STATUS OF ARSENIC CONTAMINATION AND ASSESSMENT OF OTHER PROBABLE HEAVY METAL CONTAMINANTS IN GROUND WATER OF DANG DISTRICT IN NEPAL

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Abstract: Issue of arsenic contamination in drinking water in Terai belt has been a prevalent phenomenon in Nepal. So, this study has been conducted to visualize the status of arsenic contamination in ground water in Dang district located at central west Terai in Nepal. A total of 26,878 Tubewells and Dugwells were tested in 36 Village Development Committees (VDCs) using HACH arsenic testing field kit and 811 samples were re-tested employing Wagtech Digital Arsenator. 540 samples were analysed for confirmation by continuous flow Hydride Generation Technique using Atomic Absorption Spectrophotometer (AAS) in the DWSS laboratory. Of the total samples, 0.83% was found to contain Arsenic above WHO drinking water Qualty guidelines value of 0.01 mg/l (10 ppb) and 0.2% was found to contain arsenic above National Drinking Water Quality Guidelines value of 50 ppb. Gobardiha and Gangaparaspur are the two most affected VDCs with 1.75 and 1.16 percents of Tubewells being affected by arsenic of concentration above 50 ppb. The highest Arsenic concentration of 150 ppb was found in Bela and Gobardiha VDCs and a severe case of *Arsenicosis* was identified in Bela VDC. 20 samples were randomly chosen and analyzed for other heavy and trace metal contaminants like Cu, Fe, Mn, and Cd using flame AAS method. Ground water in this area seems to be affected by high concentration of Iron upto 11.01 mg/l and of Manganese upto 0.51 mg/l. Statistical tools were employed to assess the probable association among them but no significant correlation among arsenic and other metals could be retrieved.

Keywords: Atomic Absorption; Spectrophotometry; Standard Reduction Potential; Arsenicosis; Heavy and Trace metals.

INTRODUCTION

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). Pentavalent form having Standard Reduction Potential of 0.56V is strongly reduced to trivalent form. The ability of arsenic to undergo redox conversion between As(III) and As(V) makes its availability in the environment more abundant[4]. It forms colourless, tasteless, and odourless crystalline oxides As_2O_3 and As_2O_5 which are hygroscopic and readily soluble in water to form weak acidic solutions of. 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 poisonous. 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 fixed the maximum concentration of arsenic in drinking water to be 50 ppb.

Arsenic is abundantly distributed in earth's crust (52nd in abundance)[3] 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 severely contaminated with arsenic. Although arsenic is essential to 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 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

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eventually can lead to severe renal and pulmonary dysfunction and even skin cancer. In Nepal, 400 cases of Arsenicosis have been reported in 2006[7].

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. Concerning these facts a research was conducted to assess the presence of probable contaminants along with Arsenic.

MATERIALS AND METHODS

26,878 water samples of tube wells and dug wells from 36 VDCs in Dang district were tested in field by employing HACH Arsenic field test kit. Of which, 811 samples were retested for confirmation in field by using WAGTECH Digital Arsenator. Again, 540 of the sample were transported to Central Drinking Water Quality Testing Laboratory for the cross checking purpose. Out of 540 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 Atomic Absorption Spectrophotometer (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 APHA and 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 conc. HCl and 10% (v/v) NaI and kept for about 20 minutes. On the other hand, water samples were undergone 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[1] which gives absorbance at 193.7 nm.

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

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

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

RESULT AND DISCUSSIONS

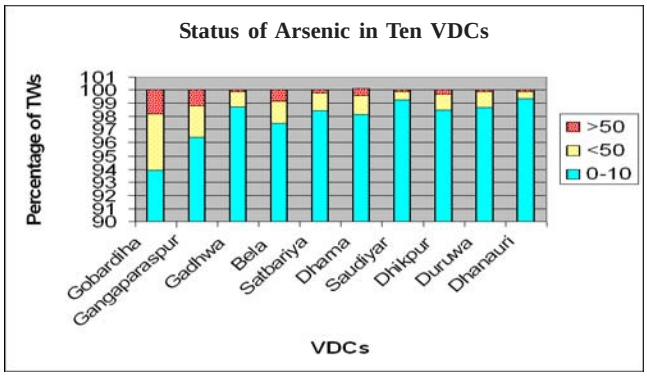
A total of 26,878 Ground Water samples from 36 VDCs were tested for arsenic in field level and 99.17% of them were found to be within 10 ppb concentration, 0.63%of them found to contain arsenic concentration of 11-50 ppb which is above WHO tolerable limit and 0.2% were found to contain arsenic concentration more than 50 ppb violating National Drinking Water Quality Guidelines Value for arsenic. Of 41 VDCs of Dang, 5 VDCs contain no ground water source for drinking purpose and among rest of 36 VDCs: 17 VDCs possess ground water concentration of arsenic upto 10 ppb ie safe, 10 VDCs contain above 50 ppb and remaining VDCs contain no arsenic concentration in Ground Water. A case of severe arsenicosis was identified in Bela VDC. (Table 1 & 2)

Table 1: Status of Arsenic in VDCs having concentration above 50 ppb

SN	VDCs	Total no. of Samples	Concentration of Arsenic in ppb						Highest Conc in ppb
			0-10		11-50		>50		
			No.	%	No.	%	No.	%	
1	Gobardiha	686	644	93.88	30	4.37	12	1.75	150
2	Gangaparas	1116	1076	96.42	27	2.42	13	1.16	80
3	Gadhwa	1468	1450	98.77	16	1.09	2	0.14	74
4	Bela	676	659	97.49	11	1.63	6	0.89	150
5	Satbariya	1060	1043	98.4	15	1.42	2	0.19	56
6	Dharna	853	837	98.12	13	1.52	4	0.47	80
7	Saudiyar	1708	1696	99.30	10	0.59	2	0.12	51
8	Dhikpur	1005	990	98.51	12	1.19	3	0.3	51
9	Duruwa	914	902	98.69	11	1.20	1	0.11	60
10	Dhanauri	738	733	99.32	4	0.54	1	0.14	75

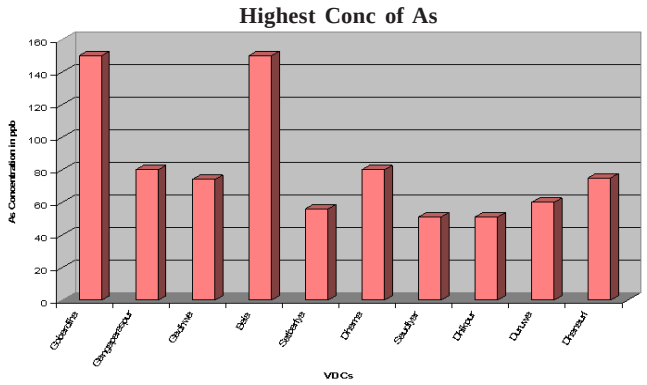
More than 90% of Tubewells were safe in each VDC. Gobardiha possesses the highest number of arsenic affected TW and DW above 50 ppb with the percentage of 1.75 followed by Gangaparaspur with 1.16%.

Figure 1: Graphical Representation of Arsenic status in ten VDCs.



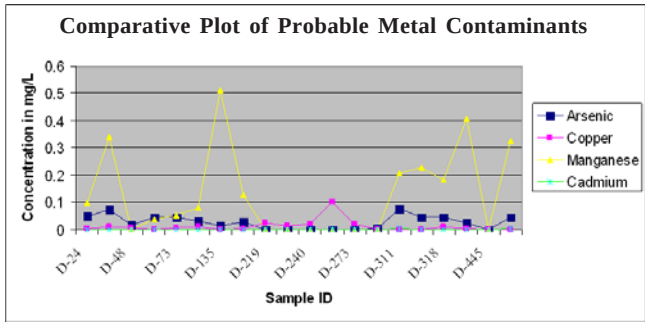
Highest Arsenic concentration was plotted against VDC and following graph was obtained.

Figure 2: Highest Concentration of Arsenic in Different VDCs.



Among highly Arsenic contaminated VDCs, the highest concentration of Arsenic of 150 ppb was found in two VDCs namely Bela and Gobardiha. Moreover, an *Arsenicosis* patient was identified in Bela VDC.

Figure 3: Comparative Concentration of four metals.



Statistical tools were employed to ascertain probable correlation between Iron and Arsenic and no significant correlation was found.

CONCLUSIONS AND RECOMMENDATION

On the basis of study, Dang district was found to be moderately affected by arsenic contamination in ground water with almost 0.2% of total Tube Wells containing Arsenic concentration transcending National Drinking Water Quality Standard Value of 0.05mg/L. A case of severe Arsenicosis was identified in Bela VDC. So, possible means of mitigation is necessary for the inhabitants of highly affected VDCS. 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. In future, some large scale research can be conducted to find out such correlation.

Table2: AAS analysis of probable Heavy 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

Among 540 samples brought to central laboratory, 20 were selected randomly for the assessment of other probable heavy metal contaminants like iron, copper, Manganese and cadmium. 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.

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