Assessment of Heavy Metals Concentrations in Groundwater- Kefal District A Case Study

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Abstract:

The purpose of current study is zoning and determining the concentration of heavy metals including Manganese (Mn), Lead (Pb), Cadmium (Cd), Copper (Cu), Iron (Fe), Zinc (Zn), and Boron (B) in the groundwater resources of Al-Kefal area located around the area in the southern part of Babil governorate. The amounts of heavy metals in the collected samples were determined by the Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) technique. The maximum concentrations of Mn, Pb , Cd , Cu, Fe, Zn, and B were 6.0, 4.0 , 0.05, 1.6, 4.6 and 3.5 mg/l, respectively. The correlation analysis shows highly positive correlation between Cadmium, Copper and Iron, and Boron shows high correlation with lead. The area of Tarabls primary S 1 and well no. 14 recognized as a highly polluted by heavy metals. The results of PCA recognized three factors i,e, D1, D2, D3, based on factor loading and factor scores, D1 indicate that well no. 14 is highly polluted by Mn, Cd, and Fe , while D2 shows well nos. 3-6 and 12 are highly polluted by B and Lead, whereas, D3 recognized wells nos, 1 and 15 are highly polluted by Cu.

Keywords: Heavy metals Groundwater,

قييم تركيزات المعادن الثقيلة في المياه الجوفية– منطقة كيفال دراسة حالة

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الملخص:

الغرض من الدراسة الحالية هو تقسيم المناطق وتحديد تركيز المعادن الثقيلة بما في ذلك المنغنيز (Mn)والرصاص (Pb) والكادميوم (Cd) والنحاس (Cu) والحديد (Fe) والزنك (Zn) والبورون (B) في مصادر المياه الجوفية لمنطقة الكفل الواقعة حول المنطقة في الجزء الجنوبي من محافظة بابل. تم تحديد كميات المعادن الثقيلة في العينات التي تم جمعها بواسطة تقنية قياس طيف الانبعاث البصري للبلازما المقترنة بالحث .(ICP–OES) كانت التركيزات القصوى من Mn و Pb و Cd و Cu و Fe و Zn و B 6.0و ٤.٠ و ٠.٠٠٥ و ١.٦ و ٤.٦ و ٣.٥ ملغم / لتر على التوالي. يُظهر تحليل الارتباط ارتباطًا إيجابيًا للغاية بين الكادميوم والنحاس والحديد ، ويظهر البورون ارتباطًا كبيرًا بالرصاص. منطقة طرابلس S 1 وبئر رقم. ١٤ المعترف بها على أنها شديدة التلوث بالمعادن الثقيلة. تعرفت نتائج PCA على ثلاثة عوامل i ، و e ، وD1 ، وD2 ، وD3 ، بناءً على تحميل العامل ودرجات العوامل ، وتشير D1إلى أنه لا يوجد كذلك. ١٤ ملوث للغاية بواسطة Mn و Cd و Fe ، بينما يظهر D2 عددًا جيدًا. ٣–٦ و ١٢ ملوثة بشدة بالنحاس B والرصاص ، بينما الآبار D3 المعترف بها رقم ١ و ١٥ ملوثة بشدة بالنحاس.

كلمات مفتاحية: المعادن الثقيلة المياه الجوفي

INTRODUCTION

The study of groundwater pollution is of great importance in hydrological studies, especially in areas that suffering from scarcity of surface water during dry seasons. The pollution of groundwater reduces the water quality for different uses. Anthropogenic activities are the main sources of groundwater pollution. Groundwater makes up 20% of the world’s fresh water supply, there is no doubt that groundwater plays a significant role in strengthening the economic growth of developing countries and where it is also indispensable for drinking, domestic use, industry, and agriculture and therefore directly or indirectly influences daily life (Liu and Ma, 2020). Groundwater as one of the natural resources is of fundamental importance to human life, because of its perceived good microbiological quality in the natural state and as a result, it is often the preferred source of drinking water supply as treatment is limited to disinfection (Edokpayi et al., 2018). Groundwater resources are mainly polluted due to anthropogenic activities such as chemical industries involved in extraction, manufacturing, and processing of minerals and chemicals, and the use of pesticides and fertilizers in the agricultural sector(Akhtar et al., 2020) Heavy metals are encountered in various emission sources related to industrial, transportation and urban activities and agricultural practices(Nouri et al., 2008) Among the various pollutants that affect water resources, pollutants containing heavy metals are particularly important due to their high toxicity, even at low concentrations (Vatandoost et al., 2018). Heavy metals are normally present in the groundwater at low concentrations(Akhtar et al., 2020). Their occurrence in water can be due to generic sources including the dissolution of natural minerals comprising heavy metals in the soil moisture zone or human activities such as the disposal of industrial waste, mining activities, ore smelting, and fertilizers (Bani, 2015). However, in several regions of the developing world, groundwater pumped from private wells is directly used for domestic purpose, including drinking. This poses a great threat in a rapidly urbanising world and results in serious concerns on the quality of water resources (Vetrimurugan et al., 2017) World Health Organisation (WHO) lists four heavy metals (arsenic, lead, mercury and cadmium) in its list of ten chemicals as a major public health concern (Vetrimurugan et al., 2017). Heavy metal (HM) contamination is one the significant health issue in the world, due to indestructibility of metals and their impact on living organism in concentration greater than thresholds and Estimation of spatial patterns of heavy metals contaminations in groundwater is an important step in the health risk assessment (Belkhiri et al., 2017). Initial information about groundwater quality characterization came from the basic statistics and correlation analysis. Moreover, multivariate statistical analysis, including cluster analysis (CA) and principal component analysis (PCA) were applied on the dataset (Belkhiri et al., 2017). Globally, the heavy metals among various contaminant contributes significant role and recognized as the most hazardous pollutants categories, remarkably due to their non-degradable nature, ecological risks, toxicity, biogeochemical recycling nature and environmental persistence (Kaur et al., 2020). Heavy metals present at trace concentrations play a major role in the metabolism and healthy growth of plants and animals. However, increased concentrations of heavy metals may have several toxicological effects on humans The area is characterized by dominant of agricultural activities that are accompanied by the use of fertilizers and pesticides (Lu et al., 2016).

The main objective of current study is to investigate and identify the pollution levels of groundwater with heavy metals based on samples collected from bore wells in study area and presenting of the statistical results on choropleth maps using GIS techniques to determine the spatial variation of heavy elements over the area.

2. STUDY AREA

The study was conducted on area in the southern part of Babil governorate and bounded between latitudes 32° 11'00" to 32° 23' 00" N and longitudes 44° 17' 00" to 44° 52' 00" E and cover an area about (1862) square kilometers (Figure 1). The selected Al-Kefal area is located on either side of the road that connects Babil and Najaf Governorates. The dominant land use in the area is agriculture fields. Geologically, the recent sediment and quaternary deposits are exposed in study area (Jassim and Goff, 2006).

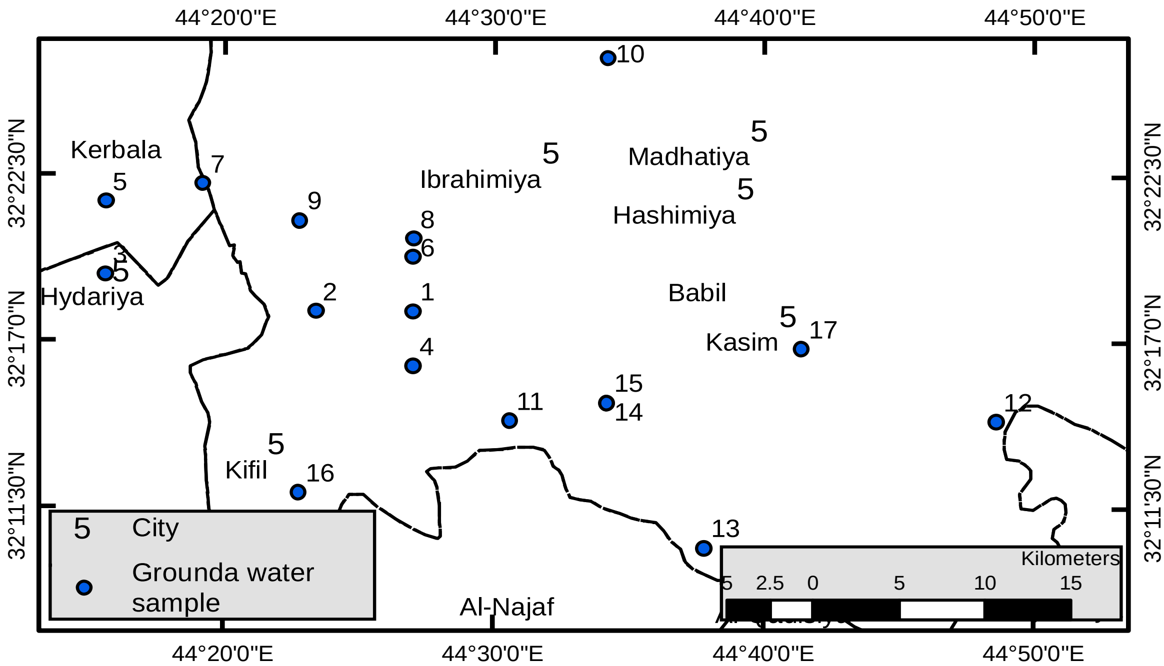

Figure 1. Location map of study area

3. DATA AND METHOD OF ANALYSIS

3.1 Collection of data

The sample containers were washed three times with distilled water and from each well 1.5 liter of water sample was obtained. The samples were acidified to a pH less than 2 with concentration with nitric acid at collection sites, transported to laboratory and then stored in a refrigerator at approximately –20□C to prevent change in volume due to evaporation (Nouri et al., 2008).

3.2 Method of analysis

The collected water samples are analysed using Phoenix-986 AAS Atomic Absorption Spectrophotometer and seven heavy metals are analysed i.e., lead, zinc, cadmium, copper, lead , iron and boron (Table 1). The data of heavy elements are tested statically using correlation coefficient and principal component analysis (PCA) method using XLSTAT 2016. The results of PCA are presented spatially as choropleth maps using ArcGIS v. 10.7.

4 RESULTS AND DISCUSSION

the results of chemical concentration of heavy elements given in table 1 , identified that Cadmium, Lead and Iron are exceeded all the limits of WHO standards in most samples, while Manganese (Mn) values are exceeding the standard in samples 2, 6,8 and 14, whereas, Zinc (Zn) element exceeded the standards in samples 5, 8, 15 and 16. While Boron (B) element concentrated in samples 5 and 6 of study area.

According to the correlation measurements between heavy metals given in table 3, shows very high direct correlation between Cd and Mn, with r value up to 0.994 and same correlation between Fe and Mn with r of 0.825, also B and Pb shows high correlation with value of r up to 0.670, these correlation values indicate that these elements are come from the same sources.

To test the spatial distribution of heavy metals in the study area principal component analysis (PCA) method are used and identified three factors based on Eigenvalues variability of the factors greater than 1.0 which represent accumulative Eigenvalues variability of 81.1% (Table 2).

The results of factor loading and factor score (Table 4&5, and Figure 2&3), shows that in factor D1 and based on factor loading values identified that

Manganese, Cadmium and iron having high correlation values with factor D1 and these elements are concentrated in sample number 14 according to factor score values . while, factor loading D2 shows that a dominant of Boron and Lead with high correlation with this factor and identified with high concentration in samples numbers 6, 5,4,3 and 12 as shown in table 5 and figure no 3. the last factor is Factor D3 which gives high factor loading for the heavy element of Cupper (Cu) and this element is concentrated in samples numbers 1 and 15

Table 1. Concentrations of heavy elements in the samples of the study area during 2017

well no.	Name	Long.	Lat.	Mn	Cd	Cu	Fe	Pb	Zn	B
١	HorAlsltan	٤٥.٤٥	٣٢.٣٠	٠.٠٠١	٠.٠٢٠	٠.٢٠٠	٠.٠٥٠	٠.٣٠٠	١.١٢٠	١.٠٢٠
٢	Rustumaia	٤٥.٣٩	٣٢.٣٠	٠.٢٠٠	٠.٠٢٥	٠.٠١٠	٠.٠٥٠	٠.٥٠٠	٠.٩١٠	١.٣٨٠
٣	Abu Ghazal	٤٥.٢٦	٣٢.٣٢	٠.٠٠١	٠.٠٢١	٠.٠٠٧	٠.١٠٠	٠.٤٧٠	١.٥٦٠	١.٨١٠
٤	Dhahirmjbl	٤٥.٤٥	٣٢.٢٧	٠.٠٣٠	٠.٠٢٦	٠.٠٠٨	٠.٠٠٨	٠.٥١٠	١.٠٣٠	٢.٠٣٠
٥	Humaisanya-1	٤٥.٢٦	٣٢.٣٦	٠.٠٥٠	٠.٠٦٠	٠.٠٥٠	٠.٣٠٠	١.٠٠٠	٤.٦٥٠	٢.٩٨٠
٦	Humaisanya-2	٤٥.٤٥	٣٢.٣٣	٠.٥٠٠	٠.٠٥٠	٠.٠٣٠	٠.٣٥٠	٠.٧١٠	٣.٥٥٠	٣.٥٩٠
٧	Rarnjia-1	٤٥.٣٢	٣٢.٣٧	٠.١٠٠	٠.٠٤٢	٠.٠٣٠	٠.٣٨٠	٠.٦٠٠	٢.٠٧٠	٠.٤١٠
٨	Rarnjia-2	٤٥.٤٥	٣٢.٣٤	٠.٥٠٠	٠.٠٤٠	٠.٠١٠	٠.٩٠٠	٠.٤٤٠	٤.٦٠٠	٠.١٦٠
٩	Rarnjia-3	٤٥.٣٨	٣٢.٣٥	٠.٠٠١	٠.٠٣٥	٠.٠١٠	٠.٦٤٠	٠.٤٣٠	١.٨٣٠	٠.٩٥٠
١٠	Jazria-1	٤٥.٥٧	٣٢.٤٤	٠.٠٠١	٠.٠٤٠	٠.٠١٠	٠.٤٠٠	٠.٤٣٠	١.٨٦٠	٠.٤٢٠
١١	Jazria-2	٤٥.٥١	٣٢.٢٤	٠.٠٠١	٠.٠٤٠	٠.٠٢٠	٠.٠٤٠	٠.١٨٠	٣.٥١٠	٠.٨٠٠
١٢	Abu Sumaij-1	٤٥.٨١	٣٢.٢٤	٠.٠١٠	٠.٠٣٥	٠.٠١٠	١.٦٠٠	٠.١٨٠	١.٥٢٠	١.٠١٠
١٣	Abu Sumaij-2	٤٥.٦٣	٣٢.١٧	٠.٠٢٦	٠.٠٤٥	٠.٠٢٠	٠.٥٠٠	٠.٣٠٠	٢.٤٠٠	٠.١٩٠
١٤	Tarabls primary S	٤٥.٥٧	٣٢.٢٥	٦.٠٠٠	٤.٠٠٠	٠.٠٢٠	٢.٧٠٠	٠.١٦٠	١.١١٠	١.١٢٠
١٥	sabaAalama P. S.	٤٥.٥٨	٣٢.٢٦	٠.٠٣٠	٠.٠٥٠	٠.٠٥٠	٠.٤٠٠	٠.٢٣٠	٤.٦٢٠	٠.٤٥٠
١٦	Alshahabia P.	٤٥.٣٨	٣٢.٢٠	٠.٠٢٠	٠.٠٤٠	٠.٠٢٠	٠.٣٠٠	٠.٢٠٠	٤.٥٠٠	٠.٤٠٠
١٧	Altaliaa P.S.	٤٥.٦٩	٣٢.٢٨	٠.٠٠١	٠.٠٤٠	٠.٠١٠	٠.٤٢٠	٠.٤١٠	١.٨٤٠	٠.٤١٠
WHO	MCL			0.4	0.01	2.0		0.05	4.0	2.4
	Pl			0.1	0.003	0.05	0.1 - 0.3	0.01	0.5	0.5

Table 2. Eigenvalues of correlation matrix, and related statistics for active variables only

	F1	F2	F3	F4
Eigenvalue	3.037	1.558	1.083	0.856
Variability (%)	43.383	22.252	15.477	12.222
Cumulative %	43.383	65.635	81.112	93.334

Table 3. Values of correlation coefficient between heavy metals concentration

Variables	Mn	Cd	Cu	Fe	Pb	Zn	B
Mn	**1**	**0.994**	-0.072	**0.825**	-0.261	-0.218	0.033
Cd	**0.994**	**1**	-0.060	**0.823**	-0.296	-0.249	0.000
Cu	-0.072	-0.060	**1**	-0.198	-0.029	-0.060	0.054
Fe	**0.825**	**0.823**	-0.198	**1**	-0.369	-0.161	-0.141
Pb	-0.261	-0.296	-0.029	-0.369	**1**	0.182	**0.670**
Zn	-0.218	-0.249	-0.060	-0.161	0.182	**1**	0.030
B	0.033	0.000	0.054	-0.141	**0.670**	0.030	**1**

Values in bold are different from 0 with a significance level alpha=0.05

Table 4. Factor loadings after Varimax rotation of the variables (Heavy metals), based on correlations

	D1	D2	D3
Mn	**0.991**	0.034	-0.020
Cd	**0.987**	0.007	-0.009
Cu	-0.059	0.027	**0.997**
Fe	**0.826**	-0.102	-0.137
Pb	-0.205	**0.427**	-0.033
Zn	-0.131	0.010	-0.034

B	0.025	**0.950**	0.035

Table 5. Factor scores after Varimax rotation of cases (water samples) based on correlations

	D1	D2	D3
1	-0.368	-0.110	**3.775**
2	-0.352	0.178	-0.547
3	-0.433	**0.839**	-0.625
4	-0.456	**1.033**	-0.625
5	0.098	**1.239**	0.529
6	-0.059	**2.671**	-0.050
7	-0.117	-1.329	0.042
8	0.149	-1.256	-0.328
9	-0.316	-0.209	-0.468
10	-0.287	-0.920	-0.463
11	-0.381	0.133	-0.303
12	-0.415	**0.425**	-0.454
13	-0.285	-0.949	-0.231
14	**3.941**	0.026	-0.030
15	-0.179	-0.459	**0.474**
16	-0.240	-0.423	-0.230
17	-0.299	-0.890	-0.466

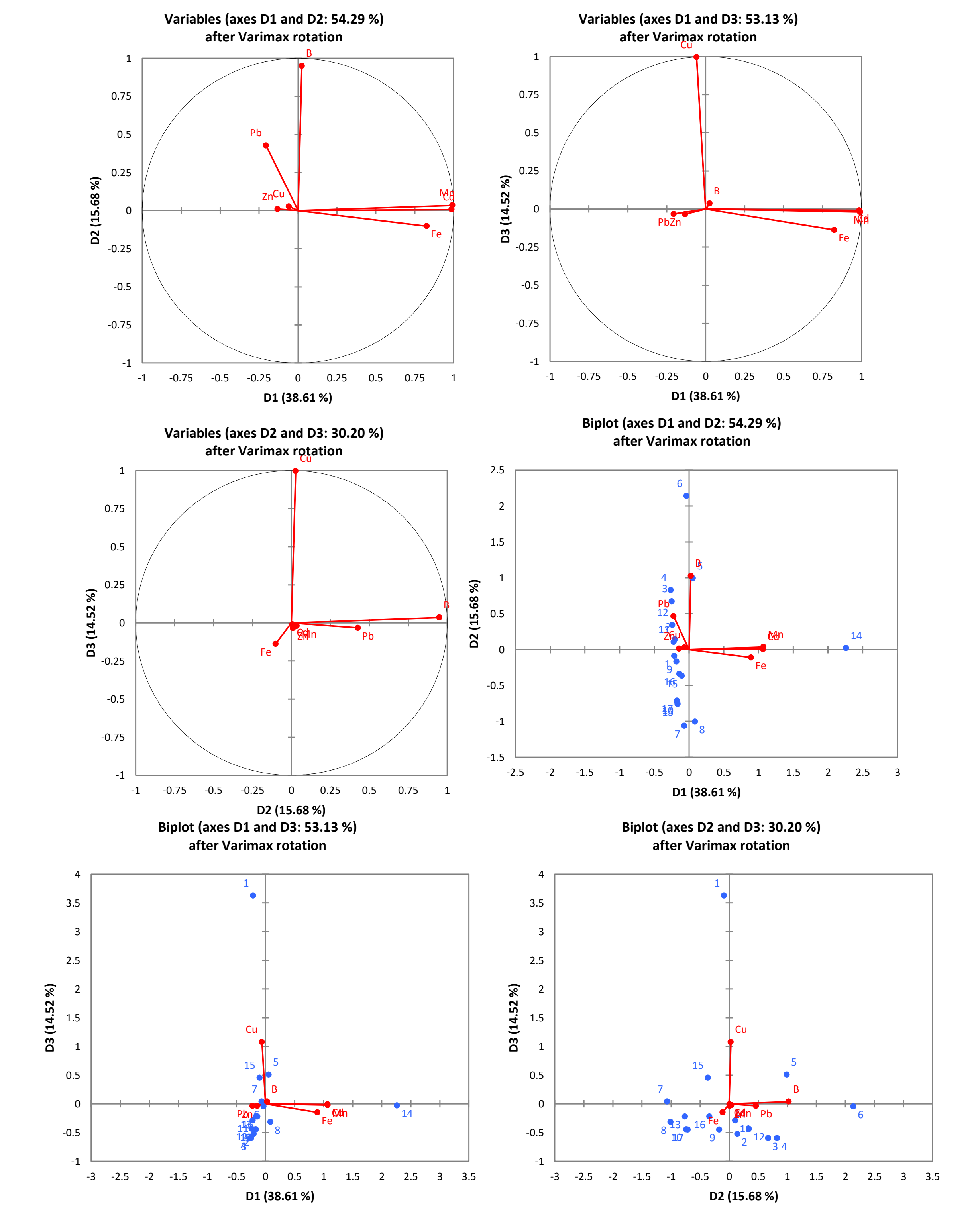

Figure 2. Factor plot diagrams of variables (Heavy metals) and cases (location of samples) projections of wells water samples: a).Heavy metals in factor 1&2, b). Heavy metals in factor 1&3, c). Heavy metals in factor 3&2, d). Well water samples in factor 1&2, e). Well water samples in factor 1 & 3 and f). Well water samples in factor 2&3.

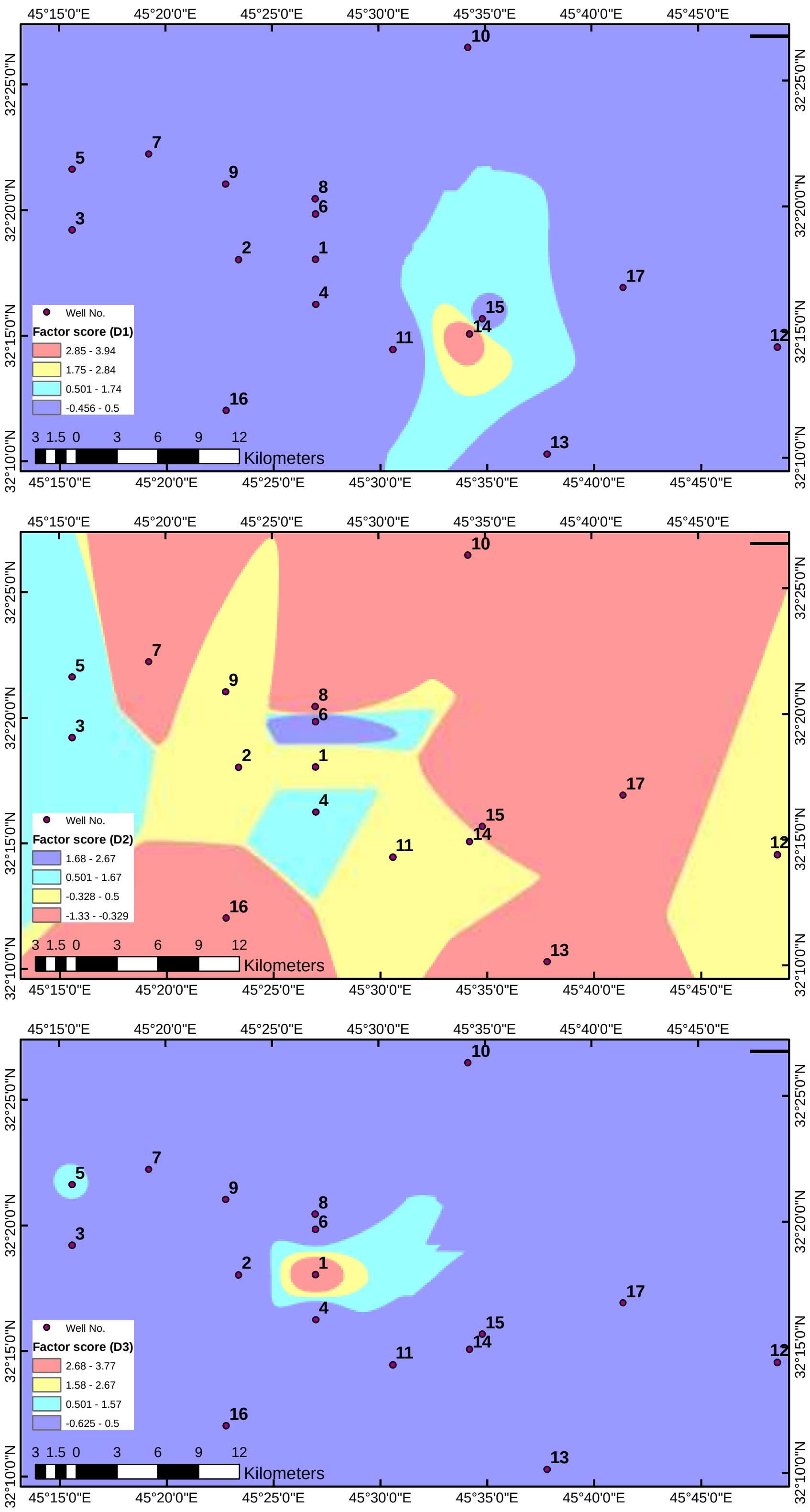

Figure 3. Factors Iso-Score maps of heavy metals in groundwater samples.

5 CONCLUSIONS

After studying the groundwater contamination of heavy elements in Al-Kefal area, there are increasing in the concentrations of cadmium, lead and iron above the permissible and MCL limits of WHO standard. Most hazards wells water for drinking and irrigation purposes are located at samples 1, 3, 4, 5, 6, 12, 14 and 15. Whereas the measurement of correlation coefficients between heavy elements indicate that, Cd, Mn and Fe are comes from the same pollution source, while B and Pb are from another pollutant. Due to high concentrations of heavy metal elements in bore wells of study area; attention and awareness of using the groundwater for drinking purposes must be avoided by local peoples.

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