Estimation of heavy metals toxicity in the groundwater of rural area near Ellenabad, Sirsa (Haryana)

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Abstract. The present investigation emphasizes on the evaluation of heavy metal pollution indices to assess the suitability of groundwater for human consumption. For this, thirty groundwater samples were collected from the villages near Ellenabad city of Sirsa during pre monsoon of 2018 from the tube-wells. The samples were collected from approximately 100 m of depth. The samples were analyzed using Inductively Coupled Plasma – Mass Spectrometry (ICP - MS) for heavy metals like As, Hg, Pb, Zn, Cu and Mn. The heavy metals As, Hg and Pb were not found in our samples. The indices like heavy metal pollution index (HPI), heavy metal evolution index (HEI) and Hazard index (HI) were calculated to assess the suitability for drinking. These indices numerically give the suitability of groundwater for human consumption. On the basis of HEI and HPI, all the samples were found to be suitable for human consumption. The value of HI > 1 shows the unsuitability of groundwater for consumption. On the basis of the analysis, it can be said that children areat more risk followed by adults and then infants. The value of HI > 1 has been found for only two samples and which was also for children in sample number 20 and 24. So, majority of the samples have been found to be suitable for human consumption. Principal component analysis was performed for factor analysis which shows the initial Eigen value of more than two and total variance of more than 41.

Keywords – Contamination, factor analysis, groundwater, heavy metal pollution, statistical analysis

1. Introduction

Groundwater is supposed to be the purest form of water below the earth's surface but a large number of human activities make it contaminated for drinking. In the recent years population explosion has taken place in India that result in rapid industrialization and urbanization (Jalali 2009). Improper management of the waste results in the degradation in the environmental quality. The contaminated soil, water and air are known to have significant relationship between contaminated drinking water and the diseases (USEPA 1983). A very low concentration of heavy metals is required to regulate the metabolism. These metals are non degradable and hence they get accumulated in human body. A number of researchers have reported the mechanism of transportation of heavy metals to human body (Gupta 2008, Bhuiyan 2010, Kale 2010). So, the heavy metal pollution in drinking water is found to be most toxic in nature. The presence of heavy metals in groundwater by natural sources is very limited. However, it is mostly known by the anthropogenic activities (Purushotham 2013). The Industrial and mine waste, dumping waste is the significant source of heavy metals in ground water. The various quality indices give an overall idea about the pollution. So it becomes vital to screen the convergence of heavy metals in drinking water so as to avoid any health issue. Therefore, a number of indices like Heavy metal pollution index (HPI), heavy metal evolution index (HEI), Pollution index (PI), Ecological risk assessment (ER) and non-carcinogenic risk assessment has been calculated by various researchers to assess the groundwater pollution (Pawar 2016, Heerojeet 2015, Singh 2017, Vetrimurugan 2016). These indices give the combined effect of various heavy metals on the drinking water quality (Singh 2017, Brindha 2016). The current study was carried out in an intensively agricultural belt of Haryana state where groundwater is the chief source of irrigation and drinking. The farmers are using a lot of agro – chemicals for better crop production that may influence the content of heavy metals in groundwater. So, the present analysis was carried out with the objective i) to analyze the content of heavy metals in the groundwater of the study area and ii) to assess the health effects on consumption of such water with the help of various indices.

2. Sample collection and analysis

Representative groundwater samples were collected from different villages near Ellenabad city from tube well in May 2018. The groundwater samples were filtered using 0.45 um Whatmann filter paper and collected in polyethylene bottle. The sample was separated into two sections. One section is taken to the laboratory for physico chemical examination and to the other part added 1-2 ml of Conc. HNO_3 and then analyzed for heavy metals using ICP-MS. SPSS-
16.0 was utilized for statistical analysis. The groundwater samples were analyzed for six heavy metals namely As, Pb, Hg, Zn, Cu and Mn.

2.1 Evaluation of pollution indices

In the present analysis three indices namely HPI, HEI and HI were evaluated to describe the extent of heavy metal contamination. HPI and HEI give the impact of heavy metal contamination on the overall groundwater quality (Bhuiyan etal 2010). The Hazard Index (HI) involves the calculation of non-carcinogenic risk cause by the utilization of groundwater containing heavy metals (Vetrimuru)

Heavy metal pollution index (HPI)

HPI is used to assess the combined impact of each heavy metal on the overall quality of groundwater. Therefore, a number of researchers have used this method for the determination of water quality (Brown 1970, Herojeet 2015, Vetrimurugan 2016). The HPI was calculated as

$$HPI = \Sigma WiQi / Wi$$

$$\text{Where } Qi = \sum \left| Mi\text{-}Si \right| / (Si - Ii) \times 100$$

Here n is the number of parameter, Wi is the unit weight of i^{th} parameter, Qi is the Sub index of ith parameter, Ii is the ideal value of i^{th} parameter. Si is the standard value of i^{th} parameter.

Heavy metal Evolution Index (HEI)

HEI describes the overall quality of water with respect to heavy metals (Edet and Offiong 2002). HEI was calculated as HEI = $\sum$ (Hc /MAC) x 100 where H_C is the monitored value and MAC is the maximum allowed concentration of i*th* parameter as given in table number 1.

Hazard Index (HI)

HI was calculated using the equation (USEPA 1989)

LADD = (C × IR × EF × ED) / (AT × BW), Hazard Quotient (HQ) = LADD / RfD and Hazard Index (HI) = ΣHQi , Where C is the concentration of heavy metal present in water (mg/l), IR is the ingestion rate of water [For infants – 250ml/day, for children 1.5 L/dayand for adults 3 L/day (Brindha 2016, Planning commission 2011)]. EF is the exposure frequency (days/year), ED is the exposure duration [66.4 years (UNDESA 2013)], AT is the average time (days), BW is the body weight [For infants- 6.9kg, for children – 18.7kg, for adults – 57.5 kg (ICMR 2009), LADD is the lifetime average daily dose of ingestion of heavy metal by the consumption of water (Mg/Kg/day), HQ is the hazard quotient, RfD is the reference dose for heavy metals and HI is the hazard index. The reference daily dose of each heavy metal is given in table number 2.

3. Results and discussion

Table 3 shows the minimum, maximum and standard deviation of each heavy metal found in the groundwater of the study area. The presence of heavy metal is groundwater can be attributed to the weathering and the movement of heavy metals (Handa1986). Zinc performs a number of metabolic activities in body. In deficient amount it adversely affects the resistance and growth of the body. In the present analysis, the concentration of Zn varies between 7.40 to 636 ppb with an average value of 3.46 ppb. Mn helps to regulate the biochemical cycle in both animals and plants (Bulkariya and Ravi 1999). Mn content has been found to vary between 2.80 to 45.40 ppb with the average value of 14.99 ppb. None of the sample has been found beyond the BIS limit. The role of copper (Cu) is very important in plants and animals. It helps to produce blood hemoglobin, disease resistance production of seed and regulates water in plants and human being (Davies 1988). In our analysis, Copper

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concentration varies between
1.32 to74.40 ppb with an average value of 9.37 ppb. As per the BIS guidelines, all the samples lie within the limit.

Table 1. table showing different values of parameters to calculate HPI and HEI

Heavy metal	Wi	Si	Ii	MAC
Zn	0.0002	5000	3000	5000
Cu	0.0001	1000	2000	50
Mn	0.02	100	500	1000

Table 2. table showing the reference daily dose of heavy metals

Heavy Metal	RfD (Mg/Kg/day)
Zn	0.3
Cu	0.005
Mn	0.14

Table 3. Descriptive statistics of the heavy metals

Parameter	Minimum	Maximum	Mean	Std. Deviation
Mn	2.80	45.40	14.9947	10.06675
Zn	7.40	636.00	3.4588E2	163.27811
Cu	1.32	74.40	9.3783	16.69221
HEI	.01	.15	.0267	.03298
HPI	23.60	80.97	37.3490	9.17460

Table 4. Calculated HEI, HPI and HI for each groundwater sample

Sample Number	HEI	HPI	HI		
			Infants	Children	Adults
1	0.011	38.50	0.05	0.12	0.07
2	0.012	40.98	0.06	0.13	0.08
3	0.024	39.99	0.12	0.26	0.17
4	0.021	36.01	0.09	0.21	0.13
5	0.021	23.60	0.09	0.19	0.13
6	0.018	38.50	0.08	0.17	0.11
7	0.026	38.60	0.12	0.28	0.18
8	0.015	33.53	0.07	0.15	0.09
9	0.017	36.01	0.08	0.18	0.12
10	0.021	80.97	0.10	0.22	0.14
11	0.026	41.23	0.12	0.27	0.18
12	0.011	32.04	0.06	0.13	0.08
13	0.023	34.28	0.11	0.25	0.16
14	0.021	38.40	0.10	0.22	0.14
15	0.016	27.07	0.06	0.13	0.08
16	0.012	34.28	0.05	0.12	0.07
17	0.014	36.51	0.07	0.15	0.09
18	0.011	39.74	0.06	0.12	0.08
19	0.018	38.40	0.08	0.19	0.12
20	0.150	38.50	0.54	1.21	0.79
21	0.006	39.49	0.02	0.05	0.03

22	0.011	32.54	0.05	0.10	0.06
23	0.046	40.61	0.19	0.43	0.28
24	0.140	35.77	0.52	1.16	0.75
25	0.021	36.76	0.09	0.21	0.13
26	0.021	33.78	0.09	0.20	0.13
27	0.016	31.05	0.07	0.16	0.10
28	0.015	32.29	0.07	0.15	0.10
29	0.018	34.28	0.08	0.17	0.11
30	0.018	36.76	0.08	0.18	0.11

Table 5. Classification of groundwater with respect to HEI and HI

Index Name	Extent ofpollution	Range	Total number of samples	% of samples
HEI	Low Medium High	< 400 400-800 >800	30 Nil Nil	100 0 0
HI	High Low	>1 <1	02 28	6.66 93.34

Table 6. Correlation table

	Mn	Zn	Cu	HEI	HPI
Mn	1				
Zn	-.377*	1			
Cu	-.120	-.129	1		
HEI	-.129	-.041	.996**	1	
HPI	-.591**	.238	.024	.028	1

Heavy metal pollution index (HPI) - For tree heavy metals Zn, Cu and Mn in total 30 groundwater samples, the HPI varies between 23.60 to 80.97 with an average valueof 37.34 as evident from table number 4. All the samples lie below the critical value of HPI of 100 and therefore suitable for dinking.

Heavy Metal Evolution Index - The HEI varies from 0.01 to 0.15 with an averagevalue of 0.0267. Table 4 gives the value of HEI for each groundwater sample.

Hazard Index - By considering the three heavy metals Zn, Cu and Mn we have calculated the non-carcinogenic risk by the consumption of groundwater through HazardIndex (HI) and the values are reported in table number 4. The minimum value of HI for infants, children and adults was 0.02, 0.05 and 0.03 whereas the maximum value 0.54, 1.21 and 0.79 respectively.

Correlation matrix - From the correlation table it is evident that there is a strong positive correlation between Cu and HEI with r = 0.996. It shows that there is a significant contribution of Cu concentration in heavy metal evolution index. A moderate negative correlation of Mn and Zn has been observed as in table number 6.

Factor analysis – Principal component analysis (PCA) has been used for factor analysis. This technique is used to determine the relative information confined in each dataset. The result of PCA is shown in table number 7. From the table it becomes clear thatthe first and second components explain 76.968 % of the total variance with eigen values 2.052 and 1.796 respectively. The first four factors totally explain the 99.99 % of the variance in the original data set.

Table 7. Table showing the factor analysis

Component	Initial Eigen values			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
	2.052	41.039	41.039	2.052	41.039	41.039
	1.796	35.929	76.968	1.796	35.929	76.968
1	.774	15.486	92.455			
2	.377	7.545	99.999			
5	3.072E-5	.001	100.000			

4. Conclusion

The heavy metals contamination of an agricultural belt was assessed by using heavy metals indices and statistical techniques. The potential source of the heavy metals in the groundwater is the use of agro – chemicals. HEI, HPI and HI have been used to explain the health risk associated by the consumption of groundwater by considering the total six heavy metals namely As, Pb, Hg, Zn, Cu and Mn. In addition to these indices, correlation table and principal component analysis have been used to determine the groundwater quality with respect to heavy metals. The HPI values for all the samples have been found to be less than critical value of 100. So, all the samples have been found to be fit for human consumption. Also the values of HEI suggest that the groundwater is suitable for consumption. The value of hazard index (HI) is found to be more than one for only two samples.

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