and two samples with cadmium (0.351 and 0.004 mg/L). Lactose fermenter was present in one sample and was confirmed to be a coliform (Gram negative bacilli). In all, portable water in Enugu is relatively safe and fit for consumption as the level of heavy metal and microbial contamination was low. However, there is need for regular quality control monitoring of portable water to minimize the risk of related health consequences due to heavy metal and microbial contamination. This will partly contribute towards the attainment of the Millennium Development Goal objective of making available quality portable water to the society.

Key words: Portable water, physiochemical, heavy metal, Enugu, coliform, contamination.

INTRODUCTION

Water serves as a major constituent of the human body for physiological and chemical processes and thus essential for health and life. Its availability and consumption is very vital for mans survival and sustainability (Sobsey, 2002). This is guaranteed if the quality of the water is good and safe for consumption. Good quality water or otherwise known as portable water is that which is odourless, colourless, practically tasteless and free from physical, chemical and biological contaminants and safe for consumption (Meybeck et al., 1996). Water also serve humans for various industrial processes in the production of beverages and are important for domestic activities such as cleaning, washing, bathing cooking, etc.

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Table 1. Samples collected and code.

Sample	Code
Overhead reservoir water tank from GOU	OR1
Sachet water 1 (Name Withheld)	SW1
St. Stephen reservoir water tank collected GOU	OR2
Sachet water 2 (Name Withheld)	SW2
Empty water tank from Ninth mile	EW
Bore-hole 1 from Ninth mile	BH1
Bore-hole 2 from Ninth mile	BH2
Bore-hole 3 from Ninth mile	BH3
Bore-hole 4 from Ninth mille	BH4
Loaded Water tank from Ninth mile	LW
Bore-hole 5 from Ninth mile	BH5
Bore-hole 6 from Ninth mile	BH6

The non-availability of potable water constitutes a major public health dilemma as the world is constantly challenged with waterborne diseases (Hunter, 1997). According to the World Health Organisation (WHO), more than one billion people worldwide do not have access to safe drinking water (WHO, 2000). It has also been estimated by WHO that more than two million deaths due to waterborne diseases occur annually and there are more than four billion cases of diarrhea recorded annually. In African, it is estimated that every child has five episodes of diarrhea per year and that 800,000 children die each year from diarrhoea and dehydration (WHO, 2000). These waterborne diseases such as typhoid fever, cholera, infectious hepatitis, dysenteries, diarrhoea and many varieties of gastro-intestinal diseases are mostly due to microbial contaminations in water particularly bacteria (Adeyinka et al., 2014; Raji and Ibrahim, 2011). Several studies in Nigeria have shown the presence of microbial contaminant in water (Aminu and Amadi, 2014; Anake et al., 2013; Bisi-Johnson et al., 2013; Ndamitso et al., 2013; Eze and Madumere, 2012; Odeyemi and Agunbiade, 2012; Adekoyeni and Salako, 2012; Odeyemi et al., 2011, Nyanganji et al., 2011).

Apart from waterborne diseases, heavy metal contamination in water has also been responsible for mortality and morbidity in human due to intoxication and constitutes a major public health problem (Ibrahim et al., 2006; Cabrera et al., 2005). The most important heavy metals of public health concern due to intoxication include lead, mercury, cadmium, chromium, arsenic, etc (Galadima and Garba, 2012; Ibrahim et al., 2006; Godt et al., 2006; Duffus, 2002). Although some of the heavy metals such as zinc, manganese, nickel, aluminium and copper act as micro-nutrients at lower concentrations, they can become toxic at higher concentrations (Singh et al., 2010). Health risk due to heavy metal contamination of water through soil has been reported (Eriyanremu et al., 2005).

As a result, the WHO, Food and Agricultural Organisation (FAO), United States Environmental Protection Agency (USEPA), as well as the Nigerian Industrial Standard for drinking water have set up standard for heavy metal contamination to ensure the quality and safety of potable water (USEPA, 2011; WHO, 2011; Nigerian Industrial Standard [NIS], 2007; FAO, 1997). These standards are based on the physical, chemical and microbiological constituents in water and defined with tolerable limits.

Enugu is a fast growing and population expanding city in Nigeria whose demands for portable water is becoming critical for water purification industries to meet up with supply. This high demand for portable water may warrant rapid supply and hence, jeopardize the quality. One of the major sources of portable water in this city is the use of bore-holes whereby the water is usually carried by commercial tankers and supplied into individual owned overhead tanks within the metropolis. Also, portable water is available in sachets locally called “pure water” from various industries; majority of which are located at Ninth mille, a locality within the Enugu metropolis where most natural sources of water are found. Enugu, especially Ninth mille is noted as a good source of portable water but little or no study has been carried out to ascertain this belief.

As part of the program to ensure the quality and availability of portable water, the United Nation in its Millennium Development Goal (MDG) has as target to reduce by half the proportion of people without sustainable access to safe drinking water by 2015 (MDG, 2011). Hence, this study, with the aim to assess the physical, chemical and microbiological content of water in Enugu metropolis is targeted towards the attainment of the MDG objective to ensure the quality and safety of portable water for human consumption.

MATERIALS AND METHODS

Sample collection

A total of 12 samples of water were randomly collected within and around Enugu metropolis. Among these samples, 6 were obtained from bore-holes, 2 from water loaded tanker vehicles, 2 from overhead reservoir tanks and 2 sachet water from different producers (Table 1). These water samples were collected in sterile containers under aseptic conditions and transported to the Chemistry Laboratory of Godfrey Okoye University (GOU) for analysis.

Physicochemical analysis

Water samples were analyzed in accordance to the standard methods of the American Society for Testing and Materials (ASTM), American Public Health Association (APHA) and FAO procedures (APHA, 1998; FAO, 1997; ASTM, 1982). Physical parameters were analyzed according to the methods of APHA (1998). The odour of the water was assessed by nasal inhalation (sensory evaluation) method and the colour was determined by spectrophotometric method using distilled water as blank. The chemical parameters, acidity, water hardness were evaluated in accordance to the ASTM and AOAC method (AOAC, 2005; ASTM, 1982). The pH of the water was determined using a microprocessor pH meter while the

Table 2. Physicochemical parameters.

Sample ID	Colour (HU)	Odor	pH	Acidity (mg/L)	Total hardness (mg/L)	Calcium hardness (mg/L)	Magnesium hardness (mg/L)
OR1	0.005	-	5.8	0.6	176	34	142
SW1	0.003	-	2.2	0.4	72	80	-8
OR2	0.014	-	2.3	0.2	56	44	12
SW2	0.005	-	6.3	0.4	152	32	120
EW	0.002	-	4.5	0.2	60	10	50
BH1	0.001	-	2.1	0.6	72	30	42
BH2	0.001	-	4.3	0.4	60	38	22
BH3	0.003	-	2.0	0.6	58	10	46
BH4	0.003	-	4.2	0.1	72	50	22
LW	0.003	-	3.5	0.2	50	24	26
BH5	0.001	-	4.8	0.2	52	22	30
BH6	0.002	-	5.0	0.4	46	4	42
WHO/NIS STD	5-15	-	6.5-8.5	4.5-8.2	500	75.0	50

acidity was by titration with NAOH using phenolphthalein as indicator. Analyses of total hardness and calcium hardness in water made use of NH_4Cl and NAOH as buffers, respectively and were titrated with EDTA using Erichrome Black T-indicator. Magnesium hardness was determined by subtracting calcium hardness from total hardness.

Heavy metals analysis

Heavy metal analysis was conducted using varian AA240 atomic absorption spectrophotometer (AAS) according to the method of APHA (1998). In this method, 100 ml of the sample was thoroughly mixed by shaking in a beaker and 5 ml of concentrated nitric acid was added. The mixture was heated to evaporation until the volume was reduced to about 20 ml and concentrated nitric acid was further added till the point of complete dissolution of all the residues. This mixture was cooled and completed to a volume of 100 ml with metal free distilled water. The sample was aspired into the oxidizing air-acetylene flame of the AAS and the sensitivity for 1% absorption was observed. The wavelength (nm) for absorption was 372.0, 324.8, 228.8, 309.3, 283.3, and 193.7 for iron, cupper, cadmium, aluminium, lead, and arsenic, respectively.

Microbial analysis

The determination of coliform in water was done via two stages: firstly, the presumptive test followed by the confirmative test according to the method of APHA (1998).

In the presumptive test, 1 ml of sample and lactose was added in a culture bottle containing 10 ml of MacConkey agar broth. A Durham tube for gas collection was inverted in the culture bottle and incubated at 37°C for 48 h (Test 1). This procedure was repeated twice using 10 ml of the sample for 10 ml of the sterile broth (Test 2) and 50 ml of the sample for 50 ml of the sterile broth (Test 3). Gas formed in the inverted Durham tube was evidenced of the presence of fecal contaminants. Also, in the presence of a lactose fermenter, the colour of the media changes from violet to yellow.

In the confirmatory test, a positive sample for the presumptive test was further inoculated unto an agar medium containing Eosin blue in a Petridish and incubated at 37°C for 48 h. After incubation, the culture was examined for any metallic green coloration formed in the colonies which were gram stained and viewed under the microscope. If microorganism retained the colour of the secondary dye, coli formed bacteria (Gram negative bacilli) were confirmed to be present.

RESULTS AND DISCUSSION

Physicochemical properties of water such as odour, taste, colour and hardness are usually evaluated in water not because of their health related consequences but for the organoleptic and aesthetic qualities. Other properties such as pH and acidity are indicators of how acidic or basic water is. The results of physicochemical properties of the samples are as shown in Table 2. The samples were odourless and the colour was below the acceptable limit of the WHO, hence characteristic of good quality water.

Extreme pH in water is not usually healthy for consumption especially when the acidity is high. Low pH in water tends to be corrosive to some certain metals, asbestos, pipelines, etc., even more corrosive, while that of a high pH form scale (UNICEF, 2008). According to WHO, health effects are most pronounced in pH extremes. Drinking water with an elevated pH above 11 can cause skin, eye and mucous membrane irritation. On the opposite end of the scale, pH values below 4 also cause irritation due to the corrosive effects of low pH levels. WHO warns that extreme pH levels can worsen existing skin conditions (WHO, 2009). WHO standard pH for portable water lies between 6.5 and 7.5 as well as NIS and USEPA. Results from the study showed the pH of the samples to be low (acidic) ranging from 2.0 to 6.3 and are not within the NIS and WHO acceptable limit (Table 2). However, the acidity (acid concentration) was low ranging from 0.1 to 0.6 mg/L and was below the tolerated limits of WHO (Table 2). This suggests that though portable

Table 3. Heavy metals concentration.

Sample ID	Arsenic (mg/L)	Lead (mg/L)	Cadmium (mg/L)	Iron (mg/L)	Copper (mg/L)	Aluminum (mg/L)
OR1	ND	0.29	ND	ND	0.006	ND
SW1	ND	ND	ND	ND	ND	ND
OR2	ND	0.01	ND	ND	ND	ND
SW2	ND	ND	ND	ND	ND	ND
EW	ND	ND	0.351	ND	ND	ND
BH1	ND	ND	ND	ND	ND	ND
BH2	ND	ND	0.004	ND	ND	ND
BH3	ND	ND	ND	ND	ND	ND
BH4	ND	ND	ND	ND	ND	ND
LW	ND	0.03	ND	ND	ND	ND
BH5	ND	ND	ND	ND	ND	ND
BH6	ND	ND	ND	ND	ND	ND
WHO/NIS STD	0.01	0.05	0.003	0.3	1.0	0.2

water in Enugu metropolis is acidic in nature, it is not of a major health concern because the acid concentration (acidity) is low. However, minimum level of treatment is required to increase the pH to a fairly neutral and acceptable range.

Water hardness is a property that is defined by the quantity of calcium and magnesium found in water. Though calcium and magnesium are important minerals of the body, evaluating water hardness is usually not considered for health benefits because these minerals can be obtained from other dietary sources. Rather, hardness of water is usually a property evaluated to qualify water for domestic use. Hard water does not usually lather enough which makes it unsuitable for domestic purposes. From the result of the study as shown in Table 2, calcium hardness was low and within the tolerated limits of WHO (75 mg/L) except sample SW1 (80 mg/L). Magnesium hardness was also low in most of the sample and within the WHO and NIS limit of 50 mg/L, but except for samples SW2 and OR1 with values of 120 and 142 mg/L, respectively. However, the total hardness (the sum of calcium and magnesium hardness) of the samples were less than 500 mg/L and within the permissible limit of WHO suggesting that portable water in Enugu is fit for domestic use.

Heavy metal refers to any metallic chemical element that has a relatively high density and is toxic or poisonous at low concentrations (Danyal et al., 2006). Heavy metals are dangerous because they tend to bio-accumulate in living organism over time without been eliminated (Life Extension, 2003; Wallace, 2001). Heavy metal toxicity can result to damaged or reduced mental and central nervous function, lower energy levels, blood composition and damage of the lungs, kidneys, liver, and other vital organs (Godt et al., 2006; Sharma and Agrawal, 2005; Shaw et al., 2004; Lidsky and Schneider, 2003; Lockitch, 1993). Long-term exposure may result in slowly progressing physical, muscular, and neurological degenerative processes that mimic Alzheimer's disease, Parkinson's disease, muscular dystrophy, and multiple sclerosis (Ibrahim et al., 2006; Sharma and Agrawal, 2005). Allergies are not uncommon and repeated long-term contact with some metals or their compounds may even cause cancer (Rubio et al., 2006). In this study, arsenic, iron and aluminium were not detectable in all the samples but lead, cadmium and copper were detectable in a few. Previous studies in Nigeria have shown some of these heavy metals to be present in water (Aminu and Amadi, 2014; Eze and Madumere, 2012; Odeyemi et al., 2011; Adekoyeni and Salako, 2012). Lead was detectable in 3 samples but only sample OR1 (0.29 mg/L) was found to be above the WHO tolerated limit of 0.05 mg/L. Also, cadmium was detected in two samples and was far above the WHO limit in sample EW (0.36 mg/L). Though, copper was present in one sample (OR1), the concentration (0.006 mg/L) was far less than the WHO tolerated limit (1 mg/L). These results suggest possibilities of heavy metal contamination in water but at a very low risk of causing intoxication in humans (Table 3).

Coliforms are the most frequent bacteria in water responsible for waterborne diseases such as diarrhoea, typhoid, dysentery, etc., and have also been responsible for mortality across the world especially in Africa (Adeyinka et al., 2014; Raji and Ibrahim, 2011; WHO, 2000). Microbial analysis showed the presence of lactose fermenter in sample BH2 in test 1 and 2 for the presumptive test (Table 4). Also lactose fermenter was shown to be highly populated when the sample concentration was increased 10 fold to 10 ml in test 2 (Table 4). The confirmatory test confirmed the presence of coliform as Gram negative bacilli when observed under the microscope. This result is a confirmation of other studies in Nigeria which also showed the presence of coliforms particularly *Escherichia coli* in most portable water sources

Table 4. Presumptive test for microbial analysis.

Sample ID	Gas formed		
	Test 1	Test 2	Test 3
OR1	-	-	-
SW1	-	-	-
OR2	-	-	-
SW2	-	-	-
EW	-	-	-
BH1	-	-	-
BH2	++	+	-
BH3	-	-	-
BH4	-	-	-
LW	-	-	-
BH5	-	-	-
BH6	-	-	-

(Aminu and Amadi, 2014; Anake et al., 2013; Ndamitso et al., 2013; Odeyemi and Agunbiade, 2012).

Conclusion

Contamination of water due to heavy metals and microorganism is becoming a major public health challenge in Nigeria. This study reveals that portable water in Enugu is relatively safe and fit for consumption as the level of heavy metal and microbial contamination is relatively low as compared to WHO and NIS standards. However, there is need for regular monitoring to control the quality of water in Enugu and Nigeria as a whole to minimize possible contamination and the risk of water borne diseases. This measure will partly help towards the attainment of the MDG objective by ensuring the quality and safety of portable water to the masses.

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Conflict of interest statement

There is no conflict of interest to declare.

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