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Metal Contamination in Ground Water of Dang District

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Abstract
Drinking water quality in Nepal has been an issue of prevalent concern. So, this study was conducted to visualize the scenario of metal contamination in ground water of Dang district located at central west Terai in Nepal. A total of 523 water samples from tubewells and dugwells positioned in 16 village development committees (VDCs) were tested for arsenic in laboratory using atomic absorption spectrophotometer (AAS) employing continuous flow hydride generation technique. Randomly selected 20 samples were also tested for other heavy and trace metals like Mn, Fe, Cu, and Cd using AAS employing flame method. Of the total samples, 50.3% was found to contain arsenic above WHO drinking water qualty guidelines value of 10 ppb (0.01 mg/l) and 10.7% was found to contain arsenic above national drinking water quality guidelines value of 50 ppb (0.05 mg/l). The safest VDC is Sonpur while the most severely affected VDC is Gobardiha. A highest concentration of As of 240 ppb (0.24 mg/ l) was found in Dhikpur VDC. Ground water in this area seemed to be affected by high concentration of iron up to 11.01 mg/l and of manganese up to 0.51 mg/L. Statistical tools were employed to assess the probable association among metals but no significant correlation could be retrieved.

Key words: hydride generation-atomic absorption spectrophotometry, redox conversion, arsenicosis, heavy and trace metals

Introduction

Water is life but when contaminated, can be a cause of death. Regarding this fact, water quality has become a burning issue globally and so does in Nepal. Of the myriads of contaminants, metals, especially heavy and trace, engender serious health hazards in human and animals when present and consumed in higher concentration. Arsenic is a contaminant present pervasively in high concentration in ground water (GW) of Terai belt of Nepal. Opting this, the study was mainly focused on assessment of arsenic contamination in Dang District. Other metal contaminants like Fe, Cu, Mn, and Cd were also assessed simultaneously.

Arsenic is a metalloid presented at the group 15 of the modern periodic table. Physically, arsenic occurs in many allotropic forms and in oxidation states of –III (as in AsH_3), +III (as arsenites) and +V (as arsenates, most stable form). Penta and trivalent forms undergo redox conversion which makes its availability in the environment more abundant. It forms colourless, tasteless, and odorless crystalline oxides As_2O_3 and As_2O_5 which being hygroscopic dissolve readily in water to form weak arsenic (V) acid (H_3AsO_4). Arsenic is highly toxic element and regarded as the king of poisons. Chemically, it is found in both organic and inorganic forms and the latter is more toxic and the trivalent form is more noxious. International Agency for Research in Cancer (IARC) has identified it as a group 1 carcinogen. WHO (1993) has recommended a tolerable concentration of arsenic to be 10 ppb (0.01 mg/l) and Nepal Government in 2006 has formulated a National Drinking Water Quality Guidelines which has set the maximum concentration of arsenic in drinking water to be 50 ppb (0.05 mg/l).

Arsenic is profusely distributed in earth's crust (52nd in abundance) in the form of minerals viz. arsenopyrite, realgar (As_4S_4), and orpiment (As_2S_3), etc. Due to weathering and other process like fragmentation of arsenic rich rocks and minerals it is introduced to water, ground water, and soil and sediments. Ground water in Indian sub-continent, especially Bangladesh, West Bengal (India) and Terai belt of Nepal, is sternly contaminated with arsenic. Although arsenic is essential to human body in ultra trace amount, it is physiologically highly deleterious if consumed in high concentration. Concentration of arsenic in 100 ppb is considered to have lethal impact on human as well as animal health. Arsenic being an effective carcinogen causes keratosis, and melanoma and in severe cases arsenicosis. It is the condition in which arsenic is deposited to skin, hair, and nails where it is firmly bounded to keratin. It also has teratogenic effect. If consumed in high concentration for prolonged period, it may also be found in liver, kidney, spleen, and lungs as well. This eventually can lead to severe renal and pulmonary dysfunction and even skin cancer.

Sometimes, arsenic may be associated with some other heavy and trace metal contaminants like cadmium, manganese, iron, copper etc. Their presence in intolerable limits can produce even more rigorous effects upon human health. For instance, cadmium is highly deleterious for kidney and other vital organs and may even cause genetic mutation. Prolonged consumption of high concentration of cadmium may ultimately lead to death. Likewise, manganese in high concentration is found to be associated with nervous system disorder. Copper, in high concentration, may prove to be dangerous to infants (Lee 1999). Concerning these facts, a research was conducted to assess the presence of probable contaminants along with arsenic.

In lieu their impact on human health, iron and manganese when present in high concentration in ground water have tendency of reducing arsenic concentration by the phenomenon like co-precipitation and adsorption.

Materials and Methods

Among 41 VDCs in Dang district, 523 water samples of tube wells and dug wells from16 VDCs were tested at the Central Drinking Water Quality Testing Laboratory, Department of Water Supply and Sewerage (DWSS). Moreover, out of 523 samples, 20 samples were chosen randomly and administered to analyze other metal parameters like iron, copper, manganese, and cadmium.

Sample collection

Water samples were collected in the field in acid rinsed polythene bottle of capacity 125 ml. About 1 ml of concentrated hydrochloric acid of analytical grade, just enough to adjust sample pH below 2, was used to preserve the sample and transported to the central laboratory of DWSS.

Analytical procedure

In laboratory, water samples were analyzed by AAS (Thermo SOLAAR) employing continuous flow hydride generation technique for arsenic and other parameters were tested by simple flame method. All the analyses were carried out adopting standard methods of analysis formulated by (American Public Health Association (APHA) and National Arsenic Steering Committee (NASC). Chemicals and reagents used in the analysis were of analytical grade, double distilled water was used for solution preparation. Water samples, for testing arsenic, were pretreated prior to analysis adding 5 ml each of concentrated HCl and 10% (v/v) NaI and kept for about 20 minutes. On the other hand, water samples were kept for acid digestion for analysis of other metals. Linear calibration curve method using three standard metal solutions was employed to carry out the analysis.

Chemistry of arsenic analysis

In 50 ml of a sample 5 ml each of conc. HCl and 10% w/v NaI are added. As a result, all arsenic species, both As(III) and As(V) , are converted into arsenic (III) tri-Iodide which on reaction with 0.5% sodium borohydride ($NaBH_4$) solution in acidic medium (50% v/v HCl) gives arsine gas (AsH_3). Arsine is stable kinetically but not thermodynamically. So, it readily changes to arsenic in flame which gives absorbance at 193.7 nm.

$$\text{As(III) and As(V)} \xrightarrow{NaI/H^+} AsI_3 \quad \text{(Reduction of As(V) into As(III))}$$

$$4AsI_3 + 3NaBH_4 \xrightarrow{H^+} 4AsH_3 + 3NaI + 3BI_3 \quad \text{(Arsine Generation)}$$

$$2AsH_3 \xrightarrow[\text{Heat}]{} 2As + 3H_2 \quad \text{(Thermal Decomposition of Arsine into Arsenic)}$$

Results and Discussion

A total of 523 ground water samples from 16 VDCs were tested for arsenic in DWSS laboratory. Of them, 49.7% was found to be within 10 ppb concentration ie safe, 39.6% of them were found to contain arsenic concentration in the range 11-50 ppb which is above WHO tolerable limit and 10.7% was found to contain arsenic concentration more than 50 ppb violating National Drinking Water Quality Guidelines Value for arsenic. A case of severe arsenicosis was identified in Bela VDC. (Table 1)

Table 1. Status of arsenic in 16 VDCs

SN	**VDCs**	Total no. of Samples	Concentration of arsenic in ppb						Highest conc in ppb
			0-10		11-50		>50		
			No.	%	No.	%	No.	%	
1	Dhikpur	50	13	26	28	56	9	18	240
2	Dharna	40	14	35	18	45	8	20	183
3	Saudiyar	39	15	38.5	24	61.5	0	0	47
4	Sonpur	34	33	97	1	3	0	0	14
5	Chailahi	30	27	90	2	6.7	1	3.3	51
6	Satbariya	39	22	56.4	12	30.8	5	12.8	64
7	Rajpur	40	1	2.5	29	72.5	10	25	79
8	Bela	33	14	42.4	16	48.5	3	9.1	138
9	Gangaparspur	42	22	52.4	20	47.6	0	0	40
10	Gadhwa	37	4	10.8	30	81.1	3	8.1	77
11	Sishaniya	25	22	88	3	12	0	0	49
12	Lalmatiya	28	27	96.4	1	3.6	0	0	12
13	Gobardiha	51	20	39.2	15	29.4	16	31.4	146
14	Others	35	26	74.4	8	22.8	1	2.8	72
Total		523	260	49.7	207	39.6	56	10.7	

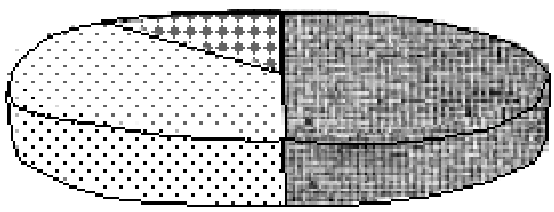

Fig.1. Status of arsenic contamination in 16 VDCs

Of the 16 VDCs chosen for our study, Saudiyar, Sonpur, Gangaparaspur, Sishaniya and Lalmatiya were found to possess 100% safe tubewells (TW) and dugwells i.e. no well having arsenic concentration above 50 ppb. In Sonpur, 97% of TWs and DWs were found to contain arsenic concentration upto 10 ppb. Gobardiha was the most affected VDC with 31.4% of wells contaminated with arsenic above 50 ppb followed by Dhikpur with 18%. Rajpur was the VDC possessing least percent of wells (2.5%) containing arsenic concentration upto 10 ppb. Gadhwa, with 81.1%, was the VDC with highest percent of well containing arsenic concentration in the range of 11-50 ppb.

Fig.1 depicts the overall status of arsenic contamination in VDCs chosen for research.

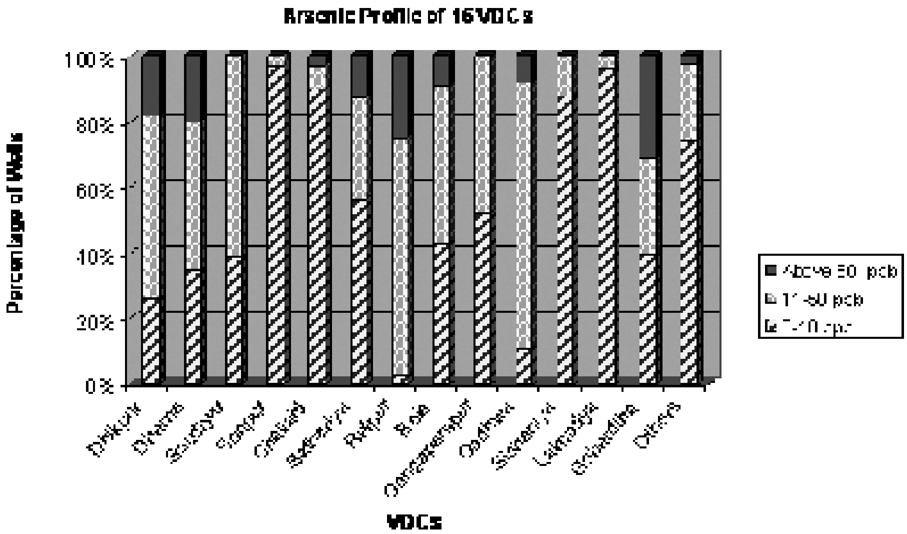

Fig. 2. Arsenic contamination profile of 16 VDCs

A graph of concentration of arsenic versus VDC was plotted. It exhibits: 4 VDCs namely Saudiyar, Sonpur, Gangaparaspur, and Lalmatiya contained highest arsenic concentration below 50 ppb; 5 VDCs viz. Chailahi, Satbariya, Rajpur, Gadhawa etc contained arsenic concentration between 50 and 100 ppb. On the other hand, rest of 4 VDCs were found to contain arsenic concentration above 100 ppb with Dhikpur possessing the highest concentration of 240 ppb followed by Dharna with 183 ppb.

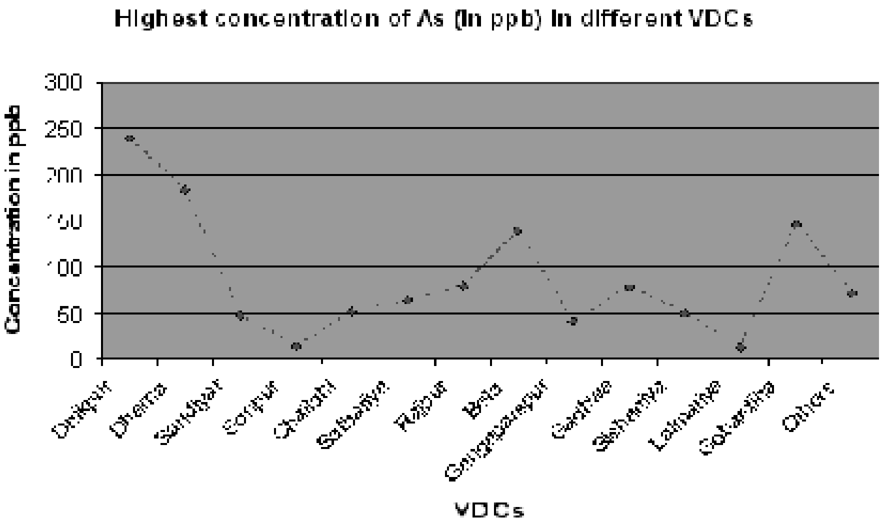

Fig 3. High concentration of arsenic in different VDCs

Among 523 samples brought to the central laboratory, 20 were selected randomly for the assessment of other probable heavy metal contaminants like iron, copper, manganese and cadmium.

Table 2. AAS analysis of heavy and trace metal contaminants

S.N.	Sample ID	Concentration of metals in mgL^{-1}, analyzed by AAS				
		Arsenic	Iron	Copper	Manganese	Cadmium
1	D-24	0.048	2.69	0.005	0.097	0.000
2	D-30	0.072	2.31	0.009	0.339	0.000
3	D-48	0.016	0.13	0.006	0.000	0.000
4	D-50	0.046	2.72	0.000	0.037	0.000
5	D-73	0.045	2.29	0.008	0.052	0.000
6	D-75	0.032	3.01	0.010	0.079	0.000
7	D-135	0.014	1.93	0.000	0.513	0.001
8	D-147	0.028	2.17	0.005	0.126	0.000
9	D-219	0.001	0.50	0.024	0.000	0.000
10	D-227	0.000	0.15	0.015	0.000	0.000
11	D-240	0.001	0.63	0.020	0.000	0.000
12	D-243	0.0004	0.23	0.101	0.000	0.000
13	D-273	0.001	0.17	0.020	0.000	0.000
14	D-275	0.002	0.13	0.000	0.000	0.000
15	D-311	0.078	8.43	0.000	0.208	0.002
16	D-316	0.047	5.18	0.000	0.228	0.000
17	D-318	0.044	4.81	0.012	0.184	0.000
18	D-342	0.025	5.86	0.004	0.407	0.001
19	D-445	0.0004	0.17	0.000	0.000	0.000
20	D-509	0.047	11.01	0.0003	0.326	0.002

Iron was found to be above Nepal water quality standard value of 0.3mg/l in 14 samples with the highest concentration of 11.1mg/l, manganese (Nepal standard value: 0.2mg/l) in 6 samples with highest concentration of 0.513 mg/L. Other metals viz. copper and cadmium were found to be within Nepal water quality standard values of 1.0 mg/l and 0.003mg/l respectively.

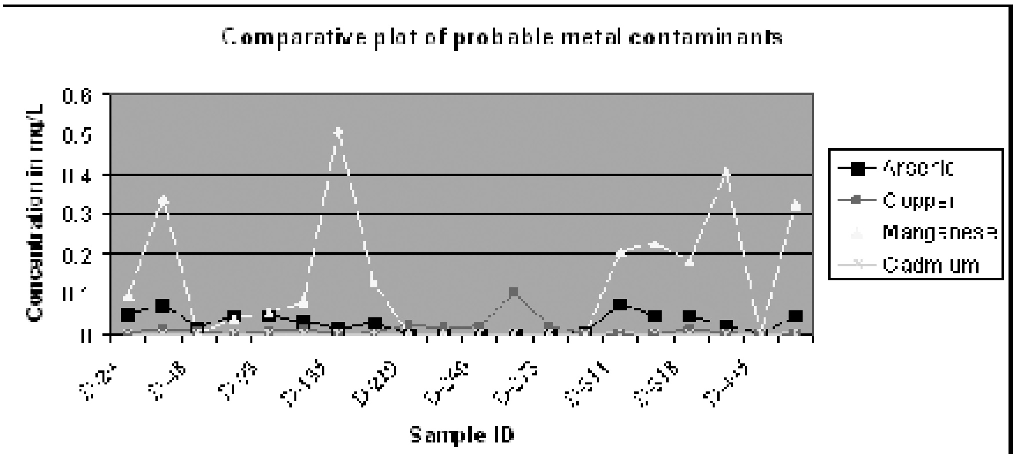

Fig. 4. Comparative concentration of four metals

Statistical tools were employed to ascertain probable correlation among these metals but no significant correlation was found

On the basis of this study, Dang district was found to be moderately affected by arsenic contamination in ground water with 10.7% of wells containing arsenic concentration transcending National Drinking Water Quality Standard Value of 50 ppb (0.05mg/l). Specifically, Gobardiha was the most arsenic affected VDC. Conversely, Sonpur, Saudiyar, Gangaparaspur, and Sishaniya were the safest VDCs as per our study.

Since arsenic is highly carcinogenic, possible means of mitigation should be promptly executed for the inhabitants of highly affected VDCs. Arsenic removal filters are the best option in household level. On the other hand, installation of deep tubewell may be the best mitigation option in community level. Prior to execution of mitigation options, public awareness programs should be launched to make people serious and concerned about the effects of arsenic in human and animal health. This will help establish mitigation program firmly and effectively.

Furthermore, other metals like iron and manganese were found to associate along with arsenic in high concentration. But the correlation among these metals could not be figured out in a significant manner as per our study. It might be due to inadequate sample size. So, in future, some large scale research can be conducted to find out such correlation. Such research may help not only to establish correlation among metal contaminants but also to locate arsenic safe source of drinking water as iron and manganese, when present in high concentration in ground water, may reduce the concentration of arsenic by the phenomenon of co-precipitation and adsorption.

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