Detailed study report of Samta, one of the arsenic-affected villages of Jessore District, Bangladesh

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In Bangladesh, arsenic in groundwater above 0.05 mg/l, the maximum permissible limit laid down by WHO, was found in 41 out of 64 districts. People suffering from arsenicosis have been identified in 20 districts out of the 21 districts we have surveyed so far. To know the magnitude of the calamity, it was necessary to survey thousands of villages in the 41 districts. To get an idea about the situation, we surveyed in detail one village, 'Samta', in Jessore district, having a population of 4841. All the tubewells in the village were analysed for arsenic. A few hundred hair, nail and urine samples were analysed as well to know the arsenic burden on the population. Furthermore, 600 people were examined for arsenical dermatosis. We have attempted a statistical interpretation of the data.

WE had reported earlier the magnitude of arsenic contamination of groundwater in Bangladesh[1] and West Bengal[2–10] and the resultant suffering of the people. Our preliminary survey report pertaining to Bangladesh, up to October 1997, is as follows.

So far we have analysed 6101 water samples from 60 out of the total 64 districts of Bangladesh. The four districts that have not been surveyed are: Khagrachari, Rangamati, Banderban and Cox's Bazar. In 52 districts we found arsenic in groundwater to be above the WHO recommended value of arsenic in drinking water (0.01 mg/l)[11]. Out of the 695 water samples analysed from 11 districts, 84% of the samples had arsenic concetration below 0.01 mg/l and arsenic in the other 16% was within the range 0.01–0.05 mg/l. In 41 districts, arsenic was above the WHO maximum permissible limit in drinking water (0.05 mg/l). Out of the 5078 water samples analysed in 41 districts, 45% contained above 0.05 mg/l of arsenic. The area and population of these 41 districts is 89,186 sq km and 76.9 million respectively. This does not indicate that the area and population of these 41 districts are affected, but no doubt they are at risk. The groundwater of the eight districts of Panchagarh, Thakurgaon, Nilphamari, Dinajpur, Gaibanda, Naogaon, Moulabi Bazar, Patuakhali was found safe with respect to the WHO recommended value (0.01 mg/l).

A preliminary survey was made of arsenic patients in only 54 villages in 21 districts where high concentrations of arsenic were present in the groundwater. Further, we identified arsenic patients in 52 villages in 20 districts. Thus, out of the 2155 people we surveyed in the affected villages, 57% showed arsenical skin lesions. The reason for such a high percentage is that our survey was carried out in highly arsenic-contaminated villages. However, to get a more realistic picture an extensive survey is necessary.

To survey all the 41 districts, hence thousands of villages, is a huge task. To obviate this, we chose a single village and made a somewhat detailed study to get an idea about the magnitude of the problem. Hopefully by extrapolating these results, we may get further insights into the extent of the calamity. Thus, in this paper we report the findings of our study on the arsenic contamination of Samta village, Jessore district. We have reported the analytical results of all the tubewell water of this village. A few hundred urine, hair and nail samples comprising four categories of population, i.e. adults with and without skin lesions; and children with and without skin lesion are reported. Attempts are made to find statistical correlations among arsenic in water and arsenic in hair, nails and urine. The dermatological symptoms manifested by 600 people examined are also reported. An attempt is also made to find a correlation between arsenic in groundwater and the abundance of arsenical skin lesions; both in adults and children.

The Samta village is situated on the eastern part of the river Bhagirathi in Jessore district, Bangladesh, just adjacent to Haridaspur of the North 24-Parganas district in neighbouring West Bengal, India. Figure 1 shows our recent findings of arsenic-affected districts of Bangla-

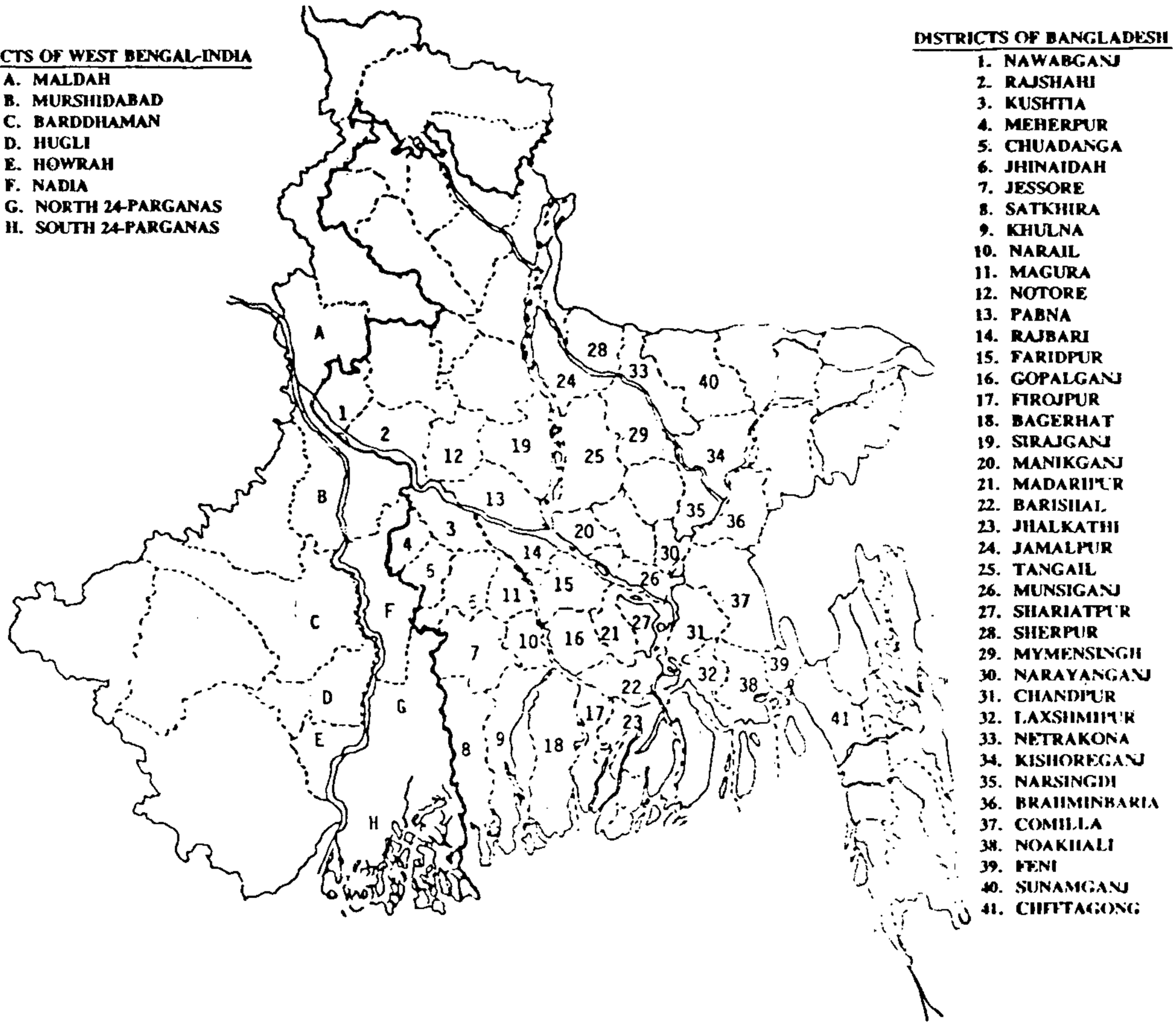


Figure 1. Map showing eight districts of West Bengal and 41 districts of Bangladesh containing arsenic above 0.05 mg/l.

desh, position of Samta village in Jessore, Bangladesh, and the arsenic-affected districts of West Bengal. The district of Jessore in Bangladesh and the arsenic-affected North 24-Parganas of West Bengal, India, are of the same deltaic deposition. So, the nature of the sediment is expected to be almost the same. The slope of Samta village is towards south, southeastern direction. Its groundwater level is shallow and in rainy season groundwater availability is up to 1.5 to 2.0 m from ground surface. Consequently, most of the tubewells are shallow and have water throughout the year. The total area and population of Samta village is 3.2 sq km (1.5 sq km residential area) and 4841 respectively. This village is divided into four areas: Purbapara (East), Uttarpara (North), Dakshinpara (South) and Paschimpara (West). The population of Paschim area is the highest (2355) and the population of Purba, Uttar and Dakshin area is 930, 784 and 772 respectively. The people of Samta village are poor and involved in agriculture and cottage industries. Surrounding the village are paddy fields. Groundwater is the source for irrigation other than the monsoon. The river Bettona flows through the eastern part of the village. The river becomes almost dry during summer.

Materials and methods

Flow Injection-Hydride Generation-Atomic Absorption Spectrometry (FI-HG-AAS) was used for analysis of most of the water, urine and digested biological samples. The detailed description of the instrumentation and FI-HG-AAS procedure was described in our earlier publications[3–12]. For estimating concentration of arsenic in water higher than 0.05 mg/l, our modified spectrophotometric method Ag-DDTC in $CHCl_3$ with hexamethylenetetramine[13] was used. All reagents were of analar grade. Details of the reagents and glass ware are given elsewhere[3,4,12].

The mode of collection of water, hair and nail samples was described in our earlier publications[3,4]. The procedure for cleaning hair and nail samples, and the mode of

Table 1. Distribution of tubewells against the arsenic range in four areas of Samta village

Zone (Para)	Total population	Total no. of tubewells	No. of tubewell samples analysed	No. of tubewell samples within the arsenic range (mg/l)						
				<0.01	0.01–0.050	0.051–0.099	0.1–0.299	0.3–0.499	0.5–0.699	>0.7
East (Purbapara)	930	59	58	5	17	24	11	1	–	–
North (Uttarpara)	784	61	61	–	1	39	19	1	1	–
South (Dakshinpara)	772	53	50	–	–	12	18	8	7	5
West (Paschimpara)	2355	106	96	–	–	29	45	3	13	6
Total	4841	279	265	5	18	104	93	13	21	11

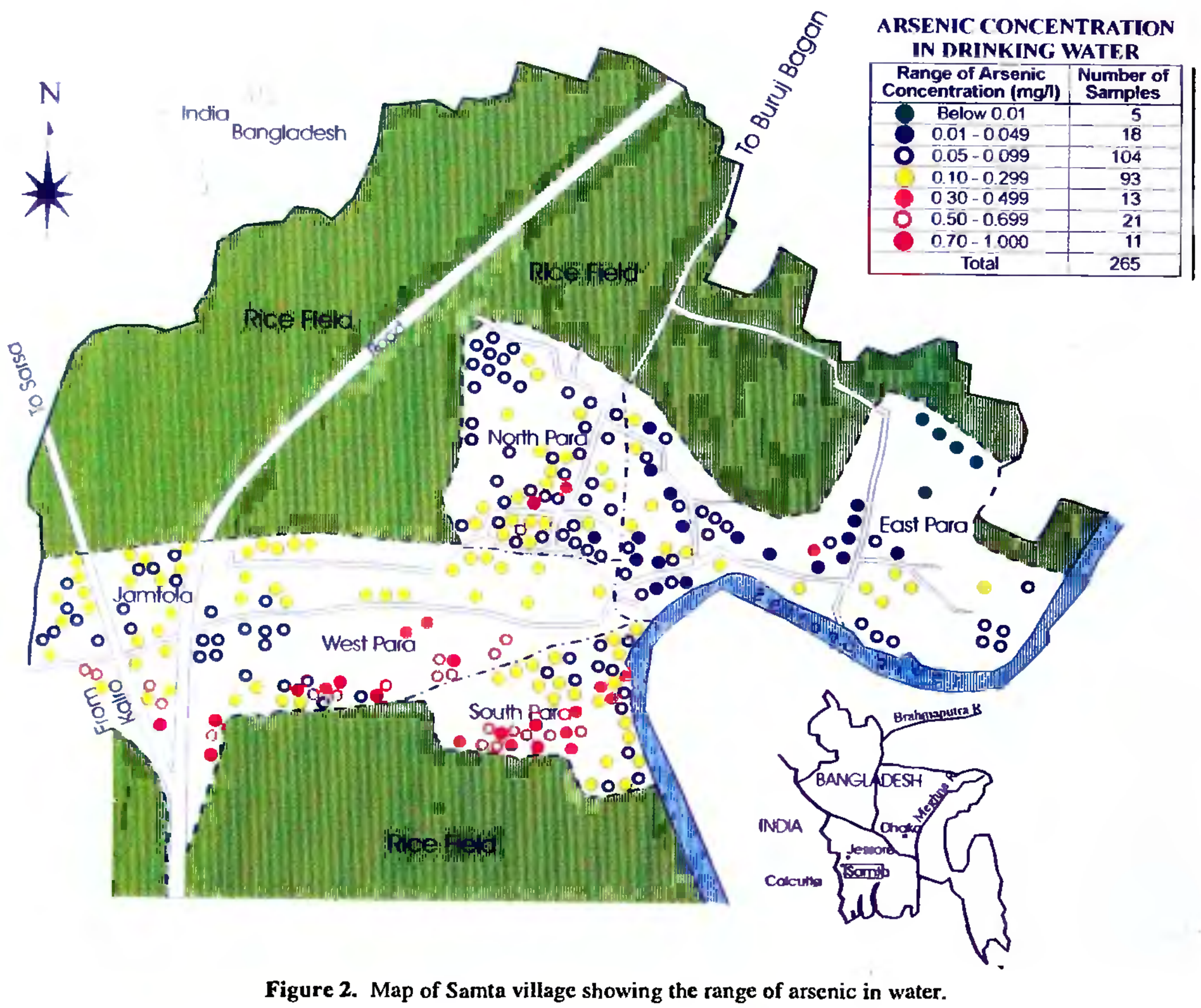


Figure 2. Map of Samta village showing the range of arsenic in water.

digestion, too, was described in earlier publications[4,6,7]. Spot urine samples were collected in pre-washed polythene bottles during sampling. The samples were not subjected to any chemical treatment. Immediately after collection, the samples were stored in a salt–ice mixture and later, after bringing back to laboratory, kept at –20°C until analyses were carried out. Inorganic arsenic and its metabolites were measured using FI-HG-AAS against arsenic as the standard. Experiments were also carried out with known amounts of arsenite, arsenate, monomethyl arsinic acid (MMAA) and dimethyl arsinic acid (DMAA) under identical condition with cysteine and without cysteine to find out the hydride generation efficiency of the individual species and by spiking these species in urine to know the recovery.

A detailed procedure for determination of arsenic in water, hair, nails and urine has been described elsewhere[1,3,4,6,7].

Results and discussion

During the period September 1996 to June 1997, we had surveyed Samta village four times at different intervals. At the time of our water collection in Samta village,

there were, in all, 279 available tubewells which the villagers were using for drinking and cooking, and out of these we could analyse only 265 tubewells, as the other 14 tubewells were defunct. In Samta village, almost 100% of the population were drinking shallow tube-well water (usual depth 15–46 m). Only very recently during July–August 1997, 3 deep tubewells (213 m) were sunk in Samta. Table 1 shows the total number of tubewells, number of tubewells analysed, the population drinking tubewell water and the distribution of tubewells with different arsenic concentration range at different areas of the village. Table 1 also shows that only 5 tubewells at Purbapara of Samta village were safe to drink according to the WHO recommended value in drinking water (0.01 mg/l), and 17 tube-wells had arsenic betwen 0.01 and 0.05 mg/l. All the tubewells in Uttarpara (except one), Dakshinpara and Paschimpara contained arsenic above 0.05 mg/l, but Dakshinpara and Paschimpara were the most affected. Figure 2 shows the groundwater arsenic contamination map of Samta village. The light green region in the map (northern and southern) shows rice fields. The groundwater arsenic concentration is divided into seven levels from red circle to green colour. The red circle indicates the arsenic concentration above 0.7 mg/l and green circle indicates arsenic concentration below 0.01 mg/l. Water analysis for arsenic was done by FI-HG-AAS. To compare the reliability of the results, 10% of water above 0.05 mg/l was analysed by our modified spectrophotometric method as well, using Ag-DDTC-$CHCl_3$ with hexamethylenetetramine[13]. A standard Reference (Quality Control Sample for Trace Metals Analysis, US Environmental Protection Agency) in acidified solution was also analysed for arsenic (received from Water Technology Division, National Environmental Engineering Research Institute, Nagpur). The results showed good agreement. Analysis of arsenic from 282 tubewells from the same village was also carried out by Asia Arsenic Network-Japan[14] by using field kit[14] and it was found that 96.5% of the tubewells were not suitable for drinking according to the WHO recommended value.

A comparative study of groundwater arsenic of Samta village with 3 other villages, two from Bangladesh (Rajarampur village of district Nawabganj and village Shibpur of district Laxmipur) and one from West Bengal (Uttar Kolsur village from Deganga block of North 24-Parganas) where we have analysed all the tubewells of the villages, is presented in Figure 3. The comparative study shows that Samta is not an exception. In the other 3 villages, higher concentration of arsenic in well water was more abundant (Figure 3) and in Shibpur village not a single tubewell was safe to drink.

Arsenic in urine from 301 persons of Samta village was measured for total inorganic arsenic and its metabolites (sum of arsenite, arsenate, MMAA and DMAA). It was found that in our experimental condition

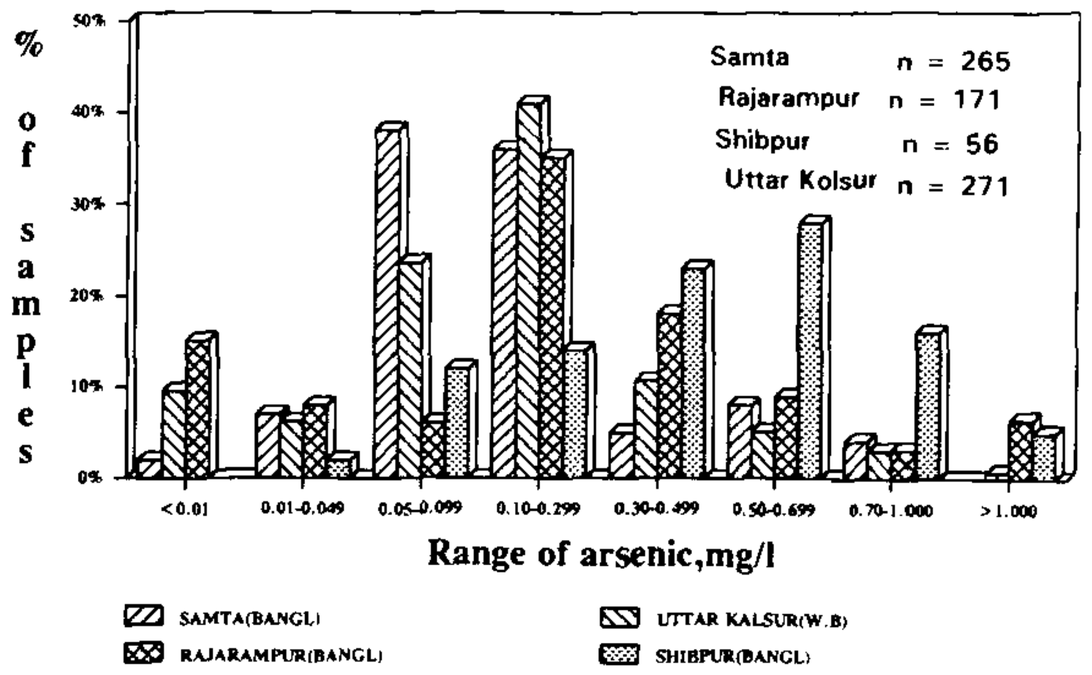


Figure 3. Comparative study of arsenic concentration in groundwater in Samta village, Rajarampur village, Shibpur village of Bangladesh and village Uttar Kolsur of West Bengal.

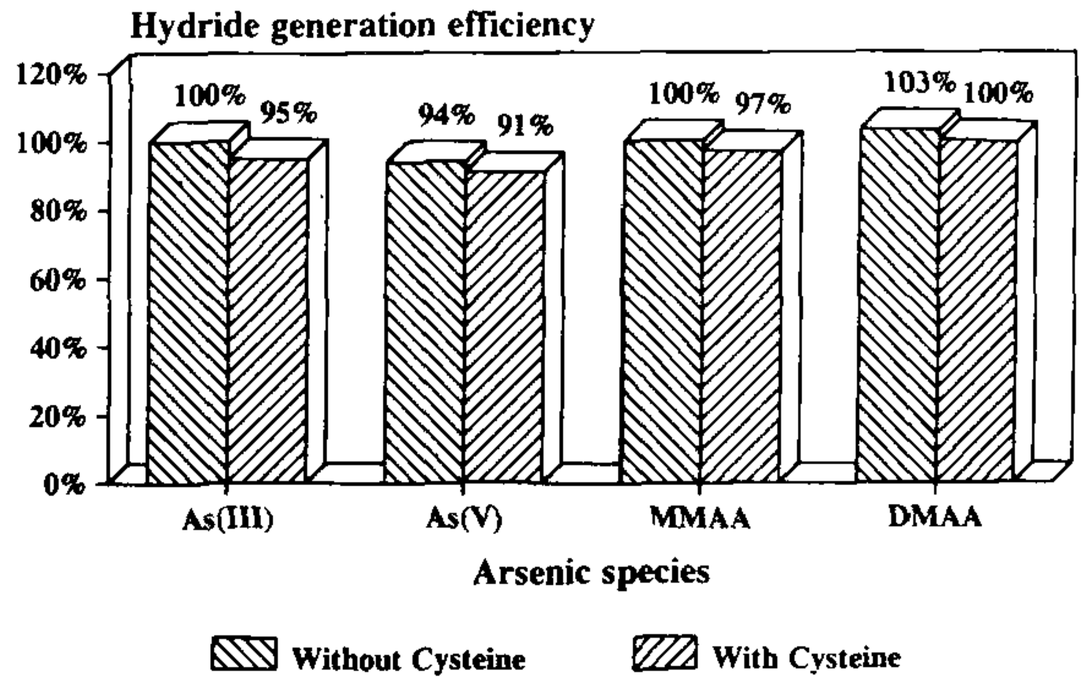


Figure 4. Hydride generation efficiency of different arsenic species in presence of cysteine and without cysteine.

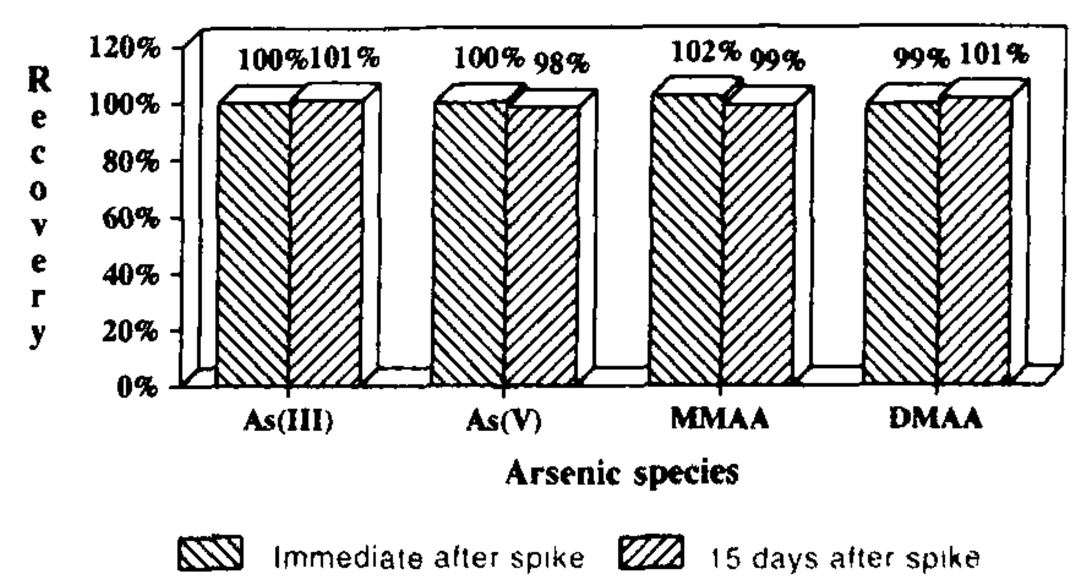


Figure 5. Recovery of arsenic species immediately after spiking and 15 days after spiking.

of FI-HG-AAS, arsenobetaine and arsenocholine do not produce any signal[3]. Some other workers have also reported the same fact using hydride generation technique[15-17]. Some researchers have reported that in

hydride generation AAS system, the species arsenite, arsenate, MMAA and DMAA show different response although they have the same concentration of arsenic[18,19]. To get rid of this discrepancy, cysteine was used as a modifier[15]. However, some workers have also reported no anomaly in sensitivity in determination of these four arsenic species by hydride generation AAS[20]. We have determined individual species – arsenite, arsenate, MMAA and DMAA, both with and without cysteine by our FI-HG-AAS system. Figure 4 presents the results obtained against arsenite standard. As with or without cysteine the deviation of results is within acceptable limit, we have not used cysteine during inorganic arsenic metabolite determination in urine. To know the exact arsenic concentration in each species, we digested arsenite, arsenate, MMAA and DMAA with HNO_3/H_2SO_4 mixture[4]. Arsenite was prepared from arsenic trioxide and before and after digestion it gave almost the same recovery. However, sodium arsenate, MMAA and DMAA showed some deviation. The standard solutions of arsenate, MMAA and DMAA were prepared considering the concentration measured after digestion. After collection of urine it was kept in icebox with salt–ice mixture. The usual time gap between urine collection and measurement for metabolites was about a few hours to 15 days. To know whether there was any loss during this period we spiked each species of arsenic in urine and kept them in the same condition as the urine samples before measurement. The recovery was measured against the urine blank (Figure 5). The results showed no significant deviation.

During our survey we collected 301 urine samples, 293 hair and 228 nail samples from the four paras of Samta village. Table 2 shows the number of urine samples from each area and their distribution with the range of urinary arsenic concentration. Water analysis showed that water of Dakshinpara and Paschimpara of Samta was highly contaminated compared to that from the other areas. Therefore we collected more biological samples from these two highly contaminated areas than the other two. Only at Purbapara, arsenic concentration in two urine samples out of 24, i.e. about 8% was within the normal range[21,22] and in the other three areas, all the urine samples contained arsenic above the normal range. On the whole, in Samta village, about 99% urine samples contained arsenic above the normal range. The reason is that in this village, 91% of the tubewells contained arsenic above 0.05 mg/l. The villagers are thus living in an arsenic environment and it is difficult to get rid of arsenic contamination.

If we plot the urinary arsenic concentration data on the map (Figure 6) of Samta village, we get a fairly superimposable map with arsenic in water (Figure 2). In the map (Figure 6) the green circles indicate urinary arsenic below the normal range (<30 µg/l) and the red circle indicates above 2000 µg/l arsenic. At Purbapara and Uttarpara of Samta village, the urinary arsenic concentrations are at a lower range (Table 2) and the same observation was also noticed for water samples (Figure 2 and Table 1). Again, higher concentrations of arsenic in water were found at Dakshinpara and Paschimpara of Samta where urinary arse-

Table 2. Distribution of urine samples against the range of arsenic metabolites of the studied group in four areas of Samta village

Zone (Para)	Total no. of urine samples analysed	No. of urine samples within the arsenic range (µg/l)								
		<30	30–60	61–150	151–300	301–800	801–1000	1001–1500	1501–2000	2000>
East (Purbapara)	24	2	2	9	8	3	–	–	–	–
North (Uttarpara)	19	–	2	7	9	1	–	–	–	–
South (Dakshinpara)	87	–	–	5	17	40	3	6	11	5
West (Paschimpara)	171	–	2	24	66	62	5	4	7	1
Total	301	2	6	45	100	106	8	10	18	6

Table 3. Distribution of hair samples against arsenic concentration range of the four studied areas of Samta village

Zone (Para)	Total no. of hair samples analysed	No. of hair samples with different arsenic concentration range (mg/kg)						
		0.08–0.25	0.26–1.00	1.01–2.00	2.01–3.00	3.01–4.00	4.01–5.00	>5.00
East (Purbapara)	29	5	7	11	5	1	–	–
North (Uttarpara)	18	–	5	9	4	–	–	–
South (Dakshinpara)	99	4	13	42	24	8	8	–
West (Paschimpara)	147	4	27	46	30	22	14	4
Total	293	13	52	108	63	31	22	4

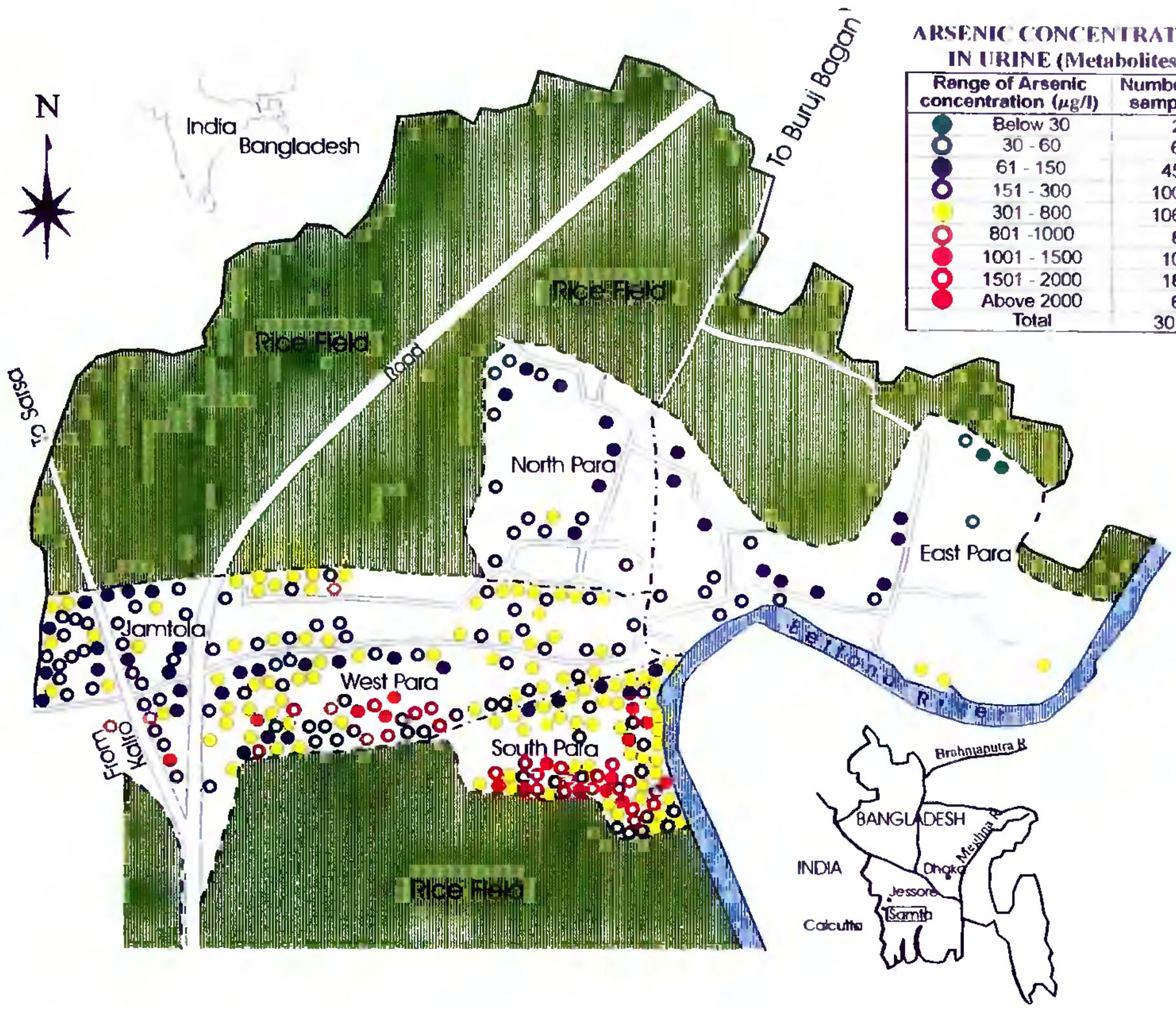


Figure 6. Map of Samta village showing the range of urinary arsenic.

nic concentrations were also high. The superimposition of these two maps (Figures 2 and 6) indicates the correlation between arsenic in urine and arsenic in water. Regression analysis was carried out to find out the correlation between arsenic in water and arsenic in urine (Figure 7). Figure 7 shows the linear regression among the average urinary arsenic with arsenic concentration in water and there is high correlation ($r^2 = 0.89$, $P < 0.0001$). During regression analysis, 36 data were discarded because PHED-Bangladesh installed three tubewells within the depth of 54 m to 60 m two months before our sampling and the arsenic concentration of these tubewells was 0.108, 0.103 and 0.08 mg/l. Urinary arsenic concentration is reflected by ingestion of arsenic-contaminated water. People who are drinking water with arsenic levels of 0.08 mg/l should not normally show elevated urinary arsenic. But urine analysis showed a few with elevated arsenic concentration in their urine. This indicates that the people sometimes drank water from the old highly-contaminated tubewells. So, for the regression analysis the data was collected from the people who had not changed their source of water.

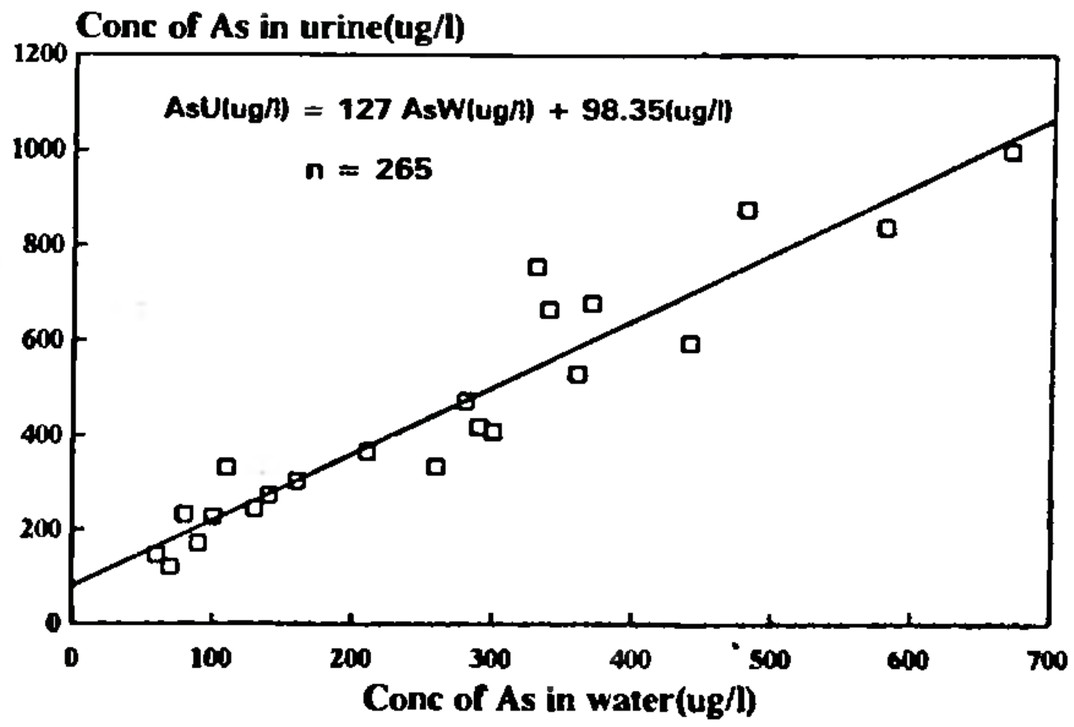


Figure 7. Correlation between inorganic arsenic and its metabolites in urine and arsenic in water.

The urinary arsenic concentration of the people of Samta was compared (Figure 8) with 2 other villages (Shibpur and Uttar Kolsur) where we had analysed all tubewells. From Figure 8 it appears that in Shibpur not a single urine sample is within the normal range. The obvious reason is that not a single tubewell is safe to drink

Table 4. Distribution of nail samples against arsenic concentration range of the four studied areas of Samta village

Zone (Para)	Total no. of nail samples analysed	No. of nail samples with different arsenic concentration range (mg/kg)						
		≤ 1.08	1.09–3.00	3.01–5.00	5.00–8.00	8.01–10.00	10.01–13.00	>13.00
East (Purbapara)	23	2	9	8	3	1	–	–
North (Uttarpara)	18	1	9	7	1	–	–	–
South (Dakshinpara)	79	3	8	15	23	14	8	8
West (Paschimpara)	116	3	14	23	27	14	13	22
Total	236	9	40	53	54	29	21	30

Table 5. Statistical presentation of urinary arsenic concentration (µg/l) among different groups in Samta village

	Adults having arsenical symptoms	Adults having no arsenical symptoms	Children having arsenical symptoms	Children having no arsenical symptoms
No. of valid observations	92	108	24	76
Mean (µg/l)	542	402	764	446
Minimum (µg/l)	47	37	110	24
Maximum (µg/l)	2285	1932	3085	2237
Standard deviation	481	419	794	471
% of samples having arsenic above normal level*	99	98	100	94

*Normal arsenic level in urine.
(i) <120 µg/24 hours collection (inorganic arsenic <25 µg/24 hours (ref. 21).
(ii) 5–40 µg 1.5 l^{-1} (ref. 22).

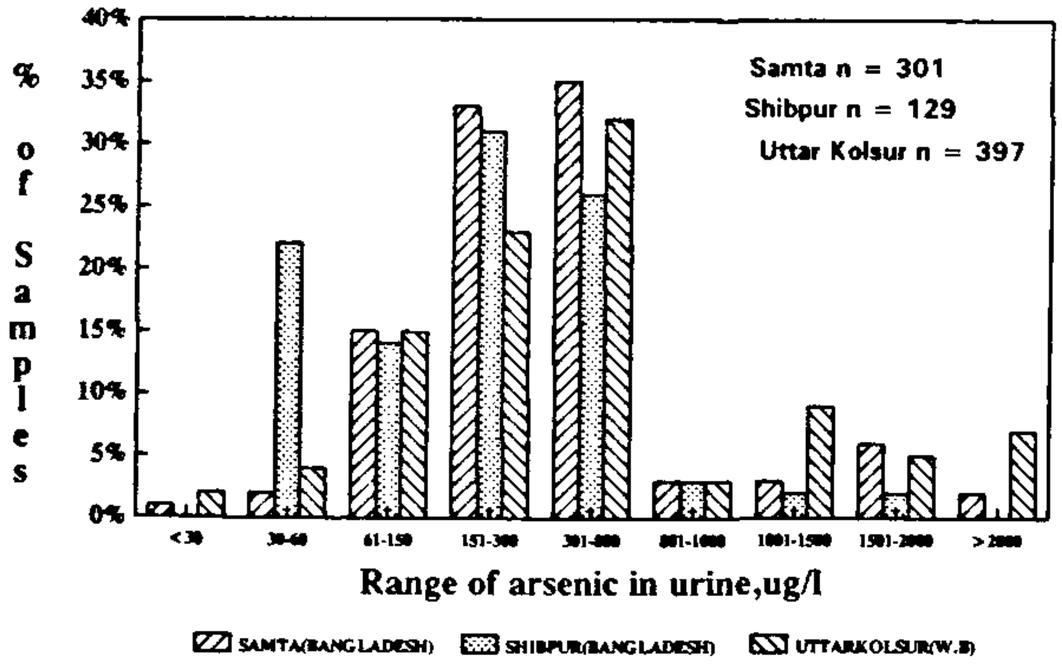


Figure 8. Comparative study of arsenic concentration in urine samples in Samta village, Shibpur village of Bangladesh and Uttar Kolsur of West Bengal.

according to WHO value. The water of Shibpur and Uttar Kolsur contained more arsenic than Samta, but Figure 8 shows that urinary arsenic of Shibpur does not show very high value. The reason is that urine samples were from those who were drinking low-arsenic-contaminated water.

Deposition and release of arsenic in hair and nails are a slow process, so, change of water for a short period is not reflected immediately on the arsenic concentration in hair and nail[10] but reflects on urinary arsenic[10]. The maximum samples of hair and nail were collected from Paschimpara and Dakshinpara of Samta village. The percentage distribution of hair and nail samples against arsenic concentration range is shown in Tables 3 and 4 respectively. Tables 3 and 4 indicate that at Purbapara only 5 hair samples out of 29 samples (≃ 17%) and 2 nail samples out of 23 samples (≃ 9%) were within the normal range[23,24] and 58% hair samples indicated arsenic toxicity[23]. At Uttarpara 72%, Dakshinpara about 83% and at Paschimpara about 79% hair samples contained arsenic above toxic levels. Similarly, for nail samples, at Purbapara about 91%, at Uttarpara 94%, at Dakshinpara 95% and at Paschimpara 97% contained arsenic above normal value[24]. Thus out of all hair and nail samples we analysed from Samta village, 78% hair samples were above toxic level and 98% nail samples contained arsenic above normal levels. Regression analysis was carried out among the arsenic concentration in hair, nail and arsenic in water. The linear regression shows (Figure 9 and 10) good correlation between arsenic in water and hair ($r^2 = 0.91$, $P < 0.0001$) and nail ($r^2 = 0.94$; $P < 0.0001$).

To compare the arsenic burden on the body of the people of Samta village, we collected hair, nails and urine from four groups of people:

i) adults with arsenical skin lesions ($n = 99$);
ii) adults without arsenical skin lesions ($n = 120$);
iii) children without arsenical skin lesions ($n = 88$);
iv) children with arsenical skin lesions ($n = 27$).

Table 5 presents the urinary arsenic concentration of these four groups. The mean urinary arsenic concentra-

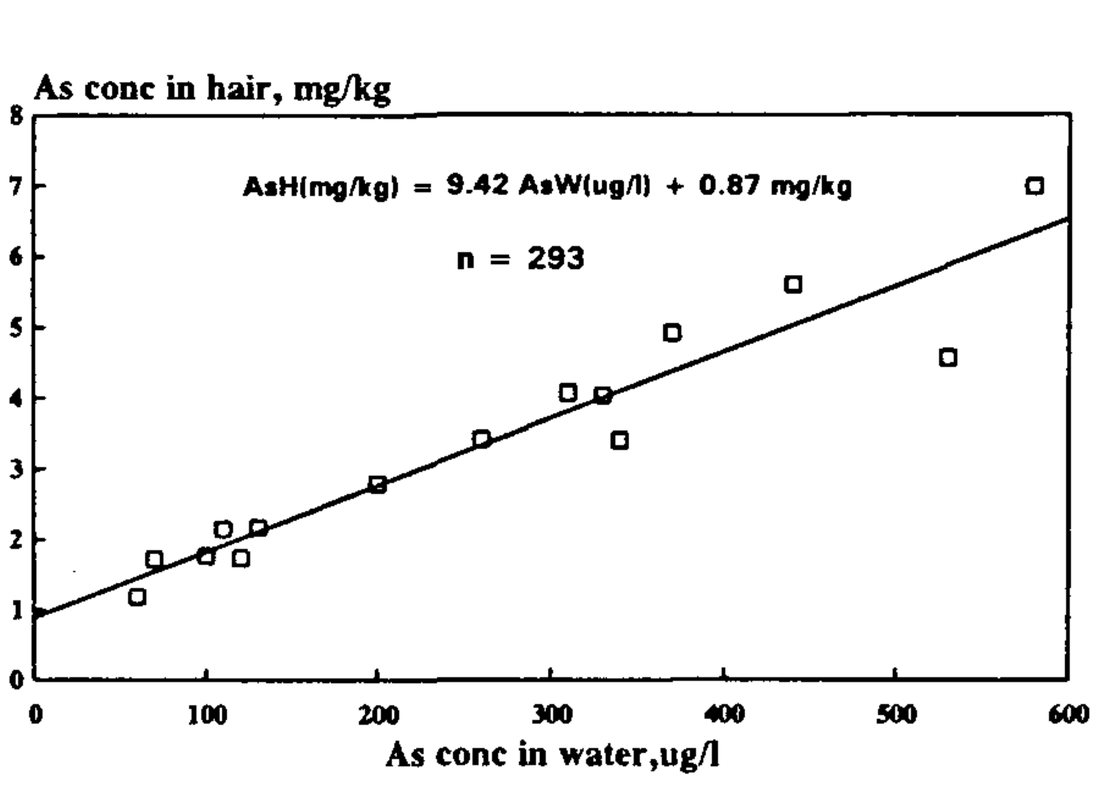
Table 6. Statistical presentation of arsenic in hair and nail (mg/kg) among different groups in Samta village

	Adults having arsenical symptoms		Adults having no arsenical symptoms		Children having arsenical symptoms		Children having no arsenical symptoms	
	Hair	Nail	Hair	Nail	Hair	Nail	Hair	Nail
No. of valid observations	91	72	108	93	20	19	62	58
Mean (mg/kg)	3.40	9.86	1.93	5.38	2.20	8.30	1.78	6.32
Minimum (mg/kg)	0.62	1.7	0.46	0.61	0.63	2.72	0.68	0.26
Maximum (mg/kg)	9.48	29.6	5.11	18.82	4.88	16.66	6.75	21.77
Standard deviation	1.90	5.50	1.10	3.70	1.00	3.50	1.20	4.60
% of samples having arsenic above toxic/normal level*	95	100	84	82	90	100	77	96

* (i) Normal range of arsenic in hair is about 0.08 to 0.25 mg/kg and 1.0 mg/kg indicates toxicity[23].
(ii) Normal arsenic content of nails 0.43–1.08 mg/kg (ref. 24).

Table 7. Percentage of people in each area drinking arsenic contaminated water above 0.25 mg/l in Samta village

Name of the para at Samta village	Total population	No. of tubewells used for drinking	No. of tubewells having arsenic above 0.25 mg/l	No. of people exposed to arsenic above 0.25 mg/l	
				Total	% of people
East (Purbapara)	930	59	3	48	5
North (Uttarpara)	784	60	2	25	3
South (Dakshinpara)	772	50	19	293	37
West (Paschimpara)	2355	96	29	711	30
Samta village	4841	265	53	1077	22 (approx)



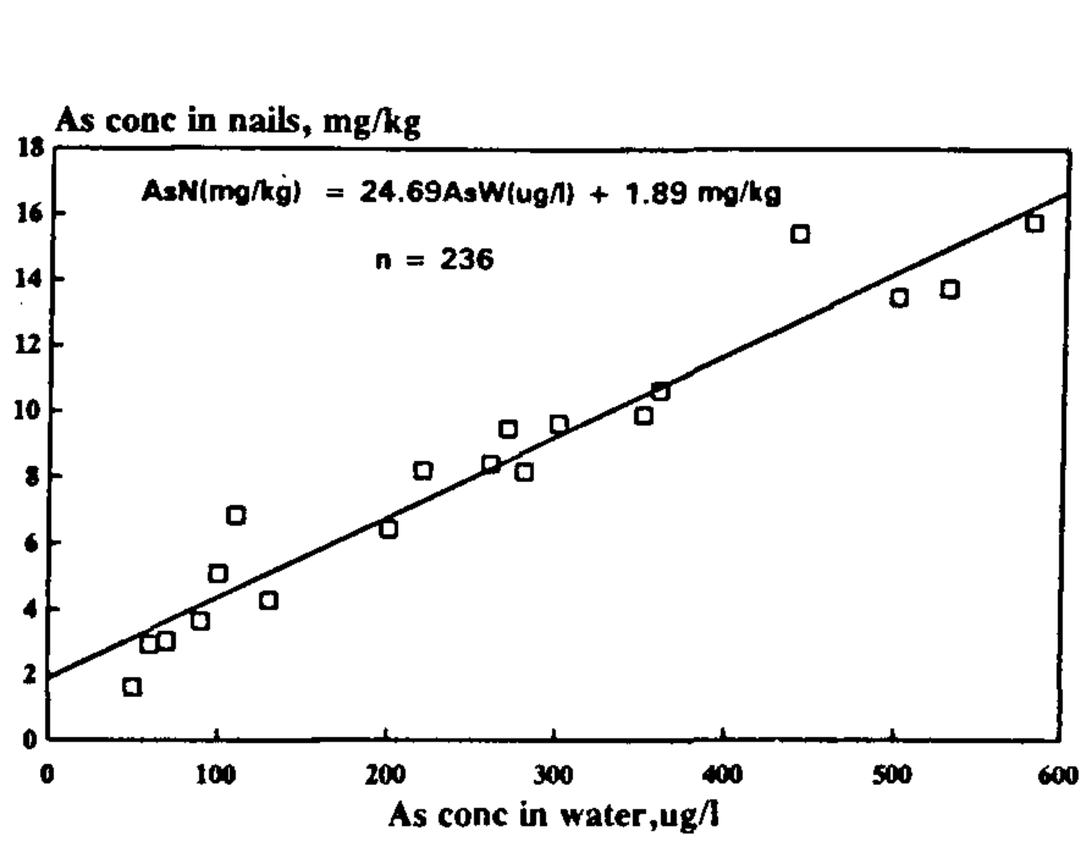


Figure 9. Correlation between arsenic in hair and arsenic in water.

Figure 10. Correlation between arsenic in nail and arsenic in water.

tion of the adults having arsenical lesions is about 1.4 time higher than the adults having no arsenical lesions and 27 times higher than the control population[1]. If we compare the data with children, the results show that children with arsenical symptoms have the maximum urinary arsenic (μg/l) than the other groups. The mean urinary arsenic concentration of children having arsenical lesions is 764 μg/l which is about 1.2 time higher than the adults having arsenical symptoms and about 1.7 time higher than the children having no symptoms but living in arsenic-affected areas.

The arsenic content in hair and nail of the different groups is given in Table 6. The nail arsenic concentration is higher than hair arsenic concentration in all the groups. It is interesting to note that mean arsenic concentration in hair and nail of the adults having arsenical lesions was higher than the children with arsenicosis. But for urinary arsenic, children were excreting more arsenic (in μg/l) than the adults (μg/l). The mean arsenic concentrations were in hair and nail of adults patients

about 8 times and about 12 times higher than the control population respectively[1]. The body burden of different groups can easily be understood from Table 6. About 84% adults who showed no symptoms had arsenic in hair above the toxic level, and 82% had arsenic in nail above normal level. Similarly 77% children showing no symptoms had arsenic in hair above the toxic level and, for nail, 96% showed an above normal level. For affected children and adults, 90 to 100% people had arsenic in their hair and nails above the toxic level and normal level respectively.

It is reported that symptomatology or arsenical toxicity may develop insidiously after six months to three years or more depending on the amount of arsenic intake[25]. The nutrition status also plays an important role in arsenic toxicity. The literature study[26,27] shows that both vitamin C and methionine reduce the toxicity of arsenic. Our survey in the affected disricts indicates that undernourished people are the worst affected[1,4,6,8]. According to Guha Mazumder[28], pigmentation was found in 13 cases and thickening of palm and sole in 4 cases out of 3235 persons drinking water having arsenic level between 0.01 and 0.05 mg/l. In Samta village 91% tubewells had arsenic concentration above 0.05 mg/l. Consequently, more people may show arsenical symptoms. According to Chakraborti and Saha[29], the lowest arsenic concentration in water producing dermatosis (diffuse and palmoplanter melanosis and keratosis) was found to be 0.2 mg/l. However, the total quantity of arsenic consumed per day and the duration of exposure are important factors[29–31]. Chen and Wu[32] in Taiwan reported high incidence of hyperkeratosis and skin cancer after consumption of water containing more than 0.3 mg/l arsenic. Tseng *et al.*[33] also observed association of skin cancer with drinking well water containing 0.5 mg/l arsenic. It is reported[31] that approximately 1 mg of arsenic per day may give rise to skin effects within a few years of exposure. In Samta village most of the people were farmers and they drank 3–5 litres water per day. Considering, on an average, if 4 l of water is consumed per day, the people who are drinking water with 0.25 mg/l of arsenic will be ingesting 1.0 mg of arsenic per day and within few years may show skin lesions. This arsenic concentration (0.25 mg/l) is close to Chakraborti and Saha's observation.

Table 7 shows the number of people exposed above 0.25 mg/l at each area of Samta village. On this basis, about 22% people of Samta village may show arsenical skin lesions (Table 7). According to a WHO task group estimation, the risk assessment for skin cancer from the ingestion of inorganic arsenic may be calculated from the linear non-threshold model[31]. The slope of the resultant linear extrapolation is about 5% skin carcinoma prevalence per 10 g of total ingested arsenic[31]. From Table 1 it can be observed that at Uttapara of Samta village only one tubewell and at Dakshinpara and

Table 8. Arsenic in hair, nail, urine and dermatological features of six patients of Samta village, Jessore, Bangladesh

Patient no.	Sex and age	Hair (mg/kg)	Nail (mg/kg)	Urine (µg/l)	Melanosis: Trunk Spotted	Melanosis: Trunk Diffuse	Melanosis: Leuco	Melanosis: Whole body	Keratosis: Palm Spotted	Keratosis: Palm Diffuse	Keratosis: Sole Spotted	Keratosis: Sole Diffuse	Keratosis: Dorsum	Non pitting Oedema
P-1	F, 22	3.02	13.97	571	±	+	+	±	±	+	±	±	+	±
P-2	M, 40	1.59	3.68	195	–	++	+	+	–	–	–	–	–	–
P-3	F, 25	1.57	5.61	97	–	+++	±	±	–	±	±	+	±	±
P-4	F, 15	2.03	9.25	337	–	+	+	+	–	+	+	++	+	±
P-5	M, 35	3.14	7.58	1904	–	+	+	+	–	+	+	++	±	±
P-6	M, 55	3.00	6.66	1244	–	+	+	+	–	+	+	++	±	±

± = mild, ++ = moderate, +++ = severe.

Figure 11. Diffuse and spotted keratosis on sole and palm, Vill: Samta (Paschimpara), P. S.: Sarsa, Dist: Jessore, Bangladesh.

Figure 12. Amputated finger of left leg due to gangrene, Vill: Samta (Dakshinpara), P.S.: Sarsa, Dist: Jessore, Bangladesh.

Paschimpara 13 tubewells contained arsenic above 0.6 mg/l. Our survey showed that in Dakshinpara and Paschimpara of Samta, there were 6 tubewells which were being used for the last 9 to 20 years by about 181 people. From calculations it is found that these people might have ingested more than 10 g of arsenic within this period. On the basis of linear non-threshold model, 5% of the people who have ingested more than 10 g of arsenic may show skin carcinoma. However, during our preliminary field survey at Samta village we could not identify any carcinoma patients but it is reported[34] that 16 people with severe arsenical skin lesion died at Samta village. Since there is no available medical report, it is not known whether they had carcinoma or not. During our field survey, out of 330 arsenical patients, we identified four gangrene patients. Table 8 shows the dermatological manifestations, arsenic in hair, nails, urine and of some patients of Samta village with photographs of 2 patients (Figures 11 and 12). In our field survey at Samta village to identify arsenic patients having dermatological symptoms, we identified 10 arsenic patients out of 27 people at Uttarpara, 19 patients out of 57 at Dakshinpara and 301 patients identified out of 493 at Paschimpara. We could not identify any arsenic patients at Purbapara (23 people clinically examined). Although out of 600 people we had examined in 4 areas of Samta village, 330 poeple had arsenical skin lesions (55%), such a high percentage is not the picture of the entire Samta village. In our study we had mainly examined people from Paschimpara, which is the most arsenic-affected area with a high prevalence of arsenic in ground-water. However, the true picture will emerge after a door-to-door survey.

The symptoms of arsenic poisoning that we observed among patients in the arsenic-affected areas of Bangladesh and West Bengal were diffused melanosis, spotted melanosis, diffused keratosis, spotted keratosis, hyper keratosis, nonpitting oedema, Bowen's disease, gangrene, skin carcinoma, etc. The most common symptoms of arsenic patients in Bangladesh and West Bengal were bronchial problem and burning sensation. We have information about a few cases from West Bengal where some arsenic patients died while some are suffering from internal cancers, i.e. lung, bladder, liver, renal cancer. The reason for such small data is due to the fact that no study has been done on internal cancer. Although from West Bengal we have a list of a few hundred with severe skin lesions who died in arsenic-affected villages, due to the nonavailability of proper death certificates we do not know the exact cause of the deaths. The most abundant symptoms in arsenic patients are melanosis and keratosis. In our field survey in Samta village we noticed Dakshinpara and Paschimpara were more arsenic contaminated than Purbapara and Uttarapara. So we tried to find a correlation between the prevalence rate and arsenic concentration in drinking water. As melanosis was the most common symptom among the arsenic victims, the prevalence rate of melanosis with respect to arsenic exposure is shown in Figure 13. The prevalence rate is as high as 80–90% when the water

Table 9. Dermatological symptoms of different age groups drinking same arsenic-contaminated water (0.94 mg/l)

	Melanosis						Keratosis			
	Palm		Trunk				Palm		Sole	
Age	Spotted	Diffuse	Spotted	Diffuse	Leuco	Whole body	Spotted	Diffuse	Spotted	Diffuse
5	–	+	+	–	–	–	–	–	–	–
7	–	+	+	–	–	–	–	–	+	–
9	–	+	+	–	–	–	+	–	–	–
11	–	+	+	+	–	–	+	+	+	+
20	–	+	+	+	+	+	+	+	+	–
25	–	+	++	–	+	+	+	+	++	+
26	–	+	++	+	+	+	++	++	++	++
32	–	+	++	+	+	+	++	+	++	+
35	–	+	+++	+	–	++	+++	++	+	++

+ = mild, ++ = moderate, +++ = severe.

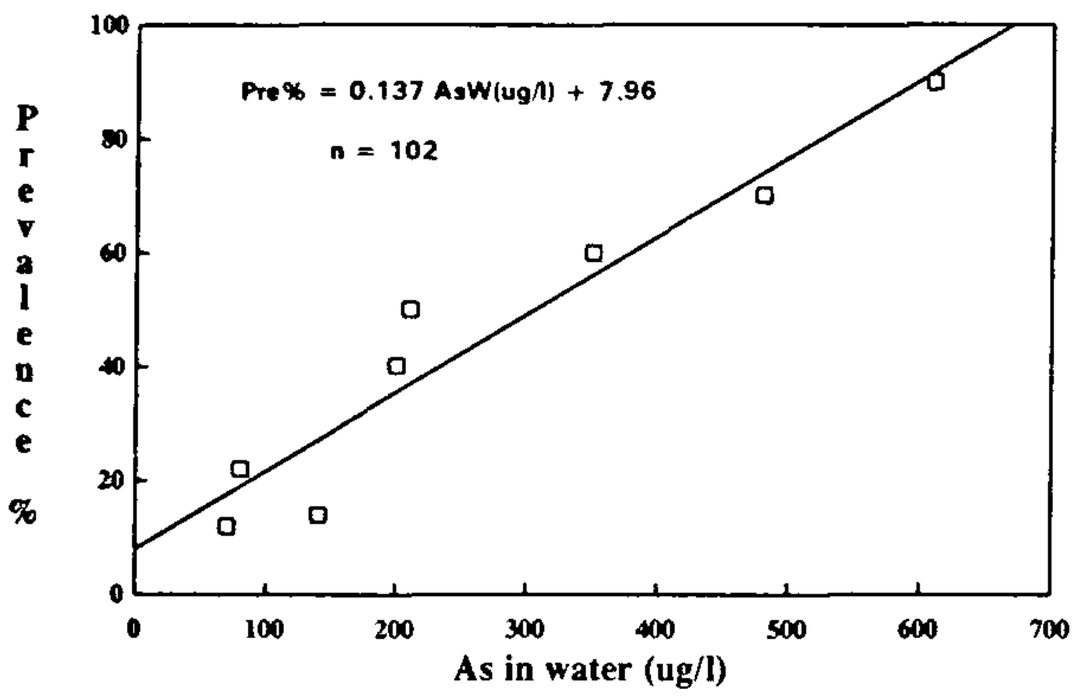


Figure 13. Correlation between prevalence percentage and arsenic concentration in water.

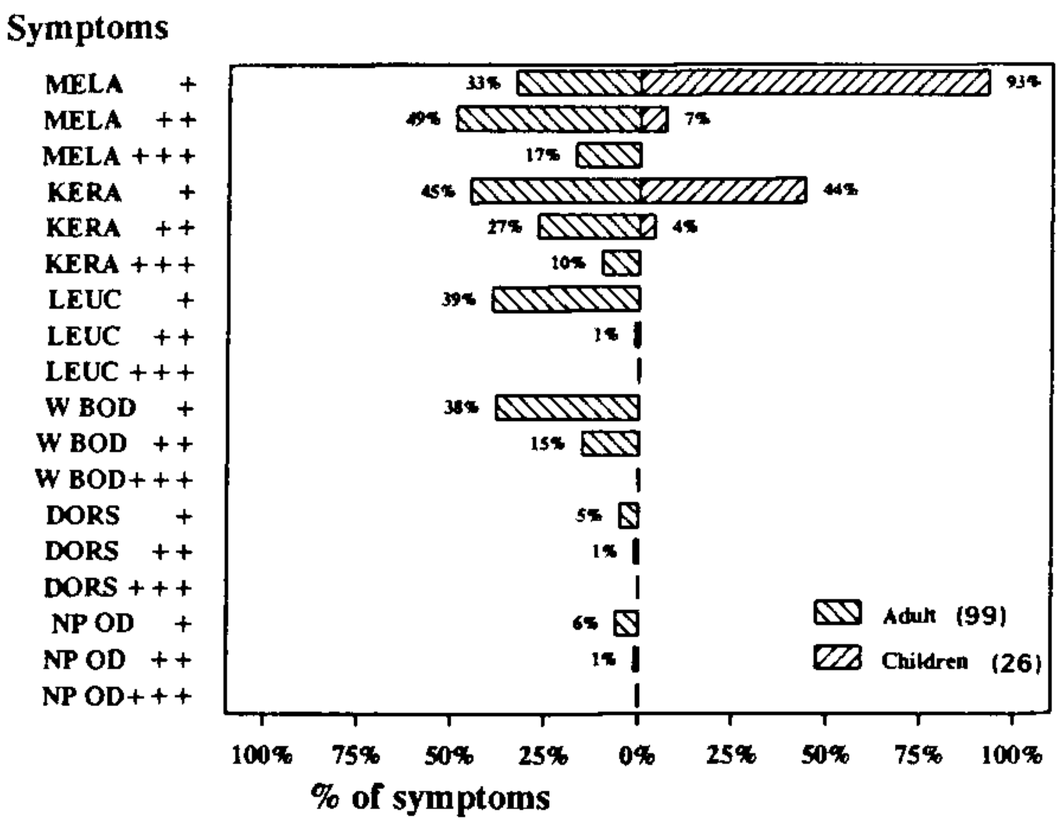


Figure 14. Comparative study of dermatological symptoms between the affected children and adults of Samta village. MELA, Melanosis; KERA, Keratosis; LEUC, Leuco melanosis; W BOD, Whole Body Melanosis; DORS, Dorsum; NP OD, Non-petting oedema; + = mild; ++ = moderate; +++ = severe.

arsenic concentration reaches 0.60 mg/l. It should be noted that duration of exposure and nutrition status are some of the important factors for the development of arsenical skin lesions. While surveying in Paschimpara, we identified two groups drinking the same water for a period of about 4 and 6 years. People drinking for 6 years had more prevalence of skin lesions than 4 years. During our last 10 years of field survey in arsenic-affected areas of West Bengal, we have observed that children up to age group of about 12 years show less arsenical skin lesions than adults. The same trend is observed in Samta village. A comparison of dermatological symptoms of the affected adults and affected children is presented in Figure 14. The above observation is further noticed in a group where all the nine members of that group from age group 5 to 35 years were drinking tube-well water having arsenic concentration 0.94 mg/l. Table 9 shows the dermatological symptoms. It appears from Table 9 that older people have more skin lesions than the younger ones. This family consumed the tubewell water for 4 years. Although children are showing less arsenical skin lesions than the adults, they are more susceptible to arsenic toxicity[35].

Conclusion

The overall study in Samta village leads to the following observations. (i) Although people may not show the arsenical skin lesions, they may be sub-clinically affected. In Samta village, 99% of the urine samples, 98% of nail samples of studied population contained arsenic above normal levels. In this village, 78% of the hair samples of the studied population contained arsenic above the toxic level. (ii) We could establish a positive correlation between concentration of arsenic in water and arsenic in

hair, nail and urine. (iii) Arsenic-affected adults showed higher arsenic concentration in hair, nails than affected children. However, the excretion of arsenic in urine (μg/l) of children was higher than adults. Children also showed less arsenical skin manifestation than adults. (iv) Nutrition plays an important role in arsenic toxicity. People of Samta village are poor and more affected than the villagers living in better condition in Shibpur (district Laxmipur), Rajarampur (district Nawabganj) even though the people of Shibpur and Rajarampur villages are consuming high arsenic-contaminated water. We have observed the same trend in many arsenic-affected villages in West Bengal. (v) The most common arsenical symptom of the people drinking contaminated water is melanosis and prevalence rate increases with increasing arsenic in drinking water. In Samta village, the prevalence rate is as high as 80–90% when the arsenic concentration increases to 0.60 mg/l.

From the findings at Samta village, it is felt that there is an urgent need to survey the 41 arsenic-affected districts to know the magnitude of the calamity.

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