Analysis of tubewell arsenic concentration test results using an updated arsenic information management system in Nepal

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ABSTRACT: Testing of more than one million tubewells for arsenic contamination in 20 districts in Nepal was carried out between 2003 and 2008 by the Government of Nepal with development partners and NGOs. The results showed that 1.69% of tubewells were contaminated with arsenic at levels of more than $50 \mu\text{g L}^{-1}$. A computerized system to manage and analyze the test results, including GPS location data for individual tube wells, was created in 2009 and updated in 2016. It was found that locations of contaminated areas are quite concentrated and a large number of people are exposure to high levels of arsenic. There were 8,660 people living in the wards where more than 80% of tube-wells are arsenic contaminated, and 55,176 people and 116,081 people living in wards where the tube-wells were 50–80% and 30–50% contaminated, respectively. It is recommended that immediate and permanent safe water options to be installed in the high arsenic contaminated wards with localized plan of ward level arsenic contamination analysis because lager area contamination status may dilute significance of high arsenic contamination in hotspots.

1 INTRODUCTION

Arsenic contamination in the groundwater was found in West Bengal, India in 1983 and it has been estimated that 10 million people may be at risk of consumption of water contaminated by arsenic at $>50 \mu\text{g L}^{-1}$. (Nickson *et al.*, 2007). Arsenic contamination in Bangladesh was confirmed by the Department of Public Health Engineering in 1993; the approximate number of people exposed to arsenic contaminated drinking water was between 21 and 28 million in 2003 (Huq *et al.*, 2010). In Nepal, the Department of Water Supply and Sewerage (DWSS) of the Government of Nepal conducted a research study in 1999 with the assistance of the World Health Organization (WHO) and found arsenic present at levels higher than $50 \mu\text{g L}^{-1}$. Consequently, DWSS, with the assistance of UNICEF and various other organizations, carried out blanket testing for arsenic in 20 districts of the Terai area (Bhattacharya *et al.*, 2003; Tandukar *et al.*, 2006). This testing was completed in 2008. The aim of this paper is to identify the actual magnitude of arsenic contamination in Nepal using newly developed software to analyze the test results from the 20 districts.

2 DATA MANAGEMENT SYSTEM

For the purpose of data entry, data management, GIS mapping, analysis, and reporting of the measured water arsenic concentrations, the arsenic information management system (AIMS) was developed as an

integrated software system by DWSS. This was not possible with the previous version of the software which was not fully functional on recent Windows operating systems (Windows 7, 8, and 10) and was unable to analyze precise localized contamination status. In 2016, it was updated as the new arsenic information management system (NAIMS), with financial and technical assistance from the Japan International Cooperation Agency (JICA). The main features of NAIMS are as follows.

- Compatible with all recent versions of operating systems including Windows 7, 8 and 10.
- Can use GIS maps while offline.
- Arsenic contamination map can show up to six levels of contamination in different colors, as compared to the previous version which could show only two levels in red or green.
- Map of percentage contamination is available up to the ward level.
- List of areas (wards and VDCs) highly contaminated by arsenic, in order of percentage of wells contaminated, is also available.

3 RESULTS

3.1 Overall tube-well test result analysis

The revised database of tube-well test results by NAIMS revealed the following facts. The total number of tube-well tests in the 20 districts was 1,097,015. Of these, 7.01% (76,952) were found to have arsenic

concentrations of more than $10 \mu\text{g L}^{-1}$, and 1.74% (19,112) had arsenic concentrations above $50 \mu\text{g L}^{-1}$. The breakdown of arsenic concentrations of more than $50 \mu\text{g L}^{-1}$ was 16,583 wells (1.51%) with concentrations of $51\text{--}100 \mu\text{g L}^{-1}$, 2,147 wells (0.2%) with $101\text{--}300 \mu\text{g L}^{-1}$, 341 wells (0.03%) with $301\text{--}500 \mu\text{g L}^{-1}$, and 41 wells (0.004%) with arsenic concentrations above $500 \mu\text{g L}^{-1}$.

Highly arsenic contaminated areas called hotspots, are shown in [Table 1](#). Although the nationwide proportion of wells in Nepal with arsenic contamination is only 1.69%, 8,660 people live in wards where more than 80% of tube-wells have arsenic concentrations above $50 \mu\text{g L}^{-1}$. Likewise, 63,836 and 179,917 people live in the wards where more than 50% and 30% of tube-wells have arsenic concentrations above $50 \mu\text{g L}^{-1}$, respectively. This result describes that a large number of people are at high risk of arsenic exposure in Nepal.

The GIS-based contamination map produced by NAIMS shows that highly arsenic contaminated areas were concentrated in particular areas in most districts. [Figure 1](#) shows the ward-level arsenic contamination

Percentage of wells contaminated by arsenic	Number of wards	Total population living in wards
>80	14	8,660
>50, ≤80	72	55,176
>30, ≤50	127	116,081
Total	213	179,917

Figure 1. Map of ward-level arsenic contamination based on tube-well test results in Nawalparasi district.

Figure 2 shows the ward-level arsenic contamination proportions in Siraha district, where the overall proportion of arsenic-contaminated wells is only 2.57%. As in Figure 1, the highly arsenic contaminated wards are located in the western part of the district and in five wards more than 80% of the wells have concentrations of arsenic of more than $50 \mu\text{g L}^{-1}$. Most of the districts showed patterns of arsenic contamination similar to those of Nawalparasi and Siraha.

The overall arsenic contamination level in Nepal is less than in India and Bangladesh. However, hotspot areas are found in concentrated locations and a large number of residents in these areas are exposed to high levels of arsenic contamination. UNICEF and Nepal Red Cross Society conducted a health survey in four districts in Nepal in 2003 and identified over 4,000 suspected cases of arsenicosis (Pahari, 2009; Neupane *et al.*, 2014). This highlights the potential danger of arsenic contamination in Nepal. The National Arsenic Steering Committee (2011) reported arsenic contamination status by district and VDC. However, a more localized mitigation plan, based on information at the ward or village level, may be more appropriate for establishing safe water facilities because status of arsenic contamination in larger area may dilute the significance of village level high arsenic contamination. The hotspot wards where many people have developed serious arsenic-caused disease need immediate and permanent safe water facilities (e.g., yellow, red and brown areas shown in [Figs. 1](#) and [2](#)) even though district wise contamination is low.

Figure 2. Map of ward-level arsenic contamination based on tube-well test results in Siraha district.

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REFERENCES

- Bhattacharya, P., Tandukar, N., Neku, A., Valero, A.A., Mukherjee, A.B. & Jacks, G., (2003) Geogenic arsenic in groundwaters from Terai alluvial plain of Nepal. *Jour. de Physique IV France* 107: 173–176.
- Department of Public Health Engineering (DPHE) and Japan International Cooperation Agency (JICA). 2010. Situation analysis of arsenic mitigation 2009. Dhaka, Bangladesh: Government of Bangladesh, DPHE, JICA Bangladesh.
- National Arsenic Steering Committee (Nepal). 2011. The state of arsenic in Nepal—2011. Draft December, 2011.
- Neupane, M., Thakur, J.K., Gautam, A., Dhakal, A. & Pahari, M. 2014. Arsenic aquifer sealing technology in wells: a sustainable mitigation option. *Water Air Soil Pollut.* 225: 2087.
- Nickson, R., Sengupta, C., Mitra, P., Dave, S.N., Banerjee, A.K., Bhattacharya, A. & Deverill, P. 2007. Current knowledge on the distribution of arsenic in groundwater in five states of India. *J. Environ. Sci. Health A* 42(12): 1707–1718.
- Pahari, M. 2009. Arsenic Testing, Mitigation and Information Management in Nepal. UNICEF Report.
- Tandukar, N., Bhattacharya, P., Neku, A. & Mukherjee, A.B. (2006) Extent and severity of arsenic poisoning in Nepal. In: R. Naidu, E. Smith, G. Owens, P. Bhattacharya & P. Nadebaum. (Eds.) *Managing Arsenic in the Environment: From soil to human health*. CSIRO Publishing, Melbourne, Australia, pp. 595–604.