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RESEARCH ARTICLE

Potential Health Risk Assessment for Nitrate Contamination in the Groundwater of Mersin Province, Türkiye

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ABSTRACT

Though groundwater is one of the most significant natural water sources, its quality is deteriorating due to the anthropogenic pressures that poses health risks for people. In this study, potential health risk assessment for nitrate pollution in groundwater of Mersin Province was determined by commonly using health indices. Study findings indicated that the calculated Hazard Index (HI) values varied between 0.001 and 17.89 for the adults whilst the HI values ranging from 0.001 to 29.87 for the children. The HI values in the groundwater of Erdemli, Göksu and Anamur regions showed low chronic health risk for the adults and children (HI≤1). However, the calculated health risk indices indicated significant health hazards for the children inhabited between Tarsus and Çeşmeli regions (HI≥4.00) due to severe nitrate contamination originated from terrestrial sources. The findings of this study performed in the Mersin Province showed the sustainable management of groundwater policies is needed to reduce nitrate contamination and potential health hazards of the groundwater of studied and other regions in Türkiye.

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1. Introduction

Though surface waters are critical sources of water supply, the amount of groundwater is about 100 times that of surface waters (Fitts, 2013; Yue et al., 2017; Ba et al., 2022). Groundwater is one of the most significant natural water supply that has been widely used for drinking water needs and irrigation purposes (Adimalla et al., 2018; Said et al., 2021). It was reported that larger than 1.5 billion people use groundwater for drinking purposes in the world directly or indirectly (Shen et al., 2008; Adimalla & Qian, 2019). Therefore, an increasing number of studies have focused on groundwater in recent years (Kuyumcu, 2023).

Though groundwater is the most significant natural water resources for human being, its quality is deteriorating due to the anthropogenic perturbations posing health risks for people who use groundwater for consumption (Li et al., 2012; Wu et al., 2012; Wu & Sun, 2016; Adimalla, 2020). For example, the increase in population growth, intense urbanization, intensive technological developments and excessive use of nitrogen-containing fertilizers have led to nitrate contamination in Türkiye (Erşahin & Bilgili, 2023).

Mersin province, located at the southern Türkiye, is an economically important tourism region for cultural heritage and

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coastal beaches (Özbay, 2023) and it was reported that its population of increases dramatically in the summer periods due to beach tourism (Özgüler et al., 2022). It was reported by the World Health Organization that approximately a quarter of mortalities have been caused by environmental risk factor (Radfard et al., 2019). Although water sources have been contaminated by nitrate and nitrite in Türkiye (Erşahin & Bilgili, 2023), their adverse effects on human health in drinking water are currently unclear (Picetti et al., 2022). This study, therefore, aimed to determine potential health risk assessment for nitrate pollution in groundwater of Mersin Province. Many studies have been reported to determine groundwater nitrate contamination in Mersin Province (Hatipoğlu & Bayarı, 2005; Güler, 2009; Demirel et al., 2011; Güler et al., 2012; Güven et al., 2022; Kuyumcu, 2023). However, this study is a first attempt to determine the health risk (non-carcinogenic risk) for inhabitants originated from nitrate pollution.

2. Materials and Methods

In order to assess potential health risk assessment for nitrate pollution in groundwater of Mersin Province, previously reported data sets that obtained from the different groundwater samples in the Mersin Province. The nitrate data were obtained from the studies of Hatipoğlu and Bayarı (2005), Güler (2009), Demirel et al. (2011), Güler et al. (2012), Güven et al. (2022), and Kuyumcu (2023) (Table 1). The studied groundwater sampling sites were shown on the map presented in Figure 1.

Table 1. The groundwater sampling sites studied between 2001 and 2022.

Region	Tarsus - Karaduvar	Tarsus - Karaduvar	Karaduvar	Karaduvar -Çeşmeli	Erdemli	Göksu	Anamur
Date	2008	2020	2006-2007	2001-2003	2022	2006-2008	2022
# of sampling locations	193	87	43	15	1	24	1
Reference	Güler et al. (2012)	Güven et al. (2022)	Güler (2009)	Hatipoğlu and Bayarı (2005)	Kuyumcu (2023)	Demirel et al. (2011)	Kuyumcu (2023)

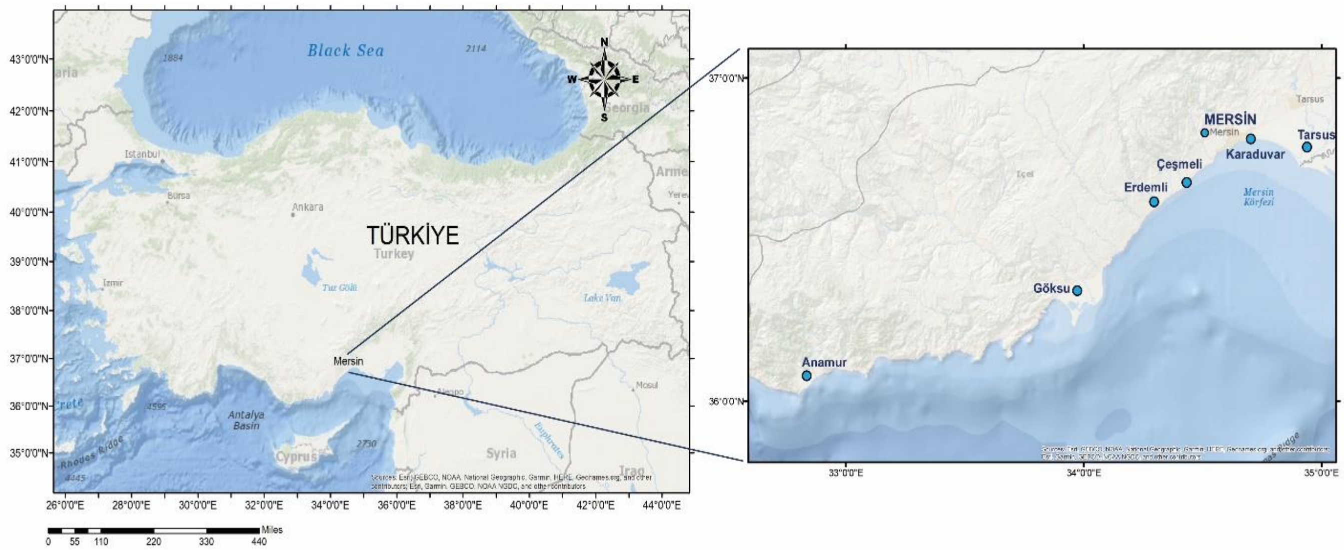

Figure 1. The studied groundwater samples between 2001 and 2022 (Sampling strategies were presented in Table 1).

In this study, health risk assessment for nitrate contamination were determined from the minimum, maximum and mean values of nitrate concentrations reported by the previous studies presented in Table 1. Potential health risk assessment can be determined by the basis of carcinogenic or non-carcinogenic effects. In this study, non-carcinogenic risk for nitrate was determined by the calculation of Chronic Daily Intake (CDI), Health Quotient (HQ) and Health Hazard (HI) for the adults and children (USEPA, 2004; USEPA, 2014; Zhang et al., 2020; IRIS, 2023). The chronic health risk assessment was performed by the classification reported by Kusa and Joshua (2023) (Table 1). Since oral ingestion and dermal contact are the main exposure pathways of nitrate, Chronic Daily Intake (Ingestion and Dermal) ($CDI_{ing.}$ and $CDI_{der.}$) values for the studied groundwater samples were calculated in this study (Table 2).

Table 2. Calculation of $CDI_{ing.}$, $CDI_{der.}$, HQ and HI values, and potential health risk assessment (USEPA, 2004; Muhammad et al., 2011; USEPA, 2014; Zhang et al., 2020; Habesoglu & Atici, 2022; IRIS, 2023; Kusa & Joshua, 2023).

$CDI_{ing.} = (C_{nitrate}$ x IR x EFq x EDr/(BWt x AvT)			
$CDI_{der.}$ = (AD x Evf x SSA x EFq x EDr)/(BWt x AvT)			
$AbsD = K_p$ x $^*C_{nitrate}$ x t_{event}		$^*C_{nitrate}$ (mg cm^{-3})	
$HQ_{ing.} = CDI_{ing.}/RefD_{ing.}$			
$HQ_{der.} = CDI_{der.}/RefD_{der.}$			
$HI = HQ_{der.} + HQ_{ing.}$			
		ADULT	CHILD
IR (L day^{-1})	Intake rate	2.5	0.78
EFq (day y^{-1})	Exposure Frequency	350	350
EDr (y)	Exposure Duration	26	6
BWt (kg)	Body Weight	80	15
SSA (cm^2)	Skin Surface Area	19652	6365
AvT (day)	Averaging Time (ED*365)	9490	2190
Evf (day)	Event Frequency	1	1
K_p (cm h^{-1})	Dermal permeability coefficient for water	0.001	0.001
t_{event} (h day^{-1})	Event Duration	0.58	1
$RefD_{ing.}$	Reference Dose for Ingestion (mg kg^{-1} day^{-1})	1.6	
$RefD_{der.}$	Reference Dose for Dermal (mg kg^{-1} day^{-1})	1.6	
$C_{Nitrate}$	Nitrate Concentration (mg L^{-1})		
CDI_{ing}.	Chronic Daily Intake for Ingestion (mg kg^{-1} day^{-1})		
CDI_{der}.	Chronic Daily Intake for Dermal (mg kg^{-1} day^{-1})		
AbsD	Absorbed Dose (mg cm^{-2} day^{-1})		
$HQ_{der.}$	Hazard Quotient for Dermal		
$HQ_{ing.}$	Hazard Quotient for Ingestion		
HI	Hazard Index		

Chronic Health Risk Classification			
HI<0.1	Negligible	4>HI≥1	Medium
1>HI≥0.1	Low	HI≥4	High/Severe
HQ<1	Safe for human health		

3. Results and Discussion

Previous studies performed in the groundwater of Mersin Province showed that nitrate concentrations displayed drastic spatial and temporal variations (Table 3). Groundwater nitrate concentrations varied from 0.03 mg L^{-1} in Anamur region to 950.8 mg L^{-1} in the region between Tarsus and Karaduvar. Maximum groundwater nitrate concentrations were consistently measured in between Tarsus and Karaduvar regions in 2020 (Table 3). Intensive irrigation in agriculture, rapid urbanization and the terrestrial inputs from the domestic wastewater and industrial discharges have led to nitrate pollution in surface waters and groundwater in Mersin Province (Özbay et al., 2012; Akçay et al., 2022; Akçay, 2023; Akçay et al., 2023; Erşahin & Bilgili, 2023; Türkeri et al., 2023). Study findings indicated that highest concentrations were consistently measured in the regions where human-induced pressures are very intense (Güler et al., 2012; Erşahin & Bilgili, 2023). According to WHO, the upper nitrate concentration limit is 50 mg L^{-1} for drinking waters (WHO, 2017). Findings of this study showed that the mean groundwater nitrate concentrations measured in the Mersin Province between 2001 and 2022 ranged from 22.9 to 210.4 mg L^{-1} and the mean nitrate concentrations in contaminated groundwater samples in Tarsus, Karaduvar, and Çeşmeli regions were much greater than the upper limit value of drinking water strongly suggested that groundwater in Mersin Province may pose significant health hazards for people (Table 3).

Table 3. Concentrations of nitrate (mg L^{-1}) in the groundwater of Mersin Province.

Region	Tarsus-Karaduvar	Tarsus-Karaduvar	Karaduvar	Karaduvar-Çeşmeli	Erdemli	Göksu	Anamur
Min.	1.77	4.87	13.73	17.91	0.12	3.54	0.03
Max.	890.59	950.81	715.57	561.43	40.27	141.23	45.62
Mean	-	210.4	147.3	205.7	27.1	34.3	22.9
Median	49.16	117.36	-	196.38	29.11	29.41	30.33
N	193	87	43	45	12	91	10
Reference	Güler et al. (2012)	Güven et al. (2022)	Güler (2009)	Hatipoğlu and Bayarı (2005)	Kuyumcu (2023)	Demirel et al. (2011)	Kuyumcu (2023)

The HQ value that is higher than 1 indicates that water contaminants may have non-carcinogenic effects whilst a calculated HQ, lower than 1, shows health effects on human health is very small (Zhang et al., 2021). By using the minimum, maximum and mean groundwater nitrate concentrations, potential health risk assessment was determined by the calculation of CDI, HQ and HI values for the adults and children, presented in Table 4 and Figure 2. It was shown that though the $HQ_{der.}$ values were less than 1, considered safe for human health (Muhammad et al., 2011; Habesoglu & Atici, 2022), $HQ_{ing.}$ values were much greater than the calculated $HQ_{der.}$ values indicating that the oral ingestion are the main exposure pathways of nitrate (Figure 2). Study findings indicated that the HQ values calculated for the children ($HQ_{ing.}$:0.001-29.63, $HQ_{der.}$:0.000-0.242) consistently greater than those calculated for the adults ($HQ_{ing.}$:0.001-17.81, $HQ_{der.}$:0.000-0.081). The study results showed the health risk due to excessive intake of nitrate contaminated groundwater for the children were higher than those for the adults, suggesting a greater health risk for the children in the Mersin province as also experienced by the previous studies performed in groundwater of different regions in the World (Wu & Sun, 2016; Zhang et al., 2020; Pazhuparambil Jayarajan & Kuriachan, 2021).

The HI values, calculated by the sum of $HQ_{ing.}$ and $HQ_{der.}$ values, in the groundwater of Erdemli, Göksu, and Anamur regions suggested low chronic health risk for the children and adults (HI≤1). The calculated HI values showed significant health hazards in the study region. The mean HI values for the children varied between 0.001 and 29.87 whilst the HI values for the adults ranged from 0.001 to 17.89 for the study region with the maximum values calculated for the region between Tarsus and Çeşmeli. Health risk assessment based on the calculated HI values also showed that some calculated HI values in the groundwater of Tarsus, Karaduvar, and Çeşmeli were greater than 4.00 suggesting "High/Severe" health risk for the adults and children (Figure 2). It was reported by the study of Güler et al. (2012) that Tarsus coastal plain was highly contaminated by the terrestrial discharges originated from anthropogenic activities as industrial and agricultural wastewater inputs. Study findings indicated that the highest groundwater nitrate concentrations were consistently measured in these regions due to the anthropogenic pressures caused to nitrate contamination that would lead to potential health hazards for the people that use groundwater of these nitrate contaminated regions (Table 1, Figure 2).

Table 4. The calculated CDI, HQ and HI values for the adults and children in the groundwater of Mersin Province.

		Tarsus-Karaduvar (2012)	**Tarsus-Karaduvar (2022)**	**Karaduvar**	**Karaduvar-Çeşmeli**	**Erdemli**	**Göksu**	**Anamur**
ADULT	**$CDI_{ing.}$**	1.4730	6.3035	4.4125	6.1639	0.8118	1.0293	0.6866
	$CDI_{der.}$	0.0067	0.0287	0.0201	0.0281	0.0037	0.0047	0.0031
	$HQ_{ing.}$	0.9206	3.9397	2.7578	3.8524	0.5074	0.6433	0.4291
	$HQ_{der.}$	0.0042	0.0180	0.0126	0.0176	0.0023	0.0029	0.0020
	HI	0.9248	3.9577	2.7704	3.8700	0.5097	0.6462	0.4311
CHILD	**$CDI_{ing.}$**	2.4511	10.4890	7.3423	10.2567	1.3508	1.7127	1.1425
	$CDI_{der.}$	0.0200	0.0856	0.0599	0.0837	0.0110	0.0140	0.0093
	$HQ_{ing.}$	1.5320	6.5557	4.5890	6.4104	0.8442	1.0704	0.7140
	$HQ_{der.}$	0.0125	0.0535	0.0374	0.0523	0.0069	0.0087	0.0058
	HI	1.5445	6.6091	4.6264	6.4627	0.8511	1.0792	0.7199

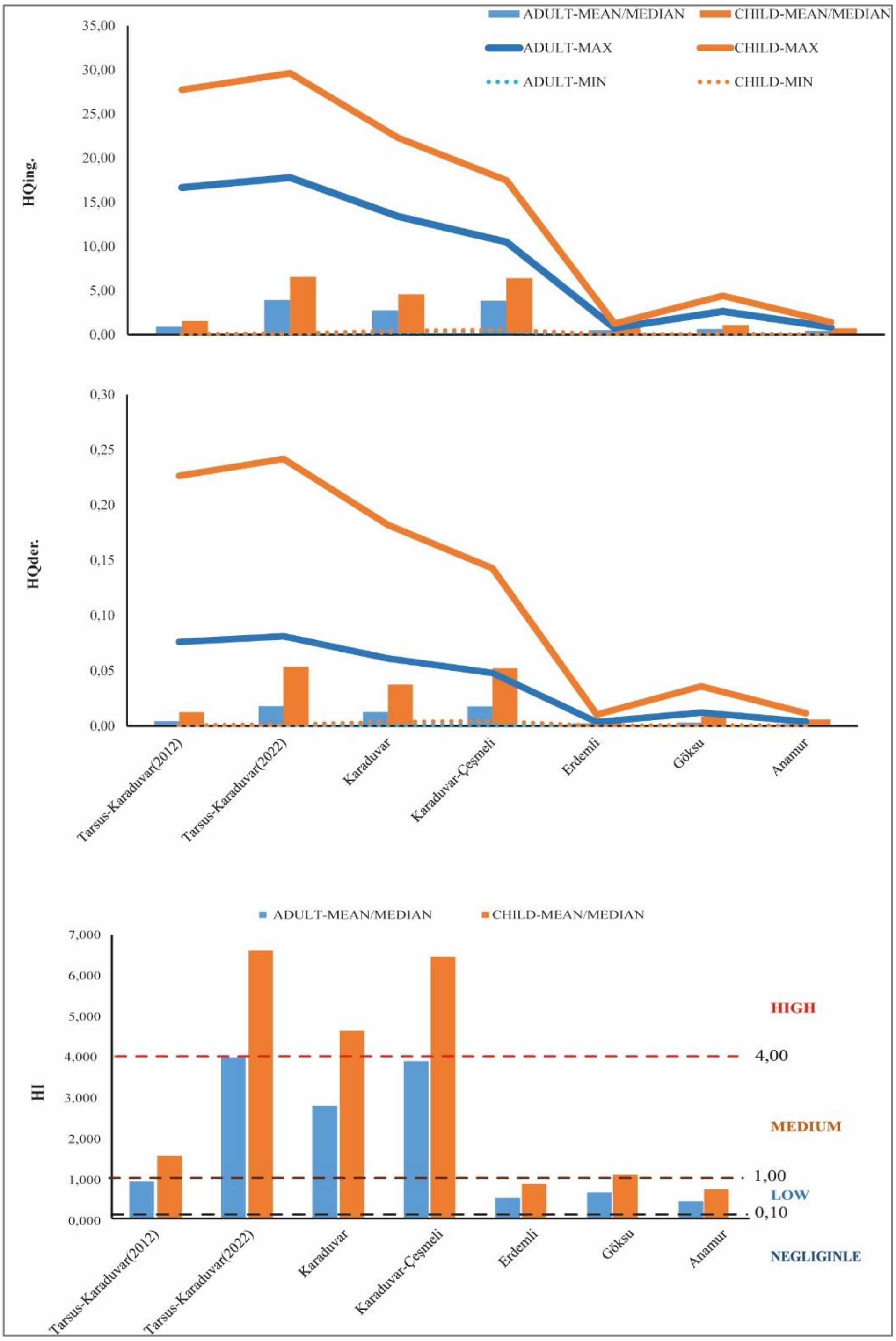

Figure 2. Health risk assessment of groundwater for nitrate in Mersin Province based on $HQ_{ing.}$, $HQ_{der.}$ and HI values calculated for the children and adults.

Anthropogenic perturbations such as the increase in population and hence domestic sewage, and the excess use of chemical fertilizer in the agriculture highly enhances nitrate pollution in the groundwater that can cause to health risks for people who use groundwater for consumption (Güler et al., 2012; Li et al., 2012; Wu et al., 2012; Wu & Sun, 2016; Adimalla, 2020; Erşahin & Bilgili, 2023). Previous studies performed in the groundwater in Mersin Province showed an apparent nitrate pollution due to intensive irrigation in agriculture and industrial activities as well as rapid urbanization in Mersin Province have led to nitrate pollution in groundwater in Mersin Province (Erşahin & Bilgili, 2023). In a recent study performed by Moeini and Azhdarpoor (2021), a sensitivity analysis was carried out to determine the most effective parameter in health risk assessment and it was shown that decreasing the nitrate concentrations can reduce the level of health risk for nitrate contamination by the reduction of HQ values for all age groups. The high levels of nitrate pollution in the groundwater of economically important Mersin Province pose to significant health hazards for the adults and children (Figure 2, Table 4), that should be reduced for the low possibility of adverse health effects for the people living in the region.

4. Conclusion

In this study, potential health risk assessment for nitrate pollution in groundwater of Mersin Province was determined. The study findings showed that nitrate concentrations ranged between 0.03 and 950.8 mg L^{-1} with the maximum values greater than the upper limit of 50 mg L^{-1} for drinking waters set by WHO recorded in the groundwater of the Tarsus, Karaduvar, and Çeşmeli regions. Health risk assessment showed that the mean HI values for the children varied between 0.001 and 29.87 whilst the HI values for the adults ranged from 0.001 to 17.89 for the study region with the maximum values calculated for the region between Tarsus and Çeşmeli. The low HI values (HI≤1) in the groundwater of Erdemli, Göksu, and Anamur regions suggested low chronic health risk for the children and adults. However, the calculated HI values in the groundwater of Tarsus, Karaduvar, and Çeşmeli regions were greater than 4.00 suggesting "High/Severe" health risk for the adults and children (Figure 2). The health risk assessment showed that the calculated HQ and HI values for the children consistently higher than the calculated HQ values for the adults, strongly suggesting that children were potentially at higher risk for health hazards from nitrate. The findings of this study indicated the sustainable management of groundwater policies for the reduction of nitrate pollution in the groundwater supplies is needed to reduce potential health hazards of the groundwater of studied and other regions in Türkiye.

Conflict of Interest

The author declares that he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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