

# Arsenic contamination of groundwater and its health impact on residents in a village in West Bengal, India

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**Abstract** An in-depth study was carried out in Rajapur, an arsenic-affected village in West Bengal, India, to determine the degree of groundwater contamination with arsenic and the impact of this contamination on residents. The flow injection hydride generation atomic absorption spectrometry (FI-HG-AAS) method was used to measure arsenic concentrations in water and biological samples. Dermatologists recorded the dermatological features of arsenicosis.

Out of a total of 336 hand-pumped tube-wells in Rajapur, 91% (307/336) contained arsenic at concentrations > 10 µg/l, and 63% (213/336) contained arsenic at > 50 µg/l. The type of arsenic in groundwater, the variation in concentrations of arsenic as the depth of tube-wells changed, and the iron concentration in the wells were also measured. Altogether 825 of 3500 residents were examined for skin lesions; of these, 149 had lesions caused by exposure to arsenic. Of the 420 biological samples collected and analysed, 92.6% (389) contained arsenic at concentrations that were above normal. Thus many villagers might be subclinically affected.

Although five arsenic-filtering devices had been installed in Rajapur, it appears that villagers are still exposed to raised concentrations of arsenic in their drinking-water. Detailed village-level studies of arsenic-affected areas in West Bengal are required in order to understand the magnitude of contamination and its effects on people. Villagers are ill-informed about the dangers of drinking arsenic-contaminated water. The contamination could be brought under control by increasing community awareness of the dangers and implementing proper watershed management techniques that involve local people.

**Keywords** Arsenic/toxicity/urine; Water pollution, Chemical/prevention and control; Fresh water/analysis; Filtration/instrumentation; Skin manifestations; India (source: MeSH, NLM).

**Mots clés** Arsenic/toxicité/urine; Pollution chimique eau/prévention et contrôle; Eau douce/analyse; Filtration/instrumentation; Manifestation cutanée; Inde (source: MeSH, INSERM).

**Palabras clave** Arsénico/toxicidad/orina; Contaminación química del agua/prevencción y control; Agua dulce/análisis; Filtración/instrumentación; Manifestaciones cutáneas; India (fuente: DeCS, BIREME).

الكلمات المفتاحية: الزرنيخ، التسمم بالزرنيخ، الزرنيخ في البول؛ تلوث المياه، التلوث الكيميائي للمياه بالزرنيخ، الوقاية من التلوث الكيميائي للمياه بالزرنيخ ومكافحته؛ المياه العذبة، تحليل المياه العذبة؛ أجهزة الترشيح؛ المظاهر الجلدية، الهند (المصدر: رؤوس الموضوعات الطبية- المكتب الإقليمي لشرق المتوسط)

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Voir page 55 le résumé en français. En la página 55 figura un resumen en español.

يمكن الاطلاع على الملخص بالعربية في صفحة 56.

## Introduction

Contamination of groundwater with arsenic and the impact of this contamination on humans have been reported from 23 countries. The magnitude of this problem is severe in Bangladesh (1-7) and West Bengal, India (5-11). In recent years evidence of arsenic groundwater contamination has also emerged in other Asian countries including Cambodia, the Lao People's Democratic Republic, Myanmar and Pakistan (8). Groundwater arsenic contamination and its associated skin lesions have also been reported in Nepal (12, 13), Viet Nam (14), a province in Iran (15) and Bihar state (16) in the Middle Gangetic Plain in India. With the discovery of arsenic in groundwater in other states in India (Uttar Pradesh, Jharkhand and Assam (17)) it

appears that some areas in all Indian states and Bangladesh that lie on the Ganga-Meghna-Brahmaputra plain (which is home to a population of over 450 million people and encompasses an area of 570 000 km<sup>2</sup>) might be at risk from groundwater arsenic contamination.

The contamination of groundwater with arsenic and its impact on people were first noted in West Bengal in 1983 (8). Since 1988 our team has been surveying arsenic-affected villages in West Bengal. We have analysed 115 000 samples from hand-pumped tube-wells and found that 50.3% of them had arsenic concentrations above 10 µg/l and 25% had concentrations above 50 µg/l (9). We also analysed 25 000 biological samples from people living in arsenic-affected villages, including samples of urine, hair, nails and skin. On average, 89% of

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the samples showed arsenic concentrations above the normal level (9). In our preliminary survey we screened 86 000 people from 325 affected villages and found that 8500 people had skin lesions associated with exposure to arsenic (9).

To better understand the degree of contamination of groundwater with arsenic and its impact on health, we conducted a systematic survey of a single district in West Bengal, India. From June 2000 until July 2003 we focused on Murshidabad. We collected 29 612 water samples from hand-pumped tube-wells in 1833 of the 2414 villages in the district. However, Murshidabad proved to be too large a district to survey in this way and we were unable to complete our survey. However, our preliminary results indicated that people in 40–50 villages were seriously affected by arsenic contamination of groundwater. From these villages we randomly selected Rajapur in the Domkal block as our study area.

In this article we describe in detail our findings from Rajapur focusing on the contamination of groundwater, the past and present health effects of arsenic toxicity and the impact of arsenic-filtering devices previously installed in the village to provide safe water. Finally, we suggest a viable solution to the problem of arsenic contamination.

## Methods

### Location

The state of West Bengal in India consists of 18 districts. Each district is divided into several blocks (also known as police stations or precincts). Each block incorporates several clusters of villages known as Gram Panchayets; the villages in each Gram Panchayet vary in size and population.

Rajapur is located in the south-eastern part of the Domkal block in the Murshidabad district. Fig. 1 shows the location of Rajapur. It is a remote agricultural village about 2.25 km<sup>2</sup> in area with a population of about 3500. The village is divided into seven small subregions. The village is surrounded by rice fields, for which groundwater is the main source of irrigation, but this is supplemented with rainwater during the monsoon periods. Prior to December 2000 almost the entire population of Rajapur drank water from shallow hand-pumped tube-wells, but after the government was alerted by various organizations that many people in this village had arsenicosis, they installed three arsenic-filtering devices in December 2000; two additional devices were installed in October 2001 and May 2003. Fig. 1 shows the location of the devices. All of these devices were for community use and were considered sufficient for the domestic needs of the 3500 inhabitants. Each device can filter 900 000 litres of water with arsenic concentrations > 1000 µg/l or 2 500 000 litres of water with concentrations of 250 µg/l before media replacement is necessary. Our study assumed that villagers were drinking safe water from hand-pumped tube-wells that were connected to the filtering devices.

### Sample collection and analysis

Water from the hand-pumped tube-wells and samples of hair, nails and urine were collected and analysed for arsenic using flow injection hydride generation atomic absorption spectrometry (FI-HG-AAS). The total concentration of arsenic in the water [As (III) + As(V)] was measured after potassium bromate oxidation. Concentrations of As (III) in the water were determined by using FI-HG-AAS in the presence of citric acid solution (0.25 mol/litre) and NaBH<sub>4</sub> (0.5%) solution so that As(V) was

not detected. As(V) was obtained by subtracting the amount of As(III) from total arsenic.

For urine samples, inorganic arsenic and its metabolites were measured together with no prior chemical treatment. FI-HG-AAS does not detect arsenobetaine and arsenocholine (18). For hair and nail samples, total arsenic was determined after digestion. The modes of sample collection, the digestion procedures for hair and nails, analytical procedures for water and biological samples and details of the instrument and flow-injection system were used as reported earlier (18–21).

### Quality assurance and quality control

For quality control, interlaboratory tests were performed on water and hair samples and reported in earlier publications (20, 22). We also analysed US Environmental Protection Agency standardized water reference materials and standardized biological reference materials including hair and urine as we have reported elsewhere (20–23).

## Findings

### Groundwater contamination and estimate of population affected

In June 2003 there were 336 hand-pumped tube-wells in working condition in the seven subregions of Rajapur; we collected samples from all of them in order to assess arsenic and iron concentrations. Fig. 1 shows the degree of contamination of the tube-wells. Table 1 shows the distribution of arsenic concentrations in the seven subregions of the village. From Table 1 it follows that only 8.63% of Rajapur's inhabitants had safe drinking-water (that is, with concentrations < 10 µg/l of arsenic). Table 2 shows the number of people drinking contaminated water for each of the various concentrations of arsenic. This calculation is based on the percentage of hand-pumped tube-wells found to have had arsenic concentrations above different levels, which is directly related to the population of Rajapur. This estimation is based on an analysis of 100% of the hand-pumped tube-wells. In our previous study we have shown the validity of such calculations (9). We had expected to find arsenical skin lesions in people who had been drinking water contaminated with ≥ 300 µg/l of arsenic for a prolonged period (8, 9).

Prior to June 2000 we analysed water samples from 52 of the hand-pumped tube-wells in Rajapur; in June 2003 we analysed samples from 336 of the wells, 12 of which had also been analysed in 2000. When we compared arsenic concentrations found in the earlier study with those found in the later study for these 12 tube-wells, we observed that the concentration of arsenic had increased substantially. A similar trend has been observed in other arsenic-affected villages in West Bengal (24, 25).

### Speciation of arsenic in groundwater

In our earlier work, we reported that the groundwater in West Bengal and Bangladesh contained only inorganic arsenic (arsenite and arsenate) and that no methylated forms of arsenic had been detected (20). Table 3 shows the results of the analysis of water taken from the 336 wells in Rajapur. The ratio of the average arsenite concentration to the average arsenate concentration in groundwater was about 2:1. This differs from our findings in other districts of West Bengal where the concentration was about 1:1 (20). The arsenic in Rajapur is located about 15–30 m deep in aquifers; concentrations decrease as the depth increases.

Fig. 1. Map of the arsenic-affected areas of Murshidabad district, showing Rajapur village in the Domkal block and the concentrations of arsenic in water samples taken from 336 hand-pumped tube-wells

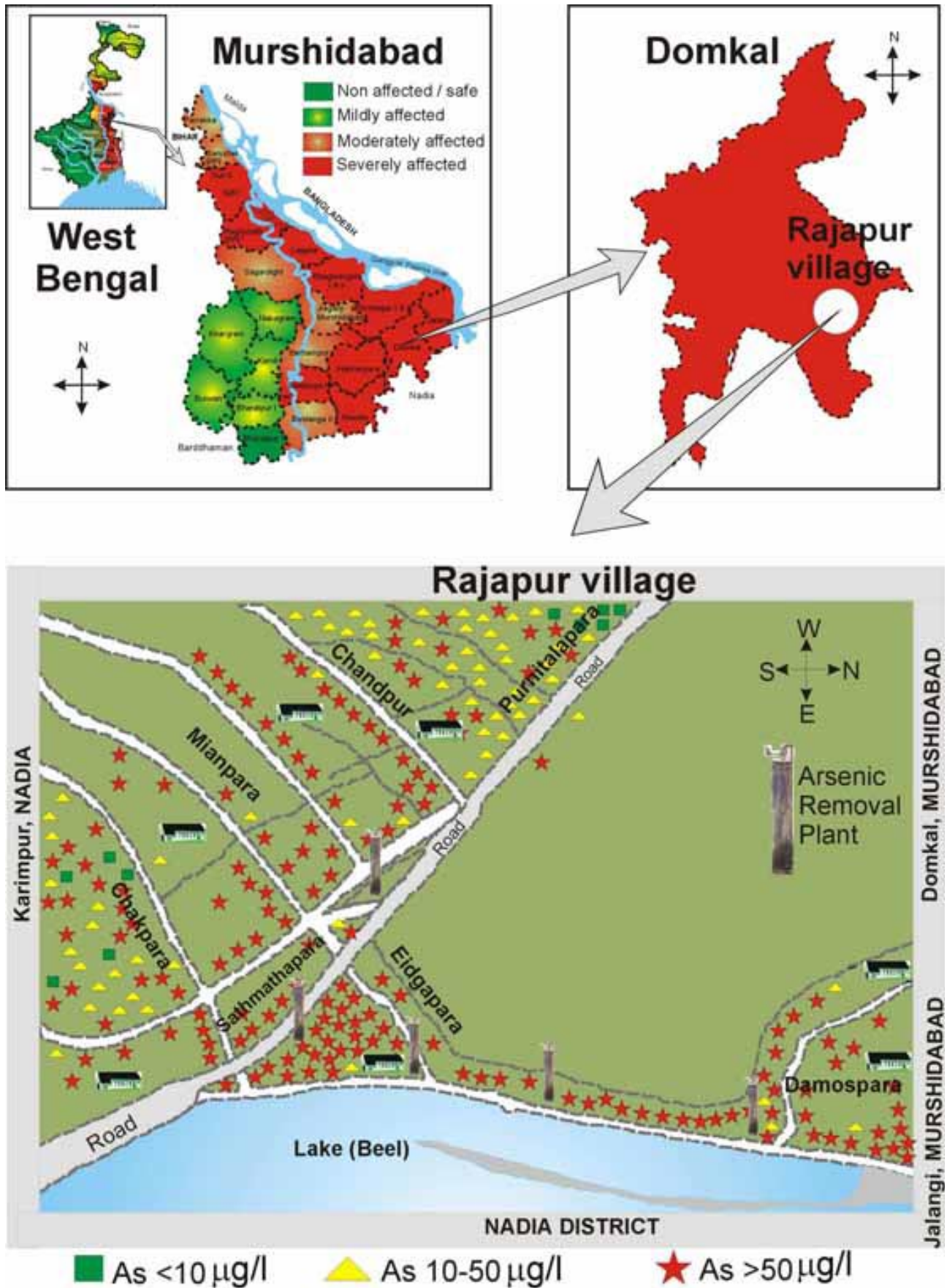


Table 1. Concentrations of arsenic in samples taken from hand-pumped tube-wells in Rajapur village, Murshidabad, India

Subregion of Rajapur	Total no. of tube-wells	Total no. water samples analysed	Concentration of arsenic ( $\mu\text{g/l}$ )										
			< 3	3–9	< 10	10–50	51–99	100–199	200–299	300–499	500–699	700–1000	> 1000
Damospara	40	40	–	1	1	5	13	9	4	3	3	–	2
Eidgapara	27	27	–	–	–	–	1	10	2	5	2	6	1
Sathmatha	24	24	–	–	–	2	7	15	–	–	–	–	–
Miapara	33	33	–	–	–	4	22	5	1	1	–	–	–
Chandpur	13	13	–	–	–	1	4	8	–	–	–	–	–
Purnitalapara	97	97	4	16	20	50	22	5	–	–	–	–	–
Chakpara	102	102	5	3	8	32	35	26	1	–	–	–	–
<b>Total<sup>a</sup></b>	<b>336</b>	<b>336</b>	<b>9</b> (2.68)	<b>20</b> (5.95)	<b>29</b> (8.63)	<b>94</b> (27.98)	<b>104</b> (30.95)	<b>78</b> (23.21)	<b>8</b> (2.38)	<b>9</b> (2.68)	<b>5</b> (1.49)	<b>6</b> (1.78)	<b>3</b> (0.89)

<sup>a</sup> Figures in parentheses are percentages.

Table 2. Number of people drinking arsenic-contaminated water in Rajapur village (an area of 2.25 km<sup>2</sup>), Murshidabad, India, by concentration of arsenic

Total population	No. of tube-wells analysed	No. of people drinking arsenic-contaminated water <sup>a</sup>									
		$\leq 10$	>10	> 50	> 100	> 125	> 200	> 250	> 300	> 500	> 1000
3500	336	315	3185	2215	1134	707	322	269	239	145	31

<sup>a</sup> Concentration of arsenic given in  $\mu\text{g/l}$ .

### Iron concentrations

Water samples from 208 tube-wells in Rajapur were analysed for iron; the mean concentration was 4089  $\mu\text{g/l}$  (range = 168–19257  $\mu\text{g/l}$ ). About 92% (192) of our samples contained iron concentrations that were higher than the WHO recommended maximum level of 300  $\mu\text{g/l}$ . There was a poor correlation ( $r = 0.319$ ) between the concentration of iron and the concentration of arsenic in water; this is the opposite of findings from a study of arsenic in borehole sediments, which found a positive correlation (26).

### Arsenical skin lesions

In a few clinical surveys, undertaken during June 2000–July 2003, we identified 149 people with arsenicosis in four of the seven subregions. We did not identify any in the subregions of Sathmatha, Chandpur and Purnitalapara. Table 4 gives detailed information on the clinical survey in the four subregions of Rajapur. Although we registered 149/825 people (18.1%) as having arsenicosis in Rajapur, the head of the Gram Panchayat and many villagers informed us that we had not examined all of the people in the village with the disease; according to local people there were about 400 people in Eidgapara and about 150 people in Damospara who exhibited arsenical skin lesions. Fig. 2 shows a man from Eidgapara with arsenical keratoses on his palms.

We also collected information from villagers about deceased family members who had had arsenical skin lesions and had died from cancer. However, we could not obtain proof that the deaths were caused by arsenic toxicity because in remote villages a death certificate showing the cause of death is not required before the body is cremated. In Damospara, villagers named 11 people who had died, all of whom were reported to

have had severe arsenical skin lesions. Most of them had died at an early age.

Eidgapara was determined to be a seriously affected village; the people there seem to have been affected by arsenic for at least 12–15 years. The proportion of tube-wells with concentrations of arsenic > 300  $\mu\text{g/l}$  is high in Eidgapara (Table 1). Through interviews and clinical examinations, we estimated that a large number of people were affected (Table 4).

### Arsenic in biological samples

During July 2003, we collected and analysed 50 urine samples, 188 hair samples and 182 nail samples both from people with symptoms and people without symptoms in Eidgapara and Damospara. On average, 50% of the samples were from people with arsenical skin lesions.

The results showed that 84% (158/188) of hair samples contained concentrations of arsenic that were higher than normal. Normal concentrations in hair range from 80  $\mu\text{g/kg}$  to 250  $\mu\text{g/kg}$ ; 1000  $\mu\text{g/kg}$  indicates toxicity (27). The mean concentration in hair samples was 1931  $\mu\text{g/kg}$ ; the median was 1587  $\mu\text{g/kg}$ ; and the range was 535–8453  $\mu\text{g/kg}$ . We found that 96% (175/182) of nail samples also contained arsenic concentrations that were higher than normal. Normal concentrations in nails range from 430  $\mu\text{g/kg}$  to 1080  $\mu\text{g/kg}$  (28). The mean concentration in nail samples was 3139  $\mu\text{g/kg}$ ; the median was 2401  $\mu\text{g/kg}$ ; and the range was 851–9706  $\mu\text{g/kg}$ . We also found that 98% (49/50) of urine samples had concentrations that were higher than normal. The normal range for excretion of arsenic in urine is 5  $\mu\text{g}$  to 40  $\mu\text{g}$  per day/1.5 l (29). The mean concentration in urine samples was 420  $\mu\text{g/l}$ ; the median was 244  $\mu\text{g/l}$ ; and the range was 33–2353  $\mu\text{g/l}$ . Thus many villagers may have been subclinically affected.

Table 3. Concentrations of total arsenic, arsenite and arsenate in samples collected from tube-wells in Rajapur village, Murshidabad, India

Subregion of Rajapur	No. of samples	Total arsenic <sup>a</sup>			Arsenite			Arsenate			Arsenite/arsenate		
		Range	Mean	Standard deviation	Range	Mean	Standard deviation	Range	Mean	Standard deviation	Range	Mean	Standard deviation
Damospara	40	9–1175	207	267	3–820	126	162	3–642	82	120	0.09–41.0	3.7	6.8
Eidgapara	27	82–1180	416	309	3–681	225	198	39–499	191	146	0.04–8.3	1.6	1.7
Sathmatha	24	28–181	103	39	3–83	33	24	18–175	73	45	0.03–2.3	0.7	0.7
Miapara	33	12–453	91	76	3–140	34	30	7–313	56	54	0.03–2.7	0.8	0.7
Chandpur	13	32–143	106	33	4–97	46	28	15–118	61	35	0.04–4.4	1.2	1.2
Purnitalapara	97	3–115	36	31	3–110	20	24	3–87	17	17	0.03–22	2.4	4.1
Chakpara	102	3–227	73	51	3–156	48	38	3–173	25	29	0.04–40	3.8	5.2
<b>Rajapur (total)</b>	<b>336</b>	<b>3–1180</b>	<b>111</b>	<b>168</b>	<b>3–820</b>	<b>61</b>	<b>101</b>	<b>3–642</b>	<b>51</b>	<b>80</b>	<b>0.03–41.0</b>	<b>2.6</b>	<b>4.5</b>

<sup>a</sup> All concentrations given in µg/l.

Table 4. Results of clinical survey of four subregions where people with arsenicosis were identified in Rajapur village, Murshidabad, India

Subregion of Rajapur	Total population	No. of people surveyed for arsenical skin lesions <sup>a</sup>	No. of people with arsenicosis	No. of males	No. of females	No. of people with Bowen's disease
Eidgapara	1000	325 (32.5)	71	55	16	16
Damospara	600	300 (50.0)	65	54	11	7
Miapara	350	100 (28.6)	4	2	2	–
Chakpara	350	100 (28.6)	9	4	5	–
<b>Total</b>	<b>2300</b>	<b>825 (35.9)</b>	<b>149</b>	<b>115</b>	<b>34</b>	<b>23</b>

<sup>a</sup> Figures in parentheses are percentages.

### Evaluating the arsenic-filtering devices

To provide safe drinking-water in Rajapur, the Government of West Bengal installed five arsenic-filtering devices. In the nine districts affected by arsenic, a total of 1900 devices (costing about US\$ 2 million and manufactured by both national and international manufacturers) have been installed.

During our preliminary field survey in 2000 we found many defunct devices and heard complaints from villagers about the quality of water. Fig. 3 shows a defunct device in the Murshidabad district. We evaluated the efficiency of 330 devices installed in the Murshidabad district and the North 24-Parganas district. Briefly, we found that: (a) 53 (16.1%) of the devices were defunct; (b) 45 (13.6%) of the devices had been installed in areas with hand-pumped tube-well where the arsenic concentration is <50 µg/l (the recommended limit of arsenic in drinking-water in India); (c) 160 (48.5%) devices functioned only intermittently and produced water that contained arsenic concentrations > 50 µg/l; (d) 245 (74.2%) devices produced treated water with iron concentrations above the WHO recommended maximum value. The minimum concentration of iron in 245 devices was 198 µg/l; the maximum concentration was 5697 µg/l; and the mean concentration was 1248 µg/l. In fact we also found that if the devices were not backwashed properly, iron and arsenic concentrations in the treated water were higher than in untreated water.

We interviewed about 800 families between 2000 and 2002. Their primary complaints were: almost 80% of the

Fig. 2. A man from Rajapur showing the keratoses and spotted melanoses on his palms



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devices worked only intermittently; attaching the device to the tube-well involved certain procedures and mechanical repairs that the villagers had not been trained to do, such as placing a valve at the mouth of the well or replacing packing material at the head of the well to facilitate the flow of water. Other problems included injuries caused by tube-well handles leaping up suddenly when depressed; water spraying from the top of the tube-well when the handle was depressed; the valve at the mouth of the tube-well getting jammed; and the devices producing yellow-coloured water. For some devices, the clean water produced was being consumed by cattle even though it was meant only for human consumption. We also found instances in which villagers were using the filtered water for washing and bathing.

Because of the problems they encountered, the villagers were unwilling to install the filtering devices on their tube-wells. Fig. 4 shows an arsenic-filtering device that lay dismantled on a village road in the Domkal block for about 6 months. Worse still, as a result of this the villagers were forced to drink contaminated water. Although most of the filtering devices were not functioning properly, we did find a few that were capable of removing arsenic and functioning well if they were properly maintained, backwashed regularly and if the community was involved in maintaining them.

Arsenic in the urine is generally considered to be the most reliable indicator of recent exposure to inorganic arsenic.

To determine the number of villagers in the Eidgapara and Damospara subregions who had been exposed to arsenic, we analysed 50 urine samples in July 2003. (We could not collect more because villagers were not willing to provide samples). Of these, 45 contained arsenic in concentrations  $> 100 \mu\text{g/l}$ ; 28 had concentrations  $> 300 \mu\text{g/l}$ ; 18 had concentrations  $> 500 \mu\text{g/l}$ ; 10 had concentrations  $> 1000 \mu\text{g/l}$ ; and 5 had concentrations  $> 1500 \mu\text{g/l}$ . Urinary arsenic usually falls to normal levels within a few days of ingestion being stopped. So the presence of arsenic in a villager's urine was most probably from recent exposure. If arsenic was being consumed through the food-chain alone then we would not expect to find such a high concentration in urine (7). Moreover, since the filtering devices were installed in Damospara and Eidgapara in December 2000 we did not expect to find such high levels of arsenic in hair and nail samples, especially considering that the excretion of arsenic from hair and nails is a slow process and it could take several years for levels to return to normal (10).

## Discussion

From our study of Rajapur village, it is obvious that the magnitude of arsenic contamination is severe. Analysis of hair, urine and nail samples indicated that a large percentage of the population in Rajapur might be subclinically affected; thus if safe water is not provided to these villagers quickly, most of

Fig. 3. An arsenic-filtering device that is no longer in use in Murshidabad



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Fig. 4. Arsenic-filtering device that lay dismantled on a village road for 6 months



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them are likely to develop the symptoms of arsenicosis and other arsenic-related diseases. A detailed study to determine whether arsenic is coming from food-chain sources is necessary, and we feel that such a study should include the type of arsenic. We also feel that sufficient effort has not been made to educate villagers about the dangers of arsenic in their drinking-water. The government has not made an honest effort to disabuse villagers of their incorrect beliefs and to address their social and socioeconomic problems.

There is no known effective medical treatment for those suffering from chronic arsenic toxicity. Some chelating agents have been used but they are still under investigation (6). In the meantime, the consensus among medical doctors and other scientists working with arsenic-affected populations is that the need to supply safe drinking-water is urgent if deaths and illness are to be prevented. For people with early or mild arsenical skin lesions, clean water and nutritious food are the only way to bring about recovery (2).

In the arsenic-affected areas of West Bengal and Bangladesh the amount of per capita surface water available is huge. Most areas have large wetlands in addition to rivers, lakes, innumerable dugwells in areas where the aquifer is very close to the surface and about 2000 mm of rainfall annually. Water is available in many of them all year round and they could also be used as reservoirs. With proper management West Bengal's and Bangladesh's supply of surface water could provide a viable source of safe drinking-water if modern water purification

technology were used. This does not mean that water from hand-pumped tube-wells will not be used: if the tube-wells are free from arsenic and other contaminants, they are a good source of potable water.

The goal of eliminating arsenic from drinking-water could be achieved by increasing awareness, educating villagers about the issues of water management and involving the community in all aspects of the maintenance of their water source. However, as far as arsenic-filtering devices are concerned, we believe that even a highly successful technology may not succeed in rural areas unless politicians are willing to make a commitment to it and the technology that is being used fits the circumstances of the area and is accepted by the population. Development of such technologies is only possible when there is collaboration between bureaucrats, technocrats and villagers. ■

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**Conflicts of interest:** none declared.

## Résumé

### Contamination par l'arsenic des eaux souterraines et impact sur la santé des habitants d'un village du Bengale occidental, en Inde

A Rajapur, village touché par la pollution à l'arsenic du Bengale occidental, Inde, on a réalisé une étude en profondeur pour déterminer le degré de contamination des eaux souterraines par l'arsenic et l'impact de cette contamination sur les habitants. On a utilisé la spectrométrie d'absorption atomique couplée à un générateur d'hydrure (FI-HG-AAS) pour mesurer les concentrations d'arsenic dans l'eau et les échantillons biologiques. Des dermatologues ont relevé les caractéristiques dermatologiques de l'arsenicose.

Parmi les 336 puits tubulaires équipés de pompes manuelles de Rajapur, 91 % (307/336) contenaient de l'arsenic à des concentrations > 10 µg/l et 63 % (213/336) renfermaient plus de 50 µg/l d'arsenic. On a également déterminé le type d'arsenic présent dans les eaux souterraines, la variation des concentrations d'arsenic en fonction de la profondeur des puits tubulaires et la concentration de fer dans ces puits. On a examiné au total 825 des 3500 habitants à la recherche de lésions cutanées : 149 d'entre eux

présentaient des lésions provoquées par l'exposition à l'arsenic. Parmi les 420 échantillons biologiques recueillis et analysés, 92,6 % (389) contenaient de l'arsenic à des concentrations supérieures à la normale. Ainsi, de nombreux villageois pourraient être affectés à un niveau subclinique.

Bien que cinq dispositifs de filtrage de l'arsenic aient été installés à Rajapur, il s'avère que les villageois sont encore exposés à des concentrations élevées d'arsenic dans l'eau de boisson. Des études détaillées à l'échelle du village des zones touchées par l'arsenic du Bengale occidental sont nécessaires pour avoir une idée de l'ampleur de la contamination et de ses effets sur les personnes. Les villageois sont mal informés des dangers liés à la consommation d'eau contaminée par l'arsenic. Il serait possible de maîtriser cette contamination en sensibilisant les communautés à ces dangers et en mettant en œuvre des techniques de gestion des bassins hydrologiques appropriées, impliquant la population locale.

## Resumen

### La contaminación de las aguas subterráneas por arsénico y su impacto sanitario en los residentes de una aldea de Bengala Occidental, India

En Rajapur, una aldea de Bengala Occidental (India) afectada por el arsénico, se llevó a cabo un estudio exhaustivo a fin de determinar el grado de contaminación de las aguas subterráneas por arsénico y los efectos de esa contaminación en los residentes. Se utilizó la técnica de espectrometría de absorción atómica, método híbrido de inyección en flujo (FI-HG-AAS), para medir las concentraciones de

arsénico en el agua y en muestras biológicas. Los signos cutáneos de arsenicosis fueron determinados por dermatólogos.

Del total de 336 pozos entubados con bomba manual existentes en Rajapur, el 91% (307/336) contenían arsénico a concentraciones superiores a 10 µg/l, y el 63% (213/336) contenían más de 50 µg/l. Se midieron también el tipo de arsénico

en las aguas subterráneas, la variación de las concentraciones de arsénico en función de la profundidad de los pozos y la concentración de hierro en los pozos. Se examinó la piel de 825 de 3500 residentes; de ellos, 149 tenían lesiones causadas por la exposición al arsénico. De las 420 muestras biológicas recogidas y analizadas, el 92,6% (389) contenían arsénico a concentraciones mayores de lo normal. Así pues, muchos lugareños podrían estar afectados de forma asintomática.

Aunque se habían instalado en Rajapur cinco dispositivos de filtro del arsénico, parece que los lugareños siguen expuestos

a concentraciones elevadas en el agua de bebida. Es necesario emprender estudios detallados a nivel de aldea en las zonas de Bengala Occidental afectadas por el arsénico para poder determinar la magnitud de la contaminación y de sus efectos en las personas. Los lugareños están mal informados acerca de los peligros que entraña el consumo de agua contaminada por arsénico. La contaminación podría controlarse sensibilizando a la comunidad sobre los peligros y aplicando técnicas adecuadas de ordenación de cuencas hidrográficas que involucren a la población local.

## ملخص

### تلوث المياه الجوفية بالزرنيخ وتأثيراته الصحية على سكان قرية في غرب البنغال، الهند

أجرى ١٤٩ شخصاً منهم يعانون من أذيات ناجمة عن التعرض للزرنيخ. ومن بين العينات البيولوجية التي جمعت وحللت، والتي بلغ عددها ٤٢٠ عينة، وجد أن ٩٢,٦٪ منها (٣٨٩ عينة) تشتمل على الزرنيخ بتركيز يزيد على التركيز المعتاد، مما يشير إلى احتمال إصابة الكثير من سكان القرية بإصابات دون سريرية.

ورغم تركيب خمسة أجهزة لترشيح الزرنيخ في قرية راجابور، يبدو أن سكان القرية لا يزالون يتعرضون لمستويات مرتفعة من الزرنيخ في مياه الشرب. والحاجة ماسة لإجراء دراسات مفصلة على مستوى القرية في المناطق التي تعاني من التلوث بالزرنيخ في منطقة غرب البنغال لمعرفة مستوى التلوث وإدراك تأثيراته على الناس، إذ عادة ما يجهل القرويون مخاطر شرب المياه الملوثة بالزرنيخ. ويمكن السيطرة على التلوث بزيادة الوعي بين أفراد المجتمع حول أخطار التلوث وتنفيذ تقنيات ملائمة لتنقية المياه يشارك فيها السكان المحليون.

الملخص: أجريت دراسة معمقة في قرية راجابور، التي تقع في غرب البنغال في الهند وتعاين من التلوث بالزرنيخ، وذلك لتقدير درجة تلوث المياه الجوفية بالزرنيخ وأثر هذا التلوث على السكان. وقد استخدمت طريقة قياس الطيف الامتصاصي الذري لتوليد الهيدريد بسريان الحقن، وذلك لقياس التلوث بالزرنيخ في الماء وفي العينات البيولوجية. وقد سجل أطباء الجلد الملامح الجلدية للتسمم بالزرنيخ.

ومن بين الآبار التي توضع باليد عبر الأنابيب في راجابور، وعددها ٣٣٦، كان ٩١٪ منها (أي ٣٠٧ آبار من بين ٣٣٦ بئراً) تحتوي على الزرنيخ بتركيز يزيد على ١٠ ميكروغرام لكل لتر، وكان ٦٣٪ منها (أي ٢١٣ بئراً من بين ٣٣٦ بئراً) تحتوي على الزرنيخ بتركيز يزيد على ٥٠ ميكروغرام لكل لتر. وتم قياس نمط الزرنيخ في المياه الجوفية، وتفاوت تركيز الزرنيخ بتغير عمق الآبار الأنبوبية، وتركيز الحديد في الآبار. وتم فحص ٨٢٥ شخصاً من جملة السكان البالغ عددهم ٣٥٠٠ شخص لفحص الأذيات الجلدية، ووجد

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