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The Monitoring and Health Risk Assessment of Nitrate in Drinking Water in the Rural and Urban Areas of Tabriz, Iran

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A B S T R A C T

Background: The present study aimed to estimate the health risk of nitrate concentration (NO_3^-) in the drinking water of Tabriz, Iran.
Methods: This descriptive, cross-sectional study was conducted on the drinking water samples collected from Tabriz city during 2016-2017. The concentration of NO_3^- was measured in 190 drinking water samples at the water and wastewater laboratory of the provincial health center using spectrophotometry.
Results: The mean concentration of NO_3^- (nitrate ion) in the drinking water of the urban and rural districts was estimated at 14.6 ± 12.8 and 13.1 ± 12.8 mg/l, respectively, which is below the national standard of Iran and the World Health Organization (WHO) guidelines. In addition, the mean hazard quotient (HQ) for the four age groups of infants, children, adolescents, and adults was less than one in the urban and rural areas, while the HQ values for children were more than one in 15.20% of the urban and 10.7% of the rural samples.
Conclusion: The non-carcinogenic risk of NO_3^- in drinking water does not threaten the exposed populations, while children are presumably at the risk of NO_3^-. Therefore, the continuous control of NO_3^- concentration is recommended to prevent the possible risks in the consumers, especially children.

1. Introduction

Water is a crucial substance for life, and humans can only survive a few days without water. Clean and safe water is essential to disease prevention, good health, and wellbeing. Drinking poor quality water may contain various pollutants and cause numerous health issues in humans as 80% of human diseases are attributed to unsafe drinking water [1, 2].

Nitrate (NO_3^-) is an important and widespread of surface water and groundwater sources across the world [3, 4]. As a nitrogenous mineral compound, nitrate is produced in the final stage of ammonia and nitrogen oxidation from organic matters. The solubility of nitrate in water may lead to its quick transfer to aquifers through the soil, while it could also accumulate in groundwater for decades [5, 6].

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The main entry pathways of nitrate into water sources include the discharge of effluents from wastewater treatment plants to surface water sources and its infiltration in to groundwater, excessive use of chemical fertilizers in agriculture, infiltration through absorption wells in rural and urban areas, and lack of sewage collection systems [7-11]. Furthermore, the leachate obtained from the landfills of municipal and industrial solid wastes may lead to the pollution of surface and groundwater sources with nitrate.

High nitrate levels in potable water cause numerous health complications in humans, especially infants. The reduction of NO_3^- to nitrite (NO_2^-) in infants under anaerobic conditions disrupts hemoglobin formation and oxygen delivery to the cells, as well as the formation of methemoglobin in the red blood cells, development of the 'blue baby' syndrome (methemoglobinemia), and even infant mortality [10-13]. Moreover, the formation of N-nitroso compounds may cause cancer in mammals [4] as these compounds might be teratogenic. Nitrate competes with the thyroid for iodide adsorption, thereby potentially affecting the thyroid function [12-15].

According to the World Health Organization (WHO) guidelines and the Iranian national standard, the maximum permissible level of this compound in potable water is 50 mg/l^{-1}. Due to the simultaneous consumption of NO_3^- and NO_2^- in potable water, the sum of the ratios of the measured values of each compound to their guideline value should be less than one [16, 17]. Considering the potential health risks of nitrate for humans, the assessment and monitoring of nitrate levels in drinking water sources are essential.

Given the health importance of NO_3^-, several studies have been performed in this regard in different countries, including Iran. According to the findings of Mondal *et al.* (2008), the NO_3^- concentration in the groundwater in India was above the maximum permissible limits in 39% of the cases [18]. In a study by Kazmi *et al.* (2005) in Pakistan, the concentration of NO_3^- in 40% of the samples was above the standards [19]. As for the studies conducted in Iran, Amoi *et al.* (2012) have reported that the concentration of NO_3^- in some areas of Khaf city was more than five times the maximum permissible limits [20]. In another research, Amarloui *et al.* (2014) observed that the concentration of NO3- was higher than the standards in 1.67% of the specimens in Ilam [21].

Nitrate-related health risks in drinking water were also assessed in the exposed populations in four age groups of infants, children, adolescents, and adults. The risk estimation was the identification of the adverse effects on human health due to exposure to the chemicals in contaminated environments. Notably, the risk estimation of human health has been extensively obtained in various studies [22, 23]. Health risk estimation is a proper procedure for the monitoring and evaluation of water quality as pollutants may cause health hazards in the consumers even at smaller doses than the permissible levels. It is notable that the International Agency for Research on Cancer (IARC) and the Environmental Protection Agency (EPA) have classified NO_3^- as a non-carcinogenic contaminant [23, 24].

Given the importance of nitrate compounds in potable water and their adverse effects on the public health, the present study aimed to determine the NO_3^- concentration in the potable water distribution network of the urban and rural areas of Tabriz, Iran during 2016-2017.

2. Materials and Methods

2.1. Study Area

This descriptive, cross-sectional study was conducted in Tabriz city, which is the capital of East Azerbaijan province in the north-west of Iran (Figure 1). This area is located within the latitude and longitude of 38°3'59.9976''N and 46°17'59.9964'', covering the total area of 1,781 square kilometers.

In the 2016 census, the population of Tabriz was reported to be 1,773,033. The area is subdivided into two districts (Central District and Khosrowshahr District), five cities (Tabriz, Basmenj, Sardrud, Malek Kian, and Khosrowshah), and 67 villages. Tabriz has an elevation range of 1,350-1,600 meters above the sea level and is surrounded by lone-standing, towering mountains of Sahand and Own-ibne-Ali on the northeast and south, respectively.

2.2. Sampling and Analysis of Nitrate Concentration

In the study area, drinking water is supplied by surface and groundwater. In total, 190 specimens (125 urban specimens and 65 rural specimens) were randomly collected to assess the level of NO_3^- in the drinking water of Tabriz and the 67 villages in 2017. The specimens were transferred to the laboratory of the water and wastewater chemistry of East Azerbaijan Health Center and preserved at an appropriate temperature before analysis. The interval between sampling and analysis was less than two days, and the samples were analyzed only once. The sampling and analysis procedures were performed using the standard methods for the examination of water and wastewater [25]. The concentration of NO_3^- was determined using a DR-6000 UV-VIS spectrophotometer (Hach USA) at 220 and 275 nm. Data analysis using descriptive statistics (Max, min, Mean, SD) was performed with Using Microsoft Excel 2013.

2.3. Human Health Risk Estimation

The sample population of the study included four age groups in accordance with the study by Yousefi *et al.* Based on physiological and behavioral differences, the study groups were infants (aged <2 years), children (aged 2-6 years), adolescents (aged 6-16 years), and adults (aged >16 years) [26].

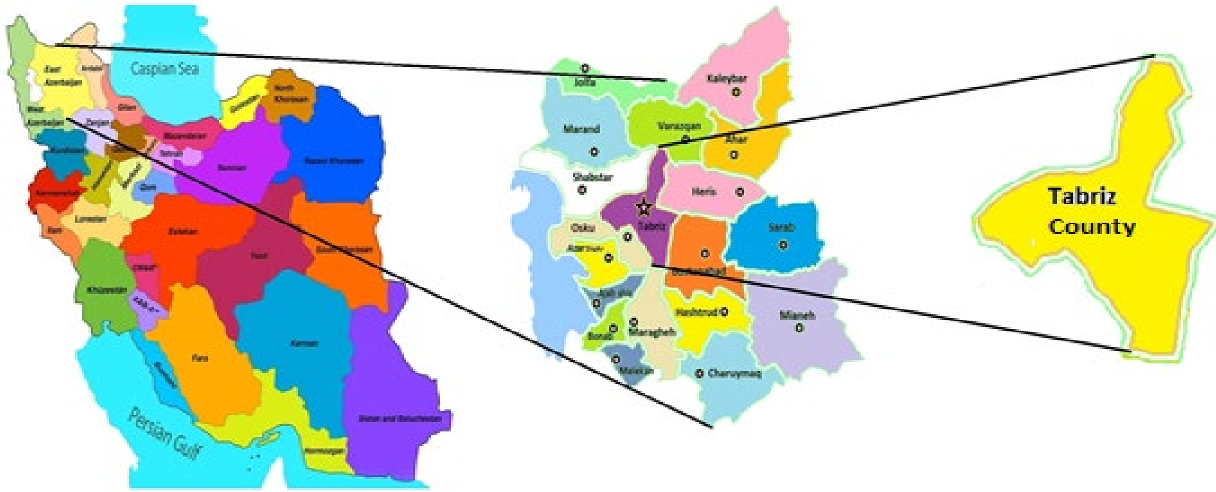

Figure 1; Study area: Tabriz, east Azerbaijan province, northwest of Iran

Non-carcinogenic risk estimation of NO_3^- in drinking water was calculated using Equation 1, as follows [27-31]:

$$HQ = \frac{CDI}{RfD} \quad (1)$$

Where HQ is the non-carcinogenic hazard quotient for a single contaminant, and RfD represents the reference dosage of a contaminant in mg/kg/d. In addition, chronic daily intake (CDI) was calculated using Equation 2, as follows:

$$CDI = \frac{Cw \times DI}{Bw} \quad (2)$$

Where Cw is the concentration of the contaminant in drinking water (mg/l), DI shows the daily mean drinking water intake (l/d), and Bw is the body weight (kg).

The data on water consumption and body weight were obtained based on previous studies [22-24]. The mean water consumption in the infants, children, adolescents, and adults was estimated to be 0.08, 0.85, 2, and 2.5 l/day^{-1}, respectively. The body weight of target groups was measured to be 10, 15, 50, and 78 kilograms, respectively. The reference dose (RfD) was expressed as the approximation of daily exposure for the public, which was presumably associated with no significant risk of exposure to harmful agents over a Lifetime. The RfD of 1.6 (mg/kg/day) was based on the USEPA [32].

The HQ was obtained by dividing the EDI into the RfD, and the HQ value of lower than one indicated the absence of adverse health effects, while the HQ value of higher than one indicated non-carcinogenic risk and possible adverse health effects. The measures taken to reduce the risk should be immediately investigated and controlled. Table 1 shows the value of the parameters used for the risk estimation of nitrate in drinking water [33-36].

3. Results and Discussion

Table 2 shows the mean concentrations of NO_3- in the drinking water of the urban and rural regions of Tabriz expressed as mean, standard deviation, minimum, and maximum. Accordingly, the NO_3^- concentration in the urban drinking water specimens was within the range of 0-78 mg/l with the mean value of 14.6 ± 12.8 mg/l. For the rural drinking water specimens, this value was determined to be 0-57 mg/l with the mean value of 13.1 ± 11.9 mg/l. The highest NO_3^- concentration in the urban and rural regions was observed in the railway area (78 mg/l) and Kandrood village (57 mg/l). Since 2018, Kondrood village has been officially annexed to the urban area of Tabriz and is currently part of the 5th metropolitan area of Tabriz city.

According to the results of the present study, the concentration of NO_3^- was higher than the WHO guidelines and Iranian national standard in 1.54% of the urban water samples and 0.8% of the rural water samples. Figures 2a and 2b depict the cumulative percentage of the NO_3^- concentration in the potable water of the rural and urban regions, respectively. Due to the percentage of the cumulative frequency, the concentrations of NO_3^- in 99.2% of the urban water samples and 98.5% of the rural water samples were below the allowable limit, which was considered favorable.

3.1. Human Health Risk Estimation

Table 3 shows the maximum and mean CDI and non-carcinogenic HQ related to NO_3^- in the potable water of the

Table 1: Values of essential parameters to calculate hazard quotient (HQ)

Parameter	Risk exposure factors	Values for groups				Unit
		Infants	Children	Teenagers	Adults	
Nitrate	Cw					mg/L
	DI	0.08	0.85	2	2.5	L/day
	Bw	10	15	50	78	Kg
	RfD	1.6	1.6	1.6	1.6	mg/kg/day

Table 2: Concentration of NO_3^- (mg/l) in Potable Water of Urban and rural regions

Statistical analysis	Nitrate concentration	
	Urban area	Rural area
Number of samples	125	65
Max	78	57
Min	0	0
Mean	14.6	13.1
SD	12.8	11.9
WHO Guideline	50	50
Iranian national organization standard	50	50
Maximum allowable	50	50
Percentage of nitrate concentration above 50 mg/L	0.8	1.54

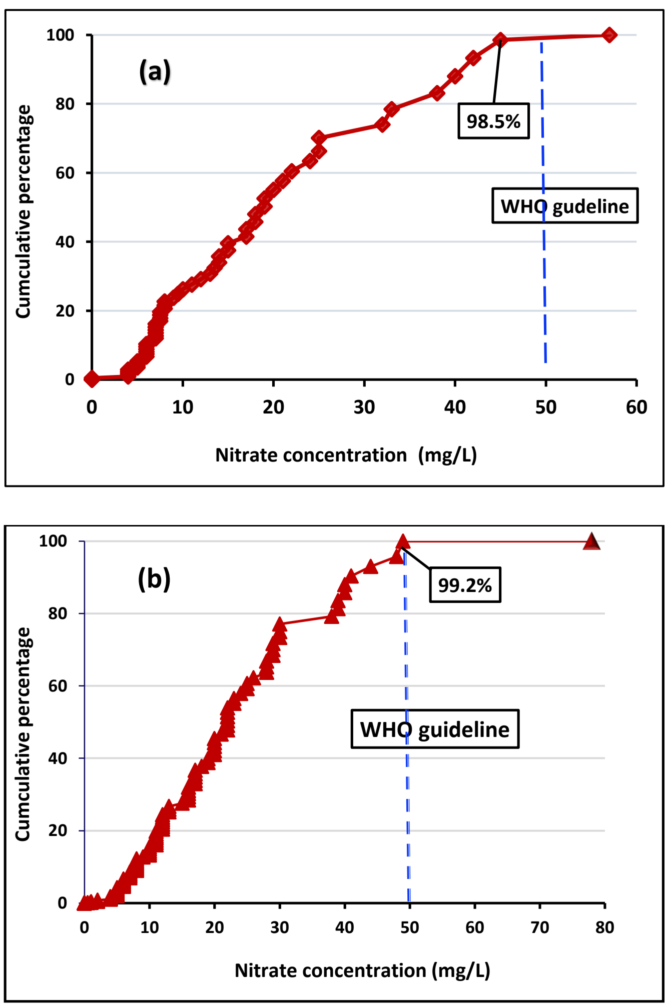

Figure 2: Cumulative percentage of NO_3 concentration in potable water; a) rural regions, b) urban regions

urban and rural regions in the infants, children, adolescents, and adults. Accordingly, the mean CDI and HQ in different age groups in the urban and rural regions was in the order children>adolescents>adults>infants.

In the current research, the highest and lowest CDI values due to the NO_3^- contamination of potable water were observed in the age groups of children (4.42) and infants (0.46), respectively. In addition, the mean CDI in the children was seven times higher than the infants. The highest and lowest HQ values due to the NO_3^- contamination of potable water were observed in the age groups of children (2.76) and infants (0.29), respectively. Therefore, it could be concluded that among the four studied age groups, children were at the highest risk of the non-carcinogenic hazards induced by the consumption of drinking water contaminated with nitrate. The mean HQ was similar across the four age groups in the urban and rural regions, and no significant difference was observed between the four age groups in urban and rural areas in terms of mean HQ.

According to the results of the present study, the mean HQ was less than one across the four age groups in the urban and rural regions. Therefore, the non-carcinogenic risk due to the nitrate contamination of potable water did not threaten the residents of the urban and rural region of Tabriz. However, the HQ value of the age group of children (aged 2-6 years) was more than one in 15.20% (19 specimens) of the urban samples and 10.8% (seven specimens) of the rural samples (Figure 3). In total, 3.2% and 2.4% of the samples (four and three specimens, respectively) with the HQ value of more than one in the age groups of adolescents and adults were observed in the urban areas, while 6.15% and 1.54% (four and one specimens, respectively) were reported in the rural areas. The HQ value of the infant age group was less than one in 100% of the urban and rural samples, which is a reasonable finding given the low water consumption in the age group of less than two years. Therefore, the continuous control and improved monitoring of nitrate and nitrite levels in drinking water are recommended to prevent the possible risks for the consumers, especially children.

We compared our findings with the similar studies conducted in Iran. The mean concentration of nitrate in the

Table 3: Nitrate concentration (mg/l), nitrate cdi, and HQ of urban and rural regions of Tabriz in four age groups

Area	Nitrate level (mg/L)		Value for age groups							
			Adults		Teenagers		Children		Infants	
			HQ	CDI	HQ	CDI	HQ	CDI	HQ	CDI
Urban	Mean	14.6	0.29	0.47	0.36	0.58	0.53	0.83	0.07	0.12
	Max	78	1.56	2.50	1.95	3.12	2.76	4.42	0.39	0.62
Rural	Mean	13.1	0.26	0.42	0.33	0.52	0.46	0.74	0.07	0.10
	Max	57	1.14	1.83	1.43	2.28	2.02	3.23	0.29	0.46

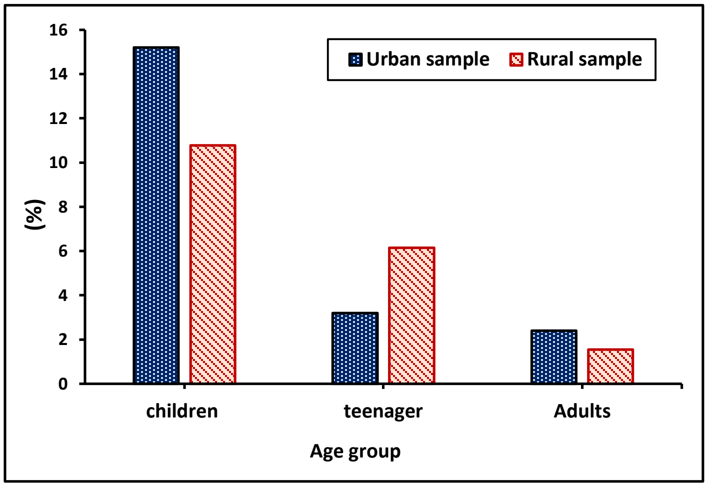

Figure 3: HQ of >1 in age groups of children, adolescents, and adults

study was below the permissible limit of the Iranian standard and WHO guidelines (Table 4), which is consistent with some of the studies conducted in Iran. Furthermore, the HQ value of the children (aged 2-6 years) was higher than one in 15.20% (19 specimens) of the urban samples and 10.8% (seven specimens) of the rural samples, indicating a potential hazard due to the consumption of drinking water with nitrate contamination by children. Table 4 shows the obtained results regarding the health risk assessment of nitrate in the drinking water of some cities in Iran. In general, our findings in this regard are consistent with the results of most of the studies conducted in Iran.

Table 4: Nitrate concentration in drinking water in some cities of Iran

City	Area	Average	Min	Max	HQ > 1 for children (%)	Reference
Azadshahr	Rural	19.75	1	51	41	1
Bardaskan	Rural	14.73	0	77.2	10	34
ghonabad	Rural	29.30	1.8	82.2	77.77	36
Bajestan	Rural	37.95	5.5	84.3	85.71	36
Sanandaj	Urban	18.8	1.28	80	22.64	37
Sanandaj	Rural	9.28	0.28	27.7	2.28	37
Khash	Rural	16.08	6	35	3.33	38
Mashhad	Urban	16.63	5.6	49.8	16.66	39
Tabriz	Rural	14.6	0	78	10.8	This study
Tabriz	Urban	13.1	0	58	15.2	This study

4. Conclusion

The present study provides useful and valuable data regarding the levels of NO_3^- in the drinking water of the urban and rural areas of Tabriz city, which could help authorities and managers to better control the drinking water network in this area. In addition, the obtained results could effectively enhance the general knowledge of water suppliers to better recognize the current status and plan to improve the control systems to protect residents against the health complications caused by high nitrate levels in drinking water.

According to the results, the NO_3^- concentration in 99% of the drinking water samples was below the Iranian drinking water standard and WHO guidelines. The mean HQ across the four age groups of infants, children, adolescents, and adults was also less than one in the urban and rural regions. Nevertheless, non-carcinogenic risks due to consuming drinking water contaminated with nitrate do not threaten the residents of the urban and rural communities of Tabriz, while the HQ values may occasionally be higher than one for the exposed age groups (except infants). Therefore, there is a potential hazard of drinking water nitrate for children, as well as adolescents and adults.

The continuous control and monitoring of nitrate and nitrite concentrations in drinking water are highly recommended in order to prevent the possible risks for the consumers, especially children. To reduce the nitrate concentration of drinking water, it is suggested that the urban areas of Tabriz metropolis be covered by sewage collection networks. Moreover, the reduction of fertilizer consumption in the rural areas could be attained through education, knowledge, and awareness in the agriculture sector and farmers. Advanced treatment processes used for the reduction of nitrate levels (e.g., reverse osmosis) are extremely costly. Therefore, the optimal preventive strategy would be to identify and continuously control the potential sources of nitrate.

Authors' Contributions

G.H.S., and B.M., designed the manuscript; M.F., performed the sample analysis; G.H.S., managed data acquisition; G.H. S., M.F., and B.M., performed the statistical analysis; G.H.S., and B.M., drafted the manuscript. All the authors contributed to the preparation of the final version of the article. As the corresponding author, I certify that the manuscript has been read and agreed upon for submission by all the named authors.

Conflicts of Interest

The Authors declare that there is no conflict of interest.

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