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Accuracy of Spatial Distribution Model (Surface Kriging) in Predicting Concentrations of Arsenic in The Groundwater; Hasht Bandi Area, Minab, Iran

KEYWORDS

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ABSTRACT *Entry of heavy metals in water resources will reduce water quality for drinking or agricultural irrigation. Various mathematical models such as spatial distribution model in the classification and prediction of arsenic concentrations in groundwater were used. Hence, it is tried in this study to assess the prediction accuracy of this model. Arsenic concentrations was measured by atomic absorption spectrophotometer model DR2800 in 2916 water samples collected from 27 wells (17 main wells, 10 control wells) performed in Hasht Bandi area of Minab. Then, predicted As concentration was statistically analyzed by the model of the spatial distribution with concentrations measured in 10 control wells. Mean and range of As concentrations in 27 main and control wells were 9.22±4.6 µg/l and 0-23.7 µg/l, respectively. The average concentration of As in the autumn, winter, spring and summer was 5.99±6.08, 13.14±6.43, 4.5± 13.06 , 4.69±4.6 µg/l. the ratio of As predicted mean concentration (7.69 µg/l) by the measured model (10.7 µg/l) equals 71.8 %. Spatial distribution model has a high accuracy to predict As concentration of groundwater.*

Introduction

heavy metals such as cadmium (Cd), chromium (Cr), manganese (Mn), lead (Pb), arsenic (As) and nickel (Ni) in water can be caused by natural processes (erosion) or from human activities (domestic, industrial or agricultural waste water discharges) [1, 2]. Entry of heavy metals in water resources will reduce water quality for drinking or agricultural irrigation [3]. Heavy metals have properties such as biological accumulation, toxicity and environmental sustainability which can be dangerous to the health of humans and other living organisms [4, 5]. Epidemiological studies show that there is a significant relationship between tooth decay, heart disease, kidney disorders, neurological disorders and cancers associated with heavy metals [6, 7]. As mentioned, one of the heavy metals is As that As can enter humans body (eating, smoking, drinking) but the most important input source is the use of contaminated water [8]. Entry of As into body in the long term can cause cancer of the bladder, liver, kidneys and the skin lesions [9-11]. A very important factor in the development of Blackfoot disease is the use of water contaminated with As [12, 13]. According to the WHO and EPA standards, the concentration of As in drinking water has been classified into Class 1 (safe): 0-5 µg/l, Class 2 (worrying): 5-10 µg/l, Class 3 (non-secure): 10 > µg/l [14, 15] . Due to health and environmental risks that As can cause in groundwater. Extensive studies is done in the field of modeling and predicting their concentration in water resources [16]. Spatial distribution model with predicting the points of having concentration higher than As can help us to manage the risk points [17]. Hence, in this study it is tried to assess prediction accuracy of As concentration of Hasht bandi area of Minab by the spatial distribution model (surface kriging).

2. Materials and Methods

1.2. Study Area

Hasht Bandi area with a population of 5 thousands and an area of 25 km is located in the north-eastern city of Minab and 125 km from Bandar Abbas (center of Hormozgan Province) and the coordinates of «19´07°27 N and»23´27°57 E (Figure 1) [18]. This region has a dry and hot climate and most of the inhabitants of this region are agriculture. The groundwater level in the area is between 50 and 80 meters.

2.2. Sample Collection

In this cross-sectional descriptive study, samples were collected from 17 main wells and 10 control wells simultaneously over an area of 20 km^2 during one year of 2012-2013 (Figure 1). During every season of every 27 sample wells and a total of 2916 water samples from 17 wells were collected. According to standard methods, After 10 minutes the water discharge out of the pipes pumps, the sample was transferred into the bottle of 1.5 liter polyethylene. Fi-

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nally, samples were transferred to the Chemical laboratory at Faculty of health Bandar Abbas [19].

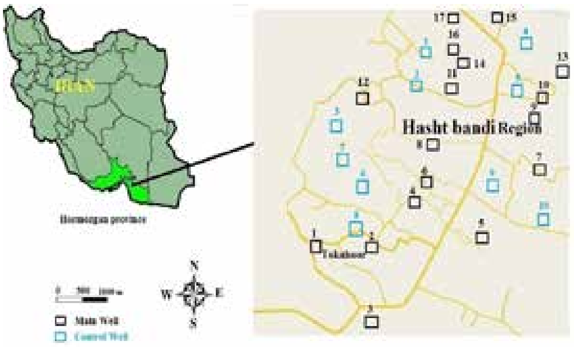

Figure 1 Hasht Bandi area in the northeastern city of Minab pre-province, Iran

3.2 Measurement concentrations of As

Water samples were filtered through Watzman 42. Then to convey PH<2, nitric acid (65 Merck) was used (to maintain heavy metals up to 28 days). Measurement of As concentration was done by atomic absorption spectrophotometry device model DR2800 in Method 8013 Silver Diethyldithiocarbamate method [20, 21].

5-5- Kriging method

Kriging method estimates the rate of regarded variable (concentrations of arsenic groundwater) in other parts accurately through finding best line without error [22];

Equation 1

$$Z^*(x_p) = \sum_{i=1}^{n} \lambda_i Z(x_i)$$

To find best line without error, the following two equations must be solved simultaneously:

Equation 2

$$\sum_{i=1}^{n} \lambda_i \gamma(x_i, x_j) - \mu = (x_i, x)$$

$$\sum_{i=1}^{n} \lambda_i = 1$$

$Z^*(x_p)$, the estimated value of the variable in x_p, $Z(x_i)$: the estimated value of the variable in x_i, λ_i data weights, μ lagrange coefficient, $\gamma(x_i, x_j)$ Variogram value according to variable size in the point x_i and the final point of x_j [36]. In this study, spatial distribution models (Kriging surface) was prepared using the software Surfer12.

3. Results

Annual Mean (M±SD) and range concentration of As in groundwater are 7.69±2.56 µg/l and 23.7-0 µg/l, respectively. Mean concentration of As (M ± SD) in autumn is (5.18±3.55 µg/l), in winter (7.7.87±5.14 µg/l), spring (10.72±6.32 µg/l) and summer is (6.99±4.34 µg/l) (Table 1).

Table 1. The mean, range and standard deviation of 17 wells Hasht Bandi area of Minab (µg/l)

	Latitude (x)	Longitude (Y)	autumn[1]	winter	spring	summer	Mean[2]	max	min	SD
W1	572348	270724	4.7	8.9	9.8	5.25	7.16	10.9	2.3	2.56
W2	572440	270730	0.45	1.85	1.27	0.9	1.12	2.1	0	0.59
W3	572437	270623	0.87	0.98	1.21	1.25	1.08	1.4	0	0.18
W4	572518	270811	0.3	0.8	1.4	0.75	0.81	1.46	0	0.45
W5	572639	270742	3.9	6.9	7.6	4.9	5.83	8.4	1.6	1.72
W6	572542	270842	4.8	2.9	8.6	11.5	6.95	12.7	2.4	3.85
W7	572723	270839	9.7	7.9	12.4	8.7	9.68	13.2	0	1.96
W8	572558	270918	9.1	9.8	11.6	11.9	10.60	12.6	2.6	1.36
W9	572738	270917	5.2	11.3	13.5	15.8	11.45	16.9	0	4.55
W10	572756	270947	3.8	4.9	6.3	3.7	4.68	7.2	0.6	1.21
W11	572609	271001	2.5	3.6	6.9	7.6	5.15	8.3	1.1	2.48
W12	572457	271001	11.3	8.1	13.4	5.9	9.68	14.1	2.9	3.33
W13	572806	271005	4.6	16.5	22.5	13.1	14.18	23.7	4.5	7.47
W14	572650	271031	10.9	10.8	17.9	8.1	11.93	19.1	5.5	4.19
W15	572719	271104	7.8	13.9	19.8	4.7	11.55	21.1	5.6	6.70
W16	572619	271052	1.8	17.8	16.3	8.6	11.13	18.2	5.3	7.41
W17	572623	271133	6.4	6.9	11.7	6.1	7.78	12.4	0	2.64
Mean			5.18	7.87	10.72	6.99	7.69			

Table 2. predicted and measured concentration of As in 10 control wells in Hasht Bandi area of Minab (µg/l)

				Measured concentration					
	Latitude (x)	Longitude (Y)	Predicted mean	summer	spring	winter	autumn	Mean	dif
W1	572557	271061	9.3	8.3	8.7	8.9	7.7	8.4	10.9
W2	572546	271007	8.2	7.5	9.81	11.2	13.7	10.5	2.1

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				Measured concentration					
	Latitude (x)	Longitude (Y)	Predicted mean	summer	spring	winter	autumn	Mean	dif
W3	572407	270954	8.4	9.8	4.5	13.2	11.4	9.7	1.4
W4	572753	271077	12.0	11.5	16.8	13.8	15.4	14.3	1.46
W5	572709	270962	9.0	8.4	14.9	13.4	12.4	12.2	8.4
W6	572421	270810	3.6	0.5	3.1	4.6	1.2	2.3	12.7
W7	572505	270845	5.5	16.4	15.6	27.4	22.3	20.4	13.2
W8	572418	270764	3.4	1.1	4.6	3.8	2.4	2.9	12.6
W9	572658	270823	8.6	14.5	11.1	9.4	2.1	9.2	16.9
W10	572724	270759	7.8	6.8	10.4	13.1	16.4	11.6	7.2
MEAN			7.6	2.4	15.4	18.4	6.8	10.7	
SD3				5.07	4.85	6.53	7.02	5.24	

The Annual mean (M±SD) and range concentrations of As in groundwater in control wells are 10.7±5.2 µg/l and 0-20.4 µg/l. The mean concentration of As (M ± SD) in the autumn, winter, spring and summer are 6.8±7.02, 18.4±6.5, 15.4±4.8, 2.4±5.02 µg/l, respectively (Table 2). The overall mean concentrations of As in groundwater in 27 wells (main and control wells) are 9.22±4.6 µg/l and 0-23.7 µg/l. The mean concentration of As in the autumn, winter, spring and summer are l 5.99±6.08, 13.14±6.43, 13.06 ± 4.5and 4.69±4.6 µg/l, respectively. Hence the order of seasons are winter> spring> autumn> summer. The lowest and highest difference of predicted and measured As concentrations relates to (well 7, -14.86 µg/l) and (well 8, 0.47 µg/l) (Figure 1). The difference in predicted with measured As concentration mean is -3.13 µg/l (table 2).

4. Discussion

The annual mean concentration of As is located in class 2 (worrying). The mean concentration of As (M ± SD) in the autumn, winter, spring and summer is located in Class 1 (safe), Class 2 (worrying), Class 3 (non-secure) and Class 2 (worrying), respectively. Statistical analysis showed a significant difference between the mean concentration of As in spring with the other seasons (p value<0.05). Also, there is no significant difference between As concentrations in winter, summer and autumn (p value> 0.05). In contrast to our study, high concentrations of As in groundwater (10 µg/l <) in much of the world such as Bangladesh [24-26], India [27],Pakistan [28], and the United States [29]is reported. This high concentration of As of groundwater in these areas could be the result of contamination of soil and water to industrial and agricultural wastewater or more As in layers of earth and its dissolution in groundwater [30].

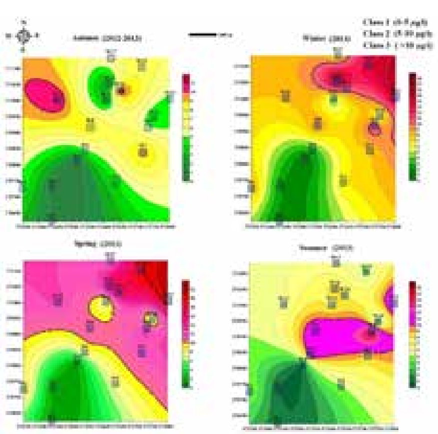

Figure 2. The spatial distribution map (surface kriging) of groundwater arsenic concentrations in Hasht Bandi area of Minab

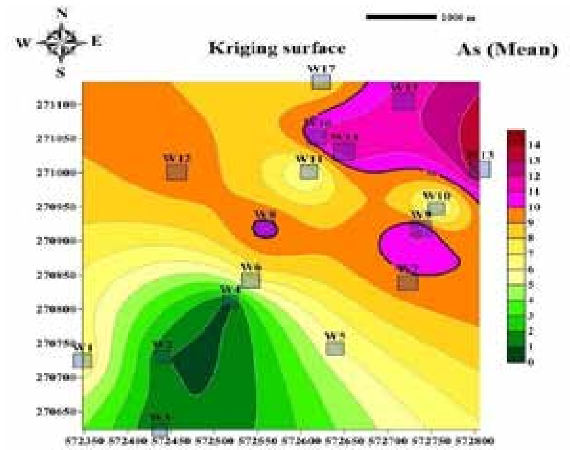

Figure 3: spatial distribution map (surface Kriging) of the average concentration of As in groundwater in 17 main wells of Hasht Bandi of Minab

The annual mean concentration of As in is located in class 2 (worrying) (2916 water samples collected from 27 wells). The mean concentration of As (M ± SD) in the autumn, winter, spring and summer is located in Class 2 (worrying), Class 3 (non-secure), Class 3 (non-secure) and Class 1 (safe), respectively (Table 2). Statistical analysis showed a significant difference between the mean concentration of As in the winter and spring seasons with other ones (p value<0.05). Also, no significant differences were observed between the two seasons (winter and spring) (p value>0.05). Given the mean concentration of As in 27 main and control wells, As concentration is in the worrying range (n = 27). The ratio of predicted mean concentration of As (7.6 µg/l) to the measured one (10.7 µg/l) is 8.71%. Since p value = 0.31 was obtained between predicted mean concentration of As and the measured one, hence it can be said that there is no statistical significant difference between predicted concentration of As with the measured one (P value> 0.05). Accuracy in study us is more than study done by Zhang et.al (63.2%)[17]. In the study done by Amin et.al, it has been indicated that the more the distance of sampling points and the number of samples from the area, the more the prediction accuracy of surface kriging map is increased [31]. Hence, high accuracy in study us can be induce to more sample number and low distance between control wells and main wells.

5. Conclusion

Mean concentrations of As in groundwater resources is in a worrying class at Hasht bandi area. Also, As concentrations in winter and spring is more than other seasons. The

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accuracy of spatial distribution model (surface kriging) in predicting As concentrations of groundwater at Hasht Bandi of minab area is high (71.8%). By increasing the points and the number of sampling in Kriging method, it can be a good way to monitor, assess and manage the quality of the groundwater. Using Kriging method, the way of moving the various pollutants, pollution sources and extent of contamination can be identified and carefully evaluated.

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