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Accuracy of bottled drinking water label content

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Abstract The purpose of the study was to compare the accuracy of the concentration of fluoride (F), calcium (Ca), pH, and total dissolved solids (TDS) levels mentioned on the labels of the various brands of bottled drinking water available in Riyadh, Saudi Arabia. Twenty-one different brands of locally produced non-carbonated (still water) bottled drinking water were collected from the supermarkets of Riyadh. The concentration of F, Ca, TDS, and pH values were noted from the labels of the bottles. The samples were analyzed for concentrations in the laboratory using the atomic absorption spectrophotometer. The mean level of F, Ca, and pH were found as 0.86 ppm, 38.47 ppm, and 7.5, respectively, which were significantly higher than the mean concentration of these elements reported in the labels. Whereas, the mean TDS concentration was found 118.87 ppm, which was significantly lower than the mean reported on the labels. In tropical countries like Saudi Arabia, the appropriate level of F concentration in drinking water as recommended by World Health Organization (WHO) should be 0.6–0.7 ppm. Since the level of F was found to be significantly higher than the WHO recommended level, the children exposed to this level could develop objectionable fluorosis. The other findings, like pH value, concentrations of Ca, and TDS, were in the range recommended by the WHO and Saudi standard limits and therefore should have no obvious significant health implications.

Keywords Bottled drinking water · Fluoride · Calcium · pH · Total dissolved solids

Introduction

According to the latest statistical report, the global consumption of bottled water reached 162 billion liters in 2005, increased by 52% from the 107 billion liters consumed 5 years earlier. Even the countries like Saudi Arabia, where tap water is safe to drink, demand for bottled water is increasing. Saudi Arabia was the 12th largest country for per capita consumption of bottled water in 2005. In that year, about 2.4 billion liters bottled water was consumed by Saudi inhabitants. That translates into an average of 92.3 l per person. Looking at the previous

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record, it appears that the use of bottled water has increased in Saudi Arabia by 23.6% since 1999 (Bottled water 2004). This increase was quite stable with reference to population growth. However, the large consumption of bottled drinking water per person was mainly due to low level of fluoride concentration (Mohamed and Abdel Fattah 1987; AlDosary et al. 2003) and apprehension about the contaminants of communal drinking water, fewer impurities, better taste, and possibly conferring higher social status (Wigle et al. 1986; Paul et al. 1998).

For effective preventive measures, it is important to know precisely the concentration of different elements in water that the people are drinking. For example, in the case of fluoride (F) level, it is well documented in literature that drinking fluoridated water reduces the incidence of dental caries. However, a significant higher concentration of F may lead to an objectionable fluorosis (Akpata et al. 1997). The critical period of susceptibility of the maxillary permanent central incisors to fluorosis has determined to be a 4-month period from 22 to 26 months of age (Evans and Stamm 1991). So, it is important to know if bottled water is providing a safe and preventive F level to the consumers. Furthermore, other elements like, Ca, TDS, and pH value may give negative effects if recommended levels are not maintained (World Health Organization Guidelines 2006).

The regulation of contents of bottled water is not stringent and the concentration printed on the labels may not be accurate. One study in Pakistan showed about 52% of bottled water were not suitable for drinking (Kiani 2001). Many studies (Toumba et al. 1994; Toumba and Duggal 1996; Weinberger 1991; Johnson and DeBiase 2003) were conducted in European countries to compare the actual level of different element to the concentration mentioned at the bottle. However, as far as the authors' knowledge is concerned, no such study has so far been conducted in Saudi Arabia. Therefore, there was a need to conduct such type of study to determine the accuracy of the concentration of different essential elements mentioned on the labels of the bottled drinking water.

The purpose of the study was to compare the accuracy of the concentration of F, Ca, pH, and TDS levels mentioned at the labels of the various brands of bottled drinking water available in Riyadh, Saudi Arabia.

Materials and methods

Twenty-one different brands of locally produced non-carbonated (still water) bottled drinking water were collected from the supermarkets of Riyadh city of Saudi Arabia in year 2004. The product name, the size of the bottle, production date, and the concentration of F, Ca, TDS, and pH values were noted from the labels of the bottles. The samples were analyzed for F, Ca, pH, and TDS concentrations in the laboratory of Riyadh Water and Sewerage Authority by using the atomic absorption spectrophotometer (HACH instrument, model DR 3000). The bottled water was kept sealed in original plastic containers at room temperature until the water was analyzed for the research elements. Before the analysis of the samples, the spectrophotometer was calibrated by testing 25 ml of distilled water with 5 ml buffer solution. The spectrophotometer was adjusted for wavelength at 850 nm throughout the procedure.

The data were entered in to the computer and analyzed using SPSS (version 10). Paired *t*-test was employed to compare the label and laboratory values. The graphs were designed using Harvard graphics. One-sample Kolmogorov–Smirnov test was performed to verify the normal distribution condition of the observations.

Short description of meaning and significance of F, Ca, pH, and TDS for the health and environment is as follows:

Fluoride

WHO recommends that the appropriate level of F in the drinking water should ranged from 0.6–0.8 ppm for annual average of maximum daily temperature of 26.3–32.6°C to 0.9–1.7 ppm for temperature of 10–12°C (WHO Guidelines 2006). However, the recommended level for tropical countries like Saudi Arabia, where the maximum temperature goes above 45°C during summer season, should be in the range of

0.6–0.7 ppm (Akpata et al. 1997; Galgan and Vermillion 1957). Presence of large amount of F is associated with dental and skeletal fluorosis (>1.5 ppm) and inadequate amounts with the dental caries (<0.6 ppm) (Chemical analysis of drinking water 2003). Furthermore, the concentration of F between 0.9–1.2 ppm may give mild dental fluorosis (WHO Guidelines 2006).

Calcium

Ca is one of the most common constituents present in natural waters ranging from zero to several hundred milligrams per liter. Ca is caused for hardness in water and incrustation in boilers (Chemical analysis of drinking water 2003). The need of Ca is higher during childhood, fetal growth, pregnancy, and lactation (Garzon and Eisenberg 1998). Epidemiological, animal, and clinical studies indicate that an inverse relationship exists between Ca intake and occurrence of osteoporosis (Heaney et al. 1982; The Surgeon General's Report on Nutrition and Health 1988). A diet that is for fortified in Ca may reduce the rate of age-related bone loss and hip fractures, especially among adult women (McDowell 1992).

pH

pH number is an expression of the concentration of H^+ ion in the solution. pH less than 6.5 or greater than 9.2 would markedly impair the potability of the water (WHO Guidelines 2006). pH lower than 4 will produce sour taste and higher value above 8.5 bitter taste. pH below 6.5 starts corrosion in pipes, thereby releasing toxic metals such as Zn, Pb, Ct, Cu etc. (Chemical analysis of drinking water 2003).

Total dissolved solids

TDS comprise inorganic salts (principally calcium, magnesium, potassium, sodium, bicarbonates, chlorides, and sulfates) and small amounts of organic matter that are dissolved in water. Health effects associated with the ingestion of TDS in drinking water are not available, and no health-based guideline value is proposed. However, a guideline value of 1,000 mg/l was established, based on taste considerations. Water with extremely low concentrations of TDS may also be unacceptable because of its flat, insipid taste (WHO Guidelines 2006).

Results

Figures 1, 2, 3, and 4 illustrate the laboratory findings and label values of F, Ca, pH, and TDS. Figure 1 demonstrates that all of the laboratory findings of F level were higher than label values for F, except Al-Qasim and Neamah brands of water. But the differences of label value and labo-

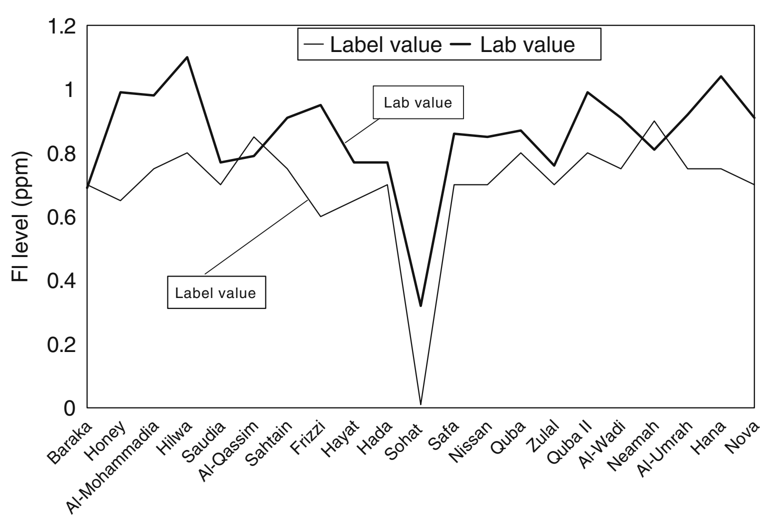
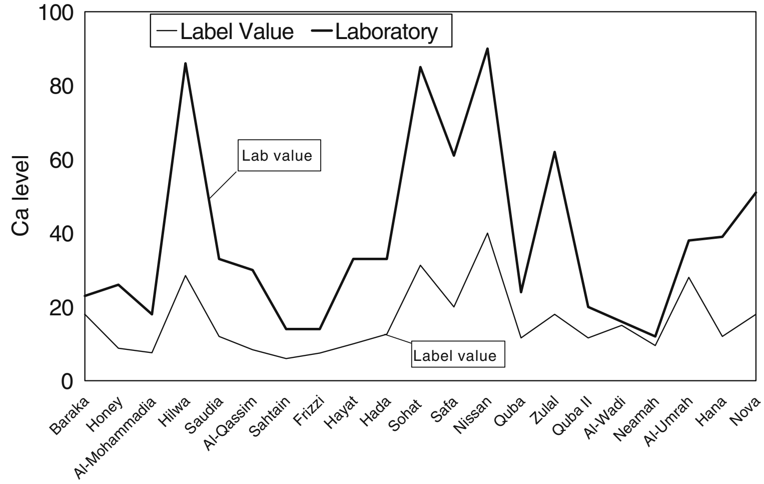


Fig. 1 Label and laboratory values of fluoride level of bottled drinking water

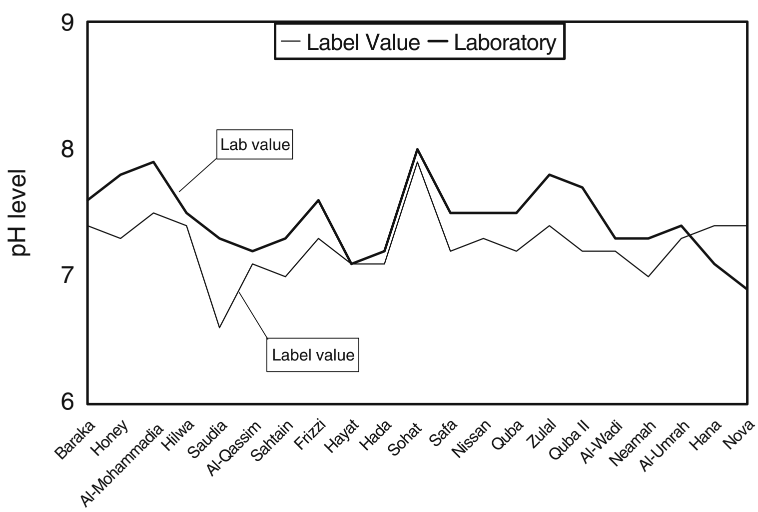
Fig. 2 Label and laboratory values of calcium level of bottled drinking water



ratory values were very small in both the products. Figure 2 shows that all the laboratory readings were much higher than the marked values for Ca concentration. Seven brands of bottled water showed more than three times than the label values. Figure 3 shows that all the laboratory findings are higher than the label values of pH, except brand name of Hana and Nova. Figure 4 indicates that 16 brands of bottled water showed lower TDS concentration than scripted values.

Table 1 describes the descriptive statistics and comparisons of mean label values and laboratory findings of F, Ca, pH, and TDS concentration of sampled bottled water. The mean (±SD) F content of 21 bottled water samples by label and laboratory findings were 0.71 (±0.17) ppm and 0.86 (±0.16) ppm, respectively. The range of the laboratory findings was 0.32 to 1.1 ppm. Two brands, Hilwa and Hana, showed more than 1 ppm concentration. The brand name 'Sohat' showed lower than recommended value of 0.32 ppm (Table 2). The mean (±SD) range of Ca concentration of label and laboratory values were 15.92 (±9.09) ppm [*R*: 6–40 ppm] and 38.47 (±24.73) ppm [*R*: 12–90 ppm], respectively. The mean (±SD) for pH values for label and laboratory were 7.25 (±0.28) and 7.45 (±0.28), respectively. All the pH values (label and laboratory) were less than 8. The mean (±SD) of TDS for label and laboratory values were 133.76 (±32.54) ppm and 118.87 (±31.69)

Fig. 3 Label and Laboratory values of pH level of bottled drinking water



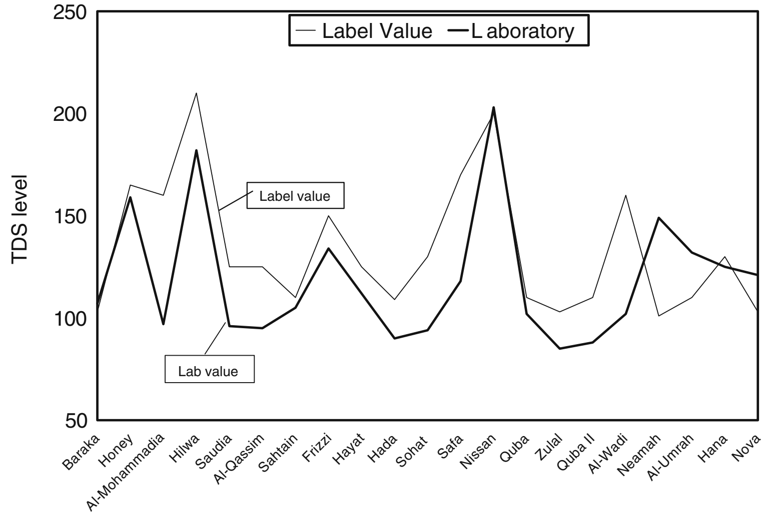


Fig. 4 Label and laboratory values of TDS level of bottled drinking water

ppm, respectively. The Kolmogorov–Smirnov statistic verified the condition of normal distribution for the difference of label and laboratory readings in all the four elements. Paired *t*-test showed that mean differences between label values and laboratory findings of all the four items were statistically significant. The mean Ca concentration was found about 142% higher than mean label values. The mean F level was also found about 21% higher than reported label values. The mean pH value was only 3% higher than reported value, whereas the TDS value was about 11% lower than the reported values. Table 2 describes the individual information for each brand of water.

Discussion

The annual increase in the consumption of bottled water in Saudi Arabia was about 4% during 1999 to 2005, which was little more than the population growth of the country. In some other countries the consumption growth was a lot faster than this marginal rate, for example India which has a growth of 25% per annum during this period (CBC News, Bottled water 2006). The reason could be that the inhabitants of Saudi Arabia were using bottled water from long period of time, and now the growth is stable. In contrast, the use of bottled water in India has recently been started, and therefore, its growth is exponential in the beginning. However, the consumption per capita in Saudi Arabia is very large as compared to many other countries and it is 12th in the list of top consumers of bottled water (CBC News, Bottled water 2006).

In Saudi Arabia, the main source of drinking water is underground water reservoirs or wells (AlDosari et al. 2008). Percentage of underground or well water resources used for drinking in Riyadh region was estimated as 94.5%, while only 5.5% used the desalinated water (AlDosari et al. 2003). Even in the desalinated water, a significant

Table 1 Descriptive statistics and comparisons of label and laboratory readings of F, Ca, pH, and TDS concentrations in the bottled water

Element	Label readings				Laboratory findings				Paired *t*-test	
	Min	Max	Mean	SD	Min	Max	Mean	SD	*t*-value	*p*-value
Fluoride	0.6	0.9	0.71	0.17	0.32	1.10	0.86	0.16	−5.686	< 0.001
Calcium	6.0	40.0	15.92	9.09	12.0	90.0	38.47	24.73	−5.886	< 0.001
pH	6.6	7.5	7.25	0.28	6.85	7.85	7.45	0.28	−3.293	0.004
TDS	101	210	133.76	32.54	82	203	118.87	31.69	2.576	0.018

Table 2 Label and laboratories values of fluoride, calcium, pH, and TDS of the sample bottled water

Brand name	Fluoride		Calcium		pH		TDS	
	LV	LF	LV	LF	LV	LF	LV	LF
Baraka	0.70	0.69	18	23	7.4	7.6	103	107
Honey	0.65	0.99	8.8	26	7.3	7.8	165	159
Al-Mohammadia	0.75	0.98	7.6	18	7.5	7.9	160	97
Hilwa	0.80	1.10	28.5	86	7.4	7.5	210	182
Saudia	0.70	0.77	12	33	6.6	7.3	125	96
Al-Qasim	0.85	0.79	8.4	30	7.1	7.2	125	95
Sahtain	0.75	0.91	6.0	14	7.0	7.3	110	105
Frizzi	0.60	0.95	7.5	14	7.3	7.6	150	134
Hayat	0.65	0.77	10	33	7.1	7.1	125	112
Hada	0.70	0.77	12.6	33	7.1	7.2	109	90
Sohat	0.01	0.32	31.3	85	7.9	8.0	130	94
Safa	0.70	0.86	20	61	7.2	7.5	170	118
Nissan	0.70	0.85	40	90	7.3	7.5	200	203
Quba	0.80	0.87	11.6	24	7.2	7.5	110	102
Zulal	0.70	0.76	18	62	7.4	7.8	103	85
Quba II	0.80	0.99	11.6	20	7.2	7.7	110	88
Al-Wadi	0.75	0.91	15	16	7.2	7.3	160	102
Neamah	0.90	0.81	9.52	12	7.0	7.3	101	149
Al-Umrah	0.75	0.92	28	38	7.3	7.4	110	132
Hana	0.75	1.04	12	39	7.4	7.1	130	125
Nova	0.70	0.91	18	51	7.4	6.9	103	121

LV label value, *LF* laboratory findings

amount of well water is added to bring up the basic important elements to an acceptable range. The desalinated water is pumped to the residential areas directly from main water reservoirs. The bottled water factories are located in the industrial areas outside of urban areas. Therefore, most probably, the source of water used by bottled companies in the Riyadh region, which was the collecting area for the samples, are underground water.

All brands of bottled water analyzed in the present study displayed the values of all dissolved ingredients including F, Ca, TDS, and pH, along with the date of production and expiration. In many other countries (Toumba et al. 1994; Weinberger 1991; Stannard et al. 1990; Ahiropoulos 2006), some bottled water companies do not mention the concentration of ingredients at the bottle label. This finding is in agreement with the study of Paul et al. (1998) of bottled water in Saudi Arabia. It was noted that all the labels of bottled water marked different concentration of F, Ca, pH, and TDS values from each other.

The low concentration of fluoride level in bottled water suggests for the supplement of fluoride with some other source, like fluoride tables or fluoridated salt, and high concentration indicates the risk of fluorosis. The mean F level determined by laboratory analysis showed significantly higher value than the mean labeled value. Recommended level of fluoride in the water for tropical countries like Saudi Arabia should be in the range of 0.6–0.7 ppm (Akpata et al. 1997; Galgan and Vermillion 1957). The finding of F concentration ranged from 0.69 to 1.10 ppm in this study. In tropical country, like Saudi Arabia, people consume much larger amount of water than temperate countries. Since there is an established relationship between caries prevalence and drinking water (Dean et al. 1942), therefore a larger amount of water consumption should reduce the dental caries. However, it is not happening in Saudi Arabia, due to other caries risk factors, such as diet and oral hygiene practices which are superimposing upon the fluoride factor (AlDosari et al. 2003). It is due to the same fact of larger consumption of water in hot climate; the optimum level of fluoride in drinking water is suggested lower than temperate countries (AlDosari et al. 2003).

Along with the concentration of fluoride in bottled water, it is also very important to determine the daily intake of water consumption among children living in different areas, with respect to age, gender, fraction of use of tap water, and seasonal mean temperature values. Based on this information of the daily intake of fluoride from water and other sources, the risk of fluorosis can be estimated. According to the data from the National Diet and Nutrition Survey for young people age 4–18 years in UK (Gregory and Lowe 2000), the mean total daily bottled and tap water intake was 108 and 155 mL, respectively. The mean total daily intake of fluoride, i.e., the combination of tap and bottled water, was estimated to be 0.264 and 0.164 mg/L, respectively. Unfortunately, as to the authors' knowledge, such information is not available for Saudi Arabia.

The American Academy of Pediatrics (1986) recommended that for optimal dental health the total daily intake should be 0.05–0.07 mg fluoride per kilogram of body weight, and to avoid the risk of dental fluorosis, the fluoride intake should not exceed a daily level of 0.10 mg fluoride per kilogram of body weight. Dentists should be careful to make the decision about the fluoride recommendations, because the values mentioned at the label of the bottle may not be accurate. In this study, 19 bottled water samples, out of 21, showed higher fluoride level than the recommended maximum value of 0.7 ppm, even some have more than 1 ppm. There was a significant difference between mean fluoride levels of laboratory findings and the indicated value on the labels. These high levels of concentration could develop the objectionable fluorosis. But it will not be on the serious level. It should also be noted that water temperature in some areas of Saudi Arabia reaches 40°C during summer time (Nabil and Bassam 1991). It could also change the equation of basic elements by higher concentration in the municipality supplied or bottled water. Therefore, the government health planners should carefully observe those brands of water to keep the teeth of new generation healthy and bright.

The laboratory findings for Ca, pH, and TDS were well within the recommended values by WHO (2006) and Saudi Standard Limits (1997) guidelines for drinking water. In contrast, literature indicates that in other countries the levels of these essential elements in some bottled water are either lower or higher than the recommended level of the countries' standard limits (Ikem et al. 2002; Pip 2002; Mahajan et al. 2006; Baba et al. 2008). Since the levels of the study research elements are within the range, therefore, there should be no serious concern regarding the health-effects due to these elements.

Conclusions

- In our sample, the manufacturers of all bottled water displayed the F, Ca, TDS concentration, and pH value on the label.
- The mean laboratory findings of F, Ca, and pH values were significantly higher than the mean values mentioned at the label. However, the mean TDS value was significantly lower than the mean label values.
- The F level of bottled water was found to be significantly higher than the recommended level by WHO (0.6–0.7 ppm) and children exposed to this level could develop objectionable fluorosis (Akpata et al. 1997).
- Findings like pH value and concentrations of Ca and TDS were in the range recommended by the WHO and Saudi Standard Limits, therefore, should have no obvious health implications.

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