EVALUATION OF HEAVY METALS TOXICITY IN THE GROUNDWATER OF SOME VILLAGES OF SIRSA DISTRICT OF HARYANA, INDIA

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ABSTRACT

An attempt was made to assess the groundwater quality in some rural parts of Sirsa district of Haryana, India with respect to heavy metals contamination. For this purpose, 23 groundwater samples were collected from the bore wells during pre-monsoon in 2017 from some selected locations in the study area where the groundwater is used for drinking and agricultural activities. The samples have been analyzed for seven heavy metals viz. Mn, As, Zn, Cd, Pb, Cu and Cr using ICP-MS. The results were compared with the BIS standards to assess the suitability of groundwater for drinking. To assess the heavy metal contamination, the heavy metal pollution index (HPI), metal index (MI) and hazard index (HI) was calculated. The groundwater with $HI > 1$ falls in the high pollution category. In our study, 10 out of 23 samples were not fit to consume by the infants and all the 23 samples were found to be unfit for both the children and the adults. The correlation matrix showed a good correlation of HPI with Mn ($r = 0.998$), As ($r = 0.993$), Cu ($r = 0.998$), Cr ($r = 0.998$) and with Pb ($r = 0.998$) whereas the correlation of MI with Mn ($r = 0.998$), As ($r = 0.994$), Cu ($r = 0.998$), Cr ($r = 0.999$) and with Pb ($r = 0.998$).

Keywords: Ground Water, Heavy Metal Pollution Index, Metal Index, Hazard Index, Sirsa, Haryana.

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INTRODUCTION

Water is the most important source of life on this planet. It is the chief constituent of all the plants, animals, many other organisms and mankind for their survival in the biosphere.¹ Groundwater is one of the major sources of fresh natural water which is being used for both domestic and irrigation purposes worldwide. In India, 90% rural and 30% of the urban population is totally dependent upon groundwater for drinking and domestic activities.^{2,3} In comparison to surface water, the groundwater is generally considered to be free from contaminants because of its infiltration by soil media.⁴ Heavy metals are very common environmental pollutants and their presence in water is through many anthropogenic and natural activities.^{5,6}

The water contaminated by heavy metals is unfit for drinking use.⁷ The behavior of heavy metals in aquifers depends on the lithology, bio-geochemical processes and the source of water.⁸ Several studies proposed the occurrence of heavy metals in groundwater by the excessive use of fertilizers and pesticides, solid waste dumping, untreated and pesticides, solid waste dumping, untreated industrial wastes, mine drainage etc.⁹⁻¹¹

The heavy metal pollution of groundwater is a serious health problem all over the world due to its accumulation¹¹. To avoid health problems, regular monitoring of heavy metals concentration is necessary. So, it becomes more important to find out the degree of heavy metal pollution and its impacts on the ecosystem and on health. To get the overall influence of Pollution, Quality, Indices are useful. The heavy metal pollution index (HPI) has been used to determine the heavy metal Pollution of ground and the surface water.^{12,13}

The metal index (MI) gives the possible additive effect of heavy metals on health and the overall drinking water quality. The HPI, MI and the non-carcinogenic risk assessment for the groundwater of some villages of Sirsa district were determined in the present study.

EXPERIMENTAL

All the heavy metals like Cadmium (Cd), Copper (Cu), Manganese (Mn), Arsenic (As), Lead (Pb), Chromium (Cr) and Zinc (Zn) were determined using ICP-MS and the data were used for the calculations. A total of 23 samples were collected from different villages of Sirsa district of Haryana state for the study. SPSS 16.0 software was used for statistical analysis. Microsoft Excel 2007 was used to draw various graphs.

Calculation of HPI: The HPI was calculated using the formula¹²:

$$HPI = \sum_{i=1}^n \frac{W_i Q_i}{\sum_{i=1}^n W_i} \quad (1)$$

$$\text{and } Q_i = \sum_{i=1}^n \frac{|M_i - I_i|}{S_i - I_i} \times 100 \quad (2)$$

Where w_i stands for the unit weight of the i th component, n gives the number of parameters, Q_i stands for the sub-index of the i th parameter, M_i is the observed value of the heavy metal in the analysis, I_i gives the ideal value for i th components and S_i gives the standard value of the i th component. All the values are given in Table-1.

Table-1

Heavy Metal	S_i (PPb)	I_i (PPb)	W_i	MAC ¹⁶	RfD ^{17,18} (Mg/Kg/Day)
Zn	1500	5000	0.000066	15000	3.0×10^{-1}
Mn	300	100	0.0033	300	1.4×10^{-1}
As	50	--	0.02	50	3.0×10^{-4}
Cd	10	--	0.1	10	5.0×10^{-4}
Cu	1500	50	0.0066	1500	5.0×10^{-3}
Pb	50	--	0.02	50	3.6×10^{-3}
Cr	50	--	0.02	50	3.0×10^{-3}

The Metal index (MI) was calculated for each sample using the formula¹⁹

$$MI = \sum_{i=1}^n \frac{C_i}{(MAC)} \times 100 \quad (3)$$

MAC is the maximum allowable concentration of the i th component and C_i is the concentration of the i th component in the sample.

Hazard Index (HI) – The non-carcinogenic risk assessment due to the intake of heavy metals polluted groundwater was calculated by HI using the equation¹⁴:

$$LADD = (C \times IR \times EF \times FD) / (AT \times BW) \quad (4)$$

Where,

LADD Lifetime average daily dose due to the intake of heavy metals by drinking in mg/kg/day

IR Ingestion rate of water (250 ml/day for infants, 1.5 L for children and 3 L for adults)

C Concentration of heavy metal in the samples

ED Exposure duration (66.4 years)

EF Exposure frequency (days/year)

AT Average time (days)

BW Bodyweight (6.9 kg for infants, 18.7 kg for children and 57.5 kg for adults)

The Hazard Quotient (HQ) was calculated using equation¹⁴: $HQ = LADD/RfD$ (5)

RfD is the reference daily dose for oral exposure of heavy metal exposed to an individual (mg/Kg/day).

The non-carcinogenic risk assessment given by HI and HI $\sum_{i=1}^n HQ_i$ (6)

Table-2 showing the maximum, minimum, mean, Std. deviation. All the concentrations are expressed in mg/l. NR means no relaxation, DI means desirable limit and PL means permissible limit.

Table 2

	DL-PL (ppm)	Minimum (ppm)	Maximum (ppm)	Mean	Std. Deviation
Mn	0.1-0.3	.00	1.03	.0902	.23069
Cd	0.003- NR	.00	.00	.0000	.00000
As	0.005-NR	.00	1.05	.0865	.23329
Cu	0.05-1.5	.00	1.02	.0860	.23214
Cr	0.05-NR	.00	1.03	.0869	.23169
Pb	0.01-NR	.00	1.00	.0803	.23408
Zn	5-15	.02	4.69	.4989	.94142
HPI		1.58	789.28	73.8357	178.03014
MI		.01	9.46	.8080	2.13713

RESULTS AND DISCUSSION

Carcinogenic Risk Assessment

The HPI value in the study area deviates from 1.50 to 789.28 for the seven heavy metals. The critical value of HPI is 100. Four samples exceed the critical value of HPI, so these are not suitable for human consumption. The main crops cultivated in the study area are wheat, mustard, cotton, Barley, Bajra, Guvar and Channa. The farmers in the study area are using fertilizers, fungicides, pesticides to improve their crop yield. The accumulation of heavy metals is continued by leaching¹⁵. Groundwater classification on the basis of HPI and MI^{19,20}. The HPI and MI for the samples are given in Table-3.

Table-3

S.No.	Sample No.	HPI	MI	S.No.	Sample No.	HPI	MI
1	Nimla	21.37	0.128	13	Rania	1.58	0.010
2	Bhuratwala	6.39	0.053	14	Nanuana	16.43	0.065
3	Chaharwala	13.06	0.128	15	Chattargarh Patti	30.74	0.212
4	Kashi Ka Bas	4.86	0.049	16	Rania	14.59	0.096
5	Sureran	17.61	0.106	17	Ahmadpur Road	3.92	0.038
6	Poharka	19.45	0.091	18	Rania	18.02	0.180
7	Mehna Khera	15.64	0.077	19	Bakriawali	55.28	0.496
8	Rania	6.92	0.050	20	Gudia Khera	105.55	1.152
9	Rania	25.49	0.168	21	Shahpuria	100.36	1.020
10	Bakriawali	3.50	0.038	22	Ganja Rupana	413.80	4.81
11	Kelnia Road	6.01	0.059	23	Rupana Bishnoia	789.28	9.463

Table-4

HPI	Pollution level	No. of Sample	Samples
< 15	Low	10	2, 3, 4, 8, 10, 11, 12, 13, 16, 17
15-30	Medium	7	1, 5, 6, 7, 9, 14, 18
> 30	High	6	15, 19, 20, 21, 22, 23

Table-5

MI	Class of water	No. of Samples	Sample
<0.3	Very pure	18	1, 2, 3, 4, 5, 6, 7, 8, 9, 10 11, 12, 13, 14, 15, 16, 17, 18
0.3 – 1.0	Pure	1	19
1.0 – 2.0	Slightly affected	2	20–21
2.0 – 4.0	Moderately affected	Nil	Nil
4.0 – 6.0	Strongly affected	1	22
>6.0	Seriously affected	1	23

Non - carcinogenic Risk Assessment

The non-carcinogenic risk was calculated using the Hazard Index (HI) for all the seven heavy metals. For the $HI < 1$, water is supposed to be safe and for $HI > 1$, it indicates risk¹⁵. The HI value for infants, children and adults is given in Table-6. Graphs showing (Fig.-1) the variation of HI for infants, children and adults:

Fig.-1

Table-6

S.No.	Sample No.	HI		
		Infants	Children	Adults
1	Nimla	0.69	15.87	25.70
2	Bhuratwala	0.49	10.78	14.33
3	Chaharwala	2.55	20.44	115.70
4	Kashi Ka Bas	0.54	11.94	18.23
5	Sureran	0.89	24.69	41.19
6	Poharka	0.82	23.86	36.30
7	Mehna Khera	0.84	22.42	37.68
8	Rania	0.81	11.15	17.44
9	Rania	2.65	21.68	117.50
10	Bakriawali	0.50	14.81	23.19
11	Kelnia Road	0.68	19.41	32.0
12	Rampur Their	1.03	28.15	42.90
13	Rania	0.09	1.89	2.93
14	Nanuana	0.74	21.0	33.96
15	Chattargarh Patti	4.82	41.65	234.54
16	Rania	1.50	41.86	67.04
17	Ahmadpur Road	0.75	21.31	35.0
18	Rania	2.19	60.04	87.42
19	Bakriawali	6.83	185.63	298.51
20	Gudia Khera	16.20	431.74	699.37
21	Shahpuria	13.45	363.85	589.92
22	Ganja Rupana	67.65	1809.47	2944.28
23	Rupana Bishnoia	149.50	3933.0	6396.38

Correlation Matrix

To find out the relationship among various heavy metals, Pearson's correlation matrix was used. A good positive correlation was observed between all the heavy metals except with Cd and Zn.

Table-7

	Mn	Cd	As	Cu	Cr	Pb	Zn	HPI	MI
Mn	1	. ^a	.993**	.997**	.998**	.994**	.137	.998**	.998**
Cd		1	. ^a	. ^a	. ^a	. ^a	. ^a	. ^a	. ^a
As			1	.992**	.993**	.988**	.093	.993**	.994**
Cu				1	.997**	.995**	.097	.998**	.998**
Cr					1	.996**	.084	.998**	.999**
Pb						1	.089	.998**	.998**
Zn							1	.097	.102
HPI								1	1.000**
MI									1

CONCLUSION

The heavy metal pollution indices and statistical methods were used to assess the groundwater quality in a highly cultivated area of the Sirsa district of Haryana state. The presence of heavy metals in groundwater was found to be due to agricultural activities mainly. The health risk due to heavy metals was ascertained by calculating HPI, MI and HI for infants, children and adults. HPI indicates that 10 samples have a low level of pollution index, 7 have a medium level and 6 have a high level of a pollution index. The MI value indicates that 18 samples are very pure, 1 is pure, 2 are slightly affected, 1 is strongly affected and 1 is seriously affected. The HI values indicate that 10 samples are not fit to consume by the infants and all the 23 samples are not suitable to consume by the children and the adults. The groundwater in the study area is contaminated by heavy metals and so immediate attention is required. To avoid any health problems in the future, the continuous monitoring of groundwater is necessary.

REFERENCES

1. L. Muthulakshmi, A. Ramu, N. Kannan, *Indian J. Environ. Protec.*, **29(5)**, 435(2009).
2. R.K. Jaiwal, S. Mukherjee, J. Krishnamurthy, R. Saxena, *Int. J. Remote Sens.*, **24(5)**, 993(2003).
3. G. Katalakute, V. Wagh, D. Panaskar, S. Mukate, *Nat. Resource Conser.*, **4(3)**, 35(2016).
4. DK Todd, *Groundwater Hydrology*, 2nd edn, Wiley, New York (1980).
5. O. Apoto, T.N. Bruce, G. Darko, *African J. Environ. Sci. Tech.*, **2(11)**, 354(2008).
6. E.O. Adaikpoh, G.E. Nwajei, J. E. Ogala, *J. Appl. Sci. Environ. Manag.*, **9(3)**, 5(2005).
7. J. Sirajudeen, S. Arul Manikadan, V. Manivel, *World J. Pharma. Pharmaceut. Sci.*, **4(1)**, 967(2014).
8. WHO, 2nd end. *Recommendation*, WHO, Geneva, pp.180-181(1993)
9. S.S. Kale, A.K. Kadam, S. Kumar, N.J. Pawar, *Environment Assess*, **162(1-4)**, 327(2010).
10. G. Tamasi. R. Cini, *Sci. Total Environ.*, **327**, 41(2014).
11. L. Belkhiril, L. Mounil, T.S. Narang, A. Tiri, *Ground Water Sustain. Dev.*, **4**, 12(2017).
12. S.V. Mohan, P. Nithila, S.J. Reddy, *J. Environ. Sci. Health A*, **31(2)**, 283(1996).
13. S.J. Reddy, *Apple Academia Press Inc., India*, (1995).
14. USEPA, *Vol. 1, Human Health Evolution Manual (Part A)*, Washington (1989).
15. K. Brindha, G. Jagadeshan, L. Kalpana, L. Elango, *Environ. Sci. Pollut. Res.*, **23**, 8302(2016).
16. Planning Commission, *(No ID: 4452)* (2011).
17. UNDESA, *Detailed Indicators 2012 Revision* (2013).
18. ICMR, *A Report of the Expert Group of ICMR, Hyderabad, India*, pp. 3340(2009).
19. I. Lyulks, T. Ambalova, T. Vasiljeva, *Netherlands*, pp. 449-452, (2001).
20. S. Caeriom M.H. Costa, T.B. Ramos, F. Fernandes, N. Silveria, A. Coimbra, M. Painho, *Ecol. Indic.*, **5**, 155(2005).

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