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Study on the cationic and anionic loads of potable drinking water marketed in Bangladesh

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ABSTRACT

A survey has been conducted in order to obtain an extensive picture about the cation and anion content in bottled drinking water of Bangladesh. A number of cations like calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), potassium (K^{+}), iron (Fe^{3+}), manganese (Mn^{2+}), arsenic (As^{3+}) ammonium (NH_4^{+}) and anions like chloride (Cl^{-}), fluoride (F^{-}), nitrite (NO_2^{-}), nitrate (NO_3^{-}), sulphate (SO_4^{2-}), phosphate (PO_4^{3-}) were determined spectrophotometrically. In addition, physico-chemical parameters like pH, EC, TDS, bicarbonate alkalinity, hardness were determined. Most of the parameters were found to be within the regulatory limits of the national and international guidelines like world health organization (WHO), US-environmental protection agency (US-EPA), Canadian drinking water quality (DWQ), European Union regulation (EEC) and the Government of Bangladesh (GOB) requirements. Some of the parameters were found to be non-conformity with the several guidelines value.

KEYWORDS

Drinking water quality;
Bottled water;
Cations;
Anions;
Spectroscopy.

INTRODUCTION

Safe drinking water is a vital element to human health and survival. It is a crucial component of the most metabolic processes and serves as a solvent for body fluids[1]. Health authorities have historically suggested at least eight glasses, 168 ml each, of water per day[2,3]. Parameters for good quality drinking water typically fall under two categories: physico-chemical and microbiological. Physico-chemical parameters include pH, EC, TDS, bicarbonate alkalinity, hardness, heavy metals, trace organic compounds and turbidity[4,5]. Microbiological parameters include Coliform bacteria- E. coli, viruses, protozoa parasites and specific pathogenic species like *Vibrio cholerae*[6-8]. Chemical parameters tend to pose more of a chronic health risk through buildup of heavy metals although some components like nitrates/nitrites and arsenic may have a more immediate impact[9]. Physical parameters affect the aesthetics and taste of the drinking water and may complicate the removal of microbial pathogens.

In Bangladesh the consumption of commercially available bottled water has increased dramatically in recent years. Diplomats and other foreign nationals staying in Bangladesh, nonresident Bangladeshis (NRBs) during their visits to Bangladesh and the well to do people are frequently using these products as occasional and regular sources of drinking water. Supplying

"mineral water" is no more a fashion, rather a common practice now-a-days in hotels and restaurants, in national and international seminars, workshops, conferences, in public and family gatherings and parties. Some domestic airlines and bus transport companies deliver bottled water to their passengers. Millions of litres of bottled water are being consumed daily by the people without knowing the quality of the goods, relying on some declarations made by the manufacturers on their product labels[10,11]. No reliable, valid and comprehensive study have been done or known publicly to date in this regard having vital health and public importance. The aim of this study was to depict a picture about the drinking water quality in Bangladesh as well as to create public awareness about what is being consumed. A total number of 58 manufacturers have been recorded to date who commercialize bottled water in varied single-serving sizes and also in 20L refill multi-serving size[12]. Physico-chemical parameters like sodium, potassium, magnesium, dissolved iron, dissolved manganese and total inorganic arsenic have been determined for eleven main brands representing 59.7% of the total of known thirty seven available brands marketing products.

MATERIALS AND METHODS

To analyze cationic and anionic species as well as the physico-chemical characteristics, bottled water were collected from the real marketplace of Dhaka city on a single day (June12, 2012). A total of 38 field samples collected comprising 26 samples, 7 field duplicates and 5 field triplicates of 11 brands available on that day (TABLE 1). Brands are coded as B01(Ampang), B02(Aqua Mineral), B03(Duncan's), B04(Everest), B05(Fresh), B06(Mountain), B07(Mum), B08(Pran), B09(Samurai), B10(Yes)and B11(Trishna).

All samples in plastic bottles were transparent and free from suspended particles. As per standard methods (AWWA/APHA/WEF, 1998, USEPA, 1997 and USEPA, 1996) one portion of the sample (~200mL) was adjusted to pH<2 adding H_2SO_4 for COD and ammonium analysis. One portion of the sample (~200mL) is adjusted to pH>12 for free cyanogens (CN) analysis . And test portion of the sample was kept untreated to analyze temperature (T), pH, electrical conductivity (EC), total dissolved solids (TDS), chloride (Cl), fluoride (F), nitrite (NO_2), nitrate(NO_3), sulfate (SO_4), phosphate (PO_4) and bicarbonate alkalinity (HCO_3). Storage condition was maintained at <4^{0}C and analyses were done upon reaching the thermal equilibrium at room temperature (from 24.8^{0}C ~27.1^{0}C). All analyses were completed within the recommended timeframe stated in the standard methods. In addition to appropriate reagent blanks a total of 49 samples consisting of 38 field samples, 8 laboratory duplicates, 3 laboratory triplicates were analyzed as per applicable validation requirements (TABLE 1). The glassware including burettes and pipettes were made of Class-1 type glass (Pyrex TM). The pH meters and the conductivity meters combined with temperature sensors were from Oakton, Singapore. The cations Na^+, K^+, Ca^{2+}, Mg^{2+}, Fe^{3+} and Mn^{2+} were determined using Flame Atomic Absorption Spectrometer Model FAAS-6601 (Shimadzu, Japan) with Hamamatsu Photonics K.K Japan Hollow Cathode Lamps for individual elements to work at 589.0nm for Na.,766.5nm for K,422.7nm for Ca,285.2nm for Mg,248.3nm for Fe,279.5nm for Mn . Total inorganic arsenic (As) was determined by flame Atomic Absorption spectrophotometer (Shimadzu Model 6601) with Shimadzu Hydride Vapor Generator HVG-1 unit following FAAA-HVG technique .The Hamamatsu Hollow Cathode Lamp

TABLE 1 : Field and laboratory sampling size

Brand	Sample (S)	Duplicates (D)	Triplicates (T)	Total
Brand 01	1	-	-	1
Brand 02	3	1	1	5
Brand 03	2	1	1	4
Brand 04	2	-	-	2
Brand 05	2	1	1	4
Brand 06	3	1	-	4
Brand 07	2	1	1	4
Brand 08	3	-	-	3
Brand 09	3	1	-	4
Brand 10	4	-	-	4
Brand 11	1	1	1	3
Total Field Samples	26	7	5	38
Total Laboratory Samples	38(field samples)	8(lab duplicates)	3(lab triplicates)	49

TABLE 2a : Physical parameters of the water samples (m±s, where m=best estimate of population mean and s=best estimate of population standard deviation)

Brand	Temp.	pH	TDS (mg/L)	EC (µs/cm)	Hardness (as mg $CaCO_3$/L)	COD (as $mgO_{2/L)}$	at Temp °C
Brand 01	26.4±0.6	7.3±0.1	318. ±14	497±22	162.9±0.1	<20	26.2
Brand 02	26.7±0.6	6.9±0.1	361±11	564±16	23.4±7.0	<20	26
Brand 03	26±0.6	8.2±0.1	186±12	290±19	94.±4.8	<20	25.9
Brand 04	26.2±0.6	7.8±0.1	157±5.	245.±8.	38±13.	<20	25.9
Brand 05	26±0.6	7.2±0.1	634±31	990.±49.	253±42.	<20	25.4
Brand 06	26±0.6	9.2±0.1	58±5	90.±8	22.6±4.2	<20	26.2
Brand 07	25.5±0.6	7.5±0.1	163±5	254.±8	83±9.7	<20	25.3
Brand 08	26±0.6	6.4±0.1	166±16.	260±25	39.±8.8	<20	25.8
Brand 09	25.7±0.6	6.7±0.1	8.6±3.6	13.5±5.7	1.6±0.8	<20	25.7
Brand 10	25.1±0.6	7.8±0.1	15.3±1.3	23.9±2	2.1±0.6	<20	26
Brand 11	25.1-26.7	6.4-9.2	493. ±7.	770.±11.	249±2.8	<20	25.2
Range of Means		6.5-8.5	8.6-634	13.5-990.	1.6-249	<20	
WHO Guideline		6.5-8.5†	1000†		500†	-	
ValueEPA MCL		6.5-8.5‡	500‡			-	
Canadian DWQ[a] Guideline		6.5-8.5*	≤500			-	
EEC		6.5-8.5		400[b]	60[e](MRC)mg Ca or equivalent cations/L	-	
GOB	20-30	6.5-8.5	100		200.500	4	

†AQ=Aesthetic Quality, ‡S=Secondary MCL, a=DWQ Canadian Drinking Water Quality Guideline, *AO=Aesthetic Objective, b GL=Guide Level, [c]MAC=Maximum Admissible Concentration, d GV=Guideline Value, NGV=No Guideline Value, GOB: Bangladesh Gazzet Additional August 28, 1997, Tofcil-3, Rule-12: Allowable Limit of Drinking Water and Allowable Limit of Groundwater

TABLE 2b : Cationic constituents (m±s, where m=best estimate of population mean and s=best estimate of population standard deviation)

Brand	Na^+ (mg/L)	K^+ (mg/L)	Ca^{2+} (mg/L)	Mg^+ (mg/L)	Dissolved Fe (mg/L)	Dissolved Mn (mg/L)	Total Inorganic As (µg/L)
Brand 01	34.6±0.3	1.9±0.04	36.5±0.26	17.4±0.03	<0.2	0.56±0.01	<0.2
Brand 02	103±8.9	1.9±0.39	6.1±1.9	1.98±0.57	<0.2	<0.2	<0.2
Brand 03	26.2±3.5	2.2±0.06	27.3±1.5	6.3±0.24	0.19±0.05	<0.2	<0.2
Brand 04	34.8±4.5	2.5±0.57	7.8±2.7	4.41±1.52	0.28±0.01	<0.2	<0.2
Brand 05	90±4.1	2.7±0.04	66.0±7.2	21.3±5.88	0.18±0.08	<0.2	1.9±0.8
Brand 06	14.4±6.3	1.6±0.13	5.2±1.2	2.34±0.29	0.19±0.13	<0.2	<0.2
Brand 07	9.9±2.3	1.7±0.1	30±3.5	2.04±0.24	0.11±0.05	<0.2	<0.2
Brand 08	36.8±1.5	1.1±0.05	10.8±3.2	2.98±0.2	<0.2	<0.2	<0.2
Brand 09	1.3±0.8	0.2±0.11	0.51±0.23	0.07±0.06	<0.2	<0.2	<0.2
Brand 10	5.4±1.4	0.3±0.04	0.6±0.16	0.14±0.04	<0.2	<0.2	<0.2
Brand 11	52±1.2	6±0.1	68±0.6	19.5±0.32	<0.2	<0.2	<0.2
Range of Means	1.3-103	0.2-6	0.51-68	0.07-21.3	<0.2-0.28	<0.2-0.56	<0.2
WHO Guideline Value	NGV	---	---	---	0.3†	0.1†	25[c]
EPA MCL	20**	---	---	---	0.3‡	0.05‡	10

Brand	Na^+ (mg/L)	K^+ (mg/L)	Ca^{2+} (mg/L)	Mg^+ (mg/L)	Dissolved Fe (mg/L)	Dissolved Mn (mg/L)	Total Inorganic As (µg/L)
Canadian DWQ[a] Guideline	≤20.0*	---	---	---	≤0.3*	≤0.05*	
EEC	20[b]	10[b]	100[b]	30[b]	0.05[b] 0.20[c]	0.02[b] 0.05[c]	50
GOB	200	12	75	30	0.3-1.0	---	50

****DWEL= Drinking Water Equivalent Level, USEPA Health Advisories for Adult of weighing 70kg consuming water 2L/day(x) , MCL=(RfD) X DWEL, RfD= Reference Dose=1.75 for Na; RfD=(NOAEL or LOAEL)/Uncertainty factors, DWEL(mg/L)=(RfD X Body weight (kg)/ drinking water volume (L/day); †AQ=Aesthetic Quality, ‡S=Secondary MCL, a = DWQ Canadian Stinking Water Quality Guideline, *AO = Aesthetic Objective, bGL= Guide Level, [c]MAC**

TABLE 2c : Anionic constituents (m±s, where m=best estimate of population mean and s=best estimate of population standard deviation)

Brand	Chloride (mg/L)	Fluoride (mg/L)	Ammonium (mg/L)	Free CN (mg/L)	Nitrite (mg/L)	Phosphate (m±g/L)	Nitrate (mg/L)	Sulfate
Brand 01	4.8±0.8	0.5±0.01	0.24±0.02	<0.009	<0.02	0.25±0.02	<0.02	<5.0
Brand 02	65±3.	0.47±0.02	0.14±0.05	<0.009	<0.02	0.37±0.05	37.±12	<5.0
Brand 03	4.3±2.21	0.39±0.03	0.13±0.03	<0.009	<0.02	0.24±0.05	0.3±0.1	<5.0
Brand 04	24±1.4	0.43±0.03	0.12±0.01	<0.009	<0.02	0.33±0.02	9.7±1.1	<5.0
Brand 05	251.±24.5	0.42±0.01	<0.1	<0.009	<0.02	0.16±0.03	0.39±0.1	<5.0
Brand 06	3.27±0.66	0.39±0.05	0.15±0.04	<0.009	<0.02	0.4±0.06	3.4±0.7	<5.0
Brand 07	28±3.	0.44±0.02	<0.1	<0.009	<0.02	0.14±0.02	3.4±0.1	<5.0
Brand 08	5.1±0.9	0.56±0.02	<0.1	<0.009	<0.02	0.38±0.07	0.8±0.7	<5.0
Brand 09	0.63±0.1	<0.1	<0.1	<0.009	<0.02	0.19±0.04	0.8±0.7	<5.0
Brand 10	1.1±0.2	0.11±0.01	<0.1	<0.009	<0.02	<0.1	0.3±0.1	<5.0
Brand 11	108.±7	0.55±0.01	<0.1	<0.009	<0.02	0.16±0.05	17.±0.7	<5.0
Range of Means	0.63-251.	<0.1-0.56	<0.1-0.24	-	-	<0.1-0.38	<0.2-37	-
WHO Guideline Value	245†	1.5		0.1			10	400†
EPA MCL	250‡(final)	4.0 2.00‡(final)		0.2(MCLG) 0.2			10.0 10.0d	400 or 500
Canadian DWQ[a] Guideline	≤250	1.5[c]					45c	≤500* -
EEC	25[b]		0.005[b] 0.5[c]	0.2[c]	0.1[c]		25[b] 50[c]	25[b] 250[c]
GOB	150-600[g]	1.0	0.5	0.1	<1	6.0	10	400

for arsenic used at 193.7nm. The anions chloride (Cl^- at 360 nm), fluoride (F^- at 525.4nm), free cyanogens (CN^- at 612nm), sulfate (SO_4^{2-} at 460 nm), phosphate (PO_3^{-2} at 709nm) and ammonium nitrogen (NH_4^+ at 637nm) were measured via UV-VIS spectrophotometer Model UV mini-1240(Shimadzu Japan)and Shimadzu Water Analysis Program Pack having built-in calibration curves using reagents and pillows from Kyoritsu Chemical – Check Lab., Corp., Japan. All reagents, buffers, and calibration standards and QC check samples were collected from Merck; Germany, Fisher Scientific; UK, Eutech Instruments; Singapore, Sigma; USA, HDH Chemicals Ltd.; UK Fluka; Germany, Lancaster; UK and Certiprex; USA . Finally CRM TMDA 53.2 was collected from Environment Canada, National Water Research Institute, Canada/Thermolyne E-pure system.

RESULTS AND DISCUSSIONS

Results of the studied parameters of the 11 brands under investigation have been presented in TABLE 2a, 2b and 2c. Regulatory guidelines and MCL values set by WHO[7,8], USEPA[3,7,8], Canadian authority[8], EEC[8] and GOB[11] have been shown in the table for convenience as most of the manufacturers claimed that their products met the international stan-

dards. Ranges of means for each parameter are also given in the table.

From the TABLE 3 it is clear that the values of pH, EC, NH_4, NO_3, Cl, HCO_3, and hardness exceed the EEC Guideline whereas the pH, NO_3 and hardness values exceed the GOB Guideline. The pH and Cl values exceed the WHO guideline whereas the pH value is the only exceeding value in case of EPA MCL. K, Ca, Mg, Mn and As are within the permissible limits of the international guidelines. The values of Fe are also within the international guideline values except for the EEC guideline. The values of Na exceed the regulatory limits for EPA MCL, Canadian DWQ and EEC guidelines.

TABLE 3 : Summary on the studied brands exceeding the regulatory limits/ranges

Parameter	pH	EC	Sodium (Na)	Iron (Fe)	NH_4	NO_3	Cl	HCO_3	Hardness
Above WHO Guideline value (%)	18% (out of range)						9%		
Above EPA MCL (%)	18% (out of range)		63.6% (Health advisory limit)						
Above Canadian DWQ[a] Guideline (%)	18% (out of range)		63.6% (AO)					27.3% (<MRC)	
Above EEC (%)	18% (out of range)	27.3%	63.6% (>GL0)	36.4% (>GL0)	45.5% (>GL)		45.5%		54.5% (<MRC)
Above GOB (%)	18% (out of range)					27.3%			81.8% (out of range)

From the analysis results, it is evident that the parameters like pH, EC, Na^+, $Fe^{2+, 3++}$, Cl^-, NO_3^- do not conform to the regulatory values. This implies that consumer rights are not preserved by the current practices followed by the manufacturers of bottled water of Bangladesh. The regulatory measures are not enough and effective to protect the public health and environment. From the concluding point of view, the problem is due to the lack of proper knowledge and ignorance to technology and management. This crisis might be overcome through the introduction of applicable industrial Quality Assurance and Quality Control (QAQC) under the frame of Total Quality Management (TQM) system. The government should take effective measures to have a Safe Water Act within which a Safe Water Regulatory Body will be formed. The Govt. should enact regulations including the consumer's right protection laws and enforce product safety regulations from any central line ministry or authority.

CONCLUSION

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