Heavy Metal Contamination of Groundwater in the Tea Garden Belt of Darrang District, Assam, India

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Abstract: A study has been carried out on heavy metal contamination of groundwater with respect to cadmium, manganese, zinc and copper in the tea garden belt of Darrang district, Assam, India. Heavy metals in groundwater are estimated by using Atomic Absorption Spectrometer, Perkin Elmer AA 200. Univariate statistics along with skewness, kurtosis and 't' test have been employed to test the distribution normality for each metal. The study reveals that the groundwater of the area is highly contaminated with cadmium. A good number of samples are also found to contain manganese at an alert level. The concentrations of copper and zinc in the groundwater of the area are within the guideline values of WHO. Statistical results show that all the metals under study exhibit an asymmetric distribution in the area with a long asymmetric tail on the right of the median. Keeping in view of the high concentrations of cadmium and manganese, it is suggested to test the potability of groundwater of the area before using it for drinking.

Keywords: Cadmium, Manganese, Skewness, Kurtosis and t-Test.

Introduction

Heavy metal contamination of groundwater more often than not goes unnoticed and remains hidden from the public view. Presently, it has raised wide spread concerns in different parts of the world and results reported by various agencies have been alarming¹⁻². There is also evidence of prevailing heavy metal contamination of groundwater in many areas of India³⁻⁵. Cadmium is today regarded as the most serious contaminant of the modern age. Copper is classified as a priority pollutant because of its adverse health effects. Manganese is most often a concern for systems that use a groundwater source. Zinc is an essential element and is generally considered to be non-toxic below 5.0 mg/L. Thus, the monitoring of groundwater

quality has been universally recognized as the quality of ground water cannot be restored once it is contaminated, by stopping the flow of pollutants from the source. The elevated metal level in groundwater is a new public concern in Assam. But unfortunately, very few data on heavy metal contamination of groundwater are available in Assam. The need is for a more systematic and careful study eliminating all possible sources of error and to build up a reliable database. Groundwater contamination of metals with respect to cadmium, manganese, zinc and copper in the tea garden belt of Darrang district, Assam has been presented in this study.

Profile of the study area

The study area Darrang district is situated in the eastern parts of India on the northeast corner of Assam. Located on the bank of mighty river Brahmaputra, the district is largely plain. The district lies between $26^{\circ}25'$ and $26^{\circ}55'$ northern latitude and $91^{\circ}45'$ and $91^{\circ}20'$ eastern longitude Figure 1.

Figure 1. Sketch map of Darrang district showing its location.

Sampling information

For the present study, twenty eight water samples were collected inside as well as outside five tea gardens of Darrang district during June to November, 2008 (Table 1).

Table 1. Water sampling locations and sources.

S. No.	Sampling stations	Source	S. No.	Sampling stations	Source
A1	Inside Tangoni Tea Garden	Tubewell	B1	Outside Tangoni Tea Garden	Tubewell
A2	Inside Tangoni Tea Garden	Tubewell	B2	Outside Tangoni Tea Garden	Tubewell
A3	Inside Tangoni Tea Garden	Tubewell	B3	Outside Paneri Tea Garden	Tubewell
A4	Inside Paneri Tea Garden	Tubewell	B4	Outside Paneri Tea Garden	Ringwell
A5	Inside Paneri Tea Garden	Tubewell	B5	Outside Dimakusi Tea Garden	Tubewell
A6	Inside Paneri Tea Garden	Tubewell	B6	Outside Dimakusi Tea Garden	Tubewell
A7	Inside Dimakusi Tea Garden	Tubewell	B7	Outside (Ghagrapara) Corramore tea garden	Ringwell
A8	Inside Dimakusi tea garden	Ringwell	B8	Outside (Ghagrapara) Corramore tea garden	Ringwell
A9	Inside (Ghagrapara division) Corramore tea garden	Ringwell	B9	Outside Corramore Tea Garden	Ringwell
A10	Inside (Ghagrapara division) Corramore tea garden	Ringwell	B10	Outside Corramore Tea Garden	Ringwell
A11	Inside Corramore tea garden	Stream	B11	Outside Singrimari Tea garden	Ringwell
A12	Inside Corramore Tea Garden	Stream	B12	Outside Tangoni Tea Garden	Ringwell
A13	Inside Singrimari Tea Garden	Tubewell	B13	Outside Paneri Tea Garden	Tubewell
A14	Inside Singrimari Tea Garden	Tubewell	B14	Outside Dimakusi Tea garden	Ringwell

Experimental

Separate water samples were selected by random selection and compiled together in clean and sterile one litre polythene cans rinsed with dilute HCl to set a representative sample and stored in an ice box. Samples were protected from direct sun light during transportation to the laboratory and metals were analyzed as per the standard procedures⁶. All the metals were estimated by using Atomic Absorption Spectrometer (Perkin Elmer AA 200). The instrument was used in the limit of precised accuracy and chemicals used were of analytical grade. Doubly-distilled water was used for all purposes.

Data analysis

Univariate statistics were used to test distribution normality for each metal. The confidence interval was calculated at 0.05 level. *t*-Test is done under null hypothesis (H_0) by taking the assumption that the experimental data are consistent with the mean rating given by WHO⁷. Simple correlation analysis was used to relate the metal concentrations among themselves. Moment coefficients of skewness and kurtosis were calculated to express how the shapes of sample frequency distribution curves differ from ideal Gaussian (normal). Skewness was calculated as third moment of the population mean. In asymmetrical distributions, skewness can be positive or negative. Kurtosis was calculated as fourth moment of the population to describe the heaviness of the tails for a distribution. Some more statistical estimates derived from the normal distribution in the form of sample variance, 1st, 2nd, 3rd Quartile, Inter Quartile Range (IQR) were also made in the present study to find out the distribution pattern of the data and other related information. Details of these may be found in standard books on statistics and software packages⁸.

Results and Discussion

The results of analysis of various metals in groundwater samples of the tea garden belt of Darrang district, Assam are given in Table 2. To get an idea about the distribution pattern of the metal contents in groundwater inside and outside the tea gardens separately, data are graphically represented in Figure 2 and 3 respectively. To look into the trend and distribution patterns of cadmium, manganese, zinc and copper in groundwater of the study

area, data obtained from 28 sampling stations were exposed to several statistical treatments as discussed briefly in the methodology section. A conventional descriptive statistics based on normal distribution has been shown in Table 3.

Table 2. Metal contents of groundwater in the tea garden belt of Darrang district.

S. No.	Cu, ppm	Mn, ppm	Cd, ppm	Zn, ppm
A1	0.147	BDL	0.102	0.011
A2	0.089	BDL	0.112	0.027
A3	0.067	BDL	0.098	0.553
A4	0.032	0.026	0.016	0.172
A5	0.021	0.065	0.086	0.066
A6	0.043	BDL	0.023	0.012
A7	0.001	BDL	0.154	0.236
A8	0.011	0.002	BDL	0.346
A9	0.012	BDL	0.272	0.308
A10	0.083	0.001	0.154	0.177
A11	0.017	BDL	0.015	0.402
A12	0.018	BDL	BDL	0.064
A13	0.039	0.028	0.051	0.067
A14	0.037	0.041	0.079	0.321
B1	0.081	3.440	BDL	0.418
B2	0.098	0.600	BDL	0.541
B3	0.005	BDL	BDL	0.022
B4	0.009	BDL	0.015	0.321
B5	0.004	BDL	0.198	0.195
B6	0.001	0.003	0.169	0.231
B7	0.047	BDL	0.081	0.355
B8	0.055	BDL	0.110	1.493
B9	0.027	BDL	0.146	0.541
B10	0.021	BDL	0.102	0.413
B11	0.033	0.0045	0.001	0.211
B12	0.005	0.107	BDL	0.511
B13	0.007	0.085	BDL	0.481
B14	0.062	BDL	0.093	0.472

*BDL: Below Detection Limit

Figure 2. Variation of metal contents of groundwater inside the tea gardens.

Figure 3. Variation of metal contents of groundwater outside the tea gardens.

Table 3. Descriptive statistics of the metal contents of groundwater in the study area.

Statistics	Cu	Mn	Cd	Zn
Mean	0.038	0.157	0.074	0.320
Standard Error	0.007	0.123	0.014	0.055
Median	0.030	0.000	0.080	0.315
Range	0.150	3.440	0.270	1.400
Standard Deviation	0.036	0.653	0.073	0.291
Variance	0.001	0.427	0.005	0.085
Skewness	1.298	5.058	0.822	2.420
Kurtosis	1.648	26.127	0.277	9.230
1 st Quartile	0.010	0.000	0.000	0.093
2 nd Quartile	0.030	0.000	0.080	0.315
3 rd Quartile	0.060	0.028	0.112	0.459
IQR	0.044	0.026	0.109	0.246
WHO Rating, in ppm	2.000	0.400	0.003	5.000 (US Limit)
t-test value	289.774	1.949	5.154	85.134
Comment, 0.05 level	Significant	Non significant	Significant	Significant
95% CL	[0.024-0.052]	[0.001-0.412]	[0.046-0.103]	[0.207-0.433]
No of Samples	28	28	28	28

Pearson's correlation coefficient matrix is presented in Table 4 to measure the linear association among different metals under study. Since the directions of association of the measured variables are unknown in advance, two-tailed test of significance was carried out.

Table 4. Correlation table.

	Cu	Mn	Cd	Zn
Cu	1.0000			
Fe				
Mn	0.2770	1.0000		
Cd	-0.0068	-0.2445	1.0000	
Zn	0.0184	0.0925	0.0431	1.0000

In most of the samples under investigation, the cadmium contents were much above the guideline value of 0.003 ppm as set by WHO⁷. Cadmium above the permissible limit can potentially cause nausea, vomiting, diarrhea, muscle cramps, salivation, sensory disturbances, liver injury, convulsions, shock and renal failure along with kidney, liver, bone and blood damage from a lifetime exposure. Differences between mean and median, significant positive skewness and kurtosis value indicate that the distribution of cadmium in the study area is highly asymmetric. This is also evident from the width of the third quartile, which is much greater than the first and second quartile. The cadmium contamination of groundwater in the area should be accorded maximum attention.

Manganese at concentrations above 0.15 ppm stains plumbing fixtures and laundry and produces undesirable taste in drinks. The WHO limit for manganese in drinking water is 0.05 ppm⁷. It is observed that as many as seven samples under observation contain manganese either at toxic or alert level. Thus, manganese contamination of groundwater in the area needs proper attention. A broad third quartile and positive skewness in case of manganese represents a long asymmetric tail on the right of the median. Heaviness of the tail for manganese distribution in the area is evident from very high positive kurtosis value.

The permissible limit for copper in drinking water is 2.0 mg/L⁷. This was set to ensure the water tastes good and to minimize staining of laundry and plumbing fixtures. The distribution of copper in groundwater of the study area is found to be within the permissible limit of WHO⁷ with an average of 0.038 ppm. Asymmetric nature of copper distribution is also apparent from the normal distribution statistics with positive skewness and kurtosis values.

Although the groundwater of the study area are by and large safe with regard to zinc as may be seen from Table 2, its distribution is still not uniform in the area. Wide data range and high standard deviation in case of zinc is likely to bias the normal distribution statistic. This observation is supported by positive kurtosis and skewness value, which point towards sharp zinc distribution with a long right tail in the study area.

From the correlation of the studied metals as shown in Table 3, significant correlation was found among cadmium, copper and manganese. Cadmium shares a clear negative correlation with manganese and copper content at the 0.05 level in the area.

Conclusions

Statistical observations on Cd, Mn, Cu and Zn in groundwater of teagarden belt of Darrang district, Assam show that all these metals exhibit an asymmetric distribution with a long asymmetric tail on the right of the median. It is observed that the groundwater of the area is contaminated with cadmium. A sizeable number of groundwater samples contain manganese at an alert level. The concentrations of copper and zinc in the groundwater of the area are either low or moderate and within the guideline values of WHO. Keeping in view of the unusually high concentrations of the harmful metals, *viz.* cadmium and manganese, it is advisable to test the potability of groundwater of the area before using it for drinking.

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