Seasonal Distribution of Trace Metals in Ground and Surface Water of Golaghat District, Assam, India

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Abstract: A study has been carried out on the quality of ground and surface water with respect to chromium, manganese, zinc, copper, nickel, cadmium and arsenic contamination from 28 different sources in the predominantly rural Golaghat district of Assam (India). The metals were analysed by using atomic absorption spectrometer. Water samples were collected from groundwater and surface water during the dry and wet seasons of 2008 from the different sources in 28 locations (samples). The results are discussed in the light of possible health hazards from the metals in relation to their maximum permissible limits. The study shows the quality of ground and surface water in a sizeable number of water samples in the district not to be fully satisfactory with respect to presence of the metals beyond permissible limits of WHO. The metal concentration of groundwater in the district follows the trend $As > Zn > Mn > Cr > Cu > Ni > Cd$ in both the seasons.

Keywords: Trace metals, Groundwater, Surface water, Assam.

Introduction

Groundwater has been used as a source of drinking water for millions of rural and urban families in India. 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. The concentration of toxic metal ions has increased beyond environmentally and ecologically sustainable levels due to natural phenomenon as well as anthropogenic impact. The poisoning effect of toxic metals from contaminated drinking water has evolved as one of the major health hazards in the 21st century^{3,4}. There is also evidence of prevailing heavy metal contamination of groundwater in many areas of India^{5,6}. Recent studies show that the levels of trace metals present in drinking water could seriously affect human health⁷⁻¹¹. In the third world countries, the common people and sometimes even in the highly educated

people are not aware of the dangers of contamination of drinking water sources. Therefore, it is utmost importance to determine the quality of drinking water with respect to all constituents and take proper remedial measures, if required, to ensure quality criteria as formulated by WHO and other regulating bodies¹². Of all the contaminants present in water, metals are very important in governing drinking water quality. The presence of some metals in drinking water is desirable to certain extents for proper maintenance of human health. Above these limits, they behave as pollutants and toxicants causing serious health hazards. Again, some metals should not be present in water even in trace amounts because of their high degree of toxicity.

The present study area lies between 93° 49'8" to 94° 12'22"N and 26° 41'15" to 26° 5'E. It is the Golaghat subdivision of northeast part of Golaghat district (source: office of deputy director, economics and statistics, Golaghat district). The Golaghat sub-division having an area of 1838 km² has total population of 591924, as per 2001 census (Source: Office of deputy director, economics and statistics, golaghat district). The most widely used sources of drinking water in the Golaghat district are ring well and tube wells and sometimes pond water and river water also. The urban water supply scheme is inadequate and supply water only in some locations in Golaghat town. A large section of the people even in urban areas has to depend on tube wells and ring wells for their water needs and in the areas, these are the only sources for the people. The objective of the present work is to study the quality of ground and surface water in the district with respect to a few important metals Cr, Mn, Fe, Co, Ni, Cu, Zn, Pb and As.

Experimental

After thorough study of the topographic and climatic conditions of the study area, it was decided to collect twenty eight ground and surface water samples from tube wells, ring wells, rivers, pond and lake and supply water from Golaghat sub-division of Golaghat district during dry and wet season of 2008. The sampling stations, the type of sources, Cr, Mn, Fe, Co, Ni, Cu, Zn and Pb and As concentrations (ppm) for both dry and wet seasons are listed in Table 1. The water samples were collected in pre-cleaned plastic containers of 5 L capacity. The samples were preheated and reserved properly and analysis for heavy metals was carried out following standard procedure (APHA, 1995). To determine the amount of metals, 100 mL of each sample was acidified with conc. HNO₃ and was then allowed to evaporate in an oven at temperature 60 - 50 °C for reducing the volume to 20-30 mL. Then volume was made up to 100 mL by the addition of doubled distilled water. Finally the resulting samples were then analyzed using atomic absorption spectrophotometer (Variant spectra AA220).

Results and Discussion

Water sampling locations and sources are presented in Table 1. The experimental results are presented in Table 2. To look into the seasonal variations and distribution patterns of the metal contents in groundwater, data were exposed to several statistical treatments. Descriptive statistics based on normal distribution has been summarised for both dry and wet season in Table 3 & 4 respectively. Seasonal distributions of various metals in groundwater are graphically presented in Figures 1-7.

In the present study chromium content in groundwater are found to be above the permissible limit (in dry season) of WHO with a mean value of 0.0612 ppm and 0.04386 ppm respectively in dry and wet season. It may be seen from Table II that some of the water samples contain chromium at toxic levels. The skewness and kurtosis values for chromium in both the seasons indicate that its distribution in the study area is not uniform.

Table 1. Water sampling locations and sources

S. No	Sampling stations	Source	S. No	Sampling stations	Source
TW1	Mission patty, Golaghat	Tube well	RW1	Kamarbandha	Ring well
TW2	Errangapara, Golaghat	Tube well	RW2	Merapani	Ring well
TW3	Tatalital, Golaghat	Tube well	RW3	Sagunpara, Golaghat	Ring well
TW4	Sagunpara, Golaghat	Tube well	RW4	Jamuguri, Golaghat	Ring well
TW5	Jamuguri, Golaghat	Tube well	RW5	Pulibor, Golaghat	Ring well
TW6	Puspaban, Golaghat	Tube well	RIW1	Dhansiri, Golaghat	River water
TW7	Fatual, Furkating	Tube well	RIW2	Doyang	River water
TW8	Ghilaghary H.S. School	Tube well	RIW3	Rangma	River water
TW9	Bahbari	Tube well	RIW4	Kakodonga	River water
TW10	Athkhelia	Tube well	RIW5	Nambor	River water
TW11	Dhekial	Tube well	RIW6	Doigrong	River water
TW12	Silonijan	Tube well	PW	Tenpur pond	Pond water
TW13	Purabangla	Tube well	LW	Sankar lake	Lake water
TW14	Latakujan tea estate	Tube well	SW	Golaghat Town	Supply water

Table 2. Metal content in ground and surface water of Golaghat district at 20 different stations

Sample No.	Season	Cr	Mn	Zn	Cu	Ni	Cd	As
		in ppm	in ppm	in ppm	in ppm	in ppm	in ppm	in ppb
TW1	Dry	0.022	0.206	0.886	0.026	0.020	0.003	8
	Wet	BDL	0.194	0.775	0.031	0.019	BDL	5
TW2	Dry	0.117	0.117	0.624	0.024	0.022	0.002	38
	Wet	0.112	0.112	0.534	0.035	BDL	BDL	12
TW3	Dry	0.125	0.119	0.622	0.023	0.028	0.012	16
	Wet	0.134	0.104	0.586	0.033	0.018	BDL	12
TW4	Dry	0.021	0.125	1.122	BDL	0.025	0.005	7
	Wet	BDL	0.091	0.962	0.021	0.022	0.002	3
TW5	Dry	0.098	0.134	1.144	0.322	0.036	BDL	9
	Wet	0.113	0.095	0.966	0.122	0.022	BDL	4
TW6	Dry	0.120	0.114	0.675	0.031	0.026	BDL	9
	Wet	0.040	0.083	0.314	BDL	0.013	BDL	7
TW7	Dry	0.122	0.013	1.065	0.221	0.018	0.003	202
	Wet	0.076	0.006	0.752	0.128	0.028	0.004	164
TW8	Dry	0.032	0.114	1.175	0.032	0.018	BDL	26
	Wet	BDL	0.088	0.878	0.024	BDL	BDL	14
TW9	Dry	0.028	0.211	0.222	0.034	0.031	0.007	200
	Wet	0.041	0.162	0.144	0.021	0.024	0.004	162
TW10	Dry	0.032	0.151	1.123	0.036	0.016	BDL	192
	Wet	BDL	0.123	1.077	0.017	0.024	BDL	162
TW11	Dry	0.130	0.211	1.534	0.008	0.032	0.002	22
	Wet	0.077	0.124	0.988	0.024	0.022	BDL	18
TW12	Dry	0.211	0.084	1.087	0.017	BDL	BDL	22
	Wet	0.163	0.073	0.843	0.012	0.011	BDL	18
TW13	Dry	0.014	0.063	0.843	0.028	0.024	0.003	9
	Wet	BDL	0.043	0.655	0.021	0.024	0.002	6

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TW14	Dry	BDL	0.172	0.746	0.018	0.025	BDL	8
	Wet	BDL	0.115	0.462	0.015	0.017	BDL	7
RW1	Dry	0.102	0.213	0.634	0.041	0.018	0.004	35
	Wet	0.100	0.085	0.248	0.012	0.015	0.002	8
RW2	Dry	0.028	0.089	0.988	0.016	0.018	0.012	36
	Wet	BDL	0.089	0.655	0.012	0.029	0.002	24
RW3	Dry	0.016	0.093	1.122	0.047	0.024	0.003	9
	Wet	0.023	0.063	0.938	0.017	BDL	0.007	6
RW4	Dry	0.162	0.085	0.845	0.046	0.062	0.36	8
	Wet	0.184	0.075	0.948	0.035	0.028	0.36	4
RW5	Dry	0.117	1.023	1.787	0.032	0.045	0.004	153
	Wet	0.115	0.462	1.132	0.017	0.016	0.004	102
RIW1	Dry	0.012	0.068	0.574	BDL	0.028	0.015	12
	Wet	0.004	0.034	0.438	0.026	0.014	0.011	8
RIW2	Dry	0.011	0.077	1.642	0.022	0.037	0.021	8
	Wet	0.006	0.037	0.849	0.021	0.038	0.015	11
RIW3	Dry	0.011	0.102	1.322	0.014	0.024	BDL	9
	Wet	BDL	0.042	0.676	BDL	BDL	BDL	5
RIW4	Dry	0.015	0.094	0.865	0.022	0.024	0.004	6
	Wet	BDL	0.046	0.434	0.012	0.022	0.002	3
RIW5	Dry	0.017	0.077	1.246	0.022	0.018	BDL	3
	Wet	0.006	0.046	0.574	0.011	BDL	BDL	BDL
RIW6	Dry	0.022	0.034	1.023	0.026	BDL	0.003	BDL
	Wet	BDL	0.072	0.324	0.018	BDL	BDL	BDL
PW	Dry	0.056	0.096	1.034	0.014	0.028	BDL	9
	Wet	0.016	0.082	0.764	BDL	BDL	BDL	BDL
LW	Dry	0.058	0.26	1.442	0.015	0.022	0.014	2
	Wet	0.018	0.112	0.798	0.014	BDL	BDL	2
SW	Dry	0.016	0.093	1.027	0.027	BDL	0.001	7
	Wet	BDL	0.071	0.964	0.013	0.024	BDL	6

Table 3. Comparison of statistical data of different metals in dry season

Statistics	Cr	Mn	Zn	Cu	Ni	Cd	As
Minimum	BDL	0.034	0.222	BDL	BDL	BDL	BDL
Maximum	0.221	0.113	1.787	0.322	0.062	0.36	202
Mean	0.0612	0.1513	1.0149	0.04157	0.02389	0.01707	38.03571
Standard error	0.0105	0.0334	0.0642	0.0125	0.00234	0.0125	11.7082
Median	0.03	0.108	0.781	0.025	0.024	0.003	9
mode	0.011	0.077	0.655	0.022	0.018	0.000	9
Standard deviation	0.05607	0.1771	0.3399	0.0661	0.0124	0.0662	61.9524
Variance	0.0031	0.0055	0.1155	0.0043	0.00015	0.0043	3838.0998
Coefficient of variance	0.916	1.170	0.3349	1.590	0.5190	3.8781	1.6287
Skewness	7.4833	1.6385	0.136312	7.5498	5.46156	0.00000	5.68035
Kurtosis	56.0000	0.90678	0.344704	57.0000	29.7752	-3.16767	34.8610
Range	0.221	0.079	1.565	0.322	0.062	0.36	202
sum	1.7149	4.2379	28.4189	1.1640	0.6690	0.4780	1065

Table 4. Comparison of statistical data of different metals in wet season

Statistics	Cr	Mn	Zn	Cu	Ni	Cd	As
Minimum	BDL	BDL	0.144	BDL	BDL	BDL	BDL
Maximum	0.184	0.184	1.132	0.128	0.038	0.36	164
Mean	0.04386	0.09746	0.70279	0.02543	0.01536	0.01482	27.60714
Standard error	0.01066	0.82290	0.04917	0.005501	0.002090	0.0125	9.49722
Median	0.011	0.084	0.758	0.0175	0.0175	0	7
mode	0.000	0.046	0.655	0.012	0	0	0
Standard deviation	0.05645	0.0802	0.2602	0.02911	0.01106	0.06652	50.25459
Variance	0.0031	0.0064	0.0677	0.00084	0.000121	0.00442	2525.52
Coefficient of variance	1.2870	0.8234	0.3702	1.1447	0.72005	4.48852	1.82034
Skewness	1.10861	0.00000	5.29150	0.00000	-0.19653	5.26768	2.25124
Kurtosis	-0.04424	-3.3646	28.0000	-3.35042	-1.00196	27.82308	3.61477
Range	0.184	0.184	0.988	0.128	0.038	0.36	164
sum	1.228	2.7289	19.6780	0.7120	0.4300	0.4150	773

Figure 1. Seasonal variations of Cr(ppb) in the study area

Figure 2. Seasonal variations of Mn(ppb) in the study area

Figure 3. Seasonal variations of Zn(ppb) in the study area

Figure 4. Seasonal variations of Cu(ppb) in the study area

Figure 5. Seasonal variations of Ni(ppb) in the study area

Figure 6. Seasonal variations of Cd(ppb) in the study area

Figure 7. Seasonal variations of As (ppb) in the study area

Manganese concentration in groundwater was found to be within the range of 0.034-0.113 ppm during dry season and BDL-0.184 ppm during wet season. It is seen from Table 2 and 3 that mean manganese contents exceed the permissible level of 0.1 ppm (WHO, 2004)¹³ in 53.5% sampling points in dry season and 32.1% in wet season. Significant Standard deviations in case of manganese in dry season and wet season are likely to bias the normal distribution statistic.

Manganese is a vital micronutrient for both plant and animals. It is found in various salts and minerals, frequently in association with iron compounds. The concentration of zinc in sampling sources is in the range of 0.222-1.787 in dry season and 0.144-1.132 in wet season. Zinc is a nutritionally essential element. It is necessary for growth and is involved in several physiological functions. In all the samples under investigation, the zinc contents are much below the guideline value of 3 ppm. Positive kurtosis and skewness value for zinc in both dry and wet season is indicative of its sharp asymmetric distribution with a long right tail from its median.

It has been found that copper levels are low with few of samples being below detection limits. Where the metal concentrations are above detection limits, they still fall below the WHO guidelines value of 1 ppm. Copper is an essential micronutrient, but in high concentration causes physiological effects in human. Water containing 3 mg copper/L was associated with gastrointestinal disturbance in adults, whereas water containing 1 mg/L was not¹⁴. Copper shows higher concentration during dry season. Positive kurtosis and skewness value for copper in dry season is indicative of its sharp asymmetric distribution with a long right tail from its median. Again in wet season the distribution (negative kurtosis) of data are platykurtic (lower peak than a normal distribution) having no longer tail with symmetrical distribution (zero skewness).

It has been observed that nickel content of some of the sampling sites is high with compared to WHO guideline value 0.02 mg/L. Average nickel contents in dry season fall outside the maximum permissible limit of 0.02 ppm as set by WHO whereas the average Ni contents in wet season fall below permissible limit of WHO. The maximum value is obtained at sampling point RW4 during dry season. Positive kurtosis and skewness value for nickel in dry season is indicative of its sharp asymmetric distribution with a long right tail from its median. Again in wet season the distribution is negatively skewed with a tail in negative direction and platykurtic with a lower peak than a normal distribution.

It has been observed that the average cadmium content in dry season is 0.01707 and in wet season 0.01482 whereas WHO guideline value is 0.005 ppm and ISI limit is 0.01 ppm. So average cadmium contents in both dry and wet season fall outside the maximum permissible limit of ISI and fall below the permissible limit of WHO. The maximum cadmium content was found in RW4 (0.36 ppm) in both dry and wet season. In dry season the distribution of data is negatively skewed with a tail in negative direction and platykurtic with a lower peak than a normal distribution. Positive kurtosis and skewness value for cadmium in wet season is indicative of its sharp asymmetric distribution with a long right tail from its median. Cadmium is not biodegradable, can accumulate in human vital organs, producing progressive toxicity. Source of occurrence (naturally) is the type soil.

Arsenic concentration in groundwater and surface was found to be within the range of BDL–202 ppb during dry season and BDL–164 ppb during wet season. It is observed that groundwater samples of Golaghat district fall under alert category with respect to arsenic as some of the samples exceed and some are approaching the WHO (2004) and USEPA (2001) guideline value 10 ppb (Table 2). Positive kurtosis and skewness value for arsenic in both the season is indicative of its sharp asymmetric distribution with a long right tail from its median. Wide data range and high standard deviation in case of arsenic in both dry and wet season are likely to bias the normal distribution statistic. Significant differences among mean, median and mode along with significant skewness and kurtosis values observed for arsenic in both the seasons are indicative of

departure of sample frequency distribution curve from normal. Mean arsenic contents exceeds the permissible level of 10 ppb (WHO, 2004)¹³ in 42.8% sampling points in dry season and 39.2% in wet season. The highest arsenic content was found in TW7 (202 ppb). So people should not drink water from this tube well.

During the study, seasonal variations are also observed for all the trace metals under investigation. By comparing the average values of all the trace metals, it is observed that the metal content of groundwater and surface in the district follows the trend As>Zn>Mn>Cr>Cu>Ni>Cd in both the seasons. It has been noticed that average arsenic concentrations in both the season fall in high alert category. Although, arsenic contents beyond the guideline value (10 ppb) of WHO and USEPA have been found in a large number of samples, no report of Arsenocosis from the areas has been known till date.

Conclusion

Statistical observations on chromium, manganese, zinc, copper and nickel in ground and surface waters of Golaghat district, Assam show that all these metals exhibit a non-uniform distribution.

Comparing the water content of trace metals with the recommended maximum values for drinking purposes, it is found that a sizeable number of ground and surface samples contain chromium, manganese, nickel, cadmium and arsenic 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 specially for arsenic at some of the sampling sites, it is concluded that regular monitoring of water sources should be ensured by the concerned authorities to prevent the outbreak of water borne diseases in the area.

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References

1. Friberg L, Nordberg G F and Vouk V B, Ed., *Handbook of the Toxicology of Metals*, Elsevier, Amsterdam, 1986, **2**, 130-184.
2. WHO/UNEP G E M S, *Global Fresh Water Quality*; Published on Behalf of the World Health Organization/United Nations Environment Programme, Oxford, Blackwell Reference, 1989.
3. Bagla P and Kaiser J, *Science*, 1996, **274**, 174-175.
4. Lepkowski W, *Arsenic Crisis in Bangladesh*, C&EN News, 1998, **27**, November 16.
5. Sharma A, Sharma D K, Jangir J P and Gupta C M, *Indian J Environ Protect*, 1989, **9**(4), 294-296.
6. Bhattacharya P, Chatterjee D and Jacks G, *Water Resources Development*, 1997, **13**, 79-92.

7. Chi-Man L and Jiu J J, *Water Res.*, 2006, **40(4)**, 753-767.
8. Demirel Z, *Environ Monit Assess.*, 2007, **132 (1-3)**, 15-23.
9. Nganje N, Edet A E and Ekwere S J, *Environmental Geosciences (DEG)*, 2007, **14(1)**, 15- 29.
10. Yasuhiro S, Duong V T, Daigo S, Doan C and Yoshito K, *J Health Sci.*, 2007, **53**, 344-346.
11. Dixit R C, Varma S R, Notnaware V and Thacker N P, *Indian J Environ Health*, 2004, **45(2)**, 107-112.
12. Sarma B C, Misra A K and Bhattacharyya K G, *Indian J Environ Protect.*, 2000, **21(4)**, 316-322.
13. WHO, Guidelines for Drinking water Quality, 3rd Edition. Geneva: World Health Organization, 2004.
14. Pizarro F, Olivares M, Uauy R, Contreras P, Rebelo A and Gidi V, *Environ Health Perspectives*, 1999, **107**, 117-121.