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Groundwater Arsenic Contamination and Human Suffering in West Bengal, India and Bangladesh

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Groundwater arsenic contamination and human suffering are increasing in West Bengal, India and Bangladesh. Out of a total of 188 million people in West Bengal and Bangladesh, 136 million people live in arsenic-affected districts where groundwater contains arsenic levels above 50 μg/L. This does not mean everyone living in contaminated areas is drinking contaminated water, but no doubt all are at risk. From our 99,153 water samples analyzed from West Bengal and 34,000 from Bangladesh by FI-HG-AAS, we estimated that around 6 million people in West Bengal and 25 million people in Bangladesh are at present drinking water contaminated with arsenic at levels above 50 μg/L. To date from arsenic-affected villages we have screened 103,896 villagers and diagnosed 12,195 people with arsenical skin lesions. We have analyzed around 35,000 biological samples collected from the affected villages and found on average 90% of the samples contained elevated levels of arsenic. Thus it is expected many more are subclinically affected. In arsenic-affected areas tons of arsenic is falling on agricultural land irrigated using water from arsenic-contaminated tubewells for its cultivation. Our preliminary study showed the presence of elevated levels of inorganic arsenic in rice and vegetables, the staple food for villagers. During our 14-year field survey we have noticed that poor people with poor nutrition are suffering more. A socio-economic study in the affected villages indicated that villagers are living in very poor conditions. Arsenic-affected people are also facing serious social problems. To combat the arsenic crisis in West Bengal and Bangladesh we desperately need to increase awareness and educate our

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people about the problem and involve the community in all developmental work. Finally, we must use our vast surface water resources, rainwater and traditional water treatment techniques to provide safe water.

1. Introduction

Out of 20 countries in different parts of the world where groundwater arsenic contamination and human suffering have been reported so far, the magnitude is considered highest in Bangladesh followed by West Bengal.[1–6]

In 1989 we started a survey for arsenic-affected villages in West Bengal. At that time, information on 22 affected villages in 12 police stations/blocks of 5 districts was available. Current statistics from our 14-year survey show that there are 2600 arsenic-affected villages in 74 police stations of 9 arsenic-affected districts. We began our work in Bangladesh in 1995. At that time there was information on three affected villages in two police stations of two districts. Our current survey report of arsenic-affected villages includes 2000 villages in 178 police stations of 47 districts. Even after a 14-year survey in West Bengal and a 7-year survey in Bangladesh, we feel we have seen only the tip of the iceberg of this calamity. In a report,[7] the World Bank and World Health Organization (WHO) described the magnitude of the arsenic contamination in Bangladesh: the local head of the World Bank stated that tens of millions of people are at risk for health problems and that 43,000 out of 68,000 villages in Bangladesh are presently at risk or could be at risk in the future. In the same report,[7] the WHO predicted that within a few years, death across much of southern Bangladesh (1 in 10 adults) could be from cancers triggered by arsenic intake. Therefore, we immediately need to know the actual magnitude of the groundwater arsenic contamination in West Bengal and Bangladesh. From our 99,153 water analyses from West Bengal and 34,000 from Bangladesh, we calculated that at least 6 million people of West Bengal and 25 million people of Bangladesh are drinking arsenic-contaminated tubewell water which exceeds the WHO maximum permissible limit of 50 μg/L. More than 100 million people are at risk of arsenic contamination in West Bengal and Bangladesh. The physical parameters and the arsenic-affected areas of West Bengal and Bangladesh are shown in Table 1.

Arsenic-contaminated hand tubewells are not only used by the villagers for drinking and cooking but also for agricultural irrigation. Our pilot study shows[8] that in a 201 km^2 area of the Deganga block in the arsenic-affected district of North 24-Parganas, West Bengal, 6.4 tons of arsenic is falling on the soil as a result of using water from 3,200 contaminated tubewells for agricultural irrigation. We expect tons of arsenic is coming with underground water in the arsenic-affected areas of West Bengal and Bangladesh and falling on irrigated land. Thus it is expected arsenic is entering the food chain.

From our last 14 years and 7 years of field experience in arsenic-affected areas of West Bengal and Bangladesh, respectively, we noticed that most sufferers belong to the rural community and are poor people. A socio-economic study in arsenic-affected villages may explain whether a relationship exists between human suffering from arsenic toxicity and poor socio-economic conditions. We have also observed that those suffering from arsenical skin lesions also face serious social problems.

This paper reports: (1) the present status of the arsenic situation in West Bengal and

Table 1
Physical parameters and arsenic-affected areas of West Bengal and Bangladesh.

Physical parameters	West Bengal	Bangladesh
Area in sq. km	89,193	148,393
Population in million	68	120
Total number of districts	18	64
Number of arsenic-affected districts (groundwater arsenic above 10 μg/L)	9	54
Number of arsenic-affected districts (groundwater arsenic above 50 μg/L)	9	47
Area of arsenic-affected districts in sq. km	38,865	112,407
Population of arsenic-affected districts in millions	42.7	93.4
Total number of hand tubewell water samples analyzed	99,153	34,000
% of samples having arsenic >10 μg/L	53	56
% of samples having arsenic > 50 μg/L	25.5	37
Number of arsenic-affected blocks/police stations with arsenic above 50 μg/L	74	178
Number of arsenic-affected villages (approx.) with groundwater arsenic above 50 μg/L	2,600	2,000
People drinking arsenic-contaminated water >50 μg/L (in millions)	6	25
Districts surveyed for arsenic patients	7	34
Number of districts where we have identified people with arsenical skin lesions	7	31
Villages surveyed for arsenic patients	306	244
Number of villages where we have identified people with arsenical skin lesions	255	217
People screened as arsenic patients from affected villages (preliminary survey)	86,000	17,896
Number of registered patients with clinical manifestations including children	8,500 (9.8%)	3,695 (20.6%)
% of children having arsenical skin lesions based on total number of patients	1.7	6.4

Bangladesh, (2) the total arsenic burden to villagers consuming contaminated water, rice and vegetables cultivated with arsenic contaminated water, (3) socio-economic conditions in the arsenic-affected villages, and (4) social problems of those suffering from arsenic toxicity.

2. The Present Status of the Arsenic Situation in West Bengal and Bangladesh

2.1 *Arsenic in hand tubewells*

The total area and population of West Bengal and Bangladesh are 89,193 $km^2$and 68 million, and 148,393 km^2 and 120 million, respectively. Figure 1 shows the arsenic-affected areas and blocks/police stations of West Bengal, and Fig. 2 shows the status of arsenic levels in groundwater in different districts of Bangladesh. In our study over the last

14 years in West Bengal and 7 years in Bangladesh, we have analyzed 99,153 and 34,000 hand tubewells for arsenic from 9 out of a total of 18 districts of West Bengal and all 64 districts of Bangladesh, respectively (Table 2). In 9 arsenic-affected districts of West Bengal we found arsenic levels in groundwater above 50 μg/L. The overall result shows that water from 47% of tubewells is safe to drink according to the WHO guideline for arsenic levels in drinking water (10 μg/L) while 53% and 25% of the tubewells contain arsenic above 10 and 50 μg/L, respectively. In Bangladesh, these values are 44%, 56% and 37%, respectively, from 47 districts where groundwater contains more than 50 μg/L of arsenic. Although in arsenic-affected areas of West Bengal and Bangladesh only 25% and

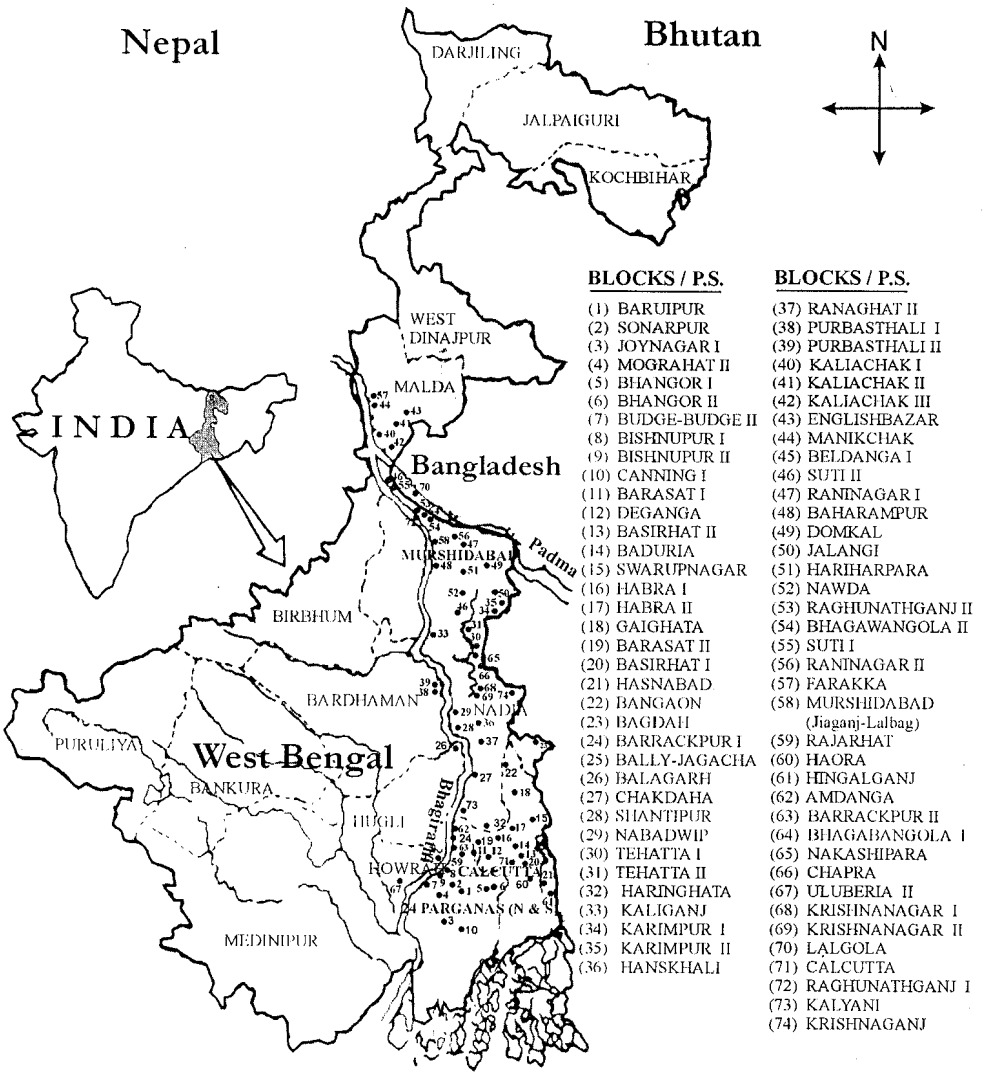

Fig. 1. Map showing the arsenic-affected areas and blocks/police stations of West Bengal.

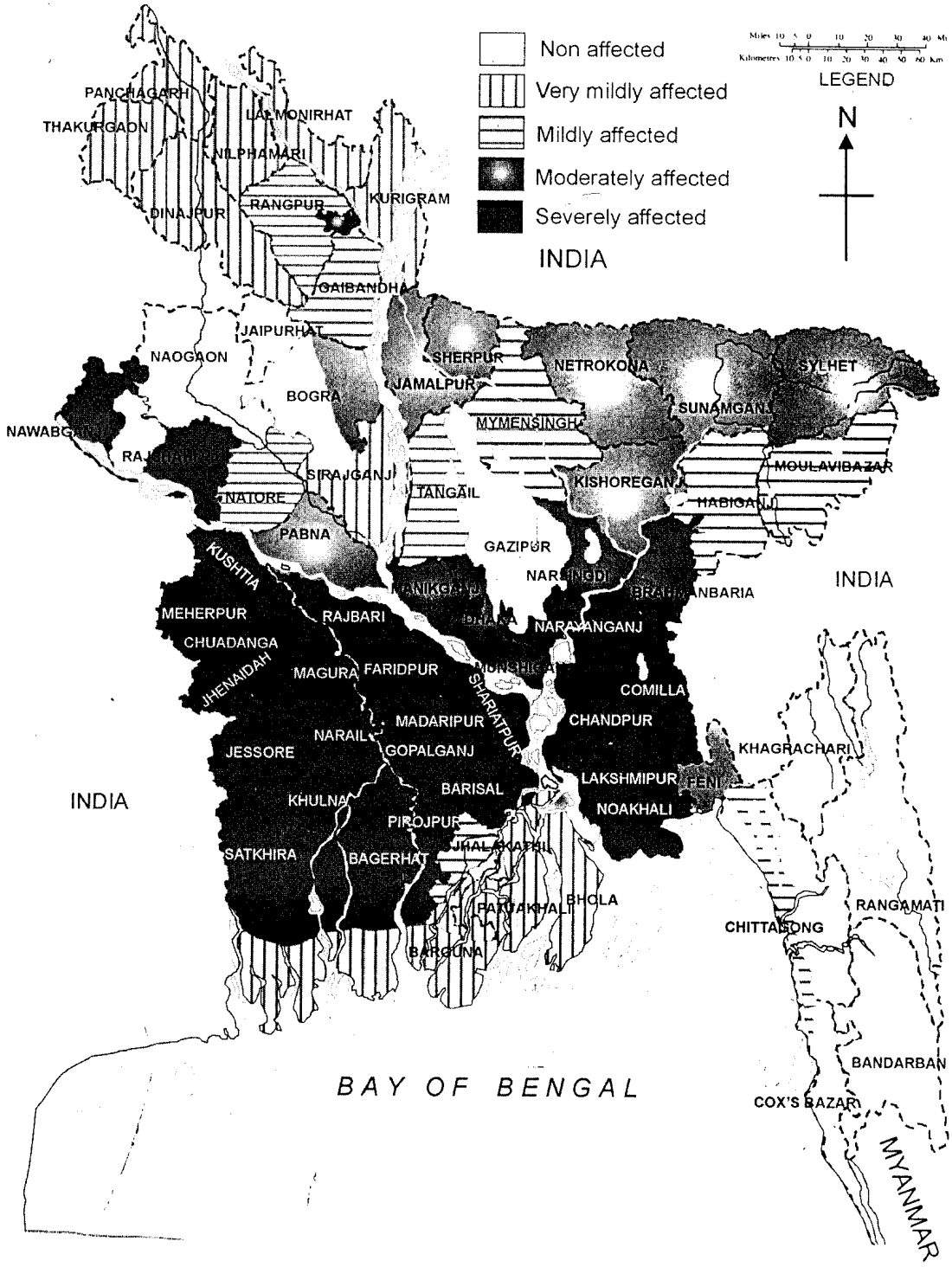

Fig. 2 . Map showing the status of arsenic levels in groundwater in all 64 districts of Bangladesh.

Table 2
Distribution of hand tubewells against the arsenic concentration ranges (μg/L) of West Bengal and Bangladesh.

	Total number of water samples analyzed	Distribution of the samples in different arsenic concentration ranges (μg/L)							
		< 10	10–50	51–99	100–299	300–499	500–699	700–1000	>1000
West Bengal	99,153	46,675 (47.1%)	27,189 (27.4%)	9,982 (10.1%)	11,779 (11.9%)	2,354 (2.4%)	724 (0.7%)	334 (0.3%)	116 (0.1%)
Bangladesh	34,000	14,991 (44.1%)	6,429 (18.9%)	2,949 (8.7%)	5,812 (17.1%)	2,174 (6.4%)	894 (2.6%)	479 (1.4%)	272 (0.8%)

37% of hand tubewells contain arsenic levels above 50 μg/L, these are overall results covering all affected districts. There are many villages in West Bengal and Bangladesh where 80–90% of hand tubewells contain arsenic above 50 μg/L. From Table 2 it appears that arsenic concentration in hand tubewells at 100 μg/L and above are more abundant in Bangladesh.

The WHO recommended value of arsenic in drinking water of 10 μg/L and the maximum permissible limit of 50 μg/L are based on water consumption of 2 L per day. West Bengal and Bangladesh are in a tropical region where the average water consumption of an adult is 4 L per day, and those who work in fields (in India and Bangladesh at least 60–70% of rural people are farmers) consume a much higher quantity of water. The recommended value and maximum permissible limit of arsenic in drinking water for villagers of West Bengal and Bangladesh should be at least half of the value recommended by the WHO. Again it is reported by WHO[9] that 1.0 mg of inorganic arsenic per day may give rise to skin lesions within a few years, and according to the US National Research Council (NRC) 500 μg of arsenic per day results in the risk of 13 out of every 100 persons developing cancer in their lifetime.[10] If WHO and NRC postulations are applied to people drinking arsenic-contaminated water in West Bengal and Bangladesh, then large numbers of people are at risk for cancer. Moreover, this arsenic burden on people of West Bengal and Bangladesh is from water consumption alone. When we consider arsenic from water and food consumption together, the risk of suffering becomes higher.

2.2 *Arsenic in biological samples from villagers in contaminated areas*

Thus far we have analyzed 7,135 hair, 7,381 nail, 9,795 urine and 165 skin-scale samples from West Bengal and 4,386 hair, 4,321 nail, 1,084 urine and 705 skin-scale samples from arsenic-affected villages in Bangladesh. About 40–50% of these samples are from people having arsenical skin lesions, and the rest are from non-patients who live in the arsenic-affected villages (skin-scale is only from those having keratosis). Analyses of these samples (Table 3) show that 57%, 83%, and 89% of hair, nail and urine samples, respectively, in West Bengal and 93%, 95% and 83% of the samples in Bangladesh have arsenic levels above the normal levels for nail and urine samples and toxic levels for hair samples (normal levels of arsenic in hair, nail and urine are given in Table 3 along with references). All skin-scale samples contained elevated levels of arsenic. It appears from Table 3 that many villagers may not be suffering from arsenical skin lesions but have

Table 3
Parametric presentation of arsenic in hair, nail, urine (metabolites) and skin-scale samples collected from people of the arsenic-affected areas of West Bengal and Bangladesh

Parameters	West Bengal				Bangladesh			
	As in hair[a] (μg/kg)	As in nail[b] (μg/kg)	As in urine[c] (μg/L)	As in skin scale[d] (μg/kg)	As in hair[a] (μg/kg)	As in nail[b] (μg/kg)	As in urine[c] (μg/L)	As in skin scale[d] (μg/kg)
No. of observations	7,135	7,381	9,795	165	4,386	4,321	1,084	705
Mean	1,480	4,560	180	6,820	3,390	8,570	280	5,730
Median	1,320	3,870	115	4,460	2,340	6,400	116	4,800
Minimum	180	380	10	1,280	280	260	24	600
Maximum	20,340	44,890	3,147	15,510	28,060	79,490	3,086	53,390
Standard deviation	1,550	3,980	268	4,750	3,330	7,630	410	9,790
% of samples having arsenic above normal/toxic level	57	83	89	—	83.15	93.77	95.11	—

a: Normal levels of arsenic in hair range from 80–250 μg/kg; 1000 μg/kg is the indication level of toxicity[15]
b: Normal levels of arsenic in nail range from 430–1080 μg/kg[16]
c: Normal levels of arsenic in urine range from 5–40 μg/1.5 L (per day)[17]
d: No normal levels for skin-scale has been reported to date

elevated levels of arsenic in hair and nails, and thus may be sub-clinically affected. The reason for such high concentrations of arsenic in biological samples of villagers is that we collected samples from contaminated areas. The outcome will be different from less contaminated and uncontaminated areas.

2.3 *People with arsenical skin lesions in villages of West Bengal and Bangladesh and the percentage of arsenic patients in the affected villages whom we could actually examine*

During the last 14 and 7 years, we carried out some preliminary surveys to establish how many people have arsenical skin manifestations in the affected villages of West Bengal and Bangladesh, respectively. We surveyed 306 villages in seven out of nine arsenic-affected districts in West Bengal, and we examined 86,000 people (including children) at random from the affected villages. We identified 255 villages where people were suffering from arsenic-induced skin lesions, and we diagnosed 8,500 (9.8%) people with arsenical skin lesions. The chief dermatological features we observed in arsenic-affected villages of West Bengal and Bangladesh were:

1. Darkening of the skin (diffuse melanosis) on the entire body or on the palms was the earliest symptom. It was not necessary that people suffering from arsenic toxicity have the symptom of diffuse melanosis.
2. Spotted pigmentation (spotted melanosis) was also an early symptom and usually seen on the chest, back, or limbs. This is a very common symptom.
3. Leucomelanosis, which is white and black spots side by side, was also seen in many

patients. Leucomelanosis was common in persons who stop drinking arsenic-contaminated water but who had spotted melanosis previously.

4. Buccal mucus membrane melanosis on the tongue, gums and lips, may also be a manifestation of arsenic (diffuse, patchy, or spotted melanosis).
5. Keratosis was a late feature of arsenical dermatosis (exceptions are found). Diffuse or nodular keratosis on the palms and soles is a sign of moderate to severe toxicity.
6. Rough, dry skin, often with palpable nodules (spotted keratosis) on dorsal side of hands, feet, and legs is a symptom seen in severe cases.

A combination of pigmentation (melanosis) and nodular rough skin (spotted palmoplantar keratosis) almost always point to arsenic toxicity excluding hundreds of other causes of isolated pigmentation and nodular rough skin.

Other symptoms sometimes found are conjunctional congestion and nonpitting swelling (solid edema) of the feet.

Complications like liver enlargement (hepatomegaly), spleen enlargement (splenomegaly) and fluid in the abdomen (ascitis) are seen in severe cases. Squamous cell carcinoma, basal cell carcinoma, Bowen's disease or carcinoma affecting the lung, uterus, bladder, genitourinary tract, or other sites is often seen in advanced neglected cases many years in duration.

In Bangladesh, we found arsenic patients in 217 out of 244 villages from 31 out of 34 districts that we surveyed to date. We examined 17,896 people (including children) and diagnosed 3,695 (20.6%) people with arsenical skin lesions. In West Bengal and Bangladesh, 1.7 and 6.4% of the children examined from the affected villages had arsenical skin lesions. To date from West Bengal and Bangladesh we have diagnosed with all details 8,500 and 3,695 patients with arsenical skin lesions, respectively, but after talking with villagers, we feel we had examined only a small percentage (10–15%) of the total population in arsenic-affected villages who have arsenical skin lesions. The reasons for this include: (1) In villages, the affected people think their disease is contagious and if other people become aware of their ailment, they will be isolated; (2) young girls and women of conservative families do not want to be examined (Photo.1); (3) people are frustrated and feel that there is no cure for the disease; (4) since village roads are not good, people who are suffering seriously did not want to come to our camp due to weakness because it required travelling a long distance; (5) normally, we were in a village during the day, and at that time of the day most of the males were working in the field. The high percentage of the population showing arsenical skin-lesions as we reported arises because we examined villagers from only arsenic-affected areas. The overall percentage will be much less when we consider less contaminated and uncontaminated areas.

Photo. 1. A conservative family not willing to exhibit their skin lesions.

In West Bengal and Bangladesh we surveyed arsenic-affected villages for about 1000 days (during the last 14 years in West Bengal) and 250 days (during the last 7 years in Bangladesh), but in our opinion this is too small a survey for measuring the magnitude of the calamity.

2.4 *A semi-microlevel comparative study of one arsenic-affected village from West Bengal with one from Bangladesh*

Although the arsenic problem in West Bengal was first recognized in 1982 and that of Bangladesh in 1995, we still do not know the overall magnitude of the calamity. It is true that in many villages people are suffering seriously but quantitative studies have not been carried out.

This semi-microlevel study compares the arsenic-affected village of Fakirpara, of Kolsur GP in Deganga police station of North 24-Parganas, West Bengal with that of the village of Samta, Sarsha police station in Jessore district, Bangladesh. Tables 4, 5 and 6 present the data from a comparative study of the groundwater contamination by arsenic, arsenic in biological samples, and people suffering from arsenic toxicity in these two villages. We came to know villagers of Fakirpara in May, 1997 who were suffering from arsenic toxicity and those of Samta, in December, 1996.

From the results it appears that both villages are seriously affected. Around 90% of the population of these two villages drink water contaminated with arsenic at levels above 50 μ/L. Values of arsenic in biological samples show around 96% of population

Table 4
A comparative study of one arsenic-affected village, Fakirpara of West Bengal, with Samta from Bangladesh.

Parameters	Fakirpara West Bengal	Samta Bangladesh
Area in sq. km	0.50	3.2
Population	764	4841
Total number of hand tubewells	46	276
Number of hand tubewells analyzed	46	265
Number of samples having arsenic > 10 μg/L	44 (95.6%)	260 (98.1%)
Number of samples having arsenic > 50 μg/L	41 (89.1%)	242 (91.3%)
Number of people screened for arsenical skin lesions (detailed survey)	764	600
Number of patients diagnosed with clinical manifestations	175 (22.9%)	330 (55%)
Number of the children having arsenical skin lesions	13 (1.7%)	27 (4.5%)
Total hair, nail, urine and skin-scales samples analyzed	870	825
Arsenic above normal level (average) in biological samples	96%	96.3%

Table 5
Distribution of tubewells against the arsenic concentration ranges (μg/L) in Fakirpara of West Bengal and Samta of Bangladesh.

	Name of village	Total number of water samples analyzed	Total distribution of samples according to arsenic concentration range (μg/L)							
			< 10	10–50	51–99	100–299	300–499	500–699	700–1000	>1000
West Bengal	Fakirpara	46	2 (4.35%)	3 (6.52%)	6 (13.04%)	12 (26.09%)	10 (21.74%)	8 (17.39%)	5 (10.87%)	—
Bangladesh	Samta	265	5 (1.89%)	18 (6.79%)	104 (39.25%)	93 (35.09%)	13 (4.91%)	21 (7.92%)	11 (4.15%)	—

Table 6
Parametric presentation of arsenic in hair, nail and urine (metabolites) samples collected from the people of Fakirpara of West Bengal and Samta of Bangladesh.

Parameters	Fakirpara, West Bengal			Samta, Bangladesh		
	As in hair[a] (μg/kg)	As in nail[b] (μg/kg)	As in urine[c] (μg/L)	As in hair[a] (μg/kg)	As in nail[b] (μg/kg)	As in urine[c] (μg/L)
No. of observations	260	285	325	283	242	300
Mean	3,340	8,190	528	2,380	7,190	538
Median	2,560	6,580	318.7	2,370	6,060	289.3
Minimum	320	850	7.81	460	260	24
Maximum	18,530	44,890	2,911.8	9,480	29,600	3,085
Standard deviation	2,850	6,450	629.1	1,580	4,880	541
% of samples having arsenic above normal/ toxic levels (hair)	91	99	98	94.5	96	98.5

a: Normal levels of arsenic in hair range from 80–250 μg/kg; 1000 μg/kg is the indication level of toxicity[15]
b: Normal levels of arsenic in nail range from 430–1080 μg/kg[16]
c: Normal levels excretion of arsenic in urine range from 5–40 μg/1.5l (per day)[17]

have elevated levels of arsenic. These data indicate that many people are affected sub-clinically. In Fakirpara all 764 villagers were examined and 22.9% had arsenical skin lesions. In Samta, out of 4,841 villagers, we examined 600 people at random (those who came to our camp), and out of that number 330 (55%) had arsenical skin lesions. However, this does not mean that 55% of the total population of Samta suffers from arsenical skin lesions, but this no doubt indicates the magnitude is high. We need a thorough study in the arsenic-affected villages of West Bengal and Bangladesh to know the magnitude of the situation. Fakirpara and Samta villages are only two examples out of thousands of arsenic-affected villages in West Bengal and Bangladesh.

3. Food Habits and Arsenic Intake from Food and Water Consumption of Those Living in Contaminated Areas

Rice and vegetables are the staple food for poor villagers of West Bengal and Bangladesh. This is true for the villagers in Kolsur Gram-Panchayet (GP) in the Deganga block of North 24 Parganas district, West Bengal, where we studied arsenic in soil, rice and vegetables from ten plots cultivated for two years using arsenic-contaminated water. Normally, the people eat rice with vegetables three times per day. Adults (male or female) normally eat 250 g of rice at each meal, i.e., 750 g of rice per day, and children (around 10 years of age) eat 400 g of rice per day. Adults eat about 165 g of cooked vegetables at each meal and children around 100 g. The average water intake per day for adult males, adult females, and children is 4 L, 3 L and 2 L, respectively. Those who work in the field consume more water (average 6 L) and during summer the average water intake for those working in the field is as high as 10 L. Villagers also consume arsenic from Pantavat* and water added to food preparations like rice, soup, curry and drinks like tea. After thorough discussions with the

villagers, it appears that this is equivalent to the consumption of 1 L of water for an adult and 500 ml for a child. Normal daily average food intake for adults at each meal is as follows:

Meal (adult)	Type of Food
Morning/Breakfast	Pantavat* with vegetables (rice, 250 g and cooked vegetables, 100 g)
Lunch	Normally rice (250 g) and vegetables (200 g)
At night	Rice (250 g) and vegetables (200 g), villagers occasionally eat fish, eggs and rarely meat.

*Pantavat: This is common breakfast food for villagers of West Bengal and Bangladesh. Pantavat is rice mixed with water. Normally they pour water on rice cooked the previous night and have it as their breakfast. Normally, villagers eat Pantavat with vegetables/mashed potatos/chili and onion.

3.1 *Total arsenic burden to the villagers from water and food consumption*

We have classified arsenic intake in three categories; Category I: Arsenic from contaminated drinking water alone, Category II: Arsenic from food (rice and vegetables), Category III: Arsenic from contaminated water added to 'Pantavat' and for food preparations (rice, soup, curry and drinks like tea).

Altogether, we analyzed 571 hand tubewells from the village of North Kolsur and, of these, 80% of the tubewells contain arsenic levels above 10 μg/L and 70% of the tubewells contain levels above 50 μg/L. The average arsenic concentration in contaminated hand tubewells ($n = 399$) is 200 μg L^{-1}. When we started our work in this village, villagers were drinking arsenic-contaminated water. We informed them about contamination of their hand tubewells and identified safe tubewells for them in their village. We do not know what percentage of villagers are consuming safe water, but we do know that for irrigation purposes they are still using contaminated tubewells water. Arsenic concentrations in the hand tubewell from which they were drinking are given in Table 7.

We collected and analyzed soil, rice, vegetables and water used for irrigation for 10 fields studied in North Kolsur. The average arsenic concentration in 10 fields is shown in Table 8. Villagers close to our studied areas are consuming rice and vegetables from these 10 fields. The average arsenic concentrations in soil ($n = 51$), rice ($n = 8$) and vegetables ($n = 30$) are 22.67 μg g^{-1} (range 11.23 μg g^{-1} to 43.08 μg g^{-1}, dry weight), 0.358 μg g^{-1}

Table 7
Distribution of arsenic levels in hand tubewell water samples of North Kolsur in the Deganga block of North 24-Parganas district.

Name of village	No. of tubewell water samples analyzed	Distribution of samples according to concentration range of arsenic (μg/L)							
		<10	10–50	51–99	100–299	300–499	500–699	700–1000	>1000
North Kolsur	571	112 (19.6%)	60 (10.5%)	171 (29.9%)	175 (30.6%)	29 (5.1%)	14 (2.5%)	8 (1.4%)	2 (0.4%)

(range 0.120 $\mu g\ g^{-1}$ to 0.663 $\mu g\ g^{-1}$, dry weight) and 0.034 $\mu g\ g^{-1}$ (range 0.008 $\mu g\ g^{-1}$ to 0.120 $\mu g\ g^{-1}$, wet weight), respectively. Our preliminary study indicates that vegetables grown in soil contain high amounts of arsenic. Villagers were also using the contaminated water from the hand tubewell for Pantavat (average As 200 $\mu g\ L^{-1}$). Control soil ($n = 6$), rice ($n = 3$) and vegetable ($n = 3$) samples contain arsenic concentrations (average) of 5.84 $\mu g\ g^{-1}$ (range 5.31 $\mu g\ g^{-1}$ to 6.60 $\mu g\ g^{-1}$), 0.089 $\mu g\ g^{-1}$ (range 0.0831 $\mu g\ g^{-1}$ to 0.0959 $\mu g\ g^{-1}$) and 0.009 $\mu g\ g^{-1}$ (range 0.007 $\mu g\ g^{-1}$ to 0.012 $\mu g\ g^{-1}$), respectively. Our preliminary study indicates that the arsenic concentration in irrigation water from the control area is $< 3\ \mu g\ L^{-1}$. Our control area is Medinipur district, which is not contaminated with arsenic. It appears that arsenic concentrations (in average) in contaminated soil, rice and vegetables are 3.9, 4 and 3.8 times higher than control samples, respectively.

Tables 9, 10 and 11 show the arsenic burden for each villager from consumption of contaminated tubewell water alone, rice, vegetables and water added to rice for Pantavat and used in food preparation.

Table 8
Analysis of arsenic levels in water from 10 irrigation tubewells used on 10 fields for cultivation.

	Arsenic concentration in water from 10 irrigation tubewells ($\mu g/L$)									
Field No.	1	2	3	4	5	6	7	8	9	10
Average arsenic concentration ($\mu g/L$) over a 2 year period	769	566	129	469	436	202	225	218	230	159

Table 9
Arsenic burden to each adult male, adult female and child from consumption water alone in North Kolsur.

	Volume of drinking water per day (L)	Arsenic concentration in drinking (average) water ($\mu g/L$)	Intake of total arsenic from drinking water per day (μg)
Adult male	4	200	800
Adult female	3	200	600
Child (around 10 years)	2	200	400

Table 10
Daily arsenic burden to each adult male, adult female and child from consumption of contaminated rice and vegetables.

	Rice			Vegetable			Total intake of arsenic from rice and vegetables per day (μg)
	Weight consumed per day (dry) (gm)	Arsenic concentration ($\mu g/g$)	Total arsenic (μg)	Weight consumed per day (dry) (gm)	Arsenic concentration ($\mu g/g$)	Total arsenic (μg)	
Adult male	750	0.358	268	500	0.034	17.0	285.0
Adult female	750	0.358	268	500	0.034	17.0	285.0
Child (around 10 years)	400	0.358	143	300	0.034	10.2	153.2

Table 11
Daily arsenic burden to each adult male, adult female and child from consumption of contaminated water added for Pantavat and used in food preparation.

	Arsenic levels in water added for Pantavat preparation (μg)	Arsenic levels in water added for food preparation (μg)	Total arsenic levels in water added for Pantavat and food preparation (μg)
Adult male	100 (0.5 L × 200 μg/L)	100 (0.5 L × 200 μg/L)	200
Adult female	100 (0.5 L × 200 μg/L)	100 (0.5 L × 200 μg/L)	200
Child (around 10 years)	50 (0.25 L × 200 μg/L)	50 (0.25 L × 200 μg/L)	100

3.2 *Body burden of total arsenic, inorganic arsenic and organic arsenic from water, food and water added for food preparation to North Kolsur villagers*

Our earlier study[6] shows that arsenic compounds present in hand tubewell water analyzed in our study area are arsenite and arsenate. The analysis of rice and vegetables shows herein (preliminary study on total inorganic and organic arsenic compounds in rice and vegetable samples carried out by US Food and Drug Administration, Forensic Chemistry Centre, Cincinnati, USA[11]) that 95% and 5% of the compounds are inorganic arsenic and organic arsenic in rice, and 96% and 4% are inorganic arsenic and organic arsenic in vegetables.

Table 12 shows the arsenic burden (total, inorganic arsenic and organic arsenic) to each adult male, adult female and child by combining categories I, II and III.

Table 13 shows a comparative study of inorganic arsenic and total arsenic intake by North Kolsur villagers with that by people from other countries.[12] The high concentration of arsenic in the populations of Japan, Spain, and the Manaus region of Brazil is due to high intake of seafood. It is also obvious that organic arsenic intake by people from other countries represented in Table 13 is also primarily from seafood. North Kolsur villagers rarely consume seafood.

From the results of the total amount of arsenic consumed (drinking water + rice + vegetables + Pantavat + water added for food preparation), the body burden to North Kolsur villagers (1185.0 μg for per adult per day, 653.2 μg for per child per day), as the amount of arsenic coming from rice, vegetables and water added for Pantavat and food preparation, is 485 μg, i.e., 41% of the total for adults, and 253.2 μg, i.e., 38.8% for children, and from rice and vegetables 285 μg, i.e., 24% of the total for adults and 153.2 μg, i.e., 23.4%, for children. Our findings show that most of the arsenic coming from food is inorganic in nature. As the toxicity of most of the organic arsenic compounds in food is less than that of the inorganic arsenic, North Kolsur people appear also at risk from arsenic in food.

According to WHO,[9] 1.0 μg of inorganic arsenic per day may give rise to skin lesions within a few years. It has been estimated that based on the current U.S. Environmental Protection Agency (EPA) standard of 50 μg l^{-1}, the lifetime risk of dying from cancer of the liver, lung, kidney, or bladder, from drinking 1 L per day of water could be as high as 13 per 1000 persons.[13] Using the same methods, the risk estimate for 500 μg/L of arsenic in drinking water is 13 per 100 persons.[10] In its latest document on arsenic in drinking water,

Table 12
Total arsenic, inorganic arsenic and organic arsenic intake by villagers in North Kolsur by combining categories I, II and III.

	From water alone (μg) [Category I]	From rice and vegetables (μg) [Category II]	Water added for Pantavat and used in food preparation (μg) [Category III]	Total arsenic intake per day (μg)	Total inorganic arsenic (μg)	Total organic arsenic (μg)
Adult male	800	285.0	200	1285.0	1270.9	14.1
Adult female	600	285.0	200	1085.0	1070.9	14.1
Child (around 10 years)	400	153.2	100	653.2	645.6	7.6

Table 13
Arsenic levels in the food of a North Kolsur villager compared with that in the food from other countries.

Country	Method of sampling	Intake of total arsenic (μg day^{-1})	Intake of total inorganic arsenic (μg day^{-1})	Reference
North Kolsur, West Bengal, India	Adult male	285.0	270.9	This study
	Adult female	285.0	270.9	
	Child (around 10 years)	153.2	145.5	
Australia	Adult male	73.3	NA	WHO, 2000[12]
	Adult female	52.8	NA	
	Child (2 years old)	17.3	NA	
Brazil	Students	18.7–19.5	NA	WHO, 2000[12]
	S. Catarina 1 region	49.2–52.9	NA	
	Manaus region	139.6–159.3	NA	
		16.5–17.0	NA	
Canada	Adult male (5 cities)	59.2	NA	WHO, 2000[12]
	1 to 4 years (5 cities)	14.9	NA	
Japan	Adult male and female	182.0	NA	WHO, 2000[12]
Spain	Basque Region adult	291.0	NA	WHO, 2000[12]
United Kingdom	Adult male and female	63	NA	WHO, 2000[12]
USA	Adult male and female	52.6	NA	WHO, 2000[12]
	0.5 to 2 years	27.6	NA	

NA = Not available

the U.S. National Research Council (NRC) concluded that exposure to 50 μg/L could easily result in a combined cancer risk[14] of 1 in 100. Comparing the values in the WHO, EPA and NRC documents with arsenic burden to Kolsur villagers from water and food consumption, it appears that Kolsur villagers' risk of suffering from arsenical skin lesions

and cancer is there. Compared to world-wide arsenic consumption from food, it appears Kolsur villagers are also consuming high amounts of inorganic arsenic from food and vegetables. The village of Kolsur is an example of many such villages in West Bengal and Bangladesh.

Furthermore, products from soil systems irrigated with water containing arsenic are being sold at the common market place, and even people who are not drinking arsenic-contaminated water may get arsenic from food products from contaminated fields. In West Bengal and Bangladesh rice, vegetables and other products are transported to cities (including Calcutta in West Bengal and Dhaka in Bangladesh) from villages, and the possibility that city dwellers consume arsenic-contaminated products cannot be ruled out.

In one of our studies[8] we mentioned that arsenic metabolites in urine in a control population using water for drinking and cooking with an arsenic level of < 3 $\mu g\ L^{-1}$ are at a higher than normal level. This shows that a level of arsenic results in the intake of arsenic in areas surrounding arsenic-contaminated areas due to arsenic in the food chain.

4. Socio-Economic Study in the Arsenic-Affected Villages

It has been noted that in the arsenic-affected areas of West Bengal and Bangladesh those consuming nutritious food suffer from arsenic toxicity the least. In the village of Kachua (Block: Basirhat II, North 24-Parganas district) most inhabitants show no skin manifestation of arsenic, although their hair, nails and urine have high arsenic contents and the average arsenic content in their contaminated tubewell water is 350 μg/L (range 50–450 μg/L). In contrast, about 2 km from Kachua, in the same block, in the village of Golabari Chandpur, we diagnosed 45 patients with arsenical skin lesions (average arsenic level 320 μg/L; range 50–440 μg/L). Our survey shows the people of Kachua have better economic conditions and consume more nutritious food than those of Golabari-Chandpur village.

In the village of Olitola, Block Kaliachak-III, Malda district, Motahar Hossain's family shows no signs of arsenical skin lesions, although they use the same water as the rest of the villagers, almost all of whom are affected. Motahar Hossain is a rich man in the village. During our interview with him, his family was consuming nourishing food.

From our 14 year study of the arsenic-affected areas of West Bengal and 7 year study of Bangladesh we noticed that people in poor socio-economic conditions suffer the most. We feel 80% of the population of West Bengal and Bangladesh could be saved from arsenic toxicity if they had better nutrition.

To understand the socio-economic conditions of the villagers, we surveyed Kolsur Gram Panchayet [Gram Panchayet (GP) is cluster of villages], of the Deganga block, district North 24-Parganas, for one year using a questionnaire. The questionnaire is shown in Fig. 3. Kolsur GP has five villages altogether; Uttar Kolsur, Dakshin Kolsur, Chandalati, Kamdebkati and Raniati. Out of these five villages, people of Dakshin Kolsur and Kamdebkati have somewhat better economic conditions than the other three. We have found that the people of Dakshin Kolsur and Kamdebkati are suffering the least.

We surveyed 11,000 people out of a total of 16,879 from Kolsur GP for one year using our questionnaire (6 people worked an average of 8 h per day for 307 days per year). The following information has been documented.

QUESTIONNAIRE FOR SOCIO-ECONOMIC STUDY

DATE	DAY	MONTH	YEAR
	13	08	1997

TO BE FILLED OUT BY THE HEAD OF THE HOUSEHOLD

SURVEY SERIAL NO.	235
HOUSE NO.	
TUBEWELL NO.	

FAMILY SURVEY ADDRESS	VILLAGE	U. KOLSUR (Palpara)	P.S.	DEGANGA	G.P.	KOLSUR	DISTRICT	NORTH 24 PARGANAS

NAME OF THE HEAD OF THE FAMILY	SANTOSH PAL	HOW MANY MEMBERS IN THE FAMILY	5 (FIVE)	HOW MANY FAMILY MEMBERS EARN	1 (ONE)				
MONTHLY INCOME	*Rs. 1000/=	WEEKLY INCOME	Rs. 250/=	TYPES OF WORK	PORTER	OTHER SOURCE OF INCOME	x		
WORKING IN OWN LAND	X	AREA OF SELF LAND	4 (FOUR) CHATAK	WORKING ON OTHERS LAND	X				
HOW MANY DAYS WORKING IN RAINY SEASON PER MONTH	16 DAYS	HOW MANY DAYS WORKING IN WINTER PER MONTH	28 DAYS	HOW MANY DAYS WORKING IN SUMMER PER MONTH	30 DAYS				

IF ILL THEY GO TO DOCTOR	HOMEOPATHY	✓	IF ILL THEY GO TO DOCTOR	MILD		ARRANGE MONEY FOR TREATMENT	EASILY	
	ALLOPATHY			SEVERE			STRESS	
	EMPIRIC MEDICINE	✓		ALMOST NEVER	✓		BY LOAN	✓

FAMILY RUNS	EASILY		PURCHASE FROM THE MARKET								DO THEY TAKE MONEY FROM LENDER?					
	STRESS	✓	FISH	✓	VEGETABLE	✓	RICE	✓	CEREAL	✓	YES	✓	NO		RATE OF INTEREST	6% PER MONTH

HOW MANY MEMBERS HAVE ARSENICAL SKIN LESIONS?	3	TYPE OF HOUSE		DEATH AND DECEASED HAD ANY SKIN LESIONS	YES		NO	SOURCES OF DRINKING WATER AND USE						
NUMBER OF LITERATE PERSON	5	BRICK BUILDING	MUD HOUSE						POND	RIVER / NALA	TUBEWELL	DUGWELL	CANAL	OTHERS
WHAT DIFFICULTIES DUE TO BODY (ARSENICAL) SYMPTOMS?	✓		✓		NO	✓		DRINKING			✓			
								COOKING			✓			
								BATHING	✓		✓			

NAME OF THE FAMILY MEMBER	M / F	AGE	BODY WEIGHT	As CONC. IN DRINKING WATER PRESENT	HOW LONG DRINKING	As CONC. IN DRINKING WATER FROM PREVIOUS SOURCES	HOW LONG DRINKING (PREVIOUS)	WATER INTAKE PER DAY	ARSENICAL SYMPTOMS	HOW LONG SYMPTOMS PERSISTING	As CONC. IN COOKING WATER
SANTOSH PAL	M	50	48 kg	0.01	2 years	0.155	10 years	4 liters	✓	12	0.155
TULURANI PAL	F	38	40 kg	0.01	2 years	0.155	10 years	4 liters	✓	13	0.155
SAMIR PAL	M	17	42 kg	0.01	2 years	0.155	10 years	3 liters	✓	12	0.155
MANTU PAL	M	12	40 kg	0.01	2 years	0.155	10 years	3 liters	x	X	0.155
BINA PAL	F	14	35 kg	0.01	2 years	0.155	10 years	3 liters	x	X	0.155

NAME OF THE FAMILY MEMBER	FOOD HABIT					SMOKING HABIT			
	MILK DAYS PER WEEK	FISH DAYS PER MONTH	MEAT DAYS PER MONTH	EGG DAYS PER MONTH	VEGETABLES DAYS PER MONTH	BIDI PER DAY	CIGARETTE PER DAY	TOBACCO PER DAY	DRINK ALCOHOL
SANTOSH PAL	Daily	4 days	1 day	4 days	Daily	12 pieces	x	X	X
TULURANI PAL	Daily	4 days	1 day	4 days	Daily				
SAMIR PAL	Daily	4 days	1 day	4 days	Daily				
MANTU PAL	Daily	4 days	1 day	4 days	Daily				
BINA PAL	Daily	4 days	1 day	4 days	Daily				

* 1 US $ = Rs. 47

Fig. 3. Questionnaire used to evaluate socio-economic conditions of the villagers.

1. There are about 3,300 families with an average of 5 members in each family living in Kolsur GP.
2. Out of 16,879 people, about 51.13% of the males, 48.87% of the females and 22.84% of the children below 11 years live in huts (80%) made of mud/galvanized tin/bamboo and 20% in brick houses. Ninety percent of the houses are one room and the remaining 10% of the houses have 2 or more rooms. Sixty percent of the population use the leaves of trees, dried branches of trees, dried cow dung and straw as the fuel for cooking, and the remaining 40% use kerosene and coal as fuel.
3. 75% of the people have their own land, the average area of which is 2000 m^2.
4. 80% of the families have one earning member, 10% of the families have two earning members, and 2% of the families have three earning members.
5. About 5.57% of the people run their household easily, while 94.28% run it with stress.
6. The literacy rate of the inhabitants is 91% (literacy means they can sign their name).
7. 75% of the residents of this GP are farmers and mainly depend on agriculture. The types of job the villagers have include: daily laborer on others' land (29%); business (18%); van driver (0.84%), tailor (1.98%), mechanic (0.65%) and about 2% are shoemakers, work in tea shops, goldsmiths, hawkers, fishermen, milk and newspaper suppliers, among others. About 18% of the males and 35% of the females do not have jobs.
8. The average monthly income of a family is one thousand four hundred rupees (US $ 30).
9. A daily laborer on others' fields works 15 days per month during the rainy season, 19 days per month during the winter and 19 days per month during the summer. They are jobless the rest of the year.
10. The two main meals (lunch and dinner) of 61% of the population are rice with edible herbs and some vegetables. The cooked food is much too spicy. 39% of the inhabitants consume local milk five days per week (200 ml), fish on average 10 days/month, eggs on average 6 days/month and meat on average 2 days/month. Normally they eat 'Pantavat' at breakfast.
11. Almost 100% of the residents purchase fish, eggs and meat, 94% of the people purchase vegetables, 56% of the people purchase rice and cereals from a market. The price per kg of fish is $1.50, meat $2.50 per kg and eggs $1.00 per dozen.
12. About 100% of the people drink water from tubewells, 94% use it for cooking, and 43% bathe in it.
13. The intake of water per day for an adult male is 4 L, for adult women 3 L and for children 2 L. Those who work in fields consume more water (6 L), and during summer the water intake for those who work in the fields is as high as 10 L per day.
14. The average arsenic concentration in water from tubewells is 170 μg/L.
15. Generally when the villagers are sick, 41% of the people go to a homeopath, 57% of the people go to an allopath, 2% of the people go to an empiric medicine and 28% of the people go to both a homeopath and an allopath.
16. About 47% of the people go to doctors for mild diseases and 53% of the people go to doctors for severe diseases.
17. About 6% of the people can afford the fees to visit a doctor and 94% of the people can do so with stress.

18. 90% of the male adults smoke 15 Biri (country cigarettes) per day. We know a good percentage of women also smoke, but we have no data, as they are shy to admit this. (Probably around 20% of the adults drink country liquor, but they are shy to admit this).
19. The percentage of people having arsenical skin lesions is 1.39% children younger than 11 years of age and 6.42% for the people above that age out of the 11,000 people we surveyed.
20. About 20% of the families borrow money from moneylenders.
21. In many interior villages, villagers are still not aware of the arsenic problem and how serious the problem is. We asked questions to 1000 villagers in the interior villages of the Deganga block during our sample collection. The questions and answers are given below:

Q: Do you know about the arsenic problem in your area and hence in West Bengal?
Ans: 78% do not know, 10% heard that some poison is found in tubewell water, and 12% know about the arsenic in tubewell water but do not actually know what it is.

Q: What do you think about skin lesions?
Ans: 60% said it was just a skin disease and can be cured with ointment, 30% have no idea, 10% understand it is a serious problem.

Q: Why do some of you have skin lesions?
Ans: 40% say it is the wrath of God or a curse of God; 60% do not know.

One villager said that one night he went outside his hut to urinate and the devil urinated on his face, and since then he has had skin lesions.

4.1 *Moneylenders in villages*

We think that unless we discuss the villagers' involvement with moneylenders, we will not be able to understand their economic condition. We read about the cruelty of moneylenders in "Merchant of Venice", but in many villages of West Bengal the exploitation is no less. The interest the villagers have to pay to moneylenders ranges from 5–20% per month. Moneylenders demand interest according to the need of borrower. If the borrower has no alternative to borrowing money, the moneylenders demand higher rates of interest. Normally, the money poor villagers borrow from moneylenders is in the range of one hundred to one thousand rupees (US $ 2 to 22). However, when the deal is for land, the amount of money involved is higher.

Villagers can borrow money from moneylenders in various ways: (1) Mortgaging ornaments made of gold and silver. This is not very common, as most of the poor villagers do not possess gold ornaments, but some of them have silver ornaments, (2) Borrowing money from moneylenders for cooking utensils is very common, (3) The system of borrowing money for land also has different categories: (a) The moneylender gives money for the entire or a portion of land and when the borrower pays back the actual amount with

interest, he gets back the land. The moneylender has the right to cultivate the land until the principle and interest are repaid; (b) The borrower does not pay any interest but allows the moneylender to do one cultivation on his land. However, the principal amount is to be paid to the moneylender and until the borrower pays back the principal amount, the moneylender has the right to cultivate the plot. It has been observed that in many cases, the interest with principal becomes so great a sum that villagers either sell their land to the moneylender or to someone else in order to pay back the money they owe. In addition to the financial burden of paying back money borrowed at exorbitant rates of interest, poor villagers also suffer a great deal of mental agony.

5. Social Problems in the Arsenic-Affected Areas of West Bengal and Bangladesh

Social problems are the biggest difficulties that result from arsenic poisoning in villages of West Bengal and Bangladesh. The prevailing social problems in villages are:

1. Affected wives are sent back, sometimes with their children, to their parents.
2. Marriage of people of either sex from the affected villages has become a serious problem.
3. It has been noted that jobs/services have been denied/ignored to the arsenic-affected persons.
4. It has been observed that when a husband or wife has been singled out as an arsenic patient, the social problems crop up and destroy the social fabric.
5. Due to ignorance, the villagers sometime view it as a case of leprosy and force the arsenic patient to maintain an isolated life or avoid him socially in wherever possible. It is a social curse and human tragedy.

A widow from Ghetugachi, a village in the Chakdaha block, Nadia district, told how people from other villages refused to arrange marriages with people in their village. It is a common saying in that village that the young lady will be a widow if she marries in this village. An old woman told how she saw within the last 10 years young boys between 20 and 30 become invalid one after another due to this deadly disease and finally collapse. We heard dozens of incidents from the villagers about newly married women being sent back to their parents after the discovery of arsenical skin lesions on their body.

A male teacher of Purandarpur Math Boys' School (Baraipur block, 24-parganas South district) and his brother Bholanath Mondal both have arsenical skin lesions. They are bachelors. When asked why they were not married, they showed their skin lesions and asked how could they be! Another male patient of Uttar Kalyanpur, Purandar Math is a 'Tabla' player. He once had 50 students. Now due to hyperkeratosis on his palm he cannot play the 'Tabla' well and is suffering a financial crisis.

A female (F/25, Village Purba Chandipur, P.S.: Ramganj, Dist: Lakshmipur, Bangladesh) was married 15 years ago. Within the first year of her marriage, her husband sent her back to her parents because of her skin lesions. She is now a burden to her parents.

Two letters below will explain the acute social and financial crises of those suffering from arsenic toxicity in affected villages.

(1) About six years ago one of the authors of the article (D.C.) requested that a young arsenic patient who was then a college student participate in a television interview to express his suffering and mental agony. He wrote a letter to the author. The letter explains

the social problems due to arsenic in an arsenic-affected village. His letter is reprinted below.

Date: February 10, 1994

Dipankar Sir,

I have received your letter. I told you earlier that I will give the TV interview in your Department of the University and not in my village house. Almost 75% people of my village avoid us. They think if I will touch them or if I go to their house they will also be affected. If you come here for Television shooting more people will know and all our friends, relatives will avoid us and we will be isolated. In my brother's office due to his arsenic manifestation already there are some problems. So I will request you, please do not come here for your television interview. I will go to your office and give the interview and answer questions. Moreover during my interview I will not show my face on screen and will not tell my name. If you agree then on 19th February I will go to Jadavpur University for TV program. In my villages it is impossible. Ending my letter.

Yours

A male patient
Vill & PO: Ramnagar
PS: Baruipur
District: South 24 Parganas
West Bengal, India

He died on 23, December 1994 at the age of 28, and his death certificate shows chronic arsenic toxicity and cardiac failure.

(2) A few months before his death, another male arsenic patient (who died of cancer, Photo. 2) wrote a letter to one of the authors (D. C).

Dear Sir,

Hope you are well. Last time you came close to my village, I could not go to see you and the main reason, I was very ill and the sore on my sole has increased. Sir, I am depending on you. You can save me and my family. You know I have two small kids. If I will not survive, they will die. Please save me and my family from starvation. I am totally depending on you.

Yours,

A male patient
Ambikanagar, Deganga
North 24-Parganas
November 2, 1995

Photo. 2. Social problem: An arsenic pateint Makhan Pal (who died of cancer) and his family; Village-Ambikanagar.

He died on 29, July 1997 and his death certificate shows squamous cell carcinoma. These are a few of the thousands of such cases in arsenic-affected villages of West Bengal and Bangladesh.

6. How to Combat the Present Arsenic Crisis

To combat the present arsenic crisis, we urgently need the following: (1) No more tubewells should be installed in contaminated areas until all of the installed tubewells are checked for arsenic contamination. The government should make and implement strict regulations for boring tubewells. Around 90% of the people in West Bengal and Bangladesh depend on water from tubewells for drinking. There are about 3–4 million hand tubewells in the arsenic-affected districts of West Bengal and 8–10 million tubewells in Bangladesh. In contaminated areas, mouths of all safe tubewells must immediately be colored green and the unsafe ones red so that the villagers can use green tubewells for drinking and cooking and the red tubewells for bathing, washing, toilet and other needs. We have evidence from West Bengal that more and more tubewells which were once safe to drink are becoming contaminated with arsenic. The safe tubewells should be tested for arsenic every 3–6 months to discover new contamination; (2) Proper watershed management is essential; (3) traditional water management like dug-wells, the three Kalsi system and rainwater harvesting take care of bacterial and other chemical contamination; (4) People should be made aware of the arsenic calamity and they must be made to realize that it is not a curse of God or the consequences of the wrath of God; (5) Old Indian custom recommends that water be drunk after it has been allowed to stand overnight and then filtered through a piece of fine cloth. Villagers are advised to collect the water and then dip a piece of aluminum wrapped in a clean white cloth for two or three seconds, keep the water overnight and then filter it through a fine cloth (or a filter candle for those who can afford one) the next morning. (It has been noticed that) More than 70% of the arsenic in the water obtained from tubewells high in iron content is removed by this procedure. The principle is that, on being kept overnight, the iron in the water is precipitated as ferric hydroxide, and the aluminium as aluminium hydroxide, and arsenic is co-precipitated and hence removed. This procedure is suggested for those who have no available source of arsenic-free tubewell water or have not yet analyzed their tubewell water. The procedure will not work where the water contains a very small amount of iron and a high degree of arsenic. A simple test to know whether tubewell water contains a high proportion of iron is to pump out some water and let it stand for some time. If it contains a lot of iron, it will turn hazy and become a brownish color. This is very common in the tubewell water in the arsenic-affected districts; and (6) we must understand that so far there is no available medicine for chronic arsenic toxicity; safe water, nutritious food, vitamins and physical exercise are the only preventive measures to fight chronic arsenic toxicity. Plenty of seasonal fruits and vegetables are available in Bangladesh and West Bengal year-round. A large percentage of villagers are not aware that they can get better nutrition from local fruits and vegetables. Most villagers cook vegetables in such a way that their nutritional value is lost. We have to teach villagers how they can get nutritious food using local seasonal fruits and vegetables. It is not necessary to eat fish, meat, eggs, apples, and grapes, which poor villagers cannot afford. The elephant is the

strongest animal and the gorilla is the strongest mammal, and both are vegetarian; (7) The scientific community and medical workers all over the world should come forward to find a solution to the problem that has put more than 100 million people at risk of arsenic contamination in West Bengal and Bangladesh alone.

The mistakes that we made in the past that occur even today are the merciless exploitation of groundwater for irrigation without ever trying to adopt effective watershed management to harness our huge surface water resources and rainwater. In West Bengal and Bangladesh, we have huge surface water resources of fresh water such as rivers, wetlands, flooded river basins and ox-bow lakes. The surface water available per capita in Bangladesh is about 11,000 cubic meters. These two delta areas are known as the land of rivers and have approximately 2000-mm annual rainfall. Instead of using these resources, we are withdrawing groundwater without proper management. Proper watershed management and villagers participation are needed to assist the proper utilization of these huge bodies of water.

We are currently moving toward extracting more and more groundwater. Even during the summer we extract groundwater through deep tubewells for irrigation. From the West Bengal and Bangladesh experience we know now that even deep tubewells are not safe in arsenic-contaminated areas. We analyzed almost all 374 samples of water from deep tubewells (depth greater than 100 m) from Deganga block of North 24 Paraganas, West Bengal. The results show 13.9% of the samples have concentration of arsenic above 50 mg/L. In many districts of West Bengal and Bangladesh, most of the aquifers are unconfined and they run a greater risk of contamination. Only in the southern part of West Bengal and Bangladesh are thick clay barriers present which can be used for deep tubewells when taking all precautions during installation against other possible contaminants. It must be realized that water held in deep aquifers takes decades, even centuries, to accumulate and recent rainfall does not replenish these resources. In Rajasthan, India, it was recently discovered that an aquifer, which nature took nearly 10,000 years to create, was exhausted within 10 months by unwise people who extracted that water for agriculture. Should we take fluoride and arsenic in groundwater as nature's preliminary warning about more dangerous toxins yet to come?

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