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SUSTAINABLE DEVELOPMENT OF WATER RESOURCES, WATER SUPPLY AND ENVIRONMENTAL SANITATION

A comprehensive strategy to tackle arsenic contamination of drinking water in Uttar Pradesh in India

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Exposure to naturally occurring arsenic through consumption of contaminated groundwater, food and soil is now widely recognized as a new threat to public health in several countries in South and South-East Asia, including parts of India. The realization that arsenic not only occurs in groundwater used for drinking in the Ganges-Brahmaputra delta of West Bengal in India, but also further upstream in Bihar and Uttar Pradesh in the middle and upper Gangetic plains, has necessitated the need to develop arsenic testing and mitigation strategies in these states. This paper outlines the strategy evolved by the state government of Uttar Pradesh, with the support of UNICEF, to tackle the problem of arsenic in groundwater used for drinking. The comprehensive approach includes testing, communication, mitigation and health aspects, and novel strategies used to overcome technological issues are detailed. A similar approach has been used in the neighbouring state of Bihar.

Introduction

Exposure to naturally occurring arsenic through consumption of contaminated groundwater, food and soil is now widely recognized as a threat to public health in many countries in South and South East Asia (WB/WSP, 2005). Although the primary, and more immediate, threat to public health in most areas undoubtedly remains diarrhoeal disease caused by poor microbiological water quality, poor hygiene and lack of adequate sanitation (WB/WSP, 20005 and Ahmed et al., 2005) in the medium to long term exposure to arsenic must be addressed to avoid chronic health effects in exposed populations (e.g. Rahman et al., 2006).

Following the WHO guideline value for arsenic in drinking water of 10 µgL-1 (WHO, 2004) the Bureau of Indian Standards has notified a standard of 10 µgL-1 for arsenic in drinking water in India (BIS, 2003). Given the other relative risks to life and health in India, and considering the difficulty in implementation of such a standard, the Rajiv Ghandi National Drinking Water Mission has instructed states to use 50 µgL-1 as the 'maximum permissible limit' in the interim until the lower figure can be achieved (MRD, GoI, 2004).

In this paper the authors describe the strategy evolved by the Uttar Pradesh Jal Nigam, with the support of UNICEF, to tackle the emerging issue in the state. To date efforts have been focussed on reducing exposure to arsenic in drinking water only, although recent data from Bangladesh suggests that arsenic in food may also be an important route of exposure in areas where crops are irrigated with arsenic contaminated groundwater (Williams et al., 2006). The state must consider the significance of this exposure route in due course.

The location of the state of Uttar Pradesh (UP) is given in Figure 1.

Figure 1. State of Uttar Pradesh in middle and upper Ganga plains in Northern India

Background to arsenic in drinking water in Uttar Pradesh

Following identification of cases of 'arsenicosis' in Chandigarh in 1976 (Datta, 1976) a limited number of drinking water samples (20) from Uttar Pradesh were tested for arsenic by Datta and Kaul (1976). Four samples from 'wells' were found to contain arsenic <50 µgl-1, however, of 16 samples from 'handpumps', 8 were found to contain arsenic >50 µgl-1 and 3 contained arsenic >100 µgl-1. A maximum concentration of 545 µgl-1 was recorded from UP. The location of the sampling sites is given only as 'Meerut district'. It can only be assumed that it was concluded by the administration of the time that these were isolated incidents, and unfortunately these findings were not taken further and to our knowledge no further investigations were taken up.

Table 1. Composition of Uttar Pradesh state 'Arsenic Task Force'

Sector	Members
Government	Uttar Pradesh Jal Nigam (PHED equivalent) State Water and Sanitation Mission Directorate of Health Department of Panchayati Raj (Local govt.) Central Groundwater Board Geological Survey of India
Academic/ Research	King George Medical University Industrial Toxicology Research Centre Indian Institute of Technology Kanpur
Non-government	UNICEF

More recently, in 2003, arsenic in groundwater in UP was investigated by the Shriram Institute of Industrial Research (SIIR) in Delhi with assistance from UNICEF. This was started following reports of arsenic in bordering districts in Nepal. 3390 samples were taken from 10 districts and analyzed for arsenic by Atomic Absorption Spectrophotometry (AAS). 4.3% of the samples collected in this study were >10 µgl-1 and only 0.1% (3 samples) were > 50 µgl-1 (SIIR, 2004).

In 2004 researchers from the School of Environmental Studies-Jadavpur University, Kokata (SOES-JU) visited Ballia district in the east of the state and took 914 samples from handpumps in 25 villages in 3 blocks of the district. After analysis by AAS they reported that 56% of these samples contained arsenic in concentrations > 10 µgl-1 and 43% of the samples with > 50 µgl-1 (SOES-JU, 2004). UP Jal Nigam subsequently analyzed 52 samples from the affected areas and found 3 sources > 50 µgl-1 with a maximum arsenic concentration of 102 µgl-1. Continued investigation by SOES-JU in Ballia and the neighbouring districts of Gazipur and Varanasi has found that out of 3901 samples analysed 46.6% contain arsenic in concentrations > 10 µgl-1 and 30.5% of the samples have > 50 µgl-1. 68 villages in 9 blocks of these 3 districts were identified as affected with arsenic in drinking water at levels > 50 µgl-1 (SOES-JU, 2005).

The current collaboration on arsenic testing and mitigation between UP Jal Nigam and UNICEF on which most of the results in this paper are based was begun late- 2004 following the results of the SIIR study. Phase 1 has been completed and Phase II is ongoing.

Arsenic task force

Following the model successfully used to guide arsenic mitigation works in West Bengal where a Joint Plan of Action was developed and agreed by the state 'Arsenic Task Force' (GoWB/UNICEF, 2002) an Uttar Pradesh state 'Arsenic Task Force' was formed in October 2004.

The aim of this group is to bring representatives of all organizations with a stake-holding in arsenic issues together in one forum to share ideas, experience and knowledge and use this to guide implementation of work to address the problem in the state. The UP Arsenic Task Force is chaired by the Chief Engineer (Rural) of UP Jal Nigam and consists of representatives from government bodies, academic and research institutions and non-government organisations. The current make-up of the task force in listed in Table 1.

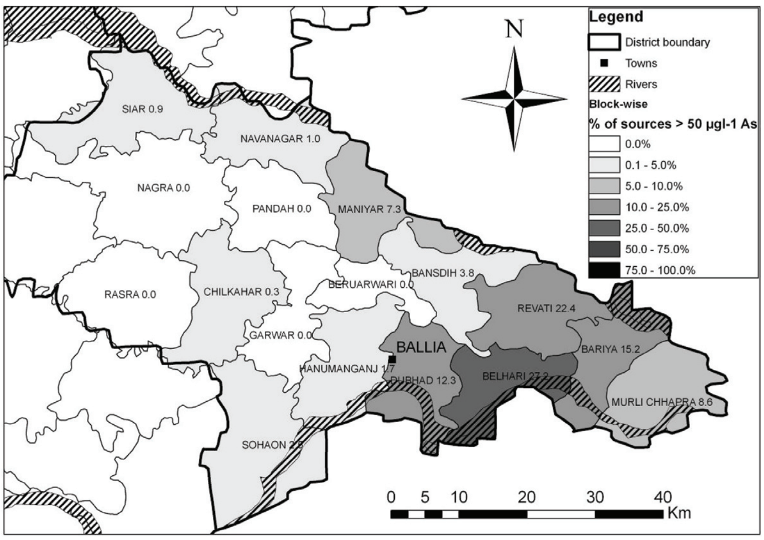


Figure 2. Block-wise percentage of handpump sources with concentration of arsenic > 50 µgl-1 in Ballia district of Uttar Pradesh.

'Screening' testing

Given the sheer size of Uttar Pradesh (total area 238,556km2, roughly equivalent to the United Kingdom) and the number of groundwater-based water points (approx. 1.45 million government installed India Mark II handpumps, many more private handpumps) it was inconceivable to test all sources for arsenic immediately. To address this issue, priority areas for testing were identified and a system for 'screening' was devised to locate arsenic 'hot spots' for further testing. This is discussed below. Further, it was inconceivable that laboratory facilities could be used on a large scale for testing of handpumps; sufficient facilities do not exist, and the logistical implications would be too great. It was thus decided that field test kits would be used for testing of handpumps, backed up by confirmatory testing in the laboratory. This protocol is discussed further in Box 1.

In Phase 1 of the project, villages and habitations (a subdivision of a village) in Ballia and Lakhimpur Kheri districts were 'screened' for arsenic by testing one government source per habitation where there were 1-10 handpumps in total, and 2 handpumps in habitations with >10 government installed handpumps. This generally amounts to around 10-20% of the total government installed handpumps. This sampling strategy was easy to implement, gave representative results, and was achievable given the supplies and human resources available. The results of the field testing were confirmed by laboratory testing following the protocol described in Box 1.

Summary results of the screening with field test kits in Ballia and Lakhimpur Kheri districts are shown in Table 2 and 3 respectively, and a map of the distribution of affected sources in Ballia in Figure 2. The pattern seen, whereby arsenic contamination is seen to occur in the areas of younger alluvium near to the major rivers, in itself indicates the reliability of the data.

Box 1. Protocol for field screening testing followed by laboratory confirmation

It has been conservatively assumed that the NCL field test kit has an accuracy of ±20% or better. As such a result of 50 µgl-1 (the prevailing maximum permissible limit) could lie between 40 µgl-1 (-20%) and 60 µgl-1 (+20%).

In this testing programme all sources screened using field test kits and found to contain arsenic at concentrations >40 µgl-1 are sampled for re-testing in the laboratory with more accurate equipment. Sources found to contain arsenic concentrations <40 µgl-1 can be assumed to be within the permissible limit, as with an error of ±20% a result of 40 µgl-1 should lie between 32 and 48 µgl-1.

Using this protocol a large number of sources can be screened in a short period of time, and cost and logistical implications are kept to a minimum. The overall accuracy of testing is maintained by confirmation of all positive field test results in the laboratory.

In addition 5% of sources tested with field test kits (every 20th source) are sampled and these samples tested in the laboratory. This is done to check for human or equipment error in the field testing process.

The relationship seen between arsenic and geologically younger strata seen in these two districts was used to identify blocks for priority screening for arsenic elsewhere in the state. A block map was compared with the relevant units using the 1:250,000 'Geological Quadrangle' maps and the 1:250,000 'District Resource' maps of the Geological Survey of India. This revealed 289 out of 813 blocks (in 49 further districts) as potentially more 'at risk' of arsenic in groundwater. For

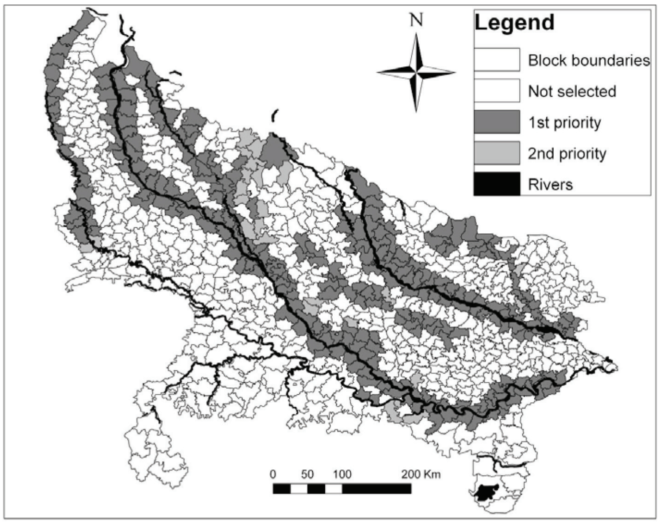


Figure 3. 289 blocks identified for state-wide screening testing of arsenic in groundwater in Uttar Pradesh.

Note: Blocks in Ballia and Lakhimpur Kheri districts are not included as screening testing is already complete in these districts.
1st priority indicates key blocks for screening testing, 2nd priority indicates blocks to be tested as supplies and time allow.

more details see Srivastava et al, 2006, in press. The blocks selected for priority screening are shown in Figure 3.

'Blanket' testing and marking of sources

Where screening testing reveals arsenic is present in groundwater, the next step is 'blanket' testing of all sources available in the affected area to differentiate between arsenic-contaminated and arsenic-safe sources. At present only government sources are being included in this blanket testing in Uttar Pradesh, ideally all public and private sources should be included and potential mechanisms for this are under consideration. This testing is also undertaken using field test kits and following the protocol outlined in Box 1.

Arsenic-contaminated sources are then marked red and arsenic-safe sources marked blue and communication undertaken to inform people of the meaning of the marking and the implications (discussed further below). Providing this information gives people living in affected areas the option to reduce their exposure to arsenic by well-switching i.e. use of arsenic-safe sources in preference to arsenic-contaminated ones (e.g. Van Geen et al, 2002). This is the easiest and simplest mitigation option available.

In addition sources are also being located using GPS. This enables detailed mapping of the affected areas and can be used for locating priority areas for mitigation and, in consultation with the community, can be used as a guide for siting of alternative sources.

Communication

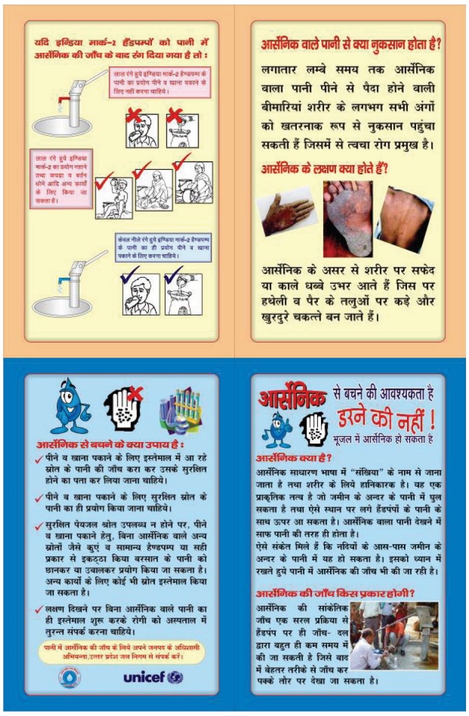
As arsenic-affected areas are generally 'water-rich' with groundwater sources (i.e. handpumps) generally easily accessible within a short distance of the household, convincing people of the necessity to change their practise to avoid arsenic (perhaps use another source at a greater distance) has been seen to be difficult in affected areas in Bangladesh and West Bengal.

Coupled with the testing and marking, a strong, simple and clear communication strategy is required if programmes are to stand any chance of influencing the behaviour of people in arsenic-affected areas to reduce their exposure.

In UP the ultimate aim will be to replace arsenic-contaminated sources with arsenic-safe ones (see 'Alternative water sources' below), however, in the interim attempts are being made to encourage people to change their practice to use arsenic-safe sources already available e.g. tested and marked arsenic-safe shallow handpumps, community deep handpumps or piped water supply standposts.

Communication is being undertaken by NGO workers and UP Jal Nigam staff based on a communication strategy developed by UP Jal Nigam/UNICEF. The primary channel is inter-personal communication and NGO staff are provided with training and materials to facilitate their interactions with community persons directly and community groups (e.g. Village Water and Sanitation Committee).

The impact of the communication campaign will be assessed by comparing baseline and endline survey data on the knowledge, attitude and practice (KAP) of people residing in the affected areas in due course.



Photograph 1. Pamphlet for use by NGO workers

An example of a pamphlet produced as a communication tool for use and distribution by the NGO staff is given in Photograph 1.

Alternative water sources

Where blanket testing and mapping indicates that there are insufficient sources supplying water of low arsenic concentration two options are available: source-substitution to an alternative source, or treatment of the water to remove arsenic. Experience has shown that, although effective under laboratory conditions, very often inadequate operation and maintenance of treatment plants or filters leads to their failure once deployed in the field (e.g. Hossain et al. 2005 for arsenic, or Operations Research Group 2005 for fluoride).

In contrast to areas where fluoride occurs in groundwater, the alluvial sedimentary environments of South Asia where arsenic is found in groundwater can be considered as 'water-rich' environments. Water resources are generally plentiful and supply exceeds demand. There are generally four alternative arsenic-safe water sources available in areas affected by arsenic-contamination: deeper groundwater; shallower groundwater; surface water and rainwater.

With these considerations in mind it has been decided that where mitigation action is required in arsenic affected areas in Uttar Pradesh under this project the concept of source-substitution will be followed. The alternative water sources being trialled include: Deep groundwater through deep handpumps, shallow groundwater through large diam-

Table 3. Summary of arsenic field testing data for Lakhimpur Kheri district

Block	Total sources tested	As 0-10 μgl^{-1}	As 10-40 μgl^{-1}	As 40-50 μgl^{-1}	As >50 μgl^{-1}	% sources >10 μgl^{-1}	% sources >50 μgl^{-1}
Paliya	316	46	207	23	40	85.4	12.7
Nighasan	419	135	272	6	6	67.8	1.4
Ramiya Behar	357	152	174	12	19	57.4	5.3
Dhaurahara	301	95	171	25	10	68.4	3.3
Issanagar	429	144	231	26	28	66.4	6.5
Mohammdi	351	348	3	0	0	0.9	0
Mitauli	365	354	11	0	0	3.0	0
Pasgawan	299	293	6	0	0	2.0	0
Behjam	296	293	3	0	0	1.0	0
Phoolbehar	332	204	128	0	0	38.6	0
Nakaha	297	215	81	0	1	27.3	0.3
Lakhimpur	336	283	53	0	0	15.8	0
Kumbhi Gola	303	282	21	0	0	6.9	0
Bijuwa	329	176	152	1	0	46.5	0
Bankeyganj	302	237	64	1	0	21.5	0
Total	**5032**	**3257**	**1577**	**94**	**104**	**35.3**	**2.1**

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Table 4. Field test results from selected deep handpumps installed in Ballia district of Uttar Pradesh.

Block	Village	Location	Depth (m)	As in deep h.p. (μgl^{-1})	As in adjacent shallow h.p. (μgl^{-1})
Belhari	Rajpur Ekouna	Satrughan Singh	76.6	0	400
Belhari	Udawant Chhapra	Shiv Mandir	85.1	0	100
Belhari	Chain Chhapra	Pratibha Choubey	70.1	10	450
Belhari	Hariharpur	Primary School	79.6	0	200
Belhari	Nem Chhapra	Surendra Nath Tiwari	79.5	0	360
Revati	Gai Ghat-I	Radhey Shyam Singh	76.0	0	130
Revati	Gai Ghat-III	Laljee Dhobi	75.0	0	110
Dubhad	Sawrubandh	P.B. School	79.0	0	95

eter open wells and rainwater through roof water harvesting systems. UP Jal Nigam is also installing piped water supply schemes in arsenic affected areas with deep tubewells fitted with a submersible pump as the source.

To date the experience with deep handpumps has been encouraging (initial field test results shown in Table 4); however, substantial further work is required before this source can be declared safe for general implementation. Testing of the full range of chemical water quality parameters with implications for human health will be carried out and surveillance of the arsenic concentrations in the water of deep handpumps over time is required. Essentially a comprehensive programme of supporting hydrogeological research is required in this area.

Health aspects

In addition to the activities described above which are essentially designed to mitigate the problem and reduce arsenic exposure, the project has aimed to support persons whose health is already affected by arsenic in drinking water. The King George Medical University (KGMU) of Lucknow are undertaking two specific activities in the arsenic affected areas: an epidemiology survey to assess the prevalence rate of arsenic-induced disease in Ballia district; and training and awareness raising of the staff of the Government of UP Directorate of Health. For the latter task, a training and reference manual has been prepared (KGMU, 2006, in press)

The field work of the epidemiology survey was completed in May 2006 and the preliminary results are given in Table 5 below. The classification given in WHO, 2006 was followed. The training and awareness raising work is due to start mid-2006.

Patients of arsenicosis have already been detected in Ballia district showing similar external symptoms as elsewhere in India and Bangladesh: melanosis and keratosis. Urgent action will be taken to ensure these people have access to arsenic-safe water sources and symptomatic treatment will be provided through Government Directorate of Health facilities available in the affected areas.

Table 5. Preliminary results of epidemiology survey in arsenic affected areas of Ballia District, UP.

Persons examined in affected block	Clinically confirmed cases	Probable cases	Suspected cases
1084	55	38	69

Co-ordination and convergence

Given the multi-sectoral nature of the problem of arsenic in groundwater used for drinking, co-ordination and convergence between all relevant bodies is critical.

In this project this aspect was recognized from the beginning and the constitution of the Uttar Pradesh 'Arsenic Task Force' was the first step towards effective co-ordination and convergence. The task force has been a successful endeavour and the membership has grown since its formation in 2004 to include other important stakeholders and those who have come forward to work on the problem. It would seem likely that more Non-governmental Organizations may become members of the task force in due course as their interest and experience in arsenic mitigation grows.

In the arsenic-affected districts convergence between the District Administration (e.g. District Magistrate, Chief Development Officer, District Panchayati Raj Officer), the UP Jal Nigam (Executive Engineer) and the Directorate of Health Staff (Chief Medical Officer) has already started. In Ballia for example several meetings have been convened to share information and map out the responsibilities of each sector to tackle the problem.

Conclusion

Exposure to arsenic, in particular through in groundwater used for drinking, is an emerging threat to public health in parts of the state of Uttar Pradesh in India. Drawing on experiences from other affected areas, such as West Bengal and Bangladesh, and experiences from a pilot project in two districts, a comprehensive strategy has been evolved to tackle the problem throughout the state.

This includes: screening testing in 51 districts to identify the affected areas; blanket testing and marking to identify the arsenic-contaminated and arsenic-safe sources in areas found to be affected during screening; communication on arsenic and arsenicosis and the implications of test results; mitigation through source-substitution to arsenic-safe sources where required; and health interventions to assist those already suffering from arsenicosis.

Phase II of this project is ongoing in Uttar Pradesh and this paper is an interim report of work in progress.

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