Original Article

Survey on the Geo-statistical Distribution of Heavy Metals Concentration in Sistan and Baluchistan's Groundwater via Geographic Information System, Iran

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Abstract

Background and purpose: The rapid urbanization and industrialization in many parts of the world have led to the accumulation of heavy metals in the terrestrial environment and pose a serious threat to human health. In this study, a broad assessment was conducted to estimate the levels of heavy metals in groundwater in Sistan and Baluchestan via geographic information system (GIS), Iran, geo-statistical distribution of these contaminants was delineated in affected areas.

Materials and Methods: In this study, a total of 357 water samples were collected from designated wells in the area and transported to laboratory according to standard methods. The levels of heavy metals including chromium, cadmium (Cd), lead (Pb), and aluminum were measured by atomic absorption spectrometry. The findings were compared with the Standard values recommended by the Institute of Standards and Industrial Research of Iran, United States Environmental Protection Agency and World Health Organizations. Moreover, employing GIS software, the geo-statistical distribution of heavy metals concentration in groundwater in Sistan and Baluchestan was revealed.

Results: In the whole samples, the concentrations of two elements, Pb and Cd, were 31.9% and 40.3%, respectively, which were higher than the maximum permissible limits. The rest of the study variables showed to be within the standards/guidelines recommended by international organizations.

Conclusion: Heavy metal levels in groundwater of most study areas were compatible with advised international criteria that indicate a very slight influence of industrialization in the area. Relatively high concentrations of Pb and Cd in few locations suggest the state authorities to give more attentions in developing plans, and consider sustainable development in the area.

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Key words: Heavy Metal, Lead, Cadmium, Chromium, Aluminum, Groundwater, Sistan and Baluchestan (Iran)

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1. Introduction

Providing safe drinking water is one of the key elements to protect public health. Environmental pollutants cause significant threats to freshwater sources, living organisms, and human health (1). In a recent century, heavy metal contamination of water bodies has been receiving tremendous attentions all over the globe due to its toxicity, abundance, and bioaccumulation nature (2,3). Heavy metals are the elements having atomic weight between 63.5 and 200.6 g and a specific gravity < 5.0 (4). Natural means (weathering and erosion of bed rocks and ore deposits) and anthropogenic activities (mining, industries, wastewater irrigation, and agricultural activities) are two main sources which have been posed the presence of heavy metals in water bodies (5).

It is reported that severe systematic health problems can appear in human body as a result of excessive dietary accumulation of heavy metals such as Cd and Pb (6). Other trace elements being worldwide concerns include aluminum (Al), chromium (Cr), arsenic, and so on (7,8). Furthermore, exposure to the high amount of heavy metals can arise serious problems to human such as neurotoxic, nephrotoxic, carcinogenic effects, impairment of cardiovascular system function, etc. (9). The intense effects of heavy metals on human body are not only due to the consumption of heavy metal via contaminated water but also irrigation of lands with polluted water releases heavy metals to the soil. The presence of elevated metal concentration can disrupt the soil microbial processes, occasionally leads to serious ecosystem disturbance (10). On the other hand, accumulation of heavy metal in soil is a potential risk to plants, carnivores and human, or food chain. Therefore, accurate determination of heavy metals has tremendously become necessary to solve the problems associated with the pollution of water bodies (7).

The distribution of heavy metals in water resources has been widely investigated around the world (11,12) but there is few information about this issue in Iran. The distribution of heavy metals using geographic information system (GIS) methods was conducted in many studies (13,14). Some applications of GIS can be referred to the capability of this tool for measuring, modeling, manipulation, retrieval, and analysis of spatial data. Additionally, identification of the most sensitive points that need immediate attention is conducted by GIS that helps to decision-making process. Despite the large array of researches carried out in Iran to investigate point sources and generation of contaminant levels, there is no adequate information about geo-statistical distribution of pollutants, particularly heavy metals, in the study area.

The main objective of this study was to determine geo-statistical distribution of lead (Pb), cadmium (Cd), Cr and Al heavy metals in water resources of Sistan and Baluchestan, Iran using GIS software, and relating the findings to Standard values recommended by the Institute of Standards and Industrial Research of Iran (ISIRI), United States Environmental Protection Agency (EPA), and World Health Organization (WHO) organizations

2. Materials and Methods

Sistan and Baluchestan is the largest province of Iran that located in south east of Iran between 25°03' and 31°28' northern latitudes and 58°47' and 63°19' eastern longitudes. It is one of the driest regions of Iran. This district is divided into 9 counties and the capital of it is Zahedan (Figure 1). In this study, the concentrations of heavy metals including Pb, Cd, Cr, and Al in water resources of Sistan and Baluchestan were conducted in autumn 2014. For this purpose, 357 samples of fresh water from all over 5000 wells according to the following formula (Eq. 1) with significance level 5% from various and possible location of ground waters of Sistan and Baluchestan resources, as much as possible due to security issues, according to standard methods were collected and tested. Because the region's surface water resources are seasonal, generally the groundwater resources are used for all purposes, including drinking and agricultural. In this study, all of them used water for drinking. All samples were stored in a cool box and then pass on to the laboratory in standard conditions. Preparation of samples procedure was considered in all of steps, including collection, storage, transportation, and final analysis to protect samples from secondary pollution. At the end, the contents of contaminants were analyzed using graphite furnace atomic absorption spectrometry (Perkin Elmer AA-Analyst 200). A handheld global positioning system (GPS, Garmin Montana 650 model) with position accuracy of less than 10 m was applied to specify the location of sampling points. The sampling locations are shown in figure 1. Finally, GIS was used to plot the geo-statistical distribution of heavy metals polluted ground water, and additionally, to identify the areas with maximum level of pollutants.

$$n = \frac{\frac{z^2pq}{d^2}}{1+\frac{1}{N}\left(\frac{z^2pq}{d^2}-1\right)} \quad (1)$$

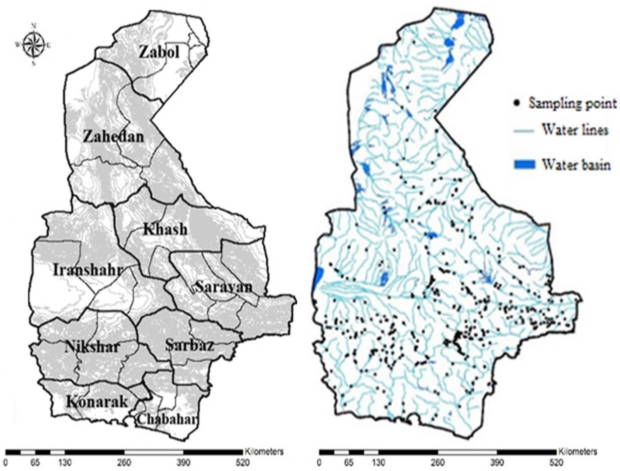

Figure 1. Sampling points in Sistan and Baluchestan

3. Results

Rajaei et al. in 2010 at one study concentration of heavy metals in Chahnimeh water reservoirs of Sistan and Baluchestan has been evaluated (15). In result of it, they were reported that Cd and Pb concentration in Chahnimeh was beyond the level of WHO standard recommendation. So in order to re-asses the findings of their research this study was investigated to survey the Geo-statistical distribution of Cd, Cr, Pb, and Al heavy metals concentration in groundwater of Sistan and Baluchistan via GIS. Table 1 shows the levels of Cd, Cr, Pb, and Al in groundwater resources of Sistan and Baluchistan in 9 different locations. The given results in table 1 demonstrate that the highest and lowest amounts of Cd were detected 7.48 µg/l in Khash and 2.21 µg/l in Sarbaz region. Among all of those, Pb was identified as the most polluting element (61.84 µg/l) in analyzed samples to compare with other elements. On the basis of results, 40.30% of samples exceeded the maximum permissible limit recommended for Cd. The same information for other elements is available in table 2.

Figure 2 illustrates the geo-statistical distribution of heavy metals concentration according to sampling points. Based on the present investigations, the value was below the maximum allowable limit for most point except for three samples that exceeded the recommended values. Two of them belonged to Khash and one sample was related to Nikshahr.

4. Discussion

The discharge of effluents to receive waters may contaminate the water resources to heavy metals and they can cause to deterioration of drinking water quality and the incidence of the illness in humans. Therefore, survey and tracked the heavy metal concentration in water resources is the main objective of many researchers. EPA and WHO have suggested

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maximum acceptable concentration for the presence of heavy metals in water resources. ISIRI also determined standard values. The recommended values given by these organizations are followed in table 2.

Cd considered as the heavy metal that is the most toxic. Cd releases to the environment as a result of industrial activities such as mining, plating process, the use of phosphate fertilizer (16). Cd is caused global concern due to its much higher toxicity than those of other heavy metals and threatens public health (9). Maximum permissible limit of Cd for drinking water is 5 µg/l (17). Excess exposure to Cd may Pb to diseases such as Itai-Itai, renal damage, and hypertension (18).

Table 1. Trace metal contents in ground water resources of Sistan and Baluchestan counties, Iran (µg/l)

Counties	Samples number	Statistical parameters	Cr	Cd	Pb	Al
Iranshahr	40	Max	52.36	6.12	49.00	23.00
		Min	0	0	0	1.00
		Mean ± SD	12.66 ± 14.28	3.04 ± 1.48	18.74 ± 14.45	5.91 ± 4.08
Chabahar	17	Max	42.89	6.12	37.25	25.00
		Min	0.14	2.66	0.09	3.00
		Mean ± SD	5.48 ± 7.70	4.03 ± 1.00	6.03 ± 12.70	7.18 ± 4.75
Khash	35	Max	41.50	7.45	61.84	23.00
		Min	2.03	0	0.28	1.00
		Mean ± SD	7.64 ± 7.49	2.33 ± 1.94	10.16 ± 14.20	5.53 ± 4.00
Zabol	1	Max	0.35	2.14	15.54	9.40
		Min	0.29	1.49	12.30	0.50
		Mean ± SD	0.38 ± 4.27	19.08 ± 0.29	12.80 ± 2.02	7.00 ± 2.42
Zahedan	30	Max	41.34	6.14	54.38	32
		Min	2.00	0.93	0.15	1.00
		Mean ± SD	13.41 ± 129	3.19 ± 241.00	13.66 ± 15.40	6.02 ± 7.39
Saravan	83	Max	46.81	6.73	53.17	36.00
		Min	0.03	0	0	1.00
		Mean ± SD	4.31 ± 5.30	2.6 ± 1.6	7.95 ± 13.00	5.45 ± 5.19
Sarbaz	72	Max	23.00	7.04	33.87	20.00
		Min	0.02	0.12	0	1.00
		Mean ± SD	3.72 ± 4.00	2.21 ± 1.40	6.71 ± 6.20	5.67 ± 4.12
Konarak	12	Max	8.14	5.73	44.53	14.00
		Min	1.60	1.09	0.10	2.00
		Mean ± SD	4.61 ± 7.60	3.38 ± 2.80	11.11 ± 8.30	6.17 ± 3.20
Nikshahr	67	Max	20.00	6.39	38.14	28.00
		Min	0.49	0	0.01	1.00
		Mean ± SD	4.59 ± 3.75	2.23 ± 1.68	7.08 ± 8.80	5.45 ± 4.12
Total	357	Max	52.36	7.45	61.84	36.00
		Min	0	0	0	1.00
		Mean ± SD	6.40 ± 8.05	2.60 ± 1.60	9.68 ± 12.38	5.67 ± 4.53
Number of samples exceeded maximum permissible levels (%)			0.44	40.30	31.90	0

SD: Standard deviation; Cd: Cadmium; Cr: Chromium; Pb: Lead, Al: Aluminum; Max: Maximum; Min: Minimum

Table 2. Maximum acceptable concentration of heavy metals in water supplies reported by national and international organizations, (µg/l)

Organizations	Pb	Cd	Cr	Al
WHO	10	3	50	50-200
USEPA	15	5	100	50-200
ISIRI	10	3	50	100

WHO: World Health Organization, USEPA: United States Environmental Protection Agency, ISIRI: Institute of Standards and Industrial Research of Iran

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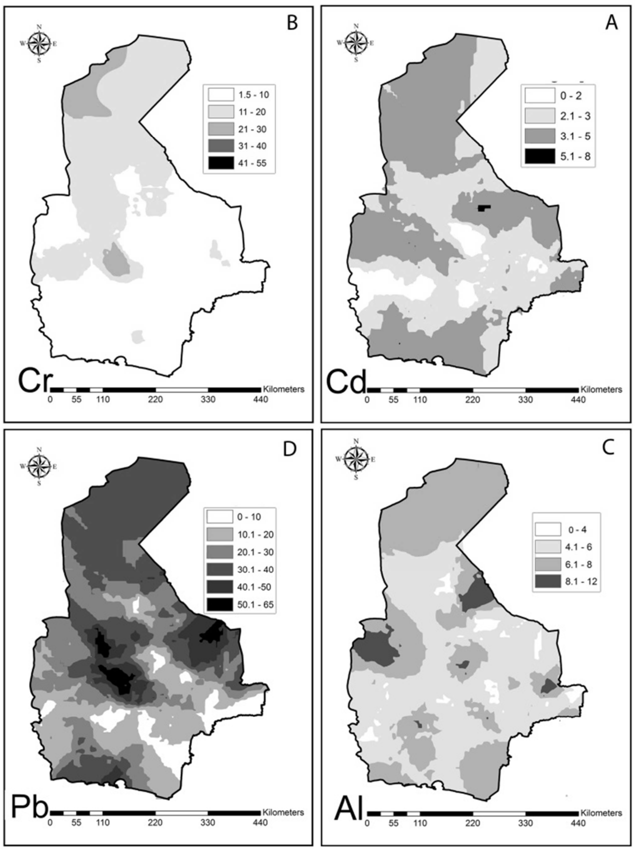

Figure 2. Distribution of heavy metal concentrations in groundwater of Sistan and Baluchestan (µg/l)

According to obtained results, around 40% of analyzed samples exceeded the maximum per liter (MPL). The analyzed data revealed that the highest and lowest amounts of Cd were 7.48 µg/l in Khash and 2.21 µg/l in Sarbaz. Among all mentioned heavy metals, Pb was identified as the most polluting element (61.84 µg/l) in analyzed samples in compare with other elements. The level of Pb in earth's crust is about 20 µg/g (19). The average content of Pb in sandstone, basaltic, granitic and carbonate rocks is 13.7, 3.7, 23, and 5.6 mg/l, respectively (20). It is identified as a general metabolic poison and enzyme inhibitor. Long term exposure to high level of Pb can cause severe disorders such as anemia, kidney disease and mental retardation (21). The entrance of polluted effluent from industries such as acid battery manufacturing, metal plating, and finishing to the water stream is the major sources of Pb contamination. The maximum allowable concentration for Pb in drinking water is 10 µg/l (22). As shown in tables 1 and 2, figure 2, average content and standard deviation of Pb in all collected samples were 9.68 ± 12.38 µg/l and maximum level (61.84 µg/l) was found in water resources of Khash. These amounts were obtained around 54.38 and 53.17 µg/l for Zahedan and Saravan districts, respectively. These levels of pollutants are higher than recommended values. Based on investigations, no industrial sources were found in areas to threaten water resources. As a result, water pollution may be correlated to presence of andesite, basalt, dacite, pegmatite, diorite, and granodiorite rocks in mentioned regions. At the end, replacement of new pure sources or application of water treatment methods providing safe drinking water seem necessary. Cr exists in several valence state. The trivalent state is the one, mostly found in foods and supplements while the hexavalent state recognized as toxic and carcinogenic element. This pollutant is entered into the water environment by industries using Cr in electroplating, leather tanning, metal finishing, and chromate preparation (23). Cr is considered as a powerful carcinogenic agent by International Agency for Research on Cancer (IARC) (24,25). The maximum allowable limit has been reported 100 µg/l for hexavalent Cr in drinking water (26). The average concentration of Cr in earth's crust is about 100 µg/g and is higher in basaltic rocks with average concentration of 200 µg/g than in granite rocks which have average content of about 10 µg/l (27). According to tables 1 and 2, figure 2, Mean concentrations and standard deviation of total experimented samples were 6.40 ± 8.05 µg/l and maximum value was detected 52.36 µg/l in Iranshahr. High concentration of Cr in water samples of Iranshahr can be related to the presence of chromite in geological structure of soils due to the existence of andesite, basalt, diorite, and granodiorite rocks in soils of this region as well as agricultural activities and hence, there is no industrial activity around the region so increases the possibility of its pollution by aforementioned approaches. Although these values are lower than maximum allowable limit recommended, it seems essential to find secure sources providing public health. The results showed that 40.30%, 31.9%, and 0.44% of samples were exceeded the maximum permissible limit recommended for Cd, Pb, and Cr, respectively. Al is one of the most abundant elements in the earth's crust. Formerly, it seems to be nontoxic. But recently, it has been explored that can cause severe damages to hemodialysis patients such as injury to bone, liver, and erythropoietin organs. Because of the health risk of this element to human health, maximum permissible limit is determined 200 μg/l in drinking water (28,29). On the basis of results demonstrated in tables 1 and 2, figure 2, mean concentration and standard deviation of Al in all investigated samples were 5.67 ± 4.53 μg/l. Moreover, maximum amount (32 μg/l) was detected in water resources of Saravan. These values are below the reported contents determined by global organizations. So, there is no serious risk to human health. Consequently, acquired results from this study showed that among all, investigated Al metal levels were thoroughly compatible with amounts suggested by health organizations in water matrices. The Cr concentration, in 99.56% of samples were below the maximum limit for drinking water. Additionally, Pb and Cd existed in 31.9% and 40.3% of samples was more than contents have been allowed by international organizations, respectively. Thus, it requires vast researches on discovering original sources polluting waters. So the result revealed that the levels of heavy metal concentration in Sistan and Baluchestan groundwater in most of study areas were compatible with advised international criteria which indicate a very slight influence of industrialization in the area. Relatively, high concentrations of Pb and Cd in few locations suggest the state authorities to give more attentions in developing plans, and consider sustainable development in the area.

Conflict of Interests

The Authors have no conflict of interest.

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References

1. Zhuang P, Zou H, Shu W. Biotransfer of heavy metals along a soil-plant-insect-chicken food chain: field study. J Environ Sci (China) 2009; 21(6): 849-53.
2. Islam MS, Ahmed MK, Raknuzzaman M, Al Mamun M, Islam MK. Heavy metal pollution in surface water and sediment: A preliminary assessment of an urban river in a developing country. Ecological Indicators 2015; 48: 282-91.
3. Muhammad S, Shah MT, Khan S. Health risk assessment of heavy metals and their source apportionment in drinking water of Kohistan region, northern Pakistan. Microchemical Journal 2011; 98(2): 334-43.
4. Fu F, Wang Q. Removal of heavy metal ions from wastewaters: a review. J Environ Manage 2011; 92(3): 407-18.
5. Duruibe JO, Ogwuegbu MOC, Egwurugwu JN. Heavy metal pollution and human biotoxic effects. International Journal of Physical Sciences 2007; 2(5): 112-8.
6. Zhuang P, McBride MB, Xia H, Li N, Li Z. Health risk from heavy metals via consumption of food crops in the vicinity of Dabaoshan mine, South China. Sci Total Environ 2009; 407(5): 1551-61.
7. Chen D, Hu B, Huang C. Chitosan modified ordered mesoporous silica as micro-column packing materials for on-line flow

injection-inductively coupled plasma optical emission spectrometry determination of trace heavy metals in environmental water samples. Talanta 2009; 78(2): 491-7.
8. Sobhanardakani S, Zandipak R. Adsorption of Ni(II) and Cd(II) from aqueous solutions using modified rice husk. Iran J Health Sci 2015; 3(1): 1-9.
9. Kaplan O, Yildirim NC, Yildirim N, Cimen M. Toxic elements in animal products and environmental health. Asian Journal of Animal and Veterinary Advances 2011; 6(3): 228-32.
10. Sobhanardakani S, Zandipak R, Javanshir-Khoei A, Hosseini SM, Moslemi M, Delfieh P. Removal of Hg(II) and Cd(II) ions from aqueous solution using chitosan: kinetics and equilibrium studies. Iran J Health Sci 2015; 3(2): 21-30.
11. Facchinelli A, Sacchi E, Mallen L. Multivariate statistical and GIS-based approach to identify heavy metal sources in soils. Environ Pollut 2001; 114(3): 313-24.
12. Li X, Lee SL, Wong SC, Shi W, Thornton I. The study of metal contamination in urban soils of Hong Kong using a GIS-based approach. Environ Pollut 2004; 129(1): 113-24.
13. Zhou F, Guo H, Hao Z. Spatial distribution of heavy metals in Hong Kong's marine sediments and their human impacts: a GIS-based chemometric approach. Mar Pollut Bull 2007; 54(9): 1372-84.
14. Herpin U, Berlekamp J, Markert B, Wolterbeek B, Grodzinska K, Siewers U, et al. The distribution of heavy metals in a transect of the three states the Netherlands, Germany and Poland, determined with the aid of moss monitoring. Science of the Total Environment 1996; 187(3): 185-98.
15. Rajaei Q, Jahantigh H, Mir A, Hesari Motlagh S, Hasanpour M. Evaluation of concentration of heavy metals in Chahnimeh water reservoirs of Sistan-va-Baloochestan Province in 2010. J Mazandaran Univ Med Sci 2012; 22(90): 105-12. [In Persian]
16. Rashed MN. Cadmium and lead levels in fish (Tilapia nilotica) tissues as biological indicator for lake water pollution. Environ Monit Assess 2001; 68(1): 75-89.
17. Amouei AI, Amooey AA, Asgharzadeh F. A study of cadmium removal from aqueous solutions by sunflower powders and its modeling using artificial neural network. Iran J Health Sci 2013; 1(3): 28-34.
18. Kumar U, Bandyopadhyay M. Sorption of cadmium from aqueous solution using pretreated rice husk. Bioresour Technol 2006; 97(1): 104-9.
19. Casas JS, Sordo J. Chemistry, analytical aspects, environmental impact and health effects. Philadelphia, PA: Elsevier; 2011.
20. Morrison RD, Murphy BL. Environmental forensics: contaminant specific guide. London, UK: Academic Press; 2010.
21. Li YH, Wang S, Wei J, Zhang X, Xu C, Luan Z, et al. Lead adsorption on carbon nanotubes. Chemical Physics Letters 2002; 357(3-4): 263-6.
22. Goel J, Kadirvelu K, Rajagopal C, Kumar G, V. Removal of lead(II) by adsorption using treated granular activated carbon: batch and column studies. J Hazard Mater 2005; 125(1-3): 211-20.
23. Rengaraj S, Joo CK, Kim Y, Yi J. Kinetics of removal of chromium from water and electronic process wastewater by ion exchange resins: 1200H, 1500H and IRN97H. J Hazard Mater 2003; 102(2-3): 257-75.
24. Benoit DA, Mattson VR, Olson DL. A continuous-flow mini-diluter system for toxicity testing. Water Research 1982; 16(4): 457-64.
25. International Agency for Research on Cancer (IARC). Chromium, nickel and welding. IARC Monogr Eval Carcinog Risks Hum 1990; 49: 1-648.
26. Pagana AE, Sklari SD, Kikkinides ES, Zaspalis VT. Microporous ceramic membrane technology for the removal of arsenic and chromium ions from contaminated water. Microporous and Mesoporous Materials 2008; 110(1): 150-6.
27. Izbicki JA, Ball JW, Bullen TD, Sutley SJ. Chromium, chromium isotopes and selected trace elements, western Mojave Desert, USA. Applied Geochemistry 2008; 23(5): 1325-52.
28. Ebina Y, Okada S, Hamazaki S, Midorikawa O. Liver, kidney, and central nervous system

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toxicity of aluminum given intraperitoneally to rats: a multiple-dose subchronic study using aluminum nitrilotriacetate. Toxicol Appl Pharmacol 1984; 75(2): 211-8.

29. Mohammadpourfard I, Shariatifar N, Jahed-Khaniki GhR, Ebadi-Fathabad E. Determination of heavy metals in apricot (Prunus armeniaca) and almond (Prunus amygdalus) oils. Iran J Health Sci 2015; 3(1): 18-24.