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Evaluation of heavy metals level (arsenic, nickel, mercury and lead) effecting on health in drinking water resource of Kohgiluyeh county using geographic information system (GIS)

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ABSTRACT

This study was conducted to determine the amount of heavy metals (Arsenic, Nickel, Mercury, and Lead) in drinking water resource of Kohgiluyeh County using Geographic Information System (GIS). This cross-sectional study was conducted on drinking water resource of Kohgiluyeh County (33 water supplies and 4 heavy metals) in 2013. 264 samples were analyzed in this study. The experiments were performed at the laboratory of Water and Wastewater Company based on Standard Method. The Atomic Adsorption was used to evaluate the amount of heavy metals. The results were mapping by Geographic Information System software (GIS 9.3) after processing of parameters. Finally, the data were analyzed by SPSS 16 and Excel 2007. The maximum amount of each heavy metal and its resource were shown as follow: Nickel or Ni (Source of w_{12}, 124ppb), Arsenic or As (w_{33}, 42 ppb), Mercury or Hg (w_{22} and w_{30}, 96ppb), Lead or Pb (w_{21}, 1553ppb). Also, the GIS maps showed that Lead in the central region was very high, Mercury and Arsenic in the northern region were high and Nickel in the eastern and western regions was high. The Kriging method and Gauss model were introduced as best method for interpolation of these metals. Since the concentration of these heavy metals was higher than standard levels in most drinking water supplies in Kohgiluyeh County and these high levels of heavy metals can cause the adverse effects on human health; therefore, the environmental and geological studies are necessary to identify the pollution resource and elimination and removal of heavy metals.

Keywords: Arsenic, Nickel, Mercury, Lead, Drinking water, GIS

INTRODUCTION

Although the economic and industrial development and production of various types of chemical compounds has brought greater prosperity for human; however, the releasing of unwanted substance such as toxic and heavy metal can lead to severe effects on human and environment. The toxic metals are one of materials which can be released into environment. Humans are exposed to 35 toxic metals permanently or temporarily which 23 of them belong to heavy metals group. These metals (in small amount) are found in environment and diets naturally and are necessary for human health but their concentration is increased as a result of pollution from human activities and consequently, they can lead to acute and chronic toxic effects for human after interring to human food chain[1]. The non-biodegradability is considered as the main problem associated with heavy metals. In fact, these metals are not excreted from the body and are deposited and accumulated in various tissues such as lipid, muscles, bones and joints and can generate various disorders and diseases. Also, the heavy metal can be replaced with other essential salts and minerals in the body. For example, the cadmium can be replaced in case of Zinc deficiency[2]. Generally, neurological disorders, Parkinson, Alzheimer, depression, schizophrenia, cancer, poor nutrition, lack of hormones balance, obesity, abortion, respiratory and cardiovascular disease, damage in organs (liver, kidneys and brain), anorexia , arthritis, hair loss, osteoporosis and death(in severe cases) are adverse effects of heavy metals in the human body [3].On the other hand, the risks of heavy metals are become more severe due to their bioaccumulation properties in plants and interring in to chain food. Arsenic is a metalloid and carcinogenic element which it can be existed in whole of earth crust. The human are mainly exposed with inorganic arsenic through the consumption of naturally contaminated drinking water. The arsenic is existed in surface water where there are the iron ore metals and mostly, it can be released in to the water by consumption of pesticides and insecticides containing arsenic [4, 5].The large amount of metal in drinking water is related to substances which are used in plumping. The corrosive water is caused to transfer the heavy metals into drinking water due to proximity and contact with the pipes, fittings, valves of municipal distribution networks and Interior plumbing. Theses metals are included lead, cadmium, copper, zinc, iron and manganese[6]. Therefore, the contaminated water is one of expected risk for human health. The higher concentration of heavy metals (higher than standard levels) has detrimental effects on human health. These effects (toxicity, mutagenicity and carcinogenicity) can be determined by the properties of elements. Biological monitoring can be considered as a satisfactory method to measure the heavy metal concentration and their bioavailability [7, 8].The assessment of spatial variation of groundwater quality and management of water resources and land use are proper approach to prevent the water pollution. Information system of GIS is attributed as a technique or machine which can be used for following subjects: identification of data (thematic maps), analysis, interpretation and summarize of data, evaluation of ecological and socio-economic needs for use of land, the environmental changes, the recognition of damages, wastes and pollution, and finally, it can be used in regional planning (or environmental planning). Indeed, the GIS can be considered as bridge between databases, resources and management [9]. The classical statistical methods consider the values of the variables at different points but the geostatical method considers the location of the points and it provides the possibility of estimation of the desired variable in the continues surface by optimal interpolation of the variables in missing data points. The results of Karimpour et al demonstrated that the average concentration of lead, cadmium and chromium in drinking water resource of Hamadan was higher than standards levels [10, 11]. The study of Gin et al showed that the heavy metal concentration changes over time and various concentrations of heavy metals can be found in available wells at the same region. In fact, the heavy metal concentration of wells depends on location and depth of wells. The higher concentration of heavy metal can be observed in shallower depth wells in certain geological area. The purpose of this study was to determine the amount of heavy metals (Arsenic, Nickel, Mercury and Lead) in drinking water resources Kohgiluyeh county using Geographic Information System (GIS) in order to provide a clear picture for current situation of heavy metals in drinking water of this county and also, to present suitable strategies for competent organization.

MATERIALS AND METHODS

This cross-sectional study was conducted on drinking water resource of Kohgiluyeh County (33 water supplies and 4 heavy metals) in 2014**.** A total of 264 samples were analyzed**.** The experiments were performed at the laboratory of Water and Wastewater Company based on standard methods**.** The maps of Management and Planning Organization of Kohgiluyeh and Boyerahmad were used to identify the studied region. The results of heavy metals experiments were recorded by GIS software and saved as a database. The results were mapping by Geographic Information System software (GIS 9.3) after processing of parameters to describe the spatial and temporal variation trend of parameter. Then, the data was analyzed by SPSS 16 software and descriptive statistics and the Kolmogorov-Smirnov test (to confirm the normality). The mapping of various parameters in form of conceptual model is shown in Figure 1.

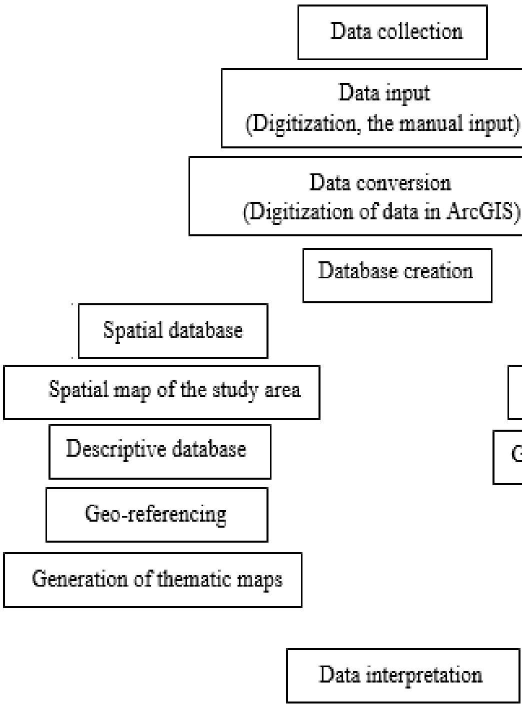

Figure 1. Mapping process

RESULTS

Figure 1 shows sampling point of drinking water of Kohgiluyeh city. Since the normality of the data is assumed to perform the geostatic calculation; therefore, it is necessary that the distribution be normal. Geographic situation and the concentration of heavy metals in drinking water supply of Kohgiluyeh city are shown in Table 1.

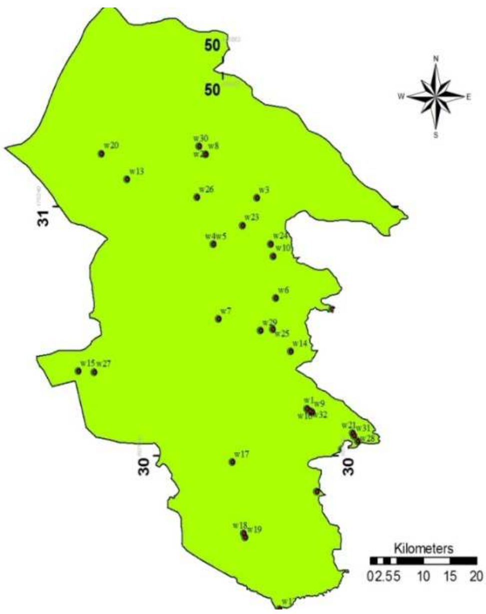

Figure 2.Sampling point of drinking water of kohgiluyeh city

Table1. Geographic situation and concentration of heavy metals

CODE	x	y	Ni(ppb)	As(ppb)	Hg(ppb)	Pb(ppb)
W1	464465	3416049	0	0	0	1253
W2	468504	3432440	95	15	12	0
W3	456494	3450812	35	0	0	0
W4	449486	3443237	65	0	0	209
W5	449499	3443257	12	14	14	139
W6	459492	3434314	0	0	11	1076
W_7	450231	3430864	32	14	14	549
W_8	448334	3458106	0	0	0	0
W_9	465226	3415480	0	11	0	1439
W_{10}	459108	3441224	45	23	11	1228
W_{11}	465985	3402358	25	0	0	95
W_{12}	459890	3382922	124	0	0.15	32.68
W_{13}	435664	3453985	36	0	0	1037
W_{14}	461805	3425500	2.9	13	0	1398
W_{15}	427604	3422380	0	0	8	387
W_{16}	464465	3416049	0	0	0	1253
W_{17}	452347	3407252	75	11	24	502
W_{18}	454162	3395456	56	0	6	1168
W_{19}	454368	3394786	30	14	15	520
W_{20}	431582	3458290	28	0	57	1151
W_{21}	471766	3411968	117	13	10	1553
W_{22}	447248	3459421	0	24	96	133
W_{23}	454177	3446310	94	8.42	0	1029
W_{24}	458713	3443242	75	21	35	145
W_{25}	458949	3429116	0	12	8	461
W_{26}	446875	3450974	23	41	11	1200
W_{27}	430158	3422246	75	13	14	1187
W_{29}	456946	3428912	110	0	0	709
W_{30}	447248	3459421	0	24	96	133
W_{31}	472006	3411514	0	11	6	191
W_{32}	464957	3415656	0	0	0	253
W_{33}	438804	3368851	98	42	68	608

The maximum amount of each heavy metal and its resource were shown as follow: Nickel (Source of W_{12}, 124ppb), Arsenic (W_{33}, 42 ppb), Mercury (W_{22} and W_{30}, 96ppb), Pb (W_{21}, 1553ppb).

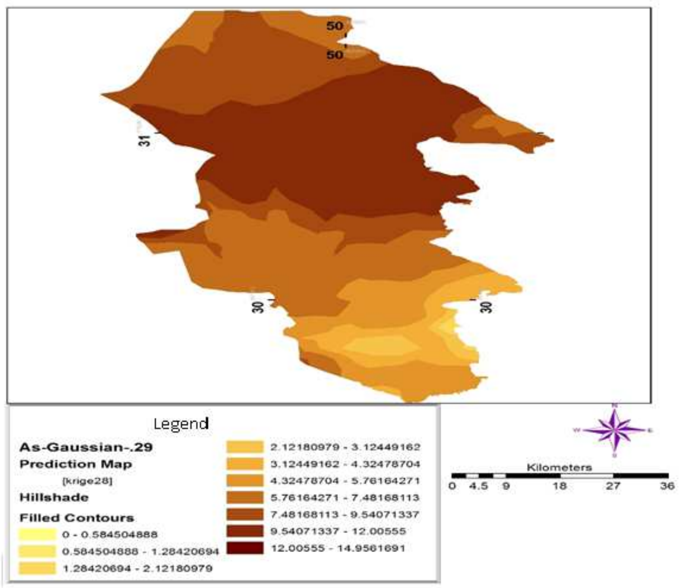

Figure 3. The spatial variations of arsenic in drinking water of Kohgiluyeh city

Table 2 The correlation coefficient between heavy metals and some water chemical parameters

	Hardness	**EC**	**Talk**	**Cl**	**HCO_3^-**	**NO^-_3**	**Ca**	**Mg**	**K**	**Ni**	**Pb**	**pH**	**TDS**	**$_4SO^-$**	**Na**	**Cr**	**As**	**Hg**	**V**	**Sb**	**Fe**
Hardness	1	0.745 0.000	0.309 0.09	0.097 0.605	0.513 0.003	0.218 0.240	0.061 0.744	0.476 0.007	0.342 0.007	-0.018 0.925	-0.039 0.837	-0.098 0.600	0.733 0.000	0.487 0.129	0.591 0.000	0.058 0.788	-0.083 0.752	-0.542 0.016	0.062 0.814	-0.244 0.287	0.649 0.082
EC		1	0.336 0.065	0.340 0.061	0.515 0.003	0.325 0.075	0.572 0.001	0.198 0.285	0.372 0.039	0.035 0.854	0.027 0.883	-0.226 0.221	0.996 0.000	0.755 0.007	0.836 0.000	0.010 0.964	0.063 0.711	-0.376 0.113	-0.024 0.927	-0.062 0.790	0.376 0.358
Talk			1	-0.268 0.144	0.254 0.168	0.212 0.253	0.111 0.553	-0.021 0.911	0.052 0.783	-0.047 0.701	0.095 0.610	-0.230 0.214	0.351 0.053	0.424 0.194	0.233 0.207	0.303 0.150	0.161 0.536	0.367 0.121	-0.162 0.535	-0.196 0.395	0.128 0.762
Cl				1	0.042 0.824	0.243 0.188	0.538 0.002	-0.036 0.849	0.119 0.532	0.301 0.100	-0.335 .065	0.139 0.455	0.322 0.078	0.414 0.206	0.439 0.014	-0.255 0.228	0.039 0.782	-0.587 0.008	0.084 0.748	0.015 0.949	0.470 0.239
HCO_3^-					1	0.280 0.128	0.153 0.412	0.632 0.000	0.182 0.327	0.074 0.692	-0.001 0.994	-0.072 0.702	0.521 0.003	0.432 0.184	0.285 0.120	0.031 0.885	0.143 0.584	-0.589 0.008	-0.165 0.527	0.040 0.864	0.068 0.872
NO^-_3						1	0.088 0.639	0.176 0.345	0.352 0.052	0.072 0.692	0.056 0.767	-0.230 0.213	0.336 0.064	0.245 0.468	0.285 0.120	-0.101 0.640	-0.200 0.441	-0.309 0.199	0.089 0.735	-0.196 0.395	0.128 0.762
Ca							1	-0.355 0.050	0.065 0.728	-0.030 0.781	-0.275 0.134	-0.335 0.065	0.563 0.001	0.870 0.000	0.557 0.001	-0.003 0.990	0.101 0.699	0.097 0.692	0.015 0.956	0.444 0.044	0.243 0.561
Mg								1	0.020 0.916	0.152 0.414	0.093 0.619	0.123 0.510	0.196 0.291	0.385 0.242	-0.086 0.646	-0.239 0.262	0.068 0.796	-0.659 0.002	-0.021 0.416	-0.188 0.415	0.097 0.819
K									1	0.280 0.127	0.270 0.141	0.184 0.321	0.374 0.038	-0.183 0.589	0.436 0.015	-0.062 0.772	-0.206 0.428	-0.170 0.486	0.063 0.811	-0.177 0.442	-0.075 0.760
Ni										1	0.015 0.936	0.321 0.78	0.038 0.839	-0.137 0.687	0.066 0.724	-0.016 0.942	-0.221 0.393	-0.449 0.054	0.186 0.476	-0.179 0.437	0.492 0.215
Pb											1	0.008 0.967	0.029 0.878	-0.205 0.546	0.085 0.651	0.180 0.399	-0.106 0.686	0.043 0.862	-0.006 0.983	0.009 0.970	-0.232 0.581
pH												1	-0.220 0.234	0.027 0.938	-0.061 0.743	-0.230 0.280	-0.076 0.772	-0.285 0.237	0.167 0.523	-0.142 0.539	-0.260 0.535
TDS													1	0.755 0.007	0.816 0.000	0.004 0.985	0.071 0.787	-0.369 0.120	-0.027 0.919	-0.063 0.787	0.376 0.358
$_4SO^-$														1	0.647 0.031	0.182 0.615	0.511 0.379	-0.488 0.404	0.000 0.000	0.230 0.552	0.000 0.000
Na															1	0.264 0.212	-0.105 0.689	-0.219 0.369	0.000 0.999	-0.155 0.503	0.387 0.344
Cr																1	0.160 0.570	0.529 0.063	0.009 0.974	-0.339 0.199	-0.707 0.182
As																	1	0.416 0.139	0.043 0.901	0.034 0.916	-0.297 0.703
Hg																		1	0.541 0.107	0.208 0.496	-0.906 0.034
V																			1	0.085 0.792	-0.874 0.126
Sb																				1	-0.420 0.481
Fe																					1

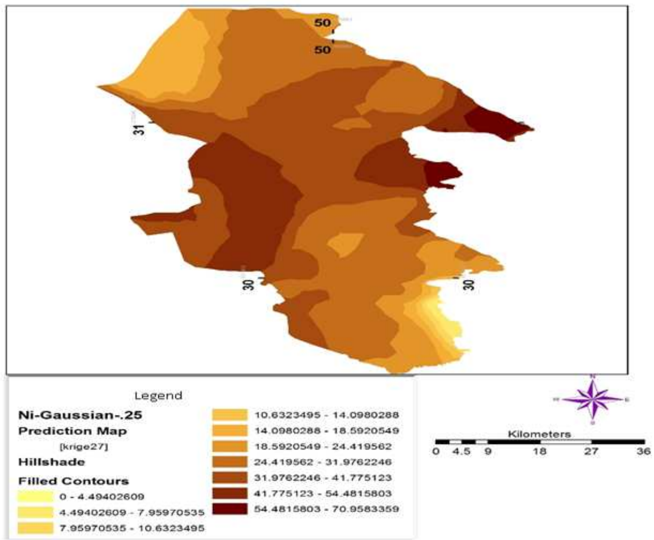

Figure 3. The spatial variations of nickel in drinking water of Kohgiluyeh city

Determination of correlation is important to characterize the significant of the relationship between the two interdependent variables. Statistically this relationship is obtained by calculating an index calledas correlation coefficient (r). As Table 2 shows the High positive correlations were observed between TDS- EC (0.996), TDS-Na (0.811), Hardness - EC (0.745) and SO_4^--Na (0.647) and HCO^-_3- Mg (0.632). While high negative correlations were observed between Hg-Fe (-0.906), V-Fe (-0.874), Cr-Fe (-0.707), HCO^-_3-Hg (-0.598) and Cl- Hg (-0.587). Analysis revealed that pH of all water samples are within range. PH showed positive correlation with Cl, Mg and negative correlation with other parameters. The average of arsenic in drinking water resources was 10.13±11.6 ppb. The spatial variations of arsenic in drinking water of Kohgiluyeh city is shown in Figure 3. The Statistical parameter of Root Mean Square Error (RMSE) was employed to estimate the Interpolation methods. The favorability of applied method is confirmed by lower values of RMSE. The ordinary Kriging and Guess model (RMSE=0.29) were best method for interpolation of arsenic. The maximum amount of pollution is observed in northern region which the arsenic concentration was higher in this region. The arsenic concentration is decreased from the north towards southern region.

The average of nickel in drinking water resources was 39.15±41.1 ppb. The Figure 3 reveals the spatial variation of nickel in drinking water resource of Kohgiluyeh city. The best interpolation method for nickel, based on the normal distribution of data, was the ordinary Kriging and Guess model (RMSE= 0.25).

According to the interpolated maps, the maximum nickel level was observed in eastern region. As it can be observed the nickel concentration decreases towards northern region. The minimum concentration of nickel exists in Northwest region. The average of mercury in drinking water resources was 16.12±26.27 ppb. Figure 4 illustrates the spatial variation of mercury in drinking water supplies of Kohgiluyeh city. The ordinary Kriging and Guess model (RMSE=0.19) were the best method for interpolation of mercury based on the normal distribution of data. The interpolated maps disclosed that the maximum and minimum amount of mercury is related to northern and southern parts, respectively.

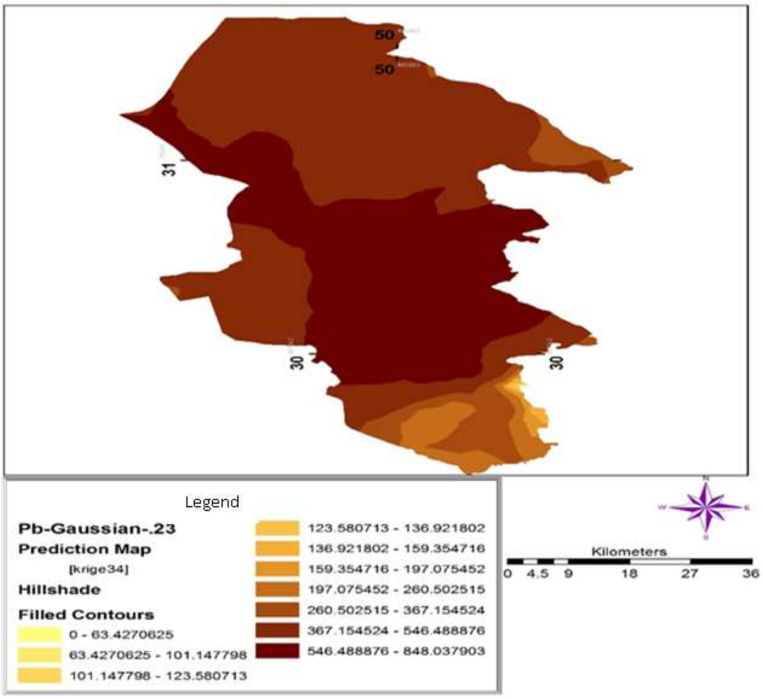

Figure 4. The spatial variations of mercury in drinking water of Kohgiluyeh city

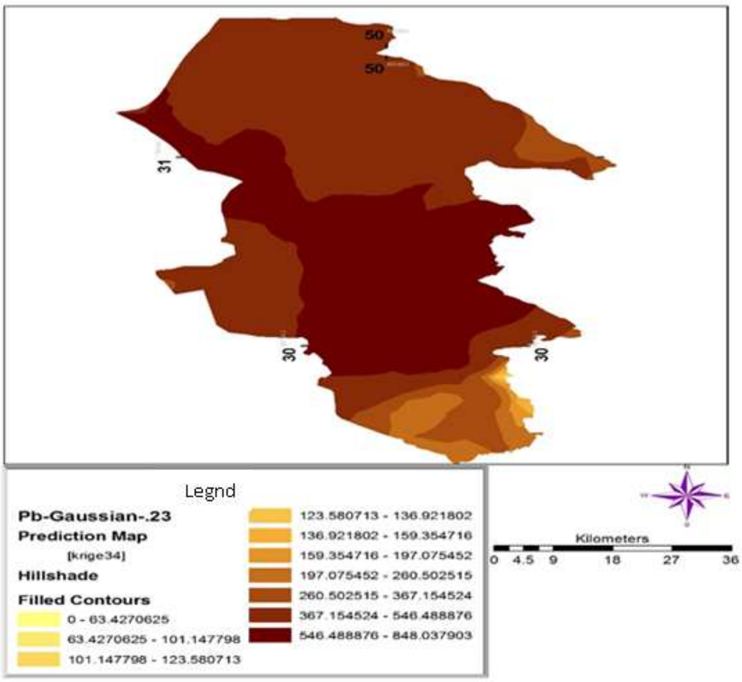

Figure 5. The spatial variations of lead in drinking water of Kohgiluyeh city

The average of lead in drinking water resources was 657.45±519.65 ppb. The spatial variation of lead is shown in Figure 5. The ordinary Kriging and Guess model (RMSE=0.23) could be used as best interpolation approach.

The higher concentrations of lead can be observed in the central parts according to the interpolated maps. Also, the lowest concentration of lead was related to the southern region.

DISCUSSION

Determination of the best interpolation method for chemical water quality

Based on all the maps obtained in this study, the best interpolation method determined is the Kriging method. The study of Spatial variation of groundwater salinity using geostatistical conducted by Taghizadeh et al showed that Kriging method is better than IDW for salinity mapping[12]. For better understanding of the spatial structure of samples and to select the best interpolation method, spatial autocorrelation between samples is studied. It can be achieved by drawing of the distance between sample and values of samples variance or semi-variograms. The semi-variogram measures the degree of association or correlation between the points based on the idea that properties of phenomena are more similar in closer places to farther distances[13]. Also, the statistical parameter of root-mean-square error (RMSE) was utilized to evaluate the interpolation methods. The lower values of this parameter indicate that the intended method would be better. In present work, the lesser values of RMSE for all heavy metals showed that both Kriging method and Gaussian model are more applicable for interpolation of these variables. Zazouli et al have conducted an study to evaluate the spatial variation of nitrate and nitrite of Kohgilouyeh city and they observed that the ordinary Kriging and exponential model (RMSE=0.312) were best interpolation method for nitrate but the ordinary Kriging and spherical model (RMSE=0.00026) were obtained as best interpolation method for nitrite[9]

Interpolation of heavy metals

The results of present study revealed that the concentration of heavy metals was higher than standard levels. The results are inconsistent with the study of Kamare'ee et al which are performed in Borujerd [14]. Kamare'ee et al reported that the average concentration of cadmium, lead, chromium, mercury, arsenic and barium in the wells was 0.0014, 0.005, 0.002, 0.0077, 0.0 and 0.3222 mg/L, respectively. The vicinity of this county with the industrial city of Ahvaz was attributed as a reason for highest concentration of heavy metals in their study. In this study, the higher concentration of heavy metal was observed in drinking water resource which it may be due to proximity of Kohgiluyeh city with the Khuzestan province and oil-rich city of Gachsaran. According to the obtained maps, the higher concentration of lead was observed in residential area with human activity. Also, the nickel amount was greater in vicinity parts of industrial cities and in geological formation of Gachsaran. The geological formation of Gachsaran is mainly constituted with Shale. The Shale have significant amount of nickel and therefore it can be attributed as a major source of nickel in the so [8]. The Movahedi Rad (2008) reported that the type of usage is an effective factor on increasing trend of Pb and Zn; however, the parental material and topography of the region is considered as significant reason for increasing of nickel concentration[15].The study of Shrani et al (2011), which was conducted to survey the spatial variation of lead, cadmium and nickel concentration within the soils of Tehran, indicated that industrial activity and the type of maternal are effective factor on nickel and zinc concentrations in the region [16]. The spatial distribution of heavy metals in surface soli of Shanghai was investigated by Binggan et al (2008). They reported that human activities are the main input resource of zinc, lead and copper but the Nickel is increased by natural factors[17]. Chen et al (2005) conducted a geostatistical study to investigate the origin of heavy metal in China. They observed (with combination of multivariate statistics and geostatic) that the concentration of Cu, Zn and Pb are controlled by human activity, whereas the nickel, chromium and cobalt can be managed by natural factors and soil properties [18].Finally, it can be concluded that further environmental and geological studies is considered as major requisites due to increase the heavy metals content in drinking water supplies of Kohgiluyeh County and the adverse effect of heavy metals.

CONCLUSION

The suitable management pattern should be provided in order to optimize productivity of groundwater resources and land use. The significant attention and monitoring are necessary due to high vulnerability of the central and northern parts. The establishment of the wastewater treatment plant (WTP) is essential requirement to prevent the contamination of groundwater resource with potential increasing of heavy metals concentration. The fundamental measures such as determination and protection of health privacy of all drinking water wells, the purification and treatment of heavy metal-contaminated resources and removing of them from the use cycle and identification of suitable water quality alternative should be performed.

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