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Water Quality Assessment of Groundwater Resources in Qaleeh Shahin Plain Based on C_d and HEI

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ABSTRACT

Aims The chemical elements in water resources, especially groundwater, can affect the water consumption purposes. The aim of this study was to evaluate the status of the overall pollution level of ground water of Qaleeh Shahin plain with respect to heavy metals by C_d and HEI methods.

Instrument & Methods This cross-sectional semi-experimental study was conducted in Sarpol-e Zahab township in Kermanshah Province, west of Iran. For this purpose, 20 groundwater wells were chosen randomly. The samples were filtered (0.45µm), stored in polyethylene bottles and were acidified at a pH lower than 2 by adding concentrated HNO_3 in order to avoid metal adsorption onto the inner bottle walls. Element concentrations were determined using ICP-OES. The correlation between the metals in the different seasons, between the indices values and concentration of metals and between different indices values was assessed by Pearson's correlation coefficient.

Findings There were no significant correlations between the concentrations of the elements in 2 seasons except between As and C_d in winter ($r=0.544$; $p<0.05$). Only the concentration of Pb had significant correlations with C_d ($r=0.937$; $p=0.0001$) and HEI ($r=0.997$; $p=0.0001$) values in winter and with C_d ($r=0.997$; $p=0.0001$) and HEI ($r=0.810$; $p=0.0001$) values in summer, which indicated Pb as the main contributory pollutant. The correlation between C_d and HEI was significant in winter ($r=0.943$; $p=0.0001$) and was significant in summer ($r=0.818$; $p=0.0001$).

Conclusion The water resources of Qaleeh Shahin plain, Kermanshah Province, Iran, are not polluted by heavy metals and are suitable for drinking.

Keywords Metals, Heavy; Water Pollution, Chemical; Groundwater; Iran

CITATION LINKS

[1] Assessment of arsenic, nitrate and phosphorus pollutions in shallow groundwater of the rural area in ... [2] Evaluation of heavy metal pollution index of groundwater in Tarkawa minning ... [3] Spatial distribution of fluoride in groundwater resources in selected parts of Kurdistan Province, Iran, using the geographical information ... [4] Analysis of total and dissolved heavy metals in surface water of a Mexican polluted river by total reflection X-ray fluorescence ... [5] Evaluation of water quality pollution indices for heavy metal contamination monitoring: A case study from Curtin Lake, Miri City, East ... [6] Evaluation of the heavy metal pollution index for surface and spring water near a Limeston mining area of the lower ... [7] Hazards of heavy metal ... [8] Research on accumulation of zinc (Zn) and cadmium (Cd) in sunflower ... [9] Assessment of metals (Co, Ni, and Zn) content in the sediments of Mighan Wetland using geo-accumulation ... [10] Characteristic levels of some pesticides and heavy metals in imported ... [11] Lead, cadmium and nickel in chocolate and candies from suburban areas of ... [12] Selected heavy metals analysis of Persian sturgeon's (Acipenser persicus) caviar from Southern Caspian ... [13] Lead levels of certain consumer products in Nigeria: A case study of smoked fish foods from ... [14] Safety of fresh fruits and juices available on the Polish market as determined by heavy metal ... [15] Quality assessment for Shatt Al-Arab River using heavy metal pollution index and metal ... [16] Assessing of water quality pollution Indices for hevay metal contamination: A study case from Medias City ... [17] Evaluation of the water quality pollution indices for groundwater resources of Ghahavand Plain, Hamadan Province, western ... [18] Assessment of pollution index of heavy metals in groundwater resources of ... [19] Assessment of Pb and Cd pollution in groundwater resources of Qaleeh Shahin Plain ... [20] Standard methods for examination of water ... [21] Evaluation of water quality pollution indices for heavy metal contamination monitoring ... [22] Application of a groundwater contamination index in Finland and ... [23] An index approach to metallic pollution in river ... [24] Assessing the effect of heavy metal ... [25] Trace element hydrochemical assessment of ... [26] Evaluation of water quality pollution ... [27] Comparing stress level of woman nurses of different units of Iran university hospitals in ... [28] Heavy metal pollution index of ground water ...

Introduction

The importance of water quality on human health has attracted a great deal of interest in recent years. The exploitation of groundwater for the water supply needs have been increased in the last decade in many urban and rural communities, especially in arid and semi-arid climates. In this regard, groundwater plays an important role in the social and economic development of Iran [1, 2].

The chemical elements in water resources, especially groundwater, can affect the water consumption purposes [3]. In this regards, heavy metals are of the important water quality parameters, which may also enriched in water from various resources, e.g. natural resources (chemical weathering of minerals and leaching of soil), and anthropogenic origin (domestic and industrial effluents, urban storm, runoff, waste leachate, mining activities), etc. [4]. Some of the heavy metals known as micronutrients become harmful to human health when their concentrations exceed the maximum permissible level (MPL) in drinking water [5]. Thus, monitoring the heavy metals in water resources (surface water and groundwater) used for drinking purposes assumes a great significance from the human health point of view [6].

Arsenic is a widely distributed metalloid, occurring in biosphere. The combustion of fossil fuel for production of energy and smelting of non-ferrous metals are two significant processes that lead to environment contamination, especially the source of atmospheric pollution for this element. Other sources of As are arsenical pesticides, manufacture and wood preservatives such as chromated copper arsenate [7].

Zinc is an essential structural and functional element in biological systems, which often catalyze the reactions and bind to substrates by favoring various reactions through the mediation of oxidation–reduction reactions, via reversible changes in the oxidation state of the metal ions. Of course, Zn harms some physiological activities like breathing and causes other diseases [8, 9].

Some of the toxic metals, e.g. Cd and Pb, may damage the kidney and cause symptoms of chronic toxicity, including poor reproductive capacity, impaired organ function, tumors, blood pressure, and hepatic abnormalities [10]. Moreover, Pb can also affect brain activity by interfering with neurotransmitter release and synapse formation. Exposure to Pb through the inadvertent ingestion of Pb paint, inhalation of traffic exhaust fumes and the consumption of Pb-contaminated food can cause the reduction of IQ, learning disabilities, hyperactivity, slow growth, impaired hearing and antisocial behaviors [11-13]. Cadmium as a cumulative nephrotoxicant is known as a toxic and carcinogenic element by IARC (International Agency for Research on Cancer). This element is absorbed into the body via smoking and dietary sources [14].

The pollution parameters monitored in order to assess the quality of any natural system, give an idea of the pollution with refer to a specific parameter. Quality indices are useful in obtaining a composite influence of all parameters of overall pollution and they combine all the pollution parameters into some easy approach. For heavy metal contamination evaluation, several methods, e.g. the Contamination index (C_d) and the Heavy metal Evaluation Index (HEI) were elaborated which help in assessing the present level of pollution [6, 15, 16]. In this regard, Sobhanardakani has evaluated the water quality pollution indices (C_d, HPI and HEI) for groundwater resources of Ghahavand Plain in Hamedan Province, Iran [17]. Nazari & Sobhanardakani have analyzed the As and Zn concentrations in groundwater resources of Qaleeh Shahin Plain in Kermanshah Province, Iran, by HPI [18]. Sobhanardakani & Nazari have also analyzed the Pb and Cd concentrations in groundwater resources of Qaleeh Shahin Plain, Iran, by HPI [19].

In this study, 4 important heavy metals (As, Zn, Pb and Cd) have been evaluated in 20 ground water samples, obtained from different places of Qaleeh Shahin plain (located at Sarpol-e Zahab township, Kermanshah, Iran) in 2 different seasons of 2014. The aim of this study was to evaluate the status of the overall pollution level of ground water of Qaleeh Shahin plain with respect to heavy metals by C_d and HEI methods.

Instrument & Methods

This cross-sectional semi-experimental study was conducted in Sarpol-e Zahab township in Kermanshah Province, west of Iran. The area of Qaleeh Shahin aquifer is 190 km^2 [18].

According to the Cochran's sample size formula, groundwater samples were collected from 20 different locations, including open and tube wells to evaluate the heavy metal contamination during the winter and summer 2014 (Figure 1). The sampling stations were selected based on different patterns of land use; agricultural and residential.

The samples were taken with acid washed 200ml polyethylene bottles to avoid unpredictable changes in characters as per standard procedures. The collected samples were filtered (Whatman No. 42), preserved with 6N of HNO_3 (Merck; Germany) and kept at 4°C for further analysis [20, 21]. Concentrations of heavy metals (As, Zn, Pb and Cd) in water samples were determined using ICP-OES (Varian, 710-ES; Australia). Two documented evaluation methods were used; the C_d, developed by Backman *et al.* [22], and HEI, proposed by Edet and Offiong [21]. In C_d method, the quality of water is evaluated by the calculation of the degree of contamination. The C_d is determined individually for every sample of analyzed water, as sum of the contamination factors of separate ingredients that had a very great maximum admissible concentration value. Hence, the C_d summarizes the combined effects of several quality parameters considered harmful to household purposes. The contamination index is calculated from equations 1 and 2:

$$\mathrm{Cd} = \sum_{i=1}^{n} \mathrm{Cfi} \quad (1)$$

$$\mathrm{Cfi} = \frac{\mathrm{CAi}}{\mathrm{CNi}} - 1 \quad (2)$$

Where C_{fi} indicates the contamination factor for the i-th component, C_{Ai} indicates the analytical value of the i-th component and C_{Ni} indicates the upper permissible concentration of the i-th component (50, 5000, 1.5 and 3µg/l for As, Zn, Pb and Cd, respectively) [21, 23]. The resultant C_d value identified the areas of varying contamination levels which are grouped into 3 categories; low (C_d< 1), medium (C_d= 1-3) and high (C_d> 3) [21, 24]. The upper permissible concentration value (C_{Ni}) was taken as the maximum admissible concentration (MAC).

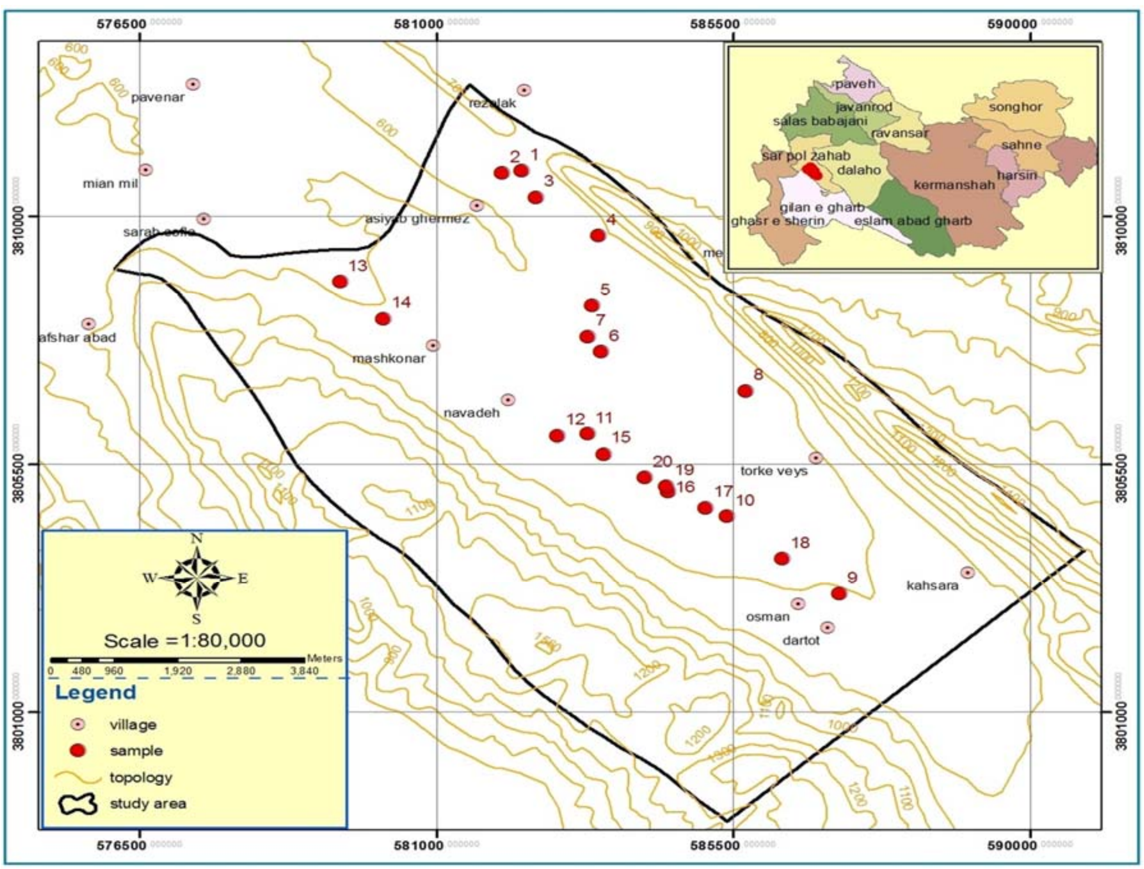

Figure 1) Map of sampling stations

HEI is a method for estimating the water quality with focus on heavy metals and classify the water quality into 3 categories; HEI<400 (low), 400<HEI<800 (moderate) and HEI>800 (high). The HEI is calculated from the equation 3 [24, 25]:

$$HEI = \sum_{i=1}^{n} \frac{Hc}{Hmac} \quad (3)$$

where H_c is the monitored value of the i-th parameter, and H_{mac} is the maximum admissible concentration of the i-th parameter [21, 25].

The statistical analysis of the obtained results consisted in a first Shapiro–Wilk normality test, followed by the study of the correlation between the metals in the different seasons, between the indices values and concentration of metals and between different indices values a Pearson's correlations study was performed.

Findings

The mean concentrations of As, Zn, Pb and Cd were 6.41±3.41, 11.21±4.83, 4.52±2.24 and 0.48±0.18µg/l in winter and 9.19±6.09, 17.32±8.71, 6.46±2.61 and 1.21±0.14µg/l in summer 2014, respectively (Figure 2). There were no significant correlations between the concentrations of the elements in 2 seasons except between As and Cd in winter ($r=0.544$; $p<0.05$).

The values of C_d were varied between -3.34 and 2.74 (-0.61±1.50) in winter and between -2.43 and 4.97 (0.90±1.74) in summer, which were both low contaminations. The HEI values were varied between 0.66 and 6.74 (3.30±1.53) in winter and between 1.56 and 7.37 (4.54±1.63) in summer, which were both low heavy metal pollutions (Figure 2).

Only the concentration of Pb had significant correlations with C_d ($r=0.937$; $p=0.0001$) and HEI ($r=0.997$; $p=0.0001$) values in winter and with Cd ($r=0.997$; $p=0.0001$) and HEI ($r=0.810$; $p=0.0001$) values in summer, which indicated Pb as the main contributory pollutant.

The correlation between C_d and HEI was significant in winter ($r=0.943$; $p=0.0001$) and was significant in summer ($r=0.818$; $p=0.0001$).

Figure 2) Concentration of As, Zn, Pb and Cd (µg/l) in groundwater samples collected from Qaleeh Shahin plain in Winter and Summer 2014 and the values of evaluation induces

Station	Winter						Summer					
	As	Zn	Pb	Cd	C_d	HEI	As	Zn	Pb	Cd	C_d	HEI
1	1.50	17.40	1.47	0.39	-2.86	1.14	3.74	10.90	5.74	1.23	0.31	4.31
2	10.20	13.70	5.78	0.67	0.28	4.28	5.15	11.90	1.55	1.28	-2.43	1.56
3	5.70	12.00	2.11	0.58	-.2.28	1.72	12.30	19.10	6.69	1.18	1.10	5.10
4	5.84	12.20	3.52	0.14	-1.49	2.51	4.32	12.40	12.70	1.25	4.97	4.74
5	9.06	1.22	0.47	0.50	-3.34	0.66	23.30	16.20	4.45	1.29	-0.13	3.86
6	6.78	7.99	5.04	0.33	-0.39	3.61	7.22	16.30	6.75	1.35	1.10	5.10
7	4.25	19.40	4.66	0.50	-0.64	3.36	20.50	16.50	8.35	1.28	2.41	6.41
8	3.90	5.52	5.05	0.55	-0.37	3.63	1.89	15.80	5.12	1.24	-0.13	3.87
9	1.11	15.30	3.62	0.22	-1.49	2.51	8.46	27.90	4.14	1.49	-0.57	2.05
10	7.01	11.28	3.02	0.11	-1.81	2.20	9.90	14.00	4.82	1.07	-0.23	2.16
11	2.25	7.07	4.92	0.38	-0.55	3.45	12.50	15.10	5.55	0.93	0.26	4.26
12	11.90	8.24	2.25	0.58	-2.07	1.93	7.42	22.30	9.26	1.12	2.70	6.70
13	1.56	5.56	6.58	0.40	0.55	4.55	5.26	48.60	6.72	1.30	1.03	5.03
14	8.44	10.00	2.77	0.52	-1.81	2.19	13.30	19.50	6.02	1.32	0.72	4.72
15	6.24	4.10	3.39	0.67	-1.39	2.61	19.80	9.82	7.67	1.03	1.85	5.85
16	9.80	14.90	6.23	0.76	0.60	4.60	5.28	22.00	9.57	1.15	2.87	6.87
17	6.27	14.00	6.64	0.45	0.70	4.70	6.72	10.50	6.16	1.20	0.64	4.64
18	10.00	14.40	9.52	0.58	2.74	6.74	7.73	10.30	10.20	1.23	3.37	7.37
19	12.00	15.60	7.67	0.77	1.61	5.61	1.92	13.40	4.43	0.97	-0.67	3.32
20	4.40	14.30	5.74	0.52	0.09	4.10	7.16	13.80	3.36	1.33	-1.17	2.83

Discussion

In order to assess the groundwater resources of Qaleeh Shahin plain, 20 groundwater samples were taken. 4 elements, including As, Zn, Pb and Cd in the samples were measured for calculating of C_d and HEI indices. Based on the results, heavy metal pollution was not observed in any cases.

The values of C_d and HEI indices were to be found in the range of -3.34 to 2.74 and 0.66-6.74, respectively, in winter. The highest values of C_d and HEI were found in the sample collected from station number 18, while during summer the values of same indices are increased up to -2.43-3.37 and 1.56 to 7.37, respectively. The highest values of C_d and HEI in this season were found in the sample collected from station number 18 again. The higher values of C_d and HEI may be attributed to agricultural activities during spring and summer. Lower C_d and HEI values in winter indicates the dilution affect due to seepage or percolation of rain water. The C_d and HEI values of the samples within study area are found below the critical pollution index (100), and this indicates the water is not critically polluted with respect to studied heavy metals.

Sobhanardakani has evaluated the water quality pollution indices for groundwater resources of Ghahavand Plain in 2012 and has reported the mean values of C_d, HPI and HEI in spring samples as -2.27, 9.01 and 1.73, respectively and in summer samples as -1.95, 8.69 and 2.04, respectively that indicates low contamination levels [17]. Nazari and Sobhanardakani have analyzed As and Zn concentrations in groundwater resources of Qaleeh Shahin plain in Kermanshah province of Iran and have reported the HPI values between 1.09 to 11.4 in winter and between 1.83 to 22.8 in summer. The HPI of all locations are lower than the critical value (100) for drinking water [18]. Sobhanardakani and Nazari have also analyzed Pb and Cd concentrations in groundwater resources of Qaleeh Shahin plain in Kermanshah province of Iran and have reported the HPI values between 0.32 to 7.69 and between 8.92 to 13.90 in summer. The HPI of all sampling stations are lower than the critical value (100) for drinking water [19].

Singh Brraich & Jangu have monitored the heavy metal contamination in the water of Harike Wetland, India using C_d, HPI and HEI indices [26]. They have reported that the water samples of study area exhibits high concentration of Cd, Cu, Pb, Cr, Ni, Co and Fe. The mean of Cd, HPI and HEI is 44.85, 1304.65 and 45.85, respectively. Prasad *et al.* have used HPI for groundwater quality evaluation near mining area in India [27]. They have shown that the HPI of summer and winter seasons are 6.2044 and 3.2028 which is lesser than the mean HPI and percentage deviation is −10.8511 and −53.9801, respectively. Prasad & Sangita have used HEI for groundwater quality assessment of an abandoned open cast mine filled with fly ash in India [28]. The HPI of the ground water of the ash filled mine was 36.67, which was below the critical index limit of 100.

Based on the correlation matrix, Pb had a great role in the quality of water samples. Therefore, the water quality indices proved to be a very useful tool in evaluating the overall pollution of the groundwater. However, the values of these two indices in collected groundwater samples from Qaleeh Shahin plain are totally below the critical values. This indicates the water is not critically polluted with respect to heavy metals, but severe precautions such as managing the use of agricultural inputs, use of wastewater and sewage sludge in agriculture, over use of organic fertilizers and establishment of pollutant industries must be taken into consideration in this area.

Conclusion

The water resources of Qaleeh Shahin plain, Kermanshah Province, Iran, are not polluted by heavy metals and are suitable for drinking.

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