Quality of Sachet Water Produced at Tarkwa, Ghana*

S. A. Ndur, J. S. Y. Kuma, W. K. Buah and J. Y. Galley

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Abstract

Cholera outbreak in some cities and towns in Ghana in early 2011 necessitated a sachet water quality study in Tarkwa to determine their wholesomeness. The study was conducted in four phases in August 2011, December 2011, August 2012 and December, 2013. Most of the physico-chemical parameters analysed were within the recommended WHO limits except for pH, Pb and Ni in the main. About 50% of the samples had their pH below the lower limit of 6.5 and 8% had Pb concentrations above the recommended limit of 0.01 mg/L. Protozoan organisms such as *Cyclospora cayetanensis* (5%), *Cryptosporidium parvum* (4%), *Ascaris lumbricoides* eggs (10%), and *Stronglyoides Stercoralis* larvae (4%) were identified in some of the water samples. *Helminth* eggs (6.7%), *Protista* (13.4%) and 6.7% *unidentified insect larvae* were also found in the samples. Faecal and total coliforms were found in 40% of the samples analysed. The presence of protozoan organisms and faecal coliforms in some of the sachet water render them unsafe for drinking.

Keywords: Sachet water quality, Protozoan organisms, Faecal coliforms

1 Introduction

In Ghana, urban communities traditionally depend on pipe borne water for most domestic use. The water is produced and distributed by the Ghana Water Company Limited (GWCL). However, in recent times, water shortage has affected most cities and towns in Ghana due to inadequate supply, as a result of rapid population increase without the commensurate expansion in the water infrastructure (Kuma and Ashley, 2008; Kuma and Ewusie, 2009 and Kuma *et al.,* 2010). In some other urban communities e.g., Tarkwa, illegal small-scale mining activities in and along river banks have become additional problems to water production because of the ensuing high pollution requiring high treatment costs. Furthermore, the use of very old water distribution systems in some of the urban areas have also led to deterioration of water quality such as colour, taste, odour and increased turbidity at some delivering points. All these problems have resulted in some individuals constructing all types of wells i.e., hand dug, hand-pump and mechanised in their homes to augment GWCL supplies. However, improper waste management practices may also affect the quality of water drawn from some of these wells.

Consequently, sachet water production has become a booming industry nowadays in both urban and rural communities. It is now the vogue in almost all households to offer either bottled or sachet water to visitors. Sachet water is sold in all public places where every day activities take place. It is produced either from GCWL water taps or from wells. The water from these sources is most often passed through some treatment mechanisms in an attempt to produce potable or better quality water.

The quality of the final sachet water product is very important and the producers, being aware of this, put "Approved by the Ghana Standards Authority (GSA)" on the labels of their products. The Food and Drugs Board (FDB) of Ghana most often test the water produced once a year to ascertain their quality. They also inspect the premises of the sachet water producers at random during the year to check the conditions under which the water is produced. Kwakye-Nuako *et al*., (2007) found protozoans in some sachet waters produced and sold in Accra and these organisms, when present, pose health threat to consumers. In March 2011, cholera outbreak was reported in a number of cities and towns in Ghana including Tarkwa, a mining municipality with a population of more than 80000. In 2014 there was another cholera outbreak in Ghana and as at November 2014 the reported cholera cases were 25414 out of which 208 deaths were recorded. In the Tarkwa-Nsuaem Municipality alone 263 cholera cases were reported in 2014, with one casualty. These outbreaks show that there is the need to investigate the processes of sachet water production and distribution in the Municipality.

1.1 Sachet Water Treatment and Production

The main sources of the sachet water are from the GWCL produced tap water and from mechanised boreholes. A typical treatment procedure is mainly by aeration, single or double stage filtration using porcelain molecular candle filters or membrane filters. In some instances, disinfection by Ultra Violet (UV) light is applied while other processes use reverse osmosis followed by filtration. However, some producers do not apply filtration in their procedures. The level of treatment generally

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depends on the source of water. Sometimes tap water is used without additional treatment and is sold in markets without clearance from the FDB or other bodies concerned with water quality (Dodoo *et al*., 2006).

A typical sachet water production line is shown Figures 1a and 1b. It can be seen from Fig. 1a that the filter is dirty and this suggests that filters are not changed at the required time. Fig. 2 shows typically how bagging of processed water is done. The bags used for packaging the sachet water are made of High Density Polyethylene (HDPE) material which has high tensile strength capable of withstanding high temperatures.

A typical plastic material and the machine used for sachet water production are shown in Fig. 3 and 4. The main parts of the machine include:

(i) A bag-forming device to fold the polythene bags used as containers of the water before they are heat-sealed;
(ii) A sealing device to seal the bags vertically and then horizontally after filling with water;
(iii) Filling and metering devices that fill the bags with water and monitor flow;
(iv) UV disinfection bulb to disinfect the inner plastic film used to package sachet water; and
(v) An automatic counter to register the number of bags produced.

From Figs. 2 and 3, it is observed that some operators do not wear protective gloves and the use of bare hands is a recipe for contamination of the water produced.

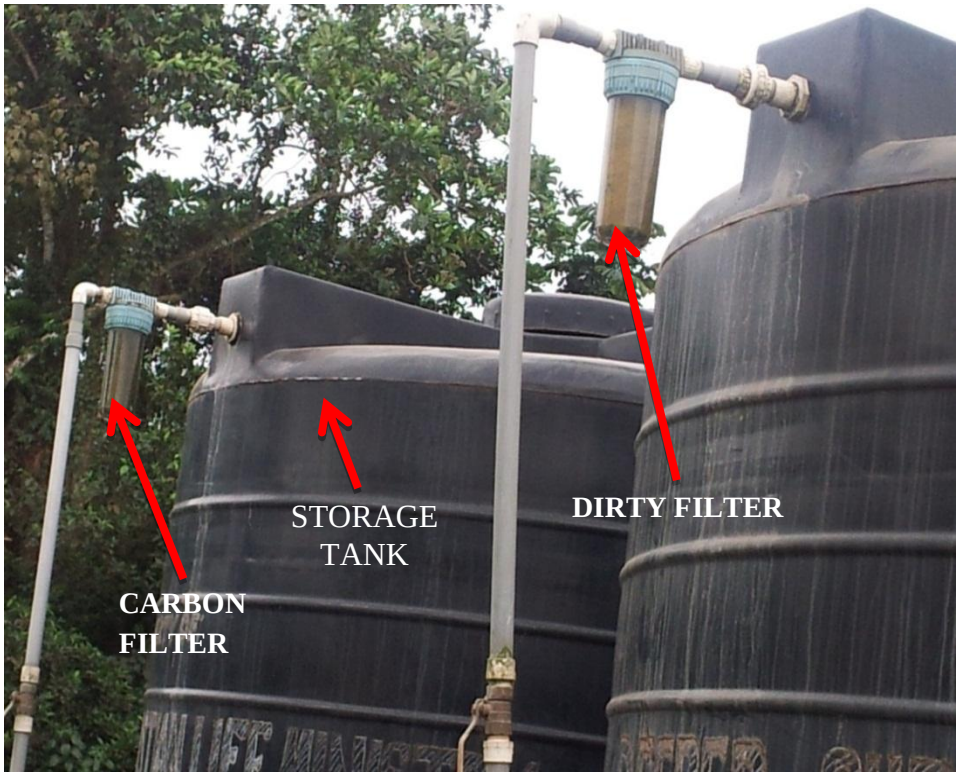

Fig. 1a A typical Sachet Water Production Line with a Dirty Filter

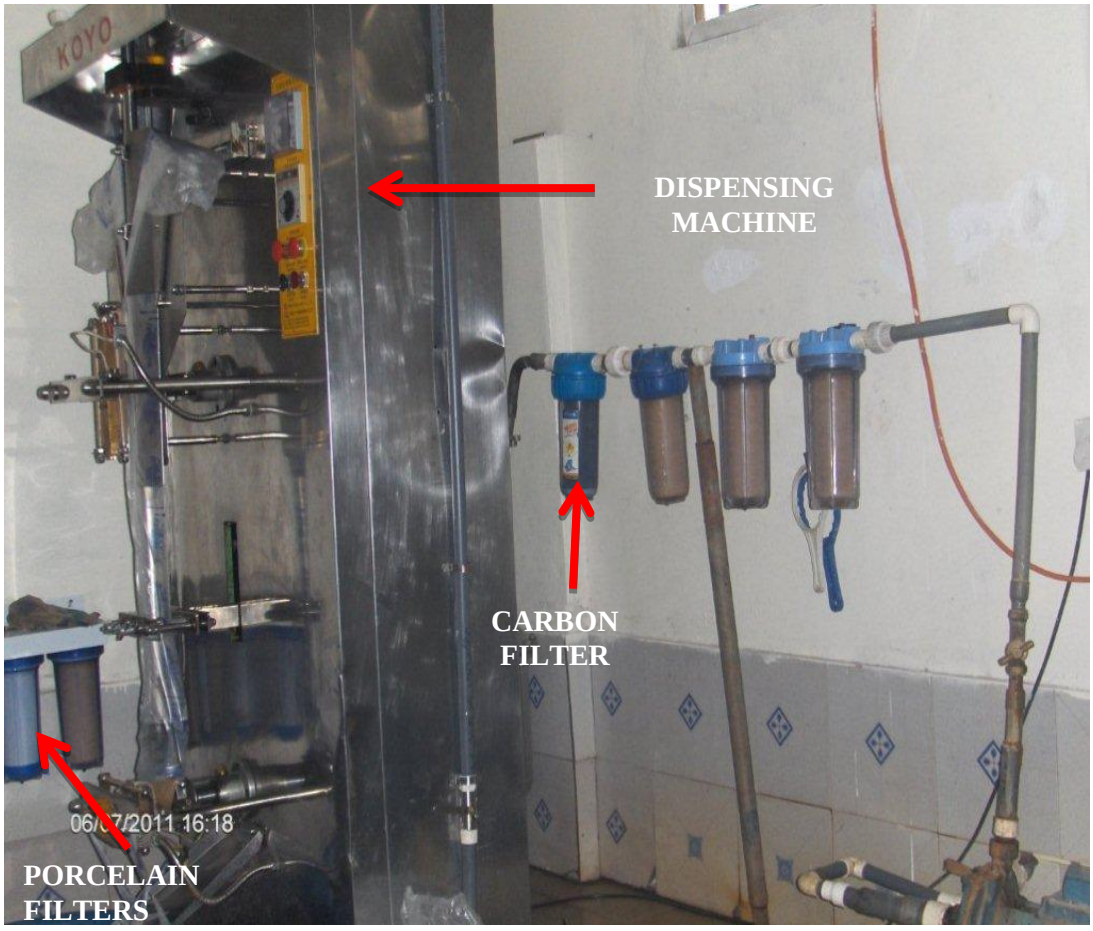

Fig. 1b A Typical Sachet Water Production Line

Fig. 2 Bagging of Sachet Water in a Production Area

Fig. 3 Sealing, Adjustment and Trimming of Sachet Rolls

Fig. 4 UV-Bulb in Sachet Water Machine used for Disinfection

2 Materials and Methods Used

Fifteen brands of sachet water produced at Tarkwa were selected for the study. Water samples were taken from the final processed water outlet for each brand. Sampling was done following established procedures and the exercise was carried out in four phases in August 2011, December 2011, August 2012 and December 2013. During the second, third and fourth phases of sampling, distributors of sachet water produced from outside Tarkwa but sold in the Municipality were also included in the study.

A Horiba U-51 water quality multi-meter was used to measure the following parameters: pH, Eh, temperature, Oxidation-Reduction Potential (ORP), Dissolved Oxygen (DO) and Total Dissolved Solids (TDS). Turbidity and colour (True and Apparent) were measured using a Smart 3 Colorimeter. The cations Cu, Pb, Mn, As, Ca, Cd, K, Zn, Fe, Mg, Na, Hg and Cr were analysed using the Varian Atomic Absorption Spectrometer (Varian AAS 240 FS) at University of Mines and Technology (UMaT) Minerals Engineering Laboratory. Total Suspended Solids (TSS), alkalinity, faecal and total coliform were measured in the Environmental Laboratory at AngloGold Ashanti, Obuasi Mine. The bacteriological and parasitological analyses were performed at the laboratory of the Council for Scientific and Industrial Research (CSIR) Water Research Institute (WRI) in Accra.

3 Results and Discussion

3.1 Results

Results of all the analyses are presented in Tables 1, 2, 3 and 4 for the August 2011, December 2011

and August 2012 and December, 2013 phases respectively.

Of the physico-chemical parameters analysed, pH values were most variable with more than 50% of the samples below the World Health Organisation (WHO) lower limit of 6.5. Low pH (<6.5) values were measured in 5/15 (33.3%) in August 2011, 14/25 (56%) in December 2011, 19/20 (95%) in the August, 2012 and 12/19 (63%) in December 2013 samples.

True colour value in 1/25 (4%) in December 2011, 9/20 (45%) in August 2012 and 6/19 (32%) in December 2013 samples were higher than the WHO limit of 0 TCU. Apparent colour values in 16/25 (64%) in December 2011, 8/20 (40%) in August 2012 and 4/19 (21%) were higher than the WHO limit of 15 TCU. Only one sample 1/20 (5%) in August 2012 had its conductivity value higher than the WHO limit of 250 mg/L.

3.1.1 Metals

Almost all metal concentrations in the samples analysed were within WHO limits. The only exceptions are the following: In August 2011, Pb concentration in 6/15 (40%) of the samples were above the WHO limit of 0.01 mg/L. Similarly, 4/25 (16%) of the samples analysed for Pb during the December 2011 phase, 1/20 (5%) during August 2012 and 1/19 (5%) in December 2013 were above the WHO limit. The Pb concentrations in these samples ranged between 0.014-0.051 mg/L. Fe concentration measured in 1/15 (6%) of August 2011 and 1/25 (4%) of December 2011 and 2/19 (10%) samples were above the WHO limit of 0.3 mg/L. In August 2012, Ni concentration measured in 8/20 (40%) of the samples were higher than the WHO limit of 0.01 mg/L. The Mn concentrations in 3/19 (16%) of December 2013 samples were above the WHO limit of 0.05 mg/L.

3.1.2 Bacteriology and Parasitology

August 2011 Sampling Phase

During this sampling period faecal coliforms were identified in 5/15 (33.3%) of the samples. The same amount of Total coliforms was identified in the samples (Table 1b). In 4/20 (20%) of the samples 4 common protozoan pathogens were identified. Helminth eggs were identified in 1/15 (6.7%) samples, *protista* in 2/15 (13%) and an unidentified insect lavae in 1/15 (6.7%) samples.

December 2011 Sampling Phase

Faecal coliform was identified in 4/25 (16%) of the samples while 1/25 (4%) Total coliforms were identified in one sample.

August 2012 Sampling Phase

Faecal coliform was identified in 5/20 (25%) of the samples while Total coliforms were identified 3/20 (15%) samples. Protozoan oocysts were identified in 2/20 (10%) of the samples namely; *Cyclospora cayetanensis* 1/20 (5%) and *Cryptosporidium parvum* 1/20 (5%). In addition, Helminths were observed in 3/20 (15%) of the samples namely; *Ascaris lubricoides* eggs 2/20 (10%) and *Stronglyoides Stercoralis* larvae 1/20 (5%).

December 2013 Sampling Phase

Faecal coliform was identified in 4/19 (21%) of the samples while Total coliforms were identified 5/19 (26%) of the samples.

Table 1a Results of Sachet Water Analysed in August 2011

AUG. 2011 A	pH	T	Cond	TDS	DO	BOD	TURB.	COLOUR		TSS	TH
SAMPLE ID		(ºC)	uS/cm	mg/L	mg/L	mg/L	(FTU)	APP.	TRUE	mg/L	mg/L
TK 001	7.43	17.70	130.00	60	8.20	7.50	1.98	<1	0	1	92
TK 002	7.31	18.80	140.00	70	8.20	7.60	1.08	<1	0	1	164
TK 003	3.94	18.90	100.00	50	7.60	7.20	0.98	<1	0	1	164
TK 004	5.21	18.80	20.00	10	8.80	8.30	1.66	<1	0	1	36
TK 005	6.60	18.30	70.00	30	10.20	9.40	0.87	<1	0	1	76
TK 006	4.20	18.10	20.00	10	7.80	7.20	1.42	<1	0	2	40
TK 007	7.00	18.30	110.00	50	9.80	9.30	1.66	<1	0	3	100
TK 008	6.04	18.10	50.00	20	8.80	8.20	0.98	<1	0	1	52
TK 009	6.71	19.30	70.00	30	7.90	7.30	1.05	<1	0	2	60
TK 010	7.01	18.50	100.00	50	8.60	8.20	1.23	<1	0	4	88
TK 011	7.22	19.40	70.00	30	9.40	9.10	1.07	<1	0	4	64
TK 012	6.73	18.60	100.00	50	7.60	7.10	1.34	<1	0	1	172
TK 013	6.39	18.80	90.00	40	8.70	8.40	0.12	<1	0	1	40
TK 014	7.00	19.40	90.00	40	9.60	9.10	1.93	<1	0	1	56
TK 015	6.66	18.00	180.00	90	10.40	9.80	1.20	<1	0	1	62
WHO STD	6.5-8.5	-	1500	1000	-	-	-	15	0	20	-

Table 1b Results of Sachet Water Analysed in August 2011

AUG. 2011 B SAMPLE ID	TH mg/L	ALK mg/L	Cl^- mg/L	PO_4^{3-} mg/L	SO_4^{2-} mg/L	NO_3^- mg/L	Faecal Col count/100mL	Total Col count/ 100mL	*Cryptosporidium spp.*	*Giardia spp.*	*Helminth eggs*	*Free Living Organisms*
TK 001	92	388	12.32	<0.01	25.36	1.25	0	0	-	-	-	*Unidentified insect Larvea*
TK 002	164	256	5.26	0.02	6.21	<0.01	0	1	-	-	-	*Protista*
TK 003	164	268	7.42	<0.01	12.36	<0.01	0	0	-	-	-	
TK 004	36	142	6.33	<0.01	17.25	<0.01	>20	>20	-	-	-	*Protista*
TK 005	76	132	11.26	<0.01	42.38	0.250	0	0	-	-	-	-
TK 006	40	188	2.35	0.510	10.24	0.320	3	2	-	-	-	-
TK 007	100	188	6.25	0.130	32.51	0.350	0	0	-	-	-	-
TK 008	52	158	3.22	<0.01	18.47	<0.01	0	0	-	-	-	-
TK 009	60	118	11.25	<0.01	47.27	<0.01	0	0	-	-	-	-
TK 010	88	146	2.51	0.250	16.98	<0.01	5	0	-	-	-	-
TK 011	64	232	8.26	0.480	25.14	0.250	8	15	-	-	-	-
TK 012	172	152	15.65	0.320	33.65	2.650	0	0	-	-	-	-
TK 013	40	144	0.25	<0.01	12.36	<0.01	0	0	-	-	-	-
TK 014	56	82	10.24	<0.01	26.53	<0.01	5	>20	-	-	-	-
TK 015	62	160	12.37	0.210	38.26	0.480	0	0	-	-	*Ascaris*	-
WHO STD	-	-	**250**	**2.500**	**400**	**10**	**0**	**0**	-	-	-	-

Table 1c Results of Sachet Water Analysed in August 2011

AUG. 2011 C	Na	K	Ca	Mg	Fe	Cu	Mn	Pb	Cr	Ni	Cd	As
SAMPLE ID	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
TK 001	6.482	0.451	3.590	0.781	0.028	0.004	0.034	0.017	<0.002	<0.002	<0.002	<0.01
TK 002	12.583	2.290	7.250	3.135	0.009	0.008	<0.002	<0.002	<0.002	<0.002	<0.002	<0.01
TK 003	15.471	0.510	5.257	1.901	<0.002	0.004	0.221	<0.002	<0.002	<0.002	<0.002	<0.01
TK 004	7.350	0.414	3.974	0.898	<0.002	0.008	0.063	<0.002	<0.002	<0.002	<0.002	<0.01
TK 005	10.638	1.243	8.636	1.608	0.004	<0.002	0.152	<0.002	<0.002	<0.002	<0.002	<0.01
TK 006	4.331	0.429	3.355	0.616	0.009	<0.002	0.069	0.051	<0.002	<0.002	<0.002	<0.01
TK 007	12.587	0.934	9.489	3.916	0.025	<0.002	0.005	<0.002	<0.002	<0.002	<0.002	<0.01
TK 008	3.692	1.265	15.384	3.178	<0.002	<0.002	0.149	0.014	<0.002	<0.002	<0.002	<0.01
TK 009	5.595	1.541	20.296	4.458	2.000	<0.002	0.091	0.030	<0.002	<0.002	<0.002	<0.01
TK 010	4.193	1.526	17.495	4.273	<0.002	<0.002	0.019	<0.002	<0.002	<0.002	<0.002	<0.01
TK 011	40.597	0.429	6.495	0.792	<0.002	<0.002	0.027	0.034	<0.002	<0.002	<0.002	<0.01
TK 012	4.554	1.266	16.875	4.370	0.006	0.002	0.107	0.008	<0.002	<0.002	<0.002	<0.01
TK 013	5.517	1.394	15.390	2.436	0.059	<0.002	0.091	0.035	<0.002	<0.002	<0.002	<0.01
TK 014	12.883	2.222	6.605	2.084	0.019	<0.002	0.016	<0.002	<0.002	<0.002	<0.002	<0.01
TK 015	3.273	1.473	15.334	2.448	<0.002	<0.002	0.303	<0.002	<0.002	<0.002	<0.002	<0.01
WHO STD	**200.00**	**30.00**	**40-80**	**150.00**	**0.300**	**2.000**	**0.500**	**0.010**	**0.050**	**0.010**	**0.050**	**0.010**

Table 2a Results of Sachet Water Analysed in December 2011

DEC 2011 A	T	pH	eH	ORP	COND	TDS	DO	BOD	TURB	COLOUR		TSS
SAMPLE ID	°C		(mV)	(mV)	(µS)	(ppm)	(ppm)	mg/L	(FTU)	APP.	TRUE	mg/L
TK 001	26.21	4.1	137	341	99	64	6.96	4.18	5	35	0	2
TK 002	25.61	6.29	7	236	171	111	4.78	6.58	6	0	0	1
TK 003	27.37	5.52	54	279	154	100	4.79	5.62	27	97	0	1
TK 004	27.67	6.05	22	238	56	36	4.8	6.88	22	76	0	1
TK 005	28.28	6.67	-15	218	105	69	6.55	8.64	22	66	0	1
TK 006	26.94	4.49	115	347	49	32	6.65	7.12	21	44	0	1
TK 007	26.79	6.20	13	272	171	111	5.69	6.08	17	51	0	1
TK 008	25.67	6.53	-7	263	97	63	7.15	6.11	25	1	0	1
TK 009	27.31	6.73	-19	244	180	117	5.04	6.38	22	0	0	2
TK 010	27.02	6.94	-31	234	138	89	4.98	5.24	20	0	0	1
TK 011	27.65	7.46	-62	207	169	110	6.77	6.87	5	0	0	1
TK 012	26.92	6.09	19	245	165	107	5.18	5.99	5	62	0	1
TK 013	27.52	6.51	-6	254	155	101	5.07	7.01	18	47	24	2
TK 014	27.92	6.64	-13	212	165	107	5.01	6.07	27	58	0	1
TK 015	27.24	6.80	-23	247	242	157	5.13	5.08	7	0	0	1
TK 016	27.37	6.71	-18	251	73	47	6.83	6.54	6	52	0	1
TK 017	26.02	4.73	100	352	37	57	5	5.98	6	26	0	1
TK 018	26.02	5.19	73	319	57	37	7.18	7.65	14	33	0	1
TK 019	26.18	4.30	126	233	143	93	5.05	6.28	2	71	0	1
TK 020	26.28	6.83	-25	232	108	70	5.99	6.37	15	55	0	2
TK 021	26.18	6.32	6	257	174	113	4.9	5.84	18	44	0	1
TK 022	27.39	6.88	-28	234	212	138	6.44	6.37	10	0	0	1
TK 023	26.07	4.88	91	336	59	39	7.14	3.54	12	46	0	2
TK 024	26.2	4.53	112	355	142	92	6.89	5.28	12	0	0	2
TK 025	26.33	5.45	58	308	88	57	7.07	6.07	8	1	0	1
WHO STD	-	**6.5-8.5**	-	**650**	**<250**	**1000**	-	-	-	**15**	**0**	**20**

Table 2b: Results of Sachet Water Analysed in December 2011

DEC 2011 B	HCO_3	T H	ALK	Cl^-	PO_4^{3-}	SO_4^{2-}	NO_3^-	Feacal Col	Total Col
SAMPLE ID	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	count/100mL	count/100mL
TK 001	18	42	28	1.265	<0.14	2.154	<0.01	0	0
TK 002	18	36	42	1.254	<0.01	1.261	<0.01	0	0
TK 003	20	28	38	2.361	0.025	0.147	<0.01	0	0
TK 004	24	26	18	1.254	<0.01	0.265	<0.01	0	0
TK 005	12	38	20	0.321	<0.01	0.214	<0.01	1	0
TK 006	24	40	24	0.654	<0.01	0.256	<0.01	0	0
TK 007	14	40	22	0.985	<0.01	1.254	<0.01	0	0
TK 008	16	52	34	0.865	<0.01	1.25	0.124	0	0
TK 009	22	50	22	1.265	<0.01	1.26	0.054	0	0
TK 010	24	60	36	1.254	<0.01	1.025	0.088	0	0
TK 011	30	50	44	1.264	<0.01	0.324	0.261	2	0
TK 012	18	40	26	2.351	<0.01	1.247	<0.01	0	0
TK 013	14	50	36	0.458	<0.01	2.354	0.024	0	0
TK 014	16	36	20	1.26	<0.01	1.254	<0.01	0	0
TK 015	30	40	42	0.258	<0.01	0.265	0.014	0	0
TK 016	24	36	24	0.241	<0.01	1.254	<0.01	0	0
TK 017	26	32	24	1.265	<0.01	0.251	<0.01	0	0
TK 018	24	44	16	1.254	<0.01	0.984	0.112	0	0
TK 019	20	42	22	2.351	<0.01	<0.01	<0.01	0	1
TK 020	22	38	26	0.258	<0.01	1.261	<0.01	1	0
TK 021	16	46	32	1.261	<0.01	0.874	0.021	2	0
TK 022	26	42	24	0.264	0.212	1.025	<0.01	0	0
TK 023	24	32	26	2.365	<0.01	2.361	<0.01	0	0
TK 024	20	42	18	1.254	<0.01	2.154	<0.01	0	0
TK 025	20	38	18	0.652	<0.01	1.658	0.025	0	0
WHO STD.	-	-	-	**250**	**2.5**	**400**	**10**	**0**	**0**

Table 2c Results of Sachet Water Analysed in December 2011

DEC 2011 C	Na	K	Ca	Mg	Fe	Cu	Mn	Pb	Cr	Ni	Cd	As
SAMPLE ID	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
TK 001	8.051	1.673	5.007	1.196	0.306	<0.002	0.151	0.037	<0.002	<0.002	0.01	<0.03
TK 002	13.109	1.808	9.158	3.924	0.061	<0.002	0.016	<0.002	<0.002	<0.002	0.02	<0.03
TK 003	16.58	1.464	3.944	2.065	0.071	0.001	0.24	<0.002	<0.002	<0.002	0.023	<0.03
TK 004	7.214	1.337	3.225	1.172	0.058	<0.002	0.095	<0.002	<0.002	<0.002	0.016	<0.03
TK 005	8.152	1.744	8.106	1.844	0.053	<0.002	0.144	0.002	<0.002	<0.002	0.019	<0.03
TK 006	5.185	0.912	2.818	0.828	0.074	<0.002	0.091	<0.002	<0.002	<0.002	0.014	<0.03
TK 007	15.325	1.404	6.828	4.232	0.06	0.018	0.023	<0.002	<0.002	<0.002	0.016	<0.03
TK 008	6.756	1.106	7.241	1.72	0.073	0.013	0.098	<0.002	<0.002	<0.002	0.018	<0.03
TK 009	8.706	1.9	18.139	3.853	0.023	0.01	0.085	<0.002	<0.002	<0.002	0.01	<0.03
TK 010	5.272	1.657	17.989	3.148	0.06	0.009	0.043	<0.002	<0.002	<0.002	0.016	<0.03
TK 011	35.915	0.676	3.115	0.841	0.031	0.011	0.055	0.001	<0.002	<0.002	0.02	<0.03
TK 020	6.035	1.762	17.34	4.258	0.044	<0.002	0.13	<0.002	<0.002	<0.002	0.018	<0.03
TK 022	4.993	2.046	20.805	3.429	0.176	0.016	0.103	<0.002	<0.002	<0.002	0.016	<0.03
TK 021	14.163	3.28	5.923	2.427	0.062	<0.002	0.065	0.022	<0.002	<0.002	0.011	<0.03
TK 017	27.203	2.992	8.573	3.478	0.101	0.017	0.438	<0.002	<0.002	<0.002	0.019	<0.03
TK 015	6.534	0.893	4.773	1.73	0.133	0.018	0.128	<0.002	<0.002	<0.002	<0.002	<0.03
TK 012	15.81	1.638	4.463	1.624	0.15	0.018	0.023	<0.002	<0.002	<0.002	<0.002	<0.03
TK 013	6.796	1.058	6.783	1.281	0.223	0.017	0.016	<0.002	<0.002	<0.002	<0.002	<0.03
TK 014	11.796	3.486	3.707	1.487	0.105	0.029	0.054	<0.002	<0.002	<0.002	<0.002	<0.03
TK 016	8.678	1.64	3.698	2.403	0.151	0.011	0.145	0.028	<0.002	<0.002	<0.002	<0.03
TK 018	5.789	1.548	17.253	4.428	0.14	0.007	0.253	0.015	<0.002	<0.002	<0.002	<0.03
TK 019	12.167	4.224	14.952	4.796	0.158	0.016	0.008	<0.002	<0.002	<0.002	<0.002	<0.03
TK 023	15.681	1.157	4.484	1.086	0.158	0.019	0.013	<0.002	<0.002	<0.002	<0.002	<0.03
TK 024	6.796	3.737	3.794	1.531	0.102	0.023	0.053	<0.002	<0.002	<0.002	<0.002	<0.03
TK 025	5.789	0.626	4.755	1.84	0.269	0.019	0.005	<0.002	<0.002	<0.002	<0.002	<0.03
WHO STD.	200	30	40-80	150	0.3	2	0.5	0.01	0.05	0.01	0.05	0.01

Table 3a Results of Sachet Water analysed in August 2012

AUG 2012 A		T	pH	eH	ORP	COND	TDS	DO	BOD	TURB	COLOUR		TSS
SAMPLE ID		°C		(mV)	(mV)	(µS)	(ppm)	(ppm)	mg/L	(FTU)	APP.	TRUE	mg/L
TK 001		26.26	3.74	140	422	94	61	4.98	4.89	1.18	7	0	1
TK 002		26.41	4.83	75	322	174	113	6.08	5.47	1.77	3	0	2
TK 003		26.62	5.5	85	304	188	122	5.37	5.04	1.42	19	2	1
TK 004		26.3	3.54	152	404	73	47	5.48	4.26	1.12	7	0	2
TK 005		26.73	5.53	34	279	122	97	6.15	5.26	1.44	3	0	1
TK 006		26.42	3.59	148	400	65	40	5.12	4.38	0	0	0	1
TK 007		26.44	5.09	60	335	191	124	7.25	4.32	1.79	7	0	1
TK 008		26.29	5.38	43	320	92	60	5	4.22	0.99	12	1	2
TK 009		26.65	5.88	13	247	192	125	6.53	4.85	1.69	27	15	1
TK 010		26.58	6.66	-34	267	5	3	5.29	5.78	0.13	15	2	1
TK 011		26.38	5.23	51	323	116	75	5.09	4.29	1.95	30	4	1
TK 015		26.48	4.67	85	338	264	171	5.84	5.52	0.56	14	0	1
TK 016		26.33	6.38	-17	270	159	103	5.83	5.22	0.57	19	3	2
TK 017		26.72	6.27	-10	290	21	13	5.94	5.29	1.47	5	0	1
TK 018		26.62	5.77	19	322	48	31	7.11	5.18	0.59	1	0	1
TK 019		26.31	5.62	28	319	45	29	6.02	6.03	0.34	36	1	1
TK 020		26.35	5.58	30	314	109	71	5.77	6.78	0.44	11	3	1
TK 021		26.28	3.85	133	405	71	46	4.67	4.68	0.22	0	0	1
TK 022		26.4	5.69	24	315	198	129	4.89	4.66	1.58	20	6	2
TK 026		26.43	4.62	88	331	20	13	5.36	6.28	0.45	0	0	1
WHO STD		-	6.5-8.5	-	650	1500	1000	-	-	-	15	0	20

Table 3b Results of Sachet Water analysed in August 2012

AUG 2012 B	HCO_3	T H	ALK	Cl^-	PO_4^{3-}	SO_4^{2-}	NO_3^-	Feacal Col	Total Col	Protozoan	Herminths
SAMPLE ID	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	count/ 100mL	count/ 100mL	oocysts	
TK 001	20	64	40	3.844	<0.001	7.881	<0.001	0	0	*Cyclospora cayetanensis*	*Ascaris lumbricoides* eggs
TK 002	22	38	42	1.255	0.266	4.877	0.788	0	0	-	-
TK 003	24	50	22	4.688	<0.001	4.889	3.669	0	0	-	-
TK 004	26	48	32	2.588	<0.001	2.448	<0.001	0	0	-	-
TK 005	18	42	28	2.477	0.225	3.626	1.559	0	2	-	-
TK 006	19	45	37	3.561	<0.001	8.667	<0.001	2	5	-	-
TK 007	32	60	36	1.226	0.668	6.288	0.636	0	0	-	-
TK 008	20	54	30	4.844	0.526	0.988	2.005	0	0	-	*Ascaris lumbricoides* eggs
TK 009	24	40	30	1.362	<0.001	4.221	2.448	1	0	-	-
TK 010	20	48	32	2.668	<0.001	4.696	0.866	0	0	-	-
TK 011	30	50	26	2.887	0.889	4.887	0.884	0	0	-	-
TK 015	20	44	18	0.988	1.447	2.166	0.685	0	0	-	-
TK 016	36	62	40	1.39	<0.001	5.889	1.227	1	0	-	*Strongyloides stercoralis* larvae
TK 017	26	60	30	2.484	1.22	5.884	0.669	0	0	-	-
TK 018	22	44	30	1.557	0.855	4.877	1.336	0	0	-	-
TK 019	24	48	32	0.889	<0.001	1.228	<0.001	1	0	*Cryptosporidium parvum*	-
TK 020	18	50	36	5.488	0.699	0.866	0.448	0	0	-	-
TK 021	16	52	30	2.655	1.636	2.188	<0.001	0	0	-	-
TK 022	20	46	36	3.666	<0.001	8.669	<0.001	2	5	-	-
TK 026	14	36	40	2.544	<0.001	5.662	0.887	0	0	-	-
WHO STD	-	-	-	**250**	**2.5**	**400**	**10**	**0**	**0**	-	-

Table 3c Results of Sachet Water analysed in August 2012

AUG. 2012 C	Free Living	Na	K	Ca	Mg	Fe	Cu	Mn	Pb	Cr	Ni
SAMPLE ID	Organisms	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
TK 001	-	9.076	0.333	<0.002	<0.002	<0.002	0.03	0.07	<0.002	<0.002	0.018
TK 002	-	12.045	0.304	4.52	3.199	0.005	0.011	0.03	<0.002	<0.002	<0.002
TK 003	-	15.432	1.227	8.19	2.73	<0.002	0.001	0.154	0.014	<0.002	0.028
TK 004	-	6.899	<0.002	<0.002	<0.002	<0.002	0.018	0.059	<0.002	<0.002	<0.002
TK 005	-	8.163	0.706	3.1	0.716	0.01	0.012	0.213	<0.002	<0.002	<0.002
TK 006	-	5.144	<0.002	<0.002	<0.002	<0.002	0.041	0.04	<0.002	<0.002	<0.002
TK 007	-	14.503	1.135	4.006	3.21	<0.002	0.016	0.018	0.01	<0.002	0.029
TK 008	-	6.908	<0.002	3.576	0.712	<0.002	<0.002	0.056	<0.002	<0.002	<0.002
TK 009	-	8.603	0.871	8.402	2.706	0.009	0.008	0.14	<0.002	<0.002	<0.002
TK 010	-	5.63	<0.002	<0.002	<0.002	<0.002	0.007	<0.002	<0.002	<0.002	<0.002
TK 011	-	34.623	<0.002	0.189	0.051	0.062	0.012	0.062	<0.002	<0.002	0.014
TK 015	-	26.204	3.264	4.611	2.549	<0.002	0.012	0.317	<0.002	0.011	0.009
TK 016	-	6.117	1.19	8.812	2.833	<0.002	<0.002	0.189	<0.002	<0.002	0.026
TK 017	-	16.705	<0.002	0.272	<0.002	<0.002	0.011	<0.002	<0.002	<0.002	0.078
TK 018	-	6.304	0.23	<0.002	<0.002	<0.002	0.021	<0.002	<0.002	<0.002	<0.002
TK 019	-	12.801	0.082	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
TK 020	-	7.998	0.802	0.45	1.075	<0.002	0.009	0.109	<0.002	<0.002	0.075
TK 021	-	7.982	0.032	<0.002	<0.002	<0.002	0.09	0.142	<0.002	<0.002	0.062
TK 022	-	12.208	4.325	9.379	3.104	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
TK 026	-	13.104	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
WHO STD	-	**200**	**30**	**40-80**	**150**	**0.3**	**2**	**0.5**	**0.01**	**0.05**	**0.01**

Table 4a Results of Sachet Water Analysed in December 2013

DEC 2013 A	pH	T/	COND	TDS	DO	BOD	TURB.	COLOUR (TCU)		TSS	T H	ALK
		°C	(µS)	(ppm)	(ppm)	mg/L	(FAU)	APP.	TRUE	mg/L	mg/L	mg/L
TK001	3.88	24.62	72	47	5.1	5.34	0.49	0	0	2	62	42
TK003	6.61	24.36	66	43	4.93	5.06	0	32	7	2	42	30
TK004	5.47	25.1	92	60	7.67	5.46	0.9	4	0	1	60	24
TK005	5.46	24.44	58	38	7.65	5.04	0.9	9	2	2	46	30
TK006	4.2	24.41	58	38	6.1	5.34	0	1	0	2	44	50
TK007	6.33	24.86	47	31	6	4.66	0	22	12	2	38	26
TK010	6.32	24.03	10	7	6.34	4.18	0.03	0	0	1	22	14
TK011	7.74	24.3	117	76	7.37	5.44	0	19	2	2	48	52
TK014	7.27	24.77	98	63	7.84	4.18	0.02	10	4	1	50	46
TK017	6.94	23.96	26	17	5.37	5.46	0	5	0	1	38	22
TK018	4.48	23.98	60	39	6.52	4.46	1.06	0	0	1	52	36
TK020	6.45	24.85	116	75	7.53	5.02	0	0	0	1	48	32
TK026	6.58	23.75	37	24	7.46	4.12	0.7	21	9	1	26	12
TK027	7.38	24.34	200	130	5.66	4.46	0.18	0	0	2	88	50
TK028	6.31	24.56	20	13	7.14	5.03	1.72	0	0	2	18	24
TK029	7.04	24.94	92	60	7.9	5.12	0	3	0	2	54	24
TK030	5.06	24.82	51	33	7.7	5.14	0.23	0	0	1	52	20
TK031	5.33	24.67	95	62	8.08	4.42	0.49	2	0	2	64	42
TK032	6.27	24.43	49	32	5.23	4.53	0.82	0	0	2	36	20
WHO STD	**6.5-8.5**	-	**1500**	**1000**	-	-	-	15	0	20	-	-

Table 4b Results of Sachet Water Analysed in December 2013

DEC 2013 B	Cl^-	PO_4^{3-}	SO_4^{2-}	NO_3^-	Feacal Col	Total Col	HCO^-_3
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	count/100mL	count/100mL	(mg/L)
TK001	0.462	<0.01	4.269	0.398	0	0	30
TK003	3.261	1.426	2.368	0.874	0	1	28
TK004	0.968	<0.01	0.958	3.295	1	2	38
TK005	2.538	<0.01	0.968	<0.01	0	0	18
TK006	0.865	<0.01	0.859	<0.01	0	0	20
TK007	0.748	<0.01	1.758	<0.01	0	0	20
TK010	0.874	<0.01	2.684	0.936	0	0	6
TK011	2.144	0.261	4.268	<0.01	0	0	30
TK014	3.266	<0.01	2.847	0.526	0	1	32
TK017	4.621	<0.01	5.268	1.264	1	1	26
TK018	4.215	0.627	4.217	1.362	0	0	22
TK020	2.481	0.562	3.261	1.243	0	0	26
TK026	1.425	628	5.127	<0.01	0	0	12
TK027	4.261	<0.01	5.687	<0.01	1	0	58
TK028	0.968	0.425	4.261	<0.01	0	0	8
TK029	1.784	<0.01	6.321	2.487	0	0	34
TK030	0.421	0.784	0.968	2.481	1	0	24
TK031	1.859	<0.01	7.214	<0.01	0	0	32
TK032	2.647	<0.01	2.014	0.847	0	1	16
WHO STD	**250**	**2.5**	**400**	**10**	**0**	**0**	-

Table 4c Results of Sachet Water Analysed in December 2013

DEC 2013 C		K	Ca	Mg	Fe	Cu	Mn	Pb	Cr	Cd
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
TK001		0.002	0.624	0.1	<0.002	0.046	<0.002	<0.002	<0.002	<0.002
TK003		0.002	1.961	0.409	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
TK004		0.002	1.585	0.659	<0.002	0.036	0.059	<0.002	<0.002	<0.002
TK005		0.002	2.01	0.458	0.147	<0.002	<0.002	<0.002	<0.002	<0.002
TK006		0.002	1.052	0.144	<0.002	0.003	<0.002	<0.002	<0.002	<0.002
TK007		0.900	1.034	0.002	0.027	<0.002	<0.002	<0.002	<0.002	<0.002
TK010		0.002	1.046	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
TK011		0.002	1.253	0.238	<0.002	<0.002	0.016	<0.002	<0.002	<0.002
TK014		0.002	1.337	1.543	<0.002	0.019	<0.002	<0.002	<0.002	<0.002
TK017		0.002	1.576	0.002	<0.002	0.014	<0.002	<0.002	<0.002	<0.002
TK018		0.002	0.954	0.474	<0.002	0.018	<0.002	<0.002	<0.002	<0.002
TK020		0.375	1.239	1.763	<0.002	0.029	0.125	<0.002	<0.002	<0.002
TK026		0.002	5.673	0.243	<0.002	0.037	0.06	<0.002	<0.002	<0.002
TK027		1.363	2.219	0.106	<0.002	0.024	<0.002	<0.002	<0.002	<0.002
TK028		0.002	3.23	0.002	<0.002	0.058	<0.002	<0.002	<0.002	<0.002
TK029		0.002	2.494	0.813	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
TK030		0.002	0.613	0.204	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
TK031		2.525	1.561	0.806	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
TK032		1.184	2.07	0.002	0.11	0.032	<0.002	0.065	<0.002	<0.002
WHO STD		**30**	**40-80**	**150**	**0.3**	**2**	**0.5**	**0.01**	**0.05**	**0.05**

3.2 Discussion

Direct water related diseases like cholera and dysentery occur in the Tarkwa Municipality. This is to be expected because refuse and sewage are improperly disposed off in some parts of the Municipality and run-off from these dumps is likely to end up in groundwater (Kuma and Ewusie, 2009). The introduction of the sachet water on the Tarkwa market to augment potable water supply is laudable. However, the quality of some of the water poses a health threat.

Physico-chemical analysis revealed low pH in about 50% of water samples. The low pH values measured for groundwater in the Municipality are attributed to a high rainfall and vegetation regime in the area leading to the production of high levels of carbonic and organic acids resulting in intense leaching. The geologic formations of aquifers where these waters are abstracted may also be a contributory factor. Of the metals analysed Pb concentrations were relatively high in some of the samples. High concentrations of Pb in water can affect the health of consumers because Pb is bio-accumulative. In addition to renal disease, cardiovascular problems and reproductive complications may lead to irreversible neurological damage (Madden *et al.,* 2002).

The presence of coliforms (faecal and total) and protozoan organisms in a number of the water samples is most worrying. Common protozoans found in sachet drinking water analysed include *Ascaris lumbricoides, Cyclospora cayetanensis* and *Strongyloides stercoralis* and unidentified insects larvae. *Ascaris lumbricoides* is the largest of the human intestinal roundworms that can the disease ascariasis. It is known to affect people living in sub-tropical and tropical areas with poor sanitation. Infestation can lead to death because it can cause inflammation of the peritoneum and appendix. Other symptoms include vomiting, constipation and abdominal pain. The adult worm can block the intestines when in large numbers which can be fatal (Spellman, 2003). Improper waste management practices in some areas in Tarkwa and poor hygiene practiced by some producers as evidenced in the study can lead to the introduction of such pathogens.

Cyclosparasis, a gastroenteric disease in humans, is caused by the protozoan *Cyclospora cayetanensis.* Transmission is by ingestion of faecal contaminated food or water which contains the oocysts. According to Anon. (2013) symptoms include "diarrhoea, loss of appetite, weight loss, abdominal bloating and cramping, increased flatulence, nausea, fatigue, and low-grade fever". In more severe cases it is accompanied by vomiting, substantial weight loss, explosive diarrhoea, and muscle aches (Tchobanoglous *et al*., 2002). In Tarkwa some of the wells and boreholes used in the sachet water production are located downstream of sewerage discharges. It is possible therefore that discharges from these tanks could end up in the water supply routes.

Cryptosporidium parvum causes cryptosporidiosis, a parasitic disease that affects mammalian

intestinal tract (Tchobanoglous *et al.*, 2002). Primary symptoms of *cryptosporidiosis* are acute, watery, and non-bloody diarrhoea.

Strongyloidiasis is caused by *Strongyloides stercoralis* a human parasitic roundworm (Spellman, 2003). Dermatitis, swelling and itching at the gluteal region, and mild haemorrhage at the site of skin penetration are the symptoms of the infection. Chest burns, wheezing and coughing alongside pneumonia-like symptoms (Löffler's syndrome) may result when parasite reaches the lung. Eventual invasion of the intestines could lead to burning pain, necrosis (tissue damage), sepsis, and ulcers. In severe cases, loss of peristaltic contractions may result (Anon, 2013).

4 Conclusions and Recommendations

The objective of this study was to assess the quality of sachet water produced at Tarkwa for human consumption following a cholera outbreak in 2011. The results of the study have revealed the presence of protozoan organisms and faecal matter in some of the sachet water on our markets. This observation suggests the existence of a significant level of contaminants in some of our sachet water. The result of this study support the findings of a similar study carried out in Accra by Kwakye-Nuako *et al.*, (2007) to determine the microbial quality of water on the streets.

Among the factors which potentially accounted for this observation are; improper processing and purification procedures and unhygienic handling of the sachet water after production. It was observed that in some of the production areas, workers did not wear gloves during packaging. In others, filters were not changed regularly. The organisms encountered in this study are potential pathogens associated with water related diarrhoea outbreaks.

There appears to be no standard in the water qualities produced, and so variations in the water quality occur. Sachet water produced at different times have different concentrations of individual parameters.

It should be mandatory that all sachet water producers register with the FDB and the regulations laid down for the business enforced as some operators do not comply with them. For example, not all factories have up to five filters as required in the regulations and some operators do not change the filters when they are due. Frequent and unannounced quality control checks should be conducted to ascertain the quality of water produced. In order to reduce the levels of contamination the FDB should prescribe a mandatory working gear where all persons who are employed to handle any aspect of the production process wear protective and hygienically clean apparel including disposable gloves. Additionally, heat sealing machines should be used and good disinfection methods should be employed during production. Periodic workshops should be organised for producers and distributors to sensitise them on issues related to their operations.

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Authors

Dr Samuel A. Ndur is a Senior Lecturer at the University of Mines and Technology, Tarkwa. He is currently the Head of the Environmental and Safety Engineering Department. He obtained his PhD (Environmental Geochemistry) from New Mexico Institute of Mining and Technology, USA in 2007 and MSc (Petrochemical Engineering) from Moscow Institute of Oil and Gas, CIS. His research areas are Environmental Pollution and Control, Mine Waste Characterization and Management, Arsenic Sequestration, and Water Quality Issues. He is a member of Society of Environmental Geochemistry and Health (SEGH), and International Association of Impact Assessments (IAIA).

Professor Jerry S. Y. Kuma is a Professor of Environmental Hydrogeology and Geophysics at the University of Mines and Technology (UMaT), Tarkwa. He was awarded a BSc (Hons) in Geology and Physics at the University of Ghana, Legon in 1985. He received the PG Dip and MSc (with distinction) degrees in Geophysics at Delft, The Netherlands in 1990 and 1991 respectively. In 2002, Professor Kuma was awarded the PhD in Water Resources Engineering from the Civil Engineering Department at the University of Newcastle upon Tyne, England. He is actively involved in the Hydrology of mining districts and other Water Management issues in Ghana. He is a member of the Ghana Institution of Geoscientists (GhIG), Ghana Institution of Engineers (GhIE) and the International Association of Hydrogeologists (IAH). He is also a fellow of the African Scientific Institute (ASI).

W. K. Buah holds a PhD in Waste Processing Engineering from the University of Leeds, Leeds, UK and a Master of Science Degree in Mineral Processing Engineering from the Mining Institute of Krivoy Rog, Krivoy Rog, Ukraine. He is currently an Associate Professor at the University of Mines and Technology, Tarkwa, Ghana. His current research interests include mineral processing and extractive metallurgy, waste management, pyrolysis-gasification of wastes and biomass to produce valuable products, including activated carbon for gold adsorption. He is a member of the Society for Mining, Metallurgical and Exploration Engineers (SME) and the Chattered Institute of Waste Management, UK.

Dr Jack Galley holds MD and MPH degrees from Kalinin Medical Institute, USSR in 1990 and Hebrew University, Hadassah, Jerusalem in 1998 respectively. He is a Public Health Physician Specialist and Epidemiologist. Dr Galley has worked at Korle-Bu Teaching Hospital, Accra, Effia-Nkwanta Regional Hospital, Takoradi and Essikado Hospital Sekondi. He has served as District Director of Health for 20 years, of which he was a Medical Superintendent for 12 years. He has been a WHO Independent Consultant and ORISE Research Program Fellow for the Center of Disease Control (CDC), Atlanta, USA. He was the former Municipal Director of Health Services for the Tarkwa-Nsuaem Municipality. He is currently the CEO of Benedict Hospital, Sekondi. Dr Galley's expertise and areas of interest are immunisation, disease control, surveillance and response, and operational research.