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Probabilistic Human Risks of Fluoride and Nitrate: A Case Study of Municipal Drinking Water in Mosul, Iraq

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Abstract

The present study aims to assess the probabilistic health risks to humans from fluoride and nitrate ions in the municipal drinking water supply of the Al-Shurta, Muhandiseen, and Al-Andalus neighborhoods on the left side of Mosul city. A total of 180 water samples, were collected from 30 sites between July 2023 to January 2024 for determination of nitrate and fluoride. The chronic daily intake and risk quotient (Rf) were also calculated to evaluate the safety of the drinking water across various demographic groups, including (infants, children, adolescents, young adults, pregnant women in early stages, and elderly males and females). The study found that nitrate levels ranged from 2.923 ± 0.736 to 3.932 ± 1.406 mg/L, while fluoride levels varied between 0.357 ± 0.070 to 0.428 ± 0.071 mg/L. The nitrate pollution index (NPI) values did not exceed (0.612) the safe level, indicating that the water is free from nitrate contamination. Studied Rf values for nitrate and fluoride were within safe limits for all age groups. However, the highest Rf values for nitrate and fluoride were observed in 3-month-old children, (0.3682 and 0.0572) followed by infants and children aged from 3 months to 1 year. Adolescents less affected, while elderly females showed slightly higher vulnerability than their male counterparts. In general, these results indicate that there are no current potential health risks, and they constitute a scientific database for the competent authorities to make decisions and manage water resources for use in drinking water supplies.

Keywords: Nitrate, fluoride, pollution index, HHR, Drinking water supply.

Introduction

The presence of excessive amounts of minerals in water is a matter of concern and a challenge to consumers' health [1-3]. This has led to a scarcity of potable water, and the available water requires treatment. It is reported that of developing and poor countries, especially rural and remote areas, rely on natural water sources, (surface or groundwater) for drinking without any treatment, which does not comply with the international standards of the World Health Organization (WHO) [4]. Thus these may cause potential health risks to consumers [5, 6]. Improper disposal of animal waste, changes in land use, extensive use of synthetic and organic fertilizers, and discharge of sewage effluent, are the most important causes of the release of nitrates into aquatic environments. Because of their health risks to consumers, the WHO and the US Environmental Protection Agency (US-EPA) have identified 50 and 45 mg/L as the maximum permissible level for drinking water [7]. To protect consumers from the problems of blue baby syndrome for infants and the elderly, as well as other health harms such as stomach and intestinal cancer, colorectal cancer, cancerous diseases, thyroid dysfunction, spontaneous premature birth, and repeated miscarriages [5]. For pregnant women, congenital malformations, sudden birth death, and type 1 insulin-dependent diabetes [8, 9]. After nitrate ions enter the body through the mouth, microbes reduce oxygen under the tongue to NO_2^{-1} ions and then react with amino compounds in the stomach to form N-Nitroso compounds (NOCs), as shown in the following reaction [10, 11]: $R_2N\text{-}H$ (Amines) + NO_2^{-1} → $R_2N{-}N = O$ (Nitrosamine).

Studies confirm that most of NOCs have a strong mutagenic and carcinogenic effect because of creating a state of oxidative stress, after testing more than 300 compounds (NOCs) on 40 species of mammals [12]. Regarding fluoride ions, the Icelandic literature of 1000 AD refers to an animal disease called 'gaddur' likely caused by fluorides emitted by volcanic eruptions. In 1925, Fredrick McKay indicated the presence of a permanent pigment in tooth enamel related to fluoride ions in drinking water, but fluorosis was referred to in 1930 [13]. Global interest in the fluoride content of drinking water has increased due to its vital role in the growth and development of teeth and bones while reducing tooth decay at moderate levels [10]. On the other hand, chronic exposure to high levels of fluoride in drinking water causes health problems in the skeleton and teeth that are a result of the metabolism of phosphorus and calcium in humans, resulting in calcium deficiency and bone fluoridation, as well as hormonal disorders, kidney toxicity and damage to muscular systems [14]. Disturbances in the regulation of glucose levels, low birth rates and changes in thyroid function, may result [15-16]. In addition, the studies conducted in Mexico, Canada, China, and Iran indicate low levels of intelligence in children whose mothers were exposed to high levels of fluoride in drinking water during pregnancy [17].

In general, more than 260 million people in different regions of the world are exposed to fluoride-contaminated drinking water at levels exceeding the guidelines set by the WHO 1.5 mg/L. Likewise, in more than thirty countries such as China, India, Pakistan, Thailand, Sri Lanka, Iran, South Africa, Mexico, etc., fluoride levels in groundwater sources reach 30 mg/L [18,19]. Though in Mosul city, the police and engineers protect consumers from any potential health risks from the presence of nitrate and fluoride ions, while giving consumers the necessary instructions to reduce the risks, if any. The current study is aimed to monitor the quality of drinking water in the Alandalus, Alshurta, and Al-Muhandiseen quarters located on the left side of Mosul city. The human risk assessment of fluoride and nitrate was also conducted in different age groups.

Materials and Methods

Description of Study Area

The current study area includes all of the Alandalus, Alshurta, and Al-Muhandiseen quarters located on the left side of Mosul city, which receive drinking water from the old Al-Issar station for municipal drinking water supply through a network of pipes. This area is considered one of the upscale residential quarters in the city. However, the problem in the city of Mosul is violations by citizens by connecting water pumps directly to the network pipes, which may lead to the entry of pollutants and wastewater through any break in the connection areas of the municipal water supply network pipes [20].

In the current study, 30 sites were selected for water sampling, distributed in the Alandalus, Alshurta, and Mohandessin quarters as listed in Table 1. The municipal water samples were collected monthly after running the tap for two minutes from July 2023 to January 2024 (180 water samples) using clean polyethylene bottles. After that, the water samples were placed in a refrigerated container away from light until they reach the laboratories of the College of Education for Pure Sciences, University of Mosul, to estimate nitrate and fluoride ions according to international standard methods [21]. Fig. 1 and Table 1 shows some characteristics of the study area.

Figure 1. **Satellite map of drinking water sample collection sites from residential quarters.**

Table 1. **Latitude (E) and longitude (N) lines of locations for collecting water samples for some quarters on the left side of Mosul city.**

	Sites	N	E		Sites	N	E
Alshurta quarter	St1.	36°37588	43°13252	quarter	St16.	36°37849	43°12817
	St2.	36°37522	43°13272		St17.	36°38121	43°12807
	St3.	36°37406	43°13396		St18.	36°37637	43°12797
	St4.	36°37351	43°13569		St19.	36°37652	43°13072
	St5.	36°37303	43°13402		St20.	36°37721	43°12960
	St6.	36°37353	43°13634	Mohandessin quarter	St21.	36°37049	43°13455
	St7.	36°37527	43°13839		St22.	36°36932	43°13571
	St8.	36°37600	43°13791		St23.	36°36828	43°13882
	St9.	36°37798	43°13879		St24.	36°36859	43°13917
	St10.	36°37640	43°13816		St25.	36°36730	43°13829
	St11.	36°37771	43°13309		St26.	36°36655	43°13861
Alandalus	St12.	36°37726	43°13201		St27.	36°36622	43°13797
	St13.	36°37818	43°13168		St28.	36°36546	43°13728
	St14.	36°37811	43°13105		St29.	36°36523	43°13435
	St15.	36°37870	43°13020		St30.	36°36623	43°13184

Methodology

The concentration of nitrate ions was measured using the NO_3-B-4500 method (ultraviolet examination) by taking a known volume of the well-filtered aqueous sample and adding a known volume of hydrochloric acid. The sample was then shaken for homogeneity. The concentration of nitrate ions is then measured using a UV spectrophotometer (Shimadzu, US Spectrophotometer - Japanese made) at wavelengths of 220 and 275 nm, along with blank to correct the readings. The concentration of nitrate in mg/L was calculated via the standard nitrate curve as reported [22]. As for fluoride ions, they were estimated in water samples by adding the Fluoride LRR agent to a known volume of the sample and then measuring it using a fluoride measuring device (HANNA Romanian) after regulating the device [22, 12].

Potential Human Health Risk Assessment (PHHR)

Humans are exposed to nitrate and fluoride ions through drinking water, eating vegetables, etc. Therefore, the HHR index is widely used globally to evaluate the potential health risks to consumers (infants, children, adolescents, young people, pregnant women for the first three months, elderly women and men. To determine the suitability of water for drinking and the potential health effects of chronic exposure to these ions on consumers [23], this indicator is proposed by the US-EPA [24], and the chronic daily intake of CdI (mg/ kg/day) and the damage quotient Hq using the following equations referred to by each [15, 25-29].

$$CdI = \frac{Twp \times AIr \times Btc \times Efd}{Nbwt \times Ret}$$

Where, CdI = Pollutants (F^{-1} and NO_3^{-1}) in (mg/kg/day), Twp = tap water pollutants (mg/L), AIr = Annual water intake rate (L/ day), Etc = exposure time for any cohorts, Efd = exposure frequency (Day/ year), Nbwt = Net body weight for any age in (Kg), Ret = Rate exposure time (days for any cohorts). Body weight values were adapted to the population of Nineveh Governorate, Iraq. The hazard (risk factor) (Rf) occurs when the levels of nitrates and fluorides exceed the standard limits of the recommended dose for water quality standards due to the potential negative impact on consumers, and the exposure dose value (EdV) for fluoride and nitrates (1.6 and 0.04 mg/kg/L) [11], consecutively. The risk factor can be calculated from the following equation. The risk factor can be calculated from the following equation [26,27]:

$$Rf = \frac{\text{CdI for any pollutant}}{\text{EdV}}$$

Regarding RF results, values < 1 are onsidered healthy, while values > 1 indicate potential health risks to consumers.

IV. Nitrate Pollution Index (NPI)

The damage caused by nitrate ions can be estimated using (NPI), as it is one of the vital parameters for evaluating the health safety of drinking water, using the index referred to by [30, 31]:

$(RNH_2) + H_2O \rightarrow NH_4^+ + CO_2CO[NH_2]_2 + H_2O \rightarrow 2NH_4^+ + CO_3^{-2}3NH_4^+ + 5O_2 \rightarrow 3NO_2^- + 4H^+ + 4H_2O\ NO_2^- + O \rightarrow NO_3^{-1}$

$$CdI = \frac{Twp \times AIr \times Etc \times Efd}{Rbwt \times Ret}$$

$$NPI = \frac{Ci - NLH}{NLH}$$

Where: NPI = Nitrate Drinking Water Pollution Index, Ci = Measured concentration of nitrate ion in drinking water, NLH = safe concentrations of nitrates for consumers (10 mg/L).

After calculating the NPI value, water quality can be classified into five categories as follows: NPI ≤ 0.0 – Clean level., 0.1 -1.0 – slightly polluted.,1.1 – 2.0 – Moderately polluted., 2.1-3.0 – Polluted water., NPI> 3.0 - highly Polluted water.

Results and Discussion

The results listed in Table 2 indicate that the levels of nitrate ions fluctuated between 1.51 and 7.10 mg/L, with a mean ranging from 2.88 ± 0.701 to 4.46 ± 1.681 mg/L. This relative increase in concentrations is likely due to the presence of dissolved amino compounds in the surface water (Tigris River) of the water treatment plant, in addition to the possibility of the entry of stagnant water containing urea through breaks that occur in the municipal water supply pipe network as a result of the violations carried out by citizens in connecting water pumps to network pipes, where amino acids and urea are biologically converted to ammonium and ammonium ions may be oxidized to nitrite and nitrate ions by nitrification bacteria, as in the following equations [32].

As for the decrease in the concentration of nitrate ions in some locations and periods, it may be attributed to the possibility of reducing nitrates in the absence of oxygen through the process of denitrification and thus losing them in the form of N_2 gas by types of microorganisms such as the genus Pseudomonas, as in the following equations [12]:

Fortunately, all nitrate concentrations were within the limits recommended by the WHO [4]. Also, low concentrations are necessary for global health, as they increase the flexibility of blood vessels and thus protect people from cardiovascular problems [10]. Current results for nitrate ions are comparable with previous studies conducted in northern Iraq (Nineveh Governorate) [33], for the quality of Tigris River water as a main source of raw water for water treatment plants. Besides, higher nitrate levels were recorded in drinking water for some schools on the right side of Mosul, which reached 0.99 mg/L [34]. Nitrate levels in the groundwater in the Sinjar district of Nineveh Governorate, reached up to 48.1 mg/L [35]. The nitrate levels in water resources varied in some areas of Erbil with an a verage value of 35.70 and 29.00 mg/L [36]. This is also the case with some regions of the world, reaching the concentration of NO^-_3 in some water resources in sites belonging to the city of Tehran, Iran (166 and 308 mg/L), Turkivskiy District in Ukraine (109 mg/L), some rural areas of Yantai (130.2 mg/L), and the north East Semiarid region in China reaches (166 and 308 mg/L) [30, 37], and in southern India it rises to (340) mg/L [38] and (1063) mg/L in some Colombian regions [39]. In general, the levels of nitrate pollution in the studied water were low according to the NPI values, whose values were negative, ranging from (-0.606 to - 0.692), as shown in Table 2. The studied water was classified as clean level. The concentration of fluoride ions, their solubility, and release into water depends on the water temperature, pH, degree of decomposition of minerals containing fluoride, ion exchange capacity, etc. Also, the released fluoride ions may exist in free form and combined with positive ions in water, or may be adsorbed on the surfaces of fine particles [10]. As for the upper and lower limits and the desired levels of fluoride ions, they depend on the average air temperatures in the region (Nineveh Governorate), because the relationship between them was found inverse. Because the rise in air temperature rates increases the consumption of larger amounts of water to compensate water lose due to sweating during the hot months of the year, compared to cold regions such as European countries. According to the available data, the average monthly temperatures for Nineveh Governorate based on more than five years (Meteorological Station data), the average annual air temperature was 28.4 °C. According to the specifications indicated by the US-EPA [11], the upper and lower limits for the concentration of fluoride ions in the drinking water of Nineveh Governorate range between 0.6 to 0.8 mg/L and the desired concentration 0.7 mg/L consecutively. The results shown in Table 3, indicates that the concentrations of fluoride ions fluctuated between 0.28 to 0.56 mg/L at a rate ranging between 0.333±0.045 to 0.428±0.071 mg/L. These concentrations may be due to the presence of salts, bicarbonate and sodium ions, ion exchange processes, and decomposition of minerals (quartz, fluorite, fluorspar, apatite, and biotite), as shown in the following equations [10].

$$5Ca_5F\,(PO_4)_3(OH)_2 \Rightarrow Ca_5(PO_4)_3(OH)_2 + 5F^{-1}$$

$$K\,(Mg, Fe)_3\,(AlSiO_3O_{10})\,F_2 + 2OH \Rightarrow K\,(Mg, Fe)_3\,(A1SiO_3O_{10})\,(OH)_2 + 2F^{-1}$$

$$Ca_5Mg_5[Si_6Al_2O_{22}]\,F_2 + 2OH^- \Rightarrow Ca_5Mg_5\text{-}[Si_6Al_2O_{22}]\,(OH)_2 + 2F^{-1}$$

$$CaF_2 + 2NaHCO_3 \Rightarrow CaCO_3 + 2Na^+ + 2F^{-1} + H_2CO_3$$

Table 2. **Results of nitrate ion levels, standard deviation, and nitrate pollution Index (NPI) values in drinking water for each of the Alshurta, Mohandessin, and Alandalus quarters (mg/L).**

Duplicates Sites		1	2	3	4	5	6	*Mean*	± *Sd*	*NPI*
Alshurta quarter	1st	2.99	6.77	3.26	3.63	3.54	3.40	3.93	1.409	-0.607
	2St	2.96	6.77	4.07	2.82	3.75	3.26	3.94	1.465	-0.606
	3St	2.94	6.78	3.58	2.92	3.44	3.32	3.83	1.469	-0.617
	4St	2.99	6.65	3.61	3.03	3.56	3.19	3.84	1.402	-0.616
	5St	3.06	6.76	3.57	3.01	3.53	3.40	3.89	1.427	-0.611
	6St	2.85	2.24	3.14	3.60	3.93	3.40	3.19	0.597	-0.681
	7St	2.86	2.90	3.60	3.58	3.75	3.40	3.35	0.380	-0.665
	8St	2.94	2.78	3.17	3.60	3.88	3.36	3.29	0.410	-0.671
	9St	3.24	2.83	3.14	3.49	3.82	3.57	3.35	0.351	-0.665
	10St	3.11	2.85	3.03	3.46	3.82	3.61	3.31	0.375	-0.669
Al-Andalus, quarter	11St	2.11	3.29	3.13	3.57	3.47	3.86	3.24	0.606	-0.676
	12St	2.89	2.82	3.17	4.72	3.50	3.53	3.44	0.695	-0.656
	13St	2.44	2.90	2.94	3.42	3.42	3.36	3.08	0.392	-0.692
	14St	2.62	2.93	3.53	3.47	3.46	3.50	3.25	0.383	-0.675
	15St	2.13	3.22	3.38	3.63	3.78	3.38	3.25	0.585	-0.675
	16St	2.42	2.88	3.06	3.40	3.44	3.33	3.09	0.393	-0.691
	17St	3.38	2.83	2.97	3.29	3.54	3.35	3.23	0.270	-0.677
	18St	1.51	2.81	3.07	3.32	3.30	3.29	2.88	0.701	-0.712
	19St	4.67	2.83	3.47	3.57	3.38	3.33	3.54	0.609	-0.646
	20St	2.19	2.82	3.14	3.43	3.46	3.32	3.06	0.487	-0.694
Mohandessin quarter	21St	2.45	6.70	3.57	3.06	3.78	3.44	3.83	1.480	-0.617
	22St	6.48	6.71	3.32	3.01	3.93	3.32	4.46	1.681	-0.554
	23St	1.74	6.65	3.39	3.35	3.89	3.44	3.74	1.603	-0.626
	24St	2.12	6.77	3.44	3.21	3.97	3.49	3.83	1.564	-0.617
	25St	1.75	7.10	3.34	3.33	3.81	3.32	3.78	1.775	-0.622
	26St	1.83	6.85	3.47	3.17	3.79	3.42	3.75	1.663	-0.625
	27St	2.27	6.87	3.50	3.24	3.94	3.44	3.88	1.567	-0.612
	28St	2.12	6.85	3.40	3.10	3.81	3.32	3.77	1.612	-0.623
	29St	1.78	6.81	3.32	3.04	3.89	3.46	3.72	1.675	-0.628
	30St	2.31	6.78	3.40	3.21	3.87	3.40	3.83	1.534	-0.617

In additions, the decrease in concentration for most drinking water samples was due to the possibility of decreased solubility of fluoride compounds or their adsorption with clay particles in the source water of the Tigris River. Unfortunately, all the samples studied were less than the minimum limits calculated for the city of Mosul 0.6 mg/L, which increases the possibility of tooth decay problems among consumers of this water [18]. When comparing the concentration with other studies, we note that it is lower than the groundwater of north Mosul, which reached 2.179 mg/L. The same was the case for water sources in central Saudi Arabia, which reached 1.8 mg/L, while it rises in some Indian, Ethiopian, and Norwegian regions to reach 68, 17, 9.5 mg/L successively [10, 27].

Table 3. **Concentration of fluoride ions in drinking water for each of the alshurta, Muhandiseen, and Al-Andalus quarters (mg/L).**

Duplicates Sites		1	2	3	4	5	6	*Mean*	± *Sd*
Alshurta quarter	1st	0.29	0.31	0.33	0.37	0.38	0.46	0.357	0.061
	2St	0.30	0.31	0.30	0.38	0.37	0.53	0.365	0.088
	3St	0.29	0.28	0.32	0.40	0.36	0.35	0.333	0.045
	4St	0.29	0.32	0.42	0.41	0.38	0.37	0.365	0.051
	5St	0.29	0.42	0.53	0.42	0.47	0.39	0.410	0.086
	6St	0.29	0.36	0.42	0.32	0.38	0.38	0.358	0.047
	7St	0.29	0.33	0.43	0.35	0.37	0.48	0.375	0.069
	8St	0.29	0.32	0.33	0.37	0.37	0.51	0.365	0.077
	9St	0.28	0.41	0.36	0.38	0.38	0.42	0.372	0.050
	10St	0.29	0.32	0.53	0. 32	0.43	0.29	0.372	0.105
Alandalus quarter	11St	0.29	0. 53	0.31	0.33	0.37	0.38	0.348	0.033
	12St	0.29	0.35	0.37	0.35	0.37	0.33	0.343	0.030
	13St	0.40	0.41	0.40	0.38	0.39	0.36	0.390	0.018
	14St	0.4 5	0.32	0.46	0.33	0.41	0.54	0.412	0.092
	15St	0.32	0.33	0.47	0.29	0.33	0.36	0.350	0.063
	16St	0.31	0.32	0.46	0.31	0.39	0.49	0.380	0.080
	17St	0.30	0.35	0.45	0.32	0.38	0.32	0.353	0.055
	18St	0.35	0.35	0.38	0.35	0.38	0.31	0.353	0.026
	19St	0.34	0.49	0.35	0.38	0.37	0.46	0.398	0.062
	20St	0.30	0.34	0.47	0.32	0.36	0.42	0.368	0.065
Mohandessin quarter	21St	0.46	0.33	0.46	0.52	0.44	0.36	0.428	0.071
	22St	0. 43	0.35	0.38	0.46	0.41	0.50	0.420	0.060
	23St	0.41	0.38	0.36	0.41	0.42	0.48	0.410	0.041
	24St	0.43	0.32	0.37	0.45	0.41	0.51	0.415	0.066
	25St	0.45	0.27	0.4	0.31	0.4	0.31	0.357	0.070
	26St	0.46	0.34	0.41	0.30	0.37	0.52	0.395	0.081
	27St	0.48	0.45	0.41	0.33	0.38	0.43	0.397	0.053
	28St	0.50	0.32	0.41	0.31	0.37	0.44	0.375	0.073
	29St	0.56	0.34	0.42	0.36	0.36	0.32	0.362	0.088
	30St	0.55	0.34	0.40	0.35	0.36	0.48	0.397	0.084

Human health risk assessment of nitrates and fluorides

The results listed in Table 4, indicate that the age groups most affected by nitrate ions are infants aged 3 months, birth (source of hydration was primarily breast milk or formula), infants aged 6 to 12 months, then cohort, whose ages ranged from 6 to 11 years, and pregnant women in the first three months, so that the values of the risk factor (Rf) reached 0.3682, 0.2954, 0.1266 and 0.1168, consecutively. This increase is due to the higher values of chronic daily intake (CdI) of nitrates i.e. 0.0603, 0.524, 0.0484, and 0.0174 mg/kg daily, consecutively. As for the age group (11 to 18 years), it was the age group least affected by the risks of nitrates, as the risk factor did not exceed (0.0802). It is also noted that the risk factors and CDI of nitrates are higher for females compared to the male group. In general, Fig. 2 indicates that the overall risk factor rate for the age groups studied was with in Safe limits (Rf > 1.0) according to US-EPA [7].

Table 4. **Results of the hazard quotient (Rf) values for nitrates in drinking water for the Alshurta, Al-Muhandiseen and Alandalus quarters.**

Cohort Site		Children			6-11 year	11-18 Year	18-21 Year	F.P 1st tri	21-Old	
		Birth	3 months	6-12 month					Male	Female
Alshurta quarter	1st	0.2739	0.3152	0.2529	0.1084	0.0687	0.0794	0.0999	0.0837	0.0887
	2St	0.2745	0.3159	0.2534	0.1086	0.0688	0.0796	0.1002	0.0839	0.0889
	3St	0.2689	0.3094	0.2482	0.1064	0.0674	0.0780	0.0981	0.0822	0.0871
	4St	0.2681	0.3086	0.2475	0.1061	0.0672	0.0777	0.0978	0.0819	0.0868
	5St	0.2706	0.3114	0.2498	0.1071	0.0678	0.0785	0.0987	0.0827	0.0876
	6St	0.1843	0.2122	0.1702	0.0729	0.0462	0.0535	0.0673	0.0563	0.0597
	7St	0.1987	0.2287	0.1834	0.0786	0.0498	0.0576	0.0725	0.0607	0.0644
	8St	0.1911	0.2199	0.1764	0.0756	0.0479	0.0554	0.0697	0.0584	0.0619
	9St	0.1929	0.2220	0.1781	0.0763	0.0484	0.0559	0.0704	0.0590	0.0625
	10St	0.1890	0.2176	0.1745	0.0748	0.0474	0.0548	0.0690	0.0578	0.0612
Alandalus quarters	11St	0.1895	0.2181	0.1749	0.0750	0.0475	0.0549	0.0691	0.0579	0.0614
	12St	0.2157	0.2482	0.1991	0.0853	0.0541	0.0625	0.0787	0.0659	0.0698
	13St	0.1800	0.2071	0.1661	0.0712	0.0451	0.0522	0.0657	0.0550	0.0583
	14St	0.1933	0.2224	0.1784	0.0765	0.0485	0.0560	0.0705	0.0591	0.0626
	15St	0.1936	0.2229	0.1788	0.0766	0.0485	0.0561	0.0707	0.0592	0.0627
	16St	0.1811	0.2084	0.1672	0.0716	0.0454	0.0525	0.0661	0.0553	0.0586
	17St	0.1895	0.2181	0.1749	0.0750	0.0475	0.0549	0.0691	0.0579	0.0614
	18St	0.1713	0.1972	0.1582	0.0678	0.0430	0.0497	0.0625	0.0524	0.0555
	19St	0.2277	0.2621	0.2102	0.0901	0.0571	0.0660	0.0831	0.0696	0.0738
	20St	0.1803	0.2074	0.1664	0.0713	0.0452	0.0523	0.0658	0.0551	0.0584
Mohandessin quarter	21St	0.2629	0.3026	0.2427	0.1040	0.0659	0.0762	0.0959	0.0803	0.0851
	22St	0.3200	0.3682	0.2954	0.1266	0.0802	0.0928	0.1168	0.1036	0.0978
	23St	0.2558	0.2943	0.2361	0.1012	0.0641	0.0742	0.0933	0.0782	0.0828
	24St	0.2611	0.3005	0.2411	0.1033	0.0655	0.0757	0.0953	0.0798	0.0846
	25St	0.2648	0.3047	0.2444	0.1048	0.0664	0.0768	0.0966	0.0809	0.0858
	26St	0.2597	0.2989	0.2398	0.1028	0.0651	0.0753	0.0948	0.0794	0.0841
	27St	0.2661	0.3062	0.2457	0.1053	0.0667	0.0772	0.0971	0.0813	0.0862
	28St	0.2609	0.3003	0.2409	0.1032	0.0654	0.0756	0.0952	0.0797	0.0845
	29St	0.2545	0.2929	0.2350	0.1007	0.0638	0.0738	0.0929	0.0778	0.0824
	30St	0.2628	0.3025	0.2427	0.1040	0.0659	0.0762	0.0959	0.0803	0.0851

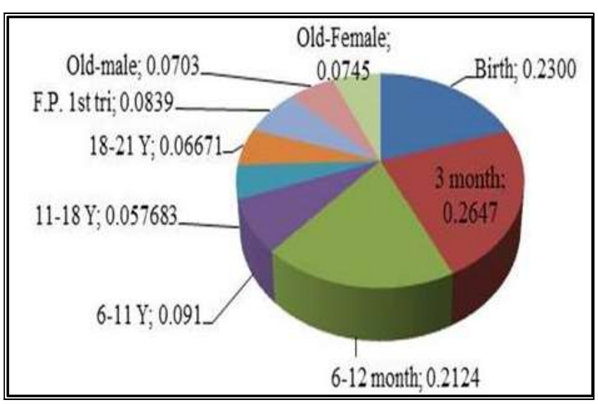

Figure 2. **Average values of the risk facor (Rf) for nitrate ions**

As for the risks of fluoride ions on the health of consumers, the results in Table 5 showed high values of the risk factor Rf for all infants aged 3 months, births, children aged 6 to 12 months, pregnant women in the first three months, then the age group (6 to 11) years, compared to the rest of the age groups studied, which reached values of 1.0046, 0.8729, 0.8059, 0.3040 and 0.3454, consecutively. Fortunately, Fig. 3 indicates that the general average concentrations of fluoride ions for all age groups do not exceed the safe limits recommended by the US Environmental Protection Agency (US-EPA), despite the high values for the category of infants aged 3 months, approaching the recommended limits (Rf > 1.0). Finally, high values of (Rf) for drinking water are likely to lead to low concentrations of calcium ions in the blood, which may cause tissue damage and disturbance of heart function, as a result of hyperkalemia resulting from electrolytes.

Table 5. **Results of the risk quotient values for fluorides in drinking water for the Alshurta, Alandalus and Mohandessin quarters.**

Cohort Site		Children			6-11 year	11-18 Year	18-21 Year	F.P 1st tri	21-Old	
		Birth	3 month	6-12month					Male	Female
Alshurta quarter	1st	0.6348	0.7306	0.5861	0.2512	0.1592	0.1841	0.2316	0.1940	0.2056
	2St	0.6546	0.7534	0.6044	0.2590	0.1641	0.1898	0.2389	0.2001	0.2120
	3St	0.6546	0.7534	0.6044	0.2590	0.1641	0.1898	0.2389	0.2001	0.2120
	4St	0.7142	0.8219	0.6593	0.2826	0.1790	0.2071	0.2606	0.2183	0.2313
	5St	0.8332	0.9589	0.7692	0.3297	0.2089	0.2416	0.3040	0.2546	0.2699
	6St	0.6348	0.7306	0.5861	0.2512	0.1592	0.1841	0.2316	0.1940	0.2056
	7St	0.6348	0.7306	0.5861	0.2512	0.1592	0.1841	0.2316	0.1940	0.2056
	8St	0.6546	0.7534	0.6044	0.2590	0.1641	0.1898	0.2389	0.2001	0.2120
	9St	0.7142	0.8219	0.6593	0.2826	0.1790	0.2071	0.2606	0.2183	0.2313
	10St	0.7538	0.8676	0.6960	0.2983	0.1890	0.2186	0.2751	0.2304	0.2442
Alandalus quarter	11St	0.4761	0.5479	0.4396	0.1884	0.1194	0.1381	0.1737	0.1455	0.1542
	12St	0.6348	0.7306	0.5861	0.2512	0.1592	0.1841	0.2316	0.1940	0.2056
	13St	0.7935	0.9132	0.7326	0.3140	0.1989	0.2301	0.2896	0.2425	0.2570
	14St	0.7340	0.8447	0.6777	0.2904	0.1840	0.2128	0.2678	0.2243	0.2377
	15St	0.6546	0.7534	0.6044	0.2590	0.1641	0.1898	0.2389	0.2001	0.2120
	16St	0.6943	0.7991	0.6410	0.2747	0.1741	0.2013	0.2534	0.2122	0.2249
	17St	0.7142	0.8219	0.6593	0.2826	0.1790	0.2071	0.2606	0.2183	0.2313
	18St	0.6745	0.7763	0.6227	0.2669	0.1691	0.1956	0.2461	0.2061	0.2185
	19St	0.7340	0.8447	0.6777	0.2904	0.1840	0.2128	0.2678	0.2243	0.2377
	20St	0.6546	0.7534	0.6044	0.2590	0.1641	0.1898	0.2389	0.2001	0.2120
Mohandessin quarter	21St	0.8729	1.0046	0.8059	0.3454	0.2188	0.2531	0.3185	0.2668	0.2827
	22St	0.7935	0.9132	0.7326	0.3140	0.1989	0.2301	0.2896	0.2425	0.2570
	23St	0.7340	0.8447	0.6777	0.2904	0.1840	0.2128	0.2678	0.2243	0.2377
	24St	0.7737	0.8904	0.7143	0.3061	0.1940	0.2243	0.2823	0.2364	0.2506
	25St	0.7142	0.8219	0.6593	0.2826	0.1790	0.2071	0.2606	0.2183	0.2313
	26St	0.6943	0.7991	0.6410	0.2747	0.1741	0.2013	0.2534	0.2122	0.2249
	27St	0.7737	0.8904	0.7143	0.3061	0.1940	0.2243	0.2823	0.2364	0.2506
	28St	0.7142	0.8219	0.6593	0.2826	0.1790	0.2071	0.2606	0.2183	0.2313
	29St	0.6943	0.7991	0.6410	0.2747	0.1741	0.2013	0.2534	0.2122	0.2249
	30St	0.6745	0.7763	0.6227	0.2669	0.1691	0.1956	0.2461	0.2061	0.2185

, F.P 1st tri: Female Pregnant 1st trimester

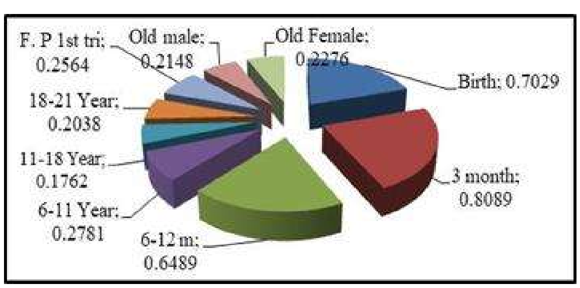

Figure 3. **Average risk factor (Rf) of fluorides for each cohort**

Conclusion

It is concluded that nitrate concentrations did not exceed the internationally recommended limits in all studied water samples. In addition, fluoride ions were within the desired limits calculated in the study area according to the US Environmental Protection Agency. The high levels of Rf of nitrate and fluoride ions in the studied water, especially the categories of infants aged 3 months and 6 to 12 months, birth, and pregnant female's in 1st trimester, who are considered among the groups most affected by risks, did not exceed the internationally recommended limits. However, a relative increase in Rf of values for 3-month-old children are close to the recommended limits. The adolescent group (11 to 18) was the age group least affected by the risks of nitrates and fluoride. Males were also less affected than females in the age group of 21 years old. Therefore, the study recommends periodic follow-up of drinking water tests to avoid harm that may occur in the future to water consumers, especially infants and pregnant women, as well as benefiting from the results of this study for managing water resources and treating drinking water when necessary. We recommend developing appropriate programs to monitor and control the quality of drinking water during emergencies, including the use of reverse osmosis treatment, to minimize potential health risks to consumers.

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Conflict of Interest

All authors declare that they have no conflicts of interest.

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