



Research Article

Assessment of nitrate concentrations in groundwater of Tal Abta Sub-District, Iraq: Health risks and pollution evaluation

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Abstract

The current study included estimating the concentration of nitrate ions in order to determine the health risks to humans and animals of the groundwater in Tal Abta sub-district, Hatra district within Nineveh governorate. The results indicated that the nitrate levels ranged between (12.31-12.71) ppm. Thus, 100% of the studied samples were within the permissible international standard limits for drinking. This relative increase in nitrates was reflected in the chronic daily intake (CDI) values and risk quotient (HQ) for nitrates, which ranged between (0.896116- 0.332057) mg/kg. day and (0.207535-0.560073), consecutively. Fortunately, the nitrate risk quotient was within the safe levels for drinking (HQ = 1.0) according to the US-EPA, and despite this, the infant group was more affected by nitrates, while the age group (18 to 16) was less affected compared to the studied age groups, With regard to the results of the nitrate pollution index (NPI), the values ranged between (0.258-0.237), so that the water quality is in the category of Light Polluted.

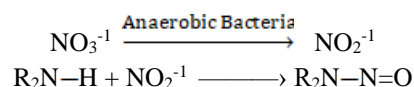
Keywords: Nitrate pollution index (NPI), HHR of NO₃, Drinking water.

Introduction

Nitrate is an inorganic ion (NO₃⁻¹) that occurs naturally in the nitrogen cycle. Nitrate can enter groundwater through various natural and anthropogenic sources, for example, rock-water reaction from weathering of nitrite-bearing rocks, septic tanks, wastewater residues, livestock waste, fertilizers, and pesticides. High levels of NO₃ in the water cause cyanosis in children (methemoglobinemia), thyroid disorders, miscarriage in pregnant women, etc. Infants and young children are most susceptible to the effects of nitrates (Malpe et al., 2021; Toolabi et al., 2021).

Groundwater is an important resource for drinking and irrigation, especially in arid and semi-arid regions. There is a growing concern about the quality of groundwater and its impact on human health when consuming water with high concentrations of nitrates, which negatively affect human health. As it was listed as a carcinogenic substance by the US Environmental Protection Agency (US-EPA) as a result of its interactions with amines and amides to form nitrous-amine or amide compounds, this topic has received global attention due to its devastating effects on human health (Patel et al., 2020; Kom et al., 2022; Alharbi and El-Sorogy, 2023). Groundwater

is used directly without any treatment, which may cause potential risks for consumers of this water as more than 85% of drinking water supplies depend on groundwater resources, especially residents of rural areas (Al Gadi et al., 2023). Despite the importance of nitrates as a nitrogen source. For plants to manufacture compounds necessary for life, but exposure to high concentrations may cause damage to plants such as deterioration in the quality and quantity of plant production with the possibility of accumulation in plant tissues that threaten the health of consumers. After nitrates enter the mouth through water or vegetables, they are reduced by the anaerobic bacteria present under the tongue to nitrite ions, and approximately 25% of the nitrates absorbed by the salivary glands are reduced to be excreted again into the mouth and then to the stomach and intestines to react with amines or amides, if any, to form nitrous-amine or amide compounds, as in the following chemical equations (Al-Mashhadany, 2022; Al Gadi et al., 2023).



Most of these compounds have a mutagenic and carcinogenic effect as a result of creating oxidative stress due to the formation of free radicals. Therefore, high concentrations of nitrates increase the possibility of developing cancerous diseases: such as cancer of the stomach, blood, colon and rectum, etc. It should also be noted that Moderate levels of nitrates have vital benefits on human health as a result of the production of nitrous oxide, which plays a vital role in increasing the elasticity of blood vessels and thus reducing the risks of cardiovascular diseases, as shown in Fig. 1 (Adimalla and Peiyue, 2019; Al-Hussein et al., 2023; Alharbi and El-Sorogy, 2023).

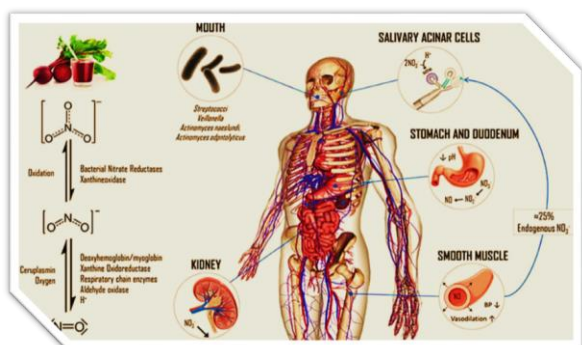


Fig. 1 A diagram showing the pathways of nitrogen (NO₃) compounds within the human body (Al-Bhar and Al-Saffawi 2021).

Materials and Methods

1. Simplified description of the study area

The study included the district of Tal Abta and nine villages affiliated to it, southwest of the city of Mosul,

about 73 Km away from it, and administratively affiliated to the district of Hatra, and 50 Km away from the center of the district of Hatra. In recent decades, the problem of drought began to appear frequently in the region due to the lack of rain, with high temperatures resulting from global warming, and the irresponsible practices of the local population, such as overgrazing, which led to the deterioration of soil and vegetation cover (Aatya et al., 2021).

2. Geology of Tell Abta District

The study area consists of the Fatha Formation, which dates back to the Middle Miocene, which is spread in the region, and contains salt rocks (Halite), gypsum (CaSO₄.2H₂O) and anhydrite (CaSO₄) in addition to limestone, clay, and sand rocks. and alluvial, and the Injana Formation dating back to the Upper Miocene era, consisting of periodic sequences of sandstone, alluvial and mudstone, where the mudstone constitutes the largest proportion of the deposits of this formation, as well as Quaternary Deposits, which includes deposits of graded gravel, clayey, sandy and celtic rocks (Al-Hussein et al., 2023; Shehab and Younis, 2022).

3. Methodology

Water samples were collected from 10 randomly selected wells in the Tal Abta region (the center and some villages affiliated to it) starting from July 2022 until December 2022, whose characteristics appear in Table 1. and Fig. 2, the well water pump was operated for five minutes, after which clean bottles of washed polyethylene terephthalate were filled with sample water.

Table 1. Characteristics of the sites of the wells under study in the district of Tal Abta and some of its affiliated villages.

		Latitude E	longitude N	Depth	Uses
St1	Muwailehat Aziz village	42°34'28"	36°03'37"N	27m	For different uses
St2	Northern Turkmen village	42°37'12"	35°58'48"N	36m	
St3	Southern Tell Faris village	42°34'41"	35°58'39"N	26m	
St4	Hazimeh Al-Bosalem vill.	42°30'50"	35°58'09"N	40m	
St5	Tal-Abta district center	42°33'41"	35°56'50"N	40m	
St6	Southern Turkmen village	42°37'40"	35°55'04"N	60m	
St7	Ashwa village	42°21'16"	36°00'30"N	36m	
St8	Khalif Al-Saleh village	42°32'35"	35°57'04"N	42m	
St9	Abta village south	42°35'56"	35°53'30"N	33m	
St10	Hajaf village	42°28'40"	35°52'46"N	35m	

After reaching the environment laboratory at the College of Education for Pure Sciences, the concentrations of nitrate ions were measured using (4500-NO₃-B) (ultraviolet sorting method), by taking a known volume of water sample, then adding 1 ml of hydrochloric acid 1N Shake to homogenize

the sample, then measure using a UV spectrophotometer of the type (Shimadzu) of Japanese origin at wavelengths of 220 and 275 nm taking into account Planck's work to correct the readings and then compare them with the standard curve and according to the concentration in ppm (APHA, 1998; 2017).



Fig. 2 A satellite view of the sites for collecting water samples from Tell Abta district

4. Environmental risk assessment of nitrates

Two mathematical models were applied to estimate the problems resulting from the presence of nitrate ions in drinking water:

• Human Health Risk of Nitrate Model

Use this model to assess the health risks of nitrate ions in drinking water, as indicated by the US Environmental Protection Agency (US-EPA), as it is one of the very few studies of Iraqi water resources, it is also considered a good and necessary means for evaluating the health risks of nitrates on human and animal health. It was calculated from the following equations (Shalyari et al., 2019; Zhange et al., 2019; Chen et al., 2021; Al-Hussein et al., 2023a).

$$CDI = \frac{Ci \times IR \times EF \times ED}{BW \times AT}$$

$$HI = HQ = \frac{CDI}{RfD}$$

Where:

- CDI: chronic daily intake (mg/kg.d),
- HQ: hazard quotient
- Ci: nitrate concentration measured for water samples.
- IR: daily rate of drinking water (l.day-1)
- EF: frequency of exposure per age group (day. year)
- ED: duration of exposure to nitrate (year)
- Bw: body weight according to age group (kg).
- AT: average time (day).
- RfD: nitrate reference dose (1.6 mg/kg/day).

After that, the risk of nitrates is estimated according to the limits indicated by the US-EPA ($HI = HQ \leq 1.0$) (Alharbi and El-Sorogy, 2023).

• Nitrate Pollution Index (NPI)

The presence of nitrate ions at high levels in water is one of the vital factors for evaluating its quality due to its serious effects on human and animal health, so the (NPI) is calculated using the following equation (Panneerselvam et al., 2020).

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

where:

- NPI: nitrate pollution index value,
- HAN: acceptable limits for nitrate levels in water (10) ppm,
- Ci: measured nitrate concentration (Muhib et al., 2023a; Al-Hussein et al., 2023).

Then the degree of nitrate contamination is classified into five categories: $PNI \leq 0.0$ (Clean level), 0.1 – 1.0 (Light polluted), 1.1 – 2.0 (Moderate polluted), 2.1 – 3.0 (Polluted water), ≥ 3.0 NPI (Very polluted water).

Results and discussion

The results shown in Table 2. indicate, that the values of the nitrate pollution index fluctuated between (0.237-0.258), and thus the studied water quality is considered to be in the category of light polluted water, this relative increase in values is attributed to the effect of human activities such as fertilization in the study area (Grout et al., 2023; Al-Hussein et al., 2023a).

Table 2. Results of the nitrate contamination index of the groundwater of Tal Abta sub-district

Sites	NPI		Site	NPI	
	Value	Class		Value	Class
1.	0.248	Light Polluted	6.	0.258	Light Polluted
2.	0.251	Light Polluted	7.	0.246	Light Polluted
3.	0.248	Light Polluted	8.	0.255	Light Polluted
4.	0.252	Light Polluted	9.	0.237	Light Polluted
5.	0.242	Light Polluted	10.	0.242	Light Polluted

When comparing our current results with other studies, we note that they are relatively close to the results of the study of Al-Bhar and Al-Saffawi (2021) for the village of Al-Manara, north of the city of Mosul, which reached NPI values 0.210 to be in the category of light pollution water. The same is the case with the results of Al-Hussein et al. (2023a) study of the groundwater of the Al-Manara sub-district at the north of Mosul city, whose values did not exceed 0.230 to classify the water as light pollution with nitrates, while it was greater than the results obtained by the study of Al-Hamdany et al. (2020) for the groundwater of some areas in the north of Mosul city, which was in the category of clean water, and the values of the nitrate pollution index in some parts of the world rise to 24.3 in the groundwater of some areas in Bangladesh to classify the water as highly polluted with nitrates (Muhib et al., 2023).

With regard to the health risks of nitrates, the results shown in Table 3. indicate that the HQ values of the groundwater of Tal Abta district were relatively high in infants compared to other cohorts, as it fluctuated between (0.55072- 0.56004), this relative increase in values resulted from the increase in the daily intake of nitrates (CDI), which ranged between 0.88116-0.89612 mg/kg. day. Fortunately, the HQ values were within the safe limits recommended by the US-EPA ($HI = HQ = 1.0$).

Table 3. Results of the chronic daily intake values and the hazard quotient for nitrates in the groundwater of Tal Abta sub-district

Cohorts sites		infant	6-11	11-16	16-18	18-21	21 to Old	
							Females	Males
1	CDI	0.88899	0.56224	0.40986	0.33501	0.43073	0.48112	0.41495
	HQI	0.55562	0.35140	0.25616	0.20938	0.26920	0.30070	0.25934
2	CDI	0.89113	0.56224	0.41084	0.33581	0.43176	0.48227	0.41594
	HQI	0.55696	0.35140	0.25678	0.20988	0.26985	0.30142	0.25997
3	CDI	0.88899	0.56224	0.40986	0.33501	0.43073	0.48112	0.41495
	HQI	0.55562	0.35140	0.25616	0.20938	0.26920	0.30070	0.25934
4	CDI	0.89184	0.56404	0.41117	0.33608	0.43211	0.48266	0.41628
	HQI	0.55740	0.35253	0.25698	0.21005	0.27007	0.30166	0.26017
5	CDI	0.88472	0.55954	0.40789	0.33340	0.42866	0.47880	0.41295
	HQI	0.55295	0.34971	0.25493	0.20837	0.26791	0.29925	0.25810
6	CDI	0.89612	0.56674	0.41314	0.33769	0.43418	0.48497	0.41827
	HQI	0.56007	0.35422	0.25821	0.21106	0.27136	0.30311	0.26142
7	CDI	0.88757	0.56134	0.40920	0.33447	0.43004	0.48035	0.41428
	HQI	0.55473	0.35084	0.25575	0.20905	0.26877	0.30022	0.25893
8	CDI	0.89398	0.56539	0.41215	0.33689	0.43314	0.48382	0.41727
	HQI	0.55874	0.35337	0.25760	0.21056	0.27071	0.30238	0.26080
9	CDI	0.88116	0.55728	0.40624	0.33206	0.42693	0.47688	0.41129
	HQI	0.55072	0.34830	0.25390	0.20754	0.26683	0.29805	0.25706
10	CDI	0.88472	0.55954	0.40789	0.33340	0.42866	0.47880	0.41295
	HQI	0.55295	0.34971	0.25493	0.20837	0.26791	0.29925	0.25810

As for the age group (21-year-old), it is noted from the table that the values of chronic nitrate intake (CDI) are relatively high, especially females; It is noted that these values are relatively higher than their counterparts in males, which ranged between 0.47688 to 0.48497 mg/kg. day, to be reflected in the values of the hazard quotient (HQ), which ranged between (0.29805 to 0.30311). The table also shows that the age group (6-11) years is more affected by nitrate problems after the infant group; Where the values of (CDI and HQ) were relatively high, ranging between 0.55728–0.56674 mg/kg. day and (0.34830-0.34830), on consecutive. By the grace of God, all the values of the hazard quotient of the groundwater of Tal Abta district are within the safe limits for drinking, because the rise of these values outside the recommended limits has serious negative effects on the public health of consumers, such as the blue baby syndrome, in addition to the elderly who can suffer from this syndrome in addition to cancerous diseases, miscarriages of pregnant women, congenital anomalies of fetuses, sudden neonatal death, etc. (Al-Hamdany et al., 2020). When comparing the current results, we notice that it is relatively higher than the results obtained by Al-Saffawi and Awa (2020) when studying the health risks of nitrates in the groundwater of Abu Wajnah village, west of Mosul city, in which the CDI values fluctuated

between (0.1800-0.0225) mg/ kg. per day and the values of the HQ ranged between (0.0142 to 0.1125). They were also higher than the results obtained by Al-Hussein et al. (2023a) for groundwater in Wana sub-district, and that the values of the hazard quotient reach 0.543, while they were lower than the results of the Al-Mashhadany study (2022). The groundwater of some villages of Sinjar district, in which the values of the hazard quotient reached 1.978, this difference in values is due to the temporal and spatial differences of these studies, while it was less than the results of the Al-Mashhadany (2022) study of groundwater for some villages of Sinjar district, in which the values of the hazard quotient (HI) reached (1.978), this difference in values is due to the temporal and spatial differences of these studies.

In general, the low values of chronic daily intake (CDI) and the risk quotient for nitrates in the studied waters result from the fact that the levels of nitrates in the studied waters are within the internationally recommended limits (WHO, 2017) despite their relatively high range from (12.35 to 12.71) at a rate of (12.37 ± 0.039 to 12.58 ± 0.057) as shown in Fig. 3 and Table 4.

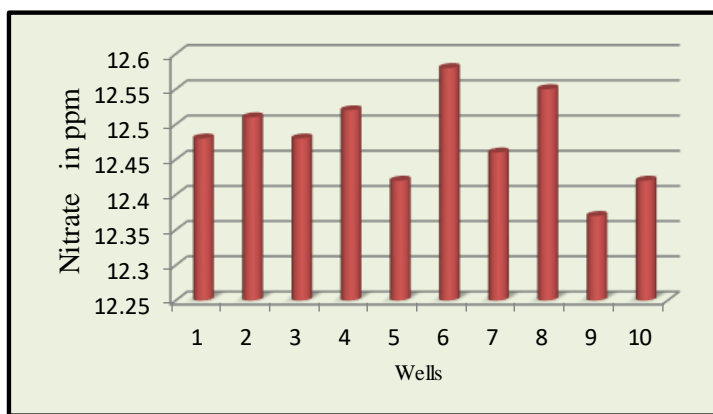


Fig. 3 Average concentrations of nitrate ions in the well water of Tal Abta sub-district

Table 4. Concentrations of nitrate ions in the well water of Tal Abta district (ppm)

Date Wells	18/7	09/8	20/8	30/8	14/9	24/9	03/10	08/10	23/10	10/12
S1	12.40	12.55	12.50	12.47	12.45	12.47	12.48	12.42	12.62	12.44
S2	12.44	12.62	12.47	12.50	12.42	12.44	12.45	12.72	12.55	12.45
S3	12.46	12.54	12.47	12.51	12.42	12.46	12.47	12.46	12.59	12.46
S4	12.48	12.51	12.50	12.53	12.48	12.50	12.51	12.61	12.59	12.48
S5	12.44	12.42	12.52	12.46	12.35	12.40	12.48	12.44	12.31	12.42
S6	12.54	12.58	12.62	12.55	12.51	12.54	12.60	12.61	12.71	12.56
S7	12.46	12.50	12.42	12.55	12.45	12.40	12.46	12.44	12.48	12.41
S8	12.46	12.61	12.63	12.57	12.49	12.56	12.55	12.51	12.56	12.51
S9	12.31	12.38	12.41	12.37	12.42	12.38	12.36	12.30	12.40	12.36
S10	12.46	12.42	12.42	12.43	12.45	12.40	12.42	12.40	12.41	12.38

This relative increase in concentrations may be due to the contamination of well water with organic waste that is transferred to it due to air currents because it is of the open type, and thus the occurrence of biological degradation processes to turn the amino acids into ammonia by the action of the Deaminizes Enzymes, then the Nitrosamines Bacteria convert them into nitrite ions that oxidize To nitrates when exposed to oxygen and these processes are called nitrification as shown in the equation referred to (Al-Hamadany et al., 2020; Al-Mashhadany, 2023).

Conclusions

The relative high concentration of nitrate ions in most of the studied samples, despite being within the permissible levels for drinking according to (WHO).

There is no problem of water pollution with nitrates, as the water was in the category (Light Polluted) according to the Nitrate Pollution Index (NPI).

Fortunately, the results of (HHR_{NO3}) values were within the safe limits for drinking, although infants were the most affected age group, followed by children aged 1 to 6 years, then females from (21 to Old), while the age group was 16 to 18. Years are the least affected age group by nitrates.

Therefore, the study recommends the continuation of conducting periodic water checks to stand in case of any emergency, while educating citizens to rationalize the consumption of fertilizers and agricultural pesticides in a scientific manner.

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Conflict of Interest

The author hereby declares no conflict of interest.

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