# Fluoride Content of Bottled Waters in Hong Kong and Qatar

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***Objectives:*** *To determine the F concentration of bottled waters that was available in Hong Kong and Qatar.* ***Study design:*** *The F concentrations of bottled waters collected from Hong Kong (n=81) and Qatar (n=32) were analysed. The F ion selective electrode method was used to measure the F concentration in the samples. Three measurements were obtained for every sample to ensure reproducibility and appropriate statistical analyses were employed.* ***Results:*** *Qatar group: F concentrations ranged from 0.06ppm to 3.0ppm with a mean value of 0.8ppm. The F concentrations displayed on the labels of the samples (60%) were significantly lower than the measured F concentration (p < 0.0001). Hong Kong group: F concentrations ranged from 0.04ppm to 2.52ppm with a mean value of 0.44ppm. The F concentrations displayed on the samples (16%) were significantly lower than the measured F concentration (p< 0.0001).* ***Conclusion:*** *Wide variations exist in the F concentration among the different brands of bottled water available in Hong Kong and Qatar. The F concentrations displayed on the labels were not consistent with the measured F concentrations.*

***Key words:*** *fluoride, bottled water, fluorosis, dental caries*

## INTRODUCTION

The important role that Fluorides (F) plays in the prevention and control of dental caries is well documented.[1] It is now widely accepted that F does not need to be ingested to be beneficial because F controls the progression of the carious lesions predominantly by its topical effect on the de- and re- mineralization processes; which occur at the interface between the tooth surface and the adjacent dental biofilm.[2,3] Recently, there have been reports of an increase in the prevalence of dental fluorosis in both fluoridated and non-fluoridated communities.[2] This increase in dental fluorosis, which is the only proven side-effect on the dentition, has been attributed to the total amount of F consumed from all sources during the critical periods of tooth development. Most authors[2,4] recognize the first three years of life as the window of maximum susceptibility to the development of fluorosis for the permanent maxillary central incisor teeth. Nevertheless, for the whole permanent dentition, excluding the third molars, the first 6 to 8 years of life is considered critical for the development of fluorosis.[5,6]

Fluoridated drinking water, F supplements, F toothpaste, and infant formulas (especially if reconstituted with fluoridated water) have all been identified as major risk factors for dental fluorosis.[2] Subsequently, concerned authorities have implemented recommendations and/or guidelines to reduce the total F intake of young children especially during the period of greatest risk for developing dental fluorosis.[7] Some of these recommendations[2] are as follows: maintaining appropriate levels of F in the public water supply, avoiding the ingestion of infant formulas which has been reconstituted with optimally fluoridated water, placing a small amount of F toothpaste onto the toothbrush and supervising tooth brushing of pre-school children, as well as not routinely prescribing F supplements for children at low risk of developing caries, those living in fluoridated areas and those below three years of age (regardless of the status of community fluoridation).

Infants receive the majority of their nutrition from infant formulas, when they are weaned from breast milk, especially in the first 4 to 6 months of life before they start receiving solid foods. Commercially prepared infant formulas are available as powder and liquid concentrates that have to be diluted with water before use, or as ready-to-feed formulations. It has been suggested that the intake of F by infants from formulas is influenced more by the water used to reconstitute the formula than by the formulas themselves.[8] Therefore, for infants and small children receiving large quantities

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of reconstituted infant formula, use of water containing <0.5ppm F is recommended.[2]

The current social trend is to prepare infant formulas using bottled water, due to the perception that bottled water is healthier than the public/tap water. With the availability of numerous brands, both national and international, in the local stores there has been a significant increase in the consumption of bottled water. Nevertheless, wide variation exists in the F concentrations among the different brands of bottled waters. Furthermore, inconsistencies have been reported to exist in the F concentrations stated on the labels and the measured F concentrations.[9-13]

Dentists and Pediatricians may be asked by new parents which type of water can be safely used to reconstitute infant formulas so as to protect their child's teeth and avoid fluorosis. Having appropriate level of F in bottled water is intended to be beneficial for children to limit or prevent carious lesions. Conversely, low level of F or no F in bottled water will put children at a higher risk for dental caries. Unfortunately, fluorosis can occur if manufacturers fail to correctly record the F concentration on the label and /or if the parents are unaware of a high level of F in a particular brand of bottled water that they give their child. Therefore, this study sought to determine the F concentration of bottled waters that are available on the commercial markets in Qatar and Hong Kong.

## MATERIALS AND METHOD

Water bottles were purchased from 8 major supermarkets and grocery stores in the city of Doha, Qatar. The 32 different brands of bottled water that were obtained were stored at room temperature until they were analysed. While in Hong Kong 81 different brands of bottled water were purchased from different major retail outlets.

Two groups of bottled waters were thus created: Qatar and Hong Kong. They were categorized and numbered according to alphabetical order based on the brand name, bottle size, water type, the country of origin and the F level according to the information label, and the batch number when affixed on each bottle was recorded for each brand.

### Electrode Standard calibration curve preparation

The F ISE method was used to determine the F level in the bottled waters that were tested. The F ion selective electrode model 94-09 (Orion Research, Inc., USA) was used in combination with a pH/mV meter (Cyberscan 1000, Eutech instruments Ltd, Singapore).

Solutions with F concentrations of 1ppm, 2ppm, and 10ppm with Total Ionic Strength Adjusting Buffer II (TISAB II, Orion Research, Inc. USA) standards in addition to 100ppm F standard solution with 1:1 solution TISAB ratio were prepared. Subsequently, 10ml of each of the F standard solutions were pipetted into small plastic vials.

The Orion F ion selective electrode model 94-09 (Orion Research, Inc., USA) which was connected to a pH/mV meter was inserted into the samples and retained until a stable mV reading was obtained. The mV readings were introduced to the calibration curve, where the log(ppm) was plotted against the mV, to generate the curve where the slope and y intersected according to the readings of the F standards; the relationship between mV and log(ppm) is linear.

According to the equation mV = slope X log(ppm) + mV, the F concentration can be automatically calculated by measuring the ppm when the slope and the mV intersects are known based upon standard F mV measurements. The voltage of 1ppm F standard solution was measured every 2 hours, throughout the process of analysis; furthermore, recalibration was done when there was more than 5% difference between the readings.

### Measurement of F concentration in bottled water

Two operators performed the measurements; the first was aware of the brand number and so this operator prepared the samples for analysis; while the second operator who was blinded for the brand name performed the measurements using the electrode and the pH/mV meter. This investigator entered the mV readings on the data collection sheet opposite to the number of the water sample.

After thorough shaking of the water bottle, a 9ml sample, of the water to be tested, was pipetted into a small clear plastic vial with the number of the sample affixed on the vial. Then 1ml of Total Ionic Strength Adjusting Buffer (TISAB II, Orion Research, Inc. USA) was added to the water sample and shaken. In the case of sparkling water, the bottles were shaken until no air bubbles were released from the sample before a reading was performed.

When the electrode was dipped in the prepared sample, care was taken to ensure intimate contact between the solution and the electrode tip without any intervening air bubbles and without allowing the electrode to touch the bottom or walls of the vial. The temperature of the sample was maintained at 25 ± 0.5°C; which was achieved by working in an air-conditioned room with a controlled average temperature, and by monitoring the temperature of each sample illustrated on the ion-analyzer screen. Furthermore, the electrode was retained in the solution until a stable reading indicated by 'ready' was noted on the pH/mV meter screen. The mV reading was then taken at that point and recorded in the calibration curve table to be automatically converted to F concentration as a ppm value.

The electrode was thoroughly rinsed with de-ionized water after every measurement and shaken to prevent solution contamination. The electrode tip was never rubbed, or wiped in strict accordance with the manufacturer's instructions.

Three samples, of each individual bottled water, were prepared and two investigators measured the F concentration on a particular day. Subsequently, to ensure reliability and reproducibility, the same investigator measured another 3 samples from the same bottled water on a different day. No variations in the F concentration were evident between the measurements taken at different time points.

### Statistical analysis

Paired *t*-test was used to compare differences in F concentrations between the different brands of bottled water. One way analysis of variance (ANOVA) and Bonferroni multiple comparisons tests were employed to determine the differences between the F concentration measurements performed for each brand of bottled water and for the brands of bottled water produced in different countries; with $P<0.05$ considered statistically significant. Mean and standard deviation was used for the descriptive data.

## RESULTS

### Qatar

The mean F concentration [six samples for each bottled water] measured for the 32 different bottled water brands are listed in Table 1 and illustrated in Figure 1. No statistically significant differences existed between the three F concentration measurements that were

**Figure 1. Frequency distribution of fluoride concentrations of the Hong Kong (n=81) and Qatar (n=32) bottled water samples.**

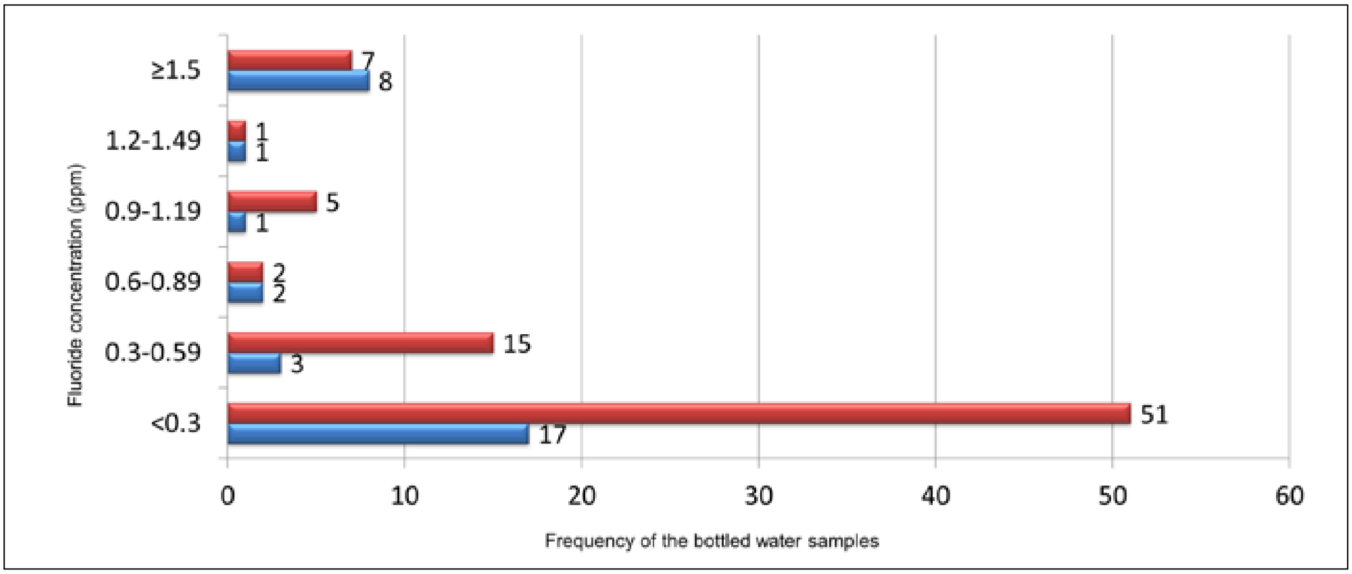



**Table 1. The mean fluoride (F) concentrations of the 32 brands of bottled waters that was commercially available in Qatar.**

| Brand name | Mean F ±SD | Brand name | Mean F ±SD | Brand name | Mean F ±SD |
|---|---|---|---|---|---|
| 1. Acqua Pann | 0.29±0.01 | 12. Dibba | 0.08±0.01 | 23. Mozn | 2.25±0.06 |
| 2. Al Ain | 0.08±0.01 | 13. Evian | 0.25±0.02 | 24. Nestle | 2.21±0.02 |
| 3. Al-Manhal | 0.77±0.02 | 14. Gulfa | 0.08±0.006 | 25. Rayyan | 0.94±0.01 |
| 4. Aloyoun | 1.97±0.04 | 15. Hada | 2.26±0.05 | 26. Rim | 0.4±0.02 |
| 5. Al-Qassim | 2.01±0.03 | 16. Hana | 1.91±0.08 | 27. Safa | 1.89±0.0 |
| 6. Aqua Gulf | 0.1±0.0 | 17. Hania | 0.8±0.04 | 28. Sannine | 0.28±0.01 |
| 7. Aquafina | 0.06±0.006 | 18. Hayawiya | 0.28±0.03 | 29.Tannouri | 0.23±0.01 |
| 8. Arwa | 0.06±0.006 | 19. Highland | 0.21±0.01 | 30. Vauban | 3±0.13 |
| 9. Baby Water | 1.4±0.03 | 20. Jeema | 0.23±0.006 | 31. Viva | 0.09±0.01 |
| 10. Buxton | 0.55±0.03 | 21. Lulu | 0.06±0.01 | 32. Volvic | 0.57±0.03 |
| 11. Carrefour | 0.19±0.01 | 22. Masafi | 0.06±0.01 | | |

performed for each brand of bottled water (ANOVA, p=0.99). The mean value and standard deviation of the F concentrations measured were 0.8 ± 0.88ppm and it ranged from 0.06ppm to 3.0ppm; 62.5% of the samples had a F concentration less than 0.6ppm, the minority (9.3%) had concentration between 0.6ppm and 1.2ppm, and 28.1% had more than 1.2ppm F. Surprisingly, eight brands of water (25%) had levels that ranged from 1.89 ppm to a high of 3.0ppm; seven of these brands bottled waters were produced in Saudi Arabia.

Only 18 (56.2%) of the 32 brands displayed the F concentration on the labels, See Figure 2. Furthermore, the displayed F concentration values of only three brands were similar to the measured F concentrations. One brand (Aqua Gulf) which indicated that the F concentration was in the range of 0.0ppm to 1.0ppm had a measured F concentration value of 0.1ppm. The mean value of the F concentration in the samples that were labelled as 0.71ppm, actually had a mean F concentration value of 1.27ppm: which was statistically significant (paired *t*-test; $p < 0.0001$).

The F concentration displayed on the label of one brand (Baby Water) was 0.1ppm, while the measured F concentration was 1.4ppm. Similarly another brand (Vauban) had a displayed F concentration on the label of 1.3ppm; while the measured F concentration was much higher at 3.0ppm; which was the highest measured F concentration among all of the bottled water brands.

Only three (9%) of the 32 tested bottled water brands were locally produced in Qatar, 9 were produced in Saudi Arabia, 8 in the United Arab Emirates, 4 in France and 3 in Lebanon. A statistically significant difference was evident in the measured F concentration among the bottled water brands produced in different countries (ANOVA, p<0.001). Furthermore, Bonferroni multiple comparisons test revealed that the bottled water brands produced in Saudi Arabia had significantly higher levels of F than those produced in Qatar, UAE and Lebanon (Table 2). The F concentration of the bottled waters which were produced in Saudi Arabia ranged from 0.8ppm to 2.26ppm with a mean value of 1.86ppm. Interestingly, all the

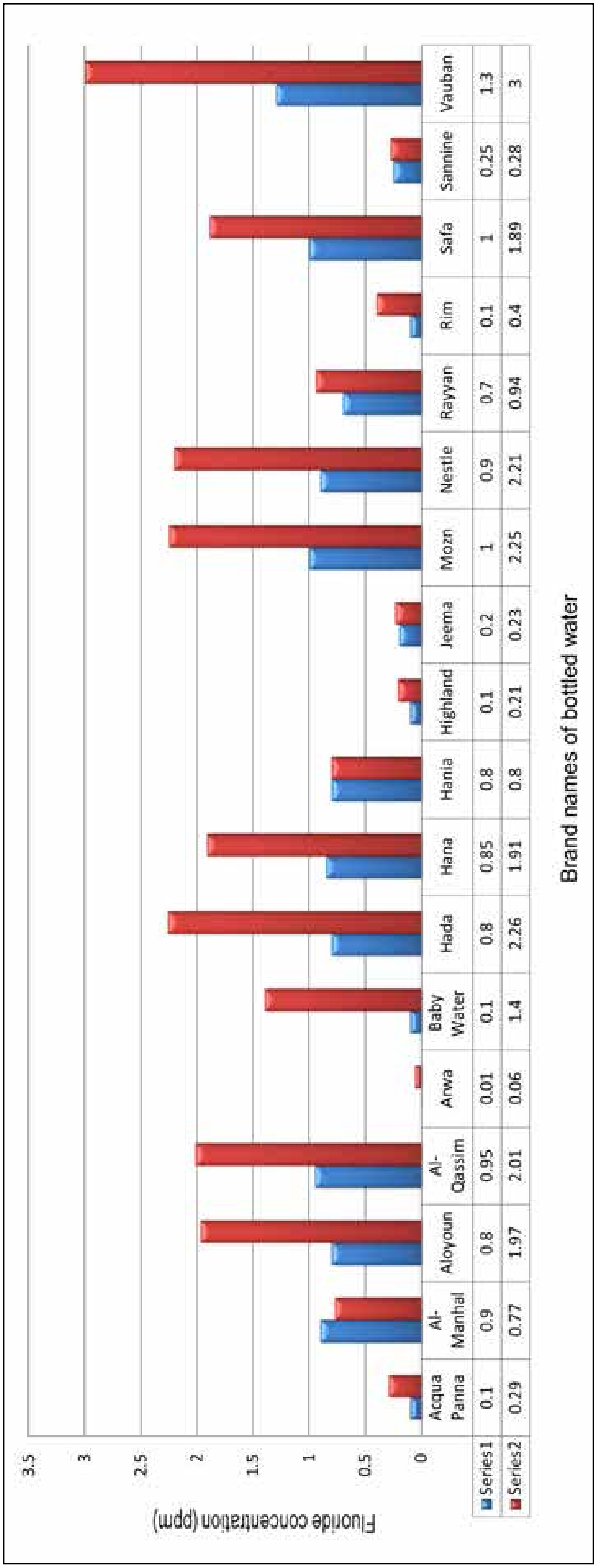



**Figure 2.** The differences between the F concentrations displayed on the labels of the bottled waters available in Qatar and the measured F concentrations.

bottled water brands produced in Saudi Arabia had their F concentration displayed on the labels; however, these values were consistently lower than the measured F concentrations. Furthermore, none of the bottled water brands stated the type or source of the water.

## Hong Kong

The measured F concentration [six samples for each bottled water] for the 81 different bottled water brands are listed in Table 2 and illustrated in Figure 1. No statistically significant differences existed between the three F concentration measurements performed for each brand of bottled water (ANOVA, $p=0.97$). The mean value and standard deviation of the F concentrations measured were 0.44 ± 0.8ppm and it ranged from 0.04ppm to 2.52ppm. The majority of the bottled water brands (81.5%) had F concentrations of less than 0.6ppm, while 8.7% had F concentrations between 0.6ppm and 1.2ppm, and in 9.8% of the sample the F concentration was higher than 1.2ppm (Figure 1).

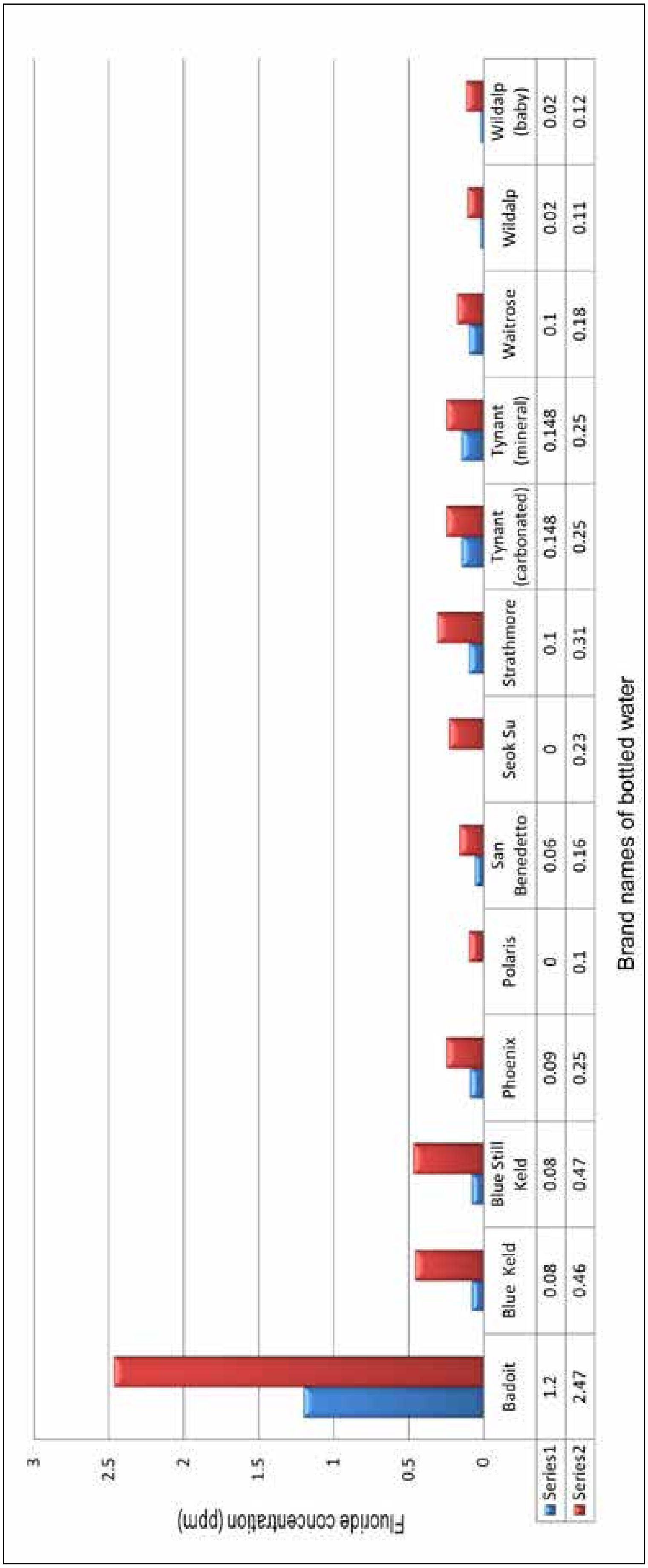
In the present study, only 13 (16%) brands stated the F concentration on the labels, of these, only one had a stated F concentration that was in agreement with the measured F concentration (stated F concentration 0.0ppm to 0.6 ppm and the measured F concentration was 0.23 ppm), See Figure 3. The remaining 12 brands had significantly higher measured F concentrations compared to the value stated on the label (paired sample *t*-test, $p<0.0001$). One of the brands (Polaris) stated the F concentration to be zero ppm while the measured F concentration was 0.1ppm; which was the lowest stated and measured F concentration among all brands with F concentration stated on their labels. Similarly, another brand (Badoit) stated the F concentration to be 1.2ppm yet the measured F concentration was 2.47ppm; which were the highest stated of the measured F concentrations. The brand Wildalp, which was introduced to the market as being specially designed for the preparation of baby formula and food, had a stated F concentration of 0.02ppm but the measured F concentration was found to be 0.l2ppm.

The types of water were predominantly distilled, mineral and spring waters, this was declared on the labels of 75 (93%) of the brands. The F concentrations of distilled waters ranged from 0.04ppm to 0.07ppm; while in the mineral and spring waters they varied from 0.04ppm to 2.47ppm and 0.07ppm to 2.52ppm respectively. However, no statistically significant differences were evident in the measured F concentrations between the different types ($p=0.22$). Similarly, no statistically significant differences existed in the F concentrations between samples produced in the different countries (ANOVA, $p=0.118$).

## DISCUSSION

The F concentration of bottled water provides an insight into its therapeutic or detrimental benefits on the dentition. Less than the optimal F concentration will increase the risk of an individual to caries while a higher F concentration may result in dental fluorosis especially when consumed during the critical periods of tooth development.[2]

Figure 3. The differences between the F concentrations displayed on the labels of the bottled waters available in Hong Kong and the measured F concentrations.




The World Health Organization[7] recommends that the appropriate level of F in the drinking water should range from 0.6ppm to 0.8ppm, in a region with a maximum daily temperature of 26.3°C to 32.6°C. In Hong Kong, the average maximum daily temperature is within this range while the F concentration in the public drinking water is currently 0.5ppm.[14] In Qatar, the maximum temperature rises above 45°C in the summer, and hence the F concentration would be slightly lower than the range of 0.6ppm to 0.8ppm. Therefore, based on the higher mean temperature and the progressive reduction in the F concentrations in drinking water it would be logical to state that the F concentrations in the waters available in Qatar and Hong Kong should be in the range of 0.5ppm to 0.8ppm. The findings of the present study reveal that only 4 (12%) brands of bottled water from Qatar and 9 (11%) brands from Hong Kong had F concentrations within this range. Furthermore, the majority of the bottled waters in Qatar (53%) and Hong Kong (63%) contained F concentrations of less than 0.3ppm, while 37.5% of the bottled waters in Qatar and 18.5% of bottled waters in Hong Kong had F concentrations higher than 0.6 ppm. Therefore, most of the bottled waters tested in this study had less than the optimal F concentration for the prevention of dental caries in children which is in agreement with previous studies.[9-13]

The widely accepted "optimal" intake of F has been empirically established to be between 0.05mg/kg and 0.07 mg/kg.[15] In the present study, 9 (28%) brands of bottled water from Qatar and 8 (10%) brands from Hong Kong had F concentrations higher than 1.2ppm. Furthermore, 7 brands of bottled water in Qatar exhibited F concentrations higher than 1.8ppm. The main sources of fluoride intake which are recognized as potential risk factors for developing dental fluorosis are high fluoride water, fluoride toothpaste, dietary fluoride supplements and infant formulas, especially if these are reconstituted with fluoridated water. Therefore, use of bottled water with a high F concentration would potentially increase the total amount of daily fluoride intake thus increasing the risk for developing dental fluorosis; especially if consumed during the critical periods of tooth development.[2]

Different guidelines and/or recommendations exist for the use of F supplements for caries prevention. For instance, the Australian Dental Association[16] recommendation states that "F drops or tablets should not be taken (swallowed) directly by an adult or child". Conversely, the American Dental Association[17] recommends dietary F supplements for children older than

**Table 2. The mean fluoride (F) concentrations of the 81 brands of bottled waters that was commercially available in Hong Kong.**

| Brand name | Mean F ±SD | Brand name | Mean F ±SD | Brand name | Mean F ±SD |
|---|---|---|---|---|---|
| 1.Acqua Panna | 0.23±0.006 | 28. H2O | 0.07±0.006 | 55. Polaris | 0.1±0.006 |
| 2. Aqua Queen | 0.09±0.006 | 29. Hida | 0.26±0.02 | 56. Qvarzia | 0.15±0.006 |
| 3. Aquarel | 0.5±0.01 | 30. Highland | 0.17±0.01 | 57. San Pellegrino | 1.04±0.04 |
| 4. Arrowhead | 2.52±0.02 | 31. Highland | 0.17±0.02 | 58. Sam Daso | 0.19±0.006 |
| 5. Asahi Citrulline | 0.08±0.006 | 32. Hildon | 0.22±0.006 | 59. San Benedetto | 0.16±0.006 |
| 6. Asahi Fuji Mountain | 0.68±0.01 | 33. House1 | 0.06±0.01 | 60. Sanfanstino | 0.54±0.02 |
| 7. Badoit | 2.47±0.1 | 34. House2 | 0.42±0.01 | 61. Select | 0.16±0.0 |
| 8. Balance | 0.12±0.006 | 35. Ice Age | 0.07±0.006 | 62. Seok Su | 0.23±0.01 |
| 9. Best Buy | 0.05±0.006 | 36. Isk Ilde | 0.51±0.05 | 63. Sifa | 0.22±0.006 |
| 10. Blue Keld | 0.46±0.05 | 37. Iwashmizu Ryusendo | 0.12±0.01 | 64. SPA | 0.1±0.006 |
| 11. Blue Still Keld | 0.47±0.02 | 38. Jyukaku | 2.1±0.03 | 65. Stone Mountain | 0.2±0.006 |
| 12. Bonaqua | 0.07±0.006 | 39. Laoshan | 1.63±0.07 | 66. Strathmore | 0.31±0.01 |
| 13. Bourbon | 0.16±0.0 | 40. Lotte Icis | 0.92±0.03 | 67. Towada Oirase | 0.09±0.01 |
| 14. Contrex | 0.67±0.04 | 41. Mannings | 0.07±0.01 | 68.Tynant | 0.25±0.01 |
| 15. Cool | 0.06±0.0 | 42. Mannings | 2.16±0.03 | 69. Tynant | 0.25±0.006 |
| 16. Crystal Geyser | 1.43±0.09 | 43. Marusan | 0.14±0.01 | 70. U | 0.54±0.006 |
| 17. Desside | 1.08±0.09 | 44. Meko | 1.12±0.07 | 71. Ucc | 0.1±0.006 |
| 18. Duchy Selection | 1.01±0.08 | 45. Mountain H2 | 0.19±0.01 | 72. Vita | 0.05±0.0 |
| 19. Echigo (Sennen Yusui) | 0.08±0.006 | 46. No Frills | 0.07±0.01 | 73. Vita | 0.04±0.0 |
| 20. Esuoushi Onsen | 1.65±0.05 | 47. No Frills | 0.3±0.02 | 74. Vittel | 0.05±0.0 |
| 21. Evian | 0.22±0.01 | 48. North Alps Azumino | 0.33±0.01 | 75. Volvic | 0.5±0.006 |
| 22. Fiji | 0.58±0.01 | 49. O2 | 0.07±0.006 | 76. Waitrose | 0.18±0.006 |
| 23. First Choice | 0.07±0.01 | 50. Okinawa | 0.09±0.006 | 77. Waiwera Infinity | 0.05±0.0 |
| 24. First Choice | 2.33±0.06 | 51. Okinawa Pai Energy | 0.11±0.006 | 78. Watson | 0.04±0.0 |
| 25. First Choice | 0.31±0.01 | 52. Perrier | 0.3±0.02 | 79. Watson | 0.04±0.006 |
| 26. Four Seas Natural | 0.34±0.02 | 53. Phoenix | 0.25±0.006 | 80. Wildalp | 0.11±0.0 |
| 27. Ganten | 0.21±0.006 | 54. Pierval | 0.24±0.01 | 81. Wildlap (baby) | 0.12±0.01 |

6 months of age and who are at-risk of developing dental caries with the recommended dose depending on the F concentration in the drinking water. Similarly, the Canadian Dental Association[18] recommends F supplements only for children who have high caries experience and whose total intake of F is lower than 0.05mg/kg to 0.07 mg/kg. While the European experts[19] recommend a dose of 0.5 mg/day F for at-risk individuals from the age of 3 years. Most often, these recommendations are impractical because it is very difficult to estimate the total F intake from all sources. Therefore, dental practitioners should be aware of the potential discrepancies in the F concentrations of bottled water when prescribing F supplements for children. Furthermore, parents should be cautioned about the consequences of changing brands of bottled water.

Only 56.2% of the bottled waters available in Qatar and 16% of the bottled waters available in Hong Kong stated the F concentrations on the labels. By contrast three studies[20-22] in the USA, reported that less than 5% of the bottled water brands displayed the F concentration on the label, while in the United Kingdom two studies[11,23] found that 25% and 32% of the bottled waters listed their F concentrations. Conversely, in Canada,[9] 100% of tested brands had the F concentration displayed on the labels; which reflects the stringent regulations imposed by the concerned authorities in Canada. In the present study, only those brands of bottled water that were produced in Saudi Arabia had the F concentrations listed on the labels which was similar to the findings of Khan and Cochan[12] who also tested bottled water brands produced in Saudi Arabia. Therefore, it would be logical to state that regulatory authorities should implement mandatory regulations for manufactures of bottled waters to display the correct F concentrations on the labels.

The findings of the present study highlight the wide disparity that exists in the F concentrations among the different brands of commercially available bottled waters in Qatar and Hong Kong.

Although, it would appear that the F concentration in the bottled water depends on several factors such as, the type of the water source (ground water or surface water), the time of the year when the water was collected, and the de-fluoridation techniques employed; this details were not mentioned by the manufacturer on the labels. Therefore, it was difficult to elicit the potential reasons for such disparities. Nevertheless, the variation in the F concentration between the mineral, distilled, or spring bottled water evident in the present study can be anecdotally attributed to factors namely, the water source, types of rocks and minerals.

Majority of the de-fluoridation techniques are based on the principle of adsorption. Some of these include ion-exchange, precipitation-coagulation, membrane separation process, electrolytic de-fluoridation, and electrodialysis.[24] Furthermore, several adsorbent materials namely, activated alumina, activated carbon, activated alumina coated silica gel, calcite, activated saw dust, activated coconut shell carbon and activated fly ash, groundnut shell, coffee husk, rice husk, magnesia, serpentine, tricalcium phosphate, bone charcoal, activated soil sorbent, carbion, defluoron-1, defluoron-2, etc., have all been reportedly used for de-fluoridation in the literature.[24] Of these, the most commonly used adsorbents materials are activated alumina and activated carbon. Each de-fluoridation techniques come with its own advantages and disadvantages. Although the ion-exchange method removes approximately 90% to 95% of F from water, it appears that the F removal efficiency varies according to many site-specific chemical, geographical and economic conditions. Therefore, any particular technique, which is suitable in a particular region, may not meet the requirements at another region. For this reason, it has been proposed that any de-fluoridation technique should be tested using the actual water to be treated before implementation.[24] This provides a logical explanation for the variations in the F concentrations among the different brands of commercially available bottled waters in the present study. Nevertheless, the present study did not analyze the F concentrations, for each brand of bottled water, from different batch numbers to cover any variation in the F concentration for a particular product; which might be considered a limitation. Therefore, one should exercise caution while interpreting these results as they may only reflect the variations present in a particular batch alone. Nonetheless, it highlights the fact that F concentration in bottled water has the potential to change considerably and hence requires regular monitoring.

Recently, a systematic review by Hujoel and co-workers[8] reported that the increased risk of dental fluorosis posed by the use of infant formulas depends mainly on the F concentration of the water supply.[8] Similarly, Siew and co-workers[25] demonstrated that the reconstitution of formulas with 0.7ppm to1.0ppm F may provide infants with a daily F intake above that likely to cause some degree of dental fluorosis. Therefore, considering the wide range of F concentrations of bottled waters in Qatar (0.06ppm to 3ppm) and Hong Kong (0.04ppm to 2.52ppm), plus the potential F concentrations present in the infant formulas, it would be logical to state that reconstitution with a bottled water especially those with a higher F concentration could increase the total daily F intake; thus, increasing the risk of dental fluorosis. Conversely, one should avoid using bottled water for reconstituting infant formulas as recommended by the UK National Health Service (NHS).

## CONCLUSIONS

Based on the findings of this study we conclude that, (i) the majority of the bottled waters commercially available in Qatar and Hong Kong had F concentrations of less than 0.3ppm while the minority had F concentrations higher than 1.5ppm, and (ii) disparities were evident between the F concentration displayed on the label and the measured F concentration.

## REFERENCES


1. Griffin SO, Regnier E, Griffin PM, Huntley V. Effectiveness of fluoride in preventing caries in adults. J Dent Res; 86: 410-415. 2007.
2. Buzalaf MA, Levy SM. Fluoride intake of children: considerations for dental caries and dental fluorosis. Monogr Oral Sci; 22: 1-19. 2011.
3. Bratthall D, Hänsel-Petersson G, Sundberg H. Reasons for the caries decline: what do the experts believe? Eur J Oral Sci; 104: 416-422. 1996.
4. Hong L, Levy SM, Broffitt B, Warren JJ, Kanellis MJ, Wefel JS, et al.Timing of fluoride intake in relation to development of fluorosis on maxillary central incisors. Community Dent Oral Epidemiol; 34: 299-309. 2006.
5. Pendrys DG, Stamm JW. Relationship of total fluoride intake to beneficial effects and enamel fluorosis. J Dent Res; 69: 529-538. 1990.
6. Pendrys DG. Analytical studies of enamel fluorosis: methodological considerations. Epidemiol Rev; 21: 233-246. 1999.
7. World Health Organization. Guidelines for drinking-water quality, third edition, incorporating first addendum, Volume 1-Recommendations 2006.
8. Hujoel PP, Zina LG, Moimaz SA, Cunha-Cruz J. Infant formula and enamel fluorosis: a systematic review. J Am Dent Assoc; 140: 841-854. 2009.
9. Cochrane NJ, Saranathan S, Morgan MV, Dashper SG. F content of still bottled water in Australia. Aust Dent J; 51: 242-244. 2006.
10. Weinberger SJ. Bottled drinking water: are F concentrations shown on the labels accurate? Int J Paediatr Dent; 1: 143-146. 1991.
11. Toumba KJ, Levy S, Curzon MEJ. The F content of bottled drinking waters. Br Dent J; 176: 266-268. 1994.
12. Zohouri FV, Maguire A, Moynihan PJ. Levels in bottled F water. Br Dent J; 195: 515-518. 2003.
13. Khan NB, Chohan AN. Accuracy of bottled drinking water label content. Environ Monit Assess; 166: 169-176. 2010.
14. Wong HM, McGrath C, Lo ECM, King NM. Association between developmental defects of enamel and different concentrations of F in the public water supply. Caries Res 2006; 40: 481-486.
15. Burt BA. The changing patterns of systemic fluoride intake. J Dent Res; 71: 1228-1237. 1992.
16. Australian Research Centre for Population Oral Health. The use of fluorides in Australia: guidelines. Aust Dent J; 51: 195-199. 2006.
17. American Academy of Pediatric Dentistry. Guideline on fluoride therapy. Pediatr Dent; 34: 166-169. 2012.
18. Swan E. Dietary fluoride supplement protocol for the new millennium. J Can Dent Assoc; 66: 362. 2000.
19. Clarkson J. A European view of fluoride supplementation. Br Dent J; 172: 357. 1992.
20. Stannard J, Rovero J, Tsamtsouris A, Gavris V. F content of some bottled waters and recommendations for F supplementation. J Pedod; 14: 103-107. 1990.
21. Van Winkle S, Levy SM, Kiritsy MC, Heilman JR, Wefel JS, Marshall T. Water and formula fluoride concentrations: significance for infants fed formula. Pediatr Dent; 17: 305-310. 1995.
22. Johnson SA, DeBiase C. Concentration levels of F in bottled drinking water. J Dent Hyg; 77: 161-167. 2003.
23. MacFadyen EE. F content of some bottled spring waters. Br Dent J; 153: 423-424. 1982.
24. Meenakshi, Maheshwari RC. Fluoride in drinking water and its removal. J Hazard Mater ; 137:456-463. 2006.
25. Siew C, Strock S, Ristic H, Kang P, Chou HN, Chen JW, et al. Assessing a potential risk factor for enamel fluorosis: a preliminary evaluation of fluoride content in infant formulas. J Am Dent Assoc; 140: 1228-1236. 2009.