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Production and vendor practices that compromise the quality of "Sachet" water in the Central Region, Ghana

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Abstract: Over the years, deteriorating quality of pipe borne water has urged most Ghanaians to patronize sachet water as a safer and cheaper source of drinking water. The study investigated production and vendor practices that compromise quality of sachet water in the Central Region of Ghana. Quasi experimental design - Single Group Interrupted Time Series (SGITS) was used. Six sachet water producing companies and 6 vendors who sell products from these companies were purposively selected. Three sachets (500ml) were sampled from each company and vendor totaling 36 sachets. Membrane Filtration (MF) and Multiple Tube Fermentation (MTF) were used to isolate Total *coliform (TC)*, Fecal *coliform (FC)*, *E. coli (EC)* and Total h*eterotrophic* bacteria (TH). Borehole water 'B' had very low pH (5.3). TC was positive (141 cfu/100ml) in one water sample while all 18 water samples were positive for TH when MF was used probably as a result of the use of inefficient filters. Samples taken from vendors' sachet packages were more contaminated than those from companies using both MF and MTF. This indicates that production and vendor practices can further contaminate sachet water as was shown by the lack of good manufacturing practices such as observing personal hygiene among company staff. A more proactive approach that identifies risks and puts in place measures at critical points in sachet water production to promote and enhance overall quality will be important. The introduction of membrane filters as a more sensitive way of detecting these parameters as well as the Presence/Absence test as an inexpensive, reliable and easy test in the analysis of sachet water hopefully will help improve and maintain quality. It is recommended that the Ghana Health Services partner with the metropolis to develop a bacteriological water quality monitoring training program to help train producers of sachet water to meet standards.

Keywords: Sachet Water, Quality, Production and Vendor Practices, Ghana

1. Introduction

Water has been described as an indispensable resource required by all living things including man yet access to sufficient clean and safe amounts remains a key issue even in the light of large freshwater supplies in many regions of the world [1-3]. The United Nations in 2005 estimated that 1.1 billion of the world's population mostly from Africa did not have access to safe drinking water. Four years later, [4] reported that 46% of Africans had access to clean safe drinking water as compared to 8% in Asia. Most people depend on others for obtaining clean and safe drinking water creating variations in the quality of water in relation to location across the world. In 2006, [5] reported that only about 51% (10.3 million) of the Ghanaian population could access clean water supply with the remaining either not having access to clean water or could not afford to pay for it even when they had access to it. This resulted in people resorting to other sources of water which were often unsafe. The supply of clean pipe borne water in Ghana is often inadequate in terms of how many people can easily access it and the quality has been deteriorating over the years. Consumers, suppliers and health authorities have raised concerns about the health implications of the poor microbiological quality of the water. Several developing economies like Ghana have limited standard industrialized model for delivering safe drinking water because they cannot afford expensive technologies [6]. This has resulted in such economies seeking local low cost alternative systems to produce safe drinking water and increase sustainable access in rural and peri-urban settings [8]. Sachet water has been suggested as a low cost, readily available alternative to providing safe water ultimately allowing contributions from local initiatives in the drive towards achieving the water target of the Millennium Development Goals (MDGs) marked for 2015 [9]. However, sachet water production in Ghana faces several challenges which tend to compromise "quality" and thus fails to meet the expectation of providing affordable safe drinking water for most Ghanaians [6, 10-13]. Other studies have identified most Ghanaian sachet water as probable vehicle for the transmission of enteric pathogens [14]. These studies raise huge concerns about contamination of sachet water which is expected to be clean and safe. Irrespective of these concerns, Ghana is still working towards achieving its Millennium Development Goal of providing clean safe water for about 76% of its population. Yet, current figures indicate that the Central Region still falls behind meeting the water needs of its population, especially those living in rural areas even though there has been great improvement in the perennial water shortage which was persistent in the region, especially in the Cape Coast Metropolis over the last few years [15]. Majority of people in the region therefore rely on sachet water because of the convenience that it provides and the knowledge that tap water is not always safe to drink.

The lack of appropriate water and sanitation infrastructure in the developing world limits economic growth especially in poor rural regions. Apart from limiting economic growth, poor access to safe water contributes to disease and malnutrition [16]. As a result of inaccessibility to safe water and basic sanitation, Africa is expected to economically lose $28.4 billion a year or around 5% of GDP [16]. In an earlier study as reported by [17], the World Health Organization (WHO) stated that investment in safe drinking water and sanitation contributes to economic growth and estimates returns of $3-$34 for each $1 spent depending on the region and technology. Considering the fact that 90% of the 3 billion people who are expected to be added to the population by 2050 is expected to occur in developing countries, primarily in regions with limited access to safe drinking water [18], it is important for industry, factories, individuals and communities to share the economic responsibility of efficiently managing and controlling indispensable water resources. Designing more appropriate interventions to improve sachet water quality and supply will be vital to achieve the set water Millennium Development Goals by 2015.

Most existing investigations on sachet water in the country focus on mineral content or microbiological quality [6, 11, 13,19]. This suggests that these investigations are often based on the end product (sachet water) which makes corrective measures more reactive than preventive. This study thus looked at the production and vendor practices that compromise the quality of sachet water produced and sold in the Central Region of Ghana. It is hoped that findings from this study will complement existing literature on the production of sachet water in Ghana and help improve production practices that will enhance quality.

2. Materials and Methods

2.1. Research Design

The single group interrupted time series of the quasi experimental design was adopted for the study. Based on the distinctive predominant source of water used for production, Cape Coast Metropolis and 'Fosu' district were purposively selected for the study together with six sachet water manufacturing companies. Companies selected for the study were identified as 'A', 'B', 'C', 'D', 'E', and 'F'. Production and vendor practices of the selected manufacturers and vendors (who sold products from selected manufacturers) were observed. Details of the study were explained to manufacturers and they were assured that their responses would be kept confidential and anonymous. Consents were obtained from participants and those who consented to participating in the study were then used. Sources of water used for production were identified and method of filtration, production and vendor practices involved in the production of sachet water were closely observed to help identify steps that were likely to introduce contaminants into the water.

2.2. Sample and Sampling Procedure

Triplicate samples of the water (500ml each) were randomly taken from the six selected companies in the morning between 9am and 10am when production started and transported to the laboratory immediately. For vendors who sold products from these manufacturers, sampling involved taking 500ml sachet water in addition to obtaining swabs from the sachet package specifically the water that had condensed from the iced sachet water into the receptacle from which they were being sold. Sampling from the vendors was carried out in the afternoon to ensure that vendors by then had sold reasonable quantities of the water sachets and would have dipped their hands into the receptacles several times to be able to detect any possible contaminants they would have introduced into the condensed water in the receptacle. All vendors sampled for the study were stationary to aid easy identification and replication. Tests which could be carried out in the Cape Coast Water Company laboratory were done immediately upon arrival in the laboratory. The remaining samples were stored overnight in the refrigerator at 1.5ºC (about 35ºF) and transferred to the Council for Scientific and Industrial Research - Food Research Microbiological laboratory, Accra in cold chambers for further analysis.

2.3. Instrument and Test Procedures

Two analytical techniques - Membrane Filtration (MF) and Multiple Tube (MT) were used to determine Total *coliform* (TC), Fecal *coliform* (FC), *Escherichia coli* and Total h*eterotrophic* (HT) bacteria. Samples were also analyzed for pH. Practices of staff at the six selected sachet water companies and vendors were observed. To draw water samples from collected sachets, sachets were first cleaned with 70% ethanol prior to opening with a sterile pair of scissors. Swabs were taken with sterile cotton wool and water. Plastic bottles and their lids were also sterilized before using.

Aliquots of 100ml of each sample were separately filtered and each membrane filter placed on appropriate medium for the parameter to be determined. The following microbiological media were used for the membrane filtration analysis: M-Endo Agar for Total coliform bacteria at 37°C for 18-24 hours; MFC Agar for fecal coliform bacteria at 44°C for 18-24 hours; Hichrome Agar for *Escherichia coli* bacteria 37°C for 18-24 hours; and Nutrient Agar for Total heterotrophic bacteria at 37°C for 18-24 hours. With the MTF analysis, 10ml of sample was dispensed into each of the 10 Lauryl Tryptose tubes containing pre-sterilized broth media. Bottles were inverted and shaken three to five times to mix contents and eliminate any air trapped in the inner vial (Durham tube). After that the tubes were incubated at 35 +/-0.5°C and observed for gas production which was accompanied by a cloudy appearance of the broth at the end of 24 and 48 hours. Positive presumptive results (gas produced) were recorded on the MPN test data sheet and the corresponding MPN index determined. Following incubation, aliquots from the cultured positive tubes were aseptically streaked on MacConkey agar for Total coliform at 37°C.

3. Results and Discussion

3.1. Production and Vendor Practices that Compromised the Quality of Sachet Water

Some staff in company 'A' and 'F' were seen working in their 'mufti' uniforms without wearing any approved protective clothing such as overalls or coats. Staff of four of the six companies did not use gloves, cups and nose guards. Some of the staff members also chatted throughout the production period although they were not wearing any nose masks or guards. This is definitely unacceptable especially along the production line where the final products are being sealed. Rather than keeping them on raised platforms prior to distribution, packaged water was left sitting in spilt water which covered the dirty untilled floor in company 'A'. Three companies out of the six did not provide hand-washing basins for workers to wash their hands and so could not enforce frequent hand-washing, an important "ritual" required to promote and maintain hygiene in such facilities. Company 'C' did not provide 'manufacturing/expiry date' on the product and vital information required by consumers' to assess the portability of the water if it has expired or not. Rather, consumers were referred to a 'seal' placed on the package (which was often inconspicuous) for best before date.

A clear and disturbing observation made was that all six vendors in the study picked water sachets from the receptacle and handed them over to consumers, and surprisingly collected money paid by these consumers with the same hand. The possibility of carrying contaminants from the monies collected to the water (cross contamination) is very high in situations like this. Interestingly enough, vendors purchased ice made out of pipe borne water and added them to the sachet water to make and keep them cold. This could be another possible source of cross contamination. Most of the receptacles used to store the cold sachet water were without covers or lids increasing the level of dust and other dirt getting onto the package or water sachet.

3.2. Quality of the Different Brands of Sachet Water

Data for the study were collected within the period of January 2012 and October 2012. Bacteriological and physiological qualities of the sachet water are presented in Tables 1 and 2. All six brands analyzed for bacteria levels and physical characteristics using the Multiple Tube method met the bacteriological and physiological requirement for portable water according to both Ghanaian and International standards [20-21]. On the contrary, when the Membrane Filtration method was used to analyze the six selected brands, one did not meet both the bacteriological and physiological requirements (Table 2). This sample indicated Total coliform was present which technically should not be detected in potable water and also exceeded the Ghanaian standard of 36 cfu/100ml [20-21]. All swabs taken from the six selected companies using the Membrane Filtration method were positive for Total coliform. On the other hand, swabs from two brands (2 companies) analyzed with the Multiple Tube Fermentation method indicated the absence of any Total coliform. Total coliform obtained from swabs taken from sachet packages from these companies ranged from 6.9 to 12.0 MPN/100 ml while that sampled from the vendors ranged from 6.9 to 23 MPN/100 ml. For the Membrane Filtration method, Total coliform detected was between 32 and 1674 cfu per 100 ml for swabs obtained from companies' packages and 36 and 2418 cfu per 100 ml for samples taken from vendors. The approved Ghanaian and WHO requirements for the various parameters by the APHA method were as follows: total coliform: 036, 0; fecal coliform: 0, 0; *Escherichia coli:* 0, 0; HT 500. pH values recorded for the six selected brands of water ranged from pH 5.3 to pH 6.5, while the approved range of pH is pH 6.5 to pH 8.5 [20].

Tables 1 and 2 show an increase in the counts of Total coliform, Fecal coliform and *Escherichia coli* as sachet packages were transported from the companies where they were produced to the vendors. This trend could result from poor handling of sachet water packages by individuals who barely know about hygiene and do not observe it. Practices such as exposure of sachet packages to dirt en route to distribution at grocery shops and supermarkets; and storage conditions at the shops contribute to the poor quality of the sachet water. Most stores store sachet water in constructed cages in open space which are exposed to dirt and sometimes rodents and other pests.

Counts of Total coliform, Fecal coliform and *Escherichia coli* from the individual brands of sachet water were related to the unhygienic practices of staff. When the Multiple Tube method of analysis was used, companies that engaged in good manufacturing practices and hygiene (Companies 'B' &'C') either had low counts or the water was of good bacteriological quality while the remaining four brands showed varying counts of *coliform*.

Table 1. *Mean number of colony forming units (MPN/100ml) and physical attributes of test samples*

Brand	Bacteriological Parameter	Physical			
A	TC	FC	*E. coli*	HT	pH
A_1	0.0	0.0	0.0	- -*	6.5
A_2	0.0	0.0	0.0	- -	6.4
A_3	9.2	2.0	0.0	- -	6.2
A_4	23.0	11.0	4.0	- -	6.2
B_1	0.0	0.0	0.0	- -	5.3
B_2	0.0	0.0	0.0	- -	5.4
B_3	0.0	0.0	0.0	- -	5.3
B_4	12.0	6.0	0.0	- -	5.3
C_1	0.0	0.0	0.0	- -*	6.4
C_2	0.0	0.0	0.0	- -	6.4
C_3	0.0	0.0	0.0	- -	6.4
C_4	6.9	4.0	0.0	- -	6.5
D_1	0.0	0.0	0.0	- -*	6.4
D_2	0.0	0.0	0.0	- -	6.5
D_3	6.9	0.0	0.0	- -	6.5
D_4	16.1	9.0	2.0	- -	6.5
E_1	0.0	0.0	0.0	- -*	6.1
E_2	0.0	0.0	0.0	- -	6.2
E_3	12.0	0.0	0.0	- -	6.4
E_4	16.0	10.0	0.0	- -	6.4
F_1	0.0	0.0	0.0	0.0*	6.1
F_2	0.0	0.0	0.0	0.0	6.2
F_3	9.2	0.0	0.0	0.0	6.4
F_4	23.0	12.0	0.0	0.0	6.4

Source: Fieldwork, 2011
*The approved Ghana and WHO requirements for the various parameters by the APHA method were as follows: total coliform: 036, 0; fecal coliform: 0, 0; Escherichia coli: 0, 0; HT: 500. Recorded pH values for the six selected brands of water ranged from pH 5.3 to pH 6.5, while the approved range was pH 6.5-pH 8.5 (GS 175:2009).

The analysis using the Membrane Filtration method however yielded different results but samples A_3 and F_3 strengthens the assumption that non compliance with good manufacturing practices compromises the bacteriological quality of water. Ironically, brands of sachet water that tested positive for Total coliform bacteria were collected from a company that complied with an appreciable number of standard regulations. Companies that abused a number of personal hygiene regulations produced sachet water of good bacteriological quality. With the former scenario, the presence of Total coliform in that water could be attributed to inefficiency of the filtration system probably due to accumulation of dirt which could easily re-contaminate the water during production.

Table 2. *Mean number of colony forming units CFU/1ml for Heterotrophic bacteria and 100ml for the other parameters) and physical attributes of test samples*

Sample	Bacteriological parameter	Physical			
A	TC	FC	*E. coli*	HT	pH
A_1	- -*	- -	- -	--	6.5
A_2	0.0	0.0	0.0	6.0	6.4
A_3	1674	930	708	9216	6.2
A_4	2418	1116	760	12672	6.2
B_1	0.0*	0.0	0.0	- -	5.3
B_2	0.0	0.0	0.0	3336	5.4
B_3	520	20	6.0	6336	5.3
B_4	1488	100	16	9216	5.3
C_1	0.0*	0.0	0.0	- -	6.4
C_2	141	0.0	0.0	172	6.4
C_3	100	10	0.0	117	6.4
C_4	2418	1116	528	6624	6.5
D_1	- -*	- -	- -	--	6.2
D_2	0.0	0.0	0.0	332	6.3
D_3	32	0.0	0.0	1436	6.3
D_4	558	2.0	0.0	4608	6.2
E_1	- -*	- -	- -	- -	7.3
E_2	0.0	0.0	0.0	704	7.1
E_3	92	2.0	0.0	1024	7.3
E_4	930	4.0	0.0	2560	7.2
F_1	- -*	- -	- -	- -	6.1
F_2	0.0	0.0	0.0	1184	6.2
F_3	544	0.0	0.0	2304	6.4
F_4	36	2.0	0.0	6336	6.4

Source: Fieldwork, 2011
*The approved Ghana and WHO requirements of the various parameters by the APHA method were as follows: total coliform 036, 0; fecal coliform 0, 0; E. coli 0, 0; HT 500. Recorded pH values for the various brands of water ranged from 5.3 to 6.5, while the approved range was 6.5-8.5 (GS 175:2009).

According to a study [22], poorly maintained filter systems can allow bacteria to grow on filters especially when it has to do with charcoal filters. The presence of Total coliform as found in this study is in line with Hunter's assertion since the brand of water sachet that tested positive for Total coliform bacteria came from a company that used carbon charcoal filter system without UV light. The company also produced huge volumes of sachet water daily (1000 packs of 30 sachets) for 7 days. Although filters were changed before each production cycle, final products were usually analyzed for quality only once a year. Most of these companies depend on the poor quality water produced by Ghana Water Company for the metropolis for their production. As such, it is important for these companies to intermittently change their filters daily or after producing 1000 packs. Absence of UV light in the filtration system could affect sterilization and possibly promote growth of coliforms. Regardless of the huge volume (100-1500) of sachet water produced on daily basis, about 30% of the companies still used a set of filters for a week or two before changing.

When both the Multiple Tube method and Membrane

Filtration method were used to analyze water from different sources used by all the six selected companies, there was no indication of Fecal coliform (FC). Fecal coliform (2 and 6 MPN per 100ml) was however determined in swabs obtained from water sachet packages from two companies. Contrary to expectation, four out of the six sachet water samples taken from the six selected companies turned out testing positive for presence of Fecal coliform when the Membrane Filtration method was used for analyses. Fecal coliform level in one of the four samples was as high as 930 cfu/100ml with the remaining three ranging from 2 to 20 cfu per 100ml. All selected brands of sachet water sold by the vendors tested positive for Fecal coliform when both the Multiple Tube method and Membrane Filtration method were used. With the exception of two of the water sachet samples collected from two of the six companies showing high Fecal coliform levels of 1116 and 100 cfu/100ml when analyzed using the Membrane Filtration method, the rest of the samples analyzed by both Multiple Tube method and Membrane Filtration method showed values ranging from 2 to 12 cfu/MPN per 100ml. The presence of Fecal coliform and *Escherichia coli* in packaged samples could be the cause of several reported cases of diarrhea and other gastrointestinal diseases in the study area and contributes to the prevalence of such diseases in the area as well [23].

Escherichia coli were not found in both sachet water samples and swabs taken from the companies. However, when the Multiple Tube method was used for analyzing samples from vendors, two of the samples tested positive for *Escherichia coli* and recorded MPN values of 2 and 4. When the Membrane Filtration method was used to analyze water samples from the six companies, they all tested negative for presence of *Escherichia coli* but swabs from the companies and vendors tested positive for presence of *Escherichia coli* with values ranging from 6 to 708 cfu per 100ml (for 2 companies) and 6, 16 and 760 cfu per 100ml (for 3 vendors). Analyses to determine the presence of Total heterotrophic microbes in water samples was done using only the Membrane Filtration method and all samples tested positive indicating the presence of heterotrophic microbes. Total heterotrophic bacteria levels in the water samples ranged from 6 to 3336 cfu per ml with packages recording higher levels. Only 1 brand of sachet water recorded Total heterotrophic levels of hundreds with the remaining brands recording levels in thousands. Total heterotrophic bacteria levels obtained from swabs taken from company packages ranged from 117 to 9216 cfu per ml while that obtained from packages sold by vendors ranged from 2560 to 12672 cfu per ml indicating that higher levels of heterotrophic bacteria were obtained from sachet water sold by vendors.

The absence of fecal contaminants in the sachet water samples reported earlier in this study does not justify classifying them as water of good bacteriological quality. The presence of high levels of Total heterotrophic bacteria in all the samples of sachet water indicates the presence of organic compounds in the water which are used by the bacteria to produce energy. Heterotrophic bacteria levels found in package samples ranged from 6 to 3336 and 12672 cfu/ml compared to 500 which has been approved by Ghana. High levels of Total heterotrophic bacteria are known to affect the taste and odor of water and indicate the incidence of contamination [10]. Findings of this study confirm that of a similar study [10] where all samples showed the presence of Total heterotrophic bacteria.

Four out of six samples from company packages were positive for Total coliform when the Multiple Tube Filtration method was used for the analysis. The remaining samples showed different levels of Total coliform when the Membrane Filtration method was used. Only two out of the 12 package samples (factory/vendor) recorded positive results that met Ghanaian standards of 36 Total coliform cfu/100ml (APHA method). Although MPN values seemed less they still did not meet the WHO guidelines for drinking water which states that for treated water, not more than 1 of 10 analytical units should have an MPN value of more than 2.2MPN/100ml of water and no analytical unit should have an MPN value of more than 9.2MPN/100ml [6]. Only 25% (6 out of/24) of samples met the requirements irrespective of the analytical method used.

Also, consumers often drink from the sachet package by simply tearing one of the ends open. With this, organisms on the surface of the package could easily be ingested along with the water. Moreover, the fact that company staff did not observe personal hygiene; inappropriately handled sachet water during transportation and distribution, and vendors did not properly store and handle sachet water all contributed to contamination of the water. Varying pH values of the water which did not meet approved standards was also of concern especially sachet water from company ‘B’ fetched from a borehole had a low pH of 5.3. This low pH infers that the source of water plays a vital role in the success of water treatment and the pH of the final product. Also, carbon charcoal filters are known to be poor at removing or dealing with acidity in water.

Ideally, if the filtration process and treatment that the water goes through are appropriate, there should be no contaminants in the sachet water after passing through all the filtration and treatments. Yet, the sachet water gets to the final consumer contaminated. It is thus important to check the whole process from production through transport to the vendors, storage and handling processes at the end of the vendors, and finally to the consumer. Water is life and good quality water is the focus of public health. Successful intervention toward improving the quality of sachet water cannot be overemphasized and should encompass the package. Consumers pouring the water out of the package into a glass before drinking could help reduce recontamination.

4. Conclusions

From the study, it can be concluded that packages of sachet water were more contaminated than the water itself although Total heterotrophic bacteria counts could indicate poor sanitation control. To protect public health, it will be mandatory to mitigate practices that contribute to contamination of sachet water during production and sale. A more proactive approach that identifies risks and puts in place measures at critical points in sachet water production to promote and enhance overall quality will be important. Introducing the use of membrane filters as a more sensitive way of detecting these parameters as well as the Presence/Absence test as an inexpensive, reliable and easy test in the analysis of sachet water could help producers provide clean and safe water for the public.

The pH of samples was generally below the limit considered suitable for human consumption, while the taste of 50% of the samples met the requisite standards. Results also indicated that lack of good manufacturing practices such as staff failing to observe personal hygiene contributed to contamination in the sachet water. Contamination could have been introduced during handling of water from the source through purification to the point where vendors sold to consumers thus there is the need to critically analyze each point along the lines of production and distribution and remedy any probable contamination that could be introduced into the water.

With the knowledge that economic growth depends on optimal levels of access to safe drinking water, poor water quality or lack of access to safe drinking water implies higher costs for all users and consumers. To help promote growth and create jobs in the Cape Coast Metropolis, it is important that all stakeholders come together to manage all water resources properly. To ensure the safety of drinking water in the Cape Coast metropolis and the Central Region as a whole, it is recommended that the Ghana Health services partner with the metropolis/region to develop a bacteriological water quality monitoring training program to help train sachet water producers to provide clean safe water for the public. Also, stakeholders need to invest more in the conservation and supply of safe drinking water to prevent higher disease burden, lower productivity of workers and slower economic growth among others.

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References

[1] Edema, M., Atayese, A O. & Bankole, M.O. (2011). Pure water syndrome: bacteriological quality of sachet- packed drinking water sold in Nigeria. *African Journal of Food, Agriculture, Nutrition and Development,* 11(1):4595-4609.

[2] World Health Organization (2003). Water in healthy villages – a guide for communities and community health workers. Chapter 3. World Health Organization, Geneva, Switzerland

[3] Levesque, D., Pereg, D., Watkinson, E., Maguire, J.S., Bissonnette, L., Gingras, P., Rouja Bergeron, M.G., Dewailly, (2008). Assessment of microbiological quality of drinking water from household tanks in Bermuda. *Canada Journal of Microbial,* 54, 495-500.

[4] Ezeugwunne, N.R., Agbakoba, N.K., Nnamah, I.C. & Anahalu (2009). The prevalence of bacteria in packaged sachets water sold in Nnewi, South East, Nigeria. *World Journal of Dairy and Food Sciences,* 4 (1), 19-21.

[5] Anonymous (2006). Proposal for a Directive of the European Parliament and of the Council on environmental quality standards in the field of water policy and amending Directive 2000/60/EC, Commission Staff Working Document 'Impact Assessment', SEC(2006) 947, Brussels, 17.7. 2006, 77 pp

[6] Addo, K. K., Mensah G. I., Bekoi M., Bonsu C., & Akyeh M. L. (2009). Bacteriological quality of sachet water produced and sold in Teshie-Nungua suburbs in Accra. *Adfand Online 4*

[7] Gadgil, A. J. & Derby, E.A. (2003). Providing Safe Drinking Water to 1.2 Billion Unserved People. Annual Air and Waste Management Association (AWMA) Conference, Paper 70492. San Diego, CA, June 22–26, 2003.

[8] United Nations Commission on Sustainable Development (UNCSD) (2004). Simple Methods Lead to Dramatic Results. UN Commission on Sustainable Development, 12th Session, New York,

[9] Dada, A. C. (2009). Sachet water phenomenon in Nigeria: assessment of the potential health impacts. *African Journal of Microbiology Research,* 3(1), 015-021.

[10] Stoler, J., Fink, G., Weeks, J. R., Appiah Otoo, R., Ampofo, J. A. & Hill, A. G. (2012). When urban taps run dry: Sachet water consumption and health effects in low income neighborhoods of Accra, Ghana, *Health and Place.* 18(2), 250-262.

[11] Obiri-Danso, K., Okore-Hanson, A., Jones, K. (2003). The microbiological quality of drinking water sold on the streets of Kumasi, Ghana. *Letters of Applied Microbiology,* 2003; 37(4), 334.

[12] Okioga, T. (2007). Water quality and business aspects of sachet vended water in Tamale, Ghana. Master's thesis, Massachusetts Institute of Technology, Cambridge, Massachusetts.

[13] Dodoo, D. K., Quagraine, E. K., Okai-Sam, F., Kambo, D. J. & Headley (2006). Quality of "sachet" waters in the Cape Coast Metropolis of Ghana. *Journal of Environmental Research,* 41(3), 329-342.

[14] Kwakye-Nuako, G., Borketey, P.B., Mensah-Attipoe, I., Asmah, H. Ayeh-Kumi, P. F. (2007). Sachet drinking water in Accra: the potential threats ff transmission of enteric pathogenic protozoan organisms. *Ghana Medical Journal,* 41(2), 62-66.

[15] Smith- Asante, E. (2010). Ghana to incorporate rainwater harvesting in building designs: Retrieved March 15, 2012 from: www.ghanabusinessnews.com

[16] World Health Organization (2006). Guidelines for drinking-water quality [electronic resource]: incorporating first addendum, 1, Recommendations. – 3rd ed. Retrieved from www.who.int./water_sanitation_health/dwg/gdwq0506.pdf.

[17] Hutton, G., Haller, L.(2004). Evaluation of the Costs and Benefits of Water and Sanitation Improvement at the Global Level. Geneva: World Health Organization (WHO/SDE/WSH/04.04): 9.

[18] United Nations (2007). Report of the United Nations High Commissioner for Human Rights on the scope and content of the relevant human rights obligations related to equitable access to safe drinking water and sanitation under international human rights instruments

[19] World Health Organization (2007). pH in drinking-water. Background document for preparation of WHO Guidelines for drinking-water quality. Geneva, World Health Organization (WHO/SDE/WSH/07.01/1).

[20] Ghana Standards Board (2009). Water Quality Requirements for Drinking Water, GS 175, Pt. 1, 2009.

[21] World Health Organization (Geneva) (1993). The bacteriological quality of drinking water quality, in Guidelines for Drinking Water Quality, 1, 17-39.

[22] Hunter, P. R. (1987). Bottled natural mineral and other bottled water. *Microbiology Europe* 2, 9.

[23] Ministry of Health (2009). Monthly out-patients morbidity report, Central Region, Cape Coast, Ghana: Health Directorate.