Tikrit Journal of Pure Science Vol. 25 (5) 2020

TJPS

Tikrit Journal of Pure Science

ISSN: 1813 – 1662 (Print) --- E-ISSN: 2415 – 1726 (Online)

Journal Homepage: http://tjps.tu.edu.iq/index.php/j

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

Hassan A.A. Al-Jumaily , Omar A.M. Mohammad , Bushra R. Rasheed

Department of applied geology, college of science, Kirkuk university, Kirkuk, Iraq

https://doi.org/10.25130/tjps.v25i5.292

ARTICLE INFO.

Article history:

-Received: 12 / 12 / 2019

-Accepted: 4 / 7 / 2020

-Available online: / / 2020

Keywords: *Health Risk Assessment, Heavy metals, Hazard quotient, Carcinogenic risk*

Corresponding Author:

Name: Omar A.M. Mohammad

E-mail: omarm@uokirkuk.edu.iq

Tel:

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 tab 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 fluviatile, 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].

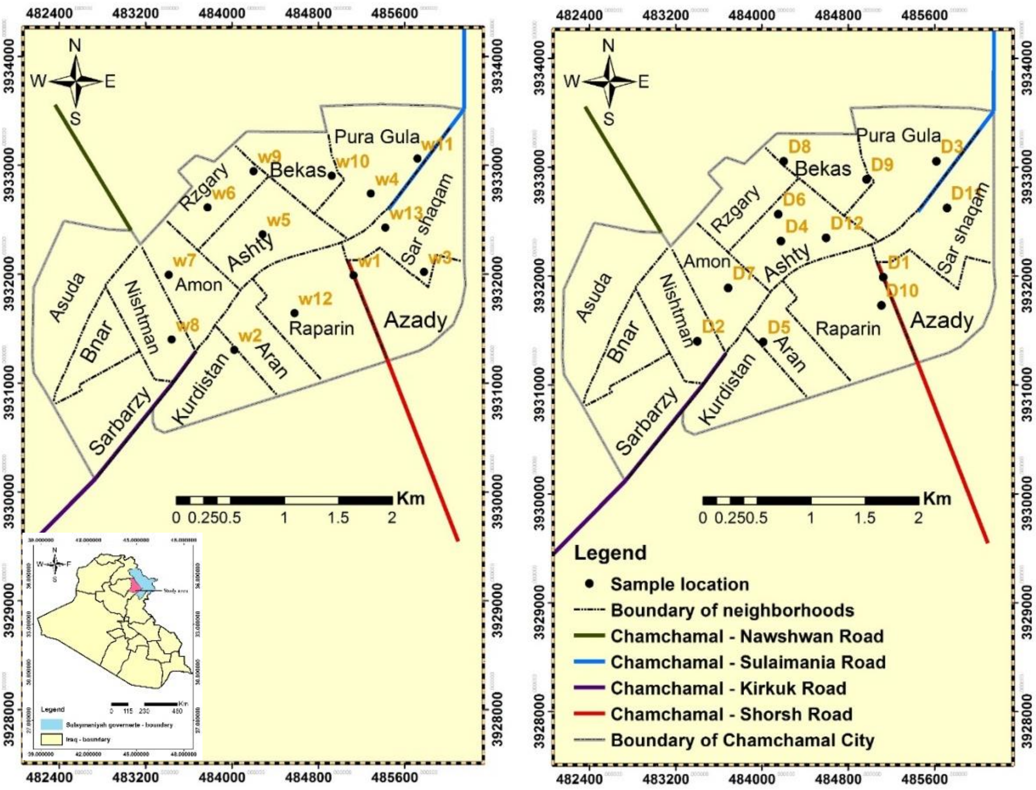

Fig. 1: Sample location map (a) groundwater (b) tap water samples.

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 HNO3. 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].

$$Wi = \frac{1}{Si} \quad \ldots..(1)$$

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

$$HPI = \frac{\sum_{i=1}^{n} Wi\,Qi}{\sum_{i=1}^{n} Wi} \quad \ldots.(3)$$

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		**∑ 0.4243**
Ground water = 0.035 - 323.23 Range Q_i [Tap water = 0.035 – 374.33		
Ground water = 5.001 -35.57 Range ∑ WiQi [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].

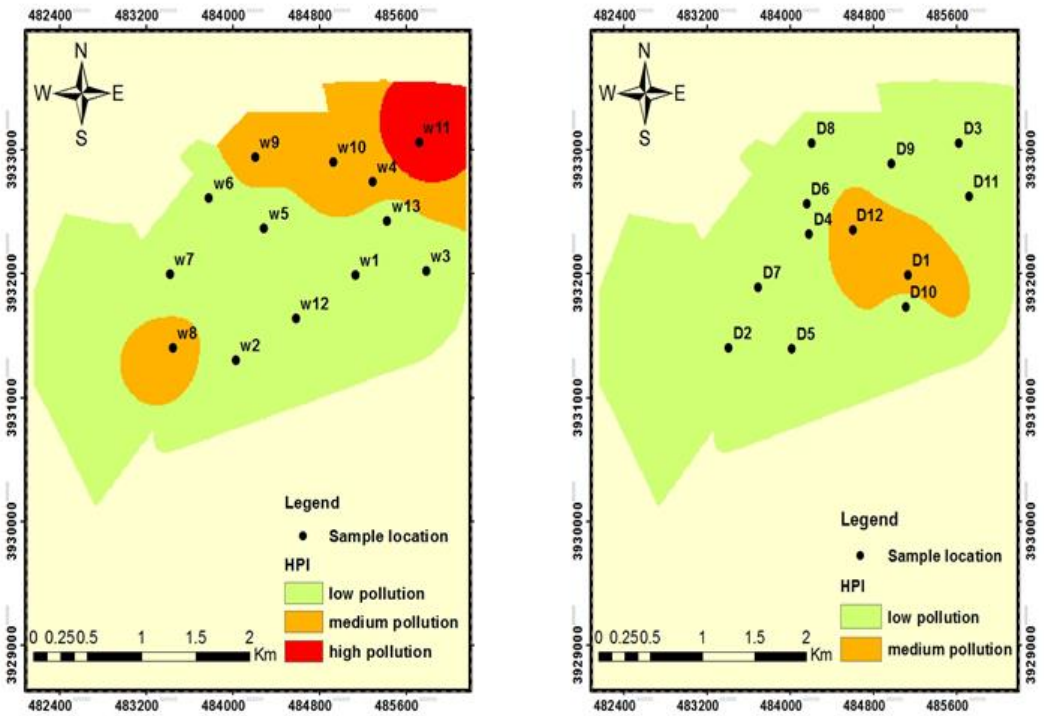

Fig. 2: Shows the calculated Heavy Metal Pollution Index (HPI) map in (a) groundwater and (b) tap water samples.

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].

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

$$\mathbf{CDI_{dermal} = C_{Water} (SA * K_P * ET * EF * ED / BW * AT) * 10^{-6}} \quad \ldots (5)$$

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):

$$\mathbf{HQ_{ing} = CDI_{ing} / RfD_{ing}} \quad \ldots\ldots (6)$$

$$\mathbf{HQ_{dermal} = CDI_{dermal} / RfD_{dermal}} \quad \ldots\ldots (7)$$

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

Since (HQing) is the hazard product of the ingestion pathway, (HQ dermal) is the hazard product of the dermal contact pathway, (CDIing-nc) is the chronic daily dose of non-carcinogenic ingestion and (RfDing) 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 (RfDdermal) 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 (HQing) and dermal (HQdermal) 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=∑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=∑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].

Cancer Risk = $Risk_{ing}$ + $Risk_{dermal}$ = (CDI_{ing}*SF_{ing} + CDI_{dermal}*SF_{dermal}) ….. (9)

If the value of (CR) reach between ($1*10^{-6}$ – $1*10^{-4}$), 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.

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	d	(a*b) + (c*d)
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	$2.19*10^{-6}$	$8.5*10^{-3}$	$1.50*10^{-9}$	$8.5*10^{-3}$	$1.87*10^{-6}$		$3.61*10^{-6}$	$8.5*10^{-3}$	$2.48*10^{-9}$	$8.5*10^{-3}$	$3.06*10^{-5}$

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 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.

5. References

[1] **Prasanna, M. V.; Praveena, S. M.; Chidambaram, S.; Nagarajan, R.; and Elayaraja, A. (2012):** Evaluation of water quality pollution indices for heavy metal contamination monitoring: A case study from Curtin Lake, Miri City, East Malaysia, *Environmental Earth Sciences, springer*, **67(7)**:1987–2001pp.

[2] **Barzegar, R.; Asghari, M. A.; and Kazemian, N. (2015):** Assessment of heavy metals concentrations with emphasis on arsenic in the Tabriz plain aquifers, *Iran. Environmental Earth Sciences*, **74(1)**: 297–313pp

[3] **Rezaei, A. and Hassani, H. (2017):** Hydrogeochemistry study and groundwater quality assessment in the north of Isfahan, *Iran. Environmental Geochemistry and Health*, **40(2)**:583-608pp

[4] **Mkadmi, Y. et al. (2018):** Study of the impact of heavy metals and physico-chemical parameters on the quality of the wells and waters of the Holcim area (Oriental region of Morocco). *Journal of Materials and Environmental Sciences*, **9(2)**: 672-679pp.

[5] **Lee, M.; Sung, P.; Insu, K.; Hyunmin, K.; and Sanghoon, L. (2007):** Remediation of heavy metal contaminated groundwater originated from abandoned mine using lime and calcium carbonate, *Journal of Hazardous Materials, Elsevier*, **114(1)**: 208-214pp.

[6] **Vanloon, G. W. and Duffy, S. J. (2005):** The Hydrosphere. In: Environmental Chemistry: A Global Perspective. 2nd Edition. New York: Oxford University Press, 197-211pp

[7] **Rasheed, B. R. (2019):** Environmental Geochemistry of Heavy Metals in Top Soil and Water in the Chamchamal City - Sulaymanya Governorate, North East of Iraq, M. Sc. Thesis, Faculty of Science, University of Kirkuk, Kirkuk, Iraq: 187pp.

[8] **Jassim, S. Z., and Goff, T. (2006):** Phanerozoic development of the northern Arabian Plate, In: Jassim S.Z., Goff, J. C., Geology of Iraq, publication of Dolin, Prague and Moravian Museum, Brno, 341pp.

[9] **Dartash, N. M. (2012):** hydrogeologyand geoelectricalstudies of groundwater in part of chamchamal area, kurdistan region NE-Iraq. M.Sc. Thesis, Sulaimani University, Sulaimani Iraq: 134pp

[10] **Buday, T. and Jassim S. Z. (1987):** The Regional geology of Iraq: tectonic, magmatism and metamorphism. Vol. 2, S.E. Geol. Survey. Min. Invest., Baghdad, Iraq: 352pp

[11] **Al- Kadhimi, J.A., Sissakian, V. K., Fattah, A. S., and Deikran, D. B., (1996):** Tectonic Map of Iraq, State Company of Geological survey and Mining, Baghdad.

[12] http://acmelab.com/services/method-descriptions/water/

[13] **WHO (World Health Organization). (2017):** Guidelines for Drinking-water Quality. 4th Edition, incorporating the first addendum. Brazil, World Health Organization, 518pp.

[14] **IQS, Drinking Water Standard: 417, (2001**): Central Organization for Quality Control and Standardization, Council of Ministers, Republic of Iraq.

[15] **Anderson, M. P. (2014):** Groundwater research and management: New directions and Rr-invention, *Groundwater as a key for Adaptation to changing climate and society*. *Springer*, 1–15pp.

[16] **Zeng, B.; Xin, Z. Z.; and Yang, M. (2017):** Risk assessment of groundwater with multi-source pollution by a long-term monitoring programme for a large mining area. *International Biodeterioration Biodegadation, Elsevier*, **128(3)**: 100–108pp.

[17] **Mohan, S. V.; Nithila, P.; and Reddy, S. J. (1996):** Estimation of heavy metal in drinking water and development of heavy metal pollution index, *Journal of Environmental Science and Health*, **31(2):** 283–289pp.

[18] **Prasad. B. and Kumari, S. (2008):** Heavy metal pollution index of groundwater of an abandoned open cast mine filled with fly Ash: a case study. *Mine Water Environment, springer*, **27(4)**: 265–267pp.

[19] **Reza, R. and Singh, G. (2010):** Heavy metal contamination and its indexing approach for river water, *International Journal Environmental Science and Technology*, **7(4)**:785-792pp.

[20] **Dede, O. T. (2016):** Application of the heavy metal pollution Index for surface waters: A Case study for Camlidere, *Hacettepe J. Biol. & Chem*, **44(4)**:323-331pp.

[21] **Edet, A. E. and Offiong, O. E. (2002):** Evaluation of water quality pollution indices for heavy metal contamination monitoring. A study case from Akpabuyo - Odukpani area, Lower Cross River Basin (southeastern Nigeria). *Springer, Geo Journal*, **57(4)**: 295–304pp.
[22] **Tiwari, A. K.; De Maio, M.; Singh, P. K.; and Mahato, M. K. (2015):** Evaluation of surface water quality by using GIS and a heavy metal pollution index (HPI) model in a coal mining Area, India. *Bulletin of Environmental Contamination and Toxicology, Springer*, .**95(3)**: 304–310pp.
[23] **Akbar, M. J. (2018):** Environmental Effects of the Soil on Groundwater Quality and Hydrogeochemical Model for Shewasoor Sub-basin. Kirkuk / NE of Iraq, M.Sc. thesis, Kirkuk University, Kirkuk, Iraq: 109pp.
[24] **Darrah, T. H.; Vengosh, A.; Jackson, R. B.; Warner, N. R.; Poreda, R. J. (2014):** Noble gases identify the mechanisms of fugitive gas contamination in drinking-water wells overlying the Marcellus and Barnett Shales, *Proceedings of the National Academy Sciences of the USA*, **111(39)**:14076–14081pp.
[25] **Jackson, R. B. et al. (2013):** Increased stray gas abundance in a subset of drinking water wells near Marcellus shale gas extraction, Proceeding of the National Academy of Sciences of the United State of America, **110(28)**: 11250-11255pp.
[26] **Warner, N. R.; Christie, C. A.; Jackson, R. B.; and Vengosh, A. (2013):** Impacts of shale gas wastewater disposal on water quality in Western Pennsylvania. *Environ. Sci. Technol*, **47(20)**: 11849–11857pp.
[27] **Lauer, N. E.; Harkness, J. S.; and Vengosh, A. (2016):** Brine spills associated with unconventional oil development in North Dakota. *Environmental Science Technology*, **50(10)**: 5389-5397pp.
[28] **Adamu, C.I.; Nganje, T. and Edet, A. (2015):** Heavy metal contamination and health risk assessment associated with abandoned barite mines in Cross River State, south-eastern Nigeria, Elsevier, *Environmental Nanotechnology, Monitoring & Management*, **3(5)**:10-21.
[29] **Finkelman, R. B. and Tian, L.W. (2018):** The health impacts of coal use in China, *International Geology Review*, **60(5)**:1–11pp.
[30] **şehnaz, ş., Erhan, S., and Ayşen, D. (2016):** Assessment of groundwater quality and health risk in drinking water basin using GIS. *Journal of Water and Health*, **15(1)**: 112-132pp.
[31] **US EPA, (1998):** Human Health Risk Assessment Protocol. EPA: 530 pp.
[32] **Chowdhury, S. and Champagne, P. (2009):** Risk from exposure to trihalomethanes during shower: Probabilistic assessment and control, *Science of the Total Environment, Elsevire*, **407(5)**: 1570-1578pp.
[33] **US EPA (United States Environmental Protection Agency). (2004**). Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment); USEPA: Washington, D.C., USA: 235pp.
[34] **Bamuwamye, M.; Ogwok, P. and Tumuhairwe, V. (2015):** Cancer and Non-cancer Risks Associated With Heavy Metal Exposures from Street Foods: Evaluation of Roasted Meats in an Urban Setting, *Journal of Environment Pollution and Human Health*, **3(2)**: 24-30pp.
[35] **Wei, H.; Le, Z.; Shuxian, L.; Dan, W.; Xiaojun, L.; Lan, J. and Xiping, M. (2015):** Health risk assessment of heavy metals and polycyclic aromatic hydrocarbons in soil at coke oven gas plants, *Environmental Engineering and Management Journal*, **14(2)**: 487-496pp.
[36] **U. S. Environmental Protection Agency (U.S. EPA), (1989).** Risk Assessment Guidance for Superfund Volume 1: Human Health Evaluation Manual (Part A). Office of Emergency and Remedial Response: Washington, D.C., USA: 291pp
[37] **US EPA (United States Environmental Protection Agency). (2006):** Risk-based concentration table. Online Available at: http://www.epa.gov/reg3hwmd/risk/human/rbc/rbc1006.pdf.
[38] **Naveedullah, N. Z., et al. (2014):** Concentration and human health risk assessment of selected heavy metals in surface water of the Siling reservoir watershed in Zhejing Province, China. *Polish Journal Environment Studies*, **23(3)**: 801-811pp.
[39] **US EPA (United States Environmental Protection Agency). (2016).** Regional Screening Levels. U.S. Environmental Protection Agency, May 2016, prepared by Oak Ridge National Laboratories. Online available at: .http://epaprgs.ornl.gov/chemicals/index.shtml
[40] **US EPA, (1999):** Guidelines for Carcinogen Risk Assessment, (review darft). Risk Assessment Forum, U.S. Environmental Protection Agency, Washington, DC, NCEA-F-0644. http:// www.epa.gov/ncea/raf/cancer.htm.
[41] **De Miguel, E.; Iribarren, I.; Chacon, E.; Ordonez, A.; and Char- lesworth, S. (2007):** Risk-based evaluation of the exposure of children to trace elements in playgrounds in Madrid (Spain). *Chemosphere*, **66**:505–513pp.

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

حسن احمد علي الجميلي , عمر عادل محمد , بشرى رسول رشيد

قسم الجيولوجيا التطبيقية , كلية العلوم , جامعة كركوك ، كركوك ، العراق

الملخص

ركزت الدراسة الحالية على تعيين محتوى العناصر الثقيلة مثل (الزرنيخ, النحاس, الكروم, الكادميوم, الكوبلت, الحديد, المنغنيز , المولبيديوم, النيكل, الرصاص, الزنك) في المياه الجوفية والحنفية وتأثيراتها الصحية في مدينة جمجمال ضمن محافظة السليمانية شمال شرقي العراق. تم جمع (13) نموذجا للمياه الجوفية و(12) نموذجا 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 اقصى الشمال الشرقي لمنطقة الدراسة وقد يعزى ذلك إلى النشاطات الصناعية وترشيح هذه العناصر الثقيلة من التربة إلى المياه. فضلا عن ذلك, فان الدراسة الحالية تظهر عدم وجود اي مخاطر مسرطنة بسبب تلوث العناصر الثقيلة ضمن منطقة الدراسة. إن مؤشر الخطر (HI) للمياه الجوفية والحنفية اقل من الواحد لجميع العناصر الثقيلة قيد الدراسة للبالغين والأطفال. وان مقدار الخطر المسرطن (CR) لعناصر الزرنيخ, الكروم والرصاص في المياه الجوفية والحنفية يقع ضمن المديات المسموح بها لكل من البالغين والأطفال في مدينة جمجمال.