Original Article

Evaluation of the Water Quality Pollution Indices for Groundwater Resources of Ghahavand Plain, Hamadan Province, Western Iran

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ABSTRACT

Background: Due to the increasing pollution of water resources, this study was carried out for evaluation of water quality pollution indices for monitoring of heavy metals (As, Zn, Pb and Cu) contamination in Ghahavand Plain, Hamadan Province, Western Iran during spring and summer 2012.

Methods: Totally, 20 ground water wells were chosen randomly. The samples were filtered (0.45 µm) and maintained cool in polyethylene bottles. Samples were taken for the analysis of metals, the former was acidified with HNO_3 to pH lower than 2. Metal concentrations were determined using ICP-OES.

Results: The mean values of Contamination index (C_d), Heavy metal pollution index (HPI) and Heavy metal evaluation index (HEI) in samples for spring season were -2.27, 9.01 and 1.73 respectively and in samples for summer season were -1.95, 8.69 and 2.04 respectively. It indicates low contamination levels. Comparing the mean concentrations of the evaluated metals with WHO permissible limits showed a significant difference (P<0.05).

Conclusion: The mean concentrations of the metals were significantly lower than the permissible limits. Although the heavy metal pollution of the ground water in Ghahavand Plain is lower than WHO permissible limits, but severe precautions consideration such as manage the use of agricultural inputs, prevention of use of wastewater and sewage sludge in agriculture, control of overuse of organic fertilizers and establishment of pollutant industries are recommended in this area.

Keywords: Health Effect, Iran, Toxic Metals, Water Quality.

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INTRODUCTION

Today heavy metals pollution of the groundwater is one of the serious environmental problems. Some of the heavy metals considered as micronutrients can cause adverse effects to human health when their contents exceed the permissible limit in drinking water [1, 2]. Thus, heavy metals assessment in groundwater used for drinking purpose is very significance from the human health viewpoint.

Heavy metals as an environmental pollutant, occurrence in waters from natural (such as chemical weathering of minerals and soil leaching) or anthropogenic sources (such as industrial and domestic effluents, urban storm, water runoff, landfill leachate, mining activities, atmospheric sources etc.) [3]. Considering that water pollution has direct implications on the aquatic life and the human health, therefore, monitoring and assessing of the water quality is of great importance [4].For evaluation of water quality pollution several methods such as the contamination index (C_d), the heavy metal pollution index (HPI) and the heavy metal evaluation index (HEI) were developed. These indices help assessing the present level of pollution in water resources and combine all the water pollution parameters into some easy approach [4-6].

Because Iran is located within the dry and semi dry regions, thus almost 90% of the required water is secured with groundwater resources [7]. In the present study, water quality pollution indices have been evaluated to know the status of overall pollution level of groundwater resources of Ghahavand Plain in 2012 with respect to four important heavy metals (As, Zn, Pb and Cu).

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MATERIALS AND METHODS

Study Area

The study area was conducted in Ghahavand Palin in Hamadan Province, western Iran. The area is 2360 km^2. Drinking water for residents of the plain is supplied from 1280 wells, 70 springs, and 65 aqueducts [8].

Sampling and Sample Analysis

Groundwater samples were collected from 20 different locations based on different land use pattern, including agricultural and residential areas during spring and summer seasons. Figure 1 shows the sampling stations in the study area. The samples were taken in acid washed 100 ml black polyethylene bottles to avoid unpredictable changes in characteristic as recommended by the standard procedures [9]. The collected samples were filtered (Whatman no. 42), preserved with 6N of nitric acid (suprapur Merck, Germany) and keep at a temperature of 4 °C for more analysis [9, 10]. Concentrations of heavy metals (As, Zn, Pb and Cu) in water specimens were determined using ICP-OES (Varian, 710-ES, Australia).

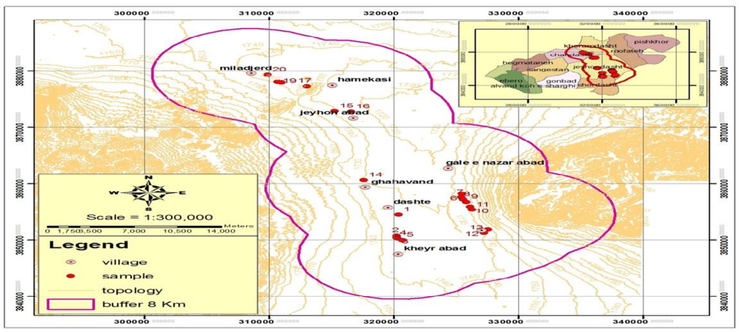

Figure 1. Map of sampling stations.

Evaluation Methods

Three documented methods evaluated in this study were C_d, HPI and HEI developed or proposed earlier [5, 10, 11].

The Contamination Index (C_d)

In this method, the water quality is assessed by the calculation of the degree of contamination and computed separately for each sample of water analyzed, as a sum of the contamination factors of individual components exceeding the upper permissible value was taken as the maximum admissible concentration (MAC). Hence, the C_d summarizes the combined effects of several quality parameters considered harmful to household water. The C_d is calculated from equation below:

$$C_d \sum_{i=1}^{n} C_{fi},$$

where

$$C_{fi} = \frac{C_{Ai}}{C_{Ni}} - 1$$

where C_{fi} is contamination factor for the i-th component, C_{Ai} is analytical value for the i-th component and C_{Ni} is upper permissible concentration of the i-th component (N denotes the 'normative value') [10, 12].

The resultant C_d value which are grouped into three categories as follows: $C_d< 1$ (low), $C_d= 1\text{-}3$ (medium) and $C_d> 3$ (high) [10, 13].

Heavy Metal Pollution Index (Hpi)

This index indicate the total quality of water with respect to heavy metals and based on weighted arithmetic quality mean method and developed in two steps. First by establishing a rating scale for each selected parameter-giving weightage and second by selecting the pollution parameter on which the index is to be based. The rating system is an arbitrarily value between zero to one and its selection depends upon the importance of individual quality considerations in a comparative way or it can be assessed by making values inversely proportional to the recommended standard (S_i) for the corresponding parameter as proposed earlier [10, 12, 14, 15]. The HPI model [15] is calculated from equation below:

$$HPI = \frac{\sum_{i=1}^{n} W_i Q_i}{\sum_{i=1}^{n} W_i},$$

Q_i= the sub-index of the ith parameter,
W_i= the unit weightage of the ith parameter,
n= the number of parameters considered,

The sub-index (Qi) of the parameter is calculated by

where

$$Q_i = \sum_{i=1}^{n} \frac{\{M_i(-)I_i\}}{(S_i - I_i)} \times 100,$$

M_i= the monitored value of heavy metal of ith parameter,

I_i= the ideal value of the ith parameter,

S_i= the standard value of the ith parameter. The sign (−) indicates numerical difference of the two values, ignoring the algebraic sign.

HPI <100 indicated that low heavy metal pollution, HPI= 100 indicated that heavy metal pollution on the threshold risk and HPI> 100 indicated that high heavy metal pollution (critical pollution index). If the HPI values of water samples were greater than 100, water is not potable [5, 10, 12, 15].In computing the HPI for the present study, As, Zn, Pb and Cu were used. The weightage was taken as the inverse of MAC, S_i the WHO standard for drinking water and I_i the guide value for the selected element.

Heavy Metal Evaluation Index (Hei)

Heavy metal evaluation index with focus on heavy metals in water samples for estimating the water quality [16]. This index classify into three categories, which include HEI <400 (low heavy metals), 400 <HEI< 800 (moderate to heavy metals) and HEI> 800 (high heavy metals). The index is calculated from the following equation [13]:

$$HEI = \sum_{i=1}^{n} H_c/H_{mac},$$

H_c= the monitored value of the ith parameter,

H_{mac}= the maximum admissible concentration of the ith parameter [10, 16].

RESULTS

The results of the heavy metal concentrations in ground water samples of Ghahavand Plain for spring and summer seasons are given in Table 1 and 2. Moreover, the correlation matrix between elements for spring and summer seasons is presented in Table 3 and 4.

The computed indices values for each location, correlation between index values and concentration of metal and correlation between different indices values for spring and summer seasons are presented in Tables 5 to 7 respectively.

Table 1. Concentration of As, Zn, Pb and Cu ($\mu g\ l^{-1}$) in groundwater samples collected from Ghahavand Plain in spring season.

Station	As	Zn	Pb	Cu
1	6.28	7.56	0.05	1.55
2	5.19	8.87	1.88	15.32
3	6.54	11.18	1.40	10.92
4	4.90	9.16	5.23	13.29
5	3.63	19.91	0.46	10.44
6	12.41	9.81	3.32	9.36
7	7.76	17.93	1.50	10.08
8	5.12	7.85	1.98	7.27
9	9.87	32.50	4.09	8.51
10	5.93	17.73	11.92	13.40
11	5.49	28.72	2.95	3.15
12	11.76	26.71	0.51	9.42
13	6.01	14.11	0.39	10.44
14	6.52	4.25	3.08	2.38
15	13.67	4.76	2.57	11.72
16	5.19	9.97	0.46	5.70
17	12.30	2.88	1.22	2.86
18	2.92	14.10	1.08	9.79
19	11.71	13.90	1.80	15.68
20	6.58	12.53	1.24	12.99
Mean	**7.49±3.23**	**13.72±8.14**	**2.36±2.62**	**9.21±4.23**

Table 2. Concentration of As, Zn, Pb and Cu ($\mu g\ l^{-1}$) in groundwater samples collected from Ghahavand Plain in summer season.

Station	As	Zn	Pb	Cu
1	3.10	0.74	0.52	1.63
2	5.82	9.98	1.70	1.10
3	10.59	7.92	2.52	4.91
4	13.68	5.31	1.72	2.18
5	6.58	10.28	0.21	2.13
6	12.78	3.34	0.99	2.88
7	9.06	2.58	2.21	4.21
8	13.81	5.55	3.95	9.16
9	9.92	5.83	0.58	13.67
10	9.28	6.60	2.39	13.79
11	7.28	13.82	13.68	20.08
12	13.14	3.93	1.66	14.01
13	2.97	1.68	1.53	11.08
14	9.80	3.03	1.19	5.35
15	7.02	13.35	3.48	16.10
16	7.75	4.92	4.67	17.26
17	17.16	4.29	1.31	5.45
18	2.25	17.52	2.24	6.43
19	8.80	10.58	2.48	15.83
20	9.82	10.68	6.60	18.46
Mean	**9.03±3.90**	**7.10±4.52**	**2.78±2.98**	**9.29±6.37**

Table 3. Correlation matrix between elements.

	As	Zn	Pb	Cu
		Spring		
As		-0.043	-0.018	0.030
Zn			0.136	0.082
Pb				0.265
		Summer		
As		-0.315	-0.053	-0.029
Zn			0.455*	0.323
Pb				0.644**

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Table 4. Standard used for the indices computation [10].

	W	S	I	MAC
As	0.02	50	10	50
Zn	0.0002	5000	3000	5000
Pb	0.70	100	10	1.50
Cu	0.001	1000	2000	1000

W weightage (1/MAC)
S Standard permissible in ppb
I Highest permissible in ppb
MAC Maximum admissible concentration/upper permissible

Table 5. Evaluation indices.

Station	Spring			Summer		
	C_d	HPI	HEI	C_d	HPI	HEI
1	-3.84	11.30	0.16	-3.59	11.02	0.41
2	-2.62	9.41	1.37	-2.75	9.56	1.25
3	-2.92	9.83	1.08	-2.10	8.43	1.90
4	-0.40	5.81	3.60	-2.58	9.50	1.42
5	-3.61	11.05	0.39	-3.72	11.11	0.27
6	-1.53	7.69	2.47	-3.01	10.23	0.92
7	-2.83	9.64	1.17	-2.34	8.78	1.66
8	-2.57	9.30	1.43	-1.01	7.11	2.92
9	-1.06	6.42	2.94	-3.40	10.48	0.60
10	4.07	2.67	8.08	-2.20	8.57	1.79
11	-1.91	8.23	2.08	5.29	4.47	9.29
12	-3.41	10.67	0.59	-2.61	9.53	1.38
13	-3.61	10.96	0.39	-2.91	9.94	1.09
14	-1.81	8.02	2.19	-3.00	9.46	0.99
15	-2.00	8.58	2.00	-1.52	7.55	2.48
16	-3.58	10.94	0.42	-0.71	6.22	3.29
17	-2.94	9.95	1.06	-2.78	10.19	1.22
18	-3.21	10.43	0.79	-2.45	9.22	1.55
19	-2.55	9.28	1.45	-2.15	8.51	1.85
20	-3.03	10.00	0.97	0.62	4.00	4.62
Mean	**-2.27**	**9.01**	**1.73**	**-1.95**	**8.69**	**2.04**

Table 6. Correlation between index values and concentration of metals.

Parameter	C_d		HPI		HEI	
	r	***P***	***r***	***P***	***r***	***P***
			Spring			
As	0.019	0.936	-0.072	0.762	0.019	0.935
Zn	0.136	0.567	-0.161	0.497	0.136	0.568
Pb	0.999**	0.000	-.0967**	0.000	0.999**	0.000
Cu	0.269	0.252	-0.249	0.290	0.269	0.252
			Summer			
As	-0.010	0.966	-0.035	0.883	-0.014	0.952
Zn	0.442	0.051	-0.421	0.065	0.444*	0.050
Pb	0.999**	0.000	-0.872**	0.000	0.999**	0.000
Cu	0.644**	0.002	-0.719**	0.000	0.646**	0.002

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Table 7. Correlation between different indices values.

	r	*P*
	Spring	
C_d vs. HPI	-0.970**	0.000
C_d vs. HEI	1.000**	0.000
HPI vs. HEI	-0.970**	0.000
	Summer	
C_d vs. HPI	-0.876**	0.000
C_d vs. HEI	1.000**	0.000
HPI vs. HEI	-0.876**	0.000

**. Correlation is significant at the 0.01 level (2-tailed).

DISCUSSION

The results indicate that the metal (As, Zn, Pb and Cu) concentrations in groundwater samples collected from Ghahavand Plain were significantly different between sampling stations. So that metal concentrations (μg l^{-1}) in spring season ranged from 2.92 to 13.67 for As, 4.25 to 32.50 for Zn, 0.05 to 11.92 for Pb and 1.55 to 15.68 for Cu, respectively and in summer season ranged from 3.10 to 17.16 for As, 0.74 to 17.52 for Zn, 0.21 to 13.68 for Pb and 1.10 to 20.08 for Cu, respectively (Tables 1 and 2).

The results of Pearson Correlation Coefficient at 5% level of significance (P <0.05), show only significant correlation between the pairs Zn/Pb, and Pb/Cu in water samples for summer season and may indicate their common source of entry (Table 3).

The computed C_d shows that the values in spring season vary between -3.84 to 4.07 (mean -2.27) and in summer season vary between -3.72 to 5.29 (mean -1.95) and indicate low contamination. The computed HPI shows that the values in spring season vary between 2.67 to 11.30 (mean 9.01) and in summer season vary from 4.00 to 11.1 (mean 8.69) and for all the locations are lower than 100 the critical value for drinking water. The computed HEI shows that the values in spring season vary from 0.16 to 8.08 (mean 1.73) and in summer season vary from 0.27 to 9.29 (mean 2.04) and indicate low heavy metal pollution (Table 5).

Nazari and Sobhanardakani analysis of As and Zn concentrations in groundwater resources of Qaleh Shahin Plain in Kermanshah province and reported the HPI values in winter 2014 vary between 1.09 to 11.4 (mean 6.11) and in summer 2014 vary between 1.83 to 22.8 (mean 8.78) and for all the locations are lower than 100 the critical value for drinking water [17]. Sobhanardakani and Nazari analysis of Pb and Cd concentrations in groundwater resources of Qaleh Shahin Plain in Kermanshah province and reported the HPI values in winter 2014 vary between 0.32 to 7.69 (mean 4.73) and in summer 2014 vary between 8.92 to 13.90 (mean 11.74) and for all the sampling stations are lower than 100 the critical value for drinking water [18]. Hosseinpour Moghaddam et al. assessing the heavy metal (Fe, Pb, Zn, Ni, Cd, As, Cu and Cr) in adjacent groundwater resources of Khorasan Steel Complex and reported the C_d average for the region was -5.41, classified as low degree of contamination class, the mean value for HPI in the water samples was 4.88 classified as low heavy metal and the average value for HEI was 2.59 so water samples are estimating at low heavy metals level pollution and water samples of the study area have been identified suitable for drinking [13].

A comparison between the indices and heavy metal concentration show strong correlation with Pb for spring and summer samples (Table 6). This indicates that Pb is the main contributory parameters. In addition, the correlation between C_d, HPI and HEI is significant (Table 7). Therefore, the three existing methods, the Contamination index, the Heavy metal pollution index and the heavy metal evaluation index provide same results.

CONCLUSION

Heavy metal pollution was not observed in any cases. According to the water quality indices, water samples of the study area have been identified suitable for drinking but based on the correlation matrix, Pb has a great role in the quality of water samples. Therefore, the water quality indices proved to be a very useful tool in evaluating overall pollution of the ground water. However, the values of these three indices in groundwater collected from Ghahavand Plain are totally below the critical values but severe precautions consideration such as manage the use of agricultural inputs, prevention of use of wastewater and sewage sludge in agriculture, control of overuse of organic fertilizers and establishment of pollutant industries are recommended in this area.

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