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A comparative study of underground water arsenic contamination and suffering of people in Flood Plain with Deltaic reason of Bangladesh

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ABSTRACT

The people were drinking arsenic-contaminated underground water in Bangladesh, and we had collected and analyzed 33,092 hand tube-well water samples for measuring arsenic. These samples were collected from all four geomorphological areas (Hill tract, Table Land, Flood Plain, and Deltaic reason i.e., from all 64 districts) in Bangladesh and found arsenic in 60 districts that were above the WHO recommended value in drinking water (10 µg/L) and in 50 districts that were above maximum permissible limit, 50 µg/L.

In this paper, I have reported the magnitude of arsenic contamination in the tubewell water samples that were collected from two districts of Bangladesh, one from Flood Plain, named Chandpur, and another one from Deltaic region, named Madaripur. It describes the analytical report of arsenic concentrations in underground drinking water and biological samples, and people suffering from arsenic toxicity in these two districts.

In the Madaripur district, 19.62% of the total tubewell water samples (n=2,309) contained arsenic concentrations that were below WHO recommended value (10 µg/L) and safe to drink, and 80.38% and 59.59% of the tubewells contained levels arsenic that were above 10 µg/L and 50 µg/L, respectively. In Chandpur district (n=1,165 tubewell water samples), these values are 4.12, 95.88, and 92.79%, respectively. Of the samples in Madaripur, the percentage of water samples with arsenic are 26.94, 12.68, 3.29. 0.91, and 0.22% in the ranges 100-299, 300-499, 500-699, 700-1,000, and above 1,000 µg As/L, respectively. In Chandpur district, these values are 57.86, 25.15, 4.81, 1.80, and 0.43%, respectively.

During our preliminary survey, arsenical patients were identified in all 42 villages, and we surveyed 8 police stations under these two districts. In this survey, 1,038 and 1,605 people (including children) were examined and 81 (7.8%) and 157 (9.78%) people had been identified with arsenical skin lesions from Madaripur and Chandpur districts, respectively. It appears that the overall arsenical skin lesions of adult females are somewhat higher than adult males. We identified arsenical skin lesions of one teenager (girl) and four children (girls) in Madaripur and Chandpur districts, respectively. We could not identify any cancer patient out of a total of 238 patients in these two districts.

The analytical results show that 100% of all hair, nail, and urine samples from Madaripur district, and 96% of hair & 100% of nail samples from Chandpur district, have levels of arsenic that were above toxic/normal level, respectively. The mean concentrations of arsenic in hair, nail, and urine samples from Madaripur district are 4,591 µg/kg, 9,004 µg/kg, and 550 µg/L; and hair & nail from Chandpur district are 3,990 µg/kg and 7,355 µg/kg, respectively. The arsenic level in hair, nail, and urine from Madaripur, and hair & nail from Chandpur districts were much higher than that of the people residing in an area where drinking water is not arsenic contaminated (<3 µg/L) i.e., control population**.** During our dermatological survey in the affected villages, it was observed that all members in a family were drinking arsenic contaminated water and have high arsenic body burden (arsenic level in hair, nail) but not all have arsenic skin lesions. The linear regressions analyses between the arsenic concentrations in drinking water samples and arsenic

concentrations in hair / nail / urine samples (combining samples from these two districts) show a positive co-relation (for hair samples r = 0.677, n = 69, p = 0.0000001; for nail samples r = 0.724, n = 67, p = 0.00000004; and for urine samples r = 0.545, n = 44, p = 0.0001). The linear regression between arsenic in hair and nail samples also shows a positive correlation (r = 0.81, n = 67, p= 0.00000006).

In conclusions, (a) it appears to be that there is a higher concentration of arsenic groundwater contamination in Chandpur district (Flood Plain) as compared to Madaripur district (Deltaic region), (b) shallow hand tube-wells (<100 meters depth) are more dominating with arsenic in both Madaripur and Chandpur districts, (c) arsenic concentration decreasing with the increase of depth in both Madaripur and Chandpur districts (above 40 meters), (d) arsenical skin lesions of adult females are higher than adult males, and the reasons could be: (i) women drink water from the same tubewell whereas men from different tubewells and (ii) in villages of Bangladesh, women suffer more from malnutrition than men, (e) common problems in arsenic patients such as intolerance to sunlight, burning sensations on whole body, and respiratory problems, (f) many villagers are sub-clinically affected due to arsenic toxicity, and (g) this study took place before 2001, and we need a follow-up study/survey to know the present status.

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Introduction:

The origin of arsenic (As) in groundwater is not clear. The opinion of many scientists that heavy groundwater withdrawal may be one of the reasons for As in groundwater. The United States Geological Survey (USGS)[1] comments "Mobilization of As in sedimentary aquifers may be, in part of result of changes in the geochemical environment due to agricultural irrigation." Though it is confirmed that the arsenic in groundwater of Bangladesh and West Bengal, India is of geological origin[2-6], but the exact source and mechanism of leaching are still not well understood[3-5].

In a period from 1995 to 2000, we had collected and analyzed 33,092 hand tubewell 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 WHO recommended value in drinking water (10 µg/L) and 50 districts that were above the maximum permissible limit[7,8], 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 contaminated (Fig. 2).

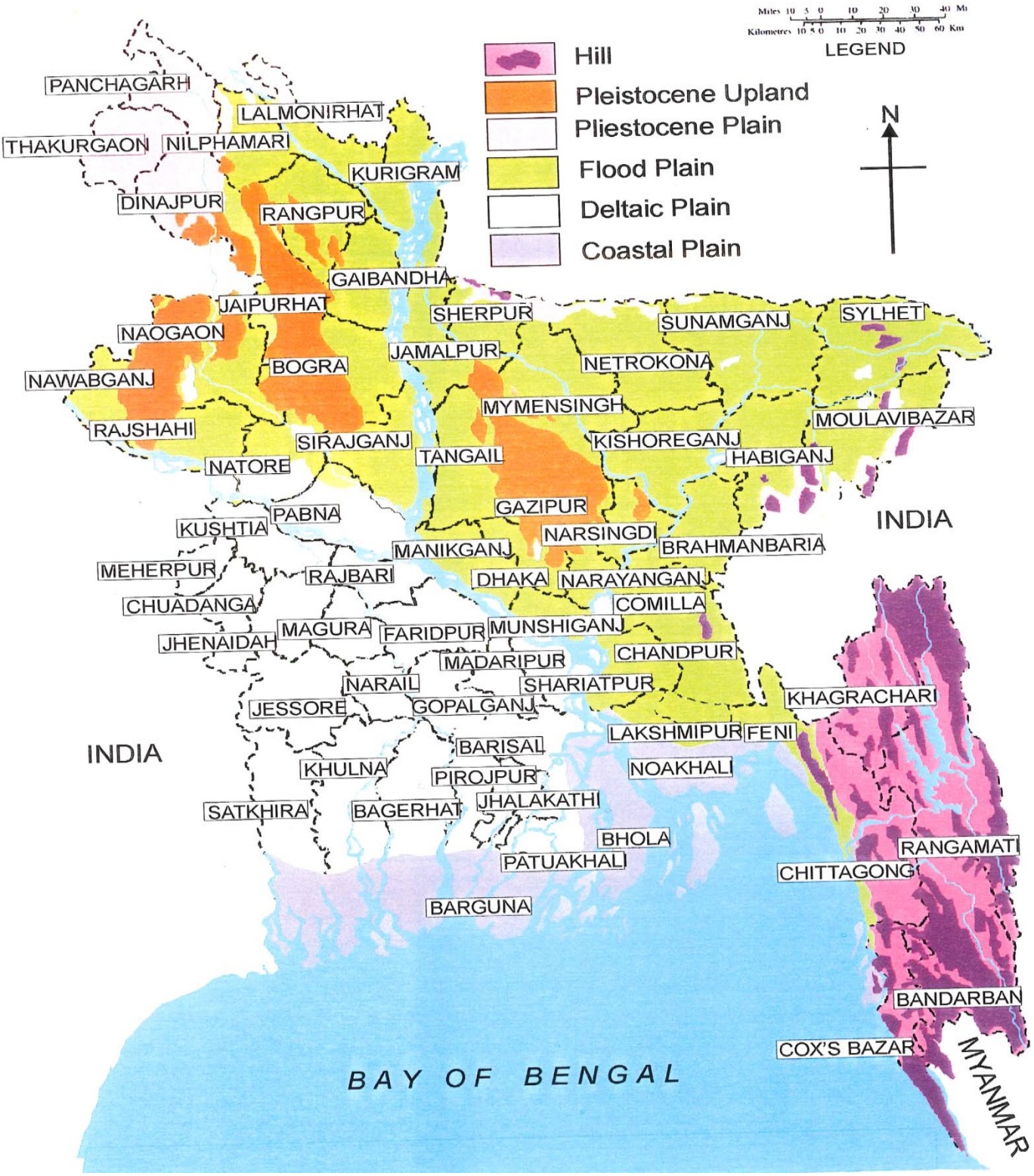


Figure 1: Four principal geomorphological reasons in Bangladesh

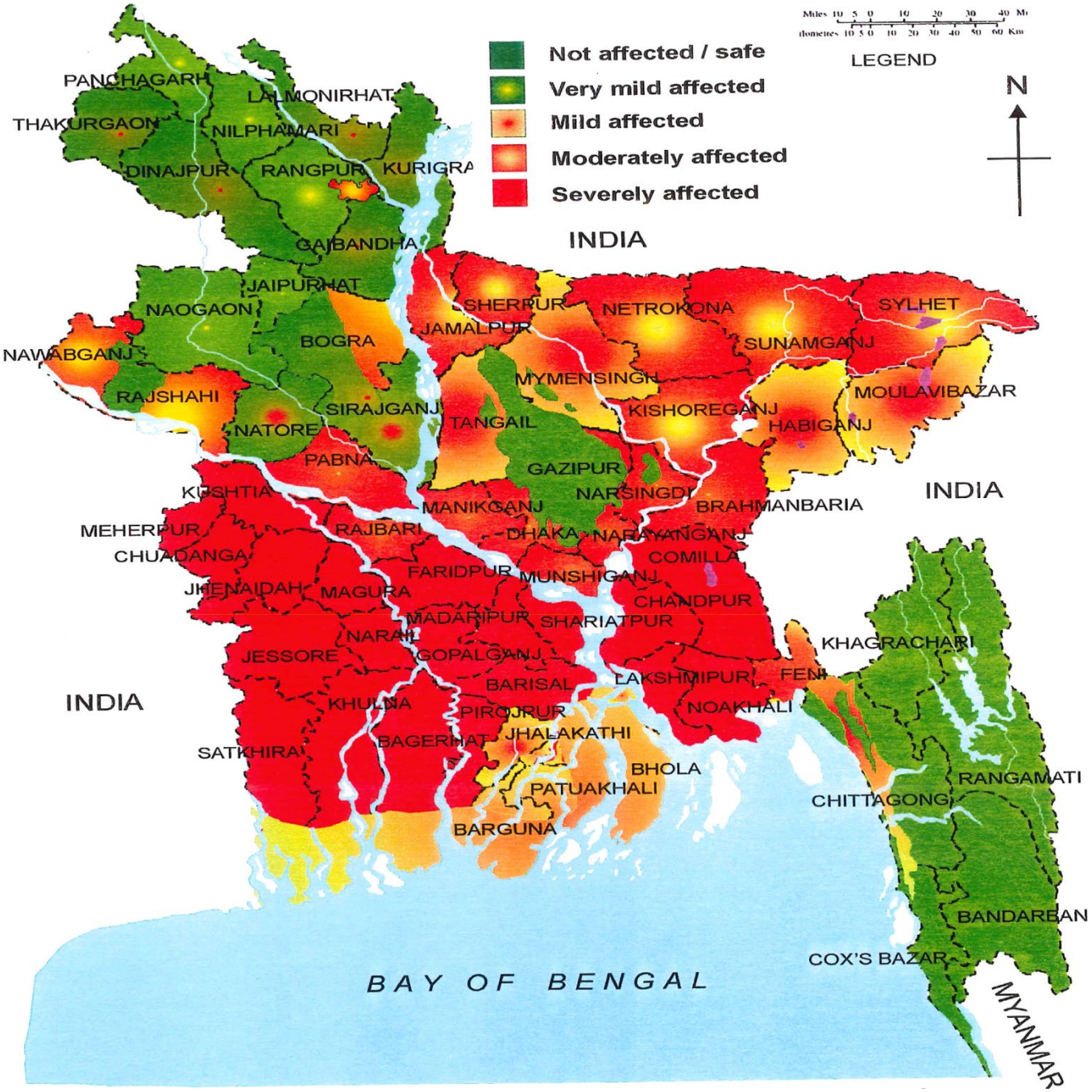


Figure 2: Groundwater arsenic status in all 64 districts of Bangladesh

Groundwater arsenic status in Bangladesh

In our study period from 1995 to December 2000 in Bangladesh, we had collected and analyzed 33,092 tubewell water samples from all four geomorphological areas (from all 64 districts)[8] and found arsenic in 60 districts that were above WHO recommended value in drinking water (10 µg/L) and in 50 districts that were above maximum permissible limit[7], 50 µg/L. This does not mean that the total areas of these 50 districts are arsenic contaminated, and people are drinking arsenic contaminated water, but no doubt they are under risk. Table 1 shows the status of arsenic in groundwater in all 64 districts of Bangladesh

Table 1: Overall arsenic situation in underground tubewell waters 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

Arsenic patients and biological samples status in 33 districts of Bangladesh

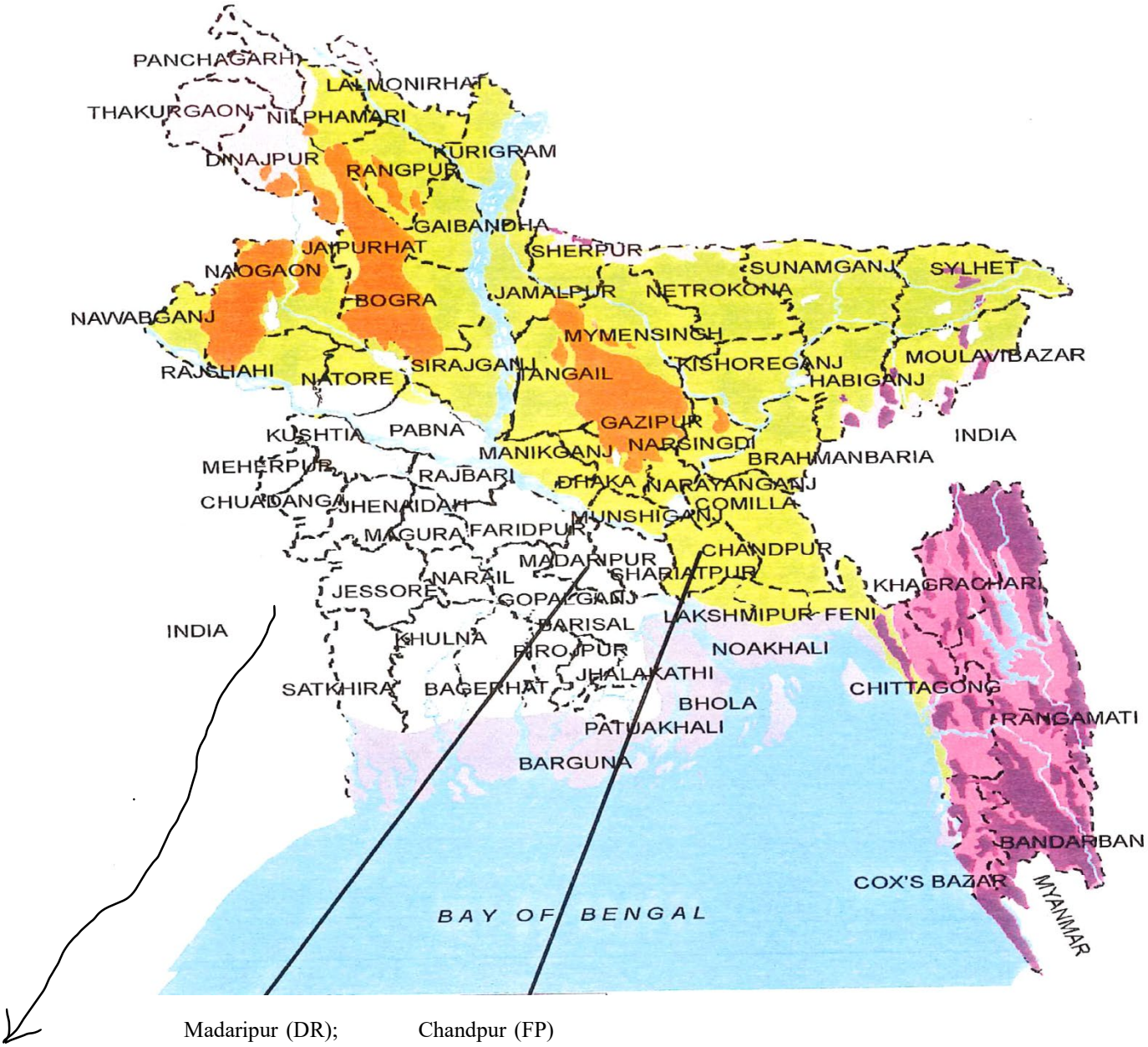
In our study for 6 years (from 1995 to December 2000) in Bangladesh, the survey was conducted by our group with a medical team (at least one dermatologist and one general physician/pediatric) in 261 villages of 80 police stations in 33 out of 50 districts where contamination of groundwater with arsenic is above 50 µg/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 µg/L	60
04	No. of districts where arsenic in groundwater > 50 µg/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	18,841
12	No. of patients identified	3,725

13	Total no. of adult examined	13,976
14	No. of adult 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 µg/ kg (mean value 5,730 µg/kg)

Out of total 64 districts in Bangladesh, there are 22 districts in Deltaic region and 28 districts in Flood Plain. Surveying all police stations and villages under each district in Flood Pain and Deltaic areas is a mammoth job for a single group. Thus, I selected, two districts, one from Flood Plain named Chandpur and another one from Deltaic region named Madaripur (Fig. 3) and made a detailed study of groundwater arsenic contamination to get an idea of the magnitude of the contamination in Flood Pain (FP) and Deltaic regions (DR) of Bangladesh. The total area and the population of Madaripur and Chandpur districts are 1,140 sq. km. & 1185000, and 1700 sq. km. & 2180000, respectively. In this paper, I have reported the magnitude of arsenic contamination in the tubewell water samples collected from these districts and described the analytical report of arsenic in tubewell water samples. Also, I have reported the analytical report of arsenic in biological samples from villagers and people suffering from arsenical skin lesions due to arsenic toxicity in these two districts of Bangladesh.



Madaripur (DR); Chandpur (FP)
North-24 Parganas, India (Deltaic region, DR)

Figure 3: Locations of Madaripur and Chandpur districts in Bangladesh map and North 24 Parganas district, WB in India

Groundwater arsenic contamination in Madaripur district from Deltaic region and Chandpur district from Flood Plain

Madaripur district is situated on the western part of Padma and Ahrial Kha river and Chandpur district on the eastern side of the Meghna River. Figure 3 shows the position of Madaripur and Chandpur districts in Bangladesh map. Table 3 shows the physical parameters of Madaripur and Chandpur districts, and this study was conducted between 1995 and December 2000.

Table 3: Physical parameters of Madaripur and Chandpur districts in Bangladesh

Parameters	Madaripur	Chandpur
Area (sq. km)	1,140	1,700
Population (million)	1.185	2.18
Total no. of police stations	4	7
No. of police stations surveyed	4	6
Total no. of villages	480 (approx.)	840 (approx.)
No. of villages from where tubewell water samples were collected	199	89
No. of arsenic affected villages	187 (93.97%)	89 (100%)
Total no. of tubewell water samples analyzed	2,309	1,165
No. of samples having arsenic > 10 µg/L	1,856 (80.38%)	1,117 (95.88%)
No. of samples having arsenic > 50 µg/L	1,376 (59.59%)	1,081 (92.79%)
Expected population drinking arsenic contaminated water > 10 µg/L (million)	0.91 (77.26%)	2.05 (94.07%)
Expected population drinking arsenic contaminated water > 50 µg/L (million)	0.61 (51.44%)	1.97 (90.66%)
No. of villages served for arsenic patients	9	33
No. of villages where patients identified	9 (100%)	33 (100%)
No. of people examined for arsenical manifestation	1,038	1,605
No. of people found with arsenical manifestation	81 (7.80%)	157 (9.78%)

Analyses of 2,309 and 1,165 tubewell water samples covering all police stations in Madaripur district and 6 out of 7 police stations in Chandpur district, respectively, had been done and found arsenic levels that were above the WHO[7] maximum permissible limit (50 µg/L) in all surveyed police stations. The preliminary survey indicates that the level of arsenic in groundwater was above 50 µg/L in 187 out of 199 surveyed villages in Madaripur, and all 89 surveyed villages in Chandpur district of Bangladesh. The total villages in Madaripur and Chandpur districts are 480 (approx.) and 840 (approx.), respectively. This does not mean that all people in these two districts were drinking arsenic contaminated water but no doubt they are at risk. Tables 4 and 5 show the distribution of arsenic in 2,309 and 1,165 hand tubewells of Madaripur and Chandpur districts, respectively. Figures 4 and 5 show the distribution of the percentage of tubewells in different arsenic concentrations ranging at different police stations of Madaripur and Chandpur districts, respectively. Figure 6 shows a comparative study of the percentage of water samples in different concentrations ranges (µg/L) in Madaripur (n=2,309) and Chandpur (n=1,165) districts of Bangladesh. In the Madaripur district 19.62% of the total tubewells contained arsenic concentrations that were below WHO recommended value (10 µg/L) and safe to drink, and 80.38% and 59.59% of the tubewells contained arsenic levels that were above 10 µg/L and 50 µg/L, respectively. In Chandpur, these values are 4.12%, 95.88%, and 92.79%, respectively. Of the samples in Madaripur, the percentage of water samples with arsenic are 26.94%, 12.68%, 3.29%. 0.91%, and 0.22% in the ranges 100-299, 300-499, 500-699, 700-1,000, and above 1,000 µg/L, respectively. In Chandpur district, these values are 57.86%, 25.15%, 4.81%, 1.80%, and 0.43%, respectively. These values appear to be of higher concentration of arsenic groundwater contamination in Chandpur district (Food Plain) as compared to Madaripur district (Deltaic region) (Tables 4 & 5 and Figures 4-6).

Table 4: Distribution of the number of tubewells against the arsenic range (µg/L) in different police stations (PS) of Madaripur district in Bangladesh

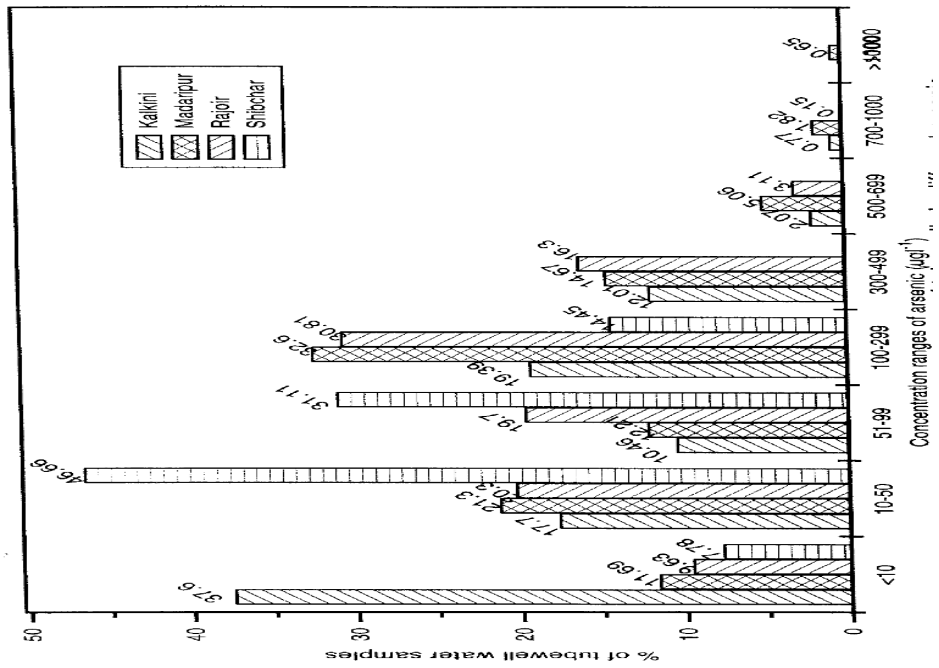
No. of PS	No. of PS surveyed	Name of PS	No. of samples analyzed	No. of samples having arsenic		Distribution of the number of tubewells with different arsenic concentration (µg/L) range							
				>10 (µg/L)	>50 (µg/L)	<10	10-50	51-99	100-299	300-499	500-699	700-1000	above 1000
4	4	Kalkini	774	483	346	291	137	81	150	93	16	6	-
		Madaripur Sadar	770	680	516	90	164	94	251	113	39	14	5
		Rajoir	675	610	473	65	137	133	208	110	21	1	-

		Shibchar	90	83	41	7	42	28	13	-	-	-	-
		Total tubewells	2,309	1,856	1,376	453	480	336	622	316	76	21	5
		% of tubewells		80.8	59.9	19.6	20.8	14.5	26.9	13.7	3.3	0.91	0.22

Table 5: Distribution of the number of tubewells against the arsenic range (µg/L) in different police stations (PS) of Chandpur district in Bangladesh

No. of PS	No. of PS surveyed	Name of PS	No. of samples analyzed	No. of samples having arsenic		Distribution of the number of tubewells with different arsenic concentration (µg/L) range							
				>10 (µg/L)	>50 (µg/L)	<10	10-50	51-99	100-299	300-499	500-699	700-1000	above 1000
7	6	Chandpur Sadar	77	72	70	5	2	3	24	35	8	-	-
		Faridganj	91	80	76	11	4	2	21	23	14	12	4
		Haziganj	106	100	100	6	-	-	20	48	24	7	1
		Kachua	31	30	27	1	3	4	18	5	-	-	-
		Matlab	119	119	116	-	3	9	68	37	2	-	-
		Shahrasti	741	716	692	25	24	14	523	145	8	2	-
		Total tubewells	1,165	1,117	1,081	48	36	32	674	293	56	21	5
		% of tubewells		95.88	92.79	4.1	3.1	2.8	57.9	25.2	4.8	1.8	0.43

Figure 4: Distribution of the percentage of tubewells against the arsenic concentration range (µg/L) in different police stations of Madaripur district



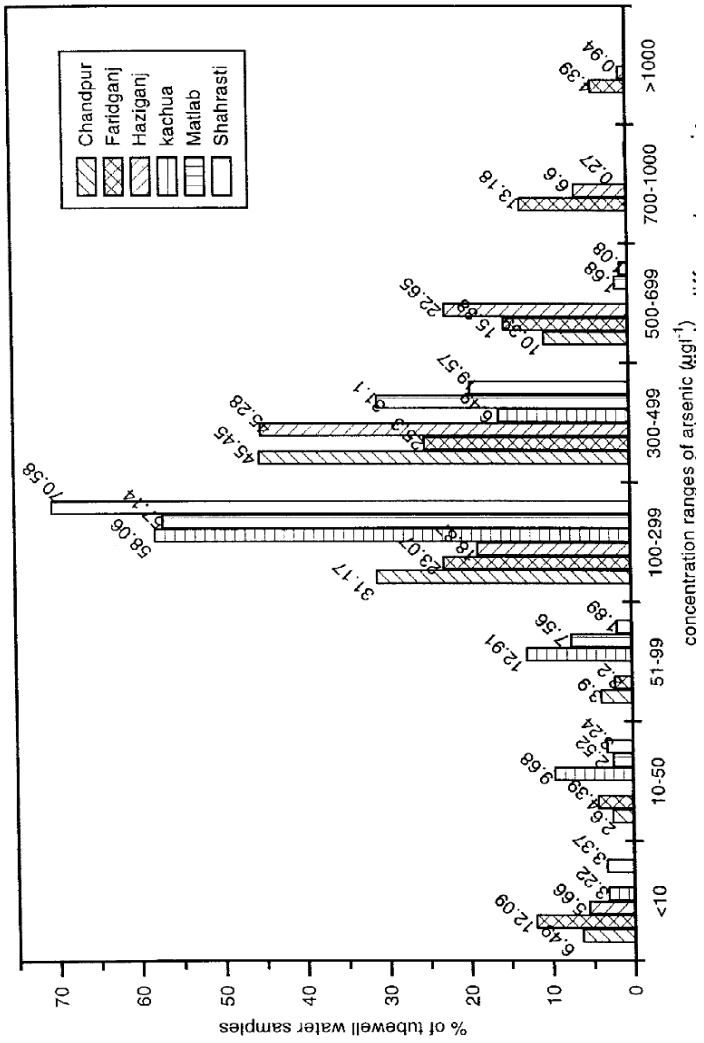


Figure 5: Distribution of the percentage of tubewells against the arsenic concentration range (µg/L) in different police stations of Chandpur district

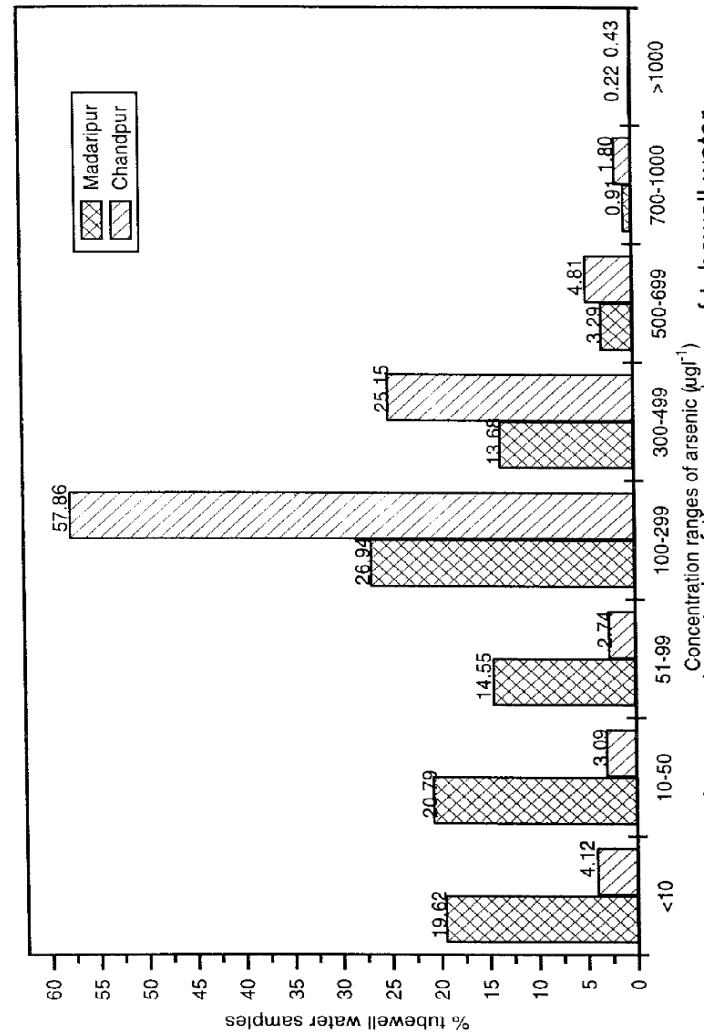


Figure 6: A comparative study of the percentage of tubewell water samples against the arsenic concentrations' ranges (µg/L) in Madaripur (Deltaic region) (n= 2,309) and Chandpur (Flood Plain) districts (n=1,165) of Bangladesh

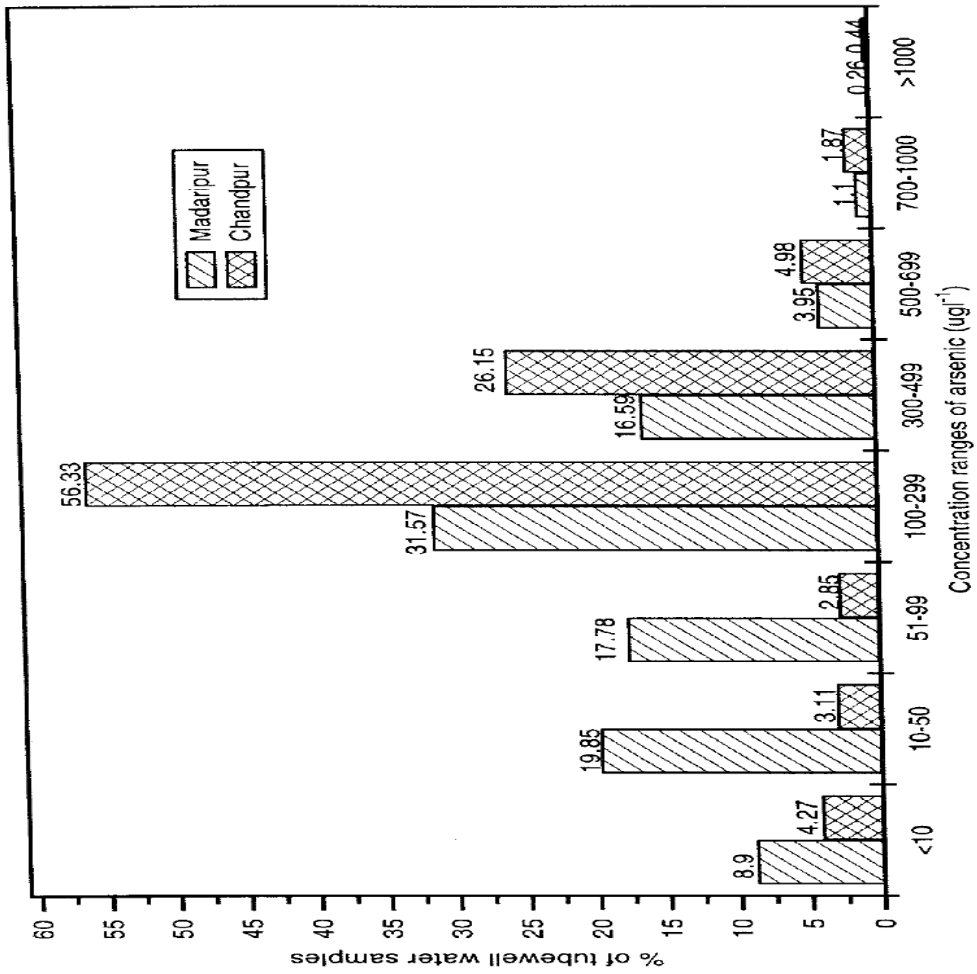


Figure 7: A comparative study of the percentage of tubewell water samples in different arsenic concentrations ranges (µg/L) in Madaripur district (Deltaic region) (n= 1,899) and Chandpur district (Flood Plain) (n=1,124) of Bangladesh where depth of the tubewells are less than 100 meters.

Figure 7 shows that the percentage of tubewell water samples in different concentration ranges (µg/L) in Madaripur (n= 1,899) and Chandpur (n=1,124) districts of Bangladesh where depth of the tubewells are less than 100 meters. This figure also supports that the underground water arsenic concentrations in Flood plain (Chandpur district) are higher compared to the Deltaic region (Madaripur district).

Arsenic concentration in underground water at different depth of tubewells in Madaripur (Deltaic region) and Chandpur (Flood plain) districts of Bangladesh

The objective of this study is to find out the distribution of arsenic at different depths in hand tubewells in Madaripur and Chandpur districts of Bangladesh from our questionnaire filled-up by villagers. The questionnaire pertains to depth and identity (including owner name, village, and police stations) of each tube well which were obtained for 2,309 and 1,083 tubewells (out of 2,309 and 1,165), covering Madaripur and Chandpur districts, respectively. The concentration of arsenic was measured by FI-HG-AAS with 3 µg/L as the detection limit with 95% confidence level. The percentage of tubewells with different depth ranges are shown in Table 6 for both Madaripur and Chandpur districts in Bangladesh.

Table 6: Distribution of the percentage of tubewells against different depth ranges (meters) in Madaripur (n = 2,309) and Chandpur (n = 1,083) districts of Bangladesh

Depth (m)	Madaripur district (n=2,309)		Chandpur district (n=1,083)	
	No. of tubewells analyzed	% of the tubewells	No. of tubewells analyzed	% of the tubewells
6.4-9.7	6	0.26	-	-
> 9.7-15.6	257	11.13	55	5.08
> 15.8-21.9	494	21.40	459	43.38
> 21.9-28.0	475	20.57	452	40.75
> 28.0-34.1	126	5.45	67	6.18
> 34.1-40.2	67	2.91	15	1.38
> 40.2-52.4	177	7.66	13	1.20
> 52.4-89.0	280	12.12	16	1.48
> 89.0-150.0	14	0.62	6	0.55
>150.0-250.0	206	8.92	-	-
> 250.0	207	8.96	-	-

From Table 6, it appears that shallow hand tubewell (<100 meters) water is more dominant with arsenic in both Madaripur and Chandpur districts of Bangladesh. The lowest depth of hand tubewells available in Bangladesh is 6.4 meters. The villagers use 4.6- or 6-meters pipes, with 1 or 2 filters (each filter 1.8 m). Therefore, all tube wells are multiple of 4.6- or 6-meters pipes with 1 or 2 filters.

The data on arsenic concentration in groundwater and depths of tubewells were proposed for statistical interpretation. Statistical parameters (mean, median, standard (std) deviation, minimum, maximum, 1st quartile and 3rd quartile) are given in Tables 7 and 8 for Madaripur district and Chandpur district, respectively. From Tables 7 and 8, mean values at different depths indicate the overall decline trend of arsenic concentration with the increase of depth. Figures 8 and 9 also show the decrease of arsenic concentration with the increase of depth (above 40 meters) in both Madaripur district (Deltaic region) and Chandpur district (Flood Plain).

Table 7: Parametric presentation of arsenic concentration (µg/L) in tubewell water samples with depth ranges (meters) of 2,309 tubewells from Madaripur district (Deltaic region) in Bangladesh

Parameters	Depth range (m)										
	6.4-9.7	>9.7-15.6	>15.8-21.9	>21.9-28.0	>28.0-34.1	>34.1-40.2	>40.2-52.4	>52.4-89.0	>89.0-150.0	>150.0-250.0	>250
No. of tubewells											
No. of samples	6	257	494	475	126	67	177	280	14	206	207
As concentration in µg/L											
Mean	250	100	214	234	255	210	102	93	89	10	10
Median	270	60	167	211	234	176	40	49	53	3	3
Std deviation	171	130	198	162	176	245	135	123	104	35	36
Minimum	15	3	3	3	3	3	3	3	3	3	3
Maximum	517	587	1200	875	794	1200	524	833	281	352	129
1st quartile	90	20	70	100	106	40	22	14	3	3	3
3rd quartile	358	148	292	342	391	300	190	113	88	12	10

Table 8: Parametric presentation of arsenic concentration (µg/L) in tubewell water samples with depth ranges (meters) of 1,083 tubewells from Chandpur district (Flood Plain) in Bangladesh

Parameters	Depth range (m)							
	9.7-15.8	>15.8-21.9	>21.9-28.0	>28.0-34.1	>34.1-40.2	>40.2-52.4	>52.4-89.0	>89.0-150.0
	No. of tubewells							
No. of samples	55	459	452	67	15	13	16	6
	As concentration in µg/L							
Mean	344	289	250	260	291	233	70	40
Median	230	250	240	245	254	220	40	30
Std deviation	267	165	120	135	171	40	80	40
Minimum	37	30	30	28	33	200	3	3
Maximum	1318	1186	706	800	625	281	227	168
1st quartile	159	190	171	190	200	133	10	7
3rd quartile	469	333	309	300	400	281	110	90

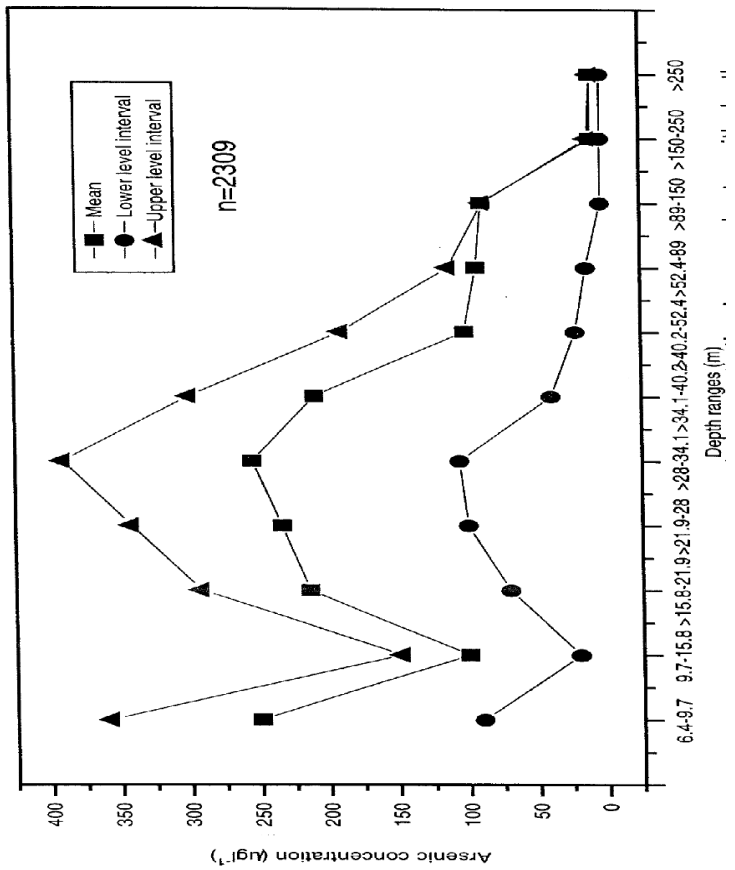
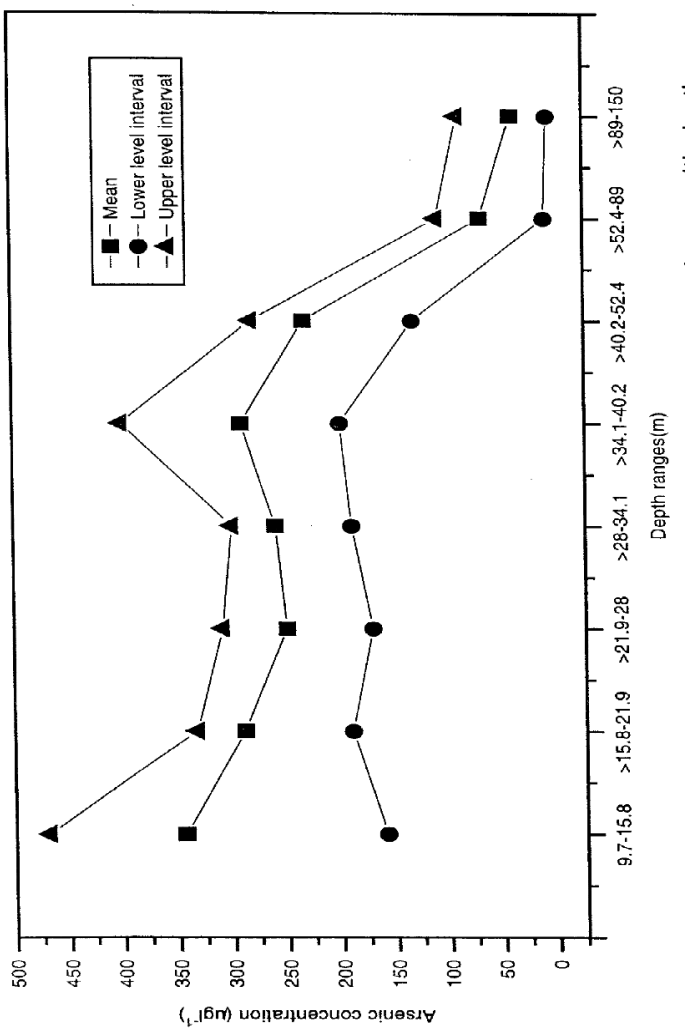


Figure 8: Variation of arsenic concentration in groundwater (n=2,309) with depth of the tubewells in Madaripur district (Deltaic region) of Bangladesh



Arsenical skin manifestation to the people from villages of Madaripur district (Deltaic region) and Chandpur district (Flood Plain) in Bangladesh

Patients with arsenical skin lesions are expected in all 4 police stations of Madaripur districts and 6 surveyed police stations (out of 7) of Chandpur district as groundwater contains elevated levels of arsenic (Tables 4 & 5). In our preliminary study with our medical team, we surveyed 9 villages of 3 police stations out of 4 in Madaripur district and 33 villages of *5* police stations out of 7 in Chandpur district to identify patients with arsenical skin lesions (Tables 9 and 10). During our survey, arsenic patients were identified in all 42 villages that we surveyed in 8 police stations under these two districts. In this study, 1,038 and 1,605 people (including children) were examined, and 81 (7.8%) and 157 (9.78%) people had been identified with arsenical skin lesions from Madaripur and Chandpur districts, respectively. Tables 9 and 10 show overall findings of arsenic patients among adults and children in different police stations of Madaripur and Chandpur districts, respectively. This is a very preliminary survey, and we expect more patients from arsenic affected villages of Madaripur and Chandpur districts of Bangladesh if we survey in detail. Figure 10 and Table 11 show the distribution of the percentage of prevalence of common arsenical dermatological symptoms among 81 and 157 people (including children) in Madaripur and Chandpur districts of Bangladesh.

Figure 9: Variation of arsenic concentrations in groundwater (n=1,083) with depth of the tubewells in Chandpur district (Flood Plain) of Bangladesh

Table 9: Overall study report of 3 police stations (PS) of Madaripur district (Deltaic region) where people with arsenical skin lesions were identified

Total No. of PS	No. of PS surveyed	No. of PS where patient identified	Name of the PS	Areas (km^2)	Population	No. of vills surveyed	No. of vills where patients identified	No. of people examined	No. of patients identified	No. of adult male patients	No. of adult female patients	No. of child patients
4	3	3	Kalkini	280	279,000	2	2	50	4	3	1	
			Madari-Pur Sadar	314	341,000	2	2	640	59	11	47	1 (F)
			Rajoir	229	226,000	5	5	348	18	9	9	
			Total	823	846,000	9	9	1,038	81	23	57	1 (F)

Table 10: Overall study report of 5 police stations (PS) of Chandpur district (Flood Plain) where people with arsenical skin lesions were identified

Total No. of PS	No. of PS surve-yed	No. of PS where patient identi-fied	Name of the PS	Areas (km^2)	Popula-tion	No. of vills surv-eyed	No. of vills where patients identi-fied	No. of people exa-mined	No. of patients identi-fied	No. of adult male patients	No. of adult female patients	No. of child patients
7	5	5	Chand-pur Sadar	309	451,000	6	6	110	10	10	-	-
			Farid-ganj	232	395,000	9	9	470	50	30	20	-
			Hazi-ganj	190	289,000	6	6	420	43	24	16	3 (F)
			Matlab	409	507,000	1	1	200	14	8	6	-
			Shahra-sti	154	205,000	11	11	405	40	26	13	1 (F)
			Total	1294	1,847,000	33	33	1,605	157	98	55	4 (F)

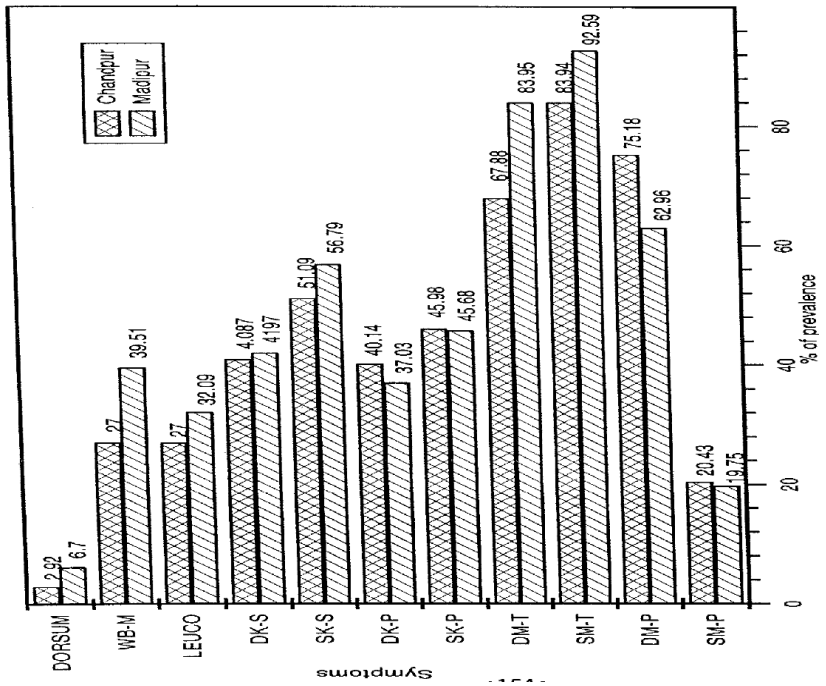


Figure 10: Distribution of arsenical skin lesions [Dorsum, WB-M (Whole Body Melanosis), Leuco, DK-S (Diffuse Keratosis-Sole), SK-S (Spotted Keratosis-Sole), DK-P (Diffuse Keratosis-Palm), SK-P (Spotted Keratosis-Palm), DM-T (Diffuse Melanosis-Trunk), SM-T (Spotted Melanosis-Trunk), DM-P (Diffuse Melanosis-Palm), SM-P (Spotted Melanosis-Palm)] among the people of Madaripur (n=81) and Chandpur (n=157) districts of Bangladesh

Table 11: Distribution of arsenical skin lesions among the people in Madaripur (n = 81) and Chandpur (n = 157) districts of Bangladesh

Symptoms	% of prevalence	
	Madaripur	Chandpur
SM-P	19.75%	20.43%
DM-P	62.96%	75.18%
SM-T	92.59%	83.94%
DM-T	83.95%	67.88%
SK-P	45.68%	45.98%
DK-P	37.03%	40.14%
SK-S	56.79%	51.09%
DK-S	41.97%	40.87%
WB-M	39.51%	27.00%
Leuco	32.09%	27.00%
Dorsum	6.17%	2.92%

Figure 10 and Table 11 show the overall skin lesions of the patients from Madaripur and Chandpur districts. Figures 11 & 12 and Table 12 show a comparative study of dermatological symptoms among the adult male and adult female patients in Madaripur and Chandpur districts, respectively. In this study, it appears (Figures 11 and 12) that the overall arsenical skin lesions of adult females are somewhat higher than males. We have no explanation for this, but the reasons may be (a) in villages of Bangladesh women drink water from the same tubewell whereas men from different tubewells (as they stay about 12 hours outside in their workplace); and (b) women suffer more from malnutrition than men.

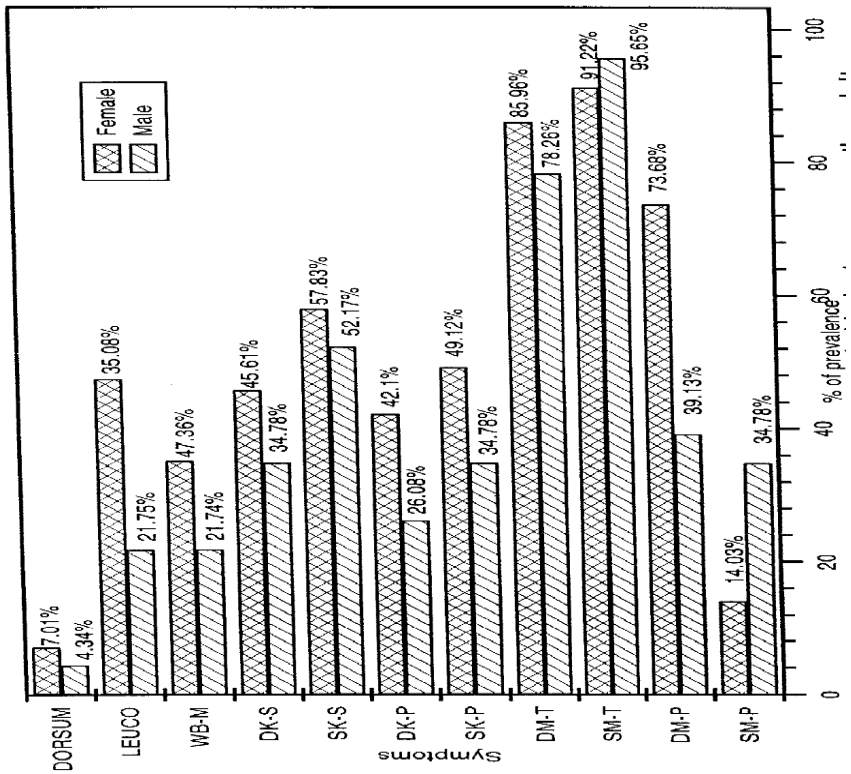


Figure 11: Distribution of arsencal skin lesions among the adult males (n=23) and females (n=57) in Madaripur district (Deltaic region)

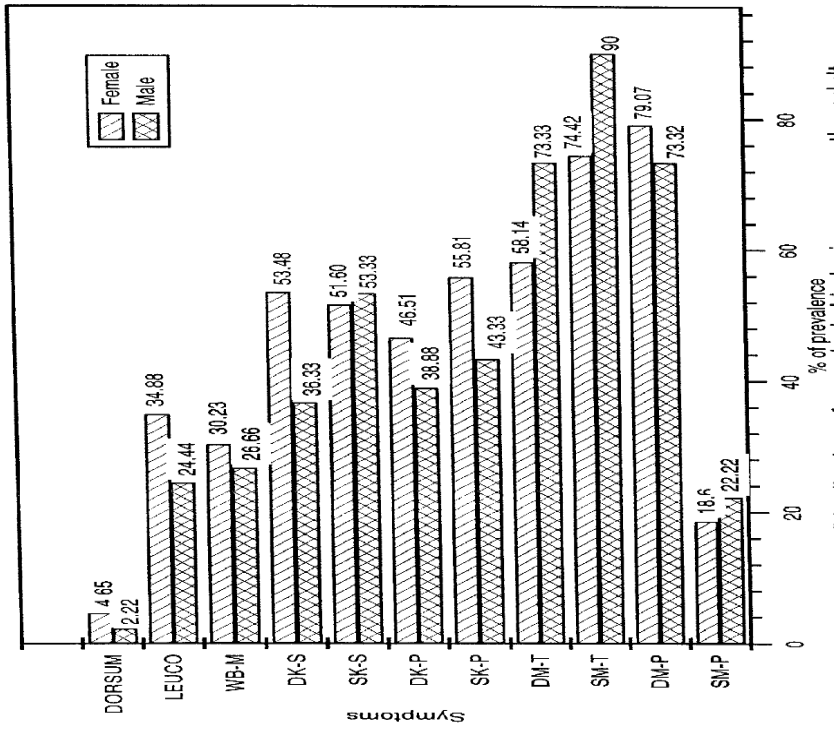


Figure 12: Distribution of arsencal skin lesions among the adult males (n=98) and females (n=55) in Chandpur district (Flood Plain)

Table 12: Distribution of the percentage of common arsenical skin lesions among the adult males and females in Madaripur and Chandpur districts of Bangladesh

Symptoms	% of prevalence			
	Madaripur		Chandpur	
	Males (23)	Females (57)	Males (98)	Females (55)
SM-P	34.78%	14.03%	22.22%	18.60%
DM-P	39.13%	73.68%	73.33%	79.07%
SM-T	95.65%	91.22%	90.00%	74.42%
DM-T	78.26%	85.96%	73.33%	58.14%
SK-P	34.78%	49.12%	43.33%	55.81%
DK-P	26.08%	42.10%	38.88%	46.51%
SK-S	52.17%	57.89%	53.33%	51.60%
DK-S	34.78%	45.61%	36.66%	53.48%
WB-M	21.74%	35.08%	26.66%	30.23%
Leuco	21.74%	47.36%	24.44%	34.88%
Dorsum	4.34%	7.01%	2.22%	4.65%

Table 13 shows the dermatological features of 8 patients from 8 police stations of these two districts (one patient from each police station), and Photographs 1-5 show the patients with all possible arsenical skin manifestations from different villages of Madaripur and Chandpur districts. In addition to dermatological symptoms, we also observed some common problems in arsenic patients such as intolerance to sunlight, burning sensations on the whole body, and respiratory problems.

Table 13: Dermatological features of patients from 3 police stations in Madaripur and 5 police stations in Chandpur districts of Bangladesh (one patient from each police station)

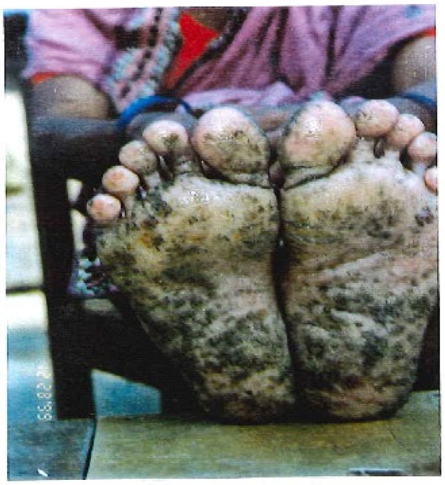
SL no	District	Police station	Sex & Age (year)	Melanosis							Keratosis						Non petting oedema	Conjunc-tional conges-tion	Bowers	Carcinoma
				Palm		Trunk		Leuco	Whole Body		Palm		Sole		Dorsum					
				Spot ted	Diff use	Spot ted	Diff use				Spot ted	Diff use	Spot ted	Diff use						
P1	Madaripur	Kalkini	M,30	-	-	ǂ	+	+	+		+	-	+	-	-		-	-	-	-
P2		Madaripur Sadar	F,35	-	-	ǂ	+	+	+		ǂ	+	ǂ	ǂ	+		-	-	-	-
P3		Rajoir	F,30	+	+	ǂ	+	+	+		ǂ	⊥	ǂ	ǂ	-		-	-	-	-
P4	Chandpur	Chandpur Sadar	M,50	-	+	ǂ	+	-	-		+	+	+	+	-		-	-	-	-
P5		Faridganj	F,40	-	-	ǂ	+	+	+		ǂ	+	ǂ	+	-		-	-	-	-
P6		Haziganj	F,30	-	-	ǂ	+	+	+		ǂ	†	ǂ	ǂ	-		-	+	-	-
P7		Matlab	M,50	+	+	+	-	-	+		+	+	+	+	-		-	-	-	-
P8		Shahrasti	M,29	+	+	ǂ	ǂ	+	ǂ		ǂ	+	ǂ	ǂ	-		-	+	-	-

Mild (+), Moderate to severe (++), Severe (+++)

Photograph-[redacted].1

Photograph-[redacted].2

Photograph-[redacted].3



Photograph-[redacted].4

Photograph-[redacted].5

Photograph Captions:

Photograph 1	Vill: Barna, PS: Shahrasti, Dist: Chandpur
Photograph 2	PS: Haziganj Dist: Chandpur
Photograph 3	Vill: Datterhat, PS: Madaripur Sadar, Dist: Madaripur
Photograph 4	Vill: Datterhat, PS: Madaripur Sadar, Dist: Madaripur
Photograph 5	Vill: Datterhat, PS: Madaripur Sadar, Dist: Madaripur

Status of total arsenic in urine, hair, nail, and skin-scale from the villagers of Madaripur district (Deltaic region) and total arsenic in hair, nail, and skin scale from the villagers of Chandpur district (Flood Plain) where we had identified arsenic patients

Urine, hair, and nails are used as the universal biomarker of arsenic body burden[9]. During our investigation, urine, hair, nail, and skin-scales samples were collected from different groups of people in arsenic-affected villages of different police stations in Madaripur and Chandpur districts. About 40-50% of these samples are from people having arsenic skin lesions, and the rest of the samples are from non-patients that live in the arsenic affected villages. The arsenic level in urine, hair, nail, and skin lesions of the people (patients + non patients) of Madaripur and Chandpur districts are given in Tables 14 & 15, respectively. The analytical results show that 100% of all urine, hair, and nail samples from Madaripur district, and 96% of hair & 100% of nail samples from Chandpur district, have arsenic levels that were above normal/toxic level, respectively. The mean concentrations of arsenic in hair, nail, and urine samples from Madaripur are 4,591 µg/kg, 9,004 µg/kg, and 550 µg/L; and hair and nail from Chandpur district are 3,990 µg/kg and 7,355 µg/kg, respectively. The arsenic level in hair, nail, and urine from Madaripur; and hair and nail from Chandpur were much higher than that of people residing in an area where drinking water is not arsenic contaminated (<3 µg/L) i.e., control population (Table 16). During our dermatological survey in the affected villages, it was observed that all members of a family were drinking arsenic-contaminated water and have high arsenic body burden (hair, nail) but not all of them have arsenic skin lesions. That means, many are sub-clinically affected in the villages. Finally, we do not expect such elevated levels of arsenic in biological samples from all villages. The probable reason for such elevated levels of arsenic in hair, nails, and urine was that we had collected these samples from those villages where arsenic patients exist, and many tubewells are highly arsenic-contaminated. The picture may be different in areas where groundwater is not contaminated with arsenic very much.

Table 14: Status of arsenic in biological samples collected from the people of arsenic-affected villages (about 40-50% samples are from people with arsenical skin lesions) of Madaripur district, Bangladesh

Parameters	Arsenic in urine[I] (µg/L)	Arsenic in hair[II] (µg/kg)	Arsenic in nail[III] (µg/kg)	Arsenic in skin scales[IV] (µg/kg)
No. of samples	72	58	60	10
Mean	550	4591	9004	6780
Median	371	4495	8705	6580
Minimum	76	1010	2180	5360
Maximum	2400	9820	20770	8720
Std deviation	462	2088	3768	1150
% of samples having arsenic above normal/toxic level (hair)	100	100	100	

[I]Normal excretion of arsenic in urine ranges from 5 - 40 µg per day[10]
[II]Normal level of arsenic in hair 80-250 µg/kg with 1000 µg/kg being the indication of toxicity[11]
[III]Normal level of arsenic in nail 430-1080 µg/kg[12]
[IV]There is no normal arsenic value for skin-scale in literature

Table 15: Status of arsenic in biological samples collected from the people of arsenic-affected villages (about 40-50% samples are from people with arsenical skin lesions) of Chandpur district, Bangladesh

Parameters	Arsenic in Hair[II](µg/L)	Arsenic in Nail[III] (µg/kg)	Arsenic in Skin Scales[IV] (µg/kg)
No. of samples	36	36	8
Mean	3990	7355	5935
Median	3785	6979	5476
Minimum	680	1670	3120
Maximum	7950	15860	6320
Std deviation	1817	3398	1084
% of samples having arsenic above normal/toxic level (hair)	96	100	-

[II]Normal level of arsenic in hair 80-250 µg/kg with 1000 µg/kg being the indication of toxicity[11]
[III]Normal level of arsenic in nail 430-1080 µg/kg[12], [IV]There is no normal arsenic value for skin-scale in literature

Table 16: Parametric presentation of arsenic in urine, hair, and nail from control population of Patiya police station of Chittagong district, Bangladesh where arsenic in groundwater below 3 µg/L

Parameters	Arsenic in urine[I] (µg/L)	Arsenic in hair[II] (µg/kg)	Arsenic in nail[III] (µg/kg)
No. of samples	62	62	62
Mean	31	410	830
Median	6	210	90
Minimum	20	180	680
Maximum	94	850	1580

[I]Normal excretion of arsenic in urine ranges from 5 - 40 µg per day[10]
[II]Normal level of arsenic in hair 80-250 µg/kg with 1000 µg/kg being the indication of toxicity[11]
[III]Normal level of arsenic in nail 430-1080 µg/kg[12]

The mean concentrations of arsenic in hair and nail are shown in Tables 14 and 15. In our survey areas, the data show that arsenic body burden is higher of the people in Madaripur district (Deltaic region) compared to that of Chandpur district (Flood Plain) (4,591 µg/kg vs. 3,990 µg/kg and 9,004 µg/kg vs. 7,355 µg/kg for hair and nail, respectively). The regression analyses were carried out between the arsenic concentrations in drinking water and arsenic concentration in hair / nail / urines (combining the samples from these two districts) and the linear regression show a positive correlation (for hair samples $r = 0.677$, $n = 69$, $p = 0.0000001$; for nail samples $r = 0.724$, $n = 67$, $p = 0.00000004$; and for urine samples $r = 0.545$, $n = 44$, $p = 0.0001$). The linear regression between arsenic in hair and nail also shows a positive correlation ($r = 0.81$, $n = 67$, $p= 0.00000006$).

Multi organizational effort to know the groundwater arsenic contamination and arsenical dermal lesions to the people in one of the police stations (Kachua police station) of Chandpur district in Bangladesh

Various organizations, including School of Environmental Studies (SOES), Jadavpur University, Kolkata, India, worked to know the arsenic situation in Kachua police station of Chandpur district. Table 17 shows their findings.

Grameen Bank[13]*:* Grameen Bank, Bangladesh tested 17,902 tubewell water samples from Kachua police stations of Chandpur district with the help of a field-testing kit. Out of this total number ($n = 17,902$) of tested water samples, 97.54% ($n=17,517$) were found having levels of arsenic that were above the Bangladesh permissible limit (50 µg/L). They have covered 12 out of 14 unions in Kachua police station.

DPHE/BGS[14] *and NGO Forum*[15]*:* Department of Public Health Engineering (Bangladesh) and British Geological Survey, and Non-Governmental Organization Forum had analyzed 83 and 32 tubewell water samples from Kachua police station and they found 98.79% and 34.37% samples have arsenic concentrations that were above WHO permissible limit (50 µg/L), respectively.

SOES and DCH: School of Environmental Studies (SOES), Jadavpur University, India jointly with Dhaka Community Hospital (DCH), Bangladesh collected 31 tubewell water samples from 5 villages of Kachua police station and analyzed by FI-HG-AAS. Results are shown in Table 5. It appears 87% of samples contain arsenic levels that were above 50 µg/L. We also analyzed 146 nails and 75 urine samples from the villagers of Kachua police station and found 99% and 64% samples contain levels of arsenic that were above normal levels, respectively (Table 18). The urine results indicate that people have already started to drink arsenic safe water (~36% urine samples contain arsenic normal level) in Kachua police station, but nail samples contain arsenic concentrations that were above normal level for both patient and non-patient (99%).

DCH: Dhaka Community Hospital (DCH), Dhaka, Bangladesh had conducted a detailed survey under UNICEF project to identify arsenic patients in the villages of Kachua police station. The area and population of this police station are 236 sq. km and 333,000, respectively.

Table 17: Findings of arsenic status in Kachua police station of Chandpur district, Bangladesh

Name of the Organization	Nature of analysis	No. of analysis	No. of samples >50 µg/L OR above normal level	Reference
Grameen Bank	Tubewell water	17,902	97.84% (17,517 samples) >50 µg/L	13
DPHE/BGS[a]	Tubewell water	83	98.79% (82 samples) >50 µg/L	14
NGO Forum[b]	Tubewell water	32	34.37% (11 samples) >50 µg/L	15
SOES[c] *&DCH*[d]	Tubewell water	31	87.10% (27 samples) >50 µg/L	This work
	Nail	146	99% (145 samples) >normal level	
	Urine	75	64% (48 samples) >normal level	
DCH[d]	People with arsenical dermal lesions	-	190 patients identified with arsenical skin lesions	

[a]*DPHE/BGS: Department of Public Health Engineering, Dhaka, Bangladesh/British Geological Survey, UK*
[b]*NGO Forum: Non-Governmental Organization Forum, Dhaka, Bangladesh*
[c]*SOES: School of Environmental Studies, Jadavpur University, Kolkata, WB, India*
[d]*DCH: Dhaka Community Hospital, Dhaka, Bangladesh*

Table 18: Status of biological samples, collected from the people of arsenic-affected villages of Kachua police station in Chandpur district

Parameters	Patient		Non-patient	
	Arsenic in urine[I] (µg/L)	Arsenic in nail[III] (µg/kg)	Arsenic in urine[I] (µg/L)	Arsenic in nail[III] (µg/kg)
No. of observation	60	122	15	24
Mean	124	5396	84	4581
Median	90	3795	55	4025
Minimum	7	780	10	1290
Maximum	515	29630	235	11810
Std deviation	116	4784	76	2656
% of samples having arsenic above normal level	64%	99%	66%	100%

[I]*Normal excretion of arsenic in urine ranges from 5 - 40 µg/ day*[10]
[III]*Normal level of arsenic in nail 430-1080 µg/kg*[12]

Under this project, a medical team and 5 field workers jointly worked for 25 days in Kachua police station. They visited different villages and identified 190 patients with arsenical skin lesions from 40 villages out of 89 villages, surveyed from all 14 unions in Kachua police station. Figure 13 shows the overall distribution of common arsenical dermatological symptoms among 190 patients (112 adult males, 67 adult females, and 11 children) in Kachua police station. During the survey in Kachua police station, they could not identify any cancer patient out of 190 patients. Figure 14 and Table 19 show a comparative study of dermatological symptoms between the affected adult males and females in Kachua police station.

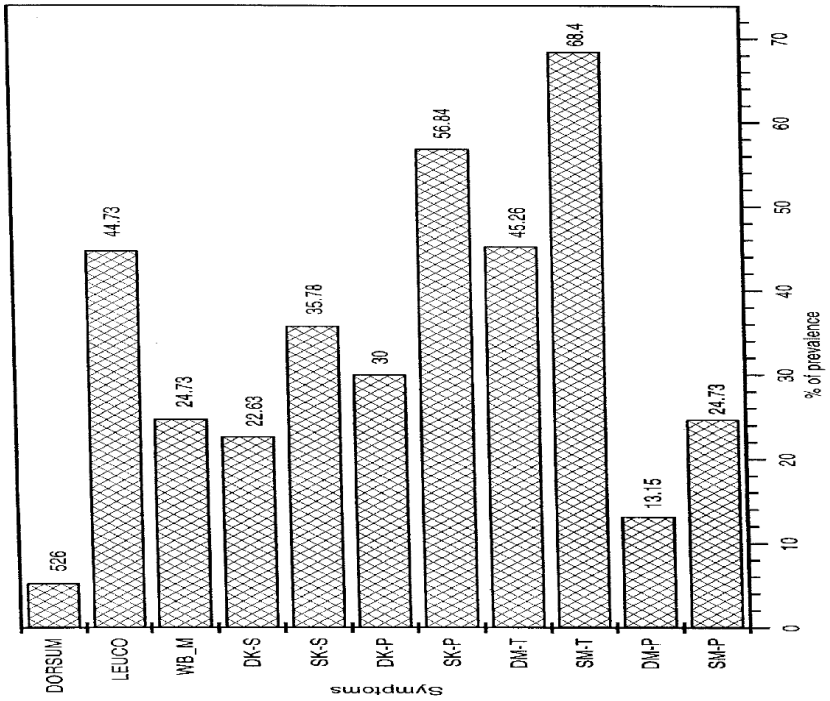


Figure 13: Distribution of the percentage of common arsenical skin lesions among the people (n=190) in Kachua police station of Chandpur district, Bangladesh

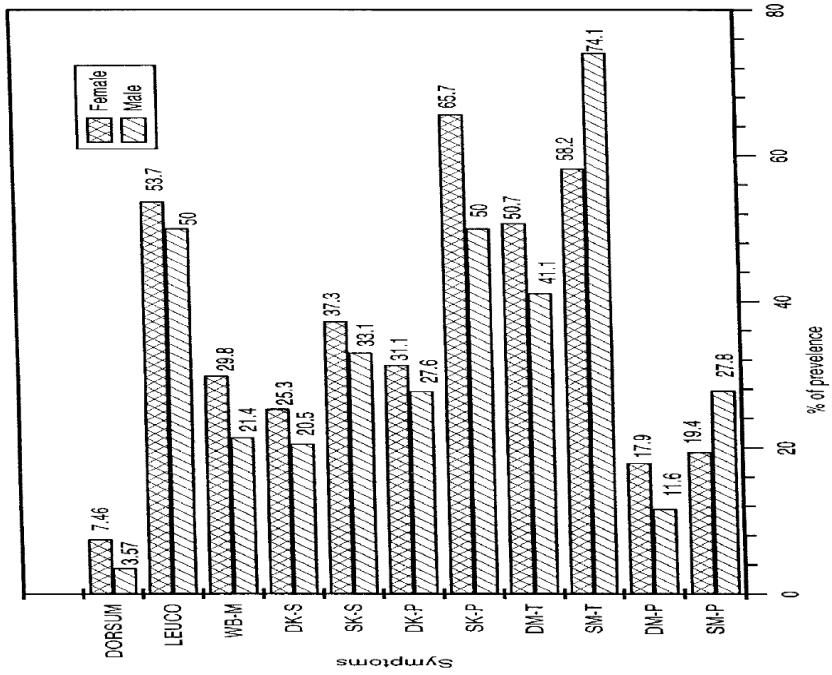


Figure 14: Distribution of the percentage of arsenical skin lesions among the adult males (n=112) and females (n=67) in Kachua police station of Chandpur district

Table 19: Distribution of the percentage of common arsenical skin lesions among the adult males and females in Kachua police station of Chandpur district

Symptoms	% of prevalence	
	Males (n=112)	Females (n=67)
SM-P	27.67%	19.40%
DM-P	11.61%	17.91%
SM-T	74.11%	58.21%
DM-T	41.07%	50.75%
SK-P	50.00%	65.67%
DK-P	27.67%	31.34%
SK-S	33.03%	37.31%
DK-S	20.53%	25.37%
WB-M	21.42%	29.85%
Leuco	50.00%	53.73%
Dorsal	3.57%	7.46%

However, overall preliminary findings from different organizations indicate that a higher percentage of groundwater samples contain concentrations of arsenic that were above 50 µg/L in Kachua police station of Chandpur district, Bangladesh.

A comparative result for the people drinking arsenic contaminated water above 10 µg/L and 50 µg/L in Madaripur (Deltaic region) and Chandpur (Flood Plain) districts

To get an idea about health risk, an estimation has been made to know the number of people in Madaripur and Chandpur dists of Bangladesh drinking groundwater that is contaminated with arsenic in levels above 10 µg/L, the WHO guideline value and above concentrations of 50 µg/L, the maximum permissible limit in drinking water. Based on the relevant information collected during fieldwork and the results obtained by FI-HG-AAS techniques for arsenic in hand tubewells water, an approach was made to calculate the number of users drinking water contaminated with arsenic levels that were above 10 µg/L and 50 µg/L from each police station in these two districts (Tables 20 and 21).

Table 20: People exposed to levels of arsenic that were above 10 µg/L and 50 µg/L in different police stations of Madaripur district (Deltaic region)

Parameters	Kalkini	Madaripur Sadar	Rajoir	Shibchar
No. of tubewells analyzed	774	770	675	90
No. of tubewells>10 µg/L	483	680	610	83
No. of tubewells> 50 µg/L	346	516	473	41
No. of users	27884	22545	18085	1171
No. of users exposed > 10 µg/L	12722	19416	14185	1094
No. of users exposed > 50 µg/L	8982	15178	10832	538
% of users > 10 µg/L	45.62	86.12	78.84	93.34
% of users > 50 µg/L	32,21	67.32	60.00	45.59
Total population in PS	279000	341000	226000	339000
Total people exposed in PS > 10 µg/L	127280	293669	178178	316423
Total people exposed in PS > 50 µg/L	89866	229561	135600	154550
Total people could be exposed > 10 µg/L	915550 (77.26%) [from all 4 PS] people in Madaripur dist.			
Total people could be exposed > 50 µg/L	609577 (51.44%) [from all 4 PS] people in Madaripur dist.			

Table 21: People exposed to levels of arsenic that were above 10 µg/L and 50 µg/L in different police stations of Chandpur district (Flood Plain)

Parameters	Chandpur Sadar	Farisganj	Haziganj	Kachua	Matlab	Shahrasti
No. of tubewells analyzed	77	91	106	31	119	741
No. of tubewells>10 µg/L	72	80	100	30	119	716
No. of tubewells> 50 µg/L	70	76	100	27	116	692
No. of users	1864	2133	2398	2215	2637	16310
No. of users exposed > 10 µg/L	1704	1875	2272	2144	2637	14974
No. of users exposed > 50 µg/L	1680	1789	2272	2122	2422	14371
% of users > 10 µg/L	91.41	87.90	94.74	96.79	100.00	91.81
% of users > 50 µg/L	90.01	83.87	94.74	95.80	91.85	88.11
Total population in PS	451000	395000	289000	333000	507000	205000
Total people exposed > 10 µg/L	412259	347205	273798	322310	507000	188210
Total people exposed > 50 µg/L	405945	331286	273798	319014	465679	180625
Total people exposed > 10 µg/L	2050782 (94.07%) [from six police stations]					
Total People exposed > 50 µg/L	1976347 (90.66%) [from six police stations]					
Total people could be exposed > 10 µg/L	2160432 (93.56%) [from all seven police stations] people in Chandpur district					
Total people could be exposed > 50 µg/L	207947 (90.06%) [from all seven police stations] people in Chandpur district					

The approach adopted for calculation based on a field study report is explained below taking Madaripur district (Table 20). Madaripur has altogether 4 police stations (Kalkini, Madaripur Sadar, Rajoir and Shibchar), and water samples were collected from all these police stations (n=2,309). Analytical results show groundwater contains arsenic concentrations that were above 50 µg/L in all police stations (Table 4). The percentage of the population of these four police stations drinking arsenic-contaminated water above 10 µg/L are 45.62%, 86.12%, 78.84% and 93.34%, and above 50 µg/L are 32.21%, 67.32%,60%, and 43.59% for Kalkini, Madaripur Sadar, Rajoir and Shibchar police stations, respectively. The numbers of people in these 4 police stations are 279000, 341000, 226000 and 339000, respectively. The number of people exposed to arsenic with respect to number of tubewell water samples in these police stations are 12722, 19416, 14185 and 1094 above 10 µg/L; and 8982, 15178, 10832, and 538 above 50 µg/L, respectively. The number of people exposed in these four police stations at above 10 and 50 µg/L are shown in Table 20. The total numbers of people exposed in this district are 915550 (77.26%) above 10 µg/L and 609577 (51.44%) above 50 µg/L out of total, 1185000. On the other hand, the people exposed in Chandpur district was calculated and given in Table 21, and the total number of people exposed in this district are 2050782 (94.07%) above 10 µg/L and 1976347 (90.66%) above 50 µg/L out of total 2180000 from 6 police stations (out of 7) of Chandpur district. The people exposed in the remaining Haimchar police station is 109650 (85%) above 10 µg/Land 103200 (80%) above 50 µg/L (we consider lowest percentage from other surveyed police stations in this district). Therefore, the total number of people exposed in this district are 2160432 (93.56%) above 10 µg/L and 2079547 (90.06%) above 50 µg/L out of total 2309000. From Tables 20 and 21, it appears that more percentage of people are consuming arsenic-contaminated water (>50 µg/L) in Chandpur district than Madaripur district in Bangladesh, and these values are 90.06% and 51.44%, respectively.

A comparative study of arsenic in deep tubewells (above 100 m depth) of Kalkini police station in Madaripur district, Bangladesh with Deganga police station/block of North 24 Parganas district, West Bengal, India (both Madaripur district, Bangladesh and North 24 Parganas district, India are Deltaic reason)

In the first phase, we analyzed water samples from 1,217 hand tubewells of 100 to 415 meters depth from all four geo-morphological regions in Bangladesh. The analytical result shows that deep tubewells of both Deltaic region (including coastal belt) and Flood plain are not free from arsenic contamination, but overall results show that higher the depth, the lower is the arsenic concentration[3,16]. Analytical report of 1,217 hand tubewell water samples of more than 100 meters depth from four geo-morphological regions of Bangladesh indicate that out of 931 hand tubewells above 200 meters, 185 (19.87%) have arsenic between 10 and 49 µg/L, and 58 tubewells (6.2%) have arsenic above 50 µg/L. To get a better understanding of arsenic concentration in deep tubewells, we were looking for a police station in a district where there are maximum numbers of deep tubewells above 200 meters. We finally found the police station of Kalkini in Madaripur district where more than 1,500 deep tubewells between depths 200 and 303 meters had been installed in the recent past. We made a field trip for water collection in Kalkini police station. Tables 22 and 23 show the arsenic status (at a glance) and distribution of arsenic in water with depth range in 347 deep tubewells, respectively.

Table 22: Arsenic status in deep tubewells of Kalkini police station/ block, Madaripur, Bangladesh

Total No. of surveyed union/G.P.	10
No. of surveyed villages	57
No. of tubewells (>100 m) analyzed	347
Tubewell with maximum depth found in 57 villages	303 m

AT A GLANCE

No. of samples <5 µg/L	No. of samples ≥ 5 µg/L	No. of samples ≥ 10 µg/L	No. of samples ≥ 50 µg/L
218 (62.82%)	129 (37.18%)	95 (27.38%)	8 (2.30%)

No. of samples 6-9 µg/L	No. of samples 10-49 µg/L	No. of samples 50-99 µg/L	No. of samples 100-149 µg/L
23 (6.63%)	87 (25.07%)	7 (2.02%)	1 (0.29%)

Maximum depth where arsenic found		
≥ 5 µg/L	≥ 10 µg/L	≥ 50 µg/L
302 m	302 m	283 m

Table 23: Distribution of arsenic concentrations in tubewells water with depth above 100 m (≥100 meters) of the tubewells in Kalkini police station of Madaripur district, Bangladesh (n=347)

Arsenic concentrations (µg/L)	Depth (range) in meter vs. number of tubewells								
	≥100	≥100-125	≥125-150	≥150-175	≥175-200	≥200-225	≥225-250	≥250-275	≥275-303
<5	218 (62.82%)	N/A	1 (0.29%)	6 (1.73%)	1 (0.29%)	18 (5.19%)	29 (8.36%)	116 (33.42%)	47 (13.54%)
≥5	129 (37.18%)	N/A	N/A	1 (0.29%)	N/A	8 (2.30%)	20 (5.76%)	71 (20.47%)	29 (8.36%)
6-9	23 (6.23%)	N/A	N/A	N/A	N/A	1 (0.29%)	4 (1.16%)	11 (2.75%)	7 (2.03%)
10-49	87 (25.07%)	N/A	N/A	N/A	N/A	4 (1.16%)	12 (3.46%)	52 (14.98%)	19 (5.47%)
50-99	7 (2.03%)	N/A	N/A	N/A	N/A	N/A	2 (0.58%)	4 (1.16%)	1 (0.29%)
100-149	1 (0.29%)	N/A	N/A	N/A	N/A	N/A	N/A	1 (0.29%)	N/A

Highest concentration found 129 µg As/L at depth 252 meters

It appears (Table 22) that 23 samples (6.63%) have arsenic between 6 to 9 µg/L, 95 samples (27.38%) have arsenic above 10 µg/L, 87 samples (25.07%) have arsenic between 10 to 49 µg/L, and 8 tube-wells (2.3%) have arsenic above 50 µg/L out of total 347 samples. Only one sample has arsenic 129 µg/L at a depth of 252 meters. This is the only tubewell out of 347 containing high arsenic, and the water is saline in nature. We collected the same sample at 2 different dates and found the arsenic concentration quite similar (on 06/26/2000 arsenic concentration was 129 µg/L, and on 08/06/2000, it was 138 µg/L). From Table 23, it appears that above depth of 227 meters only 8 tubewells (2.30%) out of 347 have arsenic above 50 µg/L (Bangladesh recommended value). Finally, we expect in Kalkini of Madaripur district may have arsenic in groundwater below 50 µg/L at depth above 300 meters (Table 23). For a comparative study of deep tubewells arsenic status, I had selected a block/police station, Deganga of

North 24 Parganas district in West Bengal, India. The Deganga block is situated in the middle part of North 24 Parganas and North 24 Parganas is just adjacent to the Jessore district in neighboring Bangladesh (Figure 3). The Madaripur district in Bangladesh and the North 24 Parganas district in West Bengal, India is of the same Deltaic deposition.

Three hundred seventy-four (374) hand tubewell water samples were analyzed between depth 100 and 197 meter (197 meter is the maximum available depth) from the block/police station Deganga of North 24 Parganas, West Bengal, India. Tables 24 and 25 show the arsenic status (at a glance) and distribution of arsenic with depth in 374 tubewells (depth range 100 m to 197 m), respectively. The analytical result shows 130 (34.76%) out of 374 samples have arsenic levels that were above 10 µg/L, 78 (20.85 %) samples between 10 to 49 µg/L, and 52 (13.9%) samples above 50 µg/L (Table 24). From Table 25, it appears that 181.88 m depth tubewells are also contaminated. The highest depth of Deganga available was 196.97. Two tubewells we had analyzed at this depth, and one is safe (<5 µg/L), and the other one contains arsenic (28 µg/L). Thus, in Deganga, even depth 196.7 is not safe according to WHO guideline value (10 µg/L). Since we do not have any tubewell that is above 196.7 meters depth in Deganga, we cannot predict at what depth arsenic-safe water will be obtained.

Table 24: Arsenic status in deep tubewells (≥100 meters) in Deganga block, North 24-Parganas dist., West Bengal, India

Total No. of Gram Panchayet (G.P.)	13
No. of surveyed G.P.	13
Total no. of villages	181
No. of villages surveyed	99
Tubewells with maximum depth (m) found in 99 villages	196.97
Total no. of tubewells analyzed	374

AT A GLANCE

No. of samples <5 µg/L	No. of samples ≥ 5 µg/L	No. of samples ≥ 10 µg/L	No. of samples ≥ 50 µg/L
216 (57.75%)	158 (42.25%)	130 (34.76%)	52 (13.9%)

No. of samples 6-9 µg/L	No. of samples 10-49 µg/L	No. of samples 50-99 µg/L	No. of samples 100-149 µg/L	No. of samples 150-200 µg/L
19 (5.08%)	78 (20.85%)	38 (10.16%)	9 (2.4%)	5 (1.33%)

Maximum depth where arsenic found		
≥ 5 µg/L	≥ 10 µg/L	≥ 50 µg/L
196.96 m	181.81 m	181.81 m

Table 25: Distribution of arsenic concentrations in tubewells water with depth above 100 m (≥100 meters) of the tubewells in Deganga block, North 24-Parganas district, West Bengal, India

Arsenic concentration (µg/L)	Depth in meter vs. number of tubewells					
	≥100	≥100-125	≥125-150	≥150-175	≥175-181.88	196.97
<5	216 (57,75%)	11 (2.94%)	101 (27.05%)	99 (26.40%)	4 (1.06%)	1 (0.27%%)
≥5	158 (42,25%)	10 (2.67%)	51 (13.60%)	90 (24.06%)	7 (1.87%)	
6-9	19 (5.08%)	2 (0.53%)	5 (1.33%)	12 (3.20%)	N/A	
10-49	78 (20.85%)	4 (1,06%)	24 (6.40%)	45 (12.03%)	4 (1.06%)	1 (0.27%)

50-99	38 (10.16%)	1 (0.26%)	17 (4.40%)	20 (5.34%)	N/A	
100-149	9 (2.40%)	1 (0.26%)	2 (0.50%)	5 (1.33%)	1 (0.26%)	
150-200	5 (1.33%)	1 (0.26%)	N/A	3 (0.80%)	1 (0.26%)	

Highest concentration found 193 µg As/L

Conclusion:

The results of this study suggest concluding the following information: (a) it appears to be that there is a higher concentration of arsenic groundwater contamination in Chandpur district (Flood Plain) compared to Madaripur district (Deltaic region); (b) shallow hand tube wells (<100 meters) are more dominant with arsenic in both Madaripur and Chandpur districts; (c) the decrease of arsenic concentration with the increase of depth in both Madaripur and Chandpur districts (above 40 meters); (d) arsenical skin lesions of adult female are higher than male, and the reasons could be: (i) in village, females drink water from same tube well whereas males from different tubewells and (ii) in villages of Bangladesh, women suffer more from malnutrition than men; (e) common problems in arsenic patients such as intolerance to sunlight, burning sensations on the whole body, and respiratory problems; and (f) many villagers are sub-clinically affected due to arsenic toxicity (Note: This study took place between 1995 and 2000).

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