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Health Risk Assessment of Heavy Metals in Ground and Tap Water of Chamchamal City - Sulaymaniyah Governorate / Kurdistan Region, Iraq

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ABSTRACT

This study focused to determine the heavy metals (i.e. arsenic, copper, chromium, cadmium, cobalt, iron, manganese, molybdenum, nickel, lead and zinc) content in ground and tap water, and their health impacts in Chamchamal city, Sulaymaniyah Governorate, north-eastern Iraq. Twenty five samples were collected (i.e. thirteen groundwater and twelve tap water samples). The inductively coupled plasma mass spectrometry technology (ICP-MS), was used to measure the contents of those metals. The Heavy metal Pollution Index (HPI) values of some ground and tap waters in the northern part of the study area are moderately polluted. Whereas, far north east of the studied area registered (highly polluted) with heavy metals which could be related to the industrial activities and filtration of these heavy metals from soil to water. Moreover, this study shows that there is no carcinogenic health risk of heavy metals in the studied area. The hazard index (HI) values of the ground and tap water samples in Chamchamal city appears to be less than one for all heavy metals in adults and children. The carcinogenic risk (CR) for arsenic, chromium and lead within the ground and the tap water are within the acceptable range for both adults and children.

1. Introduction

Groundwater does not exist in pure form because it contains particulate matter, dissolved, colloidal and different concentrations. This determines its quality and uses due to the variation in its components in comparison to the surface water. The reasons for this variation could be due to the solvability of the mineral components within hosted rocks and to the interactions process that effect groundwater during the hydrological cycle. This have critical role in changing the chemical and physical properties and the ground water content of ions and heavy metals [1, 2, 3, 4]

Groundwater pollution over time causes problems for countries where groundwater is the main consumption source. Landfill areas is one of the heavy metal's major contamination sources into groundwater [5]. Heavy metals accumulation in groundwater may directly affect humans and the ecosystem, such as presence of zinc and copper elements are necessary for organism's metabolism, while other elements such as cadmium and lead are very toxic even at low levels [6]. The metal index (MI) for the groundwater and tap water in the study

area ranged (0.60 – 7.96) and (0.96-6.77) respectively and assigned strongly to seriously affected range. While the pollution load index (PLI) of soil in the study area ranged between (0.93-1.45) and illustrate a contamination affinity [7]. The groundwater is the main consumption and irrigation source in Chamchamal city. There is no previous study assessing the heavy metals contents within the groundwater and tap water within Chamchamal city. This study is focusing to evaluate the heavy metals content within the study area and assess their health hazards.

1.1 Study area

The study area is located within Chamchamal city in the northeast of Iraq, 47 km north-east Kirkuk Governorate and 65 km south-west Sulaymaniyah Governorate Figure (1). Stratigraphy of the studied reservoir composed mainly from Miocene to Pleistocene (Quaternary) clastic and non-clastic rock units (e.g. siltstone, clay, sandstone, gypsum and carbonate). Mid-Upper Miocene formations are Fatah, Injana, Muqdadiya and Bai-Hassan Formations. While the recent Quaternary deposits

compose of fluvatile, flood plain and fluvial valley deposits [8]. Geomorphology of the studied area is simple and composed mainly of plains, valleys such as Shiwasoor Valley and Zhalla Valley. In addition to ridges and drainage patterns [9]. While from the north the studied area is surrounded by high mountains

which illustrate foot hills features as well as anticlines and synclines which are in northwest –southeast trending [10]. From tectonic view point, the study area is located in the unstable shelf within Chamchamal-Arbil Subzone [11].

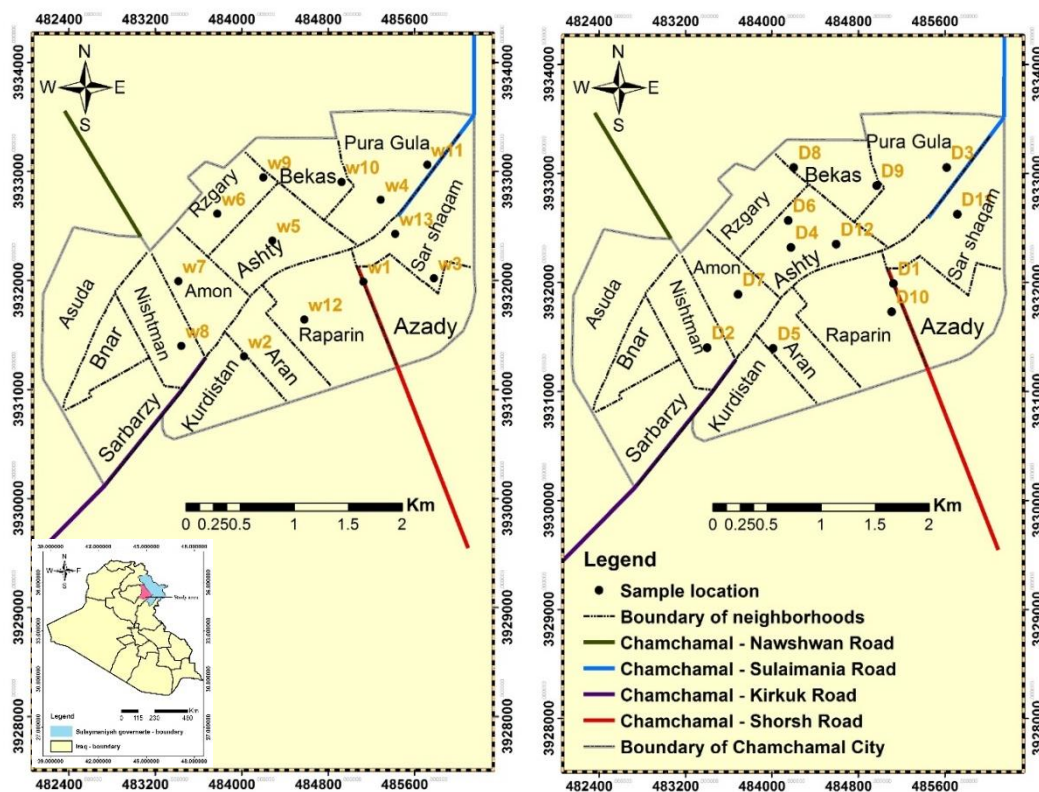


Fig. 1: Sample location map (a) groundwater (b) tap water samples.

2. Methodology

2.1 Sample collection

Thirteen representative well samples were collected from the study area covered the residential areas and symbolized by (W) and ranged in depths (65-195m). Another 12 tap water samples were collected from house tanks and some mosques inside the study area and symbolized (D). In addition, one sample (i.e. D12) represents the tap water from the main reservoir in Chamchamal water department, through which tap water is distributed to most districts of the study area. The collection of samples took place early of October 2017.

2.2 Laboratory work

After collecting the samples, the samples were filtered using a 0.45 μm filter paper. The samples were then placed in polyethylene bottles with a capacity of 50ml. After washing with distilled water, then with the sample water, samples were acidified with concentrated HNO_3 . The pipette used to acidify

the sample to reaches pH <2 to prevent bacterial growth and prevent any changes in the sample specific properties. Then the bottle is sealed tightly to avoid any air contamination [12]. Heavy metals contents were measured using ICP-MS (Elmer Elam, Perkin 6000) in Acme Laboratories Inc. Vancouver, Canada.

2.3 Uncertainty Measurement of the Chemical Analysis

Uncertainty level is recorded with each measurement regardless of their accuracy and precision. Those uncertainty levels are linked to the systematic and random errors using standards experiment techniques. In this study the measured trueness of the data is under 5% which is acceptable and it is useful for geochemical interpretations.

3. Results and discussion

3.1 Heavy metals contents

Heavy metals content within the studied ground and tap water samples are shown in Table (1).

Table 1: Heavy metals concentration of the studied samples compared to the standards values of the World Health Organization [13] and Iraqi standards [14]

Sample No	As (µg/L)	Cr (µg/L)	Cu (µg/L)	Fe (µg/L)	Mn (µg/L)	Mo (µg/L)	Ni (µg/L)	Pb (µg/L)	Zn (µg/L)
W1	0.7	4.3	0.7	122	1.28	1.3	<0.2	0.5	12.7
W2	0.5	4	1	298	1.22	1.3	<0.2	0.4	45.5
W3	0.7	4.3	1.5	491	2.52	1.4	<0.2	0.3	9.6
W4	2.3	3.3	3.2	58	1.8	2.7	<0.2	0.3	16.3
W5	0.9	2.9	2.5	190	3.32	1.4	<0.2	0.2	24.6
W6	< 0.5	2.3	1.7	966	6.87	1.4	<0.2	0.3	21.9
W7	0.6	3.9	2.4	922	3.63	1.3	<0.2	0.3	39.9
W8	0.9	4.9	1.7	233	1.75	1.7	<0.2	0.5	35.8
W9	0.7	2.6	1.6	36	1.23	2.2	<0.2	0.4	48.1
W10	1.1	7.8	1.8	139	1.64	1.9	0.3	0.3	16
W11	7	2.3	7	117	323.23	8.9	4.8	0.4	22.4
W12	1	3	33.3	199	17.81	1	1.1	0.9	24.2
W13	1	3.2	8.8	171	8.22	1.3	0.2	0.5	17.5
Rang	< 0.5-7	2.3-7.8	0.7-33.3	36-966	1.22 -323.23	1-8.9	<0.2-4.8	0.2-0.9	9.6-48.1
Average	1.33	3.75	5.16	303.23	28.80	2.13	1.6	0.40	25.73
D1	0.6	3.5	2.2	1123	6.6	1.4	0.4	1.3	109.9
D2	1.3	2.5	1.3	299	6.29	0.9	0.7	0.3	87.1
D3	1.3	2.2	0.7	556	3.09	0.9	0.7	0.3	265.6
D4	1.3	3.1	0.9	122	1.41	0.9	0.9	0.5	261.3
D5	1.3	2.5	0.6	103	1.2	0.7	0.3	0.4	239.4
D6	1	3.3	0.9	629	5.81	1	0.5	0.5	350.3
D7	1.1	3.1	1.5	136	3.2	0.8	1.9	0.6	305.5
D8	1	3.1	2	63	1.11	0.8	0.8	0.7	217.1
D9	0.5	5.3	0.8	529	2.27	1.3	<0.2	0.3	116.9
D10	1.4	3.8	7.5	134	10.66	0.9	1	1.5	98.6
D11	1.6	2.8	9.1	108	22.81	0.9	1.1	0.5	33.8
D12	1.7	3.1	8.6	183	21.39	1.1	1.3	1.1	10
Rang	0.5-1.7	2.2-5.3	0.6-9.1	63-1123	1.11-22.81	0.7-1.4	<0.2-1.9	0.3-1.5	10-350.3
Average	1.17	3.19	3.00	332.08	7.15	0.96	0.87	0.66	174.62
WHO,2017	10	50	2000	300	100	6	70	10	3000
IQS/417	10	50	1000	300	100	-	20	10	3000

Nickel high concentration within some groundwater samples are linked mainly to the industrial activities and industrial work zone (i.e. influence of car mechanics and battery recycling), which reflect the industrial and anthropological activities effects on nickel concentration. On the other hand, the spatial distribution of nickel concentration is similar to that of arsenic, manganese and molybdenum concentration in the study area which suggest similar reservoir rocks. The increase in iron concentration in tap water in the studied area could be related to corrosion in water pipes and tanks. While the obvious increase in zinc concentration in tap water than ground water is related to the numerous water sources that provided to the city (e.g. wells outside the study area and Dokan Lake). Zinc concentration in groundwater sourced mainly by the corrosion of well casing and the influence of industrial activities as well as sewage water contamination and agricultural fertilizers.

3.2. Assessment of heavy metals pollution.

Generally, water (particularly groundwater) known to be closely associated with human activities and urban development [15]. Groundwater pollution assessment methods are effective ways to protect water resources from environmental pollution, using different methods including statistical and environmental pollution indicators which represent key determining factors of water quality [16].

3.2.1 Heavy metal pollution index (HPI)

This factor explains and assesses heavy metals content and the contamination degree in water, with a critical value of 100 [17, 18, 19]. These coefficients are calculated in three steps: first calculate the (Wi), which represents the relative weight of each element i as in equation (1). Secondly calculate the quality sub index (Qi) for each element as in equation (2), thirdly, summing the subsidiary-coefficients Qi for all elements i. Then HPI calculated using equation (3) and as suggested by [17].

$$Wi = \frac{1}{Si} \dots (1)$$

$$Qi = \sum_{i=1}^n \left(\frac{Mi - Ii}{Si - Ii} \right) * 100 \dots (2)$$

$$HPI = \frac{\sum_{i=1}^n Wi Qi}{\sum_{i=1}^n Wi} \dots (3)$$

Wi = the relative weight of the element coefficient i and is between (0-1), Si = the maximum allowable i element that is used by the world health organization (WHO, 2017) scale unit in (µg/L), n the number of elements used, Qi = sub index for elements i, M = the monitored value (the analysed value) of the studied elements as shown in Table (2). Ii refers to the ideal value of the elements and is equal to zero for the studied elements according to [20]. The (-) sign indicates the numerical difference between two values. HPI was applied to the elements studied in ppb and their concentrations as shown in Table (3).

Table 2: The standards values of (Si), weight of metals (Wi) used in calculation of (HPI)

Metals	Si = (WHO, 2017)	Wi = 1/Si
As	10	0.1
Cr	50	0.02
Cu	2000	0.0005
Fe	300	0.0033
Mn	100	0.01
Mo	6	0.166
Ni	70	0.0142
Pb	10	0.1
Zn	3000	0.00033
Total		Σ 0.4243
Ground water = 0.035 - 323.23 Range Q_i [		
Tap water = 0.035 - 374.33		
Ground water = 5.001 -35.57 Range ΣWiQ_i [		
Tap water = 3.87 - 7.22		

Table 3: Shows HPI classification for water pollution level according to [21, 22]

HPI	Pollution index
< 15	Low heavy metal pollution
15-30	Heavy metal pollution on the threshold risk (Medium Pollution)
> 30	High heavy metal pollution

The studies samples proved that they did not reaches the critical value for HPI values. In comparison to the [22] HPI value, W11 register highly pollutant, the studied groundwater samples (i.e. W4, W8, W9 and W10) were medium pollutant and the other samples were low pollutant (Table 4 and Figure 2).

Table 4: Presents the (HPI) values of studied water samples

Heavy Metal Pollution Index (HPI)			
Sample No	HPI	Sample No	HPI
W1	12.357	D1	17.436
W2	12.071	D2	11.095
W3	13.522	D3	11.676
W4	24.832	D4	11.063
W5	12.877	D5	9.342
W6	14.243	D6	12.461
W7	13.776	D7	10.284
W8	15.874	D8	9.983
W9	17.734	D9	12.596
W10	17.244	D10	14.041
W11	85.864	D11	12.241
W12	13.053	D12	15.469
W13	13.274	Low pollution, Medium pollution, High pollution	

For tap water all samples HPI values were in the low pollutant zone except two samples (i.e. D1 and D12) they were medium pollutant according to [22] classification. This indicates that heavy metals mobility could be linked to the water transform [23] in addition to infiltration of these elements from soil to water. Moreover, petroleum exploration and the Chamchamal gas well existence could contribute into the water pollution in the study area as it is mention by [24] and [25]. They mention that gas production in an area influence the ground water quality especially the emission or the outburst gas which could filtrate throughout fractures into groundwater system [26, 27]. And thus, higher HPI values could refer to industrial activities in addition to those natural processes [22].

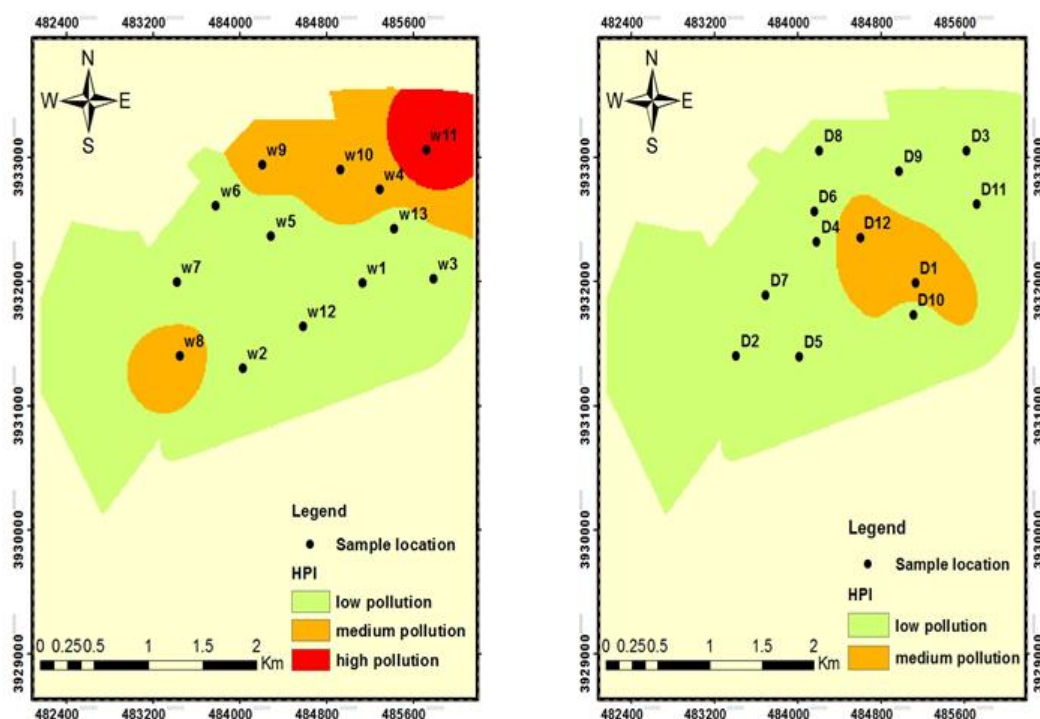


Fig. 2: Shows the calculated Heavy Metal Pollution Index (HPI) map in (a) groundwater and (b) tap water samples.

3.3 Health risk assessment of heavy metals.

Heavy metal hazard evaluation in water is vital to constrain their health impacts on human being which humans exposed through environmental pollutants in present and future [28, 29]. Therefore, general water quality assessment and tap water particularly is critical because of varied heavy metals composition in different water types [30] Thus, several factors (i.e. Table 5) were used to assess heavy elements health hazards of the studied of groundwater and tap water as follows:

3.3.1 Chronic Daily Intake (CDI)

The heavy metals chronic daily dose in water is estimated by the two pathways, ingestion and dermal [31, 32].

$$CDI_{\text{ingestions}} = C_{\text{Water}} (IR_{\text{ingestions}} * EF * ED / BW * AT) * 10^{-3} \dots (4)$$

$$CDI_{\text{dermal}} = C_{\text{Water}} (SA * K_p * ET * EF * ED / BW * AT) * 10^{-6} \dots (5)$$

The evaluation of the daily non-carcinogenic exposure of heavy metals in the studied groundwater and tap water shows that the level of exposure through ingestion was more influential on the health of the local population for both adults and children as shown in Tables (6 and 7).

3.3.2 Hazard Quotient (HQ) and Hazard Index (HI)

Hazard Index (HI) used to assess the probable non-carcinogenic effects of heavy metals. (HI) represents the sum of the hazard quotient (HQ) for both pathways if the value of HQ and HI exceeds one, then it indicates the non-carcinogenic effects of elements subtracted from the two main pathways (ingestion and dermal contact), which may cause adverse effects on human health [33, 34, 35]. HQ for both tracks (ingestion and dermal contact) is calculated by equations (6) and (7) and HI is calculated according to equation (8):

$$HQ_{\text{ing}} = CDI_{\text{ing}} / RfD_{\text{ing}} \dots\dots (6)$$

$$HQ_{\text{dermal}} = CDI_{\text{dermal}} / RfD_{\text{dermal}} \dots\dots (7)$$

$$HI = \sum HQ = HQ_{\text{ing}} + HQ_{\text{dermal}} = (CDI_{\text{ing-nc}} / RfD_{\text{ing}} + CDI_{\text{dermal-nc}} / RfD_{\text{dermal}}) \dots\dots (8)$$

Since (HQ_{ing}) is the hazard product of the ingestion pathway, (HQ_{dermal}) is the hazard product of the dermal contact pathway, (CDI_{ing-nc}) is the chronic daily dose of non-carcinogenic ingestion and (RfD_{ing}) is the oral reference dose, which is measured in (mg/kg.day) unit. (CDI_{dermal-nc}) is the chronic daily absorption dose by non-carcinogenic dermal contact and (RfD_{dermal}) is the reference dermal dose which is measured in (mg / kg.day) unit [36, 33] Furthermore, risk factor (HQ) values in groundwater and tap water (i.e. Tables 6 & 7) indicate that risk are mainly through out ingestion (HQ_{ing}) and dermal (HQ_{dermal}) pathways.

Table 5: Illustrates the used variables in assessing the health hazards in studied water samples for children and adults depending on [37, 38, 39]

Symbol	Unit	Adult	Children
Concentration of element (C _{Water})	(µg/L)	–	–
average daily intake of heavy metals ingested from water (CDI _{ingestions})	mg/kg.day	–	–
exposure dose via dermal contact (CDI _{dermal})	mg/kg.day	–	–
Ingestion Rate (IR _{ingestions})	l/day	2	1
Body weight (BW)	kg	70	15
Skin area available for soil contact (SA)	cm ²	18000	6600
Exposure Time (ET)	h/day	0.58	1
Exposure frequency (EF)	days/year	350	350
Exposure duration (ED)	years	30	6
Average time (AT) - Non-Carcinogenic Average time (AT) – Carcinogenic	days	ED * 365 70 * 365	
Dermal Permeability Coefficient (Kp)	cm/h	(1*10 ⁻³) for (As, Cu, Fe, Mn, Mo), Cr (2*10 ⁻³), Ni (2*10 ⁻⁴), Pb (1*10 ⁻⁴), Zn (6*10 ⁻⁴)	

Table 6: Show the chronic daily intake (CDI), hazard quotient (HQ) and hazard index (HI) values for the main paths of groundwater in the study area.

	G.W		Ingestion			Dermal			HI= Σ HQ
Metals	Avg	Age	CDI _{ing}	RfD _{ing}	HQ _{ing}	CDI _{dermal}	RfD _{dermal}	HQ _{dermal}	
As	1.45	Adult	3.97×10^{-5}	3×10^{-4}	0.132	2.07×10^{-7}	3×10^{-4}	6.90×10^{-4}	0.132
		Child	9.26×10^{-5}	3×10^{-4}	0.30	6.11×10^{-7}	3×10^{-4}	2.03×10^{-3}	0.302
Cu	5.16	Adult	1.41×10^{-4}	4×10^{-2}	3.53×10^{-3}	7.37×10^{-7}	4×10^{-2}	1.84×10^{-5}	3.54×10^{-3}
		Child	3.29×10^{-4}	4×10^{-2}	8.24×10^{-3}	2.17×10^{-6}	4×10^{-2}	5.42×10^{-5}	8.29×10^{-3}
Cr	3.75	Adult	1.02×10^{-4}	3×10^{-3}	0.034	1.07×10^{-6}	7.5×10^{-5}	0.014	0.048
		Child	2.39×10^{-4}	3×10^{-3}	0.079	3.16×10^{-6}	7.5×10^{-5}	0.042	0.121
Fe	303.23	Adult	8.30×10^{-3}	0.3	0.027	4.33×10^{-5}	0.14	3.09×10^{-4}	0.057
		Child	0.019	0.3	0.064	1.27×10^{-4}	0.14	9.07×10^{-4}	0.064
Mn	28.80	Adult	7.88×10^{-4}	0.14	5.63×10^{-3}	4.11×10^{-6}	1.83×10^{-3}	2.24×10^{-3}	7.87×10^{-3}
		Child	1.84×10^{-3}	0.14	0.013	1.21×10^{-5}	1.83×10^{-3}	6.61×10^{-3}	0.019
Mo	2.13	Adult	5.83×10^{-5}	5×10^{-3}	0.011	3.04×10^{-7}	1.9×10^{-3}	1.6×10^{-4}	0.011
		Child	1.36×10^{-4}	5×10^{-3}	0.027	8.96×10^{-7}	1.9×10^{-3}	4.71×10^{-4}	0.027
Ni	1.6	Adult	4.38×10^{-5}	2×10^{-2}	2.19×10^{-3}	4.57×10^{-8}	8×10^{-4}	5.71×10^{-5}	2.24×10^{-3}
		Child	1.02×10^{-4}	2×10^{-2}	5.11×10^{-3}	1.35×10^{-7}	8×10^{-4}	1.68×10^{-4}	5.278×10^{-3}
Pb	0.40	Adult	1.09×10^{-5}	3.5×10^{-3}	3.12×10^{-3}	5.72×10^{-9}	3.5×10^{-3}	1.63×10^{-6}	3.121×10^{-3}
		Child	2.55×10^{-5}	3.5×10^{-3}	7.30×10^{-3}	1.68×10^{-8}	3.5×10^{-3}	4.82×10^{-6}	7.304×10^{-3}
Zn	25.73	Adult	7.04×10^{-4}	0.3	2.34×10^{-3}	2.20×10^{-6}	0.3	7.33×10^{-6}	2.347×10^{-3}
		Child	1.64×10^{-3}	0.3	5.48×10^{-3}	6.51×10^{-6}	0.3	2.17×10^{-5}	5.501×10^{-3}

This may indicate that heavy metals in the studied water samples does not pose a threat to the health of the local consumers. Moreover, as shown in Tables

(6) and (7), the values of the Health Index (HI) for groundwater and tap water in Chamchamal city are less than one for all studied elements.

Table 7: Illustrate the chronic daily intake (CDI), hazard quotient (HQ) and hazard index (HI) values for the main paths of tap water in the study area.

	T.W		Ingestion			Dermal			HI= Σ HQ
Metals	Avg	Age	CDI _{ing}	RfD _{ing}	HQ _{ing}	CDI _{dermal}	RfD _{dermal}	HQ _{dermal}	
As	1.17	Adult	3.21×10^{-5}	3×10^{-4}	0.107	1.67×10^{-7}	3×10^{-4}	5.56×10^{-4}	1.08×10^{-1}
		Child	7.51×10^{-5}	3×10^{-4}	0.250	4.92×10^{-7}	3×10^{-4}	1.64×10^{-3}	2.52×10^{-1}
Cu	3.00	Adult	8.21×10^{-5}	4×10^{-2}	2.05×10^{-3}	4.29×10^{-7}	4×10^{-2}	1.07×10^{-5}	2.06×10^{-3}
		Child	1.91×10^{-4}	4×10^{-2}	4.79×10^{-3}	1.26×10^{-6}	4×10^{-2}	3.15×10^{-5}	4.82×10^{-3}
Cr	3.19	Adult	8.73×10^{-5}	3×10^{-3}	0.029	9.12×10^{-7}	7.5×10^{-5}	0.012	4.10×10^{-2}
		Child	2.03×10^{-4}	3×10^{-3}	0.067	2.69×10^{-6}	7.5×10^{-5}	0.035	1.02×10^{-1}
Fe	332.08	Adult	9.09×10^{-3}	0.3	0.03	4.74×10^{-5}	0.14	3.38×10^{-4}	3.03×10^{-2}
		Child	0.021	0.3	0.070	1.39×10^{-4}	0.14	9.92×10^{-4}	7.10×10^{-2}
Mn	7.15	Adult	1.95×10^{-4}	0.14	1.39×10^{-3}	1.02×10^{-6}	1.83×10^{-3}	5.57×10^{-4}	1.95×10^{-3}
		Child	4.57×10^{-4}	0.14	3.26×10^{-3}	3.01×10^{-6}	1.83×10^{-3}	1.64×10^{-3}	4.90×10^{-3}
Mo	0.96	Adult	2.62×10^{-5}	5×10^{-3}	5.25×10^{-3}	1.37×10^{-7}	1.9×10^{-3}	7.21×10^{-5}	5.32×10^{-3}
		Child	6.13×10^{-5}	5×10^{-3}	0.020	4.04×10^{-7}	1.9×10^{-3}	2.12×10^{-4}	2.02×10^{-2}
Ni	0.87	Adult	2.38×10^{-5}	2×10^{-2}	1.19×10^{-3}	2.48×10^{-8}	8×10^{-4}	3.1×10^{-5}	1.22×10^{-3}
		Child	5.56×10^{-5}	2×10^{-2}	2.78×10^{-4}	7.34×10^{-8}	8×10^{-4}	9.17×10^{-5}	3.70×10^{-4}
Pb	0.66	Adult	1.80×10^{-5}	3.5×10^{-3}	5.16×10^{-3}	9.43×10^{-9}	3.5×10^{-3}	2.69×10^{-6}	5.16×10^{-3}
		Child	4.21×10^{-5}	3.5×10^{-3}	0.012	2.78×10^{-8}	3.5×10^{-3}	7.94×10^{-6}	1.20×10^{-2}
Zn	174.62	Adult	4.78×10^{-3}	0.3	0.015	1.49×10^{-5}	0.3	4.96×10^{-5}	1.50×10^{-2}
		Child	0.011	0.3	0.036	4.42×10^{-5}	0.3	1.47×10^{-4}	3.61×10^{-2}

3.3.3. Carcinogenic Risk Assessment (CR)

These coefficients express the heavy metals cancer risk in the water and estimate it by using equation (9) [40, 28].

$$\text{Cancer Risk} = \text{Risk}_{\text{ing}} + \text{Risk}_{\text{dermal}} = (\text{CDI}_{\text{ing}} * \text{SF}_{\text{ing}} + \text{CDI}_{\text{dermal}} * \text{SF}_{\text{dermal}}) \dots (9)$$

If the value of (CR) reach between ($1 \times 10^{-6} - 1 \times 10^{-4}$), it indicates the absence of heavy metals carcinogenic effects [41]. The carcinogenic risk of arsenic, chromium and lead was within the permissible limits in groundwater and tap water for adults and children in the study area as shown in Table (8).

Table 8: Illustrates the heavy metals carcinogenic risk assessment (CR) and slope factor (SF) values of the main paths for groundwater and tap water in the study area.

main paths for groundwater and tap water in the study area.													
Ground Water								Tap Water					
			Ingestion		Dermal		Risk		Ingestion		Dermal		Risk
Metals	Avg	Age	CDI _{ing}	SF _{ing}	CDI _{dermal}	SF _{dermal}		Avg	CDI _{ing}	SF _{ing}	CDI _{dermal}	SF _{dermal}	
			a	b	c	d			(a*b) + (c*d)	a	b	c	
As	1.45	Adult	1.70*10 ⁻⁵	1.5	8.87*10 ⁻⁸	1.5	2.56*10 ⁻⁵	1.17	1.37*10 ⁻⁵	1.5	7.16*10 ⁻⁸	1.5	2.06*10 ⁻⁵
		Child	7.94*10 ⁻⁶	1.5	5.46*10 ⁻⁸	1.5	1.19*10 ⁻⁵		6.43*10 ⁻⁶	1.5	4.41*10 ⁻⁸	1.5	9.70*10 ⁻⁶
Cr	3.75	Adult	4.40*10 ⁻⁵	0.5	3.57*10 ⁻⁷	20	2.91*10 ⁻⁵	3.19	3.74*10 ⁻⁵	0.5	3.89*10 ⁻⁷	20	2.64*10 ⁻⁵
		Child	2.05*10 ⁻⁵	0.5	2.82*10 ⁻⁷	20	1.58*10 ⁻⁵		1.74*10 ⁻⁵	0.5	2.40*10 ⁻⁷	20	1.35*10 ⁻⁵
Pb	0.40	Adult	4.69*10 ⁻⁶	8.5*10 ⁻³	2.44*10 ⁻⁹	8.5*10 ⁻³	3.98*10 ⁻⁸	0.66	7.74*10 ⁻⁶	8.5*10 ⁻³	4.03*10 ⁻⁹	8.5*10 ⁻³	6.57*10 ⁻⁸
		Child	2.19*10 ⁻⁶	8.5*10 ⁻³	1.50*10 ⁻⁹	8.5*10 ⁻³	1.87*10 ⁻⁶		3.61*10 ⁻⁶	8.5*10 ⁻³	2.48*10 ⁻⁹	8.5*10 ⁻³	3.06*10 ⁻⁸

4. Conclusions

The results of this study revealed that, the Heavy metal Pollution Index (HPI) values are within the acceptable level except for some samples. Despite that the results illustrate that the north- eastern side of the city (i.e. near the industrial active area) shows significant pollution level (high pollution). In

5. References

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addition, the Hazard Quotient values (i.e. HQ_{ing} and HQ_{dermal}) of the studied samples are less than one for adults and children. Furthermore, the Carcinogenic Risk Assessment (CR) values for arsenic, chromium and lead are within the acceptable range for both adults and children.

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تقييم المخاطر الصحية للعناصر الثقيلة في المياه الجوفية ومياه الحنفية لمدينة جمجمال/ السليمانية, اقليم كردستان, العراق

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الملخص

ركزت الدراسة الحالية على تعيين محتوى العناصر الثقيلة مثل (الزرنخ, النحاس, الكروم, الكاديوم, الكوبلت, الحديد, المنغنيز, الموليبيدوم, النيكل, الرصاص, الزنك) في المياه الجوفية والحنفية وتأثيراتها الصحية في مدينة جمجمال ضمن محافظة السليمانية شمال شرقي العراق. تم جمع (13) نموذجاً للمياه الجوفية و(12) نموذجاً لمياه الحنفية. تم استخدام تقنية بلازما مزدوجة الحث (ICP-MS) لقياس تراكيز العناصر الثقيلة. بينت قيم معامل تلوث العناصر الثقيلة (HPI) لبعض عينات المياه الجوفية ومياه الحنفية في شمال منطقة الدراسة بأنها كانت متوسطة التلوث, بينما بينت تلوثها عالي بالعناصر الثقيلة في أقصى الشمال الشرقي لمنطقة الدراسة وقد يعزى ذلك إلى النشاطات الصناعية وترشيح هذه العناصر الثقيلة من التربة إلى المياه. فضلاً عن ذلك, فإن الدراسة الحالية تظهر عدم وجود أي مخاطر مسرطنة بسبب تلوث العناصر الثقيلة ضمن منطقة الدراسة. إن مؤشر الخطر (HI) للمياه الجوفية والحنفية أقل من الواحد لجميع العناصر الثقيلة قيد الدراسة للبالغين والأطفال. وإن مقدار الخطر المسرطن (CR) لعناصر الزرنخ, الكروم والرصاص في المياه الجوفية والحنفية يقع ضمن المديات المسموح بها لكل من البالغين والأطفال في مدينة جمجمال.