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Investigation of the concentration of nitrate, nitrite, fluoride anions, turbidity, and dissolved oxygen in water sources of Ilam city

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ABSTRACT

Introduction: Water is the most important life-sustaining substance for various living organisms, including humans. Among the most important physicochemical parameters in water include nitrite, nitrate, fluoride, dissolved oxygen, and turbidity. The presence of these parameters in drinking water at excessively high or low levels over the long term can pose health risks to the community. Therefore, this study aims to examine the concentrations of these physicochemical parameters in the drinking water sources of Ilam city from 2021 to 2023.

Materials & Methods: This study is descriptive-analytical. Considering the existence of 13 sources in Ilam city for supplying drinking water, data from all these sources were used. The study spanned three years from 2021 to 2023, with samples collected twice a year (every 6 months) for each parameter, resulting in a total of 78 samples (13×3×2) for each parameter. All samples were analyzed at the provincial health center laboratory after collection. Finally, the data was analyzed using Excel software and compared with WHO guidelines.

Results: The results showed that the highest average concentration of nitrate and nitrite in Ilam city's drinking water sources was found in Haft Cheshmeh well in the rural area, with levels of 54.17 mg/l and 2.22 mg/l, respectively, both exceeding national and international standards. Additionally, the highest average turbidity in Ilam city's drinking water sources was detected in Haft Cheshmeh well, at 5.92 NTU, surpassing both national and global maximum permissible levels. According to the table, the average fluoride concentration in Ilam city's drinking water sources was within the accepted range for all sources, adhering to national and international standards. The highest three-year average dissolved oxygen level was observed in Khorrmaroudi well, at 7.67 mg/l, which is within the permissible standards.

Conclusion: Since most physical and chemical parameter values in Ilam city are below national and international standards, the physicochemical quality of drinking water in Ilam city is not a health concern and is considered safe.

Keywords: Nitrite, Nitrate, Fluoride, Turbidity, Dissolved Oxygen, Ilam City

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Introduction

Water is the most essential life-sustaining substance for living organisms, especially humans, and the quality of drinking water is particularly important. Therefore, providing safe and healthy drinking water is one of the key pillars of primary healthcare (1,2). Such water must fall within the standard and desirable range for both hygiene and the amount of dissolved substances. These standards have been established by health and environmental organizations, so that through these standards, the permissible concentrations of physical, chemical, and biological parameters for the intended uses are determined (3). Some of the most important physical parameters include color, turbidity, dissolved oxygen, taste, and odor. Chemical parameters such as nitrite and nitrate, fluoride, free chlorine, and pH, and biological parameters like coliform bacteria. The presence of these parameters in excessive or insufficient amounts over the long term can endanger the health of community members (1, 3). Nitrate and nitrite compounds are among the most significant pollutants in groundwater and surface water sources. Their levels have been rising in recent years due to factors like the growth of urban, agricultural, and industrial wastewater (4, 5).

In addition to the aforementioned earlier, nitrite and nitrate ions also enter groundwater through leaking municipal and industrial wastewater facilities, raw sewage injection into the ground, the accumulation of municipal and industrial waste, wetlands, deforestation, and cemeteries (6). These compounds can have adverse effects on the health of consumers (5). Nitrate is generally harmless, but its conversion to nitrite can pose health risks to humans. If the level of drinking water exceeds 50 milligrams per liter, it can cause methemoglobinemia, a condition that often affects children and is also called blue baby syndrome. This disease causes a decrease in oxygen in the baby's body, which ultimately can lead to death. In addition to the mentioned diseases, it can also cause miscarriages in women (4, 6-8). WHO recommends a guideline of 3 mg/L for chronic nitrite effects. For nitrate ions, a level of 50 mg/L has also been proposed, although this amount is lower for nitrate concentration during the wet season compared to the dry season. Additionally, because the simultaneous presence of nitrite and nitrate in drinking water is possible, the sum of the ratios of the measured values of each of these two parameters to the values suggested by WHO must be less than one, which is the standard for drinking water in Iran (7, 8).

Fluoride is the lightest and most reactive member of the halogen group and is considered one of the 14 essential elements for living organisms, existing in specific amounts in their tissues and fluids. Fluoride enters the body through the air, toothpaste, drinking water, and food. Of course, most of the body's fluoride needs are met through drinking water, which is why determining its level in drinking water is particularly important. The amount of fluoride received from water depends on various factors, including the concentration of fluoride in the water, the altitude of the location, the air temperature, and dietary habits. Generally speaking, because more water is consumed in tropical regions, where the average temperature is higher and evaporation is greater, the amount of fluoride intake in these areas will also be higher (9).

Based on the factors mentioned for optimal fluoride levels and in accordance with the Iranian water standard, the amount ranges from 0.5 to 1.5 milligrams per liter. The fluoride content in drinking water varies depending on natural conditions. Typically, the concentration is less than 1.5 mg/L in surface waters, but it can reach several milligrams per liter in groundwater because water may pass through areas rich in fluoride as it moves underground. Soluble fluoride is quickly absorbed into the body after ingestion. WHO has set a maximum guideline of 1.5 mg/L for fluoride (10). The presence of colloidal suspended particles such as silt, clay, organic and mineral particles, and microorganisms in water reduces its clarity, a phenomenon known as turbidity. Excessive turbidity in drinking water not only diminishes its clarity but also worsens its taste and smell, leading to visual dissatisfaction and consumer discontent. Additionally, it makes water disinfectants like chlorine less effective, and consequently, disinfection costs increase (11). The required turbidity limit in Iranian and international standards is less than 1 NTU , and the maximum permissible limit in Iranian standards is specified as 5 NTU (12). Turbidity levels in surface water sources like reservoirs and dams during rainfall or river flooding can even exceed 1500 NTU. However, treatment plants are usually designed to remove turbidity at lower levels, and if such high turbidity enters these plants, the efficiency of conventional units drops significantly, causing the turbidity in the treated water to exceed the standard value (13). DO is present in all waters that come into contact with the atmosphere and is considered an indicator of water quality (2). As a result, one of the most important water quality parameters is oxygen concentration, which plays a vital role in enhancing the environmental conditions of rivers. This parameter is also crucial in the process of removing iron and manganese from drinking water in treatment plants. Additionally, the significant impact of dissolved oxygen concentration on improving the life of aquatic organisms and ecosystems is well recognized. The The importance of this parameter is so high that its value acts as a key indicator of water purity (14, 15). The recommended DO level in drinking water sources is 6.5 to 9 milligrams per liter (16). Therefore, the goal of this study is to assess the levels of nitrite, nitrate, fluoride, turbidity, and dissolved oxygen in the drinking water sources of Ilam city within a specific time period and compare them with national and WHO standards (17).

Materials and methods

The city of Ilam is situated in the northwest of Ilam Province and in the western part of the country. It lies within the geographical coordinates of 33 degrees 21 minutes 20 seconds to 33 degrees 51 minutes 48 seconds north latitude and 45 degrees 41 minutes 7 seconds to 46 degrees 51 minutes 19 seconds east longitude. This study investigates the chemical quality of drinking water sources in Ilam city from 2021 to 2023, focusing on parameters such as nitrite, nitrate, fluoride, turbidity, and DO. The research is a descriptive-analytical cross-sectional study, with data collected through the Ilam Province Health Center. Among the parameters analyzed by the provincial water and wastewater reference laboratory, nitrite, nitrate, and fluoride concentrations were measured using a DR6000 spectrophotometer, turbidity was assessed using a calibrated turbidimeter, and DO levels were determined with an oxygen meter. Since Ilam's drinking water is supplied from 13 sources, all included in this study, and considering the study period from 2021 to 2023, water samples for each parameter—nitrite, nitrate, fluoride, turbidity, and DO—were collected twice annually (every 6 months) following guidelines from the Ministry of Health and Treatment. In total, 78 samples (13×3×2) were obtained. To compare the average concentrations of these parameters with WHO guidelines and Standard 1053, Excel software was used for data description and analysis.

Results and Discussion

Nitrate and nitrite contamination can originate from fertilizers, septic systems, and natural processes. Nitrate can also react with natural organic matter in water to form nitrosamines, which are carcinogenic (18). The data on nitrate levels in the drinking water sources of Ilam city are presented in Table 1.

Table 1. Nitrate concentration in drinking water sources of Ilam city from 2021 to 2023

Resources	Nitrate									
	2021		2022		2023		Mean	SD	Max	Min
Pich Ashouri well	1.72	1.33	5.72	6.16	6.16	23.16	7.37	8.04	23.16	1.33

Ghochali Well 1	5.60	5.16	10.25	9.25	25.23	25.16	13.44	9.31	25.23	5.16
Ghochali Well 2	2.18	3.08	7.34	1.12	25.65	13.25	8.77	9.39	25.65	1.12
Ghochali Well 3	5.37	5.01	44.1	7.43	44.37	36.34	23.77	19.76	44.37	5.01
Ghochali Well 4	34.47	24.42	27.19	32.11	16.2	32.16	27.75	6.75	34.47	16.2
Taavoni Well	3.14	2.93	21.56	19.71	0.36	11.03	9.78	9.15	21.56	0.36
Terminal Well	62.90	52.57	55.72	66.34	7.9	6.25	41.94	27.45	66.34	6.25
Haft Cheshmeh (rural) Well	51.16	51.87	68.41	50.12	63.26	40.21	54.17	10.10	68.41	40.21
Haft Cheshmeh (urban) Well	53.42	55.88	58.13	61.13	2.19	17.02	41.29	25.11	61.13	2.19
Gol Gol Spring	52.02	62.64	1.77	1.76	52.16	46.25	36.09	27.11	62.64	1.76
Dampezeshki Well	24.32	32.19	5.11	5.1	12.16	16.35	15.87	10.80	32.19	5.1
Naghliyeh Shahrdari Well	10.13	14.35	4.3	4.6	24.26	25.62	13.87	9.35	25.62	4.3
Khorramroudi Boulevard	13.15	12.14	7.05	14.24	13.19	3.32	10.51	4.34	14.24	3.32

Ilam city was monitored in the Haft-Cheshmeh rural well (68.41 mg/L), while the lowest concentration was found in the Cooperative well (0.36 mg/L). The highest value exceeded the national and WHO guideline limit of 50 mg/L, likely due to agricultural activities and surface runoff. Additionally, the results show that the mean nitrate concentration in the Haft-Cheshmeh rural well (54.17 mg/L) was also above national and international standards. Nitrate is a compound that occurs naturally in soil and groundwater, but high levels of nitrate in water can be harmful to human health. Nitrate can be produced through the oxidation of ammonia in wastewater treatment plants or by the decomposition of organic matter in lakes and rivers. Nitrate is a common groundwater pollutant that can enter water sources through agricultural runoff, sewage, and industrial waste. In a study conducted by Foroughi et al. (2006) on nitrate and nitrite contamination levels in surface and groundwater resources of Golestan and Mazandaran provinces, the concentrations of nitrate and nitrite were reported as 35.5 mg/L and 0.09 mg/L, respectively, which were below the WHO guideline limits. These findings do not align with the results of our study (5). The study conducted by Kord et al. (2005) on groundwater resources of Nahavand reported nitrite and nitrate concentrations of 7.8 mg/L and 0.163 mg/L, respectively. Compared with the WHO guidelines and the latest national standards, these levels were within the acceptable limits, which contrasts with the findings of our study (19). In a study by Amouei et al. (2012) on the water quality of Khaf, it was reported that in some areas the nitrate concentration in the groundwater aquifers was more than five times higher than the permissible limit, which is not consistent with the results of our study (20).

Figure 1 also displays a graph of the average nitrate concentration in Ilam city's drinking water sources to highlight the highest levels.

The results regarding the average nitrite concentration in the drinking water sources of Ilam city are shown in Table 2. Based on the data in this table, the nitrite concentration in Ilam's drinking water sources was highest in the Haft Cheshmeh well in the village at 5.009 mg/l and lowest in the Pich Ashuri well at 0.008 mg/l, with the highest value exceeding the global and national standard of 3 mg/l. The high nitrite level in the Haft Cheshmeh well could be due to sewage entering the well's vicinity. Additionally, Table 2 shows that the highest average nitrite concentration in Ilam's water sources was in the rural Haft Cheshmeh well, at 2.22 mg/l, which was below the national and international standards.

Table 2. Nitrite concentration in drinking water sources of Ilam city from 2021 to 2023.

Resources	Nitrate									
	2021		2022		2023		Mean	SD	Max	Min
Pich Ashouri well	0.017	0.008	0.016	0.132	0.026	0.02	0.03	0.04	0.132	0.008
Ghochali Well 1	0.026	0.13	0.02	0.026	0.035	0.1	0.05	0.04	0.13	0.02
Ghochali Well 2	0.015	0.019	0.02	0.02	0.033	0.13	0.04	0.04	0.13	0.015
Ghochali Well 3	0.14	0.04	0.03	0.04	0.06	0.09	0.07	0.03	0.14	0.03
Ghochali Well 4	0.11	0.14	0.17	0.24	0.05	0.09	0.13	0.06	0.24	0.05
Taavoni Well	0.02	0.01	0.06	0.05	0.16	0.14	0.07	0.05	0.16	0.01
Terminal Well	0.03	0.02	4.01	3.02	0.03	0.15	1.71	1.83	4.01	0.02
Haft Cheshmeh (rural) Well	5.009	5.002	3.20	0.029	0.09	0.026	2.22	2.47	5.009	0.026
Haft Cheshmeh (urban) Well	0.02	0.03	4.03	0.04	2.59	0.01	1.62	1.80	4.03	0.01
Gol Gol Spring	0.12	0.22	3.01	3.00	3.38	0.06	1.63	1.64	3.38	0.06
Dampezeshki Well	0.04	0.35	0.025	0.026	0.04	0.05	0.08	0.12	0.35	0.025
Naghliyeh Shahrdari Well	0.17	0.42	0.022	0.023	0.06	0.03	0.12	0.15	0.42	0.022
Khorramroudi Boulevard	0.08	1.05	0.06	0.03	0.04	0.01	0.21	0.41	1.05	0.01

The results of this study also indicate that nitrate ion levels in the water across most of the areas examined are below the recommended standard values. This is further supported by the instability of this ion and its quick conversion in nature to nitrate. The high concentration of nitrate ions, coupled with low nitrite ion levels, suggests that the pollution did not occur recently or suddenly. Instead, this increase has developed over many years and will likely continue if the necessary controls are not put in place (21). The results of the study by Khorramabadi (2001) on nitrite and nitrate levels in the drinking water of Khorramabad showed that the mean concentrations of nitrate and nitrite were within recommended standards and below the allowable limits. The highest nitrate level was reported as 28 mg/L, which was linked to the lack of sanitary protection for the well and its proximity to residential areas. These findings are not consistent with the results of the present study (18). In the assessment of drinking water resource pollution in Zanjan during 2000–2001, the annual mean concentrations of nitrate and nitrite were reported as 17.72 mg/L and 0.03 mg/L, respectively, which were below the recommended standards. Additionally, the mean nitrate concentration during the summer was higher compared to other seasons. These results do not align with the findings of the present study (22). The findings of Shariati Feizabadi et al. (2006) on nitrite and phosphate concentrations in groundwater resources of Astaneh Ashrafieh indicated that the maximum and minimum concentrations of nitrite in the wells were 6.18 mg/L and 0.054 mg/L, respectively. In some villages, the nitrite concentrations exceeded the permissible drinking water standards, which is consistent with the findings of the present study (17). In Figure 1, the average nitrite concentration in the drinking water sources of Ilam city is also shown as a graph to indicate the highest concentration. Nitrates and nitrites are associated with a variety of health effects, including respiratory problems, thyroid disorders, and certain types of cancer. Pregnant women, infants, and individuals with underlying health conditions may be particularly vulnerable to the effects of nitrate and nitrite exposure (18).

Table 3 presents the results related to fluoride concentration in the drinking water sources of Ilam city. According to the data, the highest fluoride level was found in the Ghochali 1 well at 1.86 mg/l, while the lowest levels were in the Pich Ashouri and Terminal wells at 0.51 mg/l. These levels exceeded both global and national standards (global maximum 1.5 mg/l and national range 0.1-5.5 mg/l). Additionally, the data shows that the average fluoride concentration across all sources of Ilam's drinking water falls within the national and international standard ranges. Consequently, there is no specific public health risk associated with this parameter. In a study conducted by Rahimzadeh et al. (2008) on fluoride levels in drinking water sources of villages in Gorgan, it was found that fluoride concentrations in wells were higher than in springs. Additionally, fluoride levels in all seasons were below the minimum recommended standard, which is not consistent with the findings of the present study (24).

Table 3. Fluoride concentration in drinking water sources of Ilam city from 2021 to 2023.

Resources	**Fluoride**									
	2021		2022		2023		Mean	SD	Max	Min
Pich Ashouri well	0.51	0.95	0.56	1.56	0.55	0.67	0.80	0.40	1.65	0.51
Ghochali Well 1	0.56	1.86	0.59	0.65	0.65	0.59	0.81	0.51	1.86	0.56
Ghochali Well 2	0.65	0.55	0.67	0.57	0.63	0.64	0.61	0.04	0.67	055
Ghochali Well 3	0.58	1.69	0.63	0.65	0.63	0.66	0.80	0.43	1.69	0.58
Ghochali Well 4	0.55	1.03	0.67	0.85	0.61	0.56	0.71	0.18	1.03	0.55
Taavoni Well	0.64	0.79	0.66	0.99	0.60	0.64	0.72	0.14	0.99	0.6
Terminal Well	0.63	0.94	0.53	1.54	0.51	0.95	0.85	0.39	1.54	0.51
Haft Cheshmeh (rural) Well	0.53	1.39	0.65	1.57	0.54	1.56	1.03	0.51	1.57	0.53
Haft Cheshmeh (urban) Well	0.53	0.75	0.63	0.95	0.59	0.73	0.69	0.14	0.95	0.53
Gol Gol Spring	0.57	0.65	0.56	0.94	0.61	0.81	0.69	0.15	0.94	0.65
Dampezeshki Well	0.69	0.74	0.63	0.84	0.66	0.68	0.70	0.70	0.84	0.63

Naghliyeh Shahrdari Well	0.64	0.75	0.59	0.82	0.62	0.95	0.72	0.13	0.95	0.59
Khorramroudi Boulevard	0.56	0.64	0.62	0.68	0.52	0.63	0.60	0.05	0.68	0.52

According to a study by Samarghandi et al. (1998) on fluoride levels in drinking water of Hamedan and Bahar cities during 1998–1999, the annual mean fluoride concentrations were 0.198 mg/L and 0.6 mg/L, respectively. Based on the recommended standards, these values are below the minimum required, considering seasonal temperature variations, which does not align with the findings of the present study (25). In a study conducted by Mandinic et al. (2010) in Serbia, which investigated the relationship between dental fluorosis and drinking water, the fluoride concentrations in the studied wells were 0.07, 0.10, 0.17, and 0.15 mg/L, all below the recommended standard. This deficiency was significantly associated with dental fluorosis in children in the studied areas. Additionally, fluoride concentrations in groundwater were higher than in surface water, which is not consistent with the findings of the present study (23). In a study conducted in 2000 on the chemical and microbial quality of groundwater resources in Urmia, the fluoride concentration in the studied water sources was 0.04 mg/L, which was below the standard limit and not consistent with the findings of the present study (26, 27). In a study by Shahriari et al., which examined fluoride levels in drinking water sources in South Khorasan from 2007 to 2008, the average fluoride concentration was 0.52 mg/L. This value was below the minimum standard and did not match the findings of the present study (28). In Figure 1, the average fluoride concentration in the drinking water sources of Ilam city is also shown as a graph to indicate the highest concentration. Fluoride helps strengthen tooth enamel and reduce the risk of cavities. However, excessive levels of fluoride in water can cause dental fluorosis (a condition that affects the appearance and strength of teeth). Chronic exposure to high levels of fluoride can also lead to skeletal fluorosis (a condition that affects bones and joints (23).

Turbidity measures how cloudy or hazy water is due to floating particles. High turbidity levels can block light from reaching aquatic plants, impacting their growth and the overall health of aquatic ecosystems. Turbidity can also indicate other pollutants in the water, such as sediment and organic matter. Monitoring turbidity levels is essential for assessing water quality and determining the health of aquatic ecosystems (29). Turbidity also provides an ideal environment for microbial growth, including harmful bacteria, viruses, and parasites. In the event of natural disasters or infrastructure damage, high turbidity can serve as an early warning sign of potential water contamination (30, 31). The results related to the turbidity parameter concentration in the drinking water sources of Ilam city are shown in Table 4. As shown in Table 4, the results for the average turbidity concentration in Ilam city's drinking water sources are presented.

Based on the data presented in Table 4, the highest turbidity concentration in the drinking water sources of Ilam city was observed in the Haft-Cheshmeh rural well (9.16 NTU), while the lowest was recorded in the Taavoni well (0.29 NTU). The maximum value exceeded both national and international standards (the desirable turbidity limit in Iran and WHO guidelines is <1 NTU, and the maximum permissible limit in the Iranian standard is 5 NTU). Furthermore, the highest mean turbidity over the study period was observed in the Haft-Cheshmeh rural well (5.92 NTU), exceeding the national and international permissible limits. The lowest three-year mean turbidity was recorded in the Taavoni well (1.12 NTU), which is still above the desirable limits according to national and WHO standards. Figure 1 presents the mean turbidity concentrations of Ilam city's drinking water sources to illustrate the highest turbidity levels.

Table 4. Turbidity in drinking water sources of Ilam city from 2021 to 2023.

Resources	Turbidity									
	2021		2022		2023		Mean	SD	Max	Min
Pich Ashouri well	0.32	0.47	0.49	6.89	0.47	3.26	1.98	2.65	6.89	0.32
Ghochali Well 1	0.95	2.01	0.42	2.35	2.34	2.03	1.68	0.80	2.35	0.42
Ghochali Well 2	0.56	0.73	0.51	4.26	0.32	1.03	1.23	1.5	4.26	0.32
Ghochali Well 3	1.23	0.99	3.13	4.31	2.03	2.6	2.38	1.24	4.31	0.99
Ghochali Well 4	5.37	6.23	5.14	5.78	1.02	3.69	4.53	1.92	6.23	1.02
Taavoni Well	0.47	0.36	0.36	0.29	3.21	2.05	1.12	1.22	3.21	0.29
Terminal Well	6.44	0.57	6.26	0.71	9.16	6.35	4.91	3.48	9.16	0.57
Haft Cheshmeh (rural) Well	6.37	5.24	5.65	5.26	7.35	5.68	5.92	0.80	7.35	5.24
Haft Cheshmeh (urban) Well	5.27	0.34	0.73	5.62	8.43	2.03	3.73	3.20	8.43	0.34
Gol Gol Spring	0.34	6.26	5.56	0.56	6.26	7.26	4.37	3.08	7.26	0.34
Dampezeshki Well	6.32	7.19	2.27	2.27	1.35	1.05	3.40	2.65	7.19	1.05
Naghliyeh Shahrdari Well	5.43	5.18	3.24	3.24	2.14	1.57	3.46	1.56	5.43	1.57
Khorramroudi Boulevard	2.35	3.15	2.01	2.03	3.16	1.94	2.44	0.57	3.16	1.94

A 2012 study on the quality of drinking water in Bushehr found that the turbidity was 0.27 NTU, which is below the acceptable limits. Colloidal particles causing turbidity can serve as surfaces for biological organisms, harmful chemicals, or substances that cause taste and odor problems. They can also protect microorganisms from disinfectants, reducing disinfection effectiveness. Turbidity levels above 1 NTU can lower disinfection efficiency, while levels above 5 NTU are visible to the naked eye. These results do not align with those of the current study (32, 33).

DO plays an important role in the process of removing iron and manganese from drinking water in treatment plants. Furthermore, the undeniable impact of DO concentration on improving the life of aquatic organisms and aquatic ecosystems is also undeniable. The importance of this parameter is so great that its value serves as a basis for measuring the purity of water (34). The results related to the concentration of DO parameter in the drinking water sources of Ilam city are shown in Table 5.

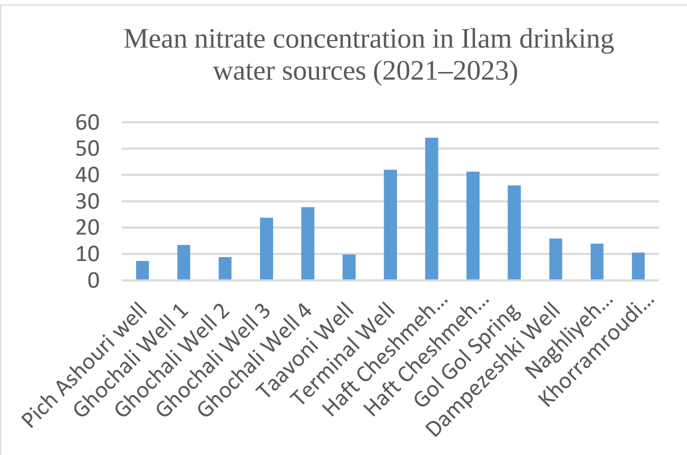
Table 5. DO concentration in drinking water sources of Ilam city from 2021 to 2023.

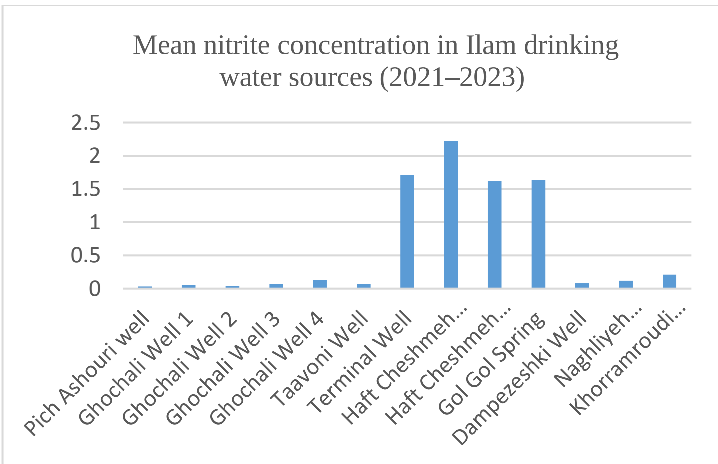
Resources	DO									
	2021		2022		2023		Mean	SD	Max	Min
Pich Ashouri well	6.75	6.93	6.51	4.14	8.35	6.52	6.53	1.35	8.35	4.14
Ghochali Well 1	7.5	6.94	7.02	6.55	6.55	8.23	7.13	0.64	8.33	6.55
Ghochali Well 2	7.30	7.76	6.71	7.26	6.94	7.62	7.26	0.39	7.76	6.71
Ghochali Well 3	7.29	7.41	6.64	7.80	8.11	6.77	7.33	0.57	8.11	6.64
Ghochali Well 4	4.34	4.72	4.16	2.45	7.26	8.25	5.19	2.15	8.25	2.45
Taavoni Well	7.13	6.61	6.74	6.51	6.67	8.75	7.06	0.85	8.75	6.51

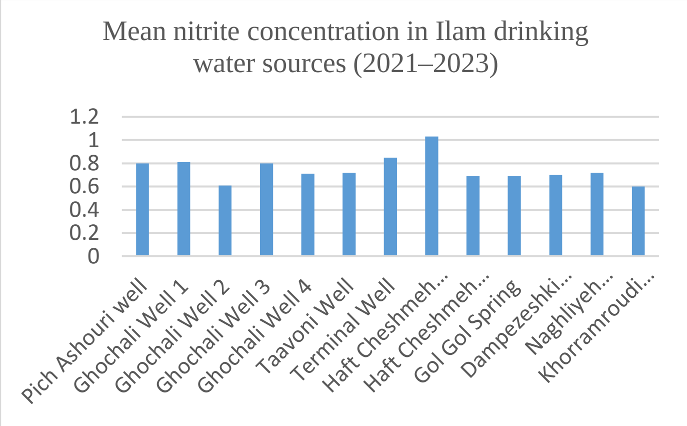
Terminal Well	4.27	3.88	2.05	6.78	3.21	2.25	3.74	1.72	6.78	2.05
Haft Cheshmeh (rural) Well	2.47	2.97	3.57	4.56	2.59	3.07	3.20	0.76	4.56	2.47
Haft Cheshmeh (urban) Well	3.17	6.79	6.59	4.20	4.63	8.94	5.72	2.11	8.94	3.17
Gol Gol Spring	8.72	3.28	4.94	6.94	2.13	4.70	5.11	2.40	8.72	2.13
Dampezeshki Well	3.45	2.81	7.35	6.95	6.75	8.65	5.99	2.32	8.65	2.81
Naghliyeh Shahrdari Well	4.95	3.73	6.70	6.70	8.06	8.56	6.45	1.83	8.56	3.73
Khorramroudi Boulevard	8.25	7.62	7.20	7.25	8.62	7.13	7.67	0.62	8.62	7.13

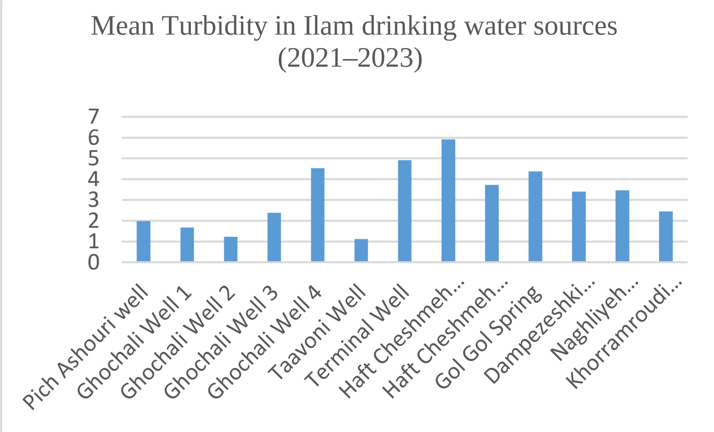
As shown in Table 5, the highest concentration of DO in Ilam city's drinking water sources was found in the Haft Cheshmeh well at 8.94 mg/l, while the lowest was in the Terminal well at 2.05 mg/l. The highest value was within the acceptable range of both international and national standards (the desirable DO level in drinking water is between 6.5 and 9 mg/l). Additionally, the table results indicate that the three-year average DO concentration was highest in the Khorrmroudi well at 7.67 mg/l, which complies with national and international standards. The lowest average was in the Haft Cheshmeh rural well at 3.20 mg/l, falling below these standards. Low DO levels can result from pollution, algal blooms, and temperature changes, leading to hypoxia or reduced oxygen in aquatic environments. Insufficient DO can harm aquatic life and disrupt ecosystems, causing fish kills and other negative impacts (34).

In Figure 1, the average concentration of DO in the drinking water sources of Ilam city is shown as a graph to highlight the highest levels. The relationship between turbidity and DO levels in water sources is complex and interconnected. Turbidity can influence DO levels by limiting the amount of light that penetrates the water. This reduction in light can hinder the ability of aquatic plants to photosynthesize, resulting in decreased oxygen production. Furthermore, suspended particles in turbid water can serve as a barrier, preventing oxygen exchange between the air and the water. As a result, water sources with high turbidity levels are often associated with low DO levels, which can harm fish and other aquatic organisms (35).









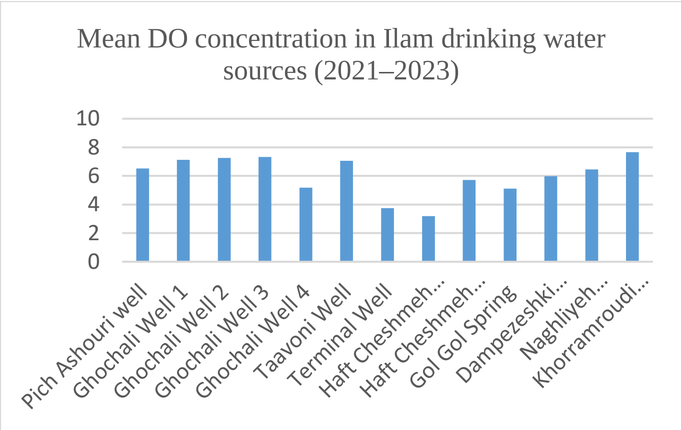


Fig 1. Average Nitrate, Nitrite, Fluoride, Turbidity, and Dissolved Oxygen Parameters in Drinking Water Sources of Ilam City from 2021 to 2023.

Conclusion

The results showed that the highest average concentration of nitrate and nitrite in the drinking water sources of Ilam city was in the Haft Cheshmeh well in the rural area, with concentrations of 17.54 mg/l and 2.22 mg/l, respectively, which were higher than the national and international standards. Also, the highest average turbidity concentration in the drinking water sources of Ilam city was found in the Haft Cheshmeh well in the rural area, with a concentration of 92.5 NTU, which was higher than the national and global maximum permissible levels. Based on the results in the table, it was observed that the average fluoride concentration in the drinking water sources of Ilam city was within the national and international standard range for all sources. The highest three-year average concentration of DO in the drinking water sources of Ilam city was found in the Khorramroudi well, with a concentration of 7.67 mg/l, which falls within the national and international standards. Considering that the values of most physical and chemical parameters in Ilam city are below national and international standards, it can be said that the physicochemical quality of drinking water in Ilam city is not problematic from a health perspective and is safe. Consequently, this article highlights the importance of examining the concentration of nitrate, nitrite, fluoride, turbidity, and dissolved oxygen in drinking water sources. Further research and continuous monitoring of these parameters can contribute to the development of more effective water management practices and the improvement of public health. Nitrate, fluoride, turbidity, and DO are key water quality indicators that play a crucial role in maintaining the health and integrity of aquatic ecosystems and human populations. Monitoring and managing these parameters in water resources is essential to ensure a clean and healthy drinking water supply, protect aquatic habitats, and safeguard public health. By prioritizing water quality protection and adopting science-based approaches to water management, we can strive toward a sustainable future with access to clean and healthy water for all.

Recommendations

Conducting qualitative studies of groundwater is a fundamental and practical step toward obtaining qualitative information about water resources. Therefore, to prevent further contamination of groundwater and surface water resources, it seems necessary to conduct extensive and comprehensive studies to monitor their chemical quality and provide practical programs, such as accelerating the implementation of sewage collection and treatment networks and determining the sanitary buffer zones of wells. In this regard, to prevent diseases related to nitrite and nitrate, treatment facilities to remove nitrate from drinking water should be considered whenever possible.

To remove these pollutants from drinking water, various treatment methods such as ion exchange and reverse osmosis can be used. Protecting water resources and land use practices are also important ways to prevent nitrate and nitrite contamination in water sources (21).

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Ethics approval

This research is approved in Ethical Committee of Ilam University of Medical Sciences (Register Code: IR.MEDILAM.REC.1403.196).

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Conflict of interest

All authors have no conflict of interest, financial or otherwise.

Authors' contributions

Data gathering, analyses and interpretation done by Zeinivand A, Aghaei A, Gholami Z, Adiban M, Sayyadi H drafting of the paper were done by All authors. Ahmadpourbirgani F, and Zangeneh F reviewed the literature. All authors read, revised, and approved the final manuscript.

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