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Original Research Article



Health effects of nitrate concentrations in the groundwater of Al-Manara village, north-east of Mosul city, Iraq

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Abstract

The current study included estimating the concentration of nitrate ions to estimate human health risks (HHR) for groundwater for ten wells in Al-Manara village of Al-Hamdaniya District within Nineveh Governorate. The results indicated that the nitrate levels ranged between (10.8 to 19.1) ppm, thus 100% of the studied samples were within the international standard limits allowed for drinking, which reflected in the CDI and HQ values that fluctuated between (0.8691 to 0.2980) mg/kg. day and (0.5432 to 0.1862) consecutively, which are within the Safe limits for public health when this water is used for drinking by the local population

Keywords Groundwater for Al-Manara village, Nitrate, CDI, HHR.

Introduction

Today, the problem of clean and safe water has become one of the challenges facing millions of people in the world, especially developing countries, as a result of neglect and poor management of water resources and the failure to activate laws that deter those who tamper with water resources and their pollution, especially developed countries. Because these problems are related to human existence, health, progress, and economy (Barzanji, & Al-Saffawi, 2020). The problem of the lack of potable water for civil uses is one of the pillars of national security for any country in the world, especially the arid and semi-arid regions whose water sources are from neighboring countries, as is the case in Iraq, Egypt, Sudan, etc., which adds threats to the climatic challenges and the scarcity of rain, as the water deficit problem may turn into an economic and political weapon, which raises the possibility of tensions and wars with the continued need for water (Al-Hamdany et al., 2020; Al-Bhar and Al-Saffawi, 2021). Many water pollutants threaten human life, such as heavy metals, agricultural pesticides, and microbial pollution, which negatively affect the health of consumers. In our current study, we focused on nitrate pollution in groundwater in Al-Manara village and as a result of their high levels in some groundwater, which is one of the dangerous water pollutants that affect people's lives, and despite the presence of nitrates

in abundance in the environment in natural concentrations, it is a nitrogen source for plants to manufacture compounds necessary for life. But the high concentrations of it in the soil cause damage to plants, such as the deterioration of the quality, and quantity of plant production and the possibility of its accumulation in the plant tissues consumed for nutrition by humans and animals, which causes health risks to consumers such as diabetes, irregular thyroid gland functions, and the so-called methemoglobinemia, which leads to an obstruction in the blood transporting oxygen (Al-Saffawi and Awad, 2020). In addition to its carcinogenic effects as a result of nitrate reduction processes since entering the mouth to form nitrite ions as shown in Fig.1, it may interact with amines and amides in the digestive system to form nitrous amine compounds (N-nitroso NOCS), most of which have carcinogenic and mutagenic effects, causing leukemia and cancer Stomach and stomach lining damage, oral, and genital damage ulcers as well as sudden death, malformations and miscarriages of pregnant women. Therefore, the concentration of nitrates in groundwater should be monitored (Nujic and Habuda-Stanic, 2017; Adimalla and Peiyue, 2019). Nitrates are often seen as agricultural pollutants of groundwater, so they are expected to be in high concentrations in groundwater in rural areas. However, the difference between nitrate concentrations in rural and urban areas is often small due to the increase in urban nitrogen

sources such as wastewater discharge, seeping sewage, solid waste, and urban landfills. The internationally permissible limits for nitrates in drinking water are 50 ppm as NO₃ or equivalent to 11.3 mg/liter NO₃-N (multiply NO₃ mg. l⁻¹ by 0.2258). (WHO, 2017) to reduce the health effects of nitrates on humans, as we mentioned the composition of N-nitroso compounds (NOC); Carcinogenicity or congenital malformations, and other harmful health effects resulting from taking nitrates through water or vegetables. Fortunately,

the presence of ascorbic acid, polyphenols and other compounds found in high levels in most vegetables inhibits the formation of NOC compounds and thus protects human health from these dangerous effects (Wakida and Lerner, 2005; Ward et al, 2018). Therefore, this study was conducted to assess the health risks (HHR) of nitrate in the groundwater of Al-Manara village as one of the very limited studies in Iraq.

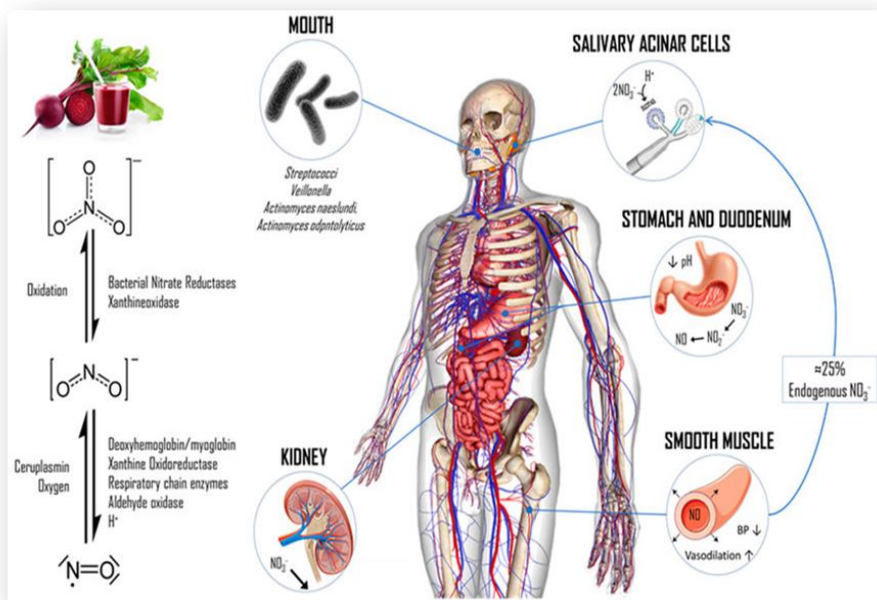


Fig.1 A diagram of the pathways of nitrogen compounds (NO⁻³) in the human body. Nearly 25% of nitrates are absorbed by the mouth by salivary glands, where sialin plays a major role in active transport and nitrate concentration. Part of nitrates is converted to nitrite by mouth bacteria and later absorbed in the stomach and intestines (net).

Materials and Methods

Al-Manara village located northeast of the city of Mosul, affiliated to Al-Hamdaniya District within the Nineveh Governorate, was selected. The local population mainly works in agriculture and animal husbandry, relying on groundwater for various uses. As shown in Fig.1 and Map 1. The geology of the region is characterized by the spread of the Plaspi Formation (the upper middle Eocene) consisting of limestone (CaCO₃), the Al-Fatha formation (middle Miocene) containing limestone rocks, gypsum (CaSO₄.2H₂O), anhydrite (CaSO₄), evaporated salts, yellow marl and the Anjana Formation (Upper Miocene). It consists of alternating layers of sand, silt, and clay (Al-Bhar and Al-Saffawi, 2021).

Ten wells scattered in the region were randomly selected to collect water samples from October 2020 to February 2021 (ten replications) using clean polyethylene packages that were washed with water samples in the field before filling. The water samples were kept in a cool place, away from light, until reaching the laboratory. Nitrate concentrations

were determined by the Ultraviolet Spectrophotometric Screening method at wavelengths 220 and 270 nm according to (APHA, 2017).

Table 1. Wells specifications in Al-Manara village, Al-Hamdaniya District in Nineveh Governorate.

Well No.	longitudes	latitudes	Depth(m)	Uses
1	43° 19'29"E	36° 19'06"N	36	For drinking, domestic uses, cooking, washing utensils, clothes, bathing, etc.
2	43° 19'27"E	36° 19'12"N	45	
3	43° 19'32"E	36° 19'12"N	16	
4	43° 19'35"E	36° 19'11"N	35	
5	43° 19'37"E	36° 19'09"N	42	
6	43° 19'37"E	36° 19'07"N	50	
7	43° 19'34"E	36° 19'00"N	35	
8	43° 19'52"E	36° 19'03"N	30	
9	43° 19'52"E	36° 18'50"N	25	
10	43° 19'05"E	36° 19'05"N	22	



Map 1. A satellite view of the sites for collecting water samples from the wells of Al-Manara village

Calculation of human health risk of nitrate

This model was used to assess the health risks of nitrates in drinking water, which was mentioned by the US Environmental Protection Agency (USEPA) as one of the very rare studies on water resources in Iraq. It is a good tool to assess the health risks of nitrates on consumers' health, which is calculated using the following equations (Tian et al., 2020; Chen et al., 2021).

$$\text{Intake}_{\text{oral}} = \frac{C \times IR \times EF \times ED}{BW \times AT}$$

$$\text{HQ}_{\text{oral}} = \frac{\text{Intake}_{\text{oral}}}{\text{RfD}_{\text{oral}}}$$

Where:

- CDI: represents Chronic Daily Intake (mg/kg. day).
- HQ: Hazard Quotient
- Cw: the measured nitrate concentration for aqueous samples.
- IR: The daily rate of drinking water (liters. day⁻¹).
- EF: Frequency of exposure by age (day. year).
- ED: duration of exposure to nitrates (years).
- Bw: body weight by age group (kg.).
- AT: average time (day)
- RfD: reference dose for nitrate (1.6 mg/Kg/Day).

Results and Discussion

The results are shown in Table 2. indicate that the values of the hazard quotient (HI_{nitrate} = HQ) for the water of Al-Manara village wells were high in infants compared to the age groups studied, which ranged between (0.5432-0.4942), this increase in values is due to the high daily intake of

nitrate CDI, which ranged between (0.08691-0.7907) mg/ kg. day. However, the hazard quotient values are within the safe limits, as the values do not exceed the limits recommended by the US Environmental Protection Agency (HI=HQ≥1.0) (Al-Saffawi and Awad, 2020). For the age group (21-old), it is noted from Table 2. that the values of chronic nitrate intake (CDI) are relatively high, especially for females; It is noted that there is a relative increase in these values compared to males, which ranged between (0.4703-0.3691) mg/kg. day, and the values of the hazard quotient (HQ), which did not exceed (0.2939), as for the rest of the age groups in Table 2. the values of the hazard quotient fluctuated between (0.3435-0.1862). As for the age group (6-11) years, it is noticeable from the results that it is more affected by nitrate problems compared to other age groups (11-21) years, as the values of (HQ and CDI) were relatively high, ranging between (0.5496-0.2980) mg/kg. day and (0.3435-0.1862), respectively. When comparing the current results with other studies, we note that they are relatively more than the results obtained by (Al-Saffawi and Awad, 2020) for the health risks of nitrates in the groundwater of Abu Wajna village, west of Mosul, which fluctuated between (0.1800-0.0228) mg/kg. day and (0.1125 -0.0142). When we compare with international studies, we notice that the values are much lower than the results obtained by Adimallaa and Qian 2019 when studying the estimation of HHR for the water wells of agricultural areas in Nanganur, south India where the risk quotient (HI_{nitrate}=HQ) values for infants, children, and adults were 9.4, 9.1 and 8.4, respectively. Fortunately, the values of the hazard quotient for Al-Manara well water are within the safe limits for drinking, These decrease in the values of the hazard quotient (HQ) is attributed to the relative decrease in the concentration of nitrate ions in the studied groundwater, which ranged between (10.8 to 19.1) ppm and with a fluctuation rate between (11.1 to 12.2) ppm as shown in Table 3 and Fig.2 on the other hand, the concentrations of nitrates in Al-Manara village an approach to the concentration obtained by Al-Hamdani (2020) for the groundwater of some quarters on the left side of Mosul city, which amounted to (10.88) ppm, as well as the results obtained by Al-Saffawi et al, (2020) for the groundwater of Nimrud district, southeast of Mosul, which amounted to (10.8) ppm.

However, there are water sources that contain high concentrations of nitrates that exceed the limits set by the World Health Organization (50) ppm, as is the case in the groundwater of some border areas between Holland and Germany in the west of the Münsterland region to reach nitrate concentrations to (100) ppm, which requires a water treatment to remove nitrate ions and this Causes higher drinking water costs for consumers (Al-Saffawi, 2019; Thang et al, 2021), Also found high concentrations of nitrates in

the groundwater of the Indian RDSA region, which amounted to (212) ppm (Adimalla and Peiyue, 2019).

Table 2. The results of the chronic daily intake (CDI_{oral}) and the hazard quotient of nitrates (HI_{nitrate} = HQ (for different age groups) in Al-Manara village, Hamdaniya district.

Age groups Wells		Infant	6 to11	11-16	16-18	18-21	21 to Old	
							males	females
1	CDI	0.8691	0.5496	0.4007	0.3275	0.4211	0.4056	0.4703
	HQ _i	0.5432	0.3435	0.2504	0.2047	0.2632	0.2535	0.2939
2	CDI	0.8406	0.5316	0.3875	0.3768	0.4073	0.3923	0.4549
	HQ _i	0.5253	0.3323	0.2422	0.1980	0.2545	0.2452	0.2843
3	CDI	0.8121	0.5136	0.3744	0.3060	0.3935	0.3790	0.4395
	HQ _i	0.5076	0.3210	0.2340	0.1913	0.2459	0.2369	0.2747
4	CDI	0.8406	0.5316	0.3875	0.3768	0.4073	0.3923	0.4549
	HQ _i	0.5253	0.3323	0.2422	0.1980	0.2545	0.2452	0.2843
5	CDI	0.8049	0.5091	0.3711	0.3033	0.3900	0.3757	0.4356
	HQ _i	0.5031	0.3182	0.2319	0.1896	0.2438	0.2348	0.2723
6	CDI	0.7978	0.5046	0.3678	0.3006	0.3865	0.3724	0.4318
	HQ _i	0.4986	0.3154	0.2299	0.1879	0.2416	0.2327	0.2699
7	CDI	0.8121	0.5136	0.3744	0.3060	0.3935	0.3790	0.4395
	HQ _i	0.5076	0.3210	0.2340	0.1913	0.2459	0.2369	0.2747
8	CDI	0.8192	0.5181	0.3777	0.3087	0.3969	0.3824	0.4433
	HQ _i	0.5120	0.3238	0.2360	0.1929	0.2481	0.2390	0.2771
9	CDI	0.8049	0.5091	0.3711	0.3033	0.3900	0.3757	0.4356
	HQ _i	0.5031	0.3182	0.2319	0.1896	0.2438	0.2348	0.2723
10	CDI	0.7907	0.5001	0.3645	0.2980	0.3831	0.3691	0.4279
	HQ _i	0.4942	0.3125	0.2278	0.1862	0.2394	0.2307	0.2674

Table 3. The concentration of nitrate ions in the groundwater of Al-Manara Village (ppm).

Date Wells	2020						2021			
	18/10	1/11	15/11	22/11	10/12	24/12	4/1	10/1	27/1	7/2
1	19.1	11.8	11.5	8.16	10.0	11.6	14.8	11	11.9	11.7
2	11.8	11.3	11.4	11.6	10.0	11.5	15	11.7	11.9	11.7
*3	11.2	11.8	11.3	---	---	---	---	---	---	---
4	11.7	11.8	11.4	11.4	10.0	11.4	15	11.6	11.8	11.6
5	11.0	11.9	11.3	11.5	10.0	11.3	11.4	11.7	11.7	11.5
6	10.8	11.8	11.1	11.4	10.0	10.3	11.4	11.7	11.8	11.6
7	10.8	11.8	11.3	11.3	11.3	11.3	11.2	11.6	11.7	11.5
8	11.0	11.9	11.7	11.6	10.0	11.5	11.6	11.9	11.8	11.7
9	11.0	11.9	11.5	11.4	10.0	10.4	11.4	11.8	11.9	11.6
10	11.0	11.8	11.4	11.5	10.0	11.2	11.3	11.2	10.5	11.5

*Failure to complete measurements of nitrate ions concentration in well water 3 due to a technical malfunction of the water pump and failure to repair it during the rainy season.

Finally, nitrate is relatively non-toxic per se, However, after entering the mouth, it can be reduced to nitrite by sublingual anaerobic bacteria, which can react with amines and amides to produce N-nitroso compounds. These compounds increase the risk of many diseases such as cancer. Also, high nitrate levels inhibit iodine uptake competitively (Parvizishad et al., 2017). However, moderate levels of nitrates have positive effects on health through their biological conversion to nitrite, nitric oxide and by-products such as nitrous, and nitrile by bacteria in the oral cavity .These compounds have a

protective effect against the incidence of some heart diseases, such as regulating blood pressure and maintaining the flexibility of blood vessels (Al-Hamdany, 2020; Al-Hamdani, 2021).

Conclusions and recommendations

The current study is one of the very limited studies in Iraq, where the HHR was estimated based on different age groups, duration of exposure, body weight, daily consumption of drinking water, and nitrate levels in drinking water, etc.

It was noticed that the concentrations of nitrates in the drinking water sources of Al-Manara village were lower than the levels allowed by WHO.

The nitrate risk quotient ($H_{\text{nitrate}} = HQ$) values were relatively low for levels that are hazardous to general health for all age groups, especially infants. Thus, the studied groundwater is healthy and safe to drink for the concentration of nitrate ions, and there are no health risks to humans and livestock, whether they are cancerous or non-cancerous.

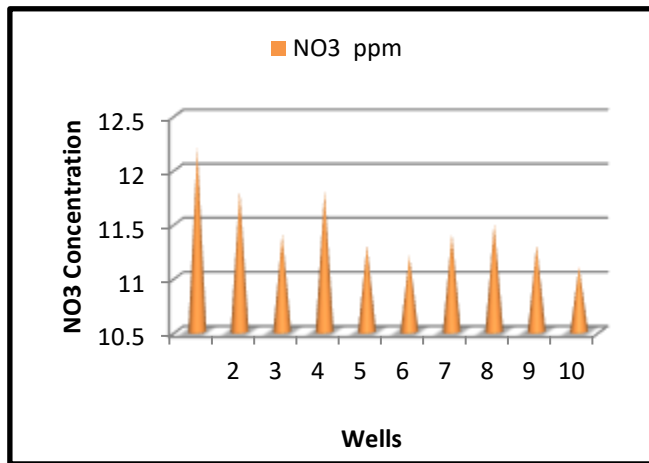


Fig. 2 Average concentrations of nitrate ions in the groundwater of Al-Manara Village, Hamdaniya District.

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