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QUANTITATIVE PROBABILISTIC RISK ASSESSMENT OF FLUORIDE, NITRATE AND NITRITE INTAKE FROM BOTTLED WATER IN WEST-IRANIAN CONSUMERS

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ABSTRACT: The presence of anions such as fluoride, nitrate, and nitrite in bottled water is of great concern, as they may affect human health and cause various illnesses. This study aims to measuring the concentration of fluoride, nitrate, and nitrite in different brands of bottled waters and assessment the non-carcinogenic health risks caused by exposure to nitrate, nitrite, and fluoride. The fluoride, nitrate, and nitrite concentration was measured by SPANDS method, the cadmium reduction method, and diazotization method, respectively. The concentration of all three mentioned anions was then measured by using Spectrophotometer (DR5000, Hatch, USA). The hazard quotient (HQ) of fluoride, nitrate, and nitrite was then calculated based on the available variables such as fluoride, nitrate, and nitrite concentration, water per capita, body weight, and reference dose. The results declared that the concentration of fluoride, nitrate, and nitrite was in the range of and 0.01 to 0.7 mg/L (mean 0.2430), 1 to 14.1 mg/L (mean 6.964 mg/L), 0.01 to 0.08 mg/L (mean 0.037 mg/L), respectively. Around 7% of fluoride, 71% of nitrate, and 78% of nitrite measured concentrations were higher than the reported concentrations on the labels. Considering the results, we can see that all the achieved concentrations were less than the WHO drinking water guideline. Then the assessment of non-cancerous health risks caused by exposure to fluoride, nitrate, and nitrite was conducted. Results showed that the HQ for all anions in all age subgroup were lower than 1 (HQ<1). So, the results declared that the range of fluoride, nitrate, and nitrite in the studied bottled waters were in acceptable range and have no human health adverse effect.

Keywords: Bottled water; Fluoride; Iran; Nitrate; Nitrite; Risk assessment.

INTRODUCTION

The rapid growth of the world's population has led to an increase in water demand. The biological and chemical contamination of drinking water resources may have some serious health effects.[1] As a result, the demand for bottled water has spiked in most countries.[2-4] The main reasons that allowed bottled waters to play such a dominant role in people's lives are their availability, low price, more pleasing taste and smell, containing fewer impurities, and higher microbial and chemical qualities compared with tap water.[5,6] Also, the poor quality of tap water in many cities has made people use bottled waters instead.[7] Generally, the main sources of bottled waters include local springs, deep groundwater aquifers, urban distribution networks, or they could be achieved from resources treated by conventional treatment processes.[8] Apart from all mentioned before, bottled waters have a dark side that can

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increase human health impacts. Nowadays, there is a growing concern over chemical parameters due to the consumption of the mentioned water resources and their related possible health effects.[9,10]

Fluoride is one of the crust elements which has correlation with other elements[13] and has differing effects on human health based on the concentration and exposure duration.[12,13] High levels of fluoride threaten an estimated 200 million people in over 29 countries, including Argentina, Mexico, Russia, China, India, Korea, Sri Lanka, Pakistan, and parts of Africa, Iran, and others.[14,15] As well as food, drugs, and cosmetics, drinking water is the only daily source of fluoride intake in humans.[16,17] While high amounts of fluoride in water are dangerous, historically some have considered that it can also have a beneficial effect on tooth and bone structure so that about 1 mg/L in the diet can prevent skeletal and dental disorders.[18,19] However, fluoride use to improve bone strength is no longer recommended as although the bone may be denser it is of inferior quality had prone to fracture. Community water fluoride at levels of approximately 0.7 mg/L is still practised in many countries but controversy continues about its safety, particularly with respect to development neurotoxicity. The long-term usage of high levels of fluoride in drinking water (e.g., over 8 mg per day) can lead to thyroid disorders, skeletal, and dental fluorosis.[20,21] WHO has reported that a decrease in the level of fluoride to <0.5 mg/L can lead to increased tooth decay. Adverse effects attributed to various levels of fluoride include decreased intelligence quotient (IQ),[22,23] developmental and functional disorders of the central nervous system,[24] and miscarriage.[12] The solubility of fluoride varies with the temperature, so a higher amount of fluoride can be found in warmer water and dry climates; therefore exposure and consumption of fluoride in these regions are of greater concern.[25,26]

Other components that exist in drinking water are nitrates and nitrites which account for several illnesses.[27] The elevated amounts of nitrite and nitrate in water can be due to anthropogenic activities such as leaching of nitrogen-containing fertilizers, improper sewage treatment, and decomposing living organisms.[28,29] Nitrate can enter the body in various ways, most notably by drinking water that contains nitrate.[30] Conventional water treatment processes cannot remove nitrate completely.[31] Children, particularly infants, are significantly more susceptible to nitrate due to their incomplete immune systems.[30] Nitrate and nitrite are rapidly absorbed through the small intestine and penetrate the blood.[32] Once absorbed in the blood, nitrite is rapidly oxidized to nitrate and the reaction between nitrate and hemoglobin leads to the production of methemoglobin.[33] In this case, hemoglobin will not be able to bind to oxygen and carbon dioxide, and therefore will not be able to transport them between tissues and lungs, which finally leads to anemia and cyanosis in the person.[34] The most prominent sign of cyanosis is blue skin, especially around the mouth and eyes.[33] The World Health Organization recommends 0.2 mg/L for chronic nitrite-related side effects. The recommended concentration of nitrate is 50 mg/L.[35] Due to the simultaneous intake of nitrate and nitrite into drinking water, the total measured ratio of these anions must be less than 1.[36]

One of the most common challenges that countries are facing is the high concentration of elements such as nitrate, nitrite, and fluoride in the aqueous bodies and drinking water.[37,38] Direct ingestion of F, NO_3, and NO_2, via food or drinking water, contributes a higher risk in humans than other exposure pathways.[39,40] As a result, ongoing monitoring of water resources in these fields as a public health concern is a requirement. This study aimed to: 1) measure the concentration of fluoride, nitrate, and nitrite in different brands of bottled waters which were currently available in Selseleh markets while this study was conducted, 2) compare the measured levels of mentioned ions with the reported amounts on the bottle labels and finally, and 3) investigate the non-carcinogenic health risks caused by exposure to nitrate, nitrite, and fluoride.

MATERIAL AND METHODS

Study area: This study was carried out in Selseleh city located at the north of Lorestan Province, Iran (33º 50’ N, 48º 10’ E) (Figure.1). The city area is about 6233 km^2, and at the 2016 census, its population was 77,306. Selseleh has a semi-humid Mediterranean climate with a high amount of rainfall during winter and spring. This city has many rivers and springs so surface water is used to supply drinking water. The elevation of this city is 1700 meters above sea level. the annual rainfall and temperature of the city are 510 millimeters (75 days) and 17ºC.[41,42]

Sample collection and analysis: In this study, 14 available samples of packaged bottles (made of polyethylene) water were purchased randomly from local supermarkets. For ethical considerations, instead of using the real names of the purchased brands, we coded them by S1 to S14. All of the purchased bottled waters had a volume of 500 mL and had a validity of 1 year. Standard operating protocols and procedures were followed according to the standard methods for water and wastewater to collect and transfer samples to the laboratory until analysis.[43] To maintain temperature and prevent it from creating errors in the final results, the samples were placed in an ice-box and then transferred to the Lorestan University of Medical Sciences laboratory for analysis of the mentioned ions: fluoride, nitrate, and nitrite. First, the concentration of fluoride, nitrate, and nitrite was measured by the relevant methods, followed by comparing the measured concentrations with the written measures on the labels, and then the risk assessment was conducted according to the US Environmental Protection Agency approach.

The SPADNS method is commonly used to determine fluoride in water samples. Stock fluoride solution was prepared from sodium fluoride. In this method, 50 mL of the water sample was combined with 10 mL of SPADNS and zirconium acid. The fluoride ion concentration was then read at 570 nm using a spectrophotometer (DR5000, Hatch, USA (and obtained limits of determination (LOD) and quantification (LOQ) were 0.12 ppm and 0.37 ppm respectively. The determination of nitrate (as mg/L NO_3^-) was based on the cadmium reduction method and nitrite (as mg/L NO_2^-) was based on the diazotization method. Spectrophotometer (DR5000, Hatch, USA) was used to determine the concentration of nitrate and nitrite ions. This device was set up in program number 190 at 220 and 275 nm. Modification of the analysis was performed at a wavelength of 275 nm to minimize the interference of organic matter in UV Method. After calibration of the spectrophotometer, the calibration curve was plotted separately with six concentrations of nitrate and fluoride. R^2 = 99.26 and 99.82 were obtained for fluoride and nitrate, respectively.[45,46]

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Figure 1. Location map of the study area.

Reagents: All chemicals used in this study were of analytical grade and supplied from Merck in Germany. Distilled water obtained by Milli-Q water purification system, was used in all solutions, rinsing of apparatus, stock and solutions preparing. A stock standard solution (500 mg L^{-1}) of nitrite and nitrate were prepared by dissolving calculated measures of $NaNO_3$, and KNO_3, in distilled water. The resulting solutions was then stored in brown bottles and kept at 4ºC, for a maximum period of 2 weeks.

Health risk assessment: Risk Assessment in the Federal Government: Managing the Process (NRC 1983; commonly referred to as the Red Book) was used as a reference.[45] According to this publication, human health risk assessment includes four steps:

a) HAZARD IDENTIFICATION: The purpose of this step is to determine some of the adverse factors caused by exposure to nitrate, nitrite and fluoride via drinking bottled water, this hazard is according to the nature of nitrate, nitrite and fluoride effects on the human health.

b) DOSE–RESPONSE ASSESSMENT: The purpose of this step is to document the relationship between dose and toxic effect; by which the increase in the chemical substances (nitrate, nitrite and fluoride) concentration can lead to an increase in the health effect.

c) EXPOSURE ASSESSMENT: The purpose of this step is to calculate a digital assessment of exposure or dose.

d) RISK CHARACTERIZATION: The purpose of this step is to summarize and integrate information from the preceding steps to synthesize an overall conclusion about risk.

In this study, to evaluate non-carcinogenic health risk chronic daily intake (CDI) (mg/kg) was calculated using the following equation [46]

$$\mathrm{CDI} = \frac{C \times IR \times \mathrm{EF} \times \mathrm{ED}}{BW \times \mathrm{AT}} \quad (1)$$

Where C is the nitrate or fluoride concentration (mg/L), IR is the daily intake of water (L/d), EF is the exposure frequency (365 days/year), ED is the exposure duration of different age groups (infants = 1.5 years, children = 4, teenagers = 14, and adults = 40), BW is the average body weight of the consumers, and AT is the average time for each age group (ED × 365 days).

We did not have access to the data on the daily consumption of bottled water, therefore we assumed that the IR of bottled water is similar to the IR of tap water. All parameters for HRA are shown in Table 1. Furthermore, the age groups are categorized as (years old): 0–2 = infants, 2–9 = children, 9–18 = teenager, and > 18 = adults.

By obtaining CDI using Eq. 1, the target hazard quotient (HQ) can be calculated by Equation 2.

$$\mathrm{HQ} = \frac{CDI}{RfD} \quad (2)$$

Where RfD is the oral reference dose, describing the effect of each milligram of pollutant on each kilogram of body weight per day (mg/kg day). The RfD level of a contaminant is crucial in non-carcinogenic risk assessment. Based on the US-EPA Integrated Risk Information System (IRIS), the RfD values for fluoride, nitrate, and nitrite are 0.06, 1.6, 0.1 and mg/kg day, respectively.[37] The obtained HQ value is interpreted as follows: an HQ value <1 indicates that no adverse health effects may occur as a result of exposure to the reported pollutant concentrations, whereas an HQ value >1 suggests that a potential adverse non-carcinogenic health effect may occur upon exposure. [47]

The risk assessment parameters are demonstrated in **Table 1**.

Table 1. Quantitative parameters used in risk assessment of age subgroups

Parameter	Unit	Distribution	Infant	Children	Teenagers	Adults	Reference
Concentration of (NO_2, NO_3, F) (C)	mg/L	Lognormal	-	-	-	-	Table 2
Intake rate (IR)	L/day	Lognormal	0.3	0.78	2	2.5	[50]
Exposure frequency (EF)	Days/year	Uniform	365	365	365	365	[50]
Exposure duration (ED)	Year	Uniform	4	4	13	40	[50]
Body weight (BW)	kg	Normal	15	15	50	72	[50]
Average time (AT)	Days	Uniform	1460	1460	4745	14600	[50]

Sensitivity and uncertainty analysis: The risk assessment process was used to estimate the potential for adverse health effects in people who were exposed to hazardous chemicals in the environment or the workplace during the day. It should be noted that this process is affected by uncertainties that, if not taken into account, can lead to overestimation or underestimation of the risk, which ultimately leads to unrealistic decisions related to public health. For this reason, in this study, Monte Carlo simulation (MCS) was performed to eliminate uncertainties. MCS considers all random scenarios to overcome uncertainty.

Statistical Analysis: All descriptive statistics such as average, standard deviation, minimum and maximum for the subjected parameters were calculated by Excel 2016 software. All statistical analyses were performed using IBM SPSS Statistics version 26.0. The normality assumption of the gathered data was tested using Kolmogorov-Smirnov test. The student's t-test was conducted to compare nitrate, nitrite, and fluoride mean concentrations between bottled waters and the standard range given by the WHO. The sample t-test was also done for the comparison of ions concentrations between bottled waters contents and their labels. In all data analysis p-value was less than 0.05 ($p\text{-value} < 0.05$) and was considered to be statistically significant.

RESULTS AND DISCUSSION

Differences in concentrations on labels and samples: As can be seen, in Table 2, we compared the concentration of the parameters in the bottled water with the results obtained *in vitro*. The safe range declared by WHO for fluoride is 0.7–1.5 mg/L, although WHO also allows countries to set Country Standards, their own national standards or local guidelines. Senegal has set a limit of 0.6 mg/L and India 1 mg/L, withe the rider the "lesser the fluoride the better, as fluoride is injurious to health."

Our results indicated fluoride measured in all samples was less than 1.5 g/L. The maximum and minimum amount of nitrite obtained from the sample was equal to 0.01 and 0.08 mg/L respectively. WHO has set the amount of 50 mg/L for nitrate, Based on the results shown in Table 2, the nitrate measured in all of the total of 14 samples were less than the WHO guidelines. Also, Table 2 shows the maximum and minimum, mean, and standard deviation are for all three parameters (F, NO_3^- and, NO_2^-).

Table 2. Comparison of the concentration of the components on bottled water and the results obtained in the laboratory

Sample	F (mg/L)		NO_3 (mg/L)		NO_2 (mg/L)	
	Sample	Label	Sample	Label	Sample	Label
S1	0.1	0.8	8	3.5	0.07	0.01
S2	0.1	0.5	4	2.9	0.03	0.02
S3	0.2	1	4	1.8	0.02	0.01
S4	0.1	0.7	12	4	0.01	0.03
S5	0.2	0.9	4	2.5	0.02	0.01
S6	0.2	0.7	8	0.5	0.02	0.02
S7	0.1	0.075	1	0.7	0.02	0.01
S8	0.3	0.7	3	4	0.03	0.01
S9	0.2	1.5	4	4.5	0.08	0.02
S10	0.6	1.2	5	3	0.01	0.02
S11	0.7	0.9	11.6	5	0.04	0.03
S12	0.2	0.5	13.1	0.9	0.06	0.02
S13	0.1	1.2	5.7	8	0.05	0.01
S14	0.3	0.7	14.1	1.5	0.06	0.02
Mean	0.243	0.813	6.964	3.057	0.037	0.017
SD	0.187	0.352	4.201	2.026	0.023	0.007
Min	0.1	0.075	1	0.5	0.01	0.01
Max	0.7	1.5	14.1	8	0.08	0.03

Table 3, shows the percent of equal, higher, and lower measured concentrations of fluoride, nitrate, and nitrite toward the mentioned amounts reported on the labels. All of the measured concentrations of fluoride, nitrate, and nitrite in the 14 samples were

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in the declared range by the WHO.[49] According to the results of the paired t-test, there was a meaningful difference between the mean concentration of the mentioned ions and the mean concentration reported on the labels ($p < 0.05$). Most articles found that there is a difference between the results on the bottle and the results analyzed in the laboratory. This difference can be referred to various factors like weather conditions such as evaporation, poor storage, or poor quality of the bottles containing water. Also, in some cases, the results of the analysis are reported deliberately less than the actual concentrations, and used, by default, the results of previous valid cases that did not cause concern.

Table 3. Comparison of real contents of bottled waters versus their reported concentrations on the label

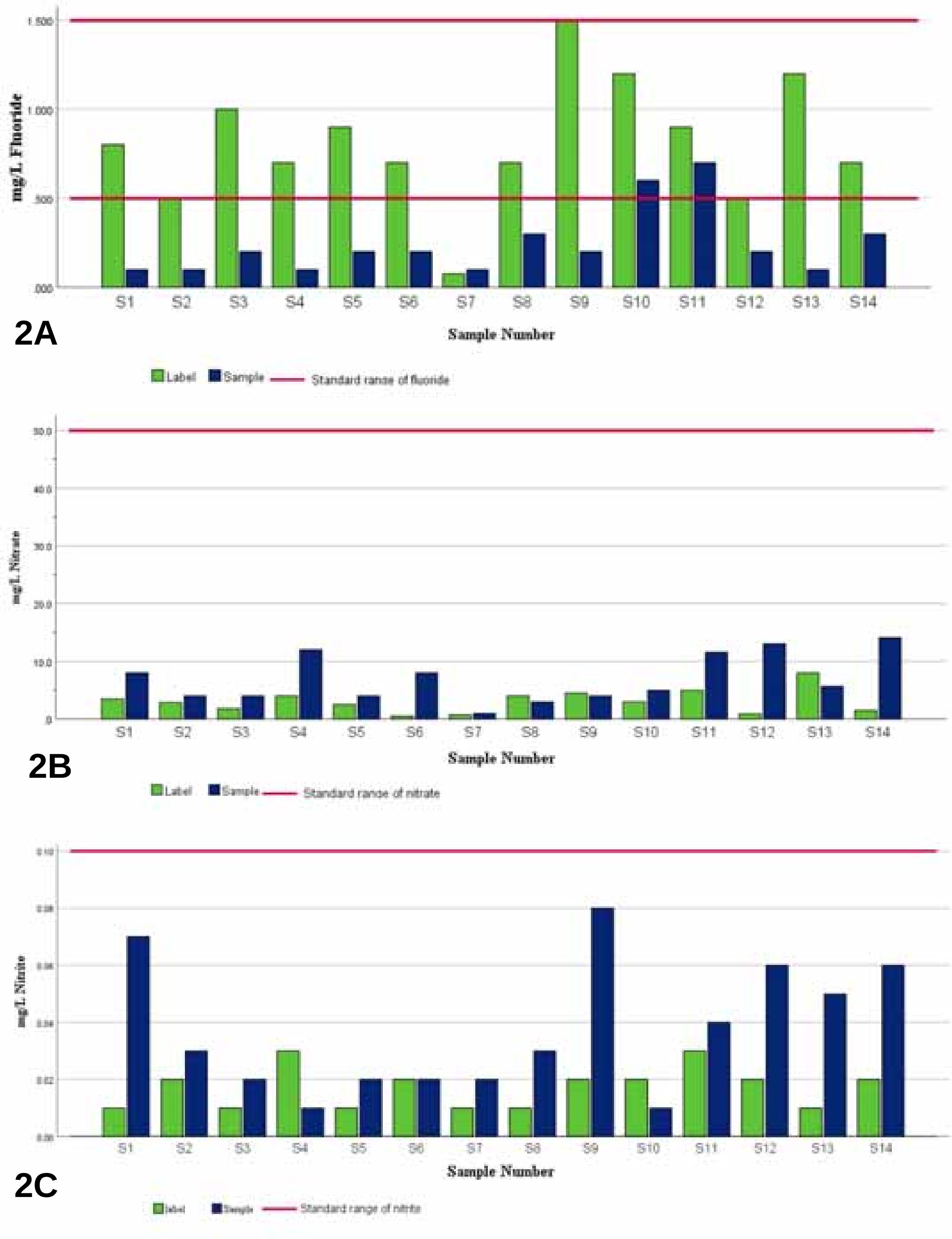
Parameter	% equal to the label	% greater than the label	% lower than the label	% not indicated in the label
F	0.00	7.15	92.85	0.00
NO_3^-	0.00	71.43	28.57	0.00
NO_2^-	7.14	78.57	14.29	0.00

The fluoride, nitrate, and nitrite actual concentrations in the analyzed samples were greatly different from the concentrations reported on the labels. In Figures 2A–2C, the comparison of actual concentrations of F, NO_3^-, and NO_2^- versus the reported concentrations on the labels are shown. The red line in Figures 2A–2C represents the codex regulations declared by the WHO.

Health risk assessment: According to the International Environmental Protection Agency, the risk assessment beneath water consumption conditions per day can be calculated throughout human life or for a specific period. Fluoride, nitrate, and nitrite pollutants are considered type D carcinogens. The number of carcinogenic health risks of nitrite, nitrate, and fluoride in 14 different sample bottled water brands in Selseleh in the current study were investigated. Firstly, we calculated CDI (mg/kg) for nitrite, nitrate, and fluoride for different age groups (i.e., infants, children, teenagers, and adults) (see Tables 4A–4C) according to Equation 1.

Uncertainty analysis: The MSC was used to calculate the probable HQ's for the four age groups for fluoride, nitrate, and nitrite with 90% confidence intervals and was performed using Oracle Crystal Ball 11.1.34190 with 10,000 iterations with the upper confidence level of fluoride, nitrate, and nitrite at the 95th centile (p95).[8]

The upper-bound intervals (95th centile) of infants, children, teenager and adult's HQs due to exposure with fluoride in the bottled water were 0.31, 0.54, 0.41, and 0.33, respectively (Figures 3A–3C). As shown in the Figures 3A–3D, the fluoride concentration in the bottled water had no adverse effect in any of the four age groups (HQ<1)



Figures 2A–2C. Comparison the measured levels of 2A:fluoride, 2B: nitrate, and 2C: nitrite) with the reported amounts on the bottle labels.

Table 4A. Fluoride HQ value in the studied area for age subgroups (infants, children, teenager and adults)

Sample	HQ for fluoride			
	Infants	Children	Teenagers	Adults
S1	0.050	0.087	0.067	0.053
S2	0.050	0.087	0.067	0.053
S3	0.100	0.173	0.133	0.107
S4	0.050	0.087	0.067	0.053
S5	0.100	0.173	0.133	0.107
S6	0.100	0.173	0.133	0.107
S7	0.050	0.087	0.067	0.053
S8	0.150	0.260	0.200	0.160
S9	0.100	0.173	0.133	0.107
S10	0.300	0.520	0.400	0.321
S11	0.350	0.607	0.467	0.374
S12	0.100	0.173	0.133	0.107
S13	0.050	0.087	0.067	0.053
S14	0.150	0.260	0.200	0.160
Mean	**0.121**	**0.211**	**0.162**	**0.130**
SD	0.093	0.162	0.125	0.100

Table 4B. Nitrate HQ value in the studied area for age subgroups (infants, children, teenager and adults)

Sample	HQ for nitrate			
	Infants	Children	Teenagers	Adults
S1	0.150	0.260	0.200	0.160
S2	0.075	0.130	0.100	0.080
S3	0.075	0.130	0.100	0.080
S4	0.225	0.390	0.300	0.240
S5	0.075	0.130	0.100	0.080
S6	0.150	0.260	0.200	0.160
S7	0.019	0.033	0.025	0.020
S8	0.056	0.098	0.075	0.060
S9	0.075	0.130	0.100	0.080
S10	0.094	0.163	0.125	0.100
S11	0.218	0.377	0.290	0.232
S12	0.246	0.426	0.328	0.262
S13	0.107	0.185	0.143	0.114
S14	0.264	0.458	0.353	0.282
Mean	**0.131**	**0.226**	**0.174**	**0.139**
SD	0.079	0.136	0.105	0.084

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Table 4C. Nitrite HQ value in the studied area for age subgroups (infants, children, teenager and adults)

Sample	HQ for nitrite			
	Infants	Children	Teenagers	Adults
S1	0.021	0.036	0.028	0.022
S2	0.009	0.016	0.012	0.010
S3	0.006	0.010	0.008	0.006
S4	0.003	0.005	0.004	0.003
S5	0.006	0.010	0.008	0.006
S6	0.006	0.010	0.008	0.006
S7	0.006	0.010	0.008	0.006
S8	0.009	0.016	0.012	0.010
S9	0.024	0.042	0.032	0.026
S10	0.003	0.005	0.004	0.003
S11	0.012	0.021	0.016	0.013
S12	0.018	0.031	0.024	0.019
S13	0.015	0.026	0.020	0.016
S14	0.018	0.031	0.024	0.019
Mean	**0.011**	**0.019**	**0.015**	**0.012**
SD	0.007	0.012	0.009	0.007

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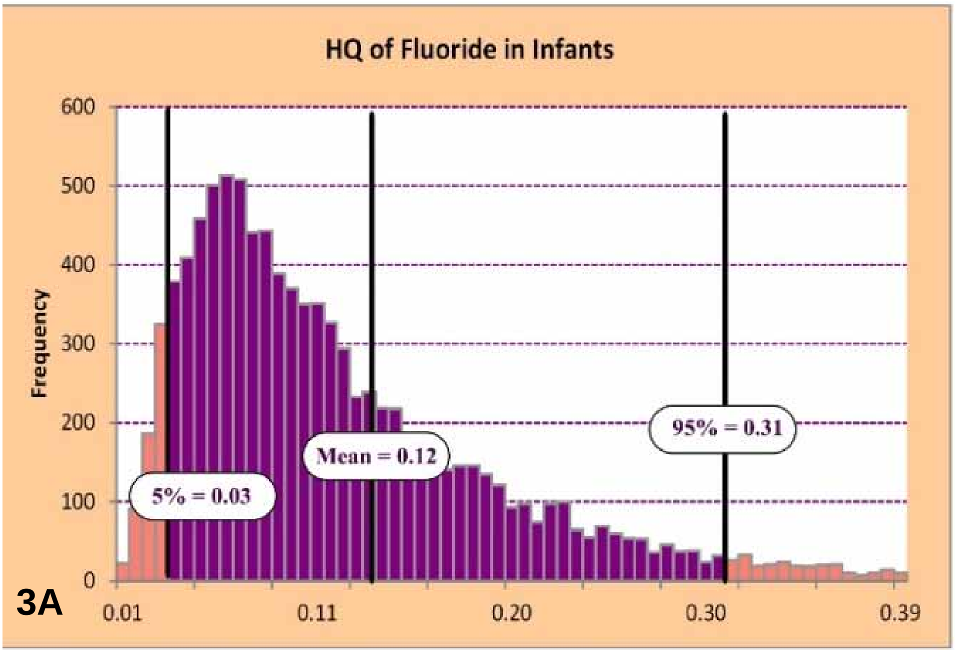
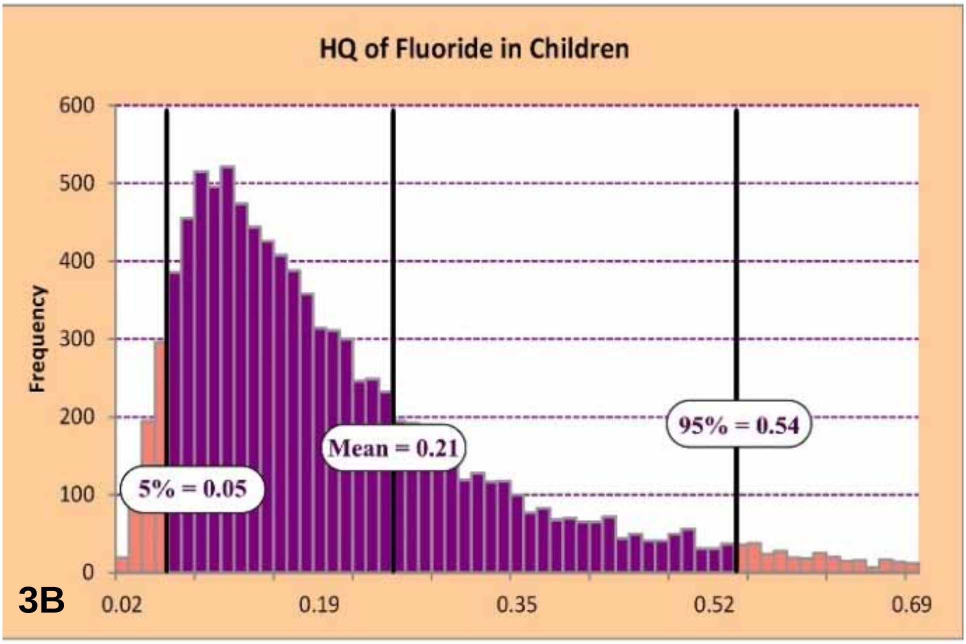
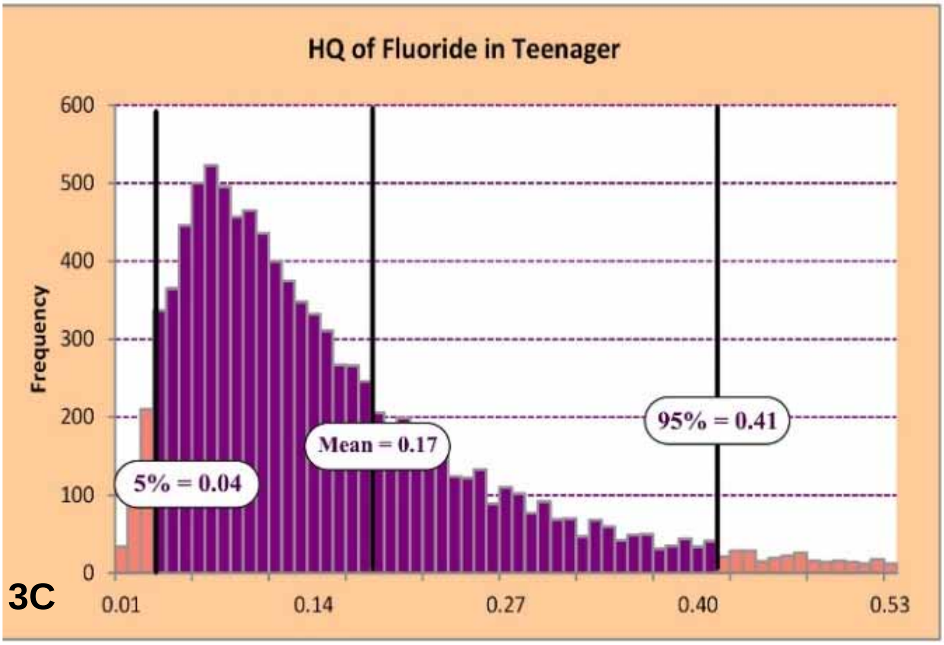
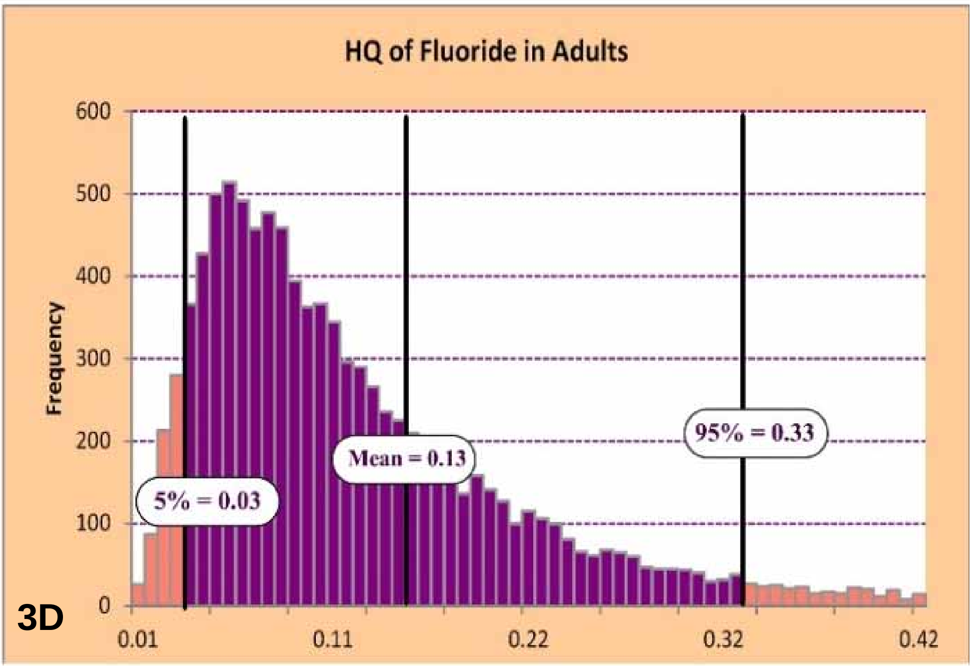




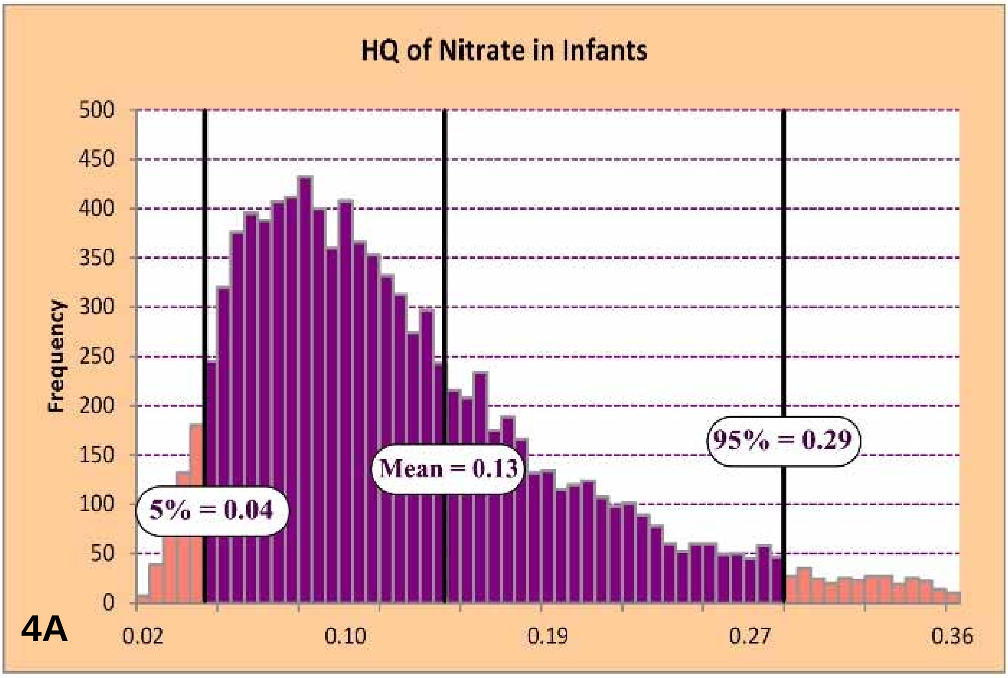
Figures 3A and 3B. Histograms of the uncertainty analysis of fluoride HQ of bottled water in 3A: infants and 3B: children.

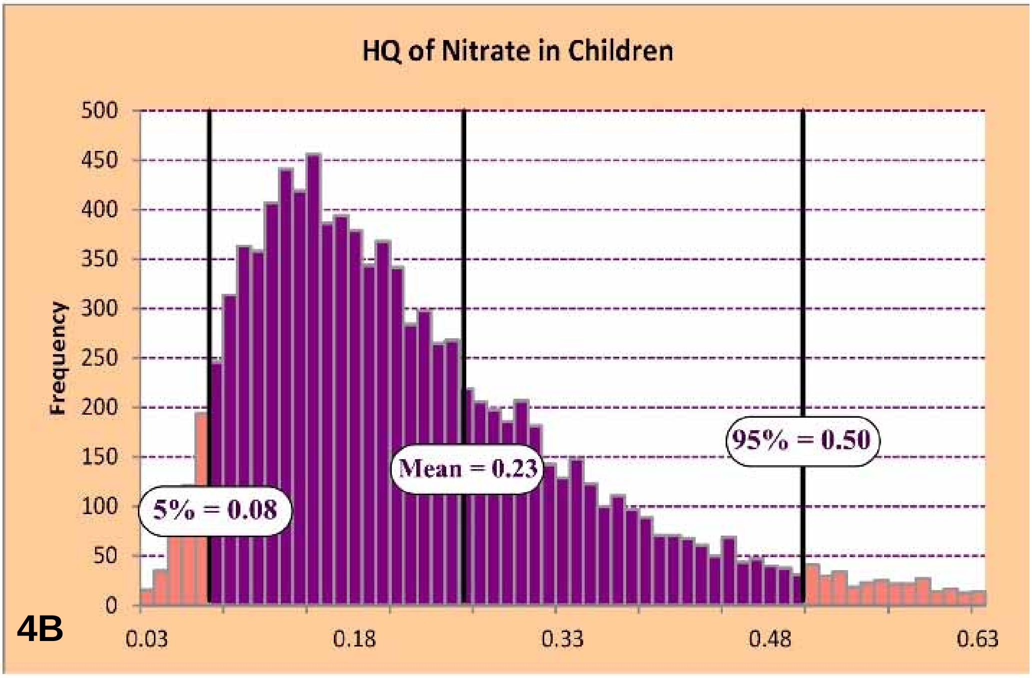




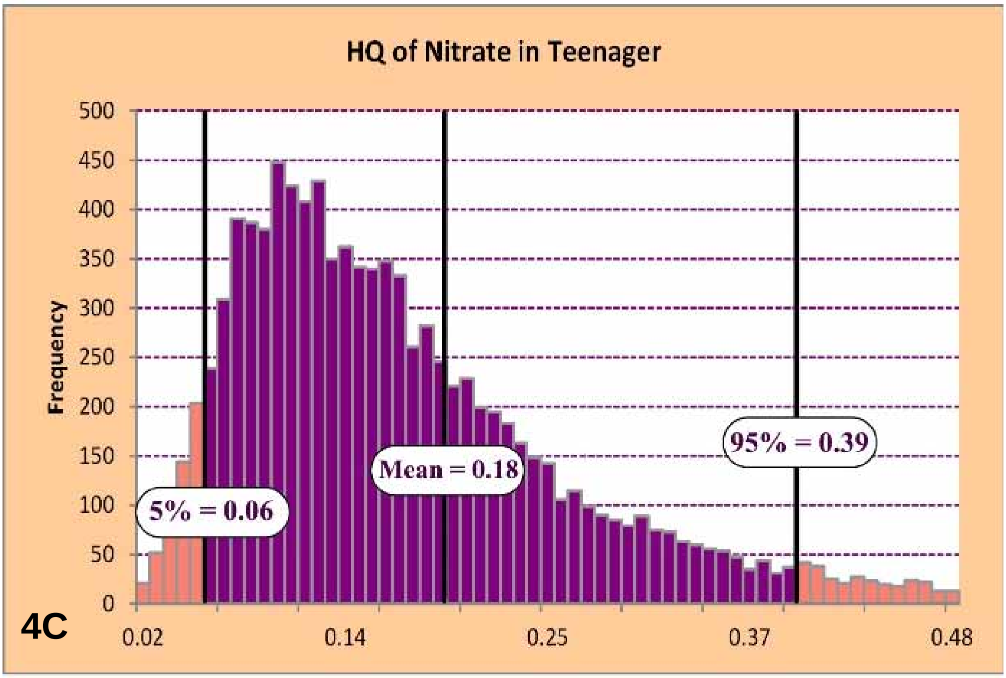
Figures 3C and 3D. Histograms of the uncertainty analysis of fluoride HQ of bottled water in 3C: teenagers and 3D: adults.

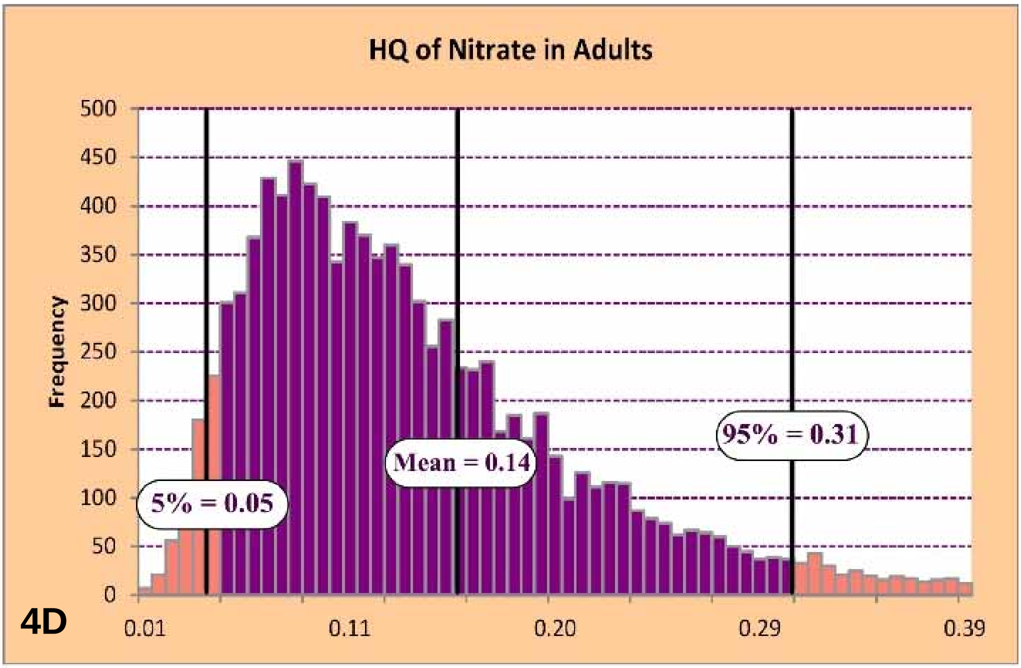
By consideration a certainty of 90% the 95th percentile of infant's, children, teenager's and adult's HQs, which were simulated based on the exposure to nitrate in the bottled water, were 0.29, 0.50, 0.39, and 0.31, respectively. Figures 4A–4D show that, in all the age categories, there was no adverse effect according the nitrate concentration in the bottled waters which are on sale in the Selseleh markets (HQ<1).





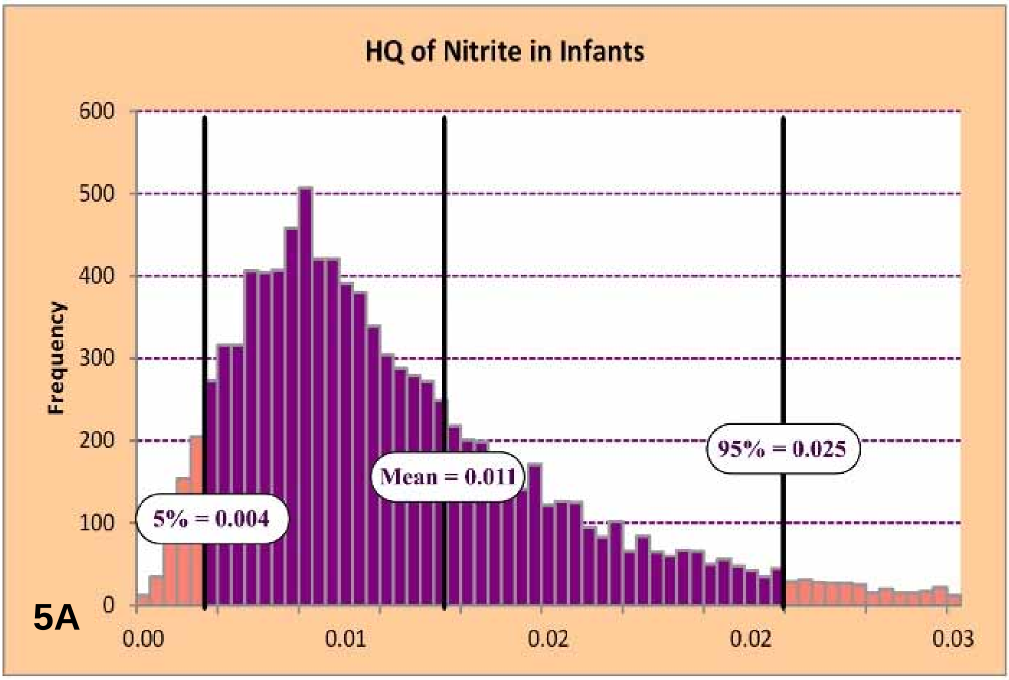
Figures 4A and 4B. Histograms of the uncertainty analysis of nitrate HQ of bottled water in 4A: infants and 4B: children.

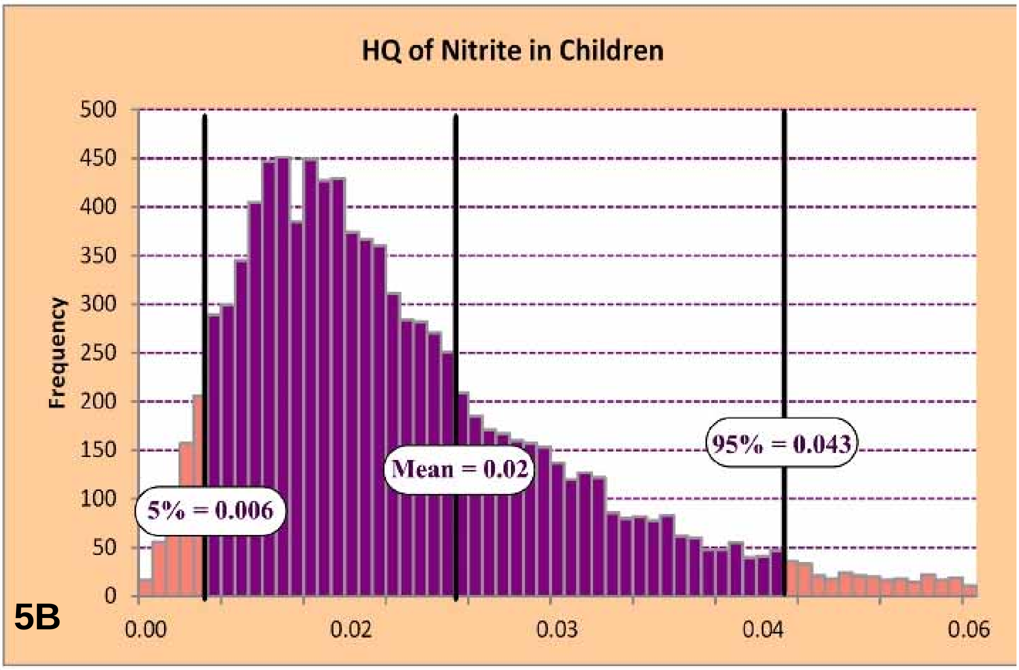




Figures 4C and 4D. Histograms of the uncertainty analysis of nitrate HQ of bottled water in 4C: teenagers and 4D: adults.

The 95th centile of HQs in all age categories due to nitrite in the bottled water were less than 1 (HQ<1). The HQs in infants, children, teenagers, and adults were 0.025, 0.043, 0.033, and 0.027, respectively (see Figure 5).





Figures 5A and 5B. Histograms of the uncertainty analysis of nitrite HQ of bottled water in 5A: infants and 5B: children.

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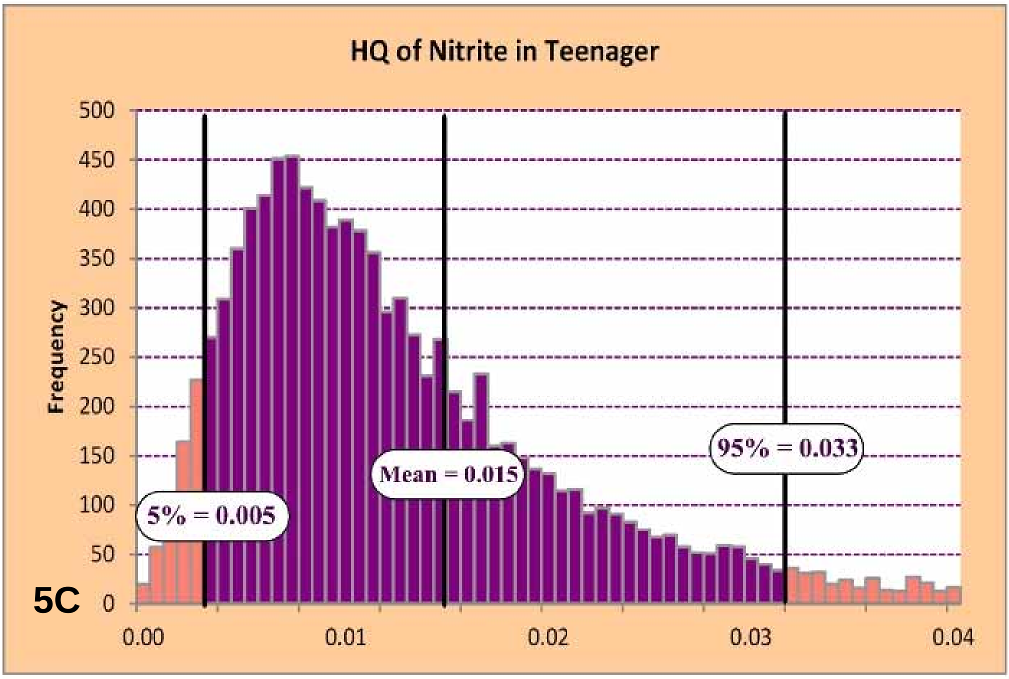
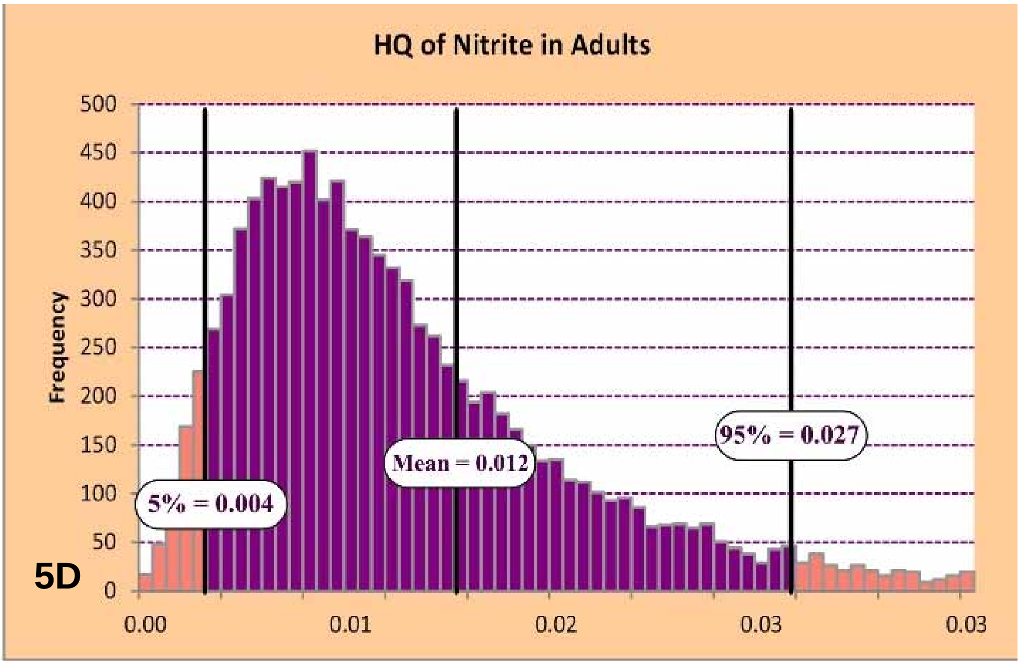




Figures 5C and 5D. Histograms of the uncertainty analysis of nitrite HQ of bottled water in 5C: teenagers and 5D: adults.

So, fluoride, nitrate, and nitrite, at the concentrations found in the bottled water on sale in Selseleh's market have no adverse effect in human health.

Sensitivity analysis: Sensitivity analysis (SA) was performed to investigate the effect of F, NO_3, and NO_2, on health. SA results for fluoride, nitrate, and nitrite in all age groups are reported in the Figures 6A–6D, 7A–7D, and 8A–8D. The results of sensitivity analysis showed that nitrate concentration had the greatest effect on health outcomes for all age groups, while parameters such as the IR and BW had a small effect. According to the results of this study, several studies have reported that the ion concentration and IR have an increasing effect, while the BW has a reducing effect on the level of risk.

As shown in the tornado plots the concentration of fluoride, nitrate and nitrite can increase the probable risk by 94%, 92.5%, and 92.6%, respectively. Also, BW can decrease about 1.8%, 2.3% and 2.1% due to fluoride, nitrate and nitrite, respectively (see Figures 6A–6D, 7A–7D, and 8A–8D). Generally, based on risk assessment equations, the chemical substances concentration, exposure frequency, exposure duration, and water daily consumption have a positive effect on increasing the adverse effect so increasing these parameters can increase the risk. Body weight and average time have a negative effect on increasing risk so increasing these parameters can decrease the adverse effect. However, both body weight and water consumption should be in the normal range because of obesity and reducing water usage can have a severe effect on human health. Controlling the chemical substances concentration in bottled water and other pathways can help to reduce the adverse effect.

CONCLUSIONS

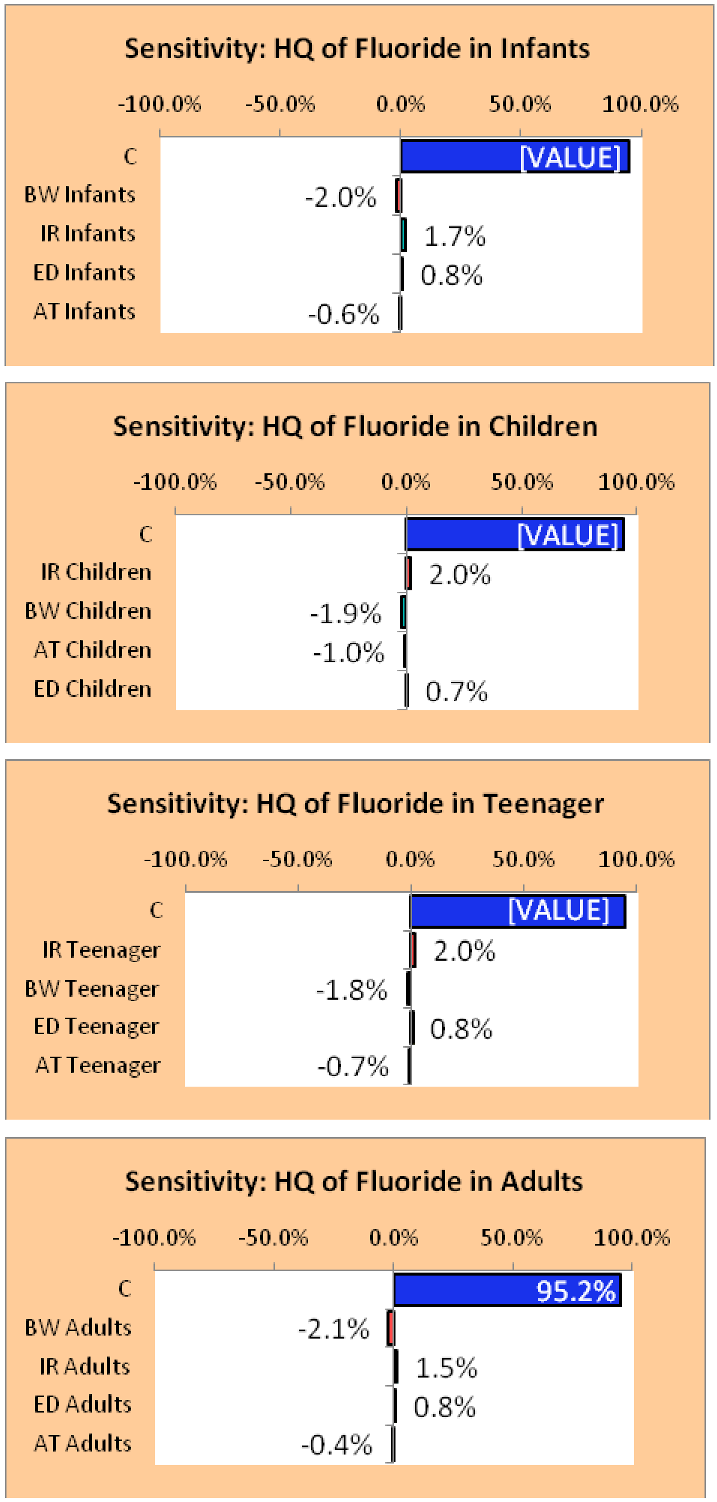
Clean and safe water as a fundamental human right is essential for public health and wellbeing. During the past decades, the rapid population growth and industrialization has put severe pressure on water quality and quantity, particularly in developing countries, so monitoring bottled water, their listed components, and the labels on the bottled water in markets are required to avoid potential health risks. The current study covered only a few bottled waters as the main brands of drinking water in markets, therefore, further investigations on other brands of bottled water are recommended. Although our results reported that the range of fluoride, nitrate, and nitrite in the studied bottled waters were in an acceptable range and they are not considered hazardous in terms of public health, policy makers' special attention to risk assessment and reducing the risks associated with water pollutants, could prevent problems related to public health.

6A

6B

6C

6D



Figures 6A–6D. Sensitivity analysis, HQ, of exposure to fluoride in bottled water. 6A: infants, 6B: children, 6C: teenagers, and 6D: adults.

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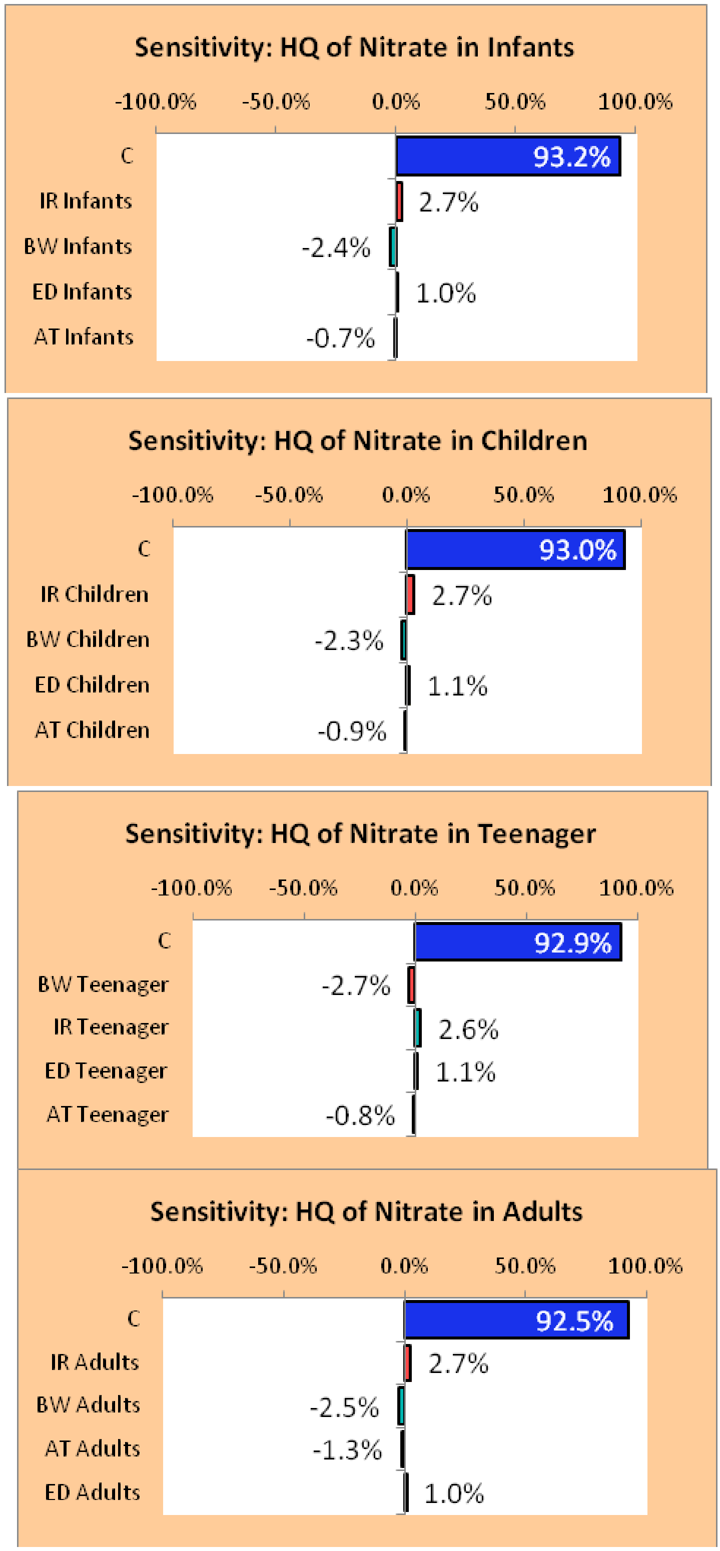
7A

7B

7C

7D



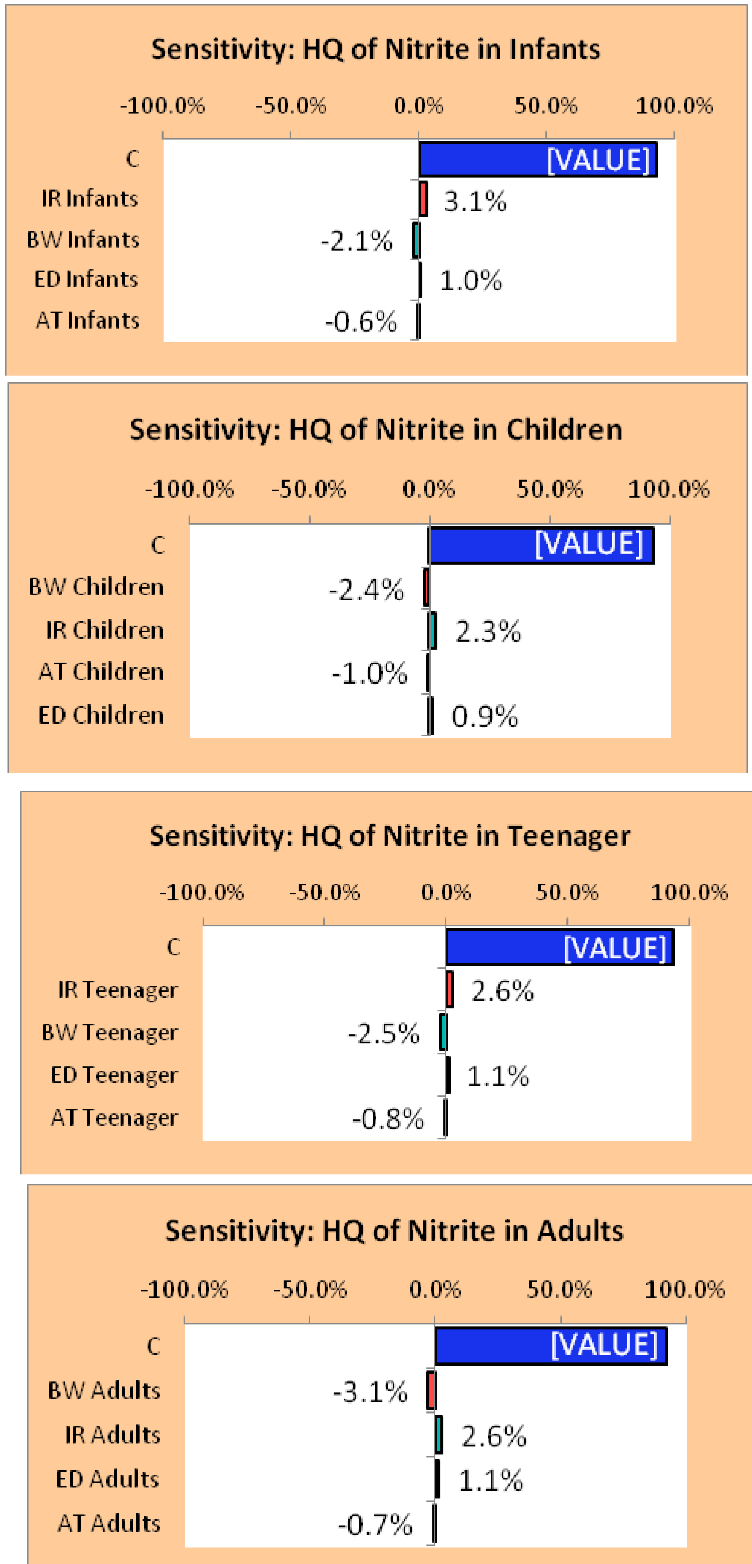
Figures 7A–7D. Sensitivity analysis, HQ, of exposure to nitrate in bottled water. 7A: infants, 7B: children, 7C: teenagers, and 7D: adults.

8A

8B

8C

8D



Figures 6A–6D. Sensitivity analysis, HQ, of exposure to nitrite in bottled water. 8A: infants, 8B: children, 8C: teenagers, and 8D: adults.

COMPETING INTERESTS

The authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

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