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Sachet Water Quality in Obuasi, Ashanti Region, Ghana.

Benjamin Spears Ngmekpele, Cheabu[*1] James Hawkins, Ephraim[1]
[1]Faculty of Public Health & Allied Sciences, Catholic University College of Ghana, P.O.Box 363, Fiapre – Sunyani. Ghana.
*Email of the corresponding author: bscheabu@gmail.com

Abstract
The advent of sachet water has increasingly filled the gap in household water security. This study investigated the quality (microbial and physicochemical) of sachet water in Obuasi in the Ashanti Region. A simple random sampling technique was employed in this study. A total of 30 samples from 10 brands were collected from vendors and hawkers for microbial analysis using the multiple tube method and results recorded as Most Probable Number (MPN) of coliform per 100ml of water. Mean MPN values ranged from 8.5-45 cfu/100mL for total coliforms. Based on the WHO and GSB standards for drinking water, all samples had elevated total coliform bacteria level. Only one sample (G) recorded faecal coliforms. Heterotrophic bacteria was also elevated in all samples ranging from $1.1 \times 10^4 – 6.5 \times 10^4$ cfu/100ml .Using the ion chromatograph method, bromide and phosphate were not detectable in any brands. Fluoride values ranged from 0.154 – 0.427mg/L, chloride ranged from 3.995 – 10.243mg/L, nitrite values ranged from 0 – 2.278mg/L, sulphate values ranged from 0.1229 – 1.214 mg/L and nitrate values ranged from 1.031 – 21.827 mg/L. Fluoride, chloride, sulphate and nitrite concentrations were within the permissible range in all samples except for nitrate which recorded an elevation in only one sample (H). Total dissolved solids and conductivity values were within the WHO permissible range. However, pH values ranged from 5.4 – 7.6 with four brands were below the WHO range of 6.5 – 8.5. It is, therefore, recommended that periodic tests are conducted on sachet water products and caution given to consumers about brands which are unwholesome.
Key Words: Multiple tube method, Quality, Sachet drinking water

1.0 Introduction

Water in its purest form is odorless, colorless and tasteless, however, human and animal activities continue to challenge the wholesomeness of drinking water. In Ghana, water services provided by the Ghana Water Company Limited (GWCL) 40% of the total urban population is directly covered by the GWCL's networks. The wholesomeness of the water from sources other than the GWCL cannot be ascertained hence the water is mostly used for other household activities rather than for direct consumption.

In cities, towns and villages across the country where electricity is available, water is packed and sold in hand tied transparent polythene bags and machine - sealed 500ml sachet bags. The latter is commonly referred to as "pure water". This phenomenon of pure water has evolved over the years. It seeks to provide a "safe" and instant drinking water to the thirsty public. This can be attributed in part, to an increase in population which does not commensurate the provision of safe drinking water especially in developing countries such as Ghana. There exists however, a difference between "pure water" and "safe drinking water". Pure water does not contain any minerals and chemicals and does not exist naturally (Environmental Protection Agency, 1999). Safe drinking water however, may contain naturally occurring minerals and chemicals such as calcium, potassium, sodium or fluoride which are actually beneficial to human health (United Nation Environmental Programme, 2008). The motive then, is to provide safe drinking water. Coliforms are the principal indicators of suitability of water for domestic, industrial and other uses. Coliform group density is a criterion of the degree of pollution and sanitary quality. Coliforms are rod-shapes Gram negative organisms which ferment lactose with the production of acid and gas when incubated at 37 °C. Faecal coliforms are a smaller group in the total coliform family that inhibit the intestines of mammals and have a relatively short lifespan. It is an indication of sewage contamination (Edberg, Rice, Karlin & Allen, 2000)

Sachet water is viewed as the latest, low-cost technological incarnation of vended water in developing cities and has allowed a steady evolvement of vended water. It is now prevalent in countries contiguous to Nigeria and Ghana, for example Cote d'Ivoire, Burkina Faso, Togo, Benin, Niger and Cameroon (Stoler 2012). Given the renewed global commitments towards the MDGs in 2015, the contribution of sachet drinking water cannot be overemphasized. There is, however, significant varying levels of contamination of the sachet drinking water which had aimed to provide a low cost and safe alternative source of drinking water.

2.0 Literature Review

Anecdotal reports have it that if the right standards and guidelines are strictly adhered to the Millennium Development Goals (MDG) and targets in regard to sanitation and water could be far reached. The

unwholesomeness of water has inherent consequences and several parameters correlate with the unwholesomeness of drinking water. Some include the presence of feacal coliforms, total coliforms, heavy metals, elevated chemical measures, etc. (Abiola, 2010; Addo *et al.* 2009; Ifeanyi *et al.* 2006; Okafor and Ogbonna, 2003; Okeri *et al*. 2009). It is however important to note that not all studies have found sachet water quality questionable. (Egwari *et al.* 2005; Olowe *et al*.2009). Moreover, compromised sachet water quality can also be attributed to its storage and transportation (Clasen and Cairncross, 2004, Gundry *et al*. 2006, Wright *et al.* 2004).

In the Greater Accra Region, the quality of "ice-water" sold in the streets was analyzed by the Stockholm Environment Institute in 1993. Here, tests were conducted to obtain the numbers of total coliform, feacal coliform and feacal streptococci. 78% of total coliforms were found in the range of 11-100 CFU/100ml, and feacal streptococci, 33% in the range of 11-100 CFU/100ml and 67% in the range of 101-1000 CFU/100ml, were found confirming the presence of feacal contamination.

Obiri – Danso *et al*. (2003) analyzed the quality of bottled water, factory produced and hand tied sachet water sold in the streets of Kumasi in the Ashanti region using the membrane filtration method. The water samples considered included eight samples of bottled water, 88 factory produced sachet water samples and 40 hand tied sachet water samples. While results showed no presence of coliforms in bottled water (0 CFU/ 100ml), 45% of the factory – produced sachet water samples showed total coliforms. (Counts ranged from 10 CFU/100ml to 13 CFU /100ml for positive results) and 2.3 % had feacal coliforms (2 samples both 10 CFU /100ml). Similarly, Dodoo *et al.* (2006) involved testing the quality of a total of 29 brands of factory produced sachet water in the Cape Coast municipality of Ghana and using 180 random samples exposed to different environmental conditions; the sun (40^0C); room(28^0C), and in the laboratory ($28\ ^0$C). The water quality test was carried out using the membrane filtration method with lauryl broth or agar medium, and or by the multiple tube fermentation method. Results indicated that 45 % of the brands of sachet water contained total coliform bacteria in at least one test. The total coliform counts ranged from 0 colony units (CFU)/ 100ml to 98 million CFU/100ml.

With current trends suggesting that sachet drinking water could be a route of transmission of enteric pathogens; Kwakye – Nuako *et al.* (2007) conducted a study in Accra were 27 different brands of 500 ml sachet water samples were subjected to microscopic examination to determine the presence of parasitic protozoa. The results indicated that 77% of the samples contained infective stages of pathogenic parasitic organisms. 93% of the samples contained unidentified impurities. 29.6 % of the samples contained at least one of parasite; 14.8 % contained at least two types of parasites; while 29.6 % contained four types of parasites. This indicates clearly the presence of contaminants of feacal and zoonotic origin.

Addo *et al.* (2009) sought to determine the bacteriological quality of sachet water produced and sold in the Teshie – Nungua suburbs of Accra, an area noted for its perennial shortage of water. Using the random sampling procedure, 30 samples from 10 different brands of sachet water were collected from hawkers and vendors in Teshie – Nungua. One sachet sample was taken from each site every forth night for six weeks in May – June 2007. Using the multiple tube method, the bacteriological quality of the samples was assessed based on the World Health Organization (WHO) classification system for drinking water. The results showed that five (16.7%) of the samples were excellent, five (16.7%) were satisfactory, 9 (30%) were suspicious and 11(36.7%) were unsatisfactory using the Most Probable Number (MPN) values recorded. Six samples were contaminated with feacal coliform and Escherichia coli were also detected in two samples.

A five- year study by Ampofo *et al*. (2007) saw one hundred and seventy – nine brands of sachet water and seventeen brands of bottled water analyzed for the presence of bacterial pathogens. Seventy – two brands of the sachet water were found to contain total coliform bacteria ranging between 1 and 1800 colony forming units (CFU) per 100 ml. 15 brands had both total and feacal coliform bacteria ranging from 2 to 62 cfu per 100ml. Twenty brands of the sachet water were found consistently contaminated with coliform bacteria were further analyzed for the presence of specific pathogens. Six recorded the presence of *Salmonella sp.* with values between 1 and 6 cfu, seven recorded the presence of *Closrtidium sp.* with values between 1and 7 cfu per cfu and 15 brands recorded the presence of *Bacillus sp.* with values between 1 and 72 cfu per ml.

The review of literature above testifies to the fact that almost all studies reported a compromise of water quality in one way or the other; physicochemically, bacteriologically and virologically among others. Ranging from microbial and physio - chemical elevation to the lax compliance of labeling requirements sachet water is compromised. It is however worthy of note that not all studies have found sachet water to be unwholesome (Egwari *et al.* 2005; Olowe *et al*. 2009).

3.0 MATERIALS AND METHODS

3.1 Study Area

The Obuasi Municipality lies in the southern part of the Ashanti Region of Ghana between latitudes 5º 35'N and 5º 65'N, and longitudes 6º 35'W and 6º 90'W. It is the second largest political authority in the region after Kumasi Metropolitan Assembly (K.M.A.) and covers a land area of about 162.4 square kilometers. It is bounded on the south by Upper Denkyira District of the Central Region, east by Adansi South, west by Amansie Central, and north by Adansi North. The municipal capital, Obuasi, is about 64km drive from Kumasi, the regional capital. At the moment, there are 52 communities in the municipality with 30 Electoral Areas, and 1 urban council. (Obuasi Municipal Assembly Medium Term Development Plan, 2006).

Generally, the Obuasi municipality has an undulating terrain with more of the hills rising above 500 meters above sea level. The municipality is drained by streams and rivers which include; the Pompo, the Kwabrafo, the Akapori, the Wheaseammo and the Kunka. All these water bodies are almost polluted by mining and other human activities. The Ghana Water and Sewage Corporation provides treated pipe water for the municipality. Estates owned by the AngloGold Ashanti are supplied treated water by the AngloGold Water Works Department. Areas in Obuasi who are not covered by any of the aforementioned treated water providers rely on wells, boreholes and streams.

3.2 Sample Collection

A total of (30) sachet water samples from ten brands of packaged drinking water samples labeled from A – J were collected from vendors and hawkers of sachet water at various markets and lorry stations in Obuasi in the Ashanti Region. These were taken to the laboratory for analysis.

3.3 Media used:

Media for both the multiple tube fermentation and plate counts were prepared according to the manufacturer's instructions. The media used were Mac Conkey broths, Brilliant Green Lactose Bile (BGLB) broth, Eosin Methylene Blue (EMB) agar and Plate Count Agar (PCA).

3.4 Total Coliform and Faecal Coliform

3.4.1 Presumptive test:

Total coliform and faecal coliform were enumerated by multiple tube fermentation tests as described by American Public Health Association, (1998). Coliform count was obtained using the three tube assay of the Most Probable Number (MPN) technique. Presumptive coliform test was carried out using Mac Conkey broth (oxoid). All the tubes contained Mac Conkey broth (oxoid) before sterilization. The three sets of the tubes received 10mL, 1mL and 0.1 mL of water samples using sterile pipettes. The tubes were incubated at 37ºC for 24-48 hours for estimation of total coliforms and at 44.5ºC for faecal coliforms for 24-48 hours and examined for acid and gas production. Acid production was determined by colour change of the broth from reddish purple to yellow and gas production was checked for by entrapment of gas in the Durham tube. The MPN was then determined from the MPN table for the three sets of tubes.

3.4.2 Confirmed test:

Confirmed test was carried out by transferring a loopful of culture from a positive tube from presumptive test into a tube of Brilliant Green Lactose Bile (BGLB) broth (oxoid) with Durham tubes. The tubes were incubated at 37ºC for 24-48 hours for total coliform and 44.5ºC for faecal coliforms and observed for gas production.

3.5 Total heterotrophic bacteria plate counts (HPC)

The total heterotrophic bacteria plate counts (HPC) in the water samples were obtained using the pour plate technique according to Anon (1994), dilutions of 10^{-1} of water samples were prepared in 0.1% buffered peptone water and triplicate 1ml aliquots of each dilution inoculated into 10 mL molten standard plate count agar in universal bottles. After thorough mixing, these were poured into sterile petri dishes and incubated for 48 hours at 35°C. Discrete colonies were counted and the results expressed as the numbers of bacteria colonies per milliliter. The plates were examined for growth after incubation and developed colonies counted using a digital colony counter (Gallenkamp, England).

3.6 Physico-chemical Analysis

Using a Metrohm 861 Advance Compact Ion Chromatograph and a METROSEP A SUPP 5 – 100 Column, samples were analyzed for fluoride, chloride, sulphate, bromide, phosphate, nitrate and nitrite. About 50ml of each sample was analyzed for the anions under the study. The calibrations of the various anions were then used to calculate their concentration in the sachet water samples.

Hydrogen ion concentration (pH), total dissolved solids and conductivity were determined by instrumental methods.

4.0 PRESENTATION AND DISCUSSION OF RESULTS

The Most Probable Number (MPN) for the presumptive total coliform count of the water samples ranged from 8.3 – 45 cfu/100ml. (Table 1). Based on the MPN values, individual sachet water samples were classified as excellent (0-2 MPN/100ml), satisfactory (1-3 MPN/100ml), suspicious (4-10 MPN/100ml and unsatisfactory (> 10 MPN/100ml). No sample fell within the excellent category of less than 2 MPN/100ml, 2 samples (6.6%) were satisfactory, 8 samples (26.7%) were suspicious and 20 samples (66.7%) were considered unsatisfactory in quality. Faecal coliforms were only detectable in only one brand (G) with a mean value of 4.3 cfu/100ml (Table 2).

Table 1. Presumptive test values obtained from water samples using MPN techniques.life

MPN INDEX(Total Coliforms)				
Samples	1	2	3	Mean MPN Value
A	3	7	15	8.3
B	4	11	20	11.7
C	11	14	28	17.8
D	3	15	21	13.0
E	7	7	20	11.3
F	4	14	28	15.3
G	28	28	79	4.5
H	11	11	9	10.3
I	15	23	28	22
J	7	14	7	9.3

Table 2. Brand(s) Contaminated with faecal coliforms.

MPN INDEX (Faecal Coliforms)				
Sample	1	2	3	Mean MPN Value
G	3	7	3	4.3

Total coliforms include bacteria that are found in the soil, in water that has been influenced by surface water, and in human or animal waste. Coliforms are the principal indicators of suitability of water for domestic, industrial and other use. Coliform group density is a criterion of the degree of pollution and sanitary quality**.** The result of this study showed the presence of coliforms in the sachet water samples tested. This is similar to the studies by Addo *et al*., (2009) in the study of bacteriological quality of sachet water produced and sold in Teshie-Nungua suburbs of Accra, Dodoo et al.,(2006) in Cape Coast and Obiri – Danso *et al.,*(2003) all in Ghana. Adekunle *et al*., (2004) in Ibadan, and Ezeugwunne *et al.*, (2009) in Nnewi in Nigeria also showed a compromise in sachet water quality. All of this can be attributed to poor treatment and handling methods in some sachet water producing companies, poor environmental conditions, poor handling by distributors and sellers or insufficient sterilization of the sachets used in packaging the water. Sachet water vending machines may also not be free from microorganisms, hence serving as an avenue for contamination.

Total heterotrophic bacteria plate counts ranged from $1.1 \times 10^4 – 6.5 \times 10^4$ cfu/100ml in all sachet water samples.

Heterotrophic plate count (HPC) is a microbial method that uses colony formation on culture media to approximate the levels of heterotrophic flora. However, HPC do not give an indication of the types of organisms present or their sources thus the results obtained using an HPC test are not an accurate assessment of total heterotrophic concentrations but, instead, are indications of culturable organisms present. Heterotrophic plate count in all sachet water brands were above the WHO standards for drinking water. A plethora of studies has, however, indicated that, heterotrophic bacteria isolated from water has shown to possess very few virulence factors (Lye and Dufour, 1991; Payment, Cofffin & Paquette 1994; Edberg, Kopps, Kontnick & Escarzaga 1997) and are therefore of no human health consequence. In a meeting of experts on HPC in drinking water management, it was also concluded that HPC in drinking water are not a health concern to the general public (WHO, 2002).

The physico-chemical properties of sachet water samples (A- J) indicated a range of 5.4 – 7.6 for pH, total dissolved solids values ranged from 11.0 mg/L – 54.0 mg/L and conductivity values ranged from 19.0 µS/cm to 81.0µS/cm. (Table 3). Bromide and phosphate were not detected in all samples. Fluoride values ranged from 0.154 – 0.427mg/L, chloride ranged from 3.995 – 10.243mg/L, nitrite values ranged from 0 – 2.278mg/L, sulphate values ranged from 0.1229 – 1.214 mg/L and nitrate values ranged from 1.031 – 21.827 mg/L (Table 4).

Table 3. Results for Physical Analysis

Samples	Conductivity µS/cm	Total Dissolved Solids mg/L	pH
A	23.6	16	6.5
B	44.9	30	7.2
C	17.5	11	5.8
D	81.0	54	7.6
E	35.8	24	6.8
F	16.7	11	5.4
G	19	13	5.6
H	56	38	6.3
I	44.8	30	7.1
J	25.1	17	6.9

Table 4. Results for chemical parameters

Samples	Fluoride (F^-)/ppm	Chloride (Cl^-)/ppm	Nitrate (NO_3^-)/ppm	Sulphate (SO^{2-})/ppm	Nitrite (NO_2^-)/ppm
A	0.427	3.995	4.529	1.415	___
B	0.243	9.933	3.237	0.438	2.278
C	0.252	6.014	1.499	0.277	___
D	0.356	6.272	1.690	0.411	___
E	0.274	7.071	7.841	0.207	___
F	0.188	5.168	3.112	___	___
G	0.231	7.745	2.237	0.129	___
H	0.290	9.560	21.827	0.699	___
I	0.154	10.243	2.207	0.499	___
J	0.193	5.651	1.031	0.345	___

The physico - chemical properties of sachet water samples indicated that the pH of six brands (A, B, D, E, I, J) were within the permissible limits. Four brands fell below the WHO standards and are, therefore, not suitable for consumption (WHO, 2004). Total dissolved solids and conductivity values were within WHO range in all sachet water brands. Bromide and phosphate were not detected in any of the water samples analyzed. Fluoride, chloride, sulphate and nitrite values were within the WHO permissible range except for nitrate which recorded an elevation in only one brand (H).

5.0 Conclusion and Recommendation

The study shows that all sachet drinking water do not comply with the WHO and GSB guidelines on safe drinking water in one one or the other, consequently, we can conclude that sampled sachet water products in Obuasi did not fulfill the appropriate standards of quality. Laboratory results showed a compromise in quality especially in the microbial analysis of samples. In the testing for physical parameters all samples recorded values which were within the permissible range for conductivity and total dissolved solids. However, pH concentrations were below the permissible range in four samples.

The chemical parameters – fluoride and chloride were within the required range in all samples. For nitrate concentrations, all samples were within range except for one. Nitrite was not detectable in nine samples but in only one which was within the permissible range. Sulphate concentrations were within the permissible range in all samples. Microbial testing reported a compromise in quality in all parameters tested. All samples had elevated total coliform count. Faecal coliforms were present in only one sample.

Taking into considerable account the results of this study and also considering the breach of regulatory measures we recommended that periodic tests are conducted on sachet water products and caution given to consumers about brands which are unwholesome. This is in the wake that, sachet water has gained an appreciable level of trust among the public. The inspection of sachet water companies to ascertain best housekeeping practices is highly recommended. The public are also advised to be cautious of the many sachet water brands they purchase. Last, it is worthy of note that sachet water companies be supported to adopt the Hazard Analysis Critical Control Point (HACCP) system to help the checking and elimination of the various levels of contamination that may occur in the sachet water production process. Further areas of research are also recommended to investigate the leaching properties of sachets used in water production and the safety of the ink used in labeling sachet products.

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