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Concentration Of Heavy Metals and Heavy Metal Pollution Index Used for Groundwater Quality Assessment in Shamamik Basin in Erbil Governorate, Northern Iraq

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ABSTRACT

Thirteen groundwater samples are collected from thirteen groundwater wells at different depths and different locations inside Shamamik basin in Erbil Governorate. The sampling was started in May 2022, then analyzed for heavy constituents such as (As, Cd, Cu, Pb, Va, Ni, Zn, Bo, Cr, Co, Li, Mn, Se, and Ag). The aim of this research is to find the concentrations are within the acceptable limits as prescribed in Iraqi drinking water standards. The average Heavy metal Pollution Index (HPI) concentration is 97.66, which is considerably less than the crucial index value of 100. The percentage of groundwater samples that exceeds 100-index value is 10% indicating that the water is completely unsuitable and unfit for drinking, while 90% are ranging from excellent to very poor quality according to HPI. The Metal Index (MI) concentration is 2.7, and 83.3 percent of groundwater samples found to be very pure water class. The results show that the groundwater in Shamamik basin of wells 27, 28, 29, 30 is highly polluted and unfit for human consumption. Impact of human activity and industrial activity on the study area has played an important role of pollution in groundwater quality in the western part of the Shamamik basin. According to the finding of current study, it can be concluded that the water can be used as safe for drinking without any negatives effect on the human health except some few wells in the western part of the basin.

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استخدام تركيز المعادن الثقيلة فى المياه الجوفية كمؤشر لتقييم جودة المياه الجوفية في حوض شمامك في محافظة أربيل، شمالي العراق

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الملخص

تم جمع ثلاثين عينة مياه جوفية من ثلاثين بئراً جوفية مختلفة الأعماق داخل حوض شمامك في محافظة أربيل. بدأت عملية أخذ العينات في مايو 2022، وتم تحليل العناصر الثقيلة مثل Pb، Bo، As، Cd، Zn، Ag، Li، Se، Ni، Cr، Mn لغرض تقييم جودة المياه الجوفية فى الحوض. تم استخدام كل من مؤشرHPI و MI على العينات المأخوذة حيث ظهر ان اغلبية العينات لديها تراكيز ضمن الحدود المقبولة حسب المعايير العراقية لمياه الشرب. وظهرمتوسط تركيز HPI بمقدار 97.66، وهو أقل من القيمة المؤشرة على التلوث وهى 100. النسبة المئوية لعينات المياه الجوفية التي تتجاوز قيمة المؤشر 100 هي 10٪ ، مما يشير إلى أن المياه غير صالحة للشرب تمامًا بينما 90٪ تتراوح من ممتازالى جودة رديئة جدًا وفقًا لـ HPI. كان تركيز MI 2.7 83.3 بالمائة من عينات المياه الجوفية كانت من فئة المياه النقية للغاية. أظهرت النتائج أن المياه الجوفية في حوض الشاماميك خصوصا الابار 27،28،29،30 ملوثة للغاية وغير صالحة للاستهلاك البشري حسب محتوياتها من العناصرالثقيلة، وتقع هذه الابارفى غربي الحوض . كل هذه الملوثات اتية من الانشطة البشرية فى المنطقة خصوصا عملية انتاج وتكرير النفط الموجودة فى الجزء الغربى من الحوض. وفقًا لنتائج الدراسة الحالية، يمكن استنتاج أن المياه يمكن استخدامها بشكل آمن للشرب دون أي تأثير سلبي على صحة الإنسان باستثناء بعض الآبار القليلة في الجزء الغربي من الحوض.

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Introduction

Shamamik Basin, which is located in the most fertile lands in Erbil City, is an unconfined aquifer basin that has seen extreme changes in its properties throughout the years due to agricultural processes and other activities. The largest renewable source of freshwater utilized for drinking, irrigation, and industry is the groundwater. Freshwater is under stress due to rising demands, which is causing water levels to drop and water quality to deteriorate (Krishan et al., 2020). Utilizing an index to evaluate drinking water is a highly useful method concerning the water quality (Naqeeb and Jazza, 2020). Heavy metal pollution in drinking waters is now one of the most serious environmental issues. When their levels in drinking water exceed the allowable limit, some of them can be harmful to human health (Jazza, Najim, and Adnan, 2022); (Prasad, Kumari, Bano, and Kumari, 2014)). Anthropogenic activities are the primary sources of heavy metals in aquatic ecosystems (Bhardwaj, Gupta, and Garg, 2017). Once too much heavy metals enter the water body, they will directly or indirectly impact the human health, and even dangerous to the aquatic ecosystem (Toma and Aziz, 2022). Metals are hazardous to both plants and animals as well as to humans. Heavy metals like zinc and copper are necessary for plant and animal life biota, whereas many others like Pb and Cd, have no known physiological applications (Gautam, Sharma, Mahiya, and Chattopadhyaya, 2014). They are major water pollutants because of their toxicity, persistence, and capacity to accumulation in biota species. They can also have an adverse effect on human body systems even at extremely low concentrations (Hamed, Disli, and Shukur, 2023). The primary sources of anthropogenic in heavy metal pollution are effluents that have been partially treated, waste of mining and untreated disposable heavy metals from different industries such as manufacturing of pharmaceutical as well as the irregular use of heavy metal containing fertilizer and pesticides in agricultural areas (Abdullah, 2013); (Kamel, Al-Zurfi, and Mahmood, 2022). Pollution by heavy metals is understood to be one of the most serious threats to water quality (Elhdad, 2019). Using of HPI and MI as pollution indices provide information about the pollution level of groundwater resources in recent years that have become a popular approach in assessing groundwater quality for heavy metal detection. Indices of pollution regarded a useful technique for water quality management, decision makers, authorities of civil, and environment because they combine all influence of those parameters into a single number (Rezaei et al., 2019). HPI is a method of evaluating and a useful technique for assessing quality of water, particularly for heavy metals (Rezaei et al., 2019). It is mainly used to determine the mobility of pollution in water and to determine the degree of pollution. Metal index is focused on a whole trend evaluation of the current situation that is excessive concentration of metal is present in comparison to each element's maximum allowable concentration (Matta et al., 2020). The Shamamik groundwater and its aquifer is one of the largest aquifers within Erbil Basin, Northern Iraq. The main clean water can be used in Erbil plain is Shamamik basin. Main goals of the current work are to evaluate heavy metal concentration and heavy metal index pollution in Shamamik basin groundwater samples to estimate their suitability for potable uses through using heavy metal pollution index (HPI); moreover, it aims to determine groundwater quality by using and applying heavy metal pollution index and the metal index to assessing the source and existence of heavy metals in groundwater, which are the result of anthropogenic source.

Study area

The basin under study is situated in the Kurdistan region of Iraq (Erbil Governorate),. The study area is located in the Shamamik Basin within the latitudes and longitudes boundaries shown in in figure (1), and it shows the geographical area of the basin.

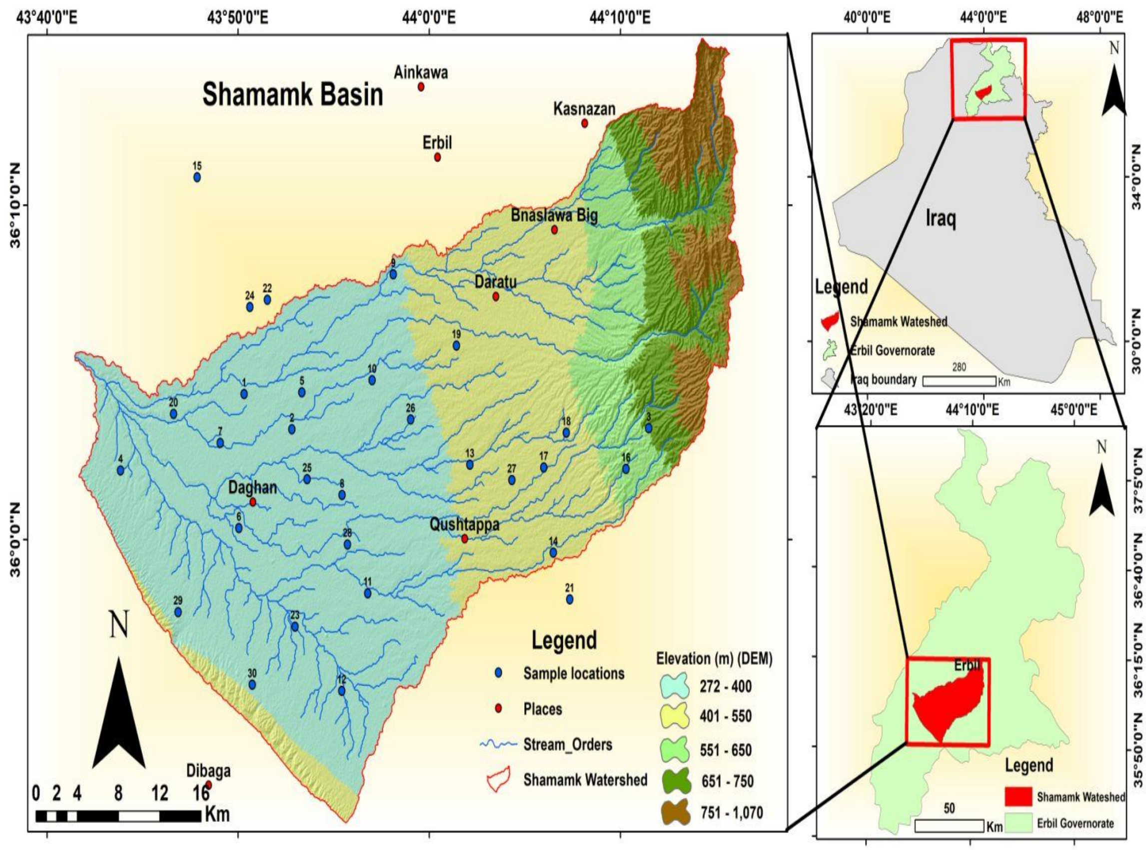

Fig.1. Location map of Shamamik Subbasin located in the southern part of Erbil Governorate

Materials and Methods

Sample collection

In the current study, 30 wells are selected inside Shamamik basin to collect 30 groundwater samples for analyses and evaluating the heavy metals concentrations (Table1). Depth of this groundwater aquifer range from 220 m to 450 m. Portable GPS is used to establish the location of each sampling site. The sampling sites are selected so as to ensure that all drinking water wells having potable water are covered. In the study area, groundwater is typically consumed without treatment. Pumping was done for 10 to 15 minutes before sampling to ensure the proper sample is received. The weather is generally stable during the collection period. Before study, the water samples are stored in pre-cleaned acid-washed high-density polyethylene (HDPE) containers after being filtered to remove suspended matter/sediments using 0.45 m nitrocellulose-millipore filters (disposable, not reusable). Next, the water samples are acidified to pH= 2 (0.2 percent v/v) utilizing ultrapure nitric acid (HNO_3) (APHA, 2012).

Table1: Longitude and latitude boundaries of Shamamik

Well ID	Village	Easting(m)	Northing(m)	Elevation(m)	Well ID	Village	Easting(m)	Northing(m)	Elevation(m)
1	Tandora/1	395410	3992610	315	16	Omera Sore	425365	3988160	577
2	Sorbash Ha	399135	3990615	329	17	Sardasht	418909	3988295	464
3	Lajan	427157	3990399	655	18	Sablagh	420692	3990208	507
4	Shex Sherw	385648	3988509	297	19	Girdarasha	412111	3995108	419
5	Daldaghan	399949	3992661	314	20	Sirawa	389853	3991579	296
6	Gird Azaba	394906	3985195	317	21	Gomagru	420884	3980972	446
7	Mastawa	393502	3989935	314	22	Duztapa	397303	3997812	329
8	Pirdawd	403042	3986933	348	23	Minara	399257	3979683	325
9	Sarkarez	407198	3999105	385	24	Yarimja	395915	3997425	320
10	Qoritan Ch	405465	3993266	360	25	Dusara Fate	400305	3987843	328
11	Dugirdkan	405002	3981465	357	26	Qocha bilb	408470	3991057	376
12	Qurshakhlo	402891	3976079	345	27	Gird Mala	416388	3987621	432
13	Murtika Sh	413106	3988511	410	28	Tirpa Spia	403438	3984191	345
14	Kardiz	419608	3983573	448	29	Helawa	390080	3980599	351
15	Satoor	391869	4004656	441	30	Jadidalak	395867	3976501	364

Samples analysis

Groundwater samples are analyzed in the laboratory inside cool-boxes, in accordance with American Public Health Association (APHA, 2012). The analysis of water samples was done in the General Directorate of Water Providing in Erbil Governorate. The total analyzed groundwater heavy metals are 14 (As, Cd, Cu, Pb, V, Ni, Zn, Bo, Cr, Co, Li, Mn, Se, and Ag) (Table 2). All analyzed heavy metals are validated with the IRQ standard for drinking water (IQS, 2001).

Table2: IRQ guideline for heavy metals

Class	Property/characteristics	HPI
1	Very pure	<0.3
2	pure	0. 3-1
3	Slightly Affected	1-2
4	Moderately Affected	2-4
5	Strongly Affected	4-6
6	Seriously Affected	>6

Heavy metal pollution index (HPI) and Metal index (MI) Estimation

Heavy metal pollution index (HPI) is a system of rankings and a useful technique for assessing the heavy metal content of water (Abou Zakhem and Hafez, 2015); (Sheykhi and Moore, 2012). This is used to exemplify how metals work together to affect the overall quality of water. (Reza and Singh, 2011). The HPI index has been used extensively by researchers to analyze surface water. The study of HPI in groundwater was presented by the (Yankey, 2013; Kumar, 2012; and Toma, 2022).

$$\mathrm{HPI} = \frac{\sum_{i=1}^{n} QiWi}{\sum_{i=1}^{n} Wi}$$ …………………1

Where, *Wi* and *Qi* represent the unit weightage and sub-index of *i* parameter. As shown in the equation (1), *n* is the total number of parameters to be considered.
The Qi (sub-index) is calculated by,

$$\mathrm{Qi} = \sum_{i=1}^{n} \frac{Mi - Ii}{Si - Ii} * 100$$ …………………..2

Where, *Mi* and *Li* depict the monitored and ideal values of the i^{th} parameter respectively, *Si* represents the standard value of the i^{th} parameter in parts per million (ppm) as shown in equation (2) and table (3).

Table3: Calculation of HPI on sample 28

		Si	Li	mg/l	Wi	Qi	Wi Qi
1	Cd	0.003		2.66	333.3333	88666.67	29555556
2	Co	0.002		0.0020	500	100	50000
3	Cu	1	1.5	0.003	1	0.3	0.3
4	Pb	0.01		0.891	100	8910	891000
5	Li	0.001		0.001	1000	100	100000
6	Zn	3		0.0055	0.333333	0.183333	0.061111
7	Va	0.001		0.01	1000	1000	1000000
8	Cr	0.05		0.0981	20	196.2	3924
9	Ba	1.3		0.06	0.769231	4.615385	3.550296
					2955.436		31600483
						HPI	10692.33

Metal index (MI) is essentially described by Tamasi and Cini (2004). It is defined as the ratio of each element's concentration in the solution to the maximum allowable concentration for each element.

$$\mathrm{MI} = \sum_{i=1}^{n} \frac{Ci}{(MAC)i}$$ ……………3

Where, MI is index of metal, *Ci* is the concentration of elements in a given solution. *MAC* is the maximum permissible concentration for each element, and subscript *i* represents the i^{th} parameter of samples as shown in equation (3) and table (4).

Table 4: Calculation of MI on sample 3

Metal	Mi (n=10)	Si	Ii	Wi	Qi	Wi*Qi	MI
Co	0.3961	50	0.85	0.02	0.9235	0.01847	
Cd	0.0527	5	0.201	0.2	3.0902	0.618045	
Zn	0.0481	3000	0.104	0.00033	0.0019	6.15E-07	
Fe	0.0925	300	0.122	0.00333	0.0098	3.28E-05	
Ni	0.1961	20	0.208	0.05	0.0601	0.003006	
Cr	2.6321	50	4.174	0.02	3.3647	0.067294	
Pb	0.421	10	0.55	0.1	1.3651	0.136508	
Li	0.1296	5	0.284	0.2	3.274	0.654792	
							0.000413

Result and Discussion

Heavy metal concentrations

The concentration of heavy metals for cadmium (Cd), copper (Cu), lead (Pb), manganese (Mn), arsenic (As), nickel (Ni) chromium (Cr), and zinc (Zn) are not coming suppressed with IRQ guideline (Table 5**)** except in wells 30, 29, and28 are higher than IRQ due to effect of hydrocarbon, and refinery industry and activity has existed in last two decades**.** Silver (Ag), manganese (Mn), cobalt (Co), and selenium (Se) are below detection limits, while another heavy metal are detected but still below IRQ guideline such as chromium (Cr) ranges from 0.0011 – 0.52 mg/l, boron (Bo) ranges from 0.02 -0.01mg/l, and lithium (Li) ranges from 0.004-0.019 mg/l. The statistical analysis including the maximum value, minimum value, average and the standard deviation are tabulated for respective heavy metals (Table 3). Antimony, aluminum, arsenic, beryllium, cadmium, boron, cobalt, selenium, silver, all groundwater samples are safe and can be used for drinking purpose according to their heavy metal content. Excess nickel and manganese concentrations are due to their presence in earth's crust (Krishan, 2021). The combined impact of industrial pollutants and agricultural fertilizers increase level of heavy metal pollution in groundwater, particularly in the southwest part of Shamamik basin. Even though each and every single parameter of the heavy metals has been analyzed and mapped separately, the study of combined effect for heavy metals is very considerably essential (Fig. 2).

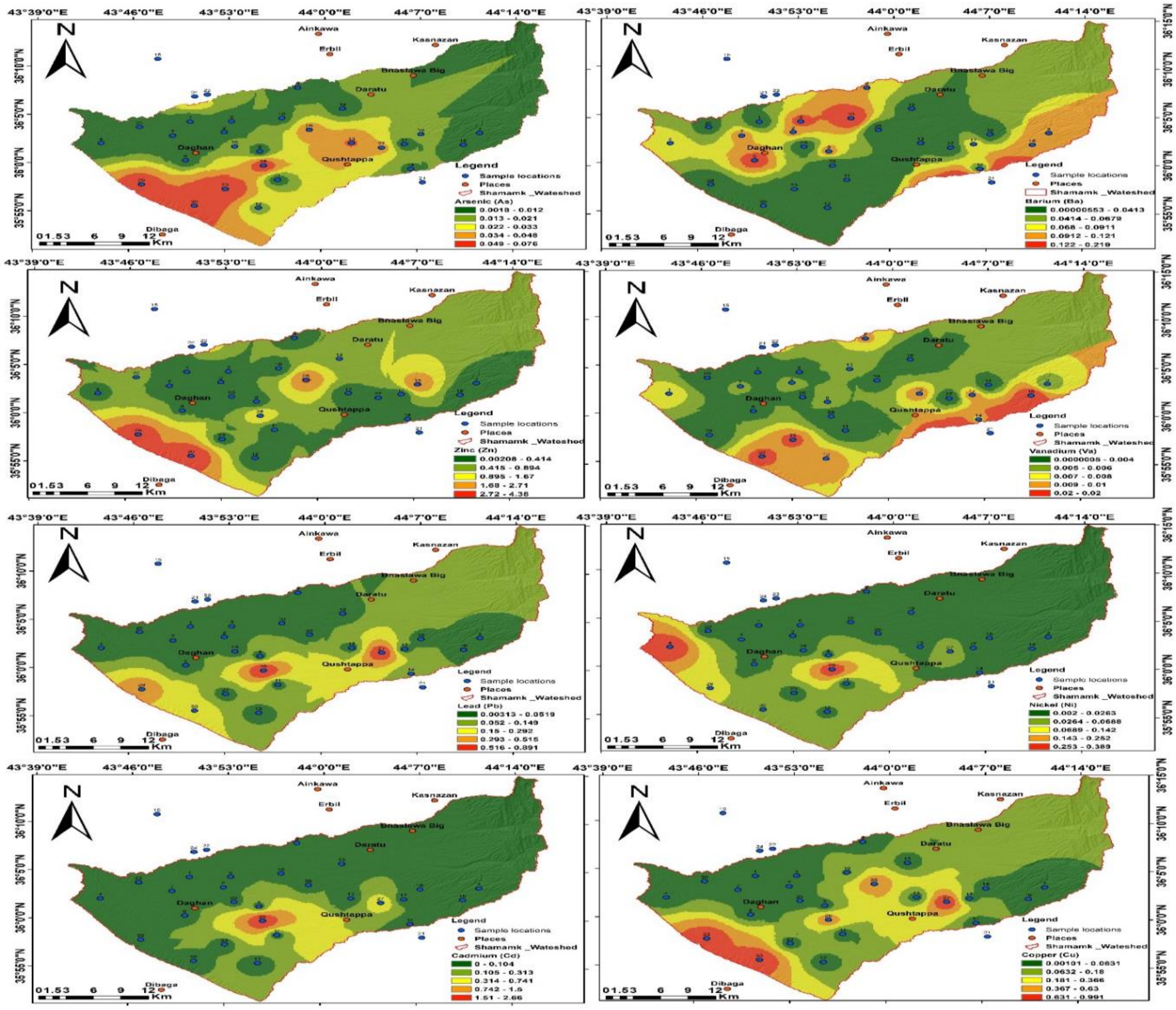

Fig.2. Spatial distribution of heavy metals in the studied basin.

Table 5: Heavy metal concentration and Statistical parameters of analyzed groundwater samples.

Well	As	Cd	Cu	Pb	Va	Ni	Zn	Boron	Cr	Co	Li	Mn	Se	Ag
ID	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
1	0.00361	0.00040	0.0010	0.005	0.0010	0.0020	0.0020	0.01	0.0010	0.0020	0.0010	<0.00050	0.0100	0.0010
2	0.00375	<0.00040	0.0015	0.0057	0.0048	0.0023	0.103	0.0985	0.0015	<0.0020	0.0142	<0.00050	<0.0100	<0.0010
3	0.00402	<0.00040	0.002	0.0031	0.0038	0.0027	0.0041	0.0997	0.0016	<0.0020	0.0153	<0.00050	<0.0100	<0.0010
4	0.0028	<0.00040	0.0031	0.0051	0.0079	0.389	0.307	0.0892	0.0026	<0.0020	0.013	<0.00050	<0.0100	<0.0010
5	0.00381	<0.00040	0.005	0.006	0.0023	0.00348	0.274	0.142	<0.0010	<0.0020	0.019	<0.00050	<0.0100	<0.0010
6	0.00571	<0.00040	0.005	0.0031	0.0027	0.00678	0.328	0.148	0.0016	<0.0020	0.0176	<0.00050	<0.0100	<0.0010
7	0.00872	<0.00040	0.0042	0.0051	0.0043	0.00519	0.0049	0.106	0.0048	<0.0020	0.0113	<0.00050	<0.0100	<0.0010
8	0.00429	<0.00040	0.0068	0.005	0.006	0.00856	0.104	0.11	0.0023	<0.0020	0.0119	<0.00050	<0.0100	<0.0010
9	0.00279	<0.00040	0.0062	0.0049	0.0084	0.00836	0.163	0.0914	0.0033	<0.0020	0.0093	<0.00050	<0.0100	<0.0010
10	0.00974	<0.00040	0.055	0.004	0.0043	0.0028	0.0073	0.18	0.0011	<0.0020	0.0182	<0.00050	<0.0100	<0.0010
11	0.005	0.00040	0.0026	0.0056	0.0010	0.0020	0.0020	0.0100	0.0010	0.0020	0.0010	<0.00050	0.0100	0.0010
12	0.018	<0.00040	0.0051	0.0054	0.0094	0.021	0.002	0.0337	0.0054	<0.0020	0.0092	<0.00050	<0.0100	<0.0010
13	0.05	<0.00040	0.002	0.0064	0.0099	0.0038	0.0084	0.0264	0.0025	<0.0020	0.004	<0.00050	<0.0100	<0.0010
14	0.0101	<0.00040	0.0017	0.052	0.0066	0.0041	0.0033	0.0273	0.0035	<0.0020	0.0067	<0.00050	<0.0100	<0.0010
15	0.0243	<0.00040	0.0038	0.005	0.0111	0.0034	0.224	0.127	0.0039	<0.0020	0.017	<0.00050	<0.0100	<0.0010
16	0.0098	<0.00040	0.0048	0.005	0.0135	0.0041	0.0434	0.103	0.0036	<0.0020	0.0052	<0.00050	<0.0100	<0.0010
17	0.00536	<0.00040	0.0047	0.0047	0.0092	0.0028	0.0617	0.0925	0.0088	<0.0020	0.0102	<0.00050	<0.0100	<0.0010
18	0.016	0.00040	0.0010	0.0041	0.0010	0.0020	2.87	0.0100	0.0010	0.0020	0.0010	<0.00050	0.0100	0.0010
19	0.00519	<0.00040	0.0014	0.0049	<0.0010	0.002	0.458	0.0237	0.0017	<0.0020	0.0035	<0.00050	<0.0100	<0.0010
20	0.00182	<0.00040	0.0018	0.0051	0.0013	0.002	0.655	0.0240	<0.0010	<0.0020	0.0037	<0.00050	<0.0100	<0.0010
21	0.0151	<0.00040	0.0030	0.005	0.0489	0.0069	0.0101	0.628	0.0024	<0.0020	0.0071	<0.00050	0.0177	<0.0010
22	0.00873	<0.00040	0.0038	0.005	0.0091	0.0033	1.6	0.0858	<0.0010	<0.0020	0.0122	<0.00050	<0.0100	<0.0010
23	0.0763	<0.00040	0.0032	0.005	0.0116	0.0068	0.186	0.02	<0.0010	<0.0020	0.0107	<0.00050	<0.0100	<0.0010
24	0.0618	<0.00040	0.002	0.006	<0.0010	0.002	0.0038	<0.0100	<0.0010	<0.0020	<0.0010	<0.00050	<0.0100	<0.0010
25	0.0189	<0.00040	0.0024	0.0071	0.0028	0.002	0.0035	<0.0100	<0.0010	<0.0020	<0.0010	<0.00050	<0.0100	<0.0010
26	0.0408	<0.00040	0.589	0.00743	0.0027	0.002	2.84	<0.0100	<0.0010	<0.0020	<0.0010	<0.00050	<0.0100	<0.0010
27	0.0391	0.594	0.964	0.802	<0.0100	0.071	0.104	<0.00200	0.0354	<0.0020	<0.0010	0.522	5.780	<0.0100
28	0.0649	2.66	0.527	0.891	<0.0100	0.389	1.58	<0.00400	0.0981	<0.0020	<0.0010	5.13	7.640	0.0114
29	0.0618	0.0155	0.928	0.431	<0.0100	0.083	3.56	<0.00020	0.52	<0.0010	<0.0010	7.86	1.11	<0.0100
30	0.0617	0.0278	0.991	0.257	0.0116	0.042	4.379	0.02	<0.0010	<0.0020	<0.0010	0.00118	<0.0100	<0.0010
Min	0.00182	0.0155	0.0015	0.0031	0.0023	0.002	0.002	0.01	0.0011	0	0.004	0.00118	1.11	0.0114
Max	0.0763	2.66	0.991	0.891	0.0135	0.389	4.379	0.18	0.52	0	0.019	7.86	7.640	0.0114
Av.	0.02146	0.82433	0.17167	0.08539	0.00699	0.04281	0.73932	0.08471	0.04118	<0.0020	0.01205	3.3783	4.473.7	0.0114
S. D	0.02331	1.25318	0.34219	0.22541	0.00358	0.10633	1.25909	0.05051	0.12566	<0.0020	0.00461	3.77348	3.983.46	<0.0010

Heavy metal pollution index (HPI) and Metal pollution (MI)

The primary goal of this work is to evaluate two major heavy metal pollution indices, heavy metal pollution index (HPI), and metal index (MI). Table (3**)** demonstrates the HPI and MI calculations in Shamamik basin (sample 2). Table (4) demonstrates the HPI and MI values in selected wells for study area, while figure (3) depicts variation of HPI and MI.

Table 4: Heavy metal pollution index and metal pollution index for Sahamamik basin.

Sample no.	HPI	MI	Sample no.	HPI	MI
1	13.151718	0.000413	16	65.895473	0.001907
2	66.255406	0.000859	17	67.650996	0.001323
3	66.403324	0.000699	18	8.7990947	0.001599
4	72.323584	0.020541	19	17.414671	0.056
5	74.834649	0.000733	20	18.310076	0.000627
6	70.007067	0.000936	21	191.96052	0.005681
7	54.020073	0.001009	22	74.837031	0.001924
8	62.809568	0.001291	23	77.671424	0.003229
9	61.056313	0.001508	24	8.8001864	0.001598
10	78.441047	0.000906	25	14.70455	0.000942
11	8.7990947	0.000454	26	14.321261	0.002518
12	64.536911	0.0025	27	289.13107	0.481128
13	49.4687	0.002351	28	1069.3258	0.382703
14	47.182715	0.002149	29	60.257567	0.565832
15	97.959568	0.001982	30	63.741147	0.58938
Mean				97.66	2.7

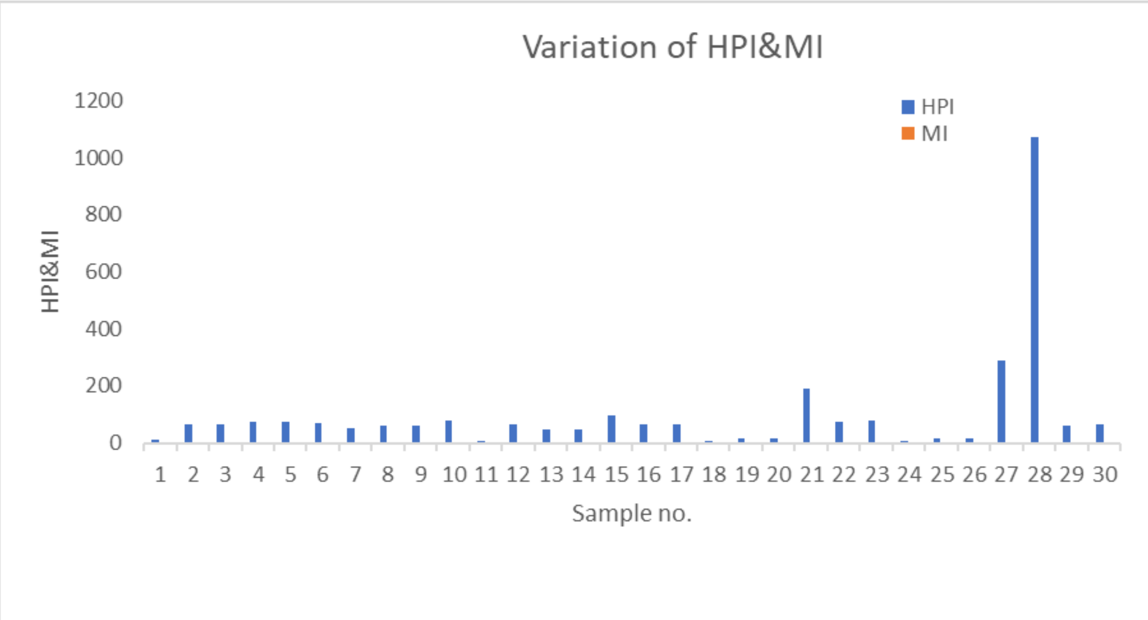

Fig.3. HPI and MI fluctuation in groundwater samples in Shamamik basin

Depending on the HPI value greater than100 (HPI > 100), the water is polluted, while less than 100 (HPI < 100) is non-polluted. HPI value of current study for all wells in total sum are 97.66 (Table 4) which is (HPI < 100) indicating that no pollution according to HPI is detected but regarded to critical limits of pollution (Anitha, 2021) and table (4). Based on table

(5), Caeriro (2005) classification of HPI 26.6% water sample is excellent, 6.6 percent of samples is good, 46.6 percent of samples is poor, 10percent of samples is very poor, and10 percent of samples is unsuitable. The water samples 1 to 27 vary from excellent to very poor, while samples 28,29, and 30 are unsuitable (Fig. 4). Excessive HPI values in the samples 28,29, and 30 are attributed to the presence of oil and gas production and industries such as refineries, EWT, and power plants close to wells 27, 28, 29, and 30. The increased HPI value is due to higher levels of total cadmium, copper, lead, nickel, zinc, and vanadium in groundwater samples.

Table 5: Groundwater quality classification based on pollution indices HPI and MI.

Index methods	**Range /Class**	**Quality /Character**	**Number of samples**	**%of samples in each class**
HPI	<25	Excellent	8	26.6
	26 to 50	Good	2	6.6
	51 to 75	Poor	14	46.6
	76 to100	Very poor	3	10
	>100	Unsuitable	3	10
Index methods	Range/Class	Quality/Character	Number of samples	%of samples in each class
MI	<0.03	Very pure (Class I)	25	83.33
	0.03 to 1	Pure (Class II)	5	16.66
	1 to 2	Slightly affected (Class III)		
	2 to 4	Moderately affected (Class IV)		
	4 to 6	Strongly affected (Class V)		
	> 6	Seriously affected (Class VI)		

The MI values have been calculated for each and every sampling well location by substituting the analysis results in the above-mentioned equation (2) to calculate Qi which have been substituted in the equation (1) to calculate metal index (MI). The results along with the geographic coordinates have been interpolated using ArcGIS to obtain the spatial distribution of whole basin. Heavy metal pollution index values are then mapped according to their results as shown in table (4) and figure (5). The MI values above 0.03 is considered as threat for the groundwater and below MI value considered pure water **(**Kumar, 2012).

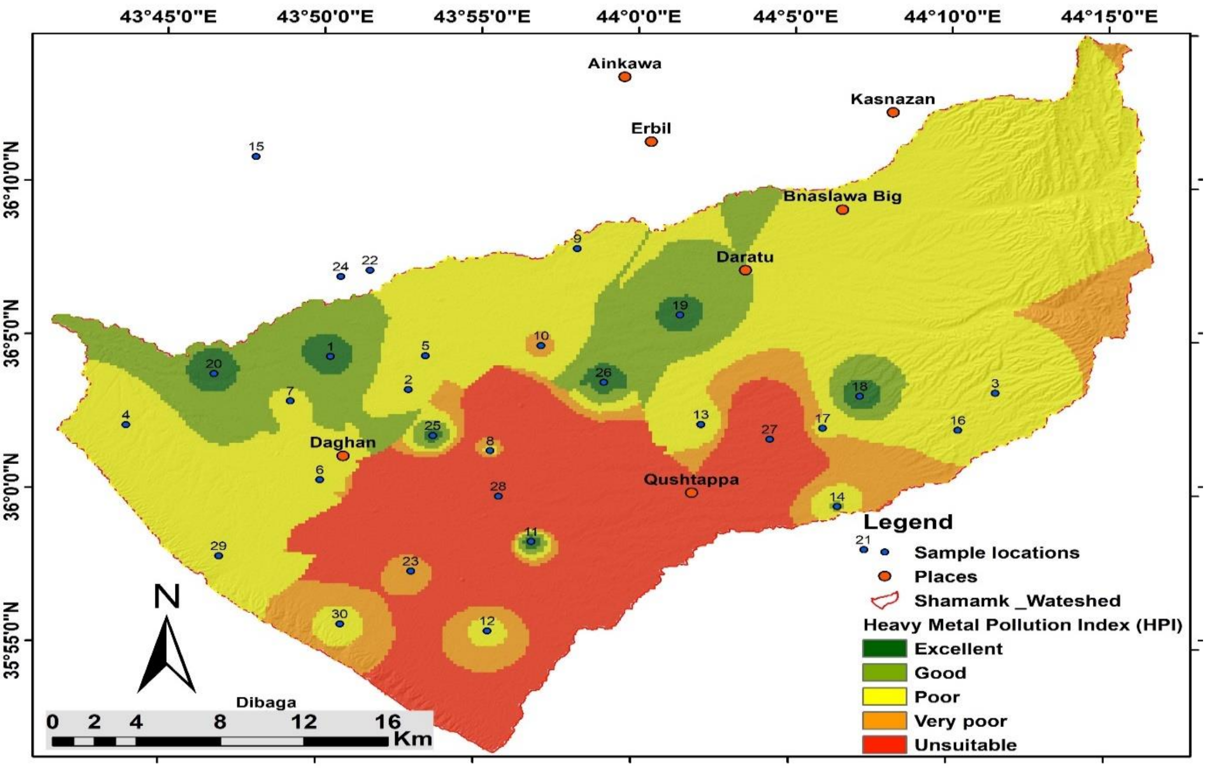

Fig.4. Spatial distribution map of HPI in Shamamik basin.

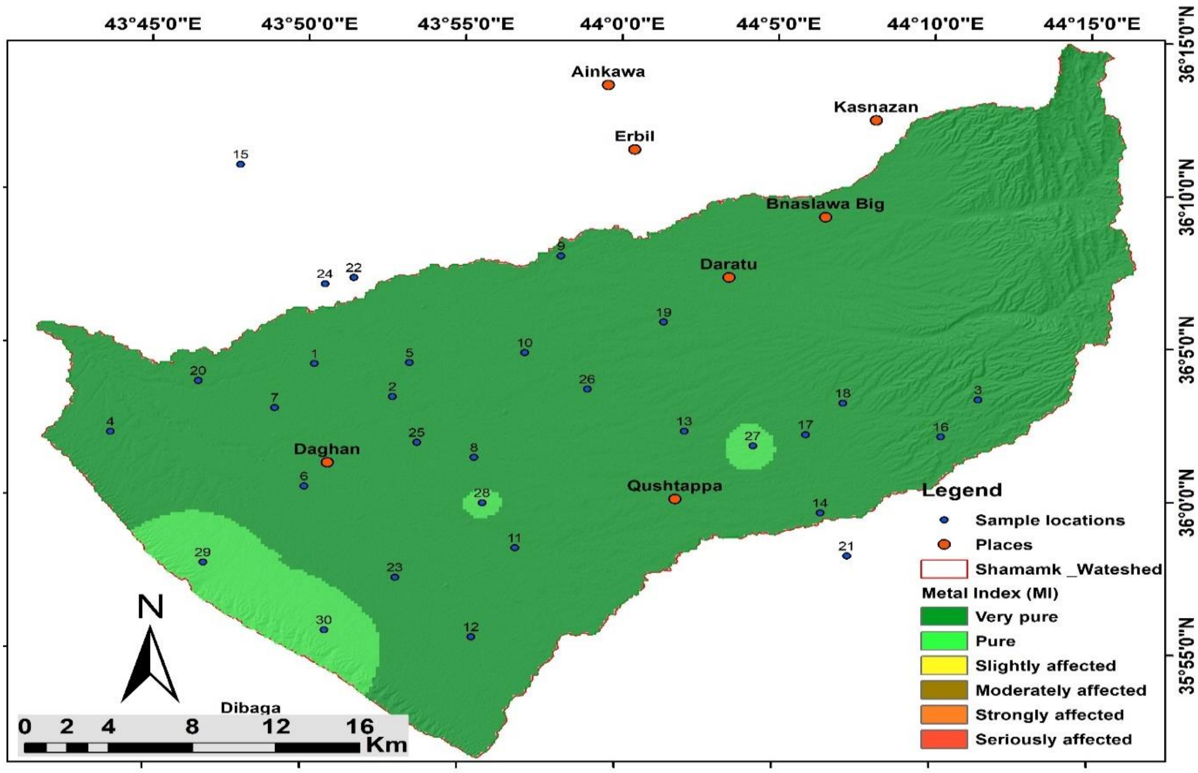

Fig.5. Spatial distribution map of MI in Shamamik basin.

Mean value of metal index concentration is 2.7 with 83.3 % of samples are classified as very pure (class I), which are suitable for drinking, with the remaining 16.6 percent of samples are as classified pure (class II) (Table 4). Table (5) demonstrates the distribution of groundwater quality in Shamamik basin based on metal index concentration. Figure (5) depicts the groundwater quality distribution of MI in the study area. From the MI spatial distribution maps (Fig. 5), it is clear that the main hazardous zones have been found in the village Minara (sample

29) and Hellawa (sample 30) in the western part of study area. The less hazardous threat zones (MI from <0.3) have been found in the eastern part of study area.

Conclusion

The primary objective of the present research is to assess the levels of heavy metal concentration in the groundwater within the Shamamik basin. The methods of Heavy metal pollution index (HPI) and metal index (MI) are emerged as the most influential and effective approaches in gauging both the concentration of heavy metals and the impact of human activities on this concentration. Based on the current investigation, the main findings are as follows: The mean value of HPI is 97.66. Extreme HPI values represent approximately 10% of the samples. The average MI concentration is 2.7, with 83.3 percent of groundwater samples classified as very pure. The conclusion emphasizes the effect of oil and gas production industry activity and poor management of influent in study area. A high concentration of heavy metals appears to be the source of groundwater pollution. As a result of which the water quality is extremely low and unsafe to drink. Pollutants from oil and gas industries should be treated separately before discharged to the natural (heavy crude oil, and waste water). The heavy metal pollution index model, which is used here as a technique for evaluating all pollution level of groundwater in terms of heavy metals, is more beneficial and promising than metal index, which is used to assess heavy metals in a given groundwater samples. According to findings, HPI is the best technique that can be used for determining the quality of groundwater. The HPI model could be applied to other suspect areas in the future. Only wells 27, 28, 29, and30 in the western part of the basin are polluted by heavy metals. These findings indicate that the water can be used for drinking purpose and safe water for human consumption with no negative effects on human health. According to the results of analyzing heavy metal concentration in groundwater of Shamamik basin, they are found to be less than guideline limits recommended by Iraqi drinking water standard except in sites 27, 28, 29, and 30 for Pb, Cd, and as depending on single constituent heavy metal. Heavy metal pollution index (HPI) values show that the groundwater of Shamamik basin is free of heavy metal pollution and can be used for human consumption.

Recommendation

Continuous monitoring of Shamamik groundwater wells is highly recommended particularly in the western polluted part.

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