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Quality assessment of the non-carbonated bottled drinking water marketed in Bangladesh and comparison with tap water

Ismail M.M. Rahman [a, *], Suman Barua [b, c], Rasel Barua [d], Rajesh Mutsuddi [e], M. Alamgir [f], Faridul Islam [g], Zinnat A. Begum [a, h], Hiroshi Hasegawa [i]

[a] Institute of Environmental Radioactivity, Fukushima University, 1 Kanayagawa, Fukushima City, Fukushima 960-1296, Japan
[b] Graduate School of Natural Science and Technology, Kanazawa University, Kakuma, Kanazawa 920-1192, Japan
[c] Department of Applied and Environmental Chemistry, University of Chittagong, Chittagong 4331, Bangladesh
[d] Department of Microbiology, University of Chittagong, Chittagong 4331, Bangladesh
[e] Department of Chemistry, University of Chittagong, Chittagong 4331, Bangladesh
[f] Department of Soil Science, University of Chittagong, Chittagong 4331, Bangladesh
[g] Analytical Research Division, Bangladesh Council of Scientific and Industrial Research Laboratories, Chittagong 4220, Bangladesh
[h] Department of Civil Engineering, Southern University, 739/A Mehedibag Road, Chittagong 4000, Bangladesh
[i] Institute of Science and Engineering, Kanazawa University, Kakuma, Kanazawa 920-1192, Japan

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ABSTRACT

The perception of choosing bottled water over tap water for drinking is based on the expectation that it will be of superior quality, more palatable and free from health hazards. The quality of bottled drinking water of 14 different brands as sold in Bangladesh market are evaluated in the current work in terms of the physical and aggregate properties, non-metal inorganic constituents, metal concentrations and microbial contents. The experimental values are compared with the information printed on the labels and regulatory recommendations from the national and international authorities. The experimental values for physical and aggregate properties and non-metal inorganic constituents are either lower or within the range of regulatory limits ($p < 0.05$). The heterotrophic plate count and total coliform count confirms that the bottled waters are microbiologically safe. A total of 24 elements are checked and the content of Al, which is an aesthetic hazard, is found higher than the permissible range, while the concentration of Pb, which is a potentially toxic element, is not significantly different ($p < 0.05$) from the guideline values. The data printed on the bottle labels are inconsistent and not informative enough and does not correspond to the real scenario of constituents in the packaged water. A comparison to the tap water quality confirms that the bottled waters possess better quality regarding aesthetic considerations, microbial hazards, and Pb contaminations. The experimental data of the bottled waters are further compared with the mineral water classification system. The characteristics are matched with the very low or low mineral content category with a hint of saline character and very soft water-hardness in most, followed by a suitability for low-sodium diets.

1. Introduction

Water was not that popular as a packaged food item even a decade ago. The scenario changed rather dramatically over the years, and millions of liters of water are now available to the consumers under a many numbers of different brand names (over 5000) in various packaging and containers (Diduch, Polkowska, & Namiesnik, 2011). The global bottled water market regarded as the fastest-growing and most dynamically expanding section of the non-alcoholic beverage sector (Bong, Ryu, & Lee, 2009), and a greater increase rate is assumed considering the population growth, environmental pollution, and climate change (Baumann, 2001).

The promotional activities of food conglomerates have discouraged people from drinking municipal water and put forward the bottled water as a healthier option. In addition to the effective sales campaigns, the consumer preferences towards the

* Corresponding author.
E-mail addresses: immrahman@ipc.fukushima-u.ac.jp, I.M.M.Rahman@gmail.com (I.M.M. Rahman).

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flavorsome alternative to the water from structured supply systems or perception conferring higher social status have contributed to the increased sale of mineral water (de Beaufort, 2007; Semerjian, 2011). The belief about the beneficial medicinal and therapeutic effects of natural mineral waters create a preference for the water in a bottle over that comes from the tap even though the market is flooded with the pseudo-mineral waters (Semerjian, 2011). Besides, concerns have been raised about the quality of bottled water considering various reasons, such as, probability of contamination during the production flow process, transportation or at storage conditions (Al-Saleh, Shinwari, & Alsabbaheen, 2011; Bharath et al., 2003; Diana & Dimitra, 2011; Kokkinakis, Fragkiadakis, & Kokkinaki, 2008), illegal re-filling of already used bottles from the unhygienic water sources (Herath, Abayasekara, Chandrajith, & Adikaram, 2012), and violation of action levels for the water-quality parameters (Karamanis, Stamoulis, & Ioannides, 2007).

The domestic bottled water industry in Bangladesh made a remarkable growth in the past five years due to the change in perception of inhabitants, traveling and need of treated water to meet the target of water facility improvement (Islam & Habib, 2009; Mordor Intelligence, 2015; Shimul, Kulsum, & Jahed, 2013). The groundwater abstracted from drilled wells processed via filtration, boiling, chlorination, deionization or reverse osmosis treatments are the sources of bottled water marketed in Bangladesh, while most are specified as *mineral* water (Rahman et al., 2012). Although the bottled water industry in Bangladesh receiving an increasing consumer base, there have been few reports with an emphasis on the microbiological quality (Ahmed et al., 2013; Khan, Saha, & Kibria, 1992; Majumder, Islam, Nite, & Noor, 2011; Rahman et al., 2012), while an overall quality assessment report is yet to be available. Therefore, we aimed to analyze the physical and aggregate properties, inorganic non-metal and metal constituents and microbiological characteristic of several non-carbonated bottled water marketed in Bangladesh. The objective includes the checking of the accuracy of label information of the bottled waters, the variations in quality with that of municipal supply waters (tap water), and to compare the experimental data with the corresponding recommendations from the authority for Bangladesh National Drinking Water Quality Standards (BNDWQS), World Health Organization (WHO), US Environmental Protection Agency (US-EPA), European Union (EU), International Bottled Water Association (IBWA) and U.S. Food and Drug Administration (US-FDA) with a focus on the projected health impacts.

2. Experimental

2.1. Samples

The samples used in the study include fourteen (14) bottled water brands and three different samples (bottles) of each brand ($n = 3$). The samples were purchased from the different registered retail stores located within the Chittagong city of Bangladesh maintaining a collection interval of seven or more days (October to December 2015). The bottled waters were sealed by the manufacturers when purchased, which were later refrigerated, treated with preservatives and/or analyzed immediately following the standard protocols (Clesceri, Greenberg, & Eaton, 1998).

2.2. Instruments, materials and methods

2.2.1. Water-quality parameters

Analytical reagent grade chemicals were used throughout, which are procured from Kanto Chemical (Tokyo, Japan) unless mentioned otherwise. The stock solutions of the standards and other reagents were diluted to prepare the working solutions using ultrapure water of resistivity >18.2 MΩ cm as produced using an Arium Pro UV water purification system from Sartorius Stedim Biotech GmbH (Göttingen, Germany).

A HI 98129 combo meter from Hanna Instruments (Woonsocket, RI) used for the measurements of pH, electrical conductivity (EC) and total dissolved solids (TDS). The dissolved oxygen (DO) contents were measured using a Jenway DO Meter from Bibby Scientific (Staffordshire, UK). The titrimetric techniques were used to determine the contents of total hardness (TH), total alkalinity (TA) and chloride, while spectrophotometric measurements using a double-beam UV–Visible spectrophotometer (Model 1800) from Shimadzu (Kyoto, Japan) were used for the determination nitrate and nitrites (Clesceri et al., 1998). Each of the analysis were performed in triplicates and averaged.

2.2.2. Microbiological quality

The heterotrophic plate count (HPC) by pour plating technique was used for analyzing the bacterial count in bottled water, and the most probable number (MPN) method was followed to assess the total coliform count (TCC) (Clesceri et al., 1998; Dubey & Maheshwari, 2011). One mL of water sample was transferred to each petri plate, and nutrient agar medium was poured followed by incubation at 37 °C for 24 h (Van Soestbergen & Lee, 1969). The plates were then checked for bacterial growth after the incubation period, which was recorded as colony forming unit per mL (cfu mL^{-1}). Three replicate from each sample carried out simultaneously, and an averaged value was reported. In the MPN method, lactose broth medium was used for inoculation, and 10, 1 and 0.1 mL of samples, respectively, were inoculated in 10 mL of medium, but double-strength medium was used for 10 mL sample. Three replicate of mediums for each dilution were prepared and incubated at 35 °C for 24 h, which was later observed for any gas production in the Durham-tubes. The presences of pathogens were examined by streaking of inoculums from TCC positive sample containing test tubes. The selective media used were thiosulfate-citrate-bile salts-sucrose agar media for *Vibrio* spp., Eosin methylene blue agar media for *E. coli*, bismuth sulfite agar for *Salmonella* spp., and McConkey agar for *Klebsiella* spp. The grown colonies on the selective agar media were then transferred to nutrient agar slants and preserved for further biochemical characterization, and the results were then compared to the description in Bergey's Manual of Determinative Bacteriology (Buchanan & Gibbons, 1974). The media used for microbiological analysis were procured from Hi-Media (Mumbai, India).

2.2.3. Metal constituents

The concentration of metals was measured using the iCAP 6300 inductively coupled plasma optical emission spectrometer (ICP-OES) from Thermo Fisher Scientific (Waltham, MA). The ICP-OES instrument used 1.15 kW radio frequency power at the EMT duo quartz torch, the gas flows in the plasma, auxiliary and nebulizer maintained, respectively, at 12, 1 and 0.5 L min^{-1} and the integration time was 30 s. Each of the measurements were set to repeat three-times.

The standards used for metal analysis were the arsenic standard solution and ICP multi-element standard solution IV consisting of 23 elements (Ag, Al, B, Ba, Bi, Ca, Cd, Co, Cr, Cu, Fe, Ga, In, K, Li, Mg, Mn, Na, Ni, Pb, Sr, Ti and Zn) in diluted nitric acid from Merck KgaA (Darmstadt, Germany).

The separation pre-treatment, while necessary, was performed using a filtration assembly consisting of an MAS-1 suction system from AS ONE (Osaka, Japan) and a 0.45 μm acetate-mixed-ester membrane filter from Advantec (Tokyo, Japan).

2.2.4. Laboratory wares

The low-density polyethylene bottles from Nalge Nunc (Rochester, NY), Digi TUBEs polypropylene test tubes from SCP Science (Quebec, Canada), and micropipette tips from Nichiryo (Tokyo, Japan) used as laboratory wares. The washing protocol of the laboratory wares includes an overnight soaking in 5% solution of Scat 20X-PF alkaline detergent from Nacalai Tesque (Kyoto, Japan) followed by a night long dipping in a solution of 3 mol L^{-1} HCl, and a pre-washing with ultrapure water preceding to each of the above steps.

2.2.5. Statistical analysis

All statistical analyses were performed using IBM SPSS Statistics 23.0 (IBM Corporation, Armonk, NY). For the data comparison, one-way ANOVA was performed using the general linear model, where the sample identities were fixed, and the water-quality parameters were the dependent variable. The means were compared using Duncan's multiple range test at $p = 0.05$.

3. Results and discussion

3.1. Water-quality parameters: experimental data vs. regulatory norms

3.1.1. Physical and aggregate properties

The physical and aggregate properties of water represent those water-quality parameters, which traditionally classified as physical properties either inherently or at least traditionally (Clesceri et al., 1998). We have measured the following physical and aggregate properties of the bottled waters marketed in Bangladesh: EC (μs cm^{-1}), TDS, (mg L^{-1}), TH (mg L^{-1}) and TA (mg L^{-1}).

Electrical conductivity (EC) is a measure of the ions present in water, as the conductivity increases with the number of ions, while it does not tell us what specific ions are present. It is used to determine mineralization, noting the variation in water-quality and determining the number of treatment chemicals to be added to a water sample (Ritter, 2010). The distribution of EC values in the different bottled waters marketed in Bangladesh were ranged from 1.99 to 443 μS cm^{-1} and 50% of the samples have EC > 100 μS cm^{-1} (Table 1). The EU only suggested a maximum admissible concentration (MAC) limit of 250 μS cm^{-1} for DWs and one sample (S11) have a notably higher value of 443 μS cm^{-1} compared to that limit, and the other values, except S14, are significantly lower ($p < 0.05$). However, the averaged EC (118 μS cm^{-1}) of the bottled waters and the regulatory value is not significantly different ($p < 0.05$) (Table 4).

TDS in natural waters consists predominantly of carbonates, bicarbonates, chloride, sulfate, Ca, Mg, Na and K, while dissolved metals and dissolved organic matter represent a small percentage (Ritter, 2010). The TDS content in natural waters is varied from less than 30 to as much as 6000 mg L^{-1}, depending on the solubility of minerals in different geological regions (WHO/UNEP & GEMS, 1989). The physical and chemical nature of drinking-water (DW) are changed due to the intrusion of TDS, which possibly create inferior palatability and may induce an unfavorable physiological reaction in the transient consumer (Bruvold & Ongerth, 1969; WHO, 2003c). The rates of total mortality were reported to be inversely correlated with TDS levels in DWs (Craun & McCabe, 1975; Crawford, Gardner, & Morris, 1968). However, no recent data on health effects associated with the ingestion of TDS in DWs appear to exist. It is widely agreed that the TDS content in DWs should not exceed 500 mg L^{-1} to be palatable, while no health-based guideline value (GV) is proposed for TDS by WHO (WHO, 2003c). The BNDWQS for TDS is set at 1000 mg L^{-1}, while the limit suggested by EPA, IBWA and FDA is 500 mg L^{-1} (Table 4). The TDS contents in maximum bottled waters (~80%) marketed in Bangladesh are below 100 mg L^{-1} (Table 1), and all the values are significantly lower ($p < 0.05$) than the regulatory suggestions.

The principal sources of TH in natural water are dissolved polyvalent metallic ions from sedimentary rocks, seepage, and runoff from soils. The predominant species of the cations are Ca and Mg, although other cations, e.g. Ba, Fe, Mg, Sr, and Zn, also contribute (WHO, 2003b). There is not enough convincing evidence to correlate between TH in DWs and adverse health effects in humans (WHO, 2004b). In contrast, an inverse relationship between the TH in DWs and cardiovascular disease has been reported (Dzik, 1989; Leoni, Fabiani, & Ticchiarelli, 1985; Masironi, Piša, & Clayton, 1979; Smith & Crombie, 1987). Some studies suggest that

Table 1
Comparison of water-quality parameters and microbiological quality of bottled waters marketed in Bangladesh based on the experimental data. The mean values in the same rows for the data-subsets of a parameter with identical letters are not significantly different at $P \leq 5\%$.*

Parameters	S. No.	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14
	Brand	Confidence	Fresh	Ananda	Pacific	Yes	Mum	Jibon	Pran	Mamia	Aquafina	Spa	Muskan	Acme	Dada
Physical and aggregate properties															
EC	Mean	8.6 a	144 f	20.4 b	37.8 c	28.5 b, c	193 h	127 e	96.4 d	10.6 a	2.0 a	444 j	154 g	136 f	246 i
(μs cm^{-1})	SD	2.1	10.3	0.5	3.2	2.2	4	5.7	5.2	0.8	2.1	9.2	8.9	5.1	6.4
TDS	Mean	3.8 a, b	73.0 g, h	11.1 b, c	20.2 d	15.3 c, d	102.5 i	64.2 f	49.3 e	5.7 a, b	1.7 a	220 k	77.9 h	67.5 f, g	120 j
(mg L^{-1})	SD	0.6	3.1	0.2	0.1	0.2	7.6	4.6	6.5	1.1	0.8	7	6.2	3.4	3.2
TH	Mean	1.90 a, b	6.20 b	1.85 a, b	2.80 a, b	0.90 a	77.5 e	45.0 d	13.0 c	0.90 a	4.08 a, b	138 f	0.80 a	0.85 a	4.20 a, b
(mg L^{-1})	SD	0.14	0.28	0.21	0.28	0.14	3.54	4.24	2.83	0.14	4.12	4.2	0.28	0.21	1.7
TA	Mean	2.4 a	13.5 c	6.3 b	18.0 d	13.5 c	46.0 f	56.3 h	52.0 g	4.0 a, b	2.3 a	16.3 c, d	2.3 a	72.3 i	30.5 e
(mg L^{-1})	SD	0.1	2.1	1.8	2.8	2.1	1.4	1.8	2.8	1.4	0.4	1.8	0.4	0.3	0.7
Inorganic non-metal constituents															
pH	Mean	7.29 c, d	7.25 c, d	6.66 a	7.0 b, c	6.77 a, b	7.22 c, d	7.16 c, d	7.40 d	7.35 c, d	7.09 b, c, d	7.18 c, d	7.04 b, c	7.28 c, d	7.19 c, d
(pH units)	SD	0.03	0.03	0.01	0.01	0.29	0.04	0.07	0.17	0.03	0.08	0.56	0.14	0.24	0.14
Chloride	Mean	1.61 a	45.1 d	3.53 a	11.4 b	9.62 b	23.5 c	12.4 b	11.7 b	1.46 a	0.46 a	57.0 e	55.0 e	3.31 a	56.4 e
(mg L^{-1})	SD	0.24	4.07	0.22	2.8	0.55	1.7	1.6	1.2	0.40	0.14	2.81	3.5	0.6	4.6
DO	Mean	5.2 b	4.8 a	4.8 a	4.8 a	4.8 a	5.4 b, c	5.2 b	5.4 b, c	5.6 c, d	5.6 c, d	6.2 e	5.2 b	5.2 b	5.8 d
(mg L^{-1})	SD	0.14	0.16	0.16	0.16	0.16	0.14	0.14	0.14	0.13	0.13	0.12	0.14	0.14	0.13
Microbiological quality															
HPC	Mean	ND	ND	37 a	ND	ND	ND	ND	ND	ND	ND	46 a	57 b	ND	39 a
(cfu L^{-1})	SD			1								8	13		6

*ND' stands for 'Not Detected.' The experimental data for nitrate and nitrite concentrations (mg L^{-1}), which are inorganic non-metal constituents, and the data for the total coliform count (TCC; MPN-100 mL^{-1}) is not shown in the comparative data table due to the contents below detectable limits in all the samples.

DWs with a TH of <75 mg L^{-1} may have an adverse effect on mineral balance, but detailed studies are not available (WHO, 2003b). The TH in DWs above 500 mg L^{-1} is considered to be aesthetically unacceptable, although this level is tolerated in some communities (WHO, 2003b; Zoeteman, 1980). Although a maximum TH of 138 mg L^{-1} was detected in one sample of bottled waters (S11), nine-samples (S1, S3, S4, S5, S9, S10, S12, S13, S14) out of total fourteen have TH below 5 mg L^{-1}, which are not significantly different at $p < 0.05$ (Table 1). The BNDWQS for TH in DWs is 200–500 mg L^{-1} as $CaCO_3$ and no GV is stated by WHO or any other regulatory agencies. The TH of bottled waters marketed in Bangladesh is significantly lower ($p < 0.05$) than the regulatory upper limit of BNDWQS (Table 4).

The TA of waters, which is a measurement of its buffering capacity or ability to react with strong acids at a designated pH, is taken primarily as an indication of the concentration of carbonate, bicarbonate, and hydroxide contents. The contributions from borates, phosphates, silicates, or other bases also considered if these are present (Clesceri et al., 1998). The bottled waters have a mean TA level of below 20 mg L^{-1} in 65% cases, and the values are significantly different at $p < 0.05$ (Table 1). There are no proposed health-based regulatory GVs for TA in DWs (Table 4).

3.1.2. Inorganic non-metal constituents

The pH is a measure of the acid-base equilibrium and, in most natural waters, is controlled by the carbon dioxide–bicarbonate–carbonate equilibrium system. It is hard to ascertain any direct relationship between human health and the pH of DWs even though pH has a close association with other water-quality aspects, e.g., taste, odor and appearance. The optimum water-pH will vary depending on the composition and distribution of system components, but expected to remain within the range of 6.5–9.5 (WHO, 2007). WHO does not propose a health-based GV for pH, while US-EPA included pH in the list of secondary drinking water standards setting a maximum contaminant level (MCL) value ranged between 6.5 and 8.5. The bottled water pH's are significantly different ($p < 0.05$) than the lower or upper limits of EPA-MCL, even though the values remain within the range (Tables 1 and 4).

Chlorides are commonly available in natural waters as salts of Na, K and Ca (WHO, 2003a). The toxicity due to chloride was not observed in humans except in the special case of impaired NaCl metabolism, such as, in congestive heart failure (Wesson, Erslev, Mulrow, & Goffinet, 1969). There is no convincing data regarding the effect of prolonged high chloride intake through diet, and it is anticipated that a healthy individual can tolerate a larger chloride intake if concomitant intake of fresh water is ensured (WHO, 1978). A detectable taste in water can occur if chloride present more than about 250 mg L^{-1} but no health-based GV is proposed for chloride in DWs (WHO, 2003a). The US-EPA mentioned it as a nuisance chemical-species and proposed an MCL of 250 mg L^{-1}, which is similar to the standard of quality (SOQ) limit set by IBWA and US-FDA for bottled waters, while the BNDWQS suggested acceptable range is 150–600 mg L^{-1}. The chloride content in the bottled waters is in the range of 0.32–61 mg L^{-1}, which are significantly lower ($p < 0.05$) than the BNDWQS, EPA-MCL, and SOQs of IBWA or FDA (Tables 1 and 4).

The sum of nitrate and nitrite ion concentrations represent total oxidized nitrogen in natural waters (Clesceri et al., 1998). The nitrate ion is the stable form of combined nitrogen while the nitrite ion contains nitrogen in a relatively unstable oxidation state. The major part of the ingested nitrate in humans is excreted in due course, while nitrite is not. The toxicity of nitrate to humans is largely attributable to its reduction to nitrite, which causes decreased oxygen transport to the tissues creating a condition called methemoglobinemia (WHO, 2011c). A higher intake of nitrate and/or nitrite also linked with the risk of cancer and endogenous nitrosation (FAO/WHO, 2003a, 2003b). The health-based GV for nitrate in DWs is 50 mg L^{-1}, and it is 3 mg L^{-1} for nitrite. However, due to the possibility of simultaneous occurrence of nitrate and nitrite in DWs, the cumulative total value of the ratios of concentration/GV is suggested to be $\leq$ 1 mg L^{-1} (WHO, 2011c). The EU-MAC for nitrate is similar to that of WHO and a lower limit for nitrite (0.5 mg L^{-1}) is suggested. The BNDWQS-GV, EPA-MCL and SOQs of IBWA or FDA are 10 mg L^{-1} nitrate and $\leq$1 mg L^{-1} nitrite. The contents of nitrate or nitrite in the bottled waters are below the detectable limits, i.e., considerably below ($p < 0.05$) than the regulatory limits (Tables 1 and 4).

The DO in waters affect both the biochemical indicators and aesthetic characteristics, such as odor, taste, and clarity, while a high DO in DWs imparts better taste (Clesceri et al., 1998). The BNDWQS suggested a GV of 6 mg L^{-1} for drinking water, whereas there are no recommended limits in other regulations. The values of DO in bottled waters, except that of S11, is significantly lower ($p < 0.05$) than the BNDWQS (Tables 1 and 4).

3.1.3. Microbiological quality

The microbiological quality characteristic of the bottled waters was assessed using the HPC and MPN indexing. The HPC denotes the total bacteria content and the microbial load in water (Aksu & Vural, 2004). The HPC counts confirmed that maximum (~71%) of the bottled water samples are free from bacteria, and the HPC counts for the remaining are within 70 cfu mL^{-1} (Table 1). The HPC count of DWs may vary between <1 and 104 cfu mL^{-1}, as influenced by water pH, temperature, residual chlorine and incorporable organic matters (LeChevallier, Seidler, & Evans, 1980). An increased HPC count in DWs does not indicate a significant health risk (Allen, Edberg, & Reasoner, 2004), and no health-based guideline is proposed so far. The US EPA proposed an MCL of 500 cfu mL^{-1} for HPC count is DWs, and the bottled waters studied in the current study have significantly lower values ($p < 0.05$) than that (Table 4).

A positive TCC count in DWs indicates that it got exposure to outer environment (Timilshina, Dahal, & Thapa, 2012). The TCC includes mainly the pathogenic enteric bacteria, such as *E. coli*, *Salmonella* spp., *Shigella* spp., *Vibrio* spp., and a positive TCC value pointed to the unhygienic conditions of water (Barua et al., 2016). In our study, all the branded bottled water samples were confirmed as coliform free via MPN index per 100 mL and are in compliance with the regulatory limits (Tables 1 and 4).

Majumder et al. (2011) reported HPC results for nine commercially available local Bangladeshi bottled water samples, and indicated that 31.1% of the bottled water samples have HPCs greater than 500 cfu mL^{-1}. Besides, positive TCC for several bottled water brands marketed in Bangladesh has been reported (Ahmed et al., 2013; Khan et al., 1992; Majumder et al., 2011). The findings of our current study, however, contradict with all those reports, which might be indicative of the better effort from the manufacturers to maintain clean production environment and to provide a better-quality end product to the consumers.

3.1.4. Metal constituents

Drinking water is one of the primary pathways of the metal ingestion in humans, and metal ions have both positive and negative impact on people's health. Some of the elements are critical to sustaining life; some are essential at a low concentration but become toxic when present in excess, while some elements are toxic even when present in trace (Goldberg, Lebowitz, Graver, & Hicks, 1990; Karamanis et al., 2007).

Elements such as Ca, K, Mg and Na are essential in humans and are seldom found in DW at levels that could be a concern. Hence, no health-based guideline values are proposed for those (WHO, 2011a), while it is mentioned that Na may affect the taste of DW at levels above about 200 mg L^{-1} (WHO, 1996). The Ca, K, Mg and Na contents in the bottled waters are significantly lower ($p < 0.05$) than the BNDWQS GVs. Also, the Na content is also below the US-EPA-MCL (Tables 2 and 5).

In terms of the aesthetic considerations, such as taste, color, and odor, the US-EPA categorized Al, Cu, Fe, Mn, Ag and Zn as the nuisance constituents in DW (US EPA, 2016). The secondary maximum contaminant level (SMCLs) is, therefore, proposed for those elements to specify the lowest content below which a risk to human health is not expected. The Ag, Fe, Mn, and Zn are not detected in the bottled waters marketed in Bangladesh and are beyond the regulatory concerns. The Cu-content, which is related to odor and taste of DWs (US EPA, 2016) as well as the gastrointestinal illness (nausea, abdominal pain, vomiting or diarrhea) in humans (WHO, 2004a), is significantly lower ($p < 0.05$) than the health-based GV and all other regulatory limits. The Al-content in the bottled waters, which is related to the color feature of DW (US EPA, 2016), is significantly higher ($p < 0.05$) than the limits suggested by BNDWQS, EU, US-EPA, IBWA and US-FDA (Tables 2 and 5). However, there is no health-based GV for Al in DWs, and an increased Al-concentration in finished water is indicative of the use of Al-salts as coagulants in water treatment (WHO, 2010).

The potentially toxic elements (PTEs), such as As, B, Ba, Cd, Cr, Ni and Pb, can induce cardiovascular sicknesses, kidney-related disorders, neurocognitive effects and various forms of cancer in humans (WHO, 2011a). The bottled waters are free from As, Cr and Ni (Table 2). The contents of B, Ba and Cd are significantly lower ($p < 0.05$) than the regulatory values (Table 5). The Pb concentrations in two bottled water brands (S6 and S7) are higher than all the regulatory recommendations, and the contents in most samples are also not significantly different ($p < 0.05$) from the GVs (Tables 2 and 5). The impacts of Pb-exposure include various neuro-developmental effects, impaired renal function, hypertensions, reduced fertility and adverse pregnancy outcomes and mortality (WHO, 2011b). Therefore, increased attention towards the Pb-content in the bottled water is recommended.

3.2. Accuracy of label information

The bottled DWs to be marketed in Bangladesh is included into the list of 155 products that brought under mandatory certification marks scheme of the Bangladesh Standards & Testing Institution (BSTI). It belonged to the sub-category 'Food and Agricultural Products', and BSTI certification is available under two distinct codes: BDS 1240:2001 (drinking water) and BDS 1414:2000 (natural mineral water) (BSTI, 2012). The label information in the non-carbonated bottled drinking waters marketed in Bangladesh, as covered in the current study, confirmed that all the products received mandatory BSTI certification under the BDS 1240:2001 code, except the S5 (brand name: Yes), has the BDS 1414:2000 code. The number of displayed parameters in the labels is varied within 8–15, which indicate that no absolute norm is imposed from the authority regarding this aspect. Although the pH, TDS, chloride, nitrate, nitrite, As, Cd and Pb are the frequently displayed parameters, there is no pattern in the information arrangement and not helpful for a consumer to yield a comparative view of the marketed

Table 2
Comparison of metal constituents in bottled waters marketed in Bangladesh based on the experimental data. The mean values in the same rows for the data-subsets of element with identical letters are not significantly different at $P \leq 5\%$.*

Element	S. No.	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14
	Brand	Confidence	Fresh	Ananda	Pacific	Yes	Mum	Jibon	Pran	Mamia	Aquafina	Spa	Muskan	Acme	Dada
Al	Mean	0.552 b	0.586 b	0.634 c	0.659 c, d	0.673 c, d, e	0.699 d, e, f	0.736 f, g, h	0.800 i	0.715 e, f, g	0.486 a	0.766 h, i	0.738 f, g, h	0.751 g, h	0.762 h, i
(mg L^{-1})	SD	0.018	0.009	0.002	0.006	0.004	0.056	0.063	0.004	0.003	0.017	0.002	0.003	0.006	0.010
B	Mean	0.051 d	0.070 h	0.082 i	0.066 g	0.050 d	0.039 a	0.048 c	0.059 e	0.451 j	0.044 b	0.063 f	0.912 l	0.064 f, g	0.522 k
(mg L^{-1})	SD	0.0002	0.001	0.0004	0.0002	0.001	0.001	0.001	0.001	0.001	0.004	0.0004	0.004	0.001	0.001
Ba	Mean	ND	2.733 b	ND	ND	ND	2.30 a	5.70 c	ND	ND	ND	13.27 d	ND	ND	ND
(μg L^{-1})	SD		0.047				0.0001	0.0002				0.05			
Ca	Mean	0.035 b	1.62 g	0.033 b	0.235 e	0.048 b, c	14.58 i	7.15 h	0.055 c, d	0.068 d	0.494 f	Too high	0.006 a	0.045 b, c	0.002 a
(mg L^{-1})	SD	0.0001	0.006	0.0002	0.0004	0.0002	0.04	0.02	0.0004	0.0003	0.001		0.002	0.0002	0.0001
Cd	Mean	ND	ND	0.033 a	0.233 b	0.200 b	0.467 c	0.067 a	0.067 a	0.067 a	ND	0.233 b	0.200 b	ND	0.533 c
(μg L^{-1})	SD			0.0095	0.047	0.094	0.089	0.029	0.026	0.0095		0.031	0.025		0.034
Cu	Mean	6.27 a, b	6.40 b	6.83 b, c	8.23 d, e	9.80 f	8.20 d, e	7.67 c, d	8.17 d, e	7.40 c, d	5.43 a	8.20 d, e	9.00 e, f	8.87 e	8.23 d, e
(μg L^{-1})	SD	0.68	0.67	0.45	0.53	0.75	0.22	0.19	0.62	0.45	0.41	0.37	0.94	0.29	0.21
K	Mean	0.71 a	430 f	63.8 d	159 e	13.3 a, b	921 h	572 g	27.4 c	0.28 a	26.5 c	2988 i	0.99 a	22.7 b, c	27.7 c
(μg L^{-1})	SD	0.93	3	1.7	2.3	0.7	1.5	3.6	20.0	0.49	1.3	17	1.71	1.6	3.6
Li	Mean	ND	2.26 b	ND	0.133 a	ND	3.37 c	3.97 d	ND	ND	ND	4.53 e	ND	ND	ND
(μg L^{-1})	SD		0.09		0.047		0.12	0.12				0.12			
Mg	Mean	12.3 a, b	1512 d	15.6 a, b	221 c	26.8 b	1672 e	3886 f	5246 g	23.7 a, b	240 c	11,977 h	2.20 a	18.5 a, b	1.63 a
(μg L^{-1})	SD	0.12	7	0.45	0.2	0.08	4	14	14	0.16	0.3	39	0.57	0.05	0.19
Na	Mean	0.29 a	23.9 j	1.79 d	4.86 f	0.60 b	7.77 g	11.4 h	16.3 i	0.92 c	0.74 b	44.7 l	0.73 b	29.3 k	2.57 e
(mg L^{-1})	SD	0.001	0.14	0.006	0.001	0.004	0.03	0.07	0.05	0.01	0.03	0.3	0.007	0.15	0.008
Pb	Mean	1.13 a	12.2 d, e	8.60 b, c, d	9.73 c, d	4.80 a, b, c	54.9 f	57.27 f	1.57 a	5.77 a, b, c, d	9.17 b, c, d	17.0 e	2.63 a, b	9.13 b, c, d	1.96 a
(μg L^{-1})	SD	1.76	3.3	3.93	2.57	5.0	4.5	1.73	1.28	2.13	5.78	4.8	2.92	2.45	2.81
Sr	Mean	ND	10.7 d	ND	1.80 b	ND	78.2 f	55.0 e	ND	0.47 a	2.83 c	205 g	ND	ND	ND
(μg L^{-1})	SD		0.05		0		0.31	0.09		0.05	0.125	0.5			

*'ND' stands for 'Not Detected.' The experimental data of Ag, As, Bi, Co, Cr, Fe, Ga, In, Mn, Ni, Ti, and Zn concentrations are not shown in the comparative data table due to the contents below detectable limits in all the samples.

Table 3
Comparison of label information (V_L) of bottled waters marketed in Bangladesh with the experimental values (V_{Exp})[a].

Parameter/element	S. No.	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14
	Brand	Confidence	Fresh	Ananda	Pacific	Yes	Mum	Jibon	Pran	Mamia	Aquafina	Spa	Muskan	Acme	Dada
Physical and aggregate properties															
TDS	V_L	<500	<250	<250	–	<100	<250	<250	<=500	<250	<=50	<500	<250	<250	<250
(mg L^{-1})	V_{Exp}	3.8 ± 0.6	73.0 ± 3.1	11.1 ± 0.2	20.2 ± 0.1	15.3 ± 0.2	103 ± 7.6	64.2 ± 4.6	49.3 ± 6.5	5.7 ± 1.1	1.7 ± 0.8	220 ± 7	77.9 ± 6.2	67.5 ± 3.4	120 ± 3
Inorganic non-metal constituents															
pH	V_L	6.4–7.4	6.4–7.4	6.4–7.4	6.4–7.4	6.4–7.4	6.4–7.4	6.4–7.4	–	6.4–7.4	6.4–7.4	6.4–7.4	6.5–7.5	6.4–7.4	6.4–7.4
(pH units)	V_{Exp}	7.29 ± 0.03	7.25 ± 0.03	6.66 ± 0.01	7.00 ± 0.01	6.77 ± 0.29	7.22 ± 0.04	7.16 ± 0.07	7.40 ± 0.17	7.35 ± 0.03	7.09 ± 0.08	7.18 ± 0.56	7.04 ± 0.14	7.28 ± 0.24	7.19 ± 0.14
Chloride	V_L	<250	<250	<250	10	–	<250	<250	<=250	<250	<15	<250	<250	<20	<250
(mg L^{-1})	V_{Exp}	1.6 ± 0.2	45.1 ± 4.1	3.5 ± 0.2	11.4 ± 2.8	9.6 ± 0.6	23.5 ± 1.7	12.4 ± 1.6	11.7 ± 1.2	1.5 ± 0.4	0.5 ± 0.1	57.0 ± 2.8	55.0 ± 3.5	3.3 ± 0.6	56.4 ± 4.6
Nitrate	V_L	<4.5	<2.5	<2.5	–	<4.5	<4.5	<4.5	<=4.5	<4.5	<4.5	<0.5	<2.5	<2.5	<2.5
(mg L^{-1})	V_{Exp}	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Nitrite	V_L	0	0	0	–	<0.005	0	0	0	0	0	0	0	0	0
(mg L^{-1})	V_{Exp}	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Metal constituents															
As	V_L	<10	0	0	0	0	0	0	<=10	0	0	0	0	0	0
(μg L^{-1})	V_{Exp}	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ca	V_L	<75	<35	<35	29	–	–	–	–	–	–	<75	<35	–	>35
(mg L^{-1})	V_{Exp}	0.03 ± 0.00	1.62 ± 0.01	0.03 ± 0.00	0.23 ± 0.00	0.05 ± 0.00	14.6 ± 0.04	7.15 ± 0.02	0.06 ± 0.00	0.07 ± 0.00	0.49 ± 0.00	ND	0.01 ± 0.00	0.05 ± 0.00	0.00
Cd	V_L	<3	<3	<3	–	0	<3	<3	<=3	<3	0	0	<3	0	0
(μg L^{-1})	V_{Exp}	ND	ND	0.03 ± 0.01	0.23 ± 0.05	0.20 ± 0.09	0.47 ± 0.08	0.07 ± 0.03	0.07 ± 0.02	0.07 ± 0.01	ND	0.23 ± 0.03	0.20 ± 0.02	ND	0.53 ± 0.03
Fe	V_L	–	–	–	30	–	–	–	–	–	–	–	–	–	–
(μg L^{-1})	V_{Exp}	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
K	V_L	–	–	–	2000	–	–	–	–	–	–	–	–	–	–
(μg L^{-1})	V_{Exp}	0.4 ± 1.4	430 ± 3	63.8 ± 1.7	159 ± 2	13.3 ± 0.7	921 ± 2	572 ± 4	27 ± 20	ND	26.5 ± 1.3	2988 ± 17	ND	22.7 ± 1.6	27.7 ± 3.6
Mg	V_L	–	–	–	3000	–	–	–	–	–	–	<35,000	–	–	–
(μg L^{-1})	V_{Exp}	12.3 ± 0.1	1512 ± 7	15.6 ± 0.4	221 ± 0.2	26.8 ± 0.1	1672 ± 4	3886 ± 14	5246 ± 14	23.7 ± 0.2	240 ± 0.2	11,977 ± 39	2.2 ± 0.6	18.5 ± 0.1	1.6 ± 0.2
Mn	V_L	–	<100	–	–	–	–	–	–	<500	<500	–	–	–	–
(μg L^{-1})	V_{Exp}	ND	ND	0.33 ± 0.12	ND	ND	ND	0.10 ± 0.14	ND	ND	ND	ND	ND	ND	ND
Na	V_L	<200	<4	<4	4	–	–	–	–	–	–	–	<4	–	<4
(mg L^{-1})	V_{Exp}	0.29 ± 0.00	24.0 ± 0.14	1.79 ± 0.01	4.86 ± 0.00	0.60 ± 0.00	7.77 ± 0.03	11.4 ± 0.07	16.3 ± 0.05	0.92 ± 0.01	0.74 ± 0.03	44.7 ± 0.31	0.73 ± 0.01	29.3 ± 0.15	2.57 ± 0.01
Pb	V_L	<10	<10	<10	–	0	<10	0	<=10	<10	0	0	<10	0	0
(μg L^{-1})	V_{Exp}	1.13 ± 7.76	12.2 ± 3.3	8.60 ± 3.93	9.73 ± 2.57	4.80 ± 5.0	54.9 ± 4.50	57.3 ± 1.73	1.57 ± 1.28	5.77 ± 2.13	9.17 ± 5.78	17.0 ± 4.85	2.63 ± 2.92	9.13 ± 2.45	1.96 ± 2.81

[a] 'ND' stands for 'Not Detected'; '–'stands for 'Not Mentioned.'

Table 4
Comparison of experimental data of water-quality parameters and microbiological quality of bottled waters marketed in Bangladesh with the waters from municipal supply systems (tap water), and the regulations and standards for water intended for human consumption. The mean values in the same rows for the data-subsets of element with identical letters are not significantly different at $P \leq 5\%$.[*]

Parameters	Bottled water of Bangladesh		Tap water of Bangladesh		Drinking-water regulations				Bottled water regulations	
	Mean	Range	Mean	Range	$V_{BNDWQS\ (GV\text{-}Max)}$[§]	$V_{WHO\ (GV)}$[§]	$V_{EU\ (MAC)}$[§]	$V_{EPA\ (MCL\ or\ MCLG)}$[§]	$V_{IBWA\ (SOQ)}$[§]	$V_{FDA\ (SOQ)}$[§]
Physical and aggregate properties										
EC (µs cm^{-1})	118 a	0–453	175 a	162–187	–	–	250 a	–	–	–
TDS (mg L^{-1})	59.5 a	0.9–227	88.1 a	81.0–95.2	1000 c	–	–	500 b	500 b	500 b
TH (mg L^{-1})	21.3 a	0–142	59.0 a	53.8–64.2	500 b	–	–	–	–	–
TA (mg L^{-1})	24.0	1.9–72.6	50.0	47.2–52.8	–	–	–	–	–	–
Inorganic non-metal constituents										
pH	7.13 a	6.48–7.73	7.52 b	7.48–7.56	–	–	–	6.5–8.5 c	–	–
Chloride (mg L^{-1})	20.9 a	0.32–61.0	15.1 a	12.2–18.0	600 c	–	–	250 b	250 b	250 b
Nitrate (mg L^{-1})[†]	ND		ND		10	50	50	10	10	10
Nitrite (mg L^{-1})[†]	ND		ND		<1	3	0.5	1	1	1
DO (mg L^{-1})	5.3 a	4.6–6.3	6.0 b	5.9–6.1	6.0 b	–	–	–	–	–
Microbiological quality										
HPC (cfu L^{-1})	13 a	0–70	247 b	242–251	–	–	–	500 c	–	–
TCC (MPN-100 mL^{-1})[†]	ND		234	228–240	0	0	–	–	<2.2	<2.2

[*]'ND' stands for 'Not Detected'; '–'stands for 'Not Mentioned.'
[†]Post hoc tests are not performed either because there are fewer than three groups, or subsets cannot be computed with alpha = 0.05.
[§]GV, Guideline value; MAC, Maximum admissible concentration; MCL, Maximum contaminant level or MCLG, Maximum contaminant level goal; SOQ, Standard of quality; V_{BNDWQS}, Bangladesh national drinking water quality standards (BBS & UNICEF, 2011; DPHE, 2009); V_{WHO}, Guideline value for chemical hazards in drinking-water from World Health Organization (WHO, 2011a); V_{EU}: Directive from The Council of the European Union on the quality of water intended for human consumption (Diduch et al., 2011; EC, 1998); V_{EPA}: Drinking water regulations from US Environmental Protection Agency (US EPA, 2016); V_{IBWA}: Regulation of bottled water from International Bottled Water Association (Diduch et al., 2011; IBWA, 2009); V_{FDA}: Requirements for bottled water from US Food and Drug Administration (US FDA, 2010).

Table 5
Comparison of experimental data of metal constituents of bottled waters marketed in Bangladesh with the waters from municipal supply systems (tap water), and the regulations and standards for water intended for human consumption. The mean values in the same rows for the data-subsets of element with identical letters are not significantly different at $P \leq 5\%$.[*]

Parameters	Bottled water of Bangladesh		Tap water of Bangladesh		Drinking-water regulations				Bottled water regulations	
	Mean	Range	Mean	Range	$V_{BNDWQS\ (GV\text{-}Max)}$[§]	$V_{WHO\ (GV)}$[§]	$V_{EU\ (MAC)}$[§]	$V_{EPA\ (MCL\ or\ MCLG)}$[§]	$V_{IBWA\ (SOQ)}$[§]	$V_{FDA\ (SOQ)}$[§]
Ag (mg L^{-1})[†]	ND		ND		0.02	–	–	0.1	0.025	0.1
Al (mg L^{-1})	0.68 b	0.47–0.80	0.83 c	0.80–0.86	0.2 a	–	0.2 a	0.2 a	0.2 a	0.2 a
As (µg L^{-1})[†]	ND		ND		50	10	10	10	10	10
B (mg L^{-1})	0.18 a, b	0.04–0.92	0.05 a	0.05–0.06	1 c	0.5 b	1 c	–	–	–
Ba (µg L^{-1})	1.71 a	0–13.3	4.48 a	4.44–4.53	10 [‡]b	700 c	–	2000 e	1000 d	2000 e
Ca (mg L^{-1})	1.74 a	0–14.6	13.3 b	13.3–13.4	75 c	–	–	–	–	–
Cd (µg L^{-1})	0.15 a	0.00–0.57	0.17 a	0.03–0.30	5 c	3 b	5 c	5 c	5 c	5 c
Cr (µg L^{-1})	ND		2.65 a	1.25–4.05	50 c	50 c	50 c	10 b	50 c	10 b
Cu (µg L^{-1})	7.76 a	5.02–10.55	9.40 a	9.04–9.76	1000 b	2000 d	2000 d	1300 c	1000 b	1000 b
Fe (mg L^{-1})	ND		1115 c	1113–1118	1.0 b	–	0.2 a	0.3 a, b	0.3 a, b	0.3 a, b
K (µg L^{-1})	375 a	0–3004	1367 a	1363–1370	12,000 b	–	–	–	–	–
Li (µg L^{-1})	1.02	0–4.66	6.10	6.06–6.14	–	–	–	–	–	–
Mg (µg L^{-1})	1775 a	1–12,015	7195 b	7173–7218	35,000 c	–	–	–	–	–
Mn (µg L^{-1})	ND		155 c	155–156	100 b	400 d	50 a	50 a	50 a	50 a
Na (mg L^{-1})	10.4 a	0.29–45.0	15.1 a	15.0–15.2	200 b	–	200 b	–	–	–
Ni (mg L^{-1})[†]	ND		ND		0.1	0.02	0.02	–	0.1	0.1
Pb (µg L^{-1})	14.0 a	0–59.4	64.6 b	61.9–67.3	50 b	10 a	10 a	15 a	5 a	5 a
Sr (µg L^{-1})[†]	25.3	0–205	123	122–123	–	–	–	–	–	–
Zn (µg L^{-1})	ND		21.5 a	21.2–21.8	5000 b	–	–	5000 b	5000 b	5000 b

[*]'ND' stands for 'Not Detected'; '–'stands for 'Not Mentioned.' The experimental data for Bi, Co, Ga, In and Ti contents are not shown in the table due to the contents below detectable limits in all the samples, and unavailability of any regulatory values.
[†]Post hoc tests are not performed either because there are fewer than three groups, or subsets cannot be computed with alpha = 0.05.
[‡]The BNDWQS for barium is set at 10 µg L^{-1}, apparently a typographical error (BBS & UNICEF, 2011).
[§]GV, Guideline value; MAC, Maximum admissible concentration; MCL, Maximum contaminant level or MCLG, Maximum contaminant level goal; SOQ, Standard of quality; V_{BNDWQS}, Bangladesh national drinking water quality standards (BBS & UNICEF, 2011; DPHE, 2009); V_{WHO}, Guideline value for chemical hazards in drinking-water from World Health Organization (WHO, 2011a); V_{EU}: Directive from The Council of the European Union on the quality of water intended for human consumption (Diduch et al., 2011; EC, 1998); V_{EPA}: Drinking water regulations from US Environmental Protection Agency (US EPA, 2016); V_{IBWA}: Regulation of bottled water from International Bottled Water Association (Diduch et al., 2011; IBWA, 2009); V_{FDA}: Requirements for bottled water from US Food and Drug Administration (US FDA, 2010).

products. The label information is mostly mentioned in ranges based on the BNDWQS or WHO GVs, and the experimental values comply with that except that of the Pb. A comparison of the label information and experimental values is compiled in Table 3.

3.3. Comparison of fit-to-drink quality: bottled water vs. tap water

Although a liter of bottled water is estimated to be 250 to 600 times more costly than a liter of tap water (Diduch et al., 2011), the quality of the bottled water is not necessarily safer than the water

Table 6
Appraisal for compliance with the mineral water classification of the bottled drinking water marketed in Bangladesh[a].

S. No.	Brand	Criteria for classification					
		Mineral content[b]		Salinity[c]		Hardness[d]	
		Value	Class	Value	Class	Value	Class
S1	Confidence	3.8	Very low	1.61	Fresh	0.0027	Very Soft
S2	Fresh	73.0	Low	45.1	Saline	0.2071	Very Soft
S3	Ananda	11.1	Very low	3.53	Fresh	0.0030	Very Soft
S4	Pacific	20.2	Very low	11.4	Slightly saline	0.0302	Very Soft
S5	Yes	15.3	Very low	9.62	Slightly saline	0.0046	Very Soft
S6	Mum	102	Low	23.5	Slightly saline	0.8682	Soft
S7	Jibon	64.2	Low	12.4	Slightly saline	0.6811	Soft
S8	Pran	49.3	Very low	11.7	Slightly saline	0.4398	Very Soft
S9	Mamia	5.7	Very low	1.46	Fresh	0.0054	Very Soft
S10	Aquafina	1.7	Very low	0.46	Fresh	0.0447	Very Soft
S11	Spa	220	Low	57.0	Saline	NC	
S12	Muskan	77.9	Low	55.0	Saline	0.0005	Very Soft
S13	Acme	67.5	Low	3.31	Fresh	0.0038	Very Soft
S14	Dada	120.1	Low	56.4	Saline	0.0002	Very Soft

[a] 'NC' stands for 'Not Computed.'
[b] Very low mineral content: Mineral content (TDS) < 50 mg L^{-1}; Low mineral content: TDS 50–500 mg L^{-1}; Intermediate mineral content: TDS 500–1500 mg L^{-1}; High mineral content: TDS > 1500 mg L^{-1} (van der Aa, 2003).
[c] Fresh: Chloride < 5 mg L^{-1}; Slightly saline: chloride 5–30 mg L^{-1}; Saline: chloride 30–150 mg L^{-1}; More saline: chloride 150–300 mg L^{-1}; Very saline: chloride 300–1000 mg L^{-1}; Mineral: chloride 1000–10,000 mg L^{-1} (van der Aa, 2003; Diduch et al., 2011).
[d] Very soft: Ca + Mg 0–0.5 mEq L^{-1}; Soft: Ca + Mg 0.5–1 mEq L^{-1}; Medium hard: Ca + Mg 1–2 mEq L^{-1}; Hard: Ca + Mg 2–4 mEq L^{-1}; Very hard: Ca + Mg 4–8 mEq L^{-1}; Extremely hard: Ca + Mg > 8 mEq L^{-1} (van der Aa, 2003).

from the supply systems in many cases, because the tap water passes through several routine controls and fulfills many compliance schemes (Dinelli et al., 2012; Saylor, Prokopy, & Amberg, 2011). The Water Supply and Sewerage Authority (WASA) is the organization for administering municipal water supply in Bangladesh. The tap water samples used in the current study have been collected from the different locations that receive water supply through Chittagong WASA (CWASA), as managed by treating waters from the *Halda* river and several deep tube wells and supplied through house connections or street hydrants (Hasna, 1995; Khan, 2006; Rahman et al., 2011).

The experimental values of the physical and aggregate properties and inorganic non-metal constituents in the tap water are within the regulatory limits. The values for tap waters also not significantly different ($p < 0.05$) from the mean data of bottled waters, except for pH and DO (Table 4). The tap water is free from the Ag, As, Ni similar to that of bottled waters. There are no significant differences ($p < 0.05$) among the contents of B, Ba, Cd, Cu, K and Na. The tap waters contain Cr, Fe, Mn, and Zn, while those are not found in the bottled waters. The contents of Al, Fe and Mn, which are marked as the aesthetic hazards for DW (US EPA, 2016), are higher than the regulatory limits in the tap water. Although the bottled waters also have higher Al contents, the higher contents of Fe and Mn along with Al in tap water will decline the palatability more. The concentrations of PTEs are under the recommended GVs, except a significantly higher Pb-content than the bottled waters as well as the regulatory values (Table 5).

Although the HPC count for tap water is greater than the bottled water, it was lower from the US-EPA-MCL ($p < 0.05$). The TCC count shows a significantly higher value (234 ± 6 MPN-100 mL^{-1}), which is recommended to be nil for safe consumption (Table 4). A further analysis of the TCC positive samples for the identification of pathogens reveals the presence of *Vibrio* spp., *E. coli*, *Salmonella* spp., *Klebsiella* spp. in the tap waters. However, the HPC and TCC count in tap water become zero after bringing it to a rolling boil and cooling before consumption, as recommended by WHO (2008) for dealing with the water-borne disease-causing pathogens.

3.4. Compliance with the mineral water classification

Bottled waters are frequently mistaken or falsely labeled as 'mineral water', whereas most of the bottled water offered to the consumers does not comply with the very concept of 'mineral water' (Diduch et al., 2011). Several criteria, such as geological, hydrogeological, physicochemical, pharmacological, microbiological, and so forth are considered during the classification of natural mineral waters (Petraccia, Liberati, Giuseppe Masciullo, Grassi, & Fraioli, 2006). There is no uniform system for classification of mineral waters; however, scales are proposed based on EU mineral water directive, German curative mineral water classification, and Stuyfzand water classification. The parameters used in those scales, respectively, are degree of mineralization (TDS; mg L^{-1}), content of specific constituents that known for a contribution in physiological or medicinal activity (mg L^{-1}) and degree of salinity (chloride; mg L^{-1}) or hardness (Ca + Mg; mEq L^{-1}) (van der Aa, 2003).

The compatibility of the bottled waters marketed in Bangladesh with different mineral water classification systems is assessed, and compiled in Table 6. None of the samples comply with the classification based on the content of specific constituents (mg L^{-1}) (containing chloride: chlorides > 200; containing sodium: Na > 200; containing calcium: Ca > 150; containing magnesium: Mg > 50; containing iron: Fe > 1; containing manganese: Mn > 1; containing arsenic: As > 0.7), and not included in Table 6. However, all the samples contain sodium below 20 mg L^{-1} and can be classified as 'suitable for low sodium diets' (van der Aa, 2003). Furthermore, the appraisal designates the following classes to the bottled waters: a) a very low or low mineral contents, b) slightly saline, saline or fresh characteristics, and c) very soft or soft water hardness.

4. Conclusion

The bottled water is preferred to tap water as it is considered as more natural, pure and healthier alternative with better taste, smell or color, and the trend is ever-increasing all around the globe. However, the bottled water quality could be compromised due to storage issues, illegal refilling or processing negligence from the manufacturer. An assessment of 14 different non-carbonated bottled drinking water brands available for Bangladeshi consumers was performed in the current work in terms of the physical and aggregate properties (EC, TDS, TH, TA), inorganic non-metal (pH, chloride, nitrate, nitrite, DO) and metal constituents (total 24: Ag, Al, As, B, Ba, Bi, Ca, Cd, Co, Cr, Cu, Fe, Ga, In, K, Li, Mg, Mn, Na, Ni, Pb, Sr, Ti, and Zn) and microbiological characteristic (HPC, TCC). The experimental data was compared with the information printed on the bottle labels, quality of tap waters from CWASA, and regulatory GVs from BNDWQS, WHO, US-EPA, EU, IBWA, and US-FDA. All the experimental values of physical and aggregate properties, inorganic non-metal constituents were within the limit of regulatory GVs ($p < 0.05$). The water in the packages was microbiologically safe. The concentrations of 22 elements out of total 24 was considerably below ($p < 0.05$) the recommended limits, while Al-content was found higher and Pb-content was not significantly different ($p < 0.05$) as compared to the GVs. The label information of the various brands was not consistent or adequate and, thus, cannot be used as a representative source for water quality facts. The tap waters from CWASA had aesthetic issues, exposed to microbial contamination with confirmed presence of *Vibrio* spp., *E. coli*, *Salmonella* spp., *Klebsiella* spp., and had higher Pb-content than the bottled waters and the recommended GVs. Hence, the tap water is a less lucrative option to be advocated as the alternative to the bottled water even though a stringent water-quality protocol was supposed to be followed during the processing of tap waters. The classification system used to categorize the *mineral water* confirmed that most of the brands had very low mineral contents, contain salinity and very-soft hardness character, and compatible for low-sodium diets only. The bottled drinking water, by definition, produced from a protected source and is not monitored on a regular basis. However, the results of the current study indicate that all non-carbonated bottled drinking waters marketed in Bangladesh need to be regularly analyzed for the chemical and bacteriological water quality.

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