International Journal of Food Science and Nutrition
ISSN: 2455-4898, Impact Factor: RJIF 5.14
www.foodsciencejournal.com
Volume 1; Issue 6; November 2016; Page No. 46-51

Exposure and health risk assessment via sachet packaged water consumption in the Tamale Metropolis, Northern Region, Ghana

[1] Ernest Bonah, [2] Sylvester Oteng Kyei, [3] Mohammed Kasim

[1, 2] Food and Drugs Authority, Tamale, Ghana
[3] Avnash Industries Ghana Limited, Tamale Ghana

Abstract

A human health risk assessment study was conducted in the Tamale Metropolis to ascertain the risk of trace metal contamination via drinking packaged sachet water. A total of 102 PSW brands sold and produced within the Tamale Metropolis was collected between February 2014 and December 2015. Chemical analyses were performed according to the procedures outlined in the Standard Methods for the Examination of Water and Wastewater, 2000.Monte Carlo simulation based on @RISK software was used to assess health risk indicators, i.e., Chronic Dietary Intake CDI, Hazard Quotient and Hazard Index. Chronic daily intake (CDI) of the trace metals were 3.8,0.06,28.18,0.59,8.26,0.01,0.08,0.10,0.01,0.00,0.01 µg/kg/day for $NO3^{-}$, $NO2^{-}$, SO4,Fl, Cl, Pb, Fe, Mn, Zn, AS respectively. The HQ (Hazard Quotient) values for each trace metal and the HI (Hazard Index) value for all eleven trace metals were below one (0.235), indicating no non-carcinogenic risks from consumption of PSW by inhabitants in the Tamale metropolis**.**

Keywords: packaged sachet water, risk assessment, tamale, dietary intake

Introduction

Safe drinking water is a developmental agenda for many developing countries around the world. Although water supply models exist in the developed countries, the social and technical cost together with the political will power to implement these systems makes it a daunting task to adopt most of these models as a means for delivering safe drinking water (Doodo *et al.* 2006).

Packaged sachet water (PSW) which refers to water packaged in plastic sachets for consumption has become an alternate source of water in most developing nations where public drinking water is endemic (Edema *et al.* 2004) [3]. However, chemical contaminants present in water poses a public health threat to its consumers. Human exposure to trace chemical contaminants from water may cause acute or chronic health (Richardson *et al.* 2007. Funari *et al.* 2008) [4, 5]. The risk posed by these chemicals vary and depends on the precise chemical and may confer either chronic or acute toxicity and in some instances both. Humans become exposed to trace metals through direct ingestion, inhalation and dermal exposures (USEPA, 2004)

The health risk posed by most toxic chemicals in water are chronic i.e. due to cumulative exposure to the said chemical in small doses over an extended period. Human health risk assessment is vital because although most of these chemicals present in drinking water are essential for some body functions at specific doses above certain levels, it becomes toxic to the body and may lead to adverse health effects (Zoni *et al.* 2013) [23].

However, high doses of chemicals found in drinking water has been associated with Neurotoxic potential producing mental diseases such as Alzheimer's and Manganism due to high copper and manganese levels (Dieter *et al.* 2005) [6]. Demyelinating diseases in humans caused by high zinc intakes (Zatta *et al.* 2003). Acute myocardial infarction and rectal cancer resulting from high calcium levels (Yang *et al.* 2006) [8]. Trace metals like arsenic and lead have significant biological toxicity and are harmful to human health (Ab Razak *et al.* 2015) [24]. Exposure to inorganic arsenic via drinking water poses a broad range of health effects ranging from skin lesions, cancers, diabetes and cardiovascular diseases (Smith *et al.* 2009; Anetor *et al.* 2007; Abernathy *et al.* 2003) [20, 21, 22].

The contamination levels of the studied trace metals in PSW sold in the Tamale metropolis is needed to assess noncarcinogenic health risk for residents exposed to these trace metals via consumption of PSW.

The objectives of this paper are to assess the dietary intake of $NO3^{-}$, $NO2^{-}$, SO4,Fl, Cl,Pb,Fe,Mn,Zn,AS in other to estimate the health risks resulting from exposure to the chemicals via drinking of packaged sachet water in the Tamale Metropolis.

Methods

Experimental Sites

A total of 102 packaged sachet water samples was collected from 102 production facilities around the Tamale metropolis between October 2014 and December 2015. At each sampling site a bag (containing 30 pieces of a sachet's) of sachet water were taken. The samples were transported in bags and sent to the Ghana Water Research Institute (WRI) in Tamale for chemical analysis.

Fig 1: Map of Study Area

Average body weight and estimation of PSW intake

A questionnaire-based on average PSW consumption survey was conducted in the Tamale metropolis in November 2015. A total of 331 participated in the face to face survey. The selection of participants was made randomly. Demographic characteristics (Age, gender and body weight) was recorded. Weight was calculated using a scale calibrated by the Ghana Standards Authority (GSA). Photographic method (a two-way dimensional picture) was used in estimating the amount of PSW drunk in a day.

Laboratory Analyses

The chemical analyses were performed according to procedures outlined in the Standard Methods for the Examination of Water and Wastewater (APHA, 2000). A description of the methods used is shown below in Table 1.

Table 1: Summary of laboratory methods of analyses

Parameters	Method of Determination
Nitrate—N	Hydrazine reduction followed by diazotisation and colour intensity measurement at an absorbance of 520 nm
Nitrite—N	Diazotisation
Sulphate	Reaction with barium chloride and measurement at an absorbance of 420 nm
Fluoride	SPADNS method
Cations and Anions	Titrimetric method
Chloride	Argentometric method using silver nitrate
Trace Metals	Atomic absorption spectrophotometer

Exposure and risk assessment

The daily intake or dose from ingestion of water is estimated by the following equation:

$$CDI = \frac{CW\ x\ IR\ x\ EF\ x\ ED}{BW\ x\ AT}$$

CW = Concentration in water (mg/L)
IR = Ingestion rate (2 L/day)
EF = Exposure frequency (350 days/year)
ED = Exposure duration (30 years)
BW = Body weight (70 kg)
AT = Averaging time for non-carcinogens (365 days/year × ED)

To estimate noncarcinogenic risk as expressed in terms of a hazard quotient (HQ) for a single substance The HQ is a ratio that compares the estimated exposure dose or intake (I) to the RfD as follows:

Where

HQ = hazard quotient (unitless),

$$HQ = \frac{I}{RfD}$$

I = estimated intake or dose (mg kg–1 day–1),
RfD = reference dose (mg kg–1 day–1).

HQ values of less than 1 indicate an unlikely potential for adverse health effects, whereas HQ values greater than 1 indicate a concern for adverse health effects or the need for further study.

Unlike a carcinogen, the toxicity is significant only during the time of exposure, which may be one day, a few days, or years. The HQ has been defined so that if it is less than 1.0, there should be no significant risk or systemic toxicity. Ratios above 1.0 could represent a potential risk, but there is no way to establish that risk with any certainty.When exposure involves more than one chemical, the sum of the individual hazard quotients for each chemical is used as a measure of the potential for harm. This sum is called the hazard index (HI):

HI = Sum of hazard quotients

Statistical analysis

To accommodate the uncertainties associated with the calculation process, the health risks for the local population due to exposure to the chemicals were evaluated using Monte Carlo simulation technique based on @RISK software (Palisade, US) and considering 10,000 iterations. Before this process, distribution characteristics of each exposure parameter were tested according to the exposure results. A probabilistic distribution of the exposure dose was then obtained as a simulation result.

The use of Monte Carlo simulations in risk assessment provides an understanding of the degree of uncertainty and variability around a risk estimate that single-point estimates of risk cannot provide (EPA 1994b).The reference dose, or RfD, of each metal, which is the intake or dose of the metal per unit body weight per day (mg/ kg/ day) that is likely to pose no appreciable risk to human populations, including such sensitive groups as children is shown in Table 2.

Table 2: Trace Metal reference doses (RFD)

Trace Metals	NO3¯	NO2¯	SO4	Fl	Cl	Pb	Fe	Mn	zn	As	Cn
RfD(mg/kg/d)	1.6[1]	0.1[2]	1.43E□013[3]	0.006[4]	7.14E□00[5]	1.4 E-04[6]	9.00E□03[7]	0.14[8]	0.3[9]	0.00003[10]	0.0006[11]

[1, 2, 4, 6, 8, 9, 10, 11] RfD from Integrated Risk Information System, US. EPA
[5, 7] secondary maximum contaminant level (SMCL) from Integrated Risk Information System US. EPA
[3] maximum contaminant level (MCL) from Integrated Risk Information System US. EPA

Results and Discussion

Trace metal concentrations

Table 1, shows descriptive statistics of the trace metal concentrations along with the Parameter values of the fitted probability distributions, Akaike (AIC), Bayesian (BIC), Chi-Sq Statistic, K-S Statistic, A-D Statistic and their ranking in Table2. The metal concentration was found in the order SO4 > CL> NO3¯> Fl > Mn> Fe > Zn > Pb > Cn> NO2¯> As

All metal concentrations studied were below their permissible limits as compared to Ghana Standards Authority (GSA) and WHO guideline values (WHO,2008), while the Mn and Fl concentrations exceeded the allowable limits by 23% and 1% of the water samples respectively, with mean concentrations of (3359.71±13249.02). (2.46± + ∞), (24299.16±12258.74), (505.53±1822.32), (7124.63±3681.43), (5.00±1.47), (72.67±135.45), (84.60±246.48), (8.88± 12.94), (1.00±0.05), (5.05±1.03)µg/l for NO3¯, NO2¯, SO4, Fl, Cl, Pb, Fe, Mn, Zn, AS and Cn respectively.

The mean values of the metal concentration were within range concentrations as reported by other literature Divrikli and Elci, 2002 [11] Sofuoglu *et al.* 2003 [12] Tamasi and Cini, 2004 [13] Gulbahar and Elhatip, 2005 [14] Xu *et al.* 2006, Kavcar *et al.* 2009 [15]. The mean concentration of Pb in our study was 5.05±1.03µg/l higher than Fakhri *et al.* 2015 [16, 19] (3.46±0.47 µg/l and Ghaderpoor *et al.* 2009. Miranzadeh *et al.* 2011 recorded a higher mean concentration of 10.5±0.12 µg/l greater than the average of our study. Arsenic (As) mean level (1.00±0.05) µg/l was below and five times lower than WHO and EPA standard of 10.1 µg/l. The mean was also lower than Fakhri1 *et al.* 2015 [16, 19] (5.67±0.73) µg/l.

Table 1 shows that the trace elements order SO4, CL, NO3¯, Fl, Mn, Fe, Zn, Cn, and NO2¯ occur at very low concentrations, mostly below detection limits in the studied PSW samples.

Drinking water contaminated with heavy metals and other chemicals are associated with a multiplicity of human health risks (Nguyen *et al.* 2009).The Tamale metropolis and its environs heavily rely on PSW as the source of their drinking water.

Table 3: Trace metal concentration in PSW

	NO3¯	NO2¯	S04	FL	Cl	Pb	Fe	Mn	Zn	As	Cn
Minimum	**-16.27**	**-0.19**	**-5163.83**	**-3.87**	**609.90**	**-Infinity**	**-1.66**	**0.08**	**-0.21**	**1.00**	**-1.32**
Maximum	+Infinity	+Infinity	54861.32	+Infinity	+Infinity	+Infinity	+Infinity	+Infinity	+Infinity	+Infinity	+Infinity
Mean	3359.71	+Infinity	24299.16	505.53	7124.63	5.00	72.67	84.60	8.88	1.05	5.05
Mode	34.56	0.63	23200.00	9.39	5624.34	5.00	5.73	3.39	4.34	1.00	4.87
Median	817.33	2.46	24035.39	70.21	6398.90	5.00	27.46	17.26	6.44	1.03	4.97
Std. Deviation	13249.02	+Infinity	12258.74	1822.32	3681.43	1.47	135.45	246.48	12.94	0.05	1.03
Skewness	72.22	+Infinity	0.05	10.73	5.27	0.00	5.47	8.75	+Infinity	2.34	0.81
Kurtosis	81997.64	+Infinity	2.40	194.97	+Infinity	6.00	52.81	130.58	+Infinity	12.07	5.88
90%	7093.27	20.62	41075.54	992.54	10967.70	6.68	178.70	186.25	16.61	1.12	6.30
95%	13037.46	46.12	45113.30	2212.55	13233.73	7.40	295.25	375.05	22.85	1.16	6.82

N=10000

Table 4: Fitted distribution, Distribution parameters AD** Rank

	Fitted distribution	Akaike (AIC)	Bayesian (BIC)	Chi-Sq Statistic	K-S Statistic	A-D Statistic	Rank				
							AIC	BIC	Chi-Sq	K-S	A-D
NO3¯	RiskLognorm	7093.27	13037.46	48.76	0.19	3.12	1ST	1ST	4TH	7TH	3TH
NO2¯	RiskPareto	551.15	558.55	268.00	0.31	8.65	1	1	5 TIE	2	
S04	RiskTriang	2188.77	2196.37	24.36	0.09	1.12	1	1	7	2	5
Fl	RiskInvgauss	1371.68	1379.31	68.82	0.22	6.25	1	1	2	2	3
Cl	RiskLoglogistic	1911.70	1919.33	55.67	0.13	1.50	1	1	5TIE	5	1
Pb	RiskLoglogistic	337.05	342.05	777.35	0.48	*	1	1	7 TIE	1	6
Fe	RiskInvgauss	976.91	984.34	240.65	0.32	8.09	1	1	3	8	3
Mn	RiskInvgauss	992.49	999.96	104.97	0.21	5.63	1	1	2	4	4
Zn	RiskPareto	527.48	534.31	366.00	0.38	13.13	1	1	6	6 TIE	*
As	RiskPareto	-380.27	-375.23	916.02	0.97	*	1	1	1 TIE	7 TIE	*
Cn	RiskLoglogistic	329.37	336.77	804.11	0.46	30.29	1	1	3 TIE	1	6

The fit statistic could not be calculated because it diverged. This does not necessarily mean the fit is wrong, but the statistic should not be used to make a judgment

Three hundred (300) food frequency questionnaires (FFQ) based packaged sachet water consumption were used to estimate the daily and weekly consumption thus determine the dietary intake and exposure to the trace metals from drinking sachet water. These FFO's were distributed to different categories of the populace comprising school children, pregnant women, lactating mothers, adult men and adult women across the study sites.

The number of standard packaged sachet water (500 ml) drunk per day converted into litres to calculate individual Daily Intake

(DI). Additional information on demographic characteristics for each respondent was also given in the questionnaire. The body weight of the subjects was taken and recorded accordingly using a calibrated scale.

The fitted probability distribution for daily intake of PSW was RiskHistogram. The average mean consumption was 2.4l/d with a standard deviation of 0.23. Maximum and minimum consumption per day were 2.9l/d and 1.5l/d respectively. The mean value was higher than the USEPA Value of 2L/day used by Khan *et al.* 2013.Other studies had found that the daily intake rate of water was different across various regions and countries due to a different climate (Lim *et al.* 2012).A Korean study found daily intake of water was 2.56L/day (Ji *et al.* 2009)

The high consumption level in this study may be attributable to the climate as Tamale lies within the savanna belt with high temperatures with mean daytime temperatures range from 28 (December and mid-April) to 43 (March, early April) degrees Celsius

Bodyweight data assumed a RiskHistogram distribution with a mean body weight (kg) of 69.6 kg and a standard deviation of 7.8. The values for respondents' weight were found less than the value used by USEPA (70 kg) and employed in many studies (Williams *et al.* 2002; Lee *et al.* 2004) [1].

The use of probability distribution for Daily Intake and bodyweight instead of point estimates as suggested by Tokmak *et al.* 2004 and Uyak, 2006 eliminates the possibility of over or under estimation and risk.

The risk to health in this study was assessed probabilistically using Montecarlo simulation. The mean exposure concentration of the trace metals was used together with exposed population variables, and the assessment determined variables to estimate contaminant intake associated with the consumption of PSW in the Tamale Metropolis.

Table 3 shows a summary of the distribution of chronic daily intake (CDI) of the trace metals. The result indicate a CDI of 3.8,0.06,28.18,0.59,8.26,0.01,0.08,0.10,0.01,0.00 ,0.01 µg/kg/day for $NO3^{-}$, $NO2^{-}$, SO4,Fl, Cl,Pb,Fe,Mn,Zn,AS respectively. The mean CDI of $NO3^{-}$, Fl, Cn, As and Pb was greater and exceeded their respective reference dose (Rfd) values as seen in table 2 whiles the other trace metals $NO2^{-}$, SO4, Cl, and Zn were within their respective RfD limit set by the United States Environmental Protection Agency (US EPA, 2005).

Probabilistic estimation of health risks

Hazard index and hazard quotient

We estimated the probabilistic exposure distribution to the trace metals via PSW by considering the consumption rate of PSW, metal concentration in PSW and body weight. Table 4 summarises derived non-carcinogenic risks for residents in the Tamale Metropolis. The mean Hazard Quotient (HQ) values were 0.00241, 0.000328, 0.19692, 0.00981, 0.001156, 7.02E-05, 0.00945, 0.00069, 3.45E-05, 0.004062, 0.009743 for $NO3^{-}$, $NO2^{-}$, S04, Fl, Cl, Pb, Fe, Mn, Zn, As, and Cn respectively. An HQ of less than 0.2 is often considered acceptable (Health Canada 2004). The HQ values for all trace metals studied was less than 0.2 except SO4 with an HQ = 0.2.

The hazard Index (HI) which is a measure of the potential harm and a summation of the individual Hazard Quotients (Khan *et al.*, 2012) for each trace metal in the PSW was imputed since the exposure involved more than two trace metals. The HI value of 0.235 of all trace metals studied in the PSW was less than one (1) indicating no significant risk or systemic toxicity through consumption of PSW in the Tamale Metropolis.

Table 5: Probabilistic estimation of exposure to trace metals due to consumption of PSW (µg/kg/day).

	$NO3^{-}$	$NO2^{-}$	S04	FL	Cl	Pb	Fe	Mn	Zn	As	Cn
Minimum	-0.02	0.00	-6.43	0.00	0.97	0.00	0.00	0.00	0.00	0.00	0.00
Maximum	526.23	331.38	105.55	62.64	107.35	0.02	3.00	5.81	0.54	0.00	0.02
Mean	3.88	0.06	28.18	0.59	8.26	0.01	0.08	0.10	0.01	0.00	0.01
Mode	0.11	0.00	24.08	0.01	6.72	0.01	0.01	0.00	0.00	0.00	0.01
Median	0.93	0.00	27.18	0.08	7.33	0.01	0.03	0.02	0.01	0.00	0.01
Std. Deviation	13.52	3.35	15.20	2.13	4.52	0.00	0.16	0.28	0.01	0.00	0.00
Skewness	17.02	96.99	0.38	10.73	3.69	0.36	5.64	8.12	12.58	0.74	0.94
Kurtosis	480.28	9584.05	2.99	182.25	41.10	5.11	54.05	102.17	355.76	4.80	5.48
90%	8.05	0.02	48.63	1.13	13.19	0.01	0.21	0.21	0.02	0.00	0.01
95%	15.00	0.05	54.78	2.54	15.94	0.01	0.34	0.44	0.03	0.00	0.01

N=10000

Table 6: Probabilistic estimation of HQ values for all trace metals due to consumption of PSW.

	$NO3^{-}$	$NO2^{-}$	S04	FL	Cl	Pb	Fe	Mn	Zn	As	Cn
Minimum	-1.59E-05	4.23E-06	-0.04547	-2.46E-05	0.000141	2.18E-05	0.000434	2.64E-06	1.12E-05	0.002122	0.002883
Maximum	0.30978	1.8688	0.73724	1.1607	0.013977	0.000262	0.59337	0.051134	0.001612	0.009657	0.027396
Mean	0.00241	0.000328	0.19692	0.00981	0.001156	7.02E-05	0.00945	0.00069	3.45E-05	0.004062	0.009743
Mode	3.57E-05	8.52E-06	0.15722	0.000155	0.000806	6.54E-05	0.00107	2.40E-05	2.22E-05	0.003878	0.009592
Median	0.000585	1.60E-05	0.19059	0.00135	0.001023	6.81E-05	0.00272	0.000139	2.65E-05	0.00397	0.009464
Std. Deviation	0.00822	0.0189	0.10576	0.0365	0.000632	1.70E-05	0.02336	0.002048	3.43E-05	0.000691	0.002545
Skewness	16.2749	96.9895	0.3603	11.2317	3.7881	1.0307	7.9599	8.8849	16.0975	0.8157	0.8737
Kurtosis	435.5883	9,577.93	2.9715	202.2004	40.7657	6.5892	105.3758	125.6086	544.4446	5.2791	4.8072
90%	0.00512	0.0001	0.34027	0.0187	0.001817	9.20E-05	0.0212	0.001511	5.43E-05	0.004932	0.012935
95%	0.00932	0.000213	0.37865	0.042	0.002228	0.000101	0.03956	0.003086	7.38E-05	0.005298	0.014441

N=10000

Conclusion

The concentration of all trace metals was in conformity with Ghana and WHO standards, results of the probabilistic estimation of non-carcinogenic risk in the population were not significant for any of the trace metals evaluated.
However, several studies have shown that people are also exposed to these trace metals through foodstuffs and dermal exposures (Zheng *et al.* 2007; Lee *et al.* 2006). It is important to note that the exposure from these other sources must be added to estimate total risk for each trace metal.

Acknowledgement

We acknowledge all 102 sachet water companies whose products we sampled for this study. We are also indebted to residents of the Tamale metropolis who participated in the survey to determine the consumption rate of PSW.

References

1. Lee SC, Guo H, Lam SMJ, Lau SLA. Multipathway Risk assessment on disinfectionby-products of drinking water in hong kong. Environmental Research. 2004; 94(1):47-56. http://dx.doi.org/10.1016/S0013-9351(03)00067-7h.
2. Dodoo DK, Quagraine EK, Okai-Sam F, Kambo Dorsa J, Headley JV. Quality of Sachet Waters in the Cape Coast Municipality of Ghana. Journal of Environmental Science and Health. 2006; Part A 41(3):329-342.
3. Edema MO, Atayese AO, Bankole MO. Pure Water Syndrome: Bacteriological Quality of Sachet- Packed Drinking Water Sold In Nigeria. African Journal of Food, Agriculture, Nutrition and Development. 2004; 11(1):4595-4609.
4. Richardson SD, Plewa MJ, Wagner ED, Schoeny R, DeMarini DM. Occurrence, genotoxicity, and carcinogenicity of regulated and emerging disinfection by-products in drinking water: A review and roadmap for research. Mutation Research-Reviews in Mutation Research. 2007; 636(1-3):178-242.
5. Funari E, Testai E. Human health risk assessment related to cyanotoxins exposure. Critical Reviews in Toxicology. 2008; 38(2):97-125.
6. Dieter HH, Bayer TA, Multhaup G. Environmental copper and manganese in the pathophysiology of neurologic diseases (Alzheimer's disease and Manganism). Acta hydrochimica et Hydrobiologica. 2005; 33:72-78.
7. Zatta P, Lucchini R, van Rensburg S, Taylor A. The role of metals in neurodegenerative processes: aluminum, manganese, and zinc. Brain Research Bulletin. 2003; 62:15e28.
8. Yang CY, Chang CC, Tsai SS, Chiu HF. Calcium and magnesium in drinking water and risk of death from acute myocardial infarction in Taiwan. Environmental Research. 2006; 101:407e411.
9. American Public Health Association (APHA), Standard methods for the examination of water and wastewater, 20th Ed. APHA. Washington DC, 2000.
10. WHO. Guidelines for Drinking-Water Quality 3rd edition, Recommendations. World Health Organisation, Geneva, 2008, 1.
11. Divrikli U, Elci L. Determination of some trace metals in water and sediment samples by flame atomic absorption spectrometry after coprecipitation with cerium- m(IV) hydroxide. Anal. Chim. Acta. 2002; 452:231-235.
12. Sofuoglu SC, Lebowitz MD, O'Rourke MK, Robertson GL, Dellarco M, Moschandreas DJ. Exposure and risk estimates for Arizona drinking water. JAWWA. 2003; 95:67-79.
13. Tamasi G, Cini R. Heavy metals in drinking waters from Mount Amiata (Tuscany, Italy): possible risks from arsenic for public health in the province of Siena. Sci. Total Environ. 2004; 327:41-51.
14. Gulbahar N, Elhatip H. Estimation of environmental impacts on the water quality of the Tahtalıdam watershed in Izmir, Turkey. Environ. Geol. 2005; 47:725-728.
15. Kavcar P, Sofuoglu A, Sofuoglu SC. A health risk assessment for exposure to trace metals via drinking water ingestion pathway. International Journal of Hygiene and Environmental Health. 2009; 212(2):216-227.
16. Fakhri Yadolah, Mohseni Seyed Mohsen, Jafarzadeh Saeedeh, Langarizadeh Ghazaleh, Moradi Bigard, Zandsalimi Yahya, *et al.* Assessment of carcinogenic and non-carcinogenic risk lead in bottled water in different age groups in Bandar Abbas City, Iran." Global journal of health science. 2015; 7(4):286-94. doi:10.5539/gjhs.v7n4p286.
17. Miranzadeh M, Hassani A, Iranshahi L, Ehsanfard M, Heidari M. Study of Microbial quality and health metal determination in 15 brands of Iranian bottled drinking water during. 2009-2010, 2011.
18. Ghaderpoor M, Jahed G, Nazmara S. Determination of toxic trace element in bottled waters consumption in the of Tehran. Twelfth environmental Health engineering Congress, 2009.
19. Fakhri1 *et al.* Concentration of arsenic in drinking water in Bandar Abbas city and quantitative risk assessment. Int. J Curr. Microbiol. App. Sci. 2015; 4(3):1024-1034.
20. Smith AH, Steinmaus CM. Health effects of arsenic and chromium in drinking water: Recent human findings. Annu. Rev. Public Health. 2009; 30:107-122.
21. Anetor JI, Wanibuchi H, Fukushima S. Arsenic exposure and its health effects and risk of cancer in developing countries: Micronutrients as host defence. Asian Pac. J Cancer Prev. 2007; 8:13-23.
22. Abernathy CO, Thomas DJ, Calderon RL. Health effects and risk assessment of arsenic. J Nutr. 2003; 133:1536S-1538S.
23. Zoni S, Lucchini RG. Manganese exposure: Cognitive, motor and behavioral effects on children: A review of recent findings. Curr. Opin. Pediatr. 2013; 25:255-260.
24. Ab Razak NH, Praveena SM, Aris AZ, Hashim Z. Drinking water studies: A review on heavy metal, application of biomarker and health risk assessment (a special focus in Malaysia). J Epidemiol. Glob. Health. 2015; 5:297-310.
25. US EPA. Risk assessment guidance for superfund, Human health evaluation manual Part E, supplemental guidance for dermal risk assessment, Tech. Rep. EPA/540/R/99/005, Office of Superfund Remediation and Technology Innovation, US Environmental Protection Agency, Washington, DC, USA, 2004, 1.
26. Ji K, Kim Y, Choi K. Water intake rate among the general korean population. Science of the Total Environment. 2010; 408(4):734-739. http://dx.doi.org/10.1016/j.scitotenv.2009.10.076
27. Williams P, Benton L, Warmerdam J, Sheehans P. Comparative risk analysis of six volatile organic compounds in california drinking water. Environmental

Science & Technology. 2002; 36(22):4721-4728. http://dx.doi.org/10.1021/es020725y

28. Nasreen I. Khan, David Bruce, Gary Owens. Modeling Dietary Intake of Arsenic and the Associated Human Health Risk for People Living in Rural Bangladesh, International Environmental Modelling and Software Society (iEMSs) 2012 International Congress on Environmental Modelling and Software Managing Resources of a Limited Planet, Sixth Biennial Meeting, Leipzig, Germany R. Seppelt AA. Voinov S, Lange D. Bankamp (Eds.), 2012. http://www.iemss.org/society/index.php/iemss-2012-proceedings