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Assessment of the quality of sachet water consumed in urban townships of Ghana using physico-chemical indicators: A preliminary study

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ABSTRACT

This research was carried out to assess the quality of sachet water vended in some urban towns of Ghana. Thirty-eight brands of sachet water vended by street sellers in Odumase-Krobo, Nsawam townships and Accra Metropolis were assessed for their physical and chemical parameters using standard methods. Physical parameters such as pH, total dissolved solids, total hardness, turbidity and conductivity were determined by instrumental methods. Chemical characteristics measured included Na, K, SO_4^{2-}, Cl^-, Mg, PO_4^{3-}, HCO_3^-, Cu, Cr and Pb. Na and K were determined using a Sherwood flame photometer. Cl^- and HCO_3^- were determined by standard titrimetric methods. $SO4^{2-}$, $PO4^{3-}$, and $NO3^-$ were determined by UV- spectrophotometric method. Cu, Cr and Pb was determined in the dissolved form using atomic absorption spectrometry technique in an air-acetylene flame. Physical examinations was also carried out on some samples to ascertain whether sachet water sold on the market bore Ghana Food and Drugs Board registration number and met product labelling requirements. The data showed variations in some investigated parameters as follows: pH 5.55-7.22, electrical conductivity 3.84-410µS/cm, Pb BDL-0.221 mg/L $SO4^{2-}$ <0.001-30.33mg/L, TDS 1.40-202.0mg/L, turbidity 0-3mg/L, bicarbonate 2.44-60.96mg/L, Na 1.3-76.1mg/L, K 0-10.0mg/L. The concentrations of copper and chromium were below detectable limits, while lead levels exceeded the WHO guideline value for majority of the samples (68%).

Key words: Drinking water quality, sachet water, townships, physico-chemical parameters

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INTRODUCTION

Access to safe drinking water is key to sustainable development and essential to food production, quality health and poverty reduction [1-3]. Safe drinking water is essential to life and a satisfactory safe supply must be made available to consumers [4-6]. Though Ghana abounds in numerous water resources, not all urban residents have access to quality drinking water. The supply of piped water is inadequate in most communities in terms of quality and quantity of the public water supply. It is only about 10.3 million people (approximately 51% of the population) are reported to have access to improved water supplies [7]. In the light of inadequate or lack of quality potable water supplies from the municipal sources, urban residents have resorted to both formal and informal sector providers to supply their water needs. The past decade has seen a dramatic increase in the consumption of bottled and, more especially, plastic bagged drinking water in Ghana [8]. The introduction of sachet water in Ghana was to provide safe, hygienic, and affordable instant drinking water to the public and to curb the magnitude of water related problems in the country [9]. Hitherto, street water sellers in Ghana used to sell water either from a bucket with a single cup for all consumers or in hand-filled hand tied polythene bags with cups [8]. Municipal authorities banned this to safeguard the health of the people. In an improved manner some business entrepreneurs imported machines for filtering the water and putting them in sealed-sachets. Most manufacturers today use multicandle pressure filters (Berkefield, Doulton, U.K) which employ an active carbon filter that removes sand, rusts, metal sediments, algal films and bacteria from the water [10]. The bags are closed using heat sealing machines. This is sold-out to retailers in quantities of 30 sachets in a bag and many in turn sell it out as iced-water either on the streets or in kiosks. In addition to drinking, sachet packed water serves the cooking needs of many urban households. The origin of such water is usually treated water and sometimes well water. The typical process the sachet water undergoes through before reaching the final consumer is shown below.

Source (usually deep well with submersible pumps)

↓

Raw water tank (usually PVC)

↓

Industrial modules(consisting of sand bed filter and activated carbon)

↓

Treated water tan (PVC)

↓

Micro-filters 1, 2, 3(5µm -2µm-0.5µm, respectively)

↓

UV sterilizer(attached to sachet water machine)

↓

Packaging(automatic machine filling and heat sealing of polythene sachets)

↓

Sachets stocked in bigger bags ready for distribution

Figure 1. Typical water treatment process in sachet water factories. Adapted from [**11**]

Some of the sachet water producers are not adequately licensed by the Ghana standards Board. While bottled water price is within the tautology, sachet water continues to be depended on by many people. Today, different types and brands of sachet water are readily available to the consumer on the streets, supermarkets, restaurants, food joints and shops. According to the Food and Drugs Board (FDB) of Ghana, there has been tremendous increase in production of sachet water culminating in over 300 registered producers and over 600 unregistered producers in Ghana. According to the FDB, majority of sachet water are produced under questionable hygienic environmental conditions, without approval and does not meet standards. Regardless of all these problems associated with sachet water, it is still considered wholesome for drinking purposes as compared to tap or well water [12]. Natural water may contain many different chemical constituents, which may be organic and inorganic [13,14]. The latter may be derived from the rocks and soil through which water percolates or over which it flows [14], while the organic componenets are derived from the breakdown of plant material or from algae and other microorganisms that grow in the water or sediments. Chemicals used in water treatment, from industrial sources and agricultural activities may introduce contaminants in final water. While a lot of studies have been done to assess the physicochemical as well as microbiological quality of sachet water in Nigeria [11,15-17], relatively fewer studies [8,12] have been conducted in Ghana on the safety of sachet water vended in Ghana. This present study was done to provide information on aspects of the physicochemical quality of vended sachet water as well as clarify concerns about its safety to consumers.

MATERIALS AND METHODS

Study area

The study areas chosen included Accra, Nsawam and Odumase-Krobo townships of Ghana. Accra is located in the Greater Accra Region of Ghana, while Nsawam and Odumase-Krobo were chosen because of unique proximity or closeness to the Accra. Nsawam Township is located on the main Accra – Kumasi Highway about 37km from Accra. Nsawam is located on latitude 5^o 48 N and longitude 0^o 21W whereas Adoagyiri is located on latitude 5^{o}49 N and longitude 0^{o}21W. Nsawam is drained by the Densu River and its tributary rivers and streams. The Densu River itself is approximately 115.8km long and its source is the Atiwa mountain ranges near Kibi in the Eastern Region. Odumase-Krobo is located in the Yilo-krobo-Osudoku municipality of Ghana. The geographical coordinates are o latitude 6^{o}6 North and longitude 0^{o}10West. Accra is located on the East coast of Ghana, approximately 5^o North of the Equator, between longitudes 0^o 05" West and 0^o 20" West and between latitudes 5^o 30" North and 5^o 5' North. The city is one of the 5 districts that make the greater Accra region. AMA covers an area of 17,362 ha. It falls within the dry equatorial climatic region, and it receives an average annual rainfall of 810 mm/year. The climate is hot and humid and reflects a bimodal rainfall pattern with a mean annual rainfall of about 1,300 mm. The mean daily temperature is 26 °C with a range of 18 °C–35 °C. The relative humidity can be as high as 97% in the mornings of wet seasons and as low as 20% in the afternoon of the dry seasons**.**

Sampling and analysis

Fifty samples belonging to thirty-eight brands of sachet water samples (Table 1) were collected from street sellers in Accra, Nsawam and Odumase-Krobo, Ghana (August 2011). The samples were collected, put separately into pre-cleaned high-density 500ml polyethylene sampling bottles and immediately transported to the laboratory for subsequent analysis. The physical parameters measured included pH, total dissolved solids (TDS), electrical conductivity, turbidity, salinity, colour and total suspended solids. The chemical parameters included chloride, sulphate, nitrates, and phosphate. Analysis of pH was conducted using a WTW model 523 pH meter. The pH electrode was calibrated with buffer solutions of pH 4, 7 and 10, prior to taking the readings. Conductivity was determined with a conductivity metre as described in [18].The probe of the instrument was rinsed first with distilled water and following rinsing with each water sample the probe was allowed to stay in the water sample for 1 min before recording the reading in micro siemen per cm (PSCM-1). Determinations were done at 25^{0}C. The total suspended solids (TSS) content and turbidity of each water sample was determined with the HACH portable colorimeter (Model DR/350) as described in [18]. The instrument was zeroed with 25 ml of deionised water which also served as the blank, subsequently the TSS was determined on 25 ml of each water sample after 2 min vigorous shaking. The instrument was adjusted to measure turbidity by pressing "program 95" on the instrument's panel. The metre was zeroed with 10 ml of deionised water (blank) and turbidity read directly from the instrument expressed in Nephelometic Turbidity Unit (NTU). Total hardness was determined by the ethylenediamine tetra acetic acid (EDTA) titrimetric method as described in [18]. For total hardness, 25ml of each water sample was measured into a 250 ml flask. It was mixed with 1 ml of NH_4Cl – NH_4OH buffer and 2 ml of eriochrome black"T" indicator and titrated with 0.02N EDTA to a blue end point. Total hardness was calculated with the expression:

$$TH = A * \frac{1000}{25}$$

Analysis of Na^+ and K^+ ion concentrations were done using a Sherwood model 420 flame photometer. Chloride was determined using the silver nitrate titration method using potassium chromate indicator. A 100 ml volume of each sample in a conical flask was mixed with 3 drops of 10% potassium chromate indicator and a pinch of titrated against 0.014N silver nitrate to a reddish tinge end point. Distilled water served as the blank. Concentration of chloride was calculated using the expression:

$$Cl(mg/L) = \frac{(A - B) * N * 35.45}{Vol. of Sample} * 1000$$

Where A = Titre value of sample
B = Titre value of distilled water
N = Normality of Silver nitrate

Sulphate ($SO4^{2-}$), nitrate (NO_3^-), phosphate (PO_4^{3-}) were measured by the UV Spectrophotometric method as described in [18]. The instrument used was a Schimadzu UV-1201 UV-VIS spectrophotometer. For nitrate, nitrate standard solutions of 0.02, 0.04, 0.06, 0.08 and 1.0M were prepared from a stock KNO3 solution (100ppm). 5ml of sample was pipette into a test tube. 1ml of 30% NaCl, 5ml of Conc. H_2SO_4 and 0.25ml of brucine reagent was added to the samples and standards and mixed thoroughly. Absorbances for the standards and samples were read on the UV-VIS spectrophotometer at a wavelength of 410nm. For sulphate analysis, a stock solution was prepared by dissolving 0.7479mg of anhydrous Na_2SO_4. 15, 20, 25, 30 and 35 mg/L of standard solutions were prepared from the stock solution. 10ml of samples, standards and blanks were measured into Erlenmeyer flasks and 1ml acid salt solution and 5ml glycerol added. 0.05g of barium chloride was added and the absorbances of the standards and samples and blanks read on a UV-VIS spectrophotometer at 420nm wavelength. For phosphate analysis, a 1000ppm stock solution was prepared by dissolving 219.5mg of anhydrous potassium hydrogen phosphate (KH_2PO_4) in 500ml distilled water and the volume topped up to the mark in a 1000ml volumetric flask using distilled water. Standard solutions of concentrations 0.2, 0.4, 0.6, 0.8 and 1.0 mg/L were prepared from the stock solution. Ten millilitres of each of the standards, blank and samples were measured into a test tube. 2ml of combined reagent (ascorbic acid and molybdate antimonyl reagent) were added to the standards, blanks and samples. 0.05ml of phenolphthalein indicator was added to the solutions. Ten minutes was allowed to elapse, after which absorbance of each solution was measured at 880nm on a UV-VIS spectrophotometer. Bicarbonate was determined by acid titration using methyl orange as an indicator.

Table 1 various sachet water brands sampled and analysed

Sampling Location	Brand name
Accra	Standard
	Ice Pack
	Mobile
	Cool Pac
	Ahenfie
	Aqua-In
	Kemida
	Ami-Ice
	Rebecca
	Royal Nsupa
	Everpure
	JEPS
Odumase Krobo	No Nine No Ten
	Diplomatic
	Nsuo Ye
	Grace
	Sparrow
	G-Promise
	Del-Quench
	TK
	Super Eagles
	E-ice
	BM
	MAY
	Handmaids Quench
	JK
	Happy
Nsawam	Hilife
	Bigben
	Savannah Spring
	Blue Spring
	ASTEK
	B Choice
	Sure cooler
	Star Splash
	Aqua Rite
	Valley spring
	Droplick
	RockStar

Physical examinations of some sachet water brands

Product requirements on labels which included product information, nutritional information, compliance levels such as registration number and batch numbers, manufacturing and expiry dates, nutritional information including mineral composition, net volumes, producers name, location and contact information were checked on sachet water labels.

RESULTS AND DISCUSSION

Physicochemical data on water quality

The results from the physicochemical analysis (minimum, maximum, median and range) values are displayed in Table 2.

There is no health based guideline for pH, although a range of 6.5-8.5 is often suggested [19]. Seventy-eight percent (78%) of the samples fell within the recommended pH range of 6.50-8.50, with the remaining 22% falling outside the range. The pH distribution of the samples is indicated with a plot of cumulative frequency versus pH as shown in Figure 1. Kemida brand sold in Accra recorded the highest pH of 7.22 whereas Ice Pak brand also sold in Accra recorded the least pH of 5.55. Turbidity is caused by suspended particles or colloidal matter that obstructs light transmission through the water. Turbidity does not have a health based guideline, but it is recommended that it should be ideally be below 1.0 NTU for effective disinfection [14]. 16% of the water samples fell above this recommendation.The turbidity range of the sachet water samples analyzed were from 0-3NTU. Conductivity is an indication of total dissolved solids (TDS), both organic and inorganic found in the water. The palatability of water with total dissolved solids (TDS) level of less than about 600mg/l is generally considered to be good, whereas drinking water becomes significantly and increasingly unpalatable at TDS levels greater than about 1000mg/l [14]. The recommended guideline value of 1200mg/L for TDS by WHO is rather based on the taste effects of water rather than health. The TDS concentrations of the samples ranged from 1.40mg/L to 202.0mg/L. The highest TDS concentration was recorded by Grace brand sold in Odumase Krobo, while the least TDS concentration was recorded by Ice Pak brand sold in Accra.

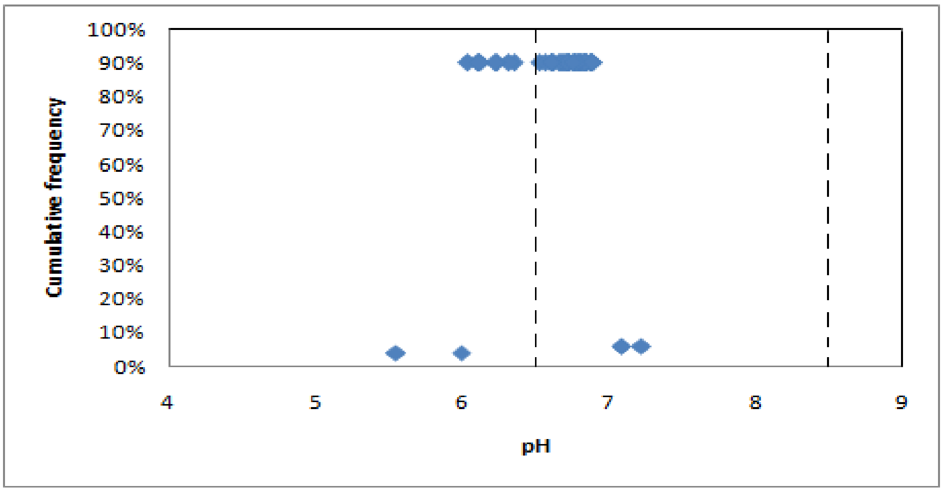

Figure 2 Cumulative frequency versus pH showing the recommended pH range

Table 2 Physicochemical data of sachet water quality of samples obtained from Accra, Odumase-Krobo and Nsawam townships

Loc/Parameters		pH	Cond (µS/cm)	TDS (mg/L)	SAL (ppt)	ALK (mg/L)	HCO3 (mg/L)	Mg (mg/L)	SO42- (mg/L)	PO43- (mg/L)	Cl (mg/L)	Na (mg/L)	K (mg/L)	TH (mg/L)	TURB (mg/L)	Pb (mg/L)
Accra	MIN	6.59	111.38	53.10	0.03	15.33	18.70	6.64	7.79	0.08	12.83	31.67	25.51	2.42	0.0	0.09
	MAX	7.22	410.0	197.50	0.2	50.00	60.96	33.05	23.67	0.15	41.99	152.00	76.10	10.00	0.0	0.15
	MEDIAN	5.55	3.84	1.40	0.0	2.00	2.44	1.94	2.00	0.01	7.99	14.00	19.60	1.25	-	0.05
	RANGE	6.59-7.22	111.38-410.0	53.1-197.5	0.03-0.2	15.33-50.0	18.7-60.96	6.64-33.05	7.79-23.67	0.08-0.15	12.83-41.99	31.67-152.0	25.51-76.1	2.42-10.0	-	0.09-0.15
Odumase-Krobo	MIN	6.62	9.10	20.30	0.0	5.20	6.44	1.94	0.17	0.003	1.99	24.00	6.70	4.30	0.0	0.02
	MAX	6.89	99.0	202.00	0.0	36.00	43.89	11.67	25.33	0.16	7.99	56.00	19.00	5.20	3.0	0.09
	MEDIAN	6.79	45.65	21.75	0.0	28.00	34.14	5.83	8.75	0.08	5.99	36.00	7.80	4.70	1.0	0.11
	RANGE	6.62-6.89	9.1-99.0	20.3-202.0	-	5.2-36.0	6.44-43.89	1.94-11.67	0.17-25.33	0.003-0.16	1.99-7.99	24.0-56.0	6.7-19.0	4.3-5.2	0-3.0	0.02-0.09
Nsawam	MIN	5.99	14.20	6.30	0.0	2.00	2.44	1.94	1.17	0.01	1.99	8.00	3.70	0.00	0.0	0.05
	MAX	6.79	305.0	66.6	0.1	32.00	39.01	6.81	30.33	0.11	15.99	32.00	28.10	4.50	3.0	0.15
	MEDIAN	6.44	47.6	19.9	0.0	8.00	9.75	2.92	5.50	0.07	3.99	12.00	8.15	0.35	1.0	0.12
	RANGE	5.99-6.79	14.2-305.0	6.3-19.9	0-0.1	2.0-32.0	2.44-39.01	1.94-6.81	1.17-30.33	0.01-0.11	1.99-15.99	8.0-32.0	3.7-28.1	0-4.5	0-3.0	0.05-0.15

Table 2 Ghana Standards Board drinking water guidelines for potable water [23] (GS 175-1:2009)

Parameter	GSB Level
pH	6.5-8.5
Chloride	250 mg/L
Total Dissolved Solids	1000 mg/L
Sulphate	250 mg/L
TOTAL HARDNESS	500
Manganese	0.4 mg/L
Iron	0.3 mg/L
Fluoride	1.5 mg/L
Calcium	0.003 mg/L
Nickel	0.02 mg/L

Table 3 physical examination of sachet water in 27 randomly selected

Label Requirement	Number of Sample	
	Positive	Negative
FDB Number	15	12
Manufacturing date	0	27
Expiry date	0	27
Nutritional Information	1	26
Batch Number	0	27
Contact Information	27	0

Excess alkalinity results to a distinct, flat and unpleasant taste and scale formation [20]. The alkalinity levels in the sachet water samples ranged from 2-50mg/L. Kemida brand sold in Accra recorded the highest alkalinity value of 50mg/L. Chloride concentrations in the sachet water samples ranged from 1.99 to 41.98 mg/L as shown in Table 2. Ami Ice brand from Accra recorded the highest chloride level of 41.98mg/L. High level of chloride is known to impart taste to potable water particularly when sodium is the predominant cation [18]. Excess chloride concentrations of about 250mg/l can give rise to detectable taste in the water and also cause corrosion [14]. Apparently, the levels of chloride in all the sachet water samples analyzed were not high enough to impact on taste or corrosion. Sulphate concentrations in sachet water ranged from below detection limit to 30.33 mg/L as shown in Table 2. No health based guideline had been derived for sulphate in drinking water by WHO, however very high levels might cause a laxative effect in unaccustomed consumers. Taste thresholds have been found to vary from 250mg/L for Sodium Sulphate and 1000mg/l for Calcium sulphate. Water has been classified on the basis of hardness as follows by WHO as follows; Soft (0-50mg CaCO3/L), Moderate Soft(50-100mg CaCO3/L, Slightly Hard (100-150mg CaCO3/L), Moderate Hard (150-200 mg CaCO3/L), Hard (200-300 mg CaCO3/L) and Very Hard (over 300mg CaCO3/L). 90% of the samples fell into the classification of soft waters, while 8% fell within moderately soft, with 2% falling into moderately hard water. Again Ami Ice brand from Accra had the highest total hardness (152 mg/L) expressed as $CaCO_3$. Sodium in drinking water has been shown to impact on taste, with the taste threshold dependent on the associated anion and the temperature of the solution. At room temperature, the average taste threshold for sodium is about 200mg/L [14]. The samples in the study areas recorded elevated concentrations of Sodium, with Na concentrations ranging from 1.3 mg/l to 76.1mg/l. These elevated concentrations may be a source of concern from human pathology perspectives [18,21]. According to NRC [21], a Na/K ratio of 1 or less than 1 is recommended. However, only 5 brands out of the 38 brands sampled recorded Na/K ratios recommended by NRC. Ami Ice brand vended in Accra recorded the highest concentration of Na. It had been reported by Kleiner [22] reported the need to adopt requirements which involved displaying the concentration of Sodium on the labels of packaged water. Potassium levels in sachet water samples ranged from 0 to 10mg/l as shown in Table 2. Currently there had not been any evidence that suggests the need for establishing a health-based guideline value for potassium. There had been seldom, if ever found that potassium occurs in levels that could be a concern in drinking water for healthy humans [14]. Kemida brand from Accra recorded the highest level of potassium concentration of 10mg/L. Table 3 shows some drinking water guideline levels adopted by the Ghana Standards Board.

Product label requirements

Dada [11], in his study on sachet water contamination physically examined samples of ‘pure water’ from the Nigerian market and recorded that none of the identified brands met the compliance levels set by the regulatory authorities in terms of label requirements such as registration number and batch numbers, manufacturing and expiry dates, nutritional information, net volumes and sometimes producers names and contact addresses. An attempt made to physically examine sachet water brands on the Ghanaian market yielded results which are displayed in Table 4. From table 4, it is evident that many sachet water brands sold on the market did not meet label requirements prescribed by regulatory authorities in Ghana.

CONCLUSION

There were wide variations in physicochemical paramters among the sachet water analyzed. Apparently samples from the Accra Metropolis recorded highest concentrations in majority of physicochemical parameters considered in this study. It is evident from this study that sachet water vended met most of the guideline values for physical and chemical qualities of potable water prescribed by the Ghana Standard Board. The source of concern however was elevated concentrations of Pb in majority of the samples. While this study serves as a preliminary study, an extensive study is required to draw further recommendations for the sachet water industry in Ghana. It is recommended there is the need for regulators to ensure strict enforcement of labeling requirements, which is lacking on some sachet water samples. This will be very useful to inform most consumers, especially those on mineral restricted diets.

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