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Arsenic Health Impacts to the People in Bangladesh

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ABSTRACT

In a period from 1995 to 2000, we had collected and analyzed 33,092 hand tube well water samples from four different/principal geomorphological regions (Hill tract, Table Land, Flood Plain, and Deltaic reason) i.e., from all 64 districts of Bangladesh and found arsenic in 60 districts that were above the WHO recommended value in drinking water (10 µg/L) and 50 districts that were above the maximum permissible limit, 50 µg/L.

In our study for 6 years in Bangladesh, the survey for identification of arsenical patients was conducted by our group with a medical team in 261 villages of 80 police stations under 33 districts out of 50 where contamination of groundwater with arsenic is above 50 µg/L. We could not identify people suffering from arsenical skin lesions who drunk water below 100 µg/L of arsenic.

During this survey, arsenic patients were identified in 222 villages of 69 police stations under 31 out of 33 districts. The number of people we examined including children was 18,840, and 3,725 people were identified with arsenical skin lesions. We had registered 1,885 males, 1,542 females, and 298 children out of the total 3,725 patients, having arsenical dermal lesions, such as: melanosis, leucomelanosis, keratosis, hyperkeratosis, dorsal, non-petting oedema, gangrene, cancer, etc. If children are included, then 19.77% (n=3,725) have arsenical dermal lesions, and for separately adults and children, these are 24.52% and 6.13%, respectively. Buccal mucus membrane melanosis (MMM) on tongue, gums, lips, etc. was also found. Rough dry skin often with palpable nodules (spotted keratosis) on dorsal of hand, feet, and legs are the symptoms seen in severe cases.

Sometimes, other symptoms are also found (1) conjunctival congestion and (2) non-petting swelling (solid oedema) of feet. Complications like liver enlargement (hepatomegaly), spleen enlargement (splenomegaly) and fluid in abdomen are seen in severe cases. Squamous cell carcinoma, basal cell carcinoma, Bowen's disease, carcinoma affecting lung, uterus, bladder, genitourinary tract, or other sites are often seen in advanced neglected cases suffering for many years. During our preliminary field survey in Bangladesh, we could identify 25 carcinoma /gangrene patients out of 3,725 patients. In addition to the above symptoms, we observe some common problems in arsenic patients with arsenical skin lesions such as intolerance to sunlight, burning sensation on whole body, weakness, and respiratory problem.

In children, our 6 years of field experience in Bangladesh show that normally children under 11 years of age do not show arsenical skin manifestations. However, we have observed a few exceptions when (1) the arsenic content in water consumed by children is very high (1000 µg/L) and (2) the arsenic content is not very high (around 500 µg/L), but the children get poor nutrition. The youngest arsenic patient was a child (age 18 months) with melanosis (+) and keratosis (++) [spotted on palm and sole] who was found in Payerpur village under Madaripur Sadar police station in Madaripur district. While discussing with his mother, I came to know that the child used to drink a very high quantity of water (2-3 liters per day) from childhood.

So far, we had examined 4,864 children, below 11 years of age, drinking arsenic contaminated water from the arsenic affected villages in Bangladesh and out of that arsenical skin lesions registered from 298 children (6.12%) whereas in adults it is 24.47%. Normally, arsenical skin lesions observed in children are diffuse melanosis and spotted melanosis. Keratosis on the palm and sole are not common in children. We have not found children suffering from+++ stage of melanosis and keratosis (we used mild+, moderate to high++, severe+++). Also, we have not found any child patient during studied years (1995 to 2000) in Bangladesh, below 11 years of age, with non-pitting oedema, gangrene, Bowens, dorsal, or cancer.

In addition to common arsenical symptoms, we also observed dorsal (15%), chronic bronchitis (30%), and vitamin deficiency among the under-poverty line family members, but such type of symptoms was not observed to the members in rich family. Children at the age around 11 years in that family had no arsenical skin lesions. The arsenic concentration in their drinking water of the tube well was 570 µg/L. But six children out of seven, around 11 years of age, were found with arsenical skin lesions in the under-poverty line family. The youngest victim was 8 years old, and the arsenic concentration in drinking water being used by this family was 690 µg/L.

Our field experience in Bangladesh, we have observed that among the adults suffering from diffuse melanosis and light spotted melanosis can recover after drinking safe water, eating nutritious food, and taking vitamins. Normally diffused melanosis disappears easily after drinking safe water, and light keratosis (+) may also disappear. But if keratosis is appreciably visible (++), drinking safe water and eating nutritious food may reduce it, but it may not disappear. In arsenic patients with moderate to severe (++ and +++) keratosis, the appearance of keratosis does not stop even after drinking safe water over a long period of time and even when hair, nail, and skin scales contain safe levels of arsenic.

We have further observed that children recover from diffuse melanosis (blackening of color) and light spotted melanosis (+) quickly if they use safe water, have better nutrition, and eat vitamins. Mild keratosis (+) also disappears, but the children having moderate to high spotted melanosis (++) and spotted keratosis (++), even after drinking safe water and nutritious food, do not recover completely. We had found diffuse melanosis in children disappear, and those who had spotted melanosis (+) and keratosis (+) are no longer showing skin lesions. Those who had ++ spotted melanosis and ++ spotted keratosis could not get rid of their skin lesions, and spotted melanosis is replaced by Leucomelanosis, and keratosis is less. However, the children are still complaining about their weaknesses, breathing problems, and suffering from cough and cold.

Finally, if it is accepted that children are at a higher risk due to arsenic exposure, then the future of the next generation in Bangladesh living in arsenic affected villages may be grim as above 84% and 89% of the children's hair and nail contain arsenic above toxic (hair) or normal level (nail), respectively. Therefore, it is very important to monitor the concentration of arsenic in their drinking water and in biological samples (hair and nail) even though they are drinking arsenic free deep tube wells water now.

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Introduction

In our study in Bangladesh (1995-2000), we had analyzed 33,092 hand tube well water samples from all 64 districts and found arsenic in 60 districts above the WHO recommended value in drinking water (10 µg/L) and in 50 districts above maximum permissible limit, 50 µg/L. This does not mean that the total population in these 50 districts are drinking arsenic contaminated

water and suffering from arsenicosis, but undoubtedly, they are at risk. Patients with arsenical skin lesions are expected in 50 out of 64 administrative districts in Bangladesh, where we have found arsenic in groundwater above 50 µg/L.

Literatures survey show that arsenic concentration in the body tissues and fluids increase as arsenic concentration in the drinking water increases^{1,2}. Arsenic concentration is higher in hair and nails than in other parts of the body because of the high content of keratin, the SH groups of which might bind trivalent inorganic arsenic³⁻⁵.

Ingestion of inorganic arsenic is now an established cause of skin cancer⁶⁻⁸. Recent studies provide evidence that ingestion of arsenic can also cause cancers of the lung and the urinary bladder. According to WHO⁶, 1.0 mg of inorganic arsenic per day may give rise to skin effects within a few years. It has been estimated that based upon the current U.S. Environmental Protection Agency (EPA) standard of 50 µg/L, the lifetime risk of dying from cancer of the liver, lung, kidney, or bladder, from drinking 1 liter per day of water could be as high as 13 per 1000 persons⁷. In the latest document on arsenic in drinking water, U.S. National Research Council (NRC)⁸ concluded that exposure to 50 µg/L could easily result in a combined cancer risk of 1 in 100.

In this paper, I will report (a) arsenic impact/toxic effects to the people due to drinking arsenic contaminated underground

water in Bangladesh, (b) arsenic effects to the people in rich family members versus under-poverty line family members, and (c) children are at risk in arsenic affected areas of Bangladesh.

Groundwater arsenic status in Bangladesh

In a period from 1995 to 2000, we had collected and analyzed 33,092 hand tube well water samples from four different/principal geomorphological regions (Hill tract, Table Land, Flood Plain, and Deltaic reason) i.e., from all 64 districts of Bangladesh (Fig. 1) and found arsenic in 60 districts that were above the WHO recommended value in drinking water (10 µg/L) and 50 districts that were above the maximum permissible limit^{2,9} 50 µg/L. In some areas of Bangladesh, the arsenic concentration in groundwater is minimum, some parts are almost arsenic contamination free, and others are highly arsenic contaminated (Fig. 2). Figure 3 shows the distribution of arsenic in tube wells water of 50 arsenic affected districts in Bangladesh, and Table 1 shows the overall status of arsenic in groundwater in all 64 districts of Bangladesh.

Table 1. Overall arsenic situation in underground tube wells water in Bangladesh

Parameters	
Total no. of districts in Bangladesh	64
No. of districts we had surveyed	64
No. of districts where arsenic in groundwater > 10 µg/L	60
No. of districts where arsenic in groundwater > 50 µg/L	50
Total no. of police stations	490
No. of police stations we had surveyed	299
No. of police stations we had found arsenic > 10 µg/L	205
No. of police stations we had found arsenic > 50 µg/L	178
Total no. of villages in Bangladesh	68,000
No. of villages we had surveyed	2,900
No. of villages we had found arsenic > 10 µg/L	2,500
No. of villages we had found arsenic > 50 µg/L	1,955
Total no. of groundwater samples we had collected and analyzed	33,092
Percent (%) of groundwater samples having arsenic > 10 µg/L	56.35
Percent (%) of groundwater samples having arsenic > 50 µg/L	37.38
Percent (%) of groundwater samples having arsenic > 1000 µg/L	0.82
Highest arsenic concentration found in groundwater (µg/L)	4,730
No. of total deep tubewells (≥100 meters depth) water samples analyzed	1,217
Percent (%) of deep tubewells water samples having arsenic > 10 µg/L	26.87
Percent (%) of deep tubewells water samples having arsenic > 50 µg/L	8.71
Depth of the tubewells for safe water (arsenic concentration <3 µg/L)	≥ 350 meters

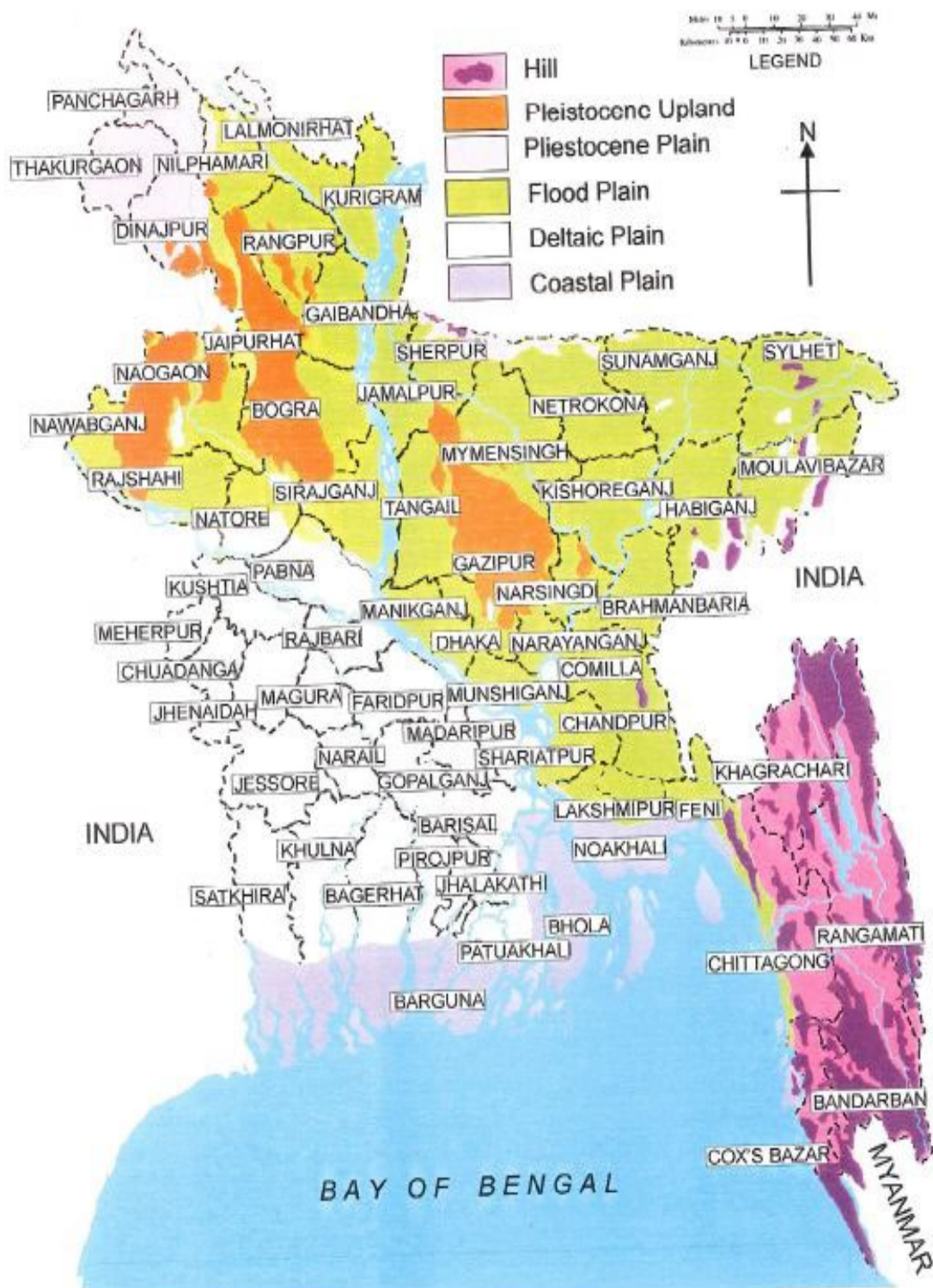


Figure1. Four principals geomorphological reasons in Bangladesh.

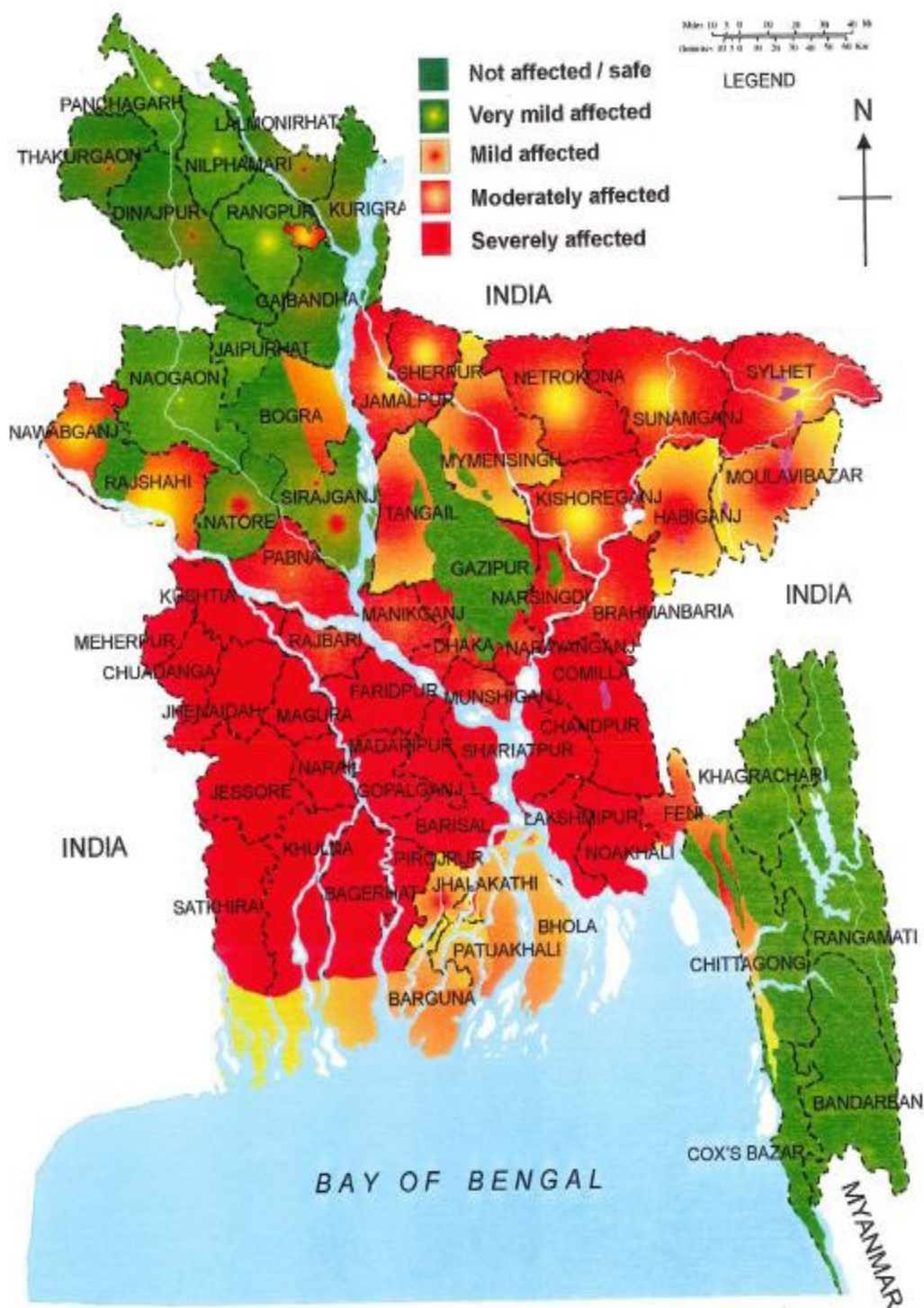


Figure 2: Groundwater arsenic status in all 64 districts of Bangladesh

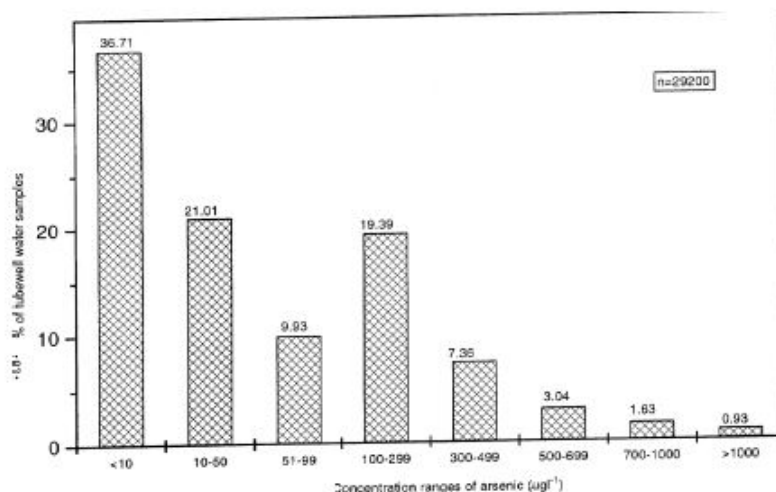


Figure 3. Distribution of arsenic in tube wells water of 50 arsenic affected districts in Bangladesh

Overall arsenic patients and biological samples status in 33 districts of Bangladesh

In our study for 6 years in Bangladesh, the survey was conducted by our group with a medical team (at least one dermatologist and one general physician/pediatric) in 261 villages (Vill.) of 80 police stations (PS) in 33 out of 50 districts (Dist.)

where contamination of groundwater with arsenic is above 50 $\mu\text{g/L}$. During our survey, we had also collected hair, nails, skin scales (skin scales from those having keratosis), and urine samples from the people of these villages. Biological samples were collected from 40-50% of those having skin lesions, and the rest of the samples were from those without skin lesions. Parametric presentation of arsenic situation (from six years study) in Bangladesh is shown in Table 2.

Table 2: Parametric presentation of arsenic situation in Bangladesh

	Parameters	
01	Total no. of districts in Bangladesh	64
02	No. of district we have surveyed	64
03	No. of districts where arsenic in groundwater > 10 $\mu\text{g/L}$	60
04	No. of districts where arsenic in groundwater > 50 $\mu\text{g/L}$	50
05	No. of districts where we have surveyed for arsenic patients	33
06	No. of districts where we have identified for arsenic patients	31
07	No. of police stations surveyed for arsenic patient	77
08	No. of police stations where we have identified arsenic patient	69
09	No. of villages surveyed for arsenic patient	253
10	No. of villages where we have identified arsenic patient	222
11	Total no. of people examined for arsenic patient	18,840
12	No. of patients identified	3,725
13	Total no. of adults examined	13,976
14	No. of adults' patient identified	3,420 (24.47%)
15	Total No. of children examined	4,864
16	No. of children patient identified	298 (6.12%)
17	Total No. of hair samples analyzed	4,386
18	Percent (%) of hair samples content arsenic above toxic level	83%
19	Total No. of nail samples analyzed	4,321
20	Percent (%) of nail samples content arsenic above normal level	94%
21	Total No. of urine samples analyzed	1,084
22	Percent (%) of urine samples content arsenic above normal level	95
23	Total No. of skin scales samples analyzed	705
24	Arsenic concentration range in skin scales samples with mean value	600 to 53,390 $\mu\text{g/kg}$ (mean value 5,730 $\mu\text{g/kg}$)

During this survey, arsenic patients were identified in 222 villages of 69 police stations under 31 out of 33 districts. The

following map shows the districts where survey was conducted, and arsenic patients identified in Bangladesh (Fig. 4). The number

of people we examined, including children, was 18,840 and 3,725 people who were identified with arsenical skin lesions. Table 3

shows our overall findings of the arsenic patients among adults and children in different districts.

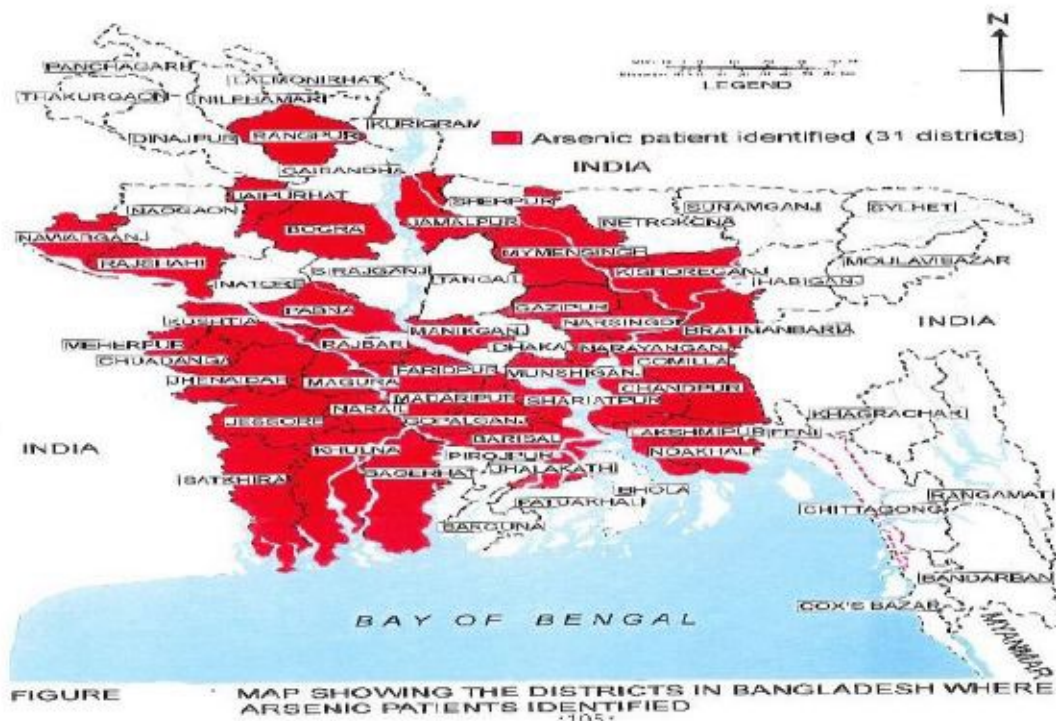


Figure 4. This map shows the districts (red) in Bangladesh where arsenic patients identified

Normally, there were 6-8 people in our team, including at least 2 medical personnel. However, I feel the number of days we spent surveying in 34 districts were negligible compared to the number of days needed. In most of the cases, we superficially surveyed the villages for patients without any in-depth study. Sometimes, due to time constraint, we had to leave one village for the next village without recording patients. At present (during the study period, 1995-2000), we have information of about 74 more villages where people have arsenical skin lesions, but we could not visit those sites. From our experience of the last 6 years from arsenic affected districts in Bangladesh, we feel we have identified only a small percentage (40-50%) of those having skin lesions, and the rest of the people were from those without skin lesions. After discussing with villagers, it appeared that 15-20% of the total number of people suffering from arsenicosis really came to the arsenic camp for examination. This is due to the following reasons:

- In villages, the affected people think their disease is contagious, and if other people get to know about their ailment, they will be isolated
- Young girls do not want to be examined and the obvious reason is that they may face difficulties during their marriage
- Young girls and women of conservative families do not want to be examined (Photograph 1)
- People are frustrated and feel that they will not be cured in the future of this disease
- Since village roads condition are not good, people who are suffering seriously did not want to come to our camp after travelling a long distance due to physical weakness
- Normally we were in a village during the day, and most of the males were in the field for work at that time of the day

Arsenic patients identified among the people in Bangladesh

People suffering from arsenical dermal lesions have been identified in 31 out of 33 districts where we had made a preliminary dermatological investigation with a medical team. From a random of 18,840 examination people in arsenic affected villages where people were drinking arsenic contaminated water during the last 6 years and 3,725 people were identified with

arsenical skin lesions (Fig. 5). We had registered 1,885 males, 1,542 females, and 298 children out of total 3,725 patients, having arsenical dermal lesions (Fig. 6), such as: melanosis, leucomelanosis, keratosis, hyperkeratosis, dorsal, non-petting oedema, gangrene, cancer, etc. If children are included, then 19.77% (n=3,725) have arsenical dermal lesions, and for

separately adults and children, these are 24.52% (Fig. 7) and 6.13% (Fig. 8), respectively. Figure 9 shows the distribution of

arsenical dermal lesions among 3,725 patients (including children) in 31 districts of Bangladesh.

Table 3. Shows the overall findings of the arsenic patients among adults and children in different districts of Bangladesh

Name of the districts (Dist)	Area in sq.km	No. of police stations (P.S.)	Population	No. of police stations surveyed	No. of police stations where patients identified	No. of villages surveyed	No. of villages where patients identified	No. of people examined	No. of patients identified	Adult male patients	Adult female patients	Child patients
Bagerhat	3959	9	1611000	2	2	9	9	670	200	133	60	7
Barisal	2791	10	2481000	3	2	5	5	358	57	25	32	-
Bogra	2920	11	3053000	1	1	1	1	280	21	6	11	4
Chuadanga	1158	4	921000	1	1	7	3	219	119	53	48	18
Chandapur	1704	7	2309000	6	5	33	33	1605	157	98	55	4
Camilla	3089	12	4751000	4	4	6	6	509	68	32	29	7
Faridpur	2073	8	1678000	3	3	14	13	804	151	76	60	15
Gopalganj	1490	5	1169000	4	2	7	7	267	34	14	15	5
Gazipur	1741	5	1899000	1	1	1	1	92	7	5	2	-
Jessore	2567	8	2387000	5	4	9	9	1871	476	187	218	71
Jhenaidaha	1961	6	1540000	2	2	2	2	235	56	33	19	4
Jamalpur	2032	7	2111000	1	1	3	3	222	79	35	35	9
Kushtia	1621	6	1691000	3	3	15	15	891	240	108	94	38
Khulna	4395	14	2417000	2	2	5	5	684	105	60	36	9
Kishoreganj	2689	13	2574000	1	1	3	3	307	18	14	4	-
Lakshmipur	1456	4	1502000	3	3	27	25	2283	521	314	191	16
Meherpur	716	2	555000	2	1	11	7	580	190	103	64	23
Madaripur	1145	4	1185000	3	3	11	9	1038	81	24	57	1
Magura	1049	4	815000	3	3	3	3	296	41	15	21	5
Munshiganj	955	6	1309000	1	1	2	2	27	5	1	4	-
Mymensing	4363	12	4450000	1	1	8	1	46	3	2	1	-
Manikganj	1379	7	1293000	3	2	7	3	103	8	3	2	3
Nawabganj	1702	5	1346000	2	2	7	7	459	212	119	88	5
Narsingdi	1141	6	1864000	3	2	2	2	178	12	8	3	1
Narayanganj	759	5	2013000	1	1	11	8	602	93	46	44	3
Noakhali	3601	6	2547000	3	3	13	13	1246	216	86	120	10
Pabna	2371	9	2266000	5	5	19	16	1860	342	171	146	25
Rajshahi	2407	13	2255000	3	3	5	5	443	107	52	43	12
Rajbari	1119	4	941000	1	1	2	2	103	8	4	4	-
Rangpur	2308	8	2475000	1	1	2	1	297	38	25	10	3
Satkhira	3858	7	1780000	3	3	3	3	266	60	34	26	-
TOTAL=31	66515	227	61188000	77	69	253	222	18840	3725	1885	1542	298

Arsenical dermal lesions among the people in Bangladesh

Figure 9 shows the distribution of arsenical dermal lesions among 3,725 patients (including children) in 31 districts of Bangladesh. We had identified people with arsenical manifestation such as spotted melanosis on palm (SM-P), spotted melanosis on trunk (SM-T), diffuse melanosis on trunk (DM-T), leucomelanosis (Leuco), whole body melanosis (WB-M), spotted keratosis on palm (SK-P), diffuse keratosis on palm (DK-P), spotted keratosis on sole (SK-S), and diffuse keratosis on sole (OK-S). Buccal mucus membrane melanosis (MMM) on tongue,

gums, lips, etc. was also found. Rough dry skin often with palpable nodules (spotted keratosis) on dorsal of hand, feet, and legs are the symptoms seen in severe cases.

Other symptoms sometimes found are (1) conjunctival congestion and (2) non-petting swelling (solid oedema) of feet. Complications like liver enlargement (hepatomegaly), spleen enlargement (splenomegaly) and fluid in abdomen (ascites) are seen in severe cases. Squamous cell carcinoma, basal cell carcinoma, Bowen's disease, carcinoma affecting lung, uterus, bladder, genitourinary tract, or other sites are often seen in advanced neglected cases suffering for many years. During our preliminary field survey in Bangladesh, we could identify 25

carcinoma /gangrene patients out of 3,725 patients (Table 4). We heard from villagers that there were cancer deaths for those who had arsenical skin lesions.



Figure 5: The percentage of the arsenical people identified

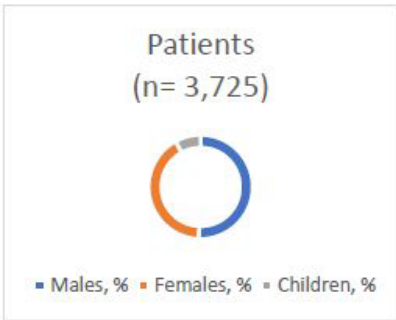


Figure 6: The percentage of the male, female, and children's patients identified

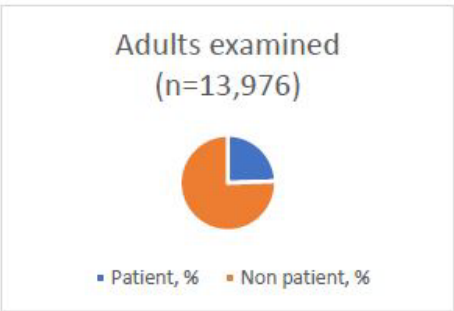


Figure 7: The percentage of patients and non-patients among the adults

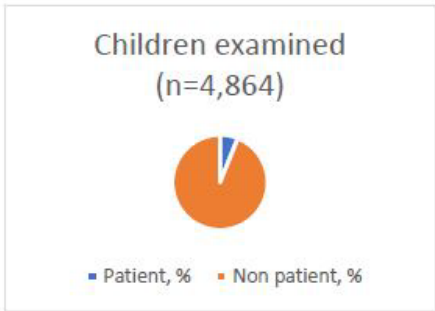


Figure 8: The percentage of patients and non-patients among the children

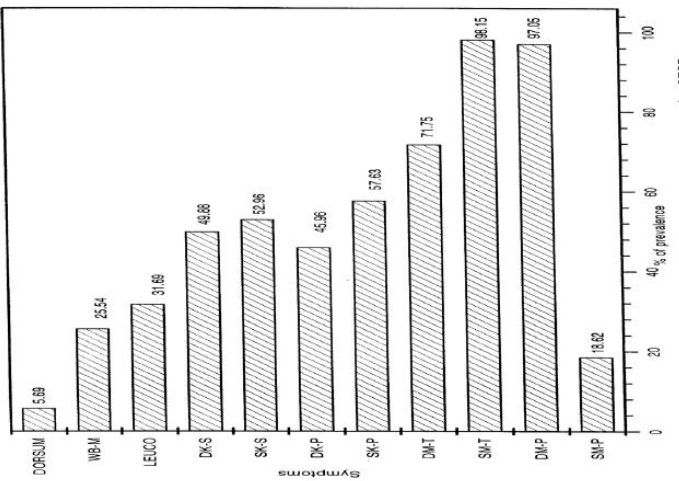


Figure 9: Distribution of arsenical skin lesions [Dorsum, WB-M (Whole Body Melanosis), Leuco, DK-S (Diffuse Keratosis-Sole), SK-S (Spotted Keratosis-Sole), DK-P (Diffuse Keratosis-Palm), SK-P (Spotted Keratosis-Palm), DM-T (Diffuse Melanosis-

Trunk), SM-T (Spotted Melanosis-Trunk), DM-P (Diffuse Melanosis-Palm), and SM-P (Spotted Melanosis-Palm)] among the 3,725 patients in 31 districts of Bangladesh

Table 4: Dermatological features of 10 carcinoma/gangrene patients out of 25 patients from different arsenic affected districts of Bangladesh.

SL#	Districts	Sex & age	Melanosis						Keratosis					Carcinoma
			Palm		Trunk		Leuco	Whole body	Palm		Sole		Dorsal	
			Spotted	Diffuse	Spotted	Diffuse			Spotted	Diffuse	Spotted	Diffuse		
1	Pabna	M,58	-	-	++	+	+	+	++	+	++	+	+	Cancer
2	Lakshmipur	F,50	-	+	++	+	+	+	++	-	++	+	-	Gangrene
3	Meherpur	M,36	-	-	++	+	+	+	++	++	++	++	+	Gangrene
4	Faridpur	M,45	+	+	+++	++	+	++	++	+	++	++	-	Gangrene
5	Meherpur	M,33	-	-	+++	++	-	++	+++	++	+++	++	+	Cancer
6	Meherpur	M,50	-	-	++	+	+	++	+++	++	+++	++	-	Cancer
7	Meherpur	M,70	-	+	+++	++	+	++	+++	++	+++	++	+	Ulcer
8	Pabna	F,15	+	+	++	+	-	+	++	-	+++	-	-	Cancer
9	Lakshmipur	M,45	-	-	++	-	+	-	++	++	++	++	+	Gangrene+Cancer
10	Lakshmipur	M,27	-	+	++	+	+	+	-	-	+	+	-	Gangrene

Table 5 shows the dermatological features of 31 patients from 31 arsenic affected districts of Bangladesh, and Photographs 2 to 32 from different arsenic affected districts of Bangladesh. These photographs show all possible arsenical skin manifestation. It is noticed that arsenical skin lesions never appear on the face (except diffuse melanosis).



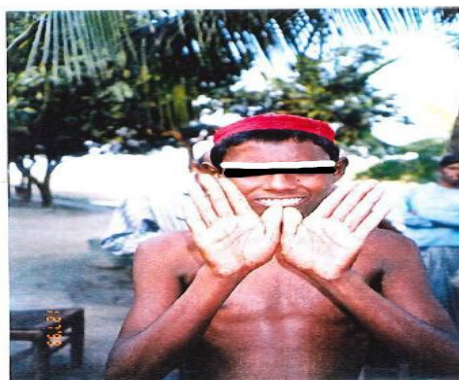
Photograph 1



Photograph 2

Table 5: Dermatological features of 31 patients from 31 arsenic affected districts of Bangladesh (One patient from each district)

SL #	Districts	Sex& age	Melanosis						Keratosis				Dorsal	Non petting Oedema	Conjunctival congestion	Bowen's	Carcinoma
			Palm		Trunk		Leuco	Whole body	Palm		Sole						
			Spotted	Diffuse	Spotted	Diffuse			Spotted	Diffuse	Spotted	Diffuse					
1	Bagerhat	M,28	+	++	++	++	-	++	++	++	++	+	-	-	-	-	-
2	Bogra	F,36	-	+	++	++	-	++	+++	++	++	+	-	-	-	-	-
3	Barisal	M,45	+	++	++	+	-	++	++	++	+	+	-	-	-	-	-
4	Chuadanga	M,30	-	+	+++	++	+	++	++	+	+++	++	-	+	-	-	-
5	Chandpur	M,29	+	+	++	++	-	++	++	-	++	++	-	-	-	-	-
6	Comilla	M,30	-	-	++	+	-	+	+++	++	+++	+	-	-	-	-	-
7	Faridpur	F,35	-	+	++	++	-	++	++	-	++	+	+	+	-	-	-
8	Gopalganj	M,22	-	-	++	+	-	+	++	++	++	++	++	-	-	-	-
9	Gazipur	M,35	-	-	++	+	-	+	++	-	++	+	-	-	-	+	-
10	Jessor	F,14	-	+	++	+	-	++	++	+	++	+	-	-	-	-	-
11	Jhnaidaha	M,14	-	+	++	+	-	+	++	++	++	++	+	+	-	-	-
12	Jamalpur	M,33	+	+	++	++	+	+	++	++	+	+	-	-	-	-	-
13	Kushtia	M,70	-	+	++	++	++	+	++	-	++	++	-	-	-	-	-
14	Khulna	F,23	-	+	+++	+	+	++	+++	-	++	+	-	+	+	-	-
15	Kishoreganj	M,20	-	-	+	+	+	-	+	-	+	+	-	-	-	-	MMM
16	Lakshimpur	F,28	-	+	+++	++	+	+++	+++	++	+++	+++	-	++	+	-	-
17	Meherpur	M,33	-	-	+++	++	-	++	+++	++	+++	++	+	-	-	-	Ulcer
18	Magura	F,26	-	+	++	+	+	+	+++	+	+++	+	-	-	-	-	-
19	Madaripur	F,35	-	+	++	+	+	+	++	++	++	++	+	-	-	-	-
20	Munshiganj	F,28	-	+	++	+	-	+	++	+	++	+	-	-	-	-	-
21	Mymensingh	M,40	-	-	++	+	+	+	++	+	++	+	+	-	-	-	-
22	Manikganj	F,37	-	-	+	+	+	-	++	++	+	+	+	-	-	-	-
23	Nawabganj	M,20	-	+	++	++	+	+	+	-	+	-	-	-	-	-	MMA
24	Narayanganj	M,55	+	+	+	+	+	+	+++	++	+++	++	+	-	-	-	-
25	Narsingdi	M,42	+++	+	+	-	-	-	+++	++	+++	++	-	-	-	-	-
26	Noakhali	F,33	-	+	++	+	-	++	++	+	++	+	+	+	-	-	-
27	Pabna	M,58	-	-	++	+	+	+	++	+	++	+	+	-	-	-	Cancer
28	Rajbari	M,25	+	+	++	+	+	+	++	+	++	++	+	-	-	-	-
29	Rajshahi	F,26	-	-	++	+	+	+	++	+	++	+	-	-	-	-	MMM
30	Rangpur	M,30	-	-	++	+	+	-	++	+++	++	+++	++	-	-	-	MMM
31	Satkhira	M,25	-	-	+++	++	++	+	+	++	++	++	+	-	-	-	-



Photograph 3



Photograph 4



Photograph 5



Photograph 6



Photograph 7



Photograph 8



Photograph 9



Photograph 10



Photograph 11



Photograph 12



Photograph 13



Photograph 14



Photograph 15



Photograph 16



Photograph 17



Photograph 18



Photograph 19



Photograph 20



Photograph 21



Photograph 22



Photograph 23



Photograph 24



Photograph 25



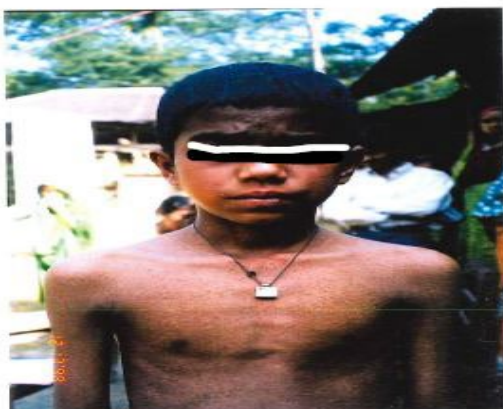
Photograph 26



Photograph 27



Photograph 28



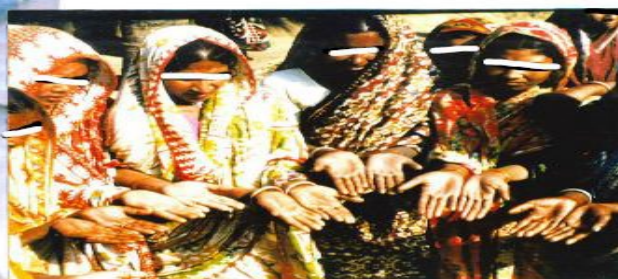
Photograph 29



Photograph 30



Photograph 31



Photograph 32

Photography Captions:

Photograph-1	A conservative family not willing to exhibit their skin lesions
Photograph-2	Squamous cell carcinoma (SCC) on leg
Photograph-3	Whole body melanosis
Photograph-4	Spotted keratosis on doles
Photograph-5	Arsenic affected children
Photograph-6	An arsenic affected family
Photograph-7	Melanosis on trunk
Photograph-8	Arsenic affected male patient
Photograph-9	A group of young arsenic affected male patients
Photograph-10	Whole body melanosis and Keratosis on palms
Photograph-11	Spotted melanosis and suspected Bowen's
Photograph-12	Spotted melanosis on trunk
Photograph-13	Spotted melanosis on trunk
Photograph-14	Leucomelanosis
Photograph-15	Dorsal keratosis
Photograph-16	Spotted/ Diffuse Keratosis
Photograph-17	Keratosis
Photograph-18	Severe Keratosis on palms and soles
Photograph-19	Arsenic affected people
Photograph-20	Dorsal keratosis
Photograph-21	Spotted keratosis on palm and sole
Photograph-22	Arsenic affected child
Photograph-23	Spotted melanosis on trunk and keratosis on soles
Photograph-24	An arsenic affected family
Photograph-25	Diffuse melanosis
Photograph-26	A severe arsenic affected patient
Photograph-27	Severe melanosis on trunk and keratosis on soles
Photograph-28	Whole body spotted and diffuse melanosis
Photograph-29	Spotted melanosis on trunk
Photograph-30	Severe Keratosis on palms and soles
Photograph-31	A severe arsenic affected patient
Photograph-32	A group of arsenic affected women

In addition to the above symptoms, we observe some common problems in arsenic patients with arsenical skin lesions such as intolerance to sunlight, burning sensation on whole body, weakness, and respiratory problem.

Normally, we found arsenical skin lesions among adult villagers in Bangladesh when water contains arsenic above 300 µg/L. The average water intake is 3.5-4.0 liters per day for adults^{10,11}. However, if the nutrition status is poor, lower arsenic levels may cause arsenical skin lesions, and if the nutrition status is good, even above 300 µg As/L may not show arsenical skin lesions. We could not identify people suffering from arsenical skin lesions who drank water below 100 µg/L of arsenic. Children younger than 11 years of age normally do not exhibit arsenical skin lesions.

Exception is found where the arsenic concentration in water is very high (>1000 µg/L) or when the arsenic concentration is low (around 500 µg/L), but the children get poor nutrition¹².

Arsenic effects to the people in a rich family versus an under-poverty line family member

We have plenty of such examples:

It was observed that an arsenic affected family in Bheramara police station of Kushita district, started drinking their tube well water from 1971 and began noticing skin lesions from 1990. Out

of 28 people in the family in the age range of 5 to 80 years, most of the adults (n=18) had arsenical skin lesions. The youngest victim was Sahadul (M/14 years), who got skin lesions in 1997. Children at the age around 11 years in that family had no arsenical skin lesions. The arsenic concentration in drinking water of the tubewell was 570 µg/L. They are a rich family (Photograph 33) of that area and get better nutrition. Basal Metabolic Index (BMI) also shows good nutrition.

Further, under the Meherpur Sadar police station in Meherpur district, there is an under-poverty line family comprising 22 members in the age range of 6 to 60 years. Twenty-one (21) numbers out of 22 have arsenical skin lesions. Six children out of seven around 11 years of age were found with arsenical skin lesions (Table 6). The youngest victim was Mafiza (F/ 8 years). The arsenic concentration in drinking water being used by this family was 690 µg/L. The family is under-poverty line (Photograph 34). The food habit and Basal Metabolic Index (BMI) also shows poor nutrition. In addition to common arsenical symptoms, we also observed dorsal (15%), chronic bronchitis (30%), and vitamin deficiency among the under-poverty line family members, but such type of symptoms was not observed to the members in rich family of Kushita district (Photograph 33).



Photograph 33. A rich family, PS: Bheramara, Dist: Kushtia

Table 6: Dermatological manifestation of a group of children in an under-poverty line family in Meherpur Sadar police station of Meherpur district of Bangladesh

Sl.No.	Sex & age	Melanosis						Keratosis			
		Palm		Trunk		Leuco	Whole body	Palm		Sole	
		Spotted	Diffuse	Spotted	Diffuse			Spotted	Diffuse	Spotted	Diffuse
CP1	M, 9	-	+	++	++	-	+	+	+	+	-
CP2	F, 9	-	+	+	+	-	-	-	-	-	-
CP3	F, 8	-	+	+	+	-	-	-	-	-	-
CP4	M, 9	-	+	++	+	-	-	+	-	+	-
CPS	M, 11	-	+	+	+	-	-	-	-	+	-
CP6	F, 10	-	+	+	-	-	-	-	+	-	-



Photograph 34. A poor family, PS: Meherpur sadar, Dist: Meherpur

Impact of arsenical skin lesions after drinking safe water, eating nutritious food, and taking vitamins

During the last 6 years of field experience in Bangladesh, we have observed that those suffering from diffuse melanosis and light spotted melanosis can recover after drinking safe water, eating nutritious food, and taking vitamins. Normally diffused melanosis disappears easily after drinking safe water, light keratosis (+) may also disappear. However, if keratosis is appreciably visible (++), drinking safe water and eating nutritious food may reduce it, but it may not disappear. In arsenic patients with moderate to severe (++ and +++) keratosis, the appearance of keratosis does not stop even after drinking safe water over a long period of time and even when hair, nail and skin scales contain safe level of arsenic (Photographs 35 and 36).



Photograph 35. Arsenic patients drinking arsenic contaminated underground water and they have skin lesions



Photograph 36. After drinking safe water over a few years, and hair, nail and skin scales contain safe level of arsenic, but he has still skin lesions

Children at risk in arsenic affected areas of Bangladesh

If we accept that the future of the world depends on its children, then all of us should try to protect them regardless of where they live. The exposure of children to environmental toxins and the resultant illness should be the concern of all. Arsenic toxicity is one example. Several studies over the years have shown that children are at higher risk of arsenic exposure¹³⁻¹⁸. Although children show less arsenical skin lesions than adults, they are more susceptible to arsenic toxicity¹⁹. Arsenic can damage the central nervous system; chronic encephalopathy symptoms include diminished recent memory and organic cognitive impairment²⁰. A recent study²¹ shows that the percentage of children in the average IQ group decreased remarkably from 56.8 (n = 44) to 40.0 (n = 95) as the arsenic level increased in hair.

Our last 6 years of field experience in Bangladesh show that normally children under 11 years of age do not show arsenical skin manifestations. However, we have observed a few exceptions when (1) the arsenic content in water consumed by children is very high (1000 µg/L) and (2) the arsenic content is not very high (around 500 µg/L), but the children get poor nutrition (Photographs 34 and 37). For example, photograph 34 shows a group of children under 11 years in a poor family having arsenical skin lesions [Bagoan village under the police station of Meherpur sadar, Meherpur, Bangladesh]. It was also observed that 21 members out of 22 (including 6 children out of 7) had arsenical skin lesions in this poor family. Table 6 shows the dermatological manifestation of these six children. The arsenic concentration in drinking water being used by this family was 690 µg/L. So far in Bangladesh, the youngest arsenic patient is a child (age 18 months) with melanosis (+) and keratosis (++) [spotted on palm and sole] was found in Payerpur village under Madaripur Sadar police station in Madaripur district (Photograph 38). While discussing with his mother, I came to know that the child used to

drink a very high quantity of water (2-3 liters per day) from childhood.

We had examined 4,864 children below 11 years of age drinking arsenic contaminated water from the affected villages of Bangladesh and out of that arsenical skin lesions registered from 298 children (6.12%), whereas in adults it is 24.47%. Normally, arsenical skin lesions observed in children are diffuse melanosis and spotted melanosis. Keratosis on the palm and sole are not common in children. A few exceptions are found when arsenic in drinking water is quite high 1000 µg/L and nutrition is also poor. However, we have not found children suffering from+++ stage of melanosis and keratosis (we used mild+, moderate to high++, and severe+++). We have not also found any child patient during the last 6 years in Bangladesh below 11 years of age with non-pitting oedema, gangrene, Bowens, dorsal, or cancer. Table 7 shows the dermatological manifestation of 24 child patients from 24 affected districts of Bangladesh (one child patient from each district) where we have identified child patients, and Figure 10 shows a comparison of dermatological symptoms of the adults and child patients in Bangladesh.

We also had analyzed hair, nail, and urine samples from children below 11 years of age from arsenic affected villages of Bangladesh. Table 8 shows a statistical comparison of arsenic in hair, nail, and urine of adults and children (both patient and non-patient). It appears that although 6.12% of 4,864 children showed arsenic skin lesions, but hair and nail analysis of children (below 11 years of age) with or without arsenical skin lesions from affected villages of Bangladesh showed that 84% of the children had arsenic in hair more than the toxic level and 89% in nail above normal level (Table 8). It appears that children living in arsenic affected villages have higher arsenic body burden but less dermatological symptoms. Table 8 also shows that the concentration (mean value) of arsenic in hair and nails of adults is

higher than that of children. For urinary arsenic, children are excreting more arsenic than that of adults.

Table 7: Shows the dermatological manifestation of 24 child patients from 24 affected districts of Bangladesh (one child patient from each district) where we have identified child patients

Sl.No.	Districts	Sex & age	Melanosis						Keratosis			
			Palm		Trunk		Leuco	Whole body	Palm		Sole	
			Spotted	Diffuse	Spotted	Diffuse			Spotted	Diffuse	Spotted	Diffuse
CP1	Lakshmipur	F,9	-	+	+	+	-	-	-	-	+	-
CP2	Jessore	F,5	-	+	++	+	-	+	+	+	+	+
CP3	Pabna	F, 10	-	+	++	+	+	+	+	+	+	+
CP4	Faridpur	F, 11	-	+	+	+	-	-	-	-	-	-
CP5	Chandpur	F, 9	-	+	+	+	-	-	-	-	-	-
CP6	Narayanganj	M, 10	+	+	+	+	-	-	+	-	+	-
CP7	Nawabganj	M, 10	-	+	++	+	-	-	-	-	-	-
CP8	Rajshahi	M, 10	-	+	-	+	-	+	+	+	+	+
CP9	Rangpur	F, 10	+	+	+	+	+	+	+	+	+	+
CP10	Meherpur	M, 10	-	+	+	+	-	-	+	-	+	+
CP11	Jhnsaidaha	F,9	-	+	+	+	-	-	-	-	-	-
CP12	Camilla	F, 11	-	+	+	+	-	-	+	-	+	-
CP13	Manikganj	M,11	-	-	+	+	+	-	+	-	+	-
CP14	Bagerhat	F, 10	-	+	+	-	-	-	-	-	+	-
CP15	Bogra	M,10	-	+	+	+	-	-	+	-	-	-
CP16	Chuadanga	M,8	-	+	++	+	-	+	-	+	-	-
CP17	Gopalganj	F,9	-	+	+	+	-	-	-	-	-	-
CP18	Jamalpur	M,9	-	+	++	+	+	-	+	-	+	-
CP19	Khulna	F,9	-	+	+	+	-	+	+	+	+	+
CP20	Madaripur	F,11	-	+	++	+	-	+	+	-	+	-
CP21	Magura	F, 10	-	+	++	+	+	+	-	-	+	-
CP22	Narsingdi	F,10	-	+	+	+	-	+	+	-	+	-
CP23	Noakhali	M,10	-	+	+	+	-	-	+	-	+	-
CP24	Kustia	F, 11	++	++	+	+	-	++	+	++	++	++

Table 8: Status of biological samples collected from the adults and children of arsenic affected villages in Bangladesh (about 40-50% of samples are from people having arsenical skin lesions)

Parameters	Adults			Children		
	Arsenic in Hair* ($\mu\text{g/kg}$)	Arsenic in Nail** ($\mu\text{g/kg}$)	Arsenic in Urine*** ($\mu\text{g/L}$)	Arsenic in Hair* ($\mu\text{g/kg}$)	Arsenic in Nail** ($\mu\text{g/kg}$)	Arsenic in Urine*** ($\mu\text{g/L}$)
No. of valid observation	350	352	300	152	148	155
Mean	3400	9860	472	1850	5850	605
Median	2161	4512	225	1031	2516	310
Minimum	620	1700	37	570	1665	24
Maximum	9480	29600	2285	5930	17700	3085
Standard deviation	1900	5500	451	1150	3600	632
% of samples having arsenic above normal/toxic (hair) level	93	100	95	84	89	97

*Normal level of arsenic in hair ranges from 80- 250 $\mu\text{g/kg}$; 1000 $\mu\text{g/kg}$ is the indication of toxicity²²

**Normal level of arsenic in nail ranges from 430 - 1080 $\mu\text{g/Kg}$ ²³

***Normal excretion of arsenic in urine ranges from 5 - 40 $\mu\text{g/L}$ ²⁴

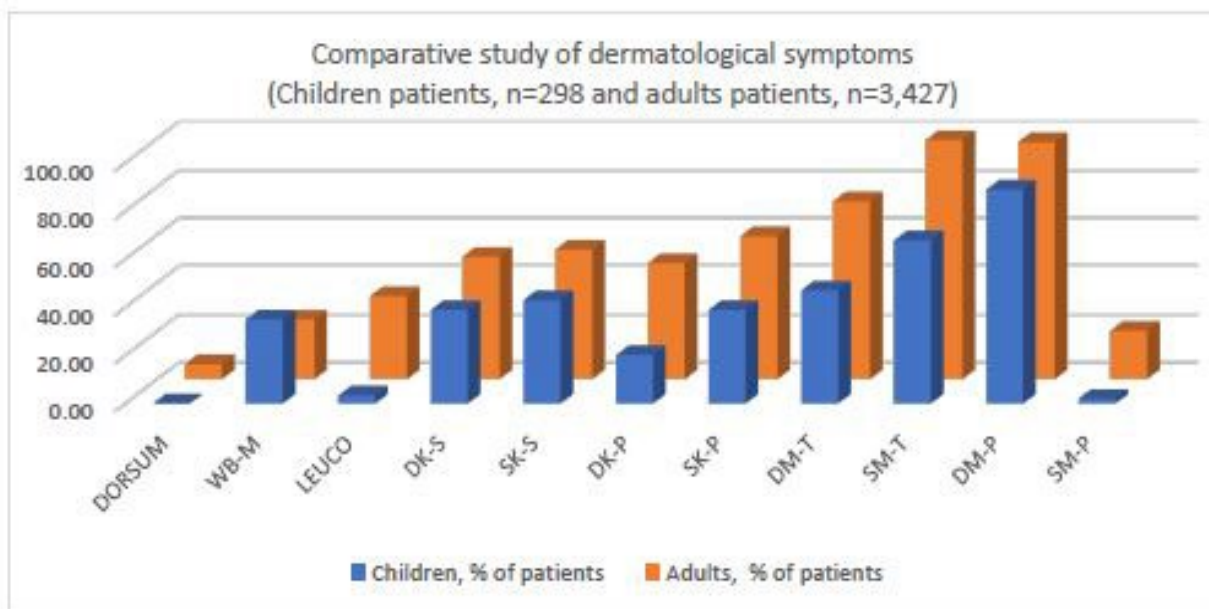


Figure 10: Comparative study (children vs adults) of dermatological symptoms [Dorsum, WB-M (Whole Body Melanosis), Leuco, DK-S (Diffuse Keratosis-Sole), SK-S (Spotted Keratosis-Sole), DK-P (Diffuse Keratosis-Palm), SK-P (Spotted Keratosis-Palm), DM-T (Diffuse Melanosis-Trunk), SM-T (Spotted Melanosis-Trunk), DM-P (Diffuse Melanosis-Palm), and SM-P (Spotted Melanosis-Palm)] of the adults (n=3,427) and child (n=298) patients in Bangladesh



Photograph 37: A group of children below 11 years of age in an under-poverty line family having arsenical skin lesions (PS: Nawabganj Sadar, Dist: Nawabganj, Bangladesh)



Photograph 38: The youngest child (age 18 months) in the Vill: Payerpur, PS: Madaripur sadar, Dist: Madaripur, Bangladesh

We have further observed that children recover from diffuse melanosis (blackening of color) and light spotted melanosis (+) quickly if they use safe water, eat better nutrition, and take vitamins. Mild keratosis (+) also disappears, but the children

having moderate to high spotted melanosis (++) and spotted keratosis (++) even after drinking safe water and nutritious food, do not recover completely. In one of our follow up studies in Harirampur village, Bagha police station in Rajshahi district of

Bangladesh, we have found during August 1996, nine children (Photograph 39) had arsenical skin lesions and was drinking arsenic contaminated water from a tube well having arsenic 1,070 µg/L. The group started taking safe water <3 µg/L of arsenic from

early 1997, and we further went to the village in April 1999 for the follow up study. We had found diffuse melanosis disappeared in children, and those who had spotted melanosis (+) and keratosis (+) are no longer showing skin lesions, but those who had ++

spotted melanosis and ++ spotted keratosis could not get rid of their skin lesions and spotted melanosis, replaced by Leucomelanosis and keratosis, is less compared to what they had during August 1996. However, the children are still complaining about their weaknesses, breathing problems, and suffering from cough and cold. Finally, if it is accepted that children are at a higher risk due to arsenic exposure, then the future of the next generation of Bangladesh living in arsenic affected villages may be grim as above 84%, and 89% of the children's hair and nail contain arsenic above toxic (hair) or normal level (nail), respectively.



Photograph 39: A group of arsenic affected children in the Vill: Harirampur, PS: Bagha, Dist: Rajshahi, Bangladesh.

Inorganic arsenic and its metabolites together in urines were analyzed by the FI-HG-AAS method. In our FI-HG-AAS system, arsenobetaine and arsenocholine do not form hydride. The results for children are given in Table 9. Exposed children's urine samples were collected from Datterhat village of Madaripur district in Bangladesh, where children use arsenic contaminated tube well water for drinking purposes. Controlled children's urine samples were collected from Medinipur district of West Bengal, India, where they are using arsenic safe water (<3 µg/L) for drinking purposes. The analytical result of control urine samples is given in Table 9.

Table 9: Concentration of arsenic (µg/L) in drinking water and corresponding urinary total arsenic of children in exposed and control groups collected from Datterhat village of Madaripur district in Bangladesh and Bautinagar block/PS in Medinipur district of West Bengal-India, respectively.

Sample No.	Age (Year)	Sex (M/F)	As in drinking Water (µg/L)	U-Asinorg+met (µg/L)
Exposed children (n=15)				
EC1	10	F	300	370
EC2	11	M	340	750
EC3	11	F	460	1350
EC4	6	M	460	370
EC5	10	M	460	350
EC6	8	M	620	1267
EC7	6	M	620	2400
EC8	7	M	540	1250
EC9	10	F	540	320
EC10	11	M	540	919
EC11	11	M	118	164
EC12	6	M	350	865
EC13	9	F	390	1172
EC14	5	M	390	340
EC15	3	M	390	665
Control children (n=12)				
CC1	8	M	<3	3
CC2	6	M	<3	35
CC3	9	M	<3	16
CC4	11	F	<3	13
CC5	6	F	<3	36
CC6	7.5	F	<3	28
CC7	10	F	<3	3
CC8	10	M	<3	3
CC9	10	M	<3	3
CC10	5	F	<3	21
CC11	10	M	<3	22
CC12	4	M	<3	17

Conclusion:

This study indicated that maybe a lot of people died, suffered, and have been suffering due to drinking arsenic contaminated water and foods. We don't know how many families were destroyed and how many children lost their future. We don't know our economic loss.

Therefore, we must learn from these arsenic impacts in Bangladesh that even though it looks good today, it could be very dangers tomorrow if we don't think about each one of it, very carefully.

Now a days, most of the people are drinking deep underground arsenic free water, but it must be a good idea to follow up this underground water for measuring contaminants, including arsenic, because the people are drinking/using safe deep tube wells water today, it could be contaminated with times in future.

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References

1. Valentine, J.L. (1994). In: Chappell, W.R., Abernathy, C.O. and Cothorn, C.R. (eds.). *Arsenic Exposure and Health*, Science and Technology Letters, Northwood, PP 139-152.
2. Curry. A.S., Pounds, C.A. (1977). Arsenic in hair. *J. Forensic. Sci. Soe.*, 17: 37-44.
3. Hopps. H.C. (1977). The biological bases for using hair and nail for analyses of trace elements. *Sci. Total Environ.*, 7: 71-89.

4. Hostynek. J.J., Hinz, R.S., Lorence, C.R., Price, M., Guy. R.H. (1993). Metals and the skin. *Crit. Rev. Toxicol.*, 23: 171-235.
5. WHO. Arsenic (1981). *Environmental Health Criteria 18*, Geneva, Switzerland: World Health Organization.
6. Smith, A.H. et al. (1981). Cancer risks from arsenic in drinking water. *Environmental Health Perspectives*. 97: 257-259.
7. National Research Council (1999). *Arsenic in drinking water*. Washington, D.C., National Academy Press.
8. WHO, *Guideline for Drinking Water Quality, Recommendation*, Vol 1. 2nd ed. Geneva: World Health Organisation, 1993, P.41.
9. Chowdhury, U.K. (2001). Groundwater arsenic contamination status at four geo-morphological areas in Bangladesh (Special reference to arsenic in biological samples and agricultural crops) (Ph.D. Thesis). Jadavpur University, Kolkata, India.
10. Monda, B.K. (1998). Status of arsenic problem in two blocks out of sixty in eight groundwater arsenic affected districts of West Bengal, India. Ph.D. Thesis. Faculty of Science, School of Environmental Studies, Jadavpur University, Calcutta, West Bengal, India.
11. Chowdhury, U.K., Rahman, M.M., Mandal, B.K., Paul, K., Lodh, D., Basu, G.K., Chanda, C.R., Saha, K.C., Mukherjee, S.C., Roy, S., Das, R., Kaies, I., Barua, A.K., Palit, S.K., Quamruzzaman, Q., and Chakraborti, D. (2001). Groundwater arsenic contamination and sufferings of people in West Bengal, India, and Bangladesh. *Environmental Sciences*, 8, 393-415.
12. Chowdhury, U.K., Biswas, B.K., Chowdhury, T.R., Samanta, G., Mandal, B.K., Basu, G.C., Chanda, C.R., Lodh, D., Saha, K.C., Mukherjee, S.C., Roy, S., Kabir, S., Quamruzzaman, Q., Chakraborti, D. (2000). Groundwater arsenic contamination in Bangladesh and West Bengal, India. *Environmental Health Perspect.*, 108, 5, 393-397; doi: 10.1289/ehp.00108393
13. Borgono, J.M., Greibeer, R. (1972). Epidemiological study of arsenicism in the city of Antofagasta. In *trace substances in environmental health*, Hemphill, D.D., Ed., University of Missouri Press: Columbia, 5, 13-24.
14. Zaldivar, R. (1974). Arsenic concentration of drinking water and food stuffs causing endemic chronic poisoning. *Beitr. Pathol.*, 151, 384-400.
15. Zaldivar, R., Guillier, A. (1977). Environmental and clinical investigation on epidemic chronic arsenic poisoning in infants and children. *Zentralbl. Bakteriell. Parasitenkd. Infektionskr. Hyg. A I. L Orig. Reihe B*. 1977, 165. 226-243.
16. Jensen, G.E., Christensen, J.M., Poulsen, O.M. (1991). Occupational and environmental exposure to arsenic increased urinary level in children. *Sci. Total Environ.*, 107, 169-177.
17. Concha, G., Nermell, B., Vahter, M. (1998). Metabolism of Inorganic arsenic in children with chronic high arsenic exposure

in Northern Argentina. *Environ. Health Perspect.*, 106(6), 355-359.

18. Abernathy, C.O., Marcu, W., Chen, C., Gibb, H., Write, P. (1998). Report on arsenic work group meeting. Office of drinking water, Office of research and development, USEPA, Memorandum to Cork, P., Preuss, P., Office of regulatory support and scientific management, USEPA.

19. USEPA (1992). Draft drinking water criteria document on arsenic. Submitted by human risk assessment branch, Health, and ecological criteria division. Office of Science and Technology, Office of Water. USEPA. Washington.

20. Morton, W.E., Dunnette, D.A. (1994). Health effects of environmental arsenic. In *arsenic in the environment, Part II: Human Health and Ecosystem Effects*, Naiagu, J.O., Ed., John Wiley and Sons Inc., New York, 17-34.

21. Siripitayakunkit, U., Visudhiphan, P., Pradipasen, M., Vorapongsathron, T. (1999). Association between chronic arsenic exposure and children's intelligence in Thailand. In *arsenic exposure and health effects*. Chappell, W.R., Abernathy, C.O., Calderon, R.L., Eds., Elsevier Science Ltd., New York. 141-149.

22. Arnold, H.L., Odam, R.B., James, W.D. (1990). *Disease of the skin clinical dermatology*, W.B. Saunders Company, Philadelphia, USA, pp 121-122.

23. Ioanid, N., Bors, G. and Popa, I. (1961). *Dtsch.Z. Gerichtl. Med.*, 52: 90.

24. Farmer, J.G., Johnson, L.R. (1990). *Br. J. Ind. Med.*, 47: 342.