Level of Arsenic Contamination in Drinking and Irrigation Water in the Narayani Irrigation Command Area, Nepal

Pradhan BK[a]

Abstract

Background Arsenic contamination in groundwater and its threat to human health is relatively new for Nepal. Groundwater is the main source for drinking and irrigation in the Tarai region of Nepal, where the arsenic risk population has been increased since the last few years. Efforts have been made by the government to harness the groundwater for year round irrigation for increasing agricultural crops in the Tarai. Since the groundwater is found to be contaminated with arsenic, continuous use of groundwater for both drinking and irrigation appears to be health catastrophe to the Tarai's communities.

Objective This study examines the arsenic state and classifies water availability in the Narayani Irrigation Command (NIC) area.

Methods The arsenic test for this study report has been based on two spatial levels. The first level includes total tube well samples for all three districts of Parsa, Bara and Rautahat lying in the command area of Narayani Irrigation System. At the second level, the data and information on the water samples of the tube wells were gathered at Village Development Committee (VDC) of those districts. The analysis of the data has been schematically presented through GIS Map. Based on the samples, the households consuming arsenic contaminated water above Nepal Interim Standard (50µg/L) were classified as risk households. Among the risk household members, the Arsenicosis patients were identified based on clinical examination. Arsenicosis prevalence rate is computed as the ratio between symptomatic patients and total risk population, expressed in terms of percent. Water Availability Index (WAI) was assigned to classify water availability situation in NIC area.

Results Of the total 2,389 tube wells sampled in the Narayani Irrigation Command area, 4.5 percent are above the Nepal Standard and 28.3 percent above the WHO guidelines. The distribution of arsenic levels in the tube wells is more or less similar pattern in all three districts of the study region. The dependency on groundwater is higher in areas where the availability of surface water is low. There exists an inverse relationship between arsenic level and water availability index. The arsenicosis prevalence rate for all three districts is less than 1 percent.

Conclusions The preliminary analysis of the arsenic levels of the tube wells demonstrates that the farm households locating in the downstream are more exposed to arsenic problem than those in the upstream of the command area. This is mainly due to higher dependency on groundwater. Three alternative strategies to reduce arsenic level may be suggested, viz. improving the performance of surface irrigation, making less dependency on groundwater and adaptation of arsenic removal strategy.

Key words Arsenic, Irrigation, Water Availability Index, Arsenicosis, Risk households

Introduction

Arsenic is ubiquitously found in air, water, fuels and soil. Through the process of bioaccumulation and bio-magnification, crops, fruits, vegetables, meats and fishes obtain arsenic depending on the concentration of arsenic in soil where they are grown and the water used for irrigation[1].

Corresponding Author: Bandana K Pradhan, **E-mail:** bandana@healthnet.org.np, [a]Department of Community Medicine and Family Health, Institute of Medicine, Tribhuvan University, Kathmandu Nepal

In the arsenic affected areas, arsenic may enter into the food chain from water to soil, and soil to foods of all varieties, viz. roots and tubers, vegetables, fruits, edible flowers, seeds, fleshy foods, eggs, etc. The ultimate recipient is human being. It is known that most of the arsenic in water is in the form As (III); it is likely that a large proportion of this arsenic remains as such in the plant depending on the rate of bio-methylation capacity of the plant species[3,4].

A preliminary survey of Chakrawarty et al (2003) indicates that some varieties of fruits and vegetables such as papaya, jack fruit (green), tomato (ripe), green chilly and parwal (pointed gourd) grown in the garden being irrigated by arsenic contaminated water have high arsenic concentration. In a survey of 500 samples of different vegetables, rice and wheat from both arsenic affected and non-affected areas in Bangladesh, Haq and Naidu (2003) found that arsenic in similar type of plants from arsenic affected areas was higher than those from unaffected areas. They also found that arsenic was mostly concentrated in the root and straw of rice and wheat plants. It was also noted that arsenic concentration in rice grain varied with its varieties. It was also observed that some green leafy vegetables and grasses acted as arsenic accumulator.

Warren et al. (2003) found that the bioavailability of arsenic to the plants in soil is depended on the types of crops and vegetables grown[6]. The higher the arsenic transfer coefficient the greater is the concentration of arsenic in the crop/vegetation. Uptake of arsenic by plants depends on soil–plant transfer coefficients ranging from 0.01 to 0.1[7]. The arsenic transfer coefficient can be significantly reduced by using 0.5 percent Fe Oxide solution in the soil[6].

Available documents indicate that Nepal's twenty Tarai and four adjoining hill districts have arsenic contamination in tube wells. Figure 1 shows the different levels of arsenic concentration in those districts based on water samples of 29,953 tube wells collected in December 2003[11]. One third of the tested wells have arsenic contamination above the WHO threshold (10 μg/L) whereas about 7 per cent have arsenic concentration above the Nepal Interim Standard (50 μg/L), which are not acceptable for consumption. This is a strong indication of arsenic problem in Nepal. Narayani Irrigated Command Area and its districts are also shown in Figure1[8].

Nepal's water development policies emphasize on the exploitation of groundwater for both drinking and irrigation purposes particularly in the Tarai districts. The Tarai region has the most potential for intensive agricultural development. The agricultural development policies adopted in the country found year round irrigation through groundwater source as the best feasible option for the Tarai region. This can be justified by the following two important irrigation development policies. The Tenth Plan (2002-2007)[9] has outlined the following strategies:

- Develop deep and shallow tube-wells with appropriate subsidy support in poverty-stricken areas and bring additional areas under irrigation through other irrigation schemes
- Increase water use efficiency in the irrigation system
- Emphasize on the use of local manpower and inputs in the construction of medium and large irrigation systems
- Intensify water management activities Likewise the National Water Resource Strategy in 2001 has envisaged the following strategies for irrigation development:
- Integrate irrigation planning and management with agricultural development
- Improve management of existing irrigation systems
- Improve planning and implementation of new irrigation systems
- Develop year round irrigation for intensification and diversification of agriculture
- Strengthen local capacity for planning, implementation and management of irrigation
- Encourage consolidation of land to promote irrigation/agriculture efficiency
- Improve groundwater development and management

Materials and Methods

The study has been based on both primary and secondary data. The primary information was obtained from the field verification of arsenic data and arsenicosis patients and water availability of the place. Secondary data were obtained from the published and gray reports. Informed consent has been obtained from the concerned organization/ authority to use the information related to this study. The VDC names were also verified in the field.

Review of literature on arsenic concentration, its use in various activities, and irrigation policy of the country has been made. The Water Availability Index (WAI) has been obtained by Rapid Appraisal of Performance (RAP) to classify the water availability in various parts of NIC area[10]. Maps, graphs and tables, and ratio and rate have been used to analyse the results.

Results and Discussion

Arsenic status in three Tarai's districts of Nepal

The Narayani Irrigation Command (NIC) area includes three districts, viz. Parsa, Bara and Rautahat, which lie in the central south part of Nepal. NIC comprises 134 VDCs (Village Development Committee) out of 283 total VDCs of these three districts.

Table 1 summarizes the arsenic contamination levels tested in 2,389 tube wells of the irrigation command areas of the districts in 2002. The NIC area has shown 4.5 percent of the total samples above the Nepal Interim Standard and 28.3 percent above the WHO guidelines. Of these, Rautahat has shared the largest percent of the samples in both guideline and standard. In terms of severity of arsenic problem, Rautahat lies in the High Extended and Acute (HEA), category where more than 50 percent of the total tested samples have arsenic concentration >10 µg/L and more than 3% of samples have arsenic concentration >50 µg/L[10]. However, the maximum arsenic level, i.e. 456 µg/L has been observed in the tested tube wells of Parsa district.

Table 1: Arsenic level in Parsa, Bara and Rautahat districts

District	Arsenic concentration (µg/L) 0-10	11-50	>50	Total Tested	Max	% sample >WHO GV	% sample >NIS	Severity of As problem
Bara	625	96	22	743	254	15.9	2.9	LEC
Parsa	915	132	37	1084	456	15.6	3.4	LEA
Rautahat	173	340	49	562	324	69.2	8.7	HEA
Total	1713	568	108	2389	456	28.3	4.5	

Source: As concentration of tube wells based on [11]

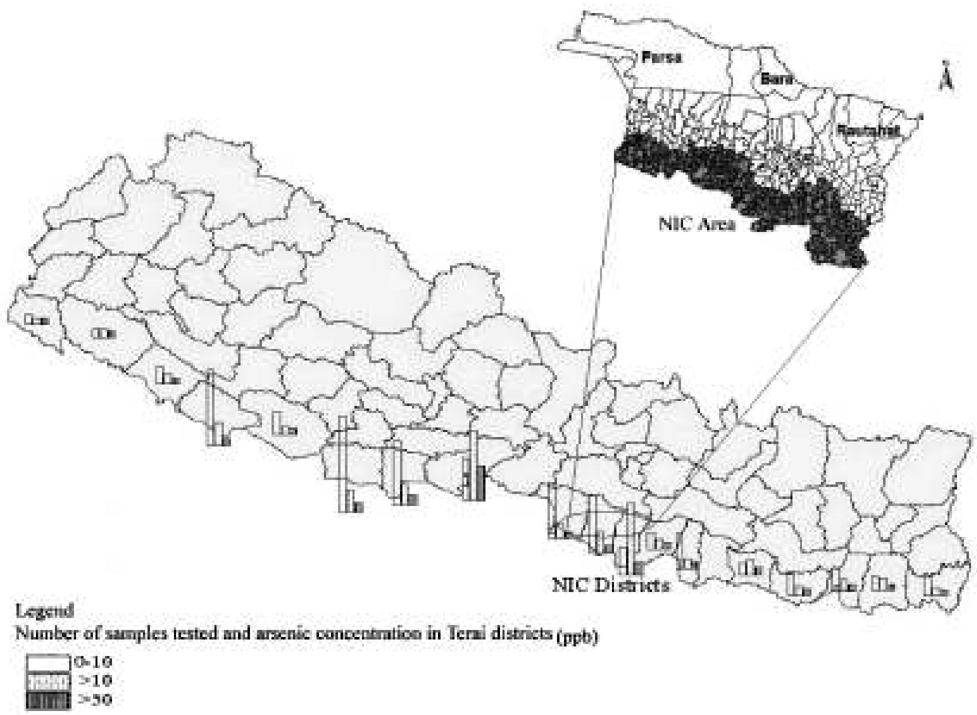
LEC = Low Extended and Chronic refers to less than 20 percent sample with arsenic concentration >10 µg/L and less than 3 percent of the samples with arsenic concentration >50 µg/L.

LEA = Low Extended and Chronic, which is less than 20 percent sample with arsenic concentration >10 µg/L and more than 3 percent of the samples with arsenic concentration >50 µg/L.

HEA = High Extended and Acute refers to more than 50 percent of the total tested samples have arsenic concentration >10 µg/L and more than 3 percent of samples have >50 µg/L[10].

NIS = Nepal Interim Standard Spatial distribution of arsenic levels of the tested tube wells in the NIC area is shown in Figure 2. There is more or less similar pattern of the distribution of arsenic levels in the tube wells between Parsa and Bara districts, whereas in Rautahat district, 69 per cent of the tested tube wells have arsenic level above 10 µg/L and 31 percent with less than 10 µg/L.

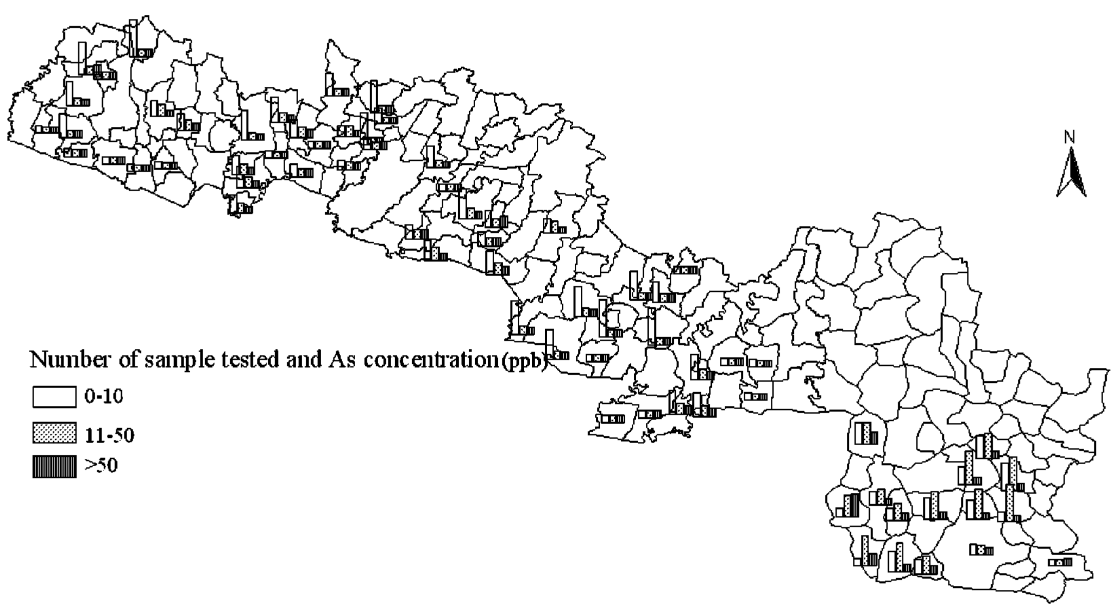
Figure 1: Level of arsenic in Nepal's Tarai districts and location of Narayani Irrigation command area (NIC)



Surface Irrigation Water Availability in NIC Area

The FAO study using the Rapid Appraisal of Performance (RAP) carried out in 2004 states that water availability is found to be varied highly in the NIC area[8]. The study indicates that the availability of amount of surface water service has determined the degree of dependency of farmers on groundwater. There were few pumping facilities in the upstream irrigation system in Parsa district, while there were numerous wells used for irrigation in the downstream part of the command area in Rautahat.

Figure 2: Spatial distribution of arsenic level in VDCs of NIC area



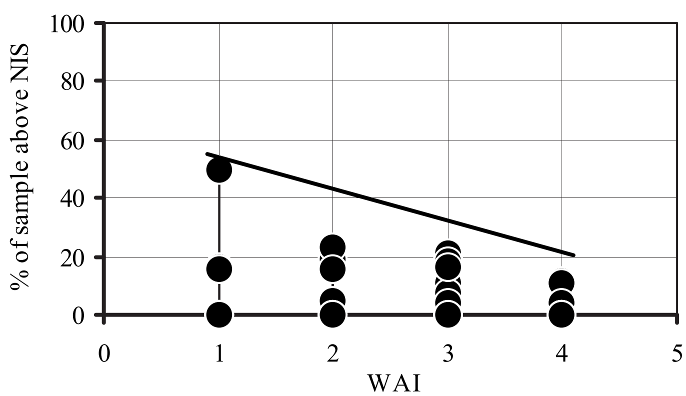
In theses circumstances, it is logical to analyze the relationship of arsenic level with the water availability through surface irrigation. It is hypothesized that the arsenic level increases with an increase in the level of extraction of groundwater. It is observed that the dependency on groundwater is higher in areas where the availability of surface water is low. The Water Availability Index (WAI)[8] has been obtained to classify the water availability in various parts of NIC area, as given in Table 2.

Table 2: Classification of water availability

WAI level	Description of water availability situation
4	Water is available in required amount at the frequency, rate and duration as per the demand of the farmers
3	Water reaches in the area but the volume is unknown and deliveries are known more than 50 percent of the time
2	Water arrives in the area but the volume is unknown and deliveries are mostly unknown more than 50 percent of the time
1	Water is not available in the area at the time of requirements but occasionally gets there when there is excess water in the upstream of the system

Water Availability Index (WAI) is assigned to each VDC based on the water availability data gathered through RAP for each block out of total 15 blocks in NIC area and the relative position of the VDC in the block. WAI data has been generalized for the whole VDC. Analysis has been made by plotting the percents of samples above Nepal Interim Standard (NIS) along the Y-axis and WAI along the X-axis. Figure 3 shows that there is an inverse relationship between arsenic level and water availability index. This means that the percent of samples above Nepal Interim Standard (50 µg/L) is high where WAI is low and vice versa in WAI class 4.

Figure 3: Percentage of water samples above nepal interim standard (NIS) versus water availability index (WAI)[8]



The changes in water availability index can be brought by various factors and one of the factors is government's year round irrigation policy for agriculture intensification As the country's planned irrigation development for agricultural land resource exploitation is heavily inclined towards exploitation of groundwater, there is high chance that arsenic may turn out to be disastrous in the future if not managed properly. This situation calls for ways and means for devising irrigation system that helps to increase agriculture intensification through year-round irrigation and mitigates arsenic threat[10].

Arsenic Concentration and Arsenicosis Patients

Table 3 indicates that the number of tested tube wells, arsenic contaminated tube wells, risk households and household members found to be varied among the districts of NIC area. The ratio calculation shows that the arsenic risk households and household members per tube well with >50 µg/L were higher in Bara and Parsa than in Rautahat. However, the arsenicosis prevalence rate for all districts was less than 1 percent[12].

Table 3: Status of arsenic and arsenicosis in NIC area

Description of Arsenic State	Parsa	Bara	Rautahat	Total
Total tube wells tested	1084	743	562	2389
Arsenic contaminated tube wells (>50 µg/L)	37	22	49	108
Risk Households	368	197	317	882
Risk Household members	2120	1238	1764	5122
Number of arsenicosis patients	18	11	6	35
Arsenicosis prevalence rate (%)	0.8	0.9	0.3	0.7
Ratio calculation Ratio of risk households/tube well tested	2.95	3.77	1.77	2.71

Source: *As concentration of tube wells based on* [7 and 13]

Conclusion

The preliminary analysis of the arsenic levels of the tube wells within the Narayani Irrigation Command (NIC) area demonstrates that the arsenic problem is found to be varied greatly among the three command districts. The farm households locating in the downstream are more exposed to arsenic problem than those in the upstream of the irrigation systems, since the former is to count more on groundwater than the latter and there is less possibility of use of surface water in the former than in the latter.

Three alternative strategies to reduce arsenic level can be suggested, viz. improve the performance of surface irrigation; make less dependency on groundwater and adopt arsenic removal strategy.

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