Original article

Arsenic contaminated drinking water and nutrition status of the rural communities in Bagahi village, Rautahat district, Nepal

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Background: Groundwater is the main source of drinking water in the Tarai region of Nepal. Analysis of arsenic contaminated groundwater of 287 tube wells and nutrition level of the rural communities of Bagahi village, Rautahat district, Tarai region has been performed.

Methods: Altogether 538 households have access to the tube wells' water for consumption.

Results: About 6% of the total tested tube wells are considered as risk tube wells, which have arsenic level above the Nepal Interim Standard 50 part per billion (ppb). Of the total risk population, about 9% have been identified as arsenicosis patients. About 80% risk populations have consumed inadequate nutrition in terms of calorie content. The risk of arsenic among the risk populations is high because they are in most cases under nutrition and consuming the contaminated water.

Conclusion: This indicates that the rural communities of the Bagahi locality are facing alarming situation. Immediate measures to mitigate the problem is warranted.

Key words: Arsenic, nutritional status, rural community, Rautahat district

Introduction

Tarai is a plain region, which lies in the southern part of Nepal and borders to India. The region consisting of 20 districts shares approximately 47% of the country's total population (23.4 million in 2001). About 90% of the Tarai people use groundwater for drinking, cooking, bathing and washing, and irrigation. It is estimated that there are 832,000 tube wells in the Tarai region (DWSS/UNICEF 2002). The present study analyses the magnitude and extent of arsenic problem, arsenic risk population, and nutrition status of the risk population of Bagahi village, Rautahat district.

Material and Methods

The methodology was adopted with the following procedures: (i) arsenic concentration of all 287 tube wells available in the village was tested with 250 Hach-EZ kits. The reliability of this arsenic field test kit was verified on 1% water sample in the field by WAGTECH Arsenator (digital kit) and 2% samples were sent to the laboratory for cross checking, which was performed by using atomic absorption spectrophotometer (AAS); (ii) a total of 538 households were found using these tube wells, of which 19 households were found consuming water with above 50 ppb; these households were identified as arsenic risk households according to the Nepal Interim Standard; (iii) nutrition status of the arsenic risk households was obtained by administrating questionnaire, which sought information on the consumption of quantity and type of foods, and (iii) data from the health post located in the village were gathered to supplement to the field data.

Two guideline values such as WHO guideline and Nepal Interim Standard are considered as the basis for analysis. The WHO guideline considers 10 ppb (part per billion) as potable water, where as the Nepal Interim Standard considers 50 ppb for potable water. These values are considered as bases for classification of arsenic concentration in water of the tube wells. Based on these levels of arsenic concentration, further analyses such as year of use of the tube wells, and their distribution, ownership patterns, and depths; distribution of arsenicosis patients, awareness of the health personnel towards arsenicosis disease; and mitigation options of arsenic problem used by the villagers are performed. Nutrition status and the food and energy consumption per person are also analysed.

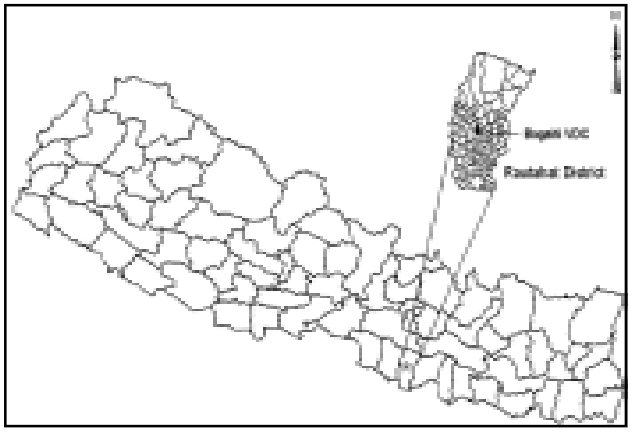

Fig.1: Location of Bagahi village, Rautahat district, Nepal

Results

3.1 Classification of arsenic concentration

Classification of arsenic concentration in the tube well water is made according to the two guideline values: WHO guideline and Nepal Interim Standard (Table 1). According to the WHO guideline, only nearly 51 percent of the total tested tube wells in Bagahi village are below 10 ppb. This means that about 49 percent tube wells with above 10 ppb are not potable for drinking. Where as the number of tube wells with arsenic concentration above 50 ppb according to the Nepal Interim Standard is nearly 6 percent.

Compare the state of arsenic concentration in Bagahi to that of the Tarai region, the situation in the village is alarming in terms of both guideline values. In terms of severity of arsenic problem, Bagahi lies in the Moderate Extended and Acute (MEA), which defines 20 to 50 percent of the total tested samples of arsenic concentration with >10 ppb and more than 3 percent of the samples have arsenic concentration >50 ppb (FAO 2004).

Table 1: Distribution of tube wells by levels of arsenic concentration

Arsenic concentration (ppb)	No. of tube wells	Percent	Tarai region %*
0 -10	146	50.9	87.4
11 - 50	124	43.2	10.1
> 50	17	5.9	2.5
Total	287	100	100

Source: Field Survey 2005; *2001.

3.2 Year of use of tube wells

The water of tube well has been used by the households in the Tarai since long time ago. Table 2 shows that the class of 5-10 years shares the largest proportion with 53.3 percent, followed by 2 – 5 years. The tube wells used over 15 years account for 2.1 percent.

Table 2: Years of use of tube wells by level of arsenic concentration

Year of tube wells	Tube wells by arsenic concentration (ppb)							
	0 - 10		11-50		> 50		Total	
	No	%	No	%	No	%	No	%
< 1	14	4.9	6	2.1	-	0.0	20	7.0
1 - 2	6	2.1	7	2.4	-	0.0	13	4.5
2 - 5	32	11.1	37	12.9	4	1.4	73	25.4
5 - 10	82	28.6	59	20.6	12	4.2	153	53.3
11 - 15	6	2.1	15	5.2	1	0.3	22	7.7
? 15	6	2.1	0	0.0	-	0.0	6	2.1
Total	146	50.9	124	43.2	17	5.9	287	100

Source: Field survey

It is also evident that the largest share of the tested tube wells with >50 ppb falls in 5-10 years, followed by 2-5 years *(Table 2).*

3.3 Distribution of users by arsenic concentration

Table 3 shows that 3.4 percent of the total population has used the tube wells with arsenic concentration >50 ppb, which is considered as risk population and accordingly, 3.5% of the total households are considered as risk households.

Table 3: Tube well users and concentration of arsenic in drinking water

Arsenic concentration (ppb)	Distribution of households		Distribution of users	
	Number	Percent	Number	Percent
0-10	347	64.5	2514	63.6
11-50	172	32	1300	33.0
> 50	19	3.5	136	3.4
Total	538	100	3950	100

Source: Field survey

3.4 Type of ownership of tube wells

Number of tube wells owned by private is larger than by public; the former accounts for 87.1 percent of the total tube wells (Table 4). Arsenic concentration above 50 ppb has not been detected in the public tube wells. It means there is arsenic problem in private tube wells.

Table 4: Ownership type of tube wells by levels of arsenic concentration

Ownership type	Tube wells by arsenic concentration (ppb)							
	< 10		10-50		> 50		Total	
	No	%	No	%	No	%	No	%
Private	117	40.8	116	40.4	17	5.9	250	87.1
Public	29	10.1	8	2.8	0	0.0	37	12.9
Total	146	50.9	124	43.2	17	5.9	287	100

Note: Percentile figures are computed from the total samples, n = 287; numerals are divided into two sets, i.e. equal & below 10 and above 10 ppb, and therefore their numerals give total sample units of 287; numerals above 50 ppb are

subset of above 10 ppb.

3.5 Depth of tube wells

The number of tube wells lying within the depths of 10-20 in all three levels of arsenic concentration is highest *(Table 5).* Not a single tube well with arsenic concentration > 50 ppb is found in depth above 20 meters.

Table 5: Distribution of tube wells by depth and level of arsenic concentration

Depth of tube wells (meter)	< 10 ppb		10-50 ppb		> 50 ppb		Total	
	No	%	No	%	No	%	No	%
1-10	28	9.8	13	4.5	1	0.3	41	14.3
10 - 20	95	33.1	105	36.6	16	5.6	216	75.3
20 - 30	1	0.3	2	0.7			3	1.0
30 - 40	12	4.2	3	1			15	5.2
40 - 50	8	2.8	1	0.3			9	3.1
> 50	2	0.7	1	0.3			3	1.0
Total	146	50.9	124	43.2	17	5.9	287	100.0

Source: Field survey

3.6 Distribution of arsenicosis patients

A total of 13 arsenicosis patients in Bagahi has been identified and provided arsenic free water since 2003 (NRCS/ ENPHO 2003). Melanosis on the trunk and keratosis on the palm are common arsenicosis symptoms (Pradhan et al 2004). The prevalence rate of arsenicosis is found at 9% of the total risk population (136; see table 3). This rate is higher compared to that of its district, Rautahat (2.7 percent) which however has been identified as the first level of arsenicosis symptom (WHO 1997). The age group of 50 years and above has the highest prevalence rate which is higher in the males than in females *(Table 6).*

Table 6: Age group and sex of the arsenicosis patients

Age group (years)	Male		Female		Total	
	Number	%	Number	%	Number	%
15-20	1	7.7		0.0	1	7.7
20-30	2	15.4	1	7.7	3	23.1
30-40	-	-	-	-	-	-
40-50	2	15.4		0.0	2	15.4
50 above	5	38.5	2	15.4	7	53.8
Total	10	76.9	3	23.1	13	100

Source: NRCS/ENPHO (2003)

3.7 Awareness of arsenicosis disease to the health personnel

A total of 25 health personnel working in Bagahi and neighbor villages were interviewed whether they aware about arsenicosis disease. They were representing from grass root level to officer levels such as MCHW (Maternal and child health worker), VHW (Village health worker), AHW (Auxiliary health worker), ANM (Auxiliary nurse midwife), CMA (Community medical assistant), Lab. Assistant, HA (Health assistant), Medical Officer and Public Health Officer. Of these, 56 percent knew about arsenicosis disease. However, this finding is higher than the finding of the study carried out in other VDCs of the same district, which was 16.1% (Bhagat, 2003).

3.8 Mitigation options of arsenic problem

NRCS/ENPHO (2003) has provided the following five types of mitigation measures to the Arsenicosis patients in all VDCs of Rautahat district. They are preventive measures intending to provide arsenic free water, viz. (i) two-Gagri (water vessel) filter, (ii) innovated dug well, (iii) Arsenic iron removal plant (AIRP), (iv) tube wells from arsenic free aquifer (v) modified bio-sand filter and (vi) awareness program on nutrition. Of these, the option of two-Gagri filter and awareness program has been provided in Bagahi.

3.9 Nutrition status

Arsenic is ingested in human body through both water and food stuffs. The food habit, nutritional status and bio-methylation activity of the individuals can be related to the manifestation of arsenicosis disease (Haq and Naidu 2003). The analysis of average per person daily food consumption pattern of the risk households in Bagahi shows that four-fifths of the sample respondents have not got adequate energy supply from their foods (Table 8). Similarly, the hospital record as given in Table 9 shows that about 23% of children below five years of age have low nutritional level, which is however higher than the national and district level records.

Table 8: Daily food consumption pattern and energy obtained of risk households

Nutrition levels	Number of respondents	Percent of respondent	Total food consumption (gm)	Fat (g)	Protein (g)	Energy obtained (kcal)
Adequate*	4	21.1	700 - 800	65	35	2450 -2800
Inadequate	15	78.9	350 - 600	40	25	1225 -2100
Total	19	100				

*Average energy required = 2450 kcal (NHDR 1998)

Table 9: Nutritional status of children under five years of age

Location	Low		Normal		Total
	No.	%	No.	%	
National*	142,830	12.1	1,040,545	87.9	1,183,375
District	3,105	18.4	13,767	81.6	16,872
VDC**	48	23.8	154	76.2	202

Source: *DHS 2004; ** Health post record (2003); VDC = Village development committee

The analysis of food eating habit of the risk households shows that about 70% were non-vegetarian and about 75% have consumed rice as their staple food and the rest have consumed rice and bread (wheat). The amount of water

required to cook food depends on the type of food, and if arsenic contaminated water is used, the retention of arsenic in the food also varies with the type of food (WHO 2003). The information shown in Table 10 is derived from the study in Bagahi VDC, and the water requirement for cooking foods and drinking per day per person is determined. Average amount of ingestion of arsenic per day has been calculated based on the factors provided by Ahmed (2003)[1]. The average ingestion per person in the risk households from food and water together is higher based on the toxicological approach, the daily exposure from food and drinking water together must not exceed 2 µg/day/kg body weight or 120 µg/day (body weight = 60 kg) (Ahmed 2003). The average percentage of arsenic consumption is higher from food than water *(Table 11)*.

Table 10: Arsenic concentration and consumption per person per day

Description of arsenic	Amount
Average As concentration (ppb)	73
Average Amount of water consumed (liter)	2.7
Average concentration of As ingested per day from water (µg)	167.1
Average Food consumption/day (gm)	511.8
Average concentration of As ingested per day from food (µg)	185.3
Average arsenic ingested per person per day (µg)	352.3
Average % of As from water	46.6
Average % of As from food	53.4

In Bagahi, the year of use of tube wells varies from one to 30. The average use of tube wells is 7 years. However, before the use of tube well, the people were used the water through dug wells. Still there are 4 dug wells using by the inhabitants in Bagahi. However, arsenic concentrations in those dug wells are within the acceptable level.

Table 11: Exposure time and arsenic risk

Average years of consumption	7 years
Average life expectancy	60 years
Average concentration of Arsenic	73 ppb
Risk[1] if options are not provided	$4258/10^6$
Risk[2] if options continued	$511/10^6$
Risk reduction (if options continued)	8.3 times

The risk of arsenic problem may be decreased if arsenic free water could be provided to the people now by more than 8 times. The nutrition status of children of the study area is poor. The children under nutrition is defined in terms of stunting (short for their age which can be a sign of early chronic under nutrition), wasting (thin for their height as an indicator of acute malnutrition), and under-weight (low weight for age) by the Nepal Demographic and Health Survey (NDHS 2001). In Table 12, the NDHS report for the national level shows that stunting children shares higher proportion (50.5%) than other two under-nutrition types. Whereas the Health Post report for the Bagahi village shows the higher proportion of under-weight children under five years of age (out of total sample 105 children) than the stunting and wasting children.

Table 12: Nutrition status of children under five years of age

Sources	Year	Location	Prevalence of under nutrition		
			Stunting	Wasting	Under-weight
NDHS report	2001	National	50.5	9.6	48.3
Health Post report	2003	VDC	45.2	13.5	48.2

Source: NDHS, 2001

The nutrition status of women of reproductive age group (15-49 years) is also analyzed based on the mean body mass index (BMI), which is defined in terms of weight of reproductive woman divided by height square. NDHS (2001) has studied about the nutrition status of women of reproductive age group for the Tarai as a whole. According to this study, about 36 percent of the reproductive women age group of Tarai women was under nutrition, which is higher than the national value of 27% of the same women age group. Though there is no data on women in the Health Post report of Bagahi village, the Tarai average value can be considered for this village too.

Conclusion

The major source of water for drinking and cooking in Bagahi VDC is tube well. The VDC has 3,950 total tube well users, of which the risk population with arsenic concentration above 50 ppb is 3.4 percent. The private tube wells share 87.1 percent. Arsenic concentration above 50 ppb is found within the depth of 10 ag:– 20 m. The largest number of tube wells with 53.3% using by the rural communities of Bagahi lies within 5-10 years. The average concentration of arsenic in the risk tube wells is 73 ppb. The average use of tube wells in this VDC is 7 years. In terms of severity of arsenic problem, Bagahi lies in the Moderate Extended and Acute (MEA).

Altogether thirteen arsenicosis patients have been identified. Melanosis on the trunk and keratosis on the palm were common arsenicosis symptoms. The highest prevalence rate of arsenicosis was found at the age group of 50 years and above. The prevalence rate was higher in the males than in females. About 78 percent of the total sample respondents (50) have not got adequate energy. The VDC health post data shows that about 50 percent of the children under five have different types of nutrition deficiency, ranging from chronic to acute. The average arsenic ingested per person from food and water is estimated to be 352 µg/day. During the study, about 56 percent of the

health personnel working in different levels were aware about the diseases caused by arsenic. The Bagahi's inhabitants require foods with adequate nutrition and arsenic free water. The village requires the mitigation measures as given above for arsenic free water. If those measures are adopted now more than 8 times risk can be minimized. Research on water quality surveillance, hydro geological monitoring, etc of the tube wells should be made for finding effective means of arsenic mitigation

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[1] For examples, the amount of water for cooking 450g rice, 50 g Dal (bean soup), 150 g potato curry, and 200g wheat flour requires 2,880 ml, 250ml, 275ml and 100ml respectively. The average retention of arsenic (if arsenic contaminated water is used) is 90 percent

[2] For carcinogenic substance (WHO 1997), the following equation is used:

$$Risk = \frac{AsConcentration * ContactRate * CarcinogenicPotential}{LifeExpectancy}$$

[3] Risk with respect to exposure time (EPA 1997) is derived from: