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ARSENIC CONTAMINATION IN THE DEEP AND SHALLOW GROUNDWATER OF BARA DISTRICT, NEPAL

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ABSTRACT
Groundwater is the main source of drinking water in the Tarai region of Nepal. Communities depend on drinking water of dug wells and tube wells. Altogether thirty six groundwater samples were randomly collected from dug wells and tube wells of Bara District, during pre-monsoon in 2012. The depths of the wells, ranged from 10 to 70 m. Atomic Absorption Spectrometer (AAS), were used to measure the concentration of arsenic. About 50% of tube wells exceeded permissible values of WHO guideline (10 ppb), but 12.5 % tube wells exceeded permissible values of Nepal interim standard of arsenic (50 ppb). The risk of arsenic is high because the contaminated water has been continuously used for cooking, drinking and other purposes. This alarming situation therefore calls for measures to mitigate the problem.

KEYWORDS: Groundwater, drinking water, arsenic, permissible values

INTRODUCTION

The majority (90%) of people living in the Terai region of Nepal depend on groundwater as their primary source of potable water. The Department of Water Supply and Sewerage (DWSS) in Nepal was the first organization to conduct a comprehensive study on groundwater arsenic (As)-contamination of the Terai region with financial assistance from the World Health Organization (WHO) in 1999. High levels of As in drinking water has severe health effects. It is a well known human carcinogen causing skin cancers, kidney, lung, and liver cancers (Liu and Waalkes, 2008). It is also a teratogen, which means that it is capable of crossing the placental membrane into the metabolic system of unborn children.

The level of arsenic allowed in drinking water has been set at 0.01 mg/l by the World Health Organization (2011) and Nepal has also set drinking water quality standard of arsenic 0.05 mg/L (GoN/MPP, 2006). More than 50% of the world's population depends on groundwater for drinking (Fry, 2005). Groundwater moves through rocks and subsurface soil, it has a lot of opportunity to dissolve substance as moves and also distributed as anthropogenic pollutants (Rangsivek and jekel, 2005). Geogenic, non-point source, carcinogenic arsenic (As) is now considered as one of the most serious natural contaminants in groundwater worldwide (Mukherjee and Bhattacharya, 2001).

The National Sanitation Steering Committee (NSSC), with the help of many other organizations, has completed arsenic blanket test in 25 districts of Nepal by analyzing 737,009 groundwater samples. The results showed that in the 89.8% of cases arsenic concentrations lower than 10 ppb in the 7.9% of cases concentrations between 10 and 50 ppb, and larger than 50 ppb in the 2.3% of samples.

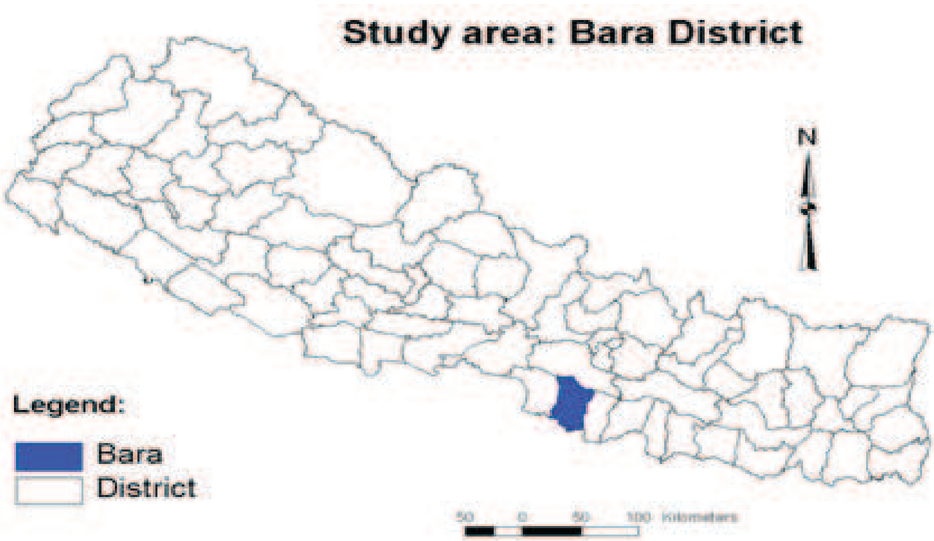
These numbers indicate a serious mass poisoning, considering the severe consequences of chronic arsenic contamination caused by drinking water. The As-pollution is a by-product of the reduction of sedimentary iron oxy-hydroxides (Berg et al., 2007). The objective of this study was to measure the As concentrations in dug wells and tube wells which are being used for water supply purposes and the relationship between arsenic concentrations and depth of tube wells.

METHODS AND MATERIALS

Study Area

The study district is Bara, which is surrounded by Rautahat district to the east Makawanpur, to the north, Parsa to the west, and Indian border to the south. Bara district, one of the seventy-five districts of Nepal, is located at the south region of Terai (Fig1).

Figure 1: Location Map of Bara, District, Nepal



Collection of Water Samples and Analysis

In total, thirty six water samples were collected from dug wells and tube wells during pre-monsoon (May and June) in 2012. Water samples were collected from 12 dug wells and 24 tube wells, respectively for arsenic analysis.

Water samples for arsenic were collected from Bara District, Nepal (Kalaiya, Barewa, Bahuari, Dohari, and Dharamnagar). Tube well water samples were collected (after pumping for few minutes) without filtration in 100-mL polyethylene bottles that were pre-washed with nitric acid and water (1:1).

After collection, two drops of concentrated nitric acid: water (1:1) per 100 ml of water sample were added as preservative (APHA, 1998). The arsenic was analyzed by atomic absorption spectrophotometer with a graphite furnace

(AAS-GF).

RESULTS AND DISCUSSION

Distribution of Arsenic Tested Tube Wells

The concentration of arsenic was compared with WHO (10 ppb) guideline value and Nepal Interim Standard (50 ppb). Out of total tube wells, about 50% of tube wells exceeded permissible values of WHO guideline (10 ppb) but 12.5 % tube wells (Table 1) exceeded permissible values of Nepal interim standard of arsenic (50 ppb). The high concentration of arsenic in some of the site of the study area is attributed to the ground water geochemistry in the study area.

Table 1: Arsenic Concentration of Tube well

Arsenic concentration (ppb)	No. of tube well	Percent
0 -10	9	37.50
> 10	12	50.00
> 50	3	12.50
Total	24	100.00

Level of Arsenic Concentration

The VDC-wise distribution (Table 2) showed that Bahuari has higher percentage of tube wells above Nepal Interim Standard (NIS) of 50 ppb with 17.4 %, followed by Dharmanagar (12.81 %), Barewa (7.7%) and Kalaiya (2 %). This is shown in Table 2.

However, the distribution also shows that Dohari has higher percentage of tube wells above WHO Guideline of 10 ppb with 70.0% followed by Barewa (30.8%), Kalaiya (21.0%), and Dharmanagar (4.7%) in Table 2. In this way, the high concentration of arsenic in some of VDC of the study area is attributed to the groundwater geochemistry.

Table 2: Arsenic Concentration in Bara (n=36)

	Below detection limit (ppb)	1 - 101 (ppb)	1- 50 (ppb)	Above 50 (ppb)	Total % (ppb)
Kalaiya	70.0	7.0	21.0	2.0	100.0
Barewa	25.1	36.5	30.8	7.7	100.0
Bahuari	61.1	21.4	0.0	17.4	100.0
Dohari	3.00	27.00	70.0	0.00	100.0
Dharmanagar	32.63	49.85	4.70	12.81	100.0

Relation of Arsenic Concentration with Depth of Tube Wells

The relation between tube wells and concentration of arsenic is shown in Table 3. Among the depth of the tube wells, 50 % have depths 10-20 m, out of which 33.3% arsenic levels higher than 10 ppb and 8.3% above 50 ppb. Similarly, deep tube wells have depth > 50 m, out of which 8.3% has arsenic level less than 10 ppb (Table 3).

Not a single tube well with arsenic concentration > 50 ppb is found in depth above 20 meters (Pradhan, 2006). In the Terai, arsenic concentration is greater in shallow tube well (<20 m) than deep wells (DWSS, 2005; Pradhan, 2006).

Table 3: Distribution of tube wells by depth and levels of arsenic concentration

Depth of tube wells (meter)	≤ 10 ppb		>10 ppb		> 50 ppb		Total	
	No	%	No	%	No	%	No	%
0-10	2	8.3	2	8.3	1	4.2	5	20.8
10-20	2	8.3	8	33.3	2	8.3	12	50.0
20 - 30	1	4.2	1	4.2			2	8.3
30 - 40	1	4.2	1	4.2			2	8.3
40 - 50	1	4.2	0	0.0			1	4.2
50-70	2	8.3	0	0.0			2	8.3
Total	**9**	**37.5**	**12**	**50**	**3**	**12.50**	**24**	**100**

Relation of Arsenic Concentration with Age of Tube Wells

The water of tube well has been used by the households in the Terai since long time ago. Table 4 showed that the class of 5-10 years shares the largest proportion with 41.67 % percent, out of which 25% and 8.33% covers higher than 10ppb and 50 ppb, respectively which followed by 2 -5 years (Table 4).

Table 4: Years of use of tube wells by levels of arsenic concentration

Year of tube wells	Tube wells by arsenic concentration (ppb)							
	0 - 10		>10		> 50		Total	
	No	%	No	%	No	%	No	%
< 1	2	8.33	1	4.17	-	0	3	12.5
1-2	1	4.17	0	0	0	0	1	4.17
2-5	2	8.33	1	4.17	1	4.17	4	16.67
5-10	2	8.33	6	25	2	8.33	10	41.67
11-15	2	8.33	2	8.33	0	0	4	16.67
≥ 15	0	0	2	8.33	0	0	2	8.33
Total	**9**	**37.50**	**12**	**50**	**3**	**12.5**	**24**	**100**

Arsenic Concentration Levels in Dug wells

The figures above show that arsenic water testing has been carried out in 12 dug wells. Out of 12 dug wells, 4 dug wells were newly improved dug well which was installed by Nepal Red Cross Society (NRCS) and community participation. In this way, about 3 % of newly improved dug wells have arsenic levels above 10 ppb and 97 % below 10 ppb.

Similarly, 5 % traditional dug wells have arsenic concentration above 5 and 95 % below 10 ppb of arsenic. Dug wells have found to be in use from much earlier times than tube wells.

This improved dug wells are mainly for the alternate option for the arsenic contaminated water consumed by the local community which is improved traditional dug well with cover, ventilation, well-plastered and about one meter raised from the ground level.

CONCLUSION

Groundwater is the main source of water for drinking and domestic use, and for irrigation. The arsenic contaminated zones mostly lie within the shallow tube wells. But in many places the shallow tube well is free from arsenic contamination because of hydro-geological setups. Arsenic concentration decreased with increasing depth. The highest number of tube wells that exceed both WHO guideline and Nepal interim standard (NIS) limits are found to have been constructed in the last 10-15 years.

From this study, out of total tube wells, about 50% of tube wells exceeded permissible values of WHO guideline (10 ppb) but 12.5 % tube wells exceeded permissible values of Nepal interim standard of arsenic (50 ppb). The high concentration of arsenic in some of the site of the study area is attributed to the groundwater geochemistry in the study area.

Since the groundwater is the main source of drinking water in the study area, it is potentially at risk of arsenic contamination and the arsenic problem will further intensify in future. From this study, dug wells provide arsenic-safer drinking water than tube wells. The risk of arsenic is high because the contaminated water has been continuously used for cooking, drinking and other purposes. This alarming situation therefore calls for measures to mitigate the problem.

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