Environmental pollution and the endangered population: A case study of arsenic-induced morbidity in West Bengal

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Introduction

The healthy living of citizens depends upon the successful and optimal exploitation of natural resources. An imbalance in the equilibrium manifests itself in the form of environmental hazards. Arsenic contamination of groundwater is one such impending hazard, which is a serious public health problem in most of the countries with detectable limits of concentration. The groundwater arsenic contamination in the Lower Ganga Plain of West Bengal in India was first identified in July 1983. Presently, Bangladesh and India are grappling with the largest mass poisoning of a population in history and the estimation predicts that of 125 million inhabitants, between 35 to 77 million are at risk of drinking arsenic contaminated water (Khan et al., 1997; Dhar et al., 1998). The scale of this environmental disaster is greater than any seen before; it is beyond the accidents at Bhopal, India, in 1984, and Chernobyl, Ukraine, in 1986.

Although the arsenic problem in West Bengal reached public concern almost 20 years ago, there are few concrete plans, much less achievements, to solve this problem. The villagers are usually more severely affected than they were 20 years ago. Even now, many who are drinking arsenic contaminated water are not aware of this fact and its consequences.

Bagla and Kaiser, 1996 and Bhattacharya et al., 1997 propounded two principal hypotheses on the origin of arsenic in groundwater with support from the UK- based *British Geological Survey (BGS),* which studied the problem and came out with its report in 1999. These are:

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- *Natural Sources*: the arsenic derived from the ferric hydroxide minerals present in the aquifer sediments.
- *Anthropogenic Sources:* the arsenic derived from the oxidation of arsenic-rich pyrite in the shallow aquifers as a result of lowering of the water table due to over extraction of groundwater for irrigation.

Most of the arsenic affected areas of West Bengal lie in the alluvial plains formed during the Quarternary period (last 1.6 million years). The broad alluvial plains of the Ganga and the Brahmaputra rivers in the Garo-Rajmahal Gap - called the Himalayan Foredeep - extend to the northwest and northeast, respectively. To the north of this line, lie the crystalline rocks and meta-sediments of the great Himalayan thrust blocks. West Bengal (Purulia district), Bihar and the Shillong Plateau (north of Sylhet and Mymensingh districts of Bangladesh) are the extensive areas of Pre-Cambrian era (last 570 million years) having metamorphic rocks and granites with widespread sulphide mineralisation. Because of their position in this arsenic-prone area, close to where the river Ganga enters Bangladesh (geologically speaking), BGS suggested that they might be the primary source of arsenic in the Bengal alluvium. With time, arsenic contamination of groundwater and sufferings of the people are increasing. The present situation is that 2600 villages in 75 blocks of nine districts (North - 24 Parganas, South – 24 Parganas, Kolkata, Hooghly, Howrah, Nadia, Barddhaman, Murshidabad and Malda) of West Bengal are affected.

In West Bengal, arsenical toxicity was practically unknown up to 1978. But of late, the appearance of this disease - Arsenical Dermatitis (ASD) or arsenicosis or arsenical toxicity - is rampant in villages having drinking water contaminated with arsenic. Arsenicosis may be divided into four stages (Mandal, et.al.,1996) viz.,

- Pre-clinical,
- Clinical,
- Internal complications, and
- Malignancy.

This study focuses in detail on the clinical stage (symptomatic or overt stage) of arsenicosis with specification of each symptom as described by Yeh, 1973. The aim is to measure the prevalence rate of skin lesions associated with arsenic exposure. A graded mean score of skin symptoms was used to measure the intensity of the problem. For the suspected and probable cases of arsenicosis, general health problems and the perceived arsenic related morbidity pattern have been studied.

Major Dermatological Symptoms of Chronic Arsenic Toxicity

The dermatological signs of the clinical stages of arsenical dermatitis are the first outward manifestations visible in chronic arsenic affected individuals exposed to the risk of contaminated water with varying concentration levels (Shannon and Strayer, 1989).

i) Melano-keratosis

Melanosis i.e., dark pigmentation – diffuse or spotted with keratosis i.e., dry, rough spotted nodules on palms and soles are the chief symptomatology of arsenical dermatitis (ASD). There are various causes of melanosis, keratosis, spotted and diffused, genetic or acquired. The combination of pigmentation (melanosis) and nodular rough skin (spotted palmo-plantar keratosis) in the same patient points to chronic arsenic toxicity and the diagnosis of arsenical dermatitis (ASD), excluding hundreds of causes of isolated pigmentation and nodular rough skin. Genetic disorders are often present since childhood and acquired diseases like arsenicosis often appear in later life.

ii) Diffuse Melanosis

Diffused darkening of skin starts in the palm, trunk and gradually spreads to the whole body. This is the earliest symptom and a comparison with the normal palm reveals mild melanosis. It is not necessary that people suffering from arsenic toxicity will have symptom of diffuse melanosis.

iii) Spotted Melanosis (Raindrop pigmentation or spotted pigmentation)

It is also an early symptom and arsenic patients normally show spotted melanosis on chest, back and sometimes on the limbs, i.e., hands and legs.

iv) Leucomelanosis

Arsenic patients having spotted melanosis develop pigmented and depigmented spots on legs or trunk. Leucomelanosis, which are black and white spots, side by side, is

also seen in many patients. Probably, stimulation of melanocyte produces pigmentation and damage in later stage is responsible for depigmented spots. Leucomelanosis is common in persons who have stopped drinking arsenic contaminated water but had spotted melanosis earlier.

v) Keratosis

Keratosis is the middle stage of arsenicosis. The skin, in portions becomes hard and fibrous; it is as if the body has broken out into hard boils, or ulcers (Cuzick, et.al., 1992). Diffuse or nodular keratosis on the palm of the hand or sole of the foot is a sign of moderately severe toxicity. Rough and dry skin, often with palpable nodules in dorsum of hands, feet and legs means severe toxicity. This can lead to formation of gangrene and cancer (Sommers and McManus, 1953).

- After 5 to 10 years of spotted melanosis, palmo-plantar skin (Cuzick, et.al., 1984) shows spotted keratosis (may be early depending on concentration of arsenic in contaminated water, amount consumed and nutritional status).
- Still later (after 10 years) skin becomes dry and thickened leading to diffused keratosis, mainly on palms and soles.
- Gradually, thickening of soles can give rise to cracks and fissures – hyperkeratosis.

If the concentration of arsenic in tube well water is high or the disease is of long duration, more than 10-15 years, keratosis also develops in the dorsal skin of hands, feet, legs (dorsal keratosis) or even other parts of the body or the skin (whole body keratosis).

Need for the study

In 1983, K.C.Saha, Department of Dermatology, School of Tropical Medicine in Kolkata, identified the first case of arsenic-induced skin lesions. After ruling out other causes, water sources used by the patients were analyzed, and the diagnosis of arsenic-caused disease was confirmed. After 20 years of the first confirmation, it is contended that not only thousands of present sufferers but, countless future generations are still gravely at risk from groundwater contamination in Bengal. The mammoth task of surveying the actual magnitude of the problem is very difficult to scale and therefore, the

present study is just an endeavour towards touching the tip of an iceberg in capturing the entire scenario in a single frame, where the poor sufferers have been studied systematically from the point of view of arsenic-specific dermal symptoms, their perceived health problems and the emerging social issues related to the problem.

To study them, specific objectives have been formulated as,

- To measure the prevalence of morbidity and arsenic-specific dermal manifestations (skin lesions) among the study population.
- To examine the extent of intensity of the arsenic-caused dermal symptoms among the affected population.

The study area

A cross-sectional case-control study was conducted in Malda district, one of the worst hit arsenic affected districts of West Bengal. This district is a low-lying plain with the land sloping towards the south. The soil of the area is alluvial formed by the rivers of Ganga, Kalindi, Tangan, Punarbhaba and Mahananda. The economy is purely rural in character as majority of the workers depend on primary activities as the principal source of livelihood.

Of the total fifteen blocks, five blocks namely English Bazar, Manickchak, Kaliachak I, II and III are severely arsenic-prone, mainly due to their natural setting though anthropogenic impact cannot be ruled out. The one-fifty arsenic afflicted villages cover a total area of 1011 sq.km. and a population base of 9,80,385, according to survey reports of the School of Environmental Studies (SOES). The minimum and maximum concentration varies in the range of 0.01 to 10.0mg/L, far above the WHO guideline value of 0.01mg/L.

Sampling design and sample size

Among the five affected blocks of Malda, two blocks, namely, Kaliachak-I and Kaliachak-II were selected purposively for the present study. From the two selected blocks, six villages, two each from high, medium and low category were chosen

Table 1: Basic data of the study villages in Malda, West Bengal

Blocks with village name	Number of tube well samples	Arsenic concentration of tube well water (mg/L)*	Depth of the tube well (in metres)*	Number of people drinking tube well water	Total number of surveyed households
KALIACHAK-I					
	1	0.07	25.0	32	
	2	0.09	39.0	28	
Bamangram	3	0.13	20.0	23	
	4	0.16	20.0	30	
	5	0.41	25.0	31	
Mean		**(0.17)**	**(25.8)**		**(n=30)**
	1	0.09	18.0	25	
	2	0.10	19.3	37	
Chaspara	3	0.16	21.0	39	
	4	0.17	19.8	43	
	5	0.17	20.0	30	
Mean		**(0.14)**	**(19.6)**		**(n=30)**
	1	0.02	60.0	37	
	2	0.03	57.8	28	
Moksudpur	3	0.04	46.3	27	
	4	0.04	62.0	33	
	5	0.05	61.3	35	
Mean		**(0.04)**	**(57.5)**		**(n=30)**
KALIACHAK-II					
	1	0.06	32.9	34	
Mothabari	2	0.90	42.6	29	
	3	0.25	27.4	35	
	4	0.33	23.5	40	
	5	0.32	23.6	31	
Mean		**(0.22)**	**(30.0)**		**(n=30)**
	1	0.05	29.0	32	
	2	0.06	25.6	32	
Debipur	3	0.07	27.5	35	
	4	0.07	36.4	32	
	5	0.16	41.0	36	
Mean		**(0.08)**	**(31.9)**		**(n=30)**
	1	0.03	59.2	38	
Protappur	2	0.04	58.1	46	
	3	0.05	63.4	36	
	4	0.05	52.4	39	
Mean		**(0.04)**	**(46.6)**		**(n=30)**
Total				**973**	**180**

*Note: *Data provided by the Public Health and Engineering Directorate (PHED), Malda.*
Name of the blocks in capital

according to the ranking given by the Public Health and Engineering Directorate (PHED) to the villages by arsenic concentration levels in the tube wells. In all, three villages, one each from *high, medium* and *low* category have been selected from Kaliachak-I and II respectively. The level of arsenic concentration and the related information of different villages selected for the study purpose are given in table 1.

The criterion for dividing the villages into *high*, *medium* and *low* category was the concentration of arsenic in the tube wells in these villages with proper matching of the demographic and socio-economic indicators like age, sex, religion, caste, education, occupation and standard of living for a case-control study. If the arsenic level was less than 0.05 mg/L, it was categorized as low, 0.05 to 0.15 mg/L was taken as the medium category and more than 0.15 mg/L as the high category. Accordingly, Bamangram and Mothabari were chosen from the *high* category, Debipur and Chaspara from the *medium* category and Protappur and Moksudpur from the *low* category. Among them, the villages falling in the high and medium category were taken as the *case* villages (Bamangram, Mothabari, Debipur and Chaspara) and the low category as the *control* villages (Protappur and Moksudpur). From each of the selected villages, (except Moksudpur) five tube wells were identified for which arsenic level was provided by the Public Health and Engineering Directorate (PHED). Six households from the users of each identified tubewells were randomly chosen. In case of Moksudpur, four tube wells were identified and eight households each from three tube wells and six households from one were selected respectively. In all, the sample size consists of 180 households; 120 and 60 for case and control villages respectively, with a sample population of 654 in case villages and 319 in control villages.

Primary data has been collected from the households of the selected villages through house-to-house visits using a semi-structured interview schedule (both household and individual). At the beginning of the interview, verbal consent was obtained from each prospective respondent of the household to participate in the study. The duration of the survey was for 34 days commencing on 5th July and ending on 8th August 2003.

Findings and Discussion

- ***Prevalence rate by case and control villages***

The disease prevalence rate of arsenic- specific skin lesions have been calculated both for case and control villages by the varying arsenic levels in the groundwater of the

Table 2: Prevalence rate of skin lesions among suspected cases per 100 study population by age, sex and case and control villages

Villages with varying arsenic concentration				
Sex / Age	**Case**		**Control**	**Total**
	High	**Medium**		
Males				
0-3	0.0 (0/9)	0.0 (0/11)	0.0 (0/14)	0.0 (0/34)
4-14	7.0 (3/43)	2.1 (1/47)	0.0 (0/31)	3.3 (4/121)
15-25	25.0 (9/36)	16.2 (6/37)	2.7 (1/36)	14.7 (16/109)
26-36	64.5 (20/31)	35.7 (10/28)	7.1 (2/28)	36.8 (32/87)
37-47	67.8 (19/28)	39.1 (9/23)	15.38 (4/26)	41.5 (32/77)
48+	78.3 (18/23)	40.0 (12/30)	16.1 (5/31)	41.7 (35/84)
All ages	40.6 (69/170)	21.6 (38/176)	7.2 (12/166)	23.2 (119/512)
Age-adj PR	41.0	22.4	6.7	23.2

Villages with varying arsenic concentration				
Sex / Age	**Case**		**Control**	**Total**
	High	**Medium**		
Females				
0-3	0.0 (0/11)	0.0 (0/11)	0.0 (0/5)	0.0 (0/27)
4-14	4.6 (2/43)	2.1 (1/47)	0.0 (0/42)	2.3 (3/132)
15-25	3.2 (1/31)	6.4 (3/47)	0.0 (0/37)	3.5 (4/115)
26-36	17.6 (6/34)	7.1 (2/28)	0.0 (0/32)	8.5 (8/94)
37-47	53.3 (8/15)	19.0 (4/21)	0.0 (0/26)	19.3 (12/62)
48+	55.5 (5/9)	9.1 (1/11)	0.0 (0/11)	19.3 (6/31)
All ages	15.4 (22/143)	6.7 (11/165)	0.0 (0/153)	7.1 (33/461)
Age-adj PR	16.6	6.8	0.0	7.2

Abbreviations: adj, adjusted; PR, prevalence rates.
Cases and total number of study subjects in parentheses.

studied villages. The respondents were stratified by sex and six age categories: 0-3, 4-14, 15-25, 26-36, 37-47 and >48 years. All the prevalence rates were directly standardized considering the age distribution of the study population as standard.

When the prevalence rate of skin lesions was calculated by villages, the age-adjusted prevalence rate was found to be 17 percent for females and 41 percent for males in the *high* category villages, and 7 and 22 percent for females and males respectively in the *medium* category villages (Table 2). In the control villages (here considered as the low category), none were affected among the females, while the rate of prevalence among males was found to be 7 percent. The reason behind this may be the prolonged duration of exposure to contaminated water above the WHO guideline value of 0.01 mg/L but below the permissible limit of 0.05 mg/L. Figure I shows the trend line for prevalence rate in the classified villages according to age and sex. It depicts a steady increase in the prevalence rate with higher ages in all the categories. For the 0-3 age group in all the villages, the prevalence rate is nil, which indicates that the minimum exposure for the occurrence of the disease is more than three years.

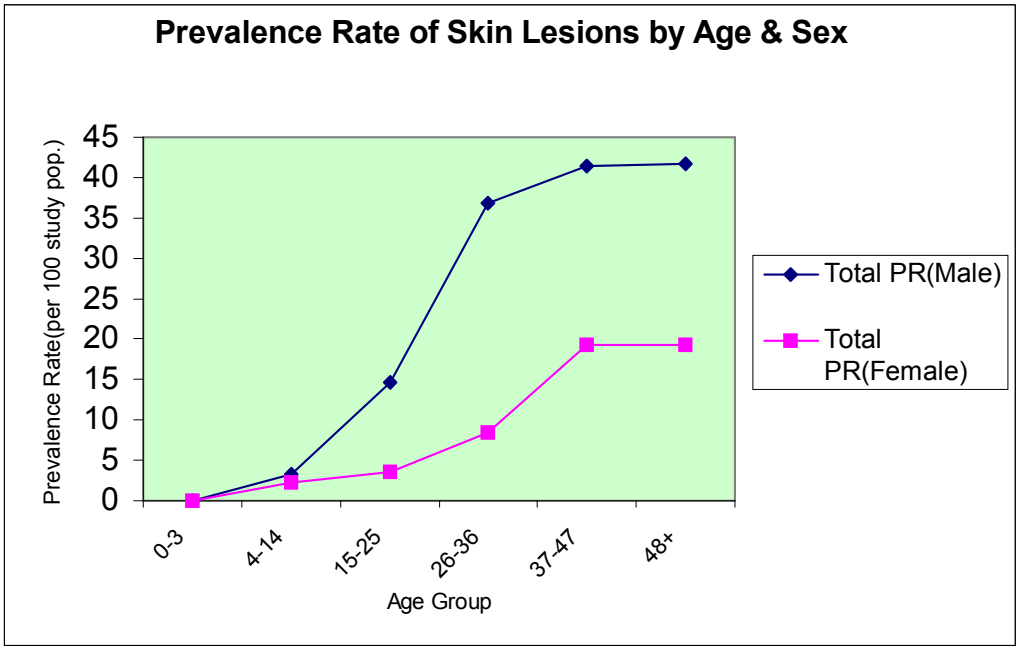

Figure I

Among males, the prevalence is as high as 78 percent compared to 55 percent for females in the 48+ age group for the villages in the high category. This rate has been lowered by 19 and 46 percent respectively for males and females in the same age group but falling in the medium category of village classification. About 16 percent of the males have one or more arsenic related dermal symptoms even in the control villages with no affected females in the age group of 48 years and above. Thus, the overall age-adjusted prevalence rate is 23 and 7 percent respectively among males and females highlighting a male-female differential of 16 percent.

- ***Individual exposure assessment***

The individual exposure to chronic arsenic toxicity has been assessed in terms of levels of arsenic contaminated water or by daily dose per body weight (μg/L-kg/day). This has been described with the help of the dose index (Tondel, et al., 1999), which is the present arsenic level in water (consumed by the individual) divided by individual body weight expressed in micrograms per litre per kilogram (μg/L-kg), which may crudely account for the arsenic intake in relation to body size. The arsenic concentration in the drinking water in micrograms per litre was taken as the current exposure level. The cut off points for the dose index has been specified as 1 for ≤3μg/L-kg, 2 for 3.01-6μg/L-kg, 3 for >6μg/ L-kg.

An apparent dose-response relationship was found, independent of all background characteristics, in case of any sort of skin lesions (Table 3). The dose-response relationship reveals that higher concentration of arsenic in drinking water is associated with the higher risk of the disease prevalence even among children. About 86 percent of the children in the age group 0-14 have a dose index >6μg/L-kg which reveals the fact that dermal manifestations are observable even at lower exposure but higher doses. For the dose index value of 2, the percent distribution of males and females are 40 and 42 percent respectively. This higher percentage in case of females can be attributed to low body mass index (BMI) and low nutritional level, which intensifies the susceptibility factors leading to detectable disease.

Table 3: Dose-response relationship among affected population according to selected background characteristics by case and control villages

Background characteristics	*Case (n=140)*			*Control (n=12)*		
	Dose Index 1*	**Dose Index 2****	**Dose Index 3*****	**Dose Index 1***	**Dose Index 2****	**Dose Index 3*****
Age						
0-14	-	14.3 (1)	85.7 (6)	-	-	-
15-30	37.5 (15)	50.0 (20)	12.5 (5)	100.0 (1)	-	-
30+	37.6 (35)	38.7 (36)	23.7 (22)	100.0 (11)	-	-
Sex						
Male	39.3 (42)	40.2 (43)	20.6 (22)	100.0 (12)	-	-
Female	24.2 (8)	42.4 (14)	33.3 (11)	-	-	-
Education						
Illiterate	35.6 (16)	48.9 (22)	15.6 (7)	100.0 (3)	-	-
Lit<pri.sch.	41.9 (13)	32.3 (10)	25.8 (8)	100.0 (7)	-	-
Pri. to mid. sch. com	35.0 (14)	42.5 (17)	22.5 (9)	100.0 (1)	-	-
High sch. & above	29.2 (7)	33.3 (8)	37.5 (9)	100.0 (1)	-	-
Occupation						
Agricultural sector	52.1 (25)	37.5 (18)	10.4 (5)	100.0 (8)	-	-
Non-agricultural sector	32.6 (14)	32.6 (14)	34.9 (15)	100.0 (3)	-	-
Not working	22.4 (11)	51.0 (25)	26.5 (13)	100.0 (1)	-	-
Standard of living						
Low	39.0 (16)	48.8 (20)	12.2 (5)	100.0 (2)	-	-
Medium	40.0 (24)	36.7 (22)	23.3 (14)	100.0 (8)	-	-
High	25.6 (10)	38.5 (15)	35.9 (14)	100.0 (2)	-	-
Duration of stay						
≤ 15 years	23.5 (4)	17.6 (3)	58.8 (10)	-	-	-
> 15 years	37.4 (46)	43.9 (54)	18.7 (23)	100.0 (12)	-	-

Note: Dose index 1 ≤3μg/L-kg, Dose index 2** 3.01-6μg/L-kg, Dose index 3*** >6μg/L-kg.*

The duration of stay has a strong association with dose-index, lower duration but higher dose and vice versa is vital for arsenic-specific disease occurrence. About 59 percent of the cases fall in the third category of the dose index with duration of stay less than 15 years. With duration of more than 15 years, the percentage is as high as 40 percent even in dose index 1. Compared to the case villages, the control villages do not show a higher dose index as arsenic level in the water is below the permissible limit of 0.05mg/L and all the suspected cases with skin symptoms have a residence history of more than 15 years in the same locality.

- ***Scoring of Symptoms***

Assuming that the early manifestations of arsenic poisoning are more frequent than the advanced cases, a score was assigned to each of the symptoms in order of increasing severity and decreasing prevalence as specified by Yeh, (1973). Appendix -I gives the score values assigned to each symptom in accordance with their occurrence in

Table 4: Mean score of dermal manifestations among affected population according to selected background characteristics by case and control villages

Background characteristics	Case	Control	Total
Age			
0-14	7.4 (4)	-	7.4 (4)
15-30	12.3 (35)	-	12.3 (35)
30+	13.2 (101)	4.35 (12)	12.2 (113)
Total	**12.8 (140)**	**4.35 (12)**	**12.15 (152)**
Sex			
Male	13.9 (93)	4.2 (11)	12.8 (104)
Female	10.7 (47)	6.0 (1)	10.6 (48)
Total	**12.8 (140)**	**4.35 (12)**	**12.15 (152)**
Education			
Illiterate	11.0 (45)	4.0 (3)	10.6 (48)
Lit<pri.sch.	13.0 (31)	5.0 (7)	11.5 (38)
Pri. to mid. sch. compl	13.3 (40)	2.5(1)	13.0 (41)
High sch. & above	15.2 (24)	2.5 (1)	14.7 (25)
Total	**12.8 (140)**	**4.35 (12)**	**12.15 (152)**
Occupation			
Agricultural sector	12.9 (48)	4.5 (8)	11.7 (56)
Non-agricultural sector	13.0 (43)	3.6 (3)	12.4 (46)
Not working	12.6 (49)	5.2 (1)	12.4 (50)
Total	**12.8 (140)**	**4.35 (12)**	**12.15 (152)**
Standard of living			
Low	13.6 (41)	3.0 (2)	13.1 (43)
Medium	12.1 (60)	5.2 (8)	11.2 (68)
High	13.1 (39)	2.5 (2)	12.6 (41)
Total	**12.8 (140)**	**4.35 (12)**	**12.15 (152)**
Duration of stay			
Less than equal to 15 years	8.0 (17)	-	8.0 (17)
More than 15 years	13.5 (123)	4.35 (12)	12.7 (135)
Total	**12.8 (140)**	**4.35 (12)**	**12.15 (152)**

Note: Sample size in parentheses.

different parts of the body. Thus, the most common and earliest manifestation has a score of 1 and the rarest 5.5. Keratosis being a much advanced dermatological symptom, a person having keratosis has been considered positive for all the other earlier symptoms of melanosis. Hence, in that case, the overall score for each individual has been derived by

adding up the scores of all the earlier symptoms. Lastly, a mean score has been calculated (range 1-35.25) to assess the severity of the problem for all the suspected and probable cases of arsenical dermatitis.

As expected, the mean score for the case villages is found higher by 8 percent than the control villages (Table 4) explaining the intensity of the problem in view of higher arsenic concentration. Children in case villages have a high mean score of 7.4 as compared to zero in the control villages. A sex-differential is apparent in the mean score of males and females with 13.9 and 10.7 respectively in the case villages. Respondents with duration of stay in the present area for less than 15 years have a lower mean score of 8.0 as compared to those having higher duration. All the suspected cases (12) even in the control villages show some skin symptom in case of longer duration of stay (more than 15 years). This reveals that longer duration and higher concentration account for the severity of arsenic-related disease incidence. The correlation coefficient of score and concentration of arsenic in the nearest tube well has come out to be positive and significant.

- ***Perceived health problems***

The symptoms of acute poisoning through oral consumption of arsenic contaminated water are often manifested through minor ailments like headache, drowsiness, confusion, convulsion, decrease in sensitivity to touch, pain, and temperature sensation, distal weakness of grip and wrist drop (Col, et. al., 1999). Among the suspected and probable cases in the study population, the most frequent complaints or health problems (faced during the past three months) involved - tingling and numbness of hands and feet, reported by 84.9 percent, followed by 78.3 percent with general weakness and fatigue (Table 5). Weakness is a highly subjective symptom, which has previously been reported, in arsenic-exposed patients (Guha Mazumdar, et.al., 1997). The other symptoms included frequent high fever with cold and cough (48.7 percent), indigestion problem (46.7), muscular and joint pain, eye and urine problem. The respondents have rarely been found to take medicine for any of these ailments, in spite of facing difficulties in daily activities.

Table 5: Perceived health problems of the affected population

Health Problems/Frequent Complaints	Percent	Number of cases (n=152)	Taken any medicine		Faced difficulty in day to day activities		
			Yes	No	No	Some	Lots
Tingling and numbness of hands and feet with burning sensation in the affected areas	84.9	129	23.2 (30)	76.8 (99)	15.4 (19)	62.3 (81)	22.3 (29)
General weakness and fatigue with body ache and complaints of weight loss	78.3	119	10.9 (13)	89.1 (106)	21.8 (26)	65.5 (78)	12.6 (15)
Often high fever with cold and cough accompanied by head ache, drowsiness, confusion and convulsions	48.7	74	63.5 (47)	36.5 (27)	1.4 (1)	62.2 (46)	36.5 (27)
Indigestion, gas, vomiting, stomach pain and constipation	46.7	71	64.8 (46)	35.2 (25)	1.4 (1)	69.0 (49)	29.6 (21)
Eye problem and headache	19.1	29	13.8 (4)	86.2 (25)	-	65.5 (19)	34.5 (10)
Muscle and joint pain with occasional complaints of pain in chest	12.5	19	52.6 (10)	47.4 (9)	-	26.3 (5)	73.7 (14)
Urine problem and prostration	11.8	18	50.0 (9)	50.0 (9)	-	38.9 (7)	61.1 (11)

*Note: *(n) Sample size in parenthesis*

- ***Disease history***

The disease history of the affected individuals for the past six months shows that the most common diseases other than skin lesions have been dysentery, jaundice, malaria, liver disease, etc (Table 6). The ingestion of inorganic arsenic in drinking water may be a contributory factor for other co-morbidity symptoms like pulmonary effects - 7 percent having complaints of chronic bronchitis; digestive system disorders, with 22 percent reporting dysentery, 7 percent diagnosed with ulcer and 14 and 7 percent suffering from jaundice and liver diseases respectively among the affected population. Although numbers were small, there was evidence of cancer (3 percent) among the suspected cases.

Table 6: Disease history of the affected population

Diseases	Percent	Number (n=152)
Heart disease	2.0	3
Blood pressure	2.6	4
Chronic bronchitis	6.6	10
Tuberculosis	0.7	1
Artharitis	8.6	13
Paralysis	1.3	2
Diabetes mellitus	3.3	5
Ulcers	7.2	11
Dysentery	21.7	33
Dyspepsia	13.8	21
Diarrhoea	9.2	14
Malaria	12.5	19
Disease of the mouth	3.9	6
Hearing problem	3.9	6
Cataract	1.3	2
Skin disease	100.0	152
Liver disease	6.6	10
Jaundice	14.5	22
Tumour/Cancer	3.3	5

Summary and Conclusion

The study, which was an effort to investigate the health effects (in the form of skin lesions) of arsenic contaminated drinking water, provides evidence that ingestion of inorganic arsenic in drinking water expose population to severe health risks. For this purpose a detailed case-control study was carried out to assess the dose-response relationship of arsenic in drinking water and skin lesions. These dermatological manifestations pose an important public health problem because advanced forms of keratoses are painful and pigmentation changes can lead to social isolation in the villages as evident from the findings of the study. In contrast to cancers that take decades to develop, the latency for the dermatological effects are shorter, depending on the levels of

past exposure. Thus, arsenic-induced skin lesions are early biomarkers of long-term exposure since they may appear after shorter periods. Skin lesions might be biomarkers for more serious long-term incidence of cancers of the skin and other internal organs.

Some of the key findings of this study are:

- The age-adjusted prevalence of skin lesions is strongly related to arsenic concentrations in water, rising from zero in the lowest exposure category (≤0.05 mg/L) to 16 per 100 for females consuming water containing >0.26001 mg/L. In males, the age-adjusted prevalence of skin lesions increased from 7 per 100 in the lowest level to 44.3 per 100 in the highest category. The overall prevalence of cutaneous manifestations was 7 per 100 females and 23 per 100 in males.

- Men had higher prevalence of dermal lesions in all exposure categories, which indicate that males are more susceptible to get the disease. But the prevalence rate shows an increasing trend for both the sexes in accordance with progressive higher levels of arsenic concentration and increasing age.

- Surprisingly, a number of individuals with skin lesions were found to be consuming lower levels of arsenic (≤0.05 mg/L). This is particularly evident in the control villages, where 7 per 100 males are affected while for females it is zero.

- Morbidity from skin lesions due to chronic arsenic toxicity has been found in almost one-third of the study population aged more than 15 years. This point to a strong dose-response when using a dose index instead of levels to assess exposure. It may be assumed therefore, that arsenic levels in relation to body weight more accurately reflect the dose of arsenic obtained by the individual rather than just the water concentration.

- There exist sex differences in dose-response relationship with varying exposure that may be accounted for by three factors. First, the cumulative exposure is much higher in males who were born in these villages, than in females who might have migrated from less contaminated areas after marriage. The other two confounding factors are sunlight

exposure (Memon, et. al., 2000) and primarily masculine habits like smoking bidi or cigarette and chewing of tobacco that may account for the observed difference.

- The intensity of arsenicosis is more among females and children rather than males, which may be a function of individual immunity, nutritional status and higher dose index as supported by Smith, et al., 2000.

- The dose-response relationship for arsenic has been controversial (Haque, 2000), but the present study assessed the participant's current drinking water sources, which helped examine the relationship using a more refined exposure assessment. There is a significant positive relationship between duration of stay (considered here as exposure period) and individual dose index.

- The individual exposure assessment suggests that as arsenic levels were higher in the case villages, the highest dose index was stipulated at >6μg/L-kg. With higher doses and lower body weight, even children with lower exposure are susceptible to the arsenic-specific morbidity.

- The age factor plays a dominant role and prevalence has been found to be higher among adults (both males and females) than in children. Based on limited exposure assessment, some cases appear to be occurring at surprisingly low levels of exposure.

- The mean score for arsenic-induced skin lesions was found to higher by 8 percent in the case villages compared to the control villages. In addition, individuals with some symptoms of arsenicosis have an enhanced susceptibility of developing respiratory problems, general weakness, stomach ailments and burning sensation in the affected areas.

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APPENDIX – I

Scores of different arsenic-induced dermatological manifestations

Arsenic-specific skin symptoms	*Scores*
DMP	1.0
DMT	1.5
SMP	2.0
SMT	2.5
LEU	2.75
WBM	3.0
DKP	3.5
DKS	4.0
SKP	4.5
SKS	5.0
DK	5.5
TOTAL	35.25

Source: Yeh, 1973

Abbreviations:

DMP - Diffuse Melanosis on Palm.

DMT - Diffuse Melanosis on Trunk.

SMP - Spotted Melanosis on Palm.

SMT - Spotted Melanosis on Trunk.

LEU - Leuco-melanosis.

WBM - Whole Body Melanosis.

DKP - Diffuse Keratosis on Palm.

DKS - Diffuse Keratosis on Sole.

SKP - Spotted Keratosis on Palm.

SKS - Spotted Keratosis on Sole.

DK- Dorsal Keratosis.