Arsenicosis: Prevalence, knowledge, attitude and practice in a rural community, Nadia, West Bengal, India, 2008

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Dissertation project submitted in partial fulfillment of the requirements for the degree of Master of Applied Epidemiology (M.A.E) of

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CERTIFICATION

This is to certify that this dissertation, entitled 'Arsenicosis: Prevalence, knowledge, attitude and practice of a rural community, Nadia, West Bengal, India,' submitted by Dr. Tapan Kumar Saha, in partial fulfillment of the requirements for the degree of Masters of Applied Epidemiology, is the original work done by him and has not been submitted earlier, in part or whole, for any other (publication or degree) purpose.

Date: 31/1/07

Director

Table of contents

Section I: Dissertation

Section II: Literature review

List of tables and figures

Table:

Figure:

Abbreviations

As	Arsenic
CHC	Community Health Centre
CCA	Chromated copper arsenate
FETP	Field Epidemiology Training Programme
IEC	Information Education Communication
KAP	Knowledge, attitude and practice
MAE	Master of Applied Epidemiology
ICMR	Indian Council of Medical Research
NIE	National Institute of Epidemiology
NGO	Non Government Organization
WHO	World Health Organization
UNICEF	United Nation's International Children's Educational Fund
STM	School of Tropical Medicine
PHED	Public health engineering deportment
SIDA	Swedish International Development Cooperation Agency
DANIDA	Danish International Development Agency
BIS	Bureau of Indian Standard
UK	United kingdom
USA	United states of America

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Dated: (Dr. Tapan Kumar Saha)

Section- I

Dissertation

Abstract

Introduction

Arsenicosis, also referred to as arsenism, is a non-communicable disease resulting from drinking arsenic contaminated groundwater. Globally, 70 countries reported ground water contamination. Nadia is one of the 12 districts in West Bengal having high arsenic in ground water in all 17 blocks and human cases in nine. We conducted a study to estimate (1) the frequency of knowledge, attitude and practices (KAP) of the rural community about arsenic and arsenicosis, arsenic content of ground water and prevalence of arsenicosis.

Methods

We randomly selected one block among nine and conducted a cross sectional analytical study in all the three villages from where cases were reported. Randomly selected 136 households and interviewed 412 adult aged ≥ 18 years for KAP and examine all 533 for prevalence using WHO case definition for arsenicosis. Ground water was tested for arsenic.

Results

Out of 533 individuals surveyed 51 met the case definition (prevalence 9.6%). The prevalence was higher among those who consumed water from present source for ≥6 years (OR 8.8, 95% CI 2.1-36.9), were farmers and illiterate. Arsenic above permissible level was detected in 76% sample. Pigmentation changes were present among all 51 case patients while 84% had hyperkeratosis. Other clinical features relating to

arsenicosis were also present. Out of 412 adult 58% knew that drinking water should be tested for arsenic but only 12% knew where water can be tested and 10% tested water from their own. 67% were willing to change the water source if contaminated. While in practice 24% changed their water source because of contamination.

Discussion

Arsenicosis was endemic in Nadia district. Lack of awareness about arsenic, arsenicosis and arsenic free water sources restrained people to use safe water sources. This incomplete knowledge was on account of poor IEC activities conducted under arsenic mitigation programme. Based on these findings, we propose to mark the Safe and unsafe tube-well and inform people to use safe tube-well for drinking purpose only. Educate the people about alternative surface water source.

Key words: Arsenic, arsenicosis, safe water, mitigation, KAP.

1. Introduction

Arsenicosis, also referred to as arsenism, is a non-communicable disease resulting from drinking arsenic contaminated groundwater. Arsenic is widely distributed throughout the earth's crust and is introduced into water through the dissolution of minerals and ores. In some areas groundwater concentrations of arsenic are elevated as a result of erosion from local rocks. [1] Groundwater contamination in excess of the WHO guideline value of 0.01mg/l, has been observed from certain parts of the world.[2] Long-term exposure to arsenic via drinking-water cause cancer of the skin, lungs, urinary bladder, and kidney, as well as other skin changes such as pigmentation changes and thickening (hyperkeratosis).[2] Both condition take several years ranging from 6 to 9 years depending on the exposure dose and other host conditions.[3]

Globally, 70 countries have reported ground water contamination from arsenic and over 137 million people are affected by arsenic poisoning of drinking water.[4] These include developed countries like USA, UK, Canada, Belgium as well as developing countries like Bangladesh, India, China, Nepal etc.[5] In WHO's South-East Asia Region, between 40 to 50 million people are exposed to unsafe levels of arsenic in drinking water and it is estimated that around 12 million people would get clinical disease within next 10 years.[6,7] Bangladesh and some Indian states including West Bengal, Uttar Pradesh, Jharkhand and Assam which lie on Ganga-Meghna-Bhramaputra plain and which are the home to a population of over 450 million, are at risk of ground water arsenic contamination. The estimated disease burden in this region is 6 million.[8, 9] Arsenic

poisoning in West Bengal was first diagnosed by a dermatologist K.C. Saha of School of Tropical Medicine (STM), Calcutta (Kolkata was previously known as Calcutta) in an outdoor patient of village Ramnagar of Baruipur police station in the district of South 24-Parganas on 6th July, 1983. Later it was realized that many patients of arsenicosis existed in several villages well before 1983, though they could not be clinically diagnosed.[5]

Since 1997, Governments of West Bengal (India) and Bangladesh, World Bank, United Nations Children's Fund (UNICEF), World Health Organization (WHO), Swedish International Development Cooperation Agency (SIDA), Danish International Development Agency (DANIDA) launched a two-phase programme to curb the arsenic crisis. The first phase involved the screening of contaminated tube wells (>0.05mg/l according to Bureau of Indian Standard) and the identification of safe ones in the arsenic-affected areas. The second phase involved ensuring supply of arsenic-safe drinking water in the affected areas through alternative source like installation of deep tube-well at safe aquifer, using surface water or sharing the safe water in the community. Government of West Bengal formally launched the arsenic mitigation programme in 1999. As a part of the programme, 75 blocks in the state were identified as arsenic contaminated. The components of mitigation programme were (a) screening of water sources to identify safe sources, (b) installing units of arsenic treatment plant, construction of deep tube-well at safe aquifer for alternative sources of safe water (c) identification and treatment of arsenic affected patients and (d) generating community

awareness about the risks of drinking contaminated water, safe water options, signs of arsenicosis and its treatment. In West Bengal high arsenic levels in groundwater have been reported from 12 out of 19 districts. About 9.5 million people are at risk of exposure to high arsenic levels (more than 0.01mg/l). By September 2006, water samples from 140,150 tube-wells were analyzed, of which 72% had arsenic above 0.01mg/l and 3% had arsenic concentrations above 0.3mg/l, the concentration predicting overt arsenical skin lesions. The maximum arsenic concentration was found at the level of 3.7 mg/l.[5]

Nadia district with a population of 4,604,827 (2001 census) located in the eastern part of state West Bengal, extending on both eastern and western bank of the river Ganga. It is one of the 12 districts in the state where arsenic contamination of ground water has been reported. Groundwater of all the 17 blocks in the district contain high arsenic levels which ranges from below 0.01mg/l to 3.2mg/l.[10] Between 1990 and 2005, a total of 5,149 human cases have been reported from nine of the 17 blocks of the district.[11] The district is under the arsenic mitigation programme since 1999. Till 2002, more than 500 arsenic free tube-wells had been installed under mitigation programme in villages where human cases were reported.

Success of the mitigation programme in an area depends on (1) community use of arsenic free water and (2) early health seeking and (3) awareness amongst the people and their participation in the programme. Information about community awareness regarding the disease and their practices about use of arsenic contaminated as well as

arsenic free water sources is therefore very useful in guiding the mitigation programme. With this background, we conducted a study with the objective to estimate (1) the frequency of knowledge, attitude and practices of the community about arsenic and arsenicosis (2) prevalence of arsenicosis and (3) arsenic content of ground water.

2. Methods

2.1 Study population: We randomly selected one Community Development Block (Haringhata) from nine blocks in Nadia district from where human cases of arsenicosis have been reported. We conducted the survey in all the three villages (Dasdia: n=3080, Mitrapur: n=2762 and Ganguria: n=3570) of this block from where arsenicosis cases have been reported by the Block medical Officer of Health. [12, 13]

2.2 Study design, sample size and sampling procedure: We conducted a cross sectional analytical study in the selected villages during May 2008 to November 2008. The present study had four components:

(1) Knowledge, attitude and practices (KAP) about arsenicosis: For assessing the KAP, we considered households as the sampling unit. Assuming 50% of the individuals had adequate knowledge about arsenicosis, confidence interval $\pm$5%, confidence co-efficient 95%, and a non-response of 10%, the required sample size for the study was 408. Assuming three persons aged above 18 years of age reside in a household, we decided to survey 136 households in the selected villages. We randomly selected 136 households from the house register

maintained by the Community Health Workers (CHWs) and interviewed all the adults in these houses.

(2) Prevalence of arsenicosis: We clinically examined all the individuals in selected households to estimate the prevalence of arsenicosis

(3) Environmental assessment and water testing for arsenic: We identified all the water sources (government, private and arsenic free tube-wells, surface water) in the three selected villages. We tested all the water sources used for drinking purposes in the selected households for arsenic content.

2.3 Data collection: Using a pre-tested, semi- structured questionnaire in Bengali, the trained field investigators collected information about knowledge, attitude and practices from all the individuals aged ≥18 years residing in the selected households. The primary investigator supervised initial interviews and also crosschecked 10% of the interviews. Primary investigator conducted physical examination of all the individuals in the selected households. We defined a case of arsenicosis as chronic health condition arising from prolonged ingestion (not less than six months) of arsenic above a safe dose, usually manifesting as characteristic skin lesion with or without involvement of internal organs.[9,11] We used the following criteria for diagnosis of arsenicosis: (1) Hyper or hypo-pigmentation: Rain drop shaped discolored spots with or without diffuse darkening of the skin in trunks and limbs, (2) Hyperkeratosis: Diffuse bilateral thickening of palms and/or soles with or without nodules of various shapes and sizes, (3) Exfoliative dermatitis: Red scaly skin lésions of the body (4) Gangrene- Fulminating ulcer with bad odor.[6,7,8]

We collected water samples from all the water sources used by the selected households in acid-washed polyethylene bottles and transported them to the Divisional Public Health Engineering Laboratory, Kalyani Nadia, West Bengal. Water samples were examined to estimate arsenic levels using silver diethyl dithio carbamate method.[14] According to WHO and Bureau of Indian Standards; drinking water should not contain arsenic more than 0.01mg/l.[15,16] We used this cut-off value to define safe water sources.

2.4 Data analysis: We analyzed data using the Epi info software version 3.3.2. We calculated frequency of knowledge, attitude and practice about arsenicosis. We estimated the prevalence of chronic arsenicosis and its 95% CI. We conducted univariate and multiple logistic regression analysis to identify risk factors associated with arsenicosis.

2.5 Human subject protection: We obtained written consent from the participants, parents/ guardians. The ethics committee of the National Institute of Epidemiology, Chennai approved the study protocol. We arranged treatment for the case patients identified during our survey at Block Rural hospital or district hospital with the help of blocks and district health authority.

3. Result

We surveyed 533 individuals from 136 households out of 551 eligible participants (96%) in the selected houses. Eighteen individuals could not be surveyed, as they were not present in the house on the day of our survey. For assessing the knowledge, attitude and practices, we interviewed 412 adults from these 136 households.

3.1 Socio-economic status: Of the 533 individuals surveyed, 272 (51%) were male, 123 (23%) were illiterate, 75 (20.5%) were farmers and 308 (58%) were below poverty line (BPL) (table- 1). The median age of the study population was 29 years (range 1-82), while the median length of stay in the present place (residence) was 20 years.

3.2. Prevalence of arsenicosis: Out of 533 individuals clinically examined, 51 met the case definition of arsenicosis with a prevalence of 9.6% (95% CI=7.3-12.3). The prevalence was higher among males (10.6%) and those aged 50 years or above (18.1%). There was no case below the age of five years (Table- 2). All the 51 patients had rain drop pigmentation (hypo or hyper pigmentation) distributed over the whole body or limbs, while 43 (84%) had hyperkeratosis of palms and soles (Fig-1). Other clinical features among the cases include severe anemia (61%), generalized weakness (65%), paresthesia (55%) and hepatomegaly (37%) (Fig-1).

3.3. Knowledge about arsenic and arsenicosis (Table-3)

Arsenic and its source: Majority (74%) of the 412 adults interviewed had heard about arsenic while 45% knew that water is the chief source of arsenic in environment. Only

15% had heard about arsenicosis during the IEC programme conducted by Panchyat or any NGO.

Development of arsenicosis: 184 (45%) individuals knew that prolonged ingestion of arsenic through drinking water cause arsenicosis.

Sign and symptoms: 207 (59%) knew about dermatological changes (Hypo or hyper pigmentation, diffuse hyperkeratosis) in arsenicosis.

Prevention and treatment: 38% knew that arsenicosis could be prevented by arsenic free water while 29% knew that there is an arsenic clinic in the Community health centre (CHC).

Water test for arsenic: While 239 (58%) knew that the water should be tested for arsenic, only 49 (12%) knew where water could be tested.

Safe water option: Only 26% of the individuals surveyed knew that their water was safe for arsenic while 51% did not know the status of their water sources. 10% informed that they had tested their water on their own while 16% informed that their water was tested by government agencies. Only one third of the individuals knew that there was arsenic free tube-well in the locality.

3.4 Attitude about arsenicosis

Water sources: Two third of population surveyed were of the opinion that they would change the water source if their present water source was found to be contaminated while 33% opined that they would continue to use the contaminated source (Table-3).

Arsenicosis and its treatment: Only a small proportion (8%) thought that arsenicosis is a curse and that arsenicosis patients should be ostracized (2%). Majority (76%) thought that they would recommend arsenicosis patient to nearest health facility, though only 30% thought that treatment at CHC was effective (Table-3).

3.5 Practices related to arsenic and arsenicosis

About one-fourth of the participants surveyed had changed their water source earlier because of arsenic contamination. 6% respondents or any of their family members had received treatment from CHC and only 9% had attended any awareness campaign for arsenic (Table-3).

3.6 Environmental assessment and Arsenic level in tube-well water:

The village Dasdia, Mitrapur and Ganguria are located in the north-eastern part of block Haringhata under Nadia district. The total land area of these villages is 7.96 km^2. [7] Agriculture is the main source of livelihood. The villages are surrounded by rice field, for which ground water is the main source of irrigation but this is supplemented by rain water during monsoon period. Almost entire population (100%) of these villages drank water from shallow hand-pumped tube-wells or public tube-wells. The depth of the shallow private hand pumps ranged from 50-180 ft and the depth of public tube-wells range from 300 to 500 ft. Other water sources are ponds (Table- 7). There were 78 ponds of different size in the village, of which 40 are being used for pisciculture. People used the pond water mainly for washing or bathing.

Of the 129 tube-wells tested, 31 (24%) had arsenic concentration below 0.01mg/l and were safe for consumption. In 19% tube-wells, the arsenic concentration ranged between 0.01-0.05mg/l while in 47% it was more than 0.05mg/l. The concentration of arsenic ranges from below detection level (BDL) to 0.238mg/l (Fig- 2).

3.7 Prevalence of arsenicosis according to selected characteristics

On univariate analysis, the prevalence of arsenicosis was significantly higher among BPL families (OR=2.6, 95% CI 1.3-5.0), illiterates (OR=2.6, CI 1.5-4.8) and those who were farmers (OR=2.6, CI 1.3-5.1). Proximity of arsenic free tube well (OR=3.4, 95% CI 1.2-9.7) and consumption of water from the present source for more than six years were also significantly associated with arsenicosis (OR=7.9, CI 2.4-25.9) (Table-4). The prevalence of arsenicosis linearly increased with the duration of taking water from the present source (χ^2 for linear trend= 30.0, p= 0.0000 (Table- 6).

Literacy, farming occupation and consumption of water from the present source for more than six years were significant predictors of arsenicosis on multiple logistic regression analysis (Table-5).

4. Discussion

The prevalence of arsenicosis in three villages of Nadia district was 9.6% while three fourth of water sources contained arsenic above permissible level and thus were not fit for consumption. Our study provided useful information on current state of knowledge, attitude and practices of the people living in villages where arsenicosis was endemic. Community knowledge about source of arsenic, its symptoms as well as arsenic-free

tube wells in the village was inadequate. About one fourth of the villagers tested their water sources for arsenic while majority did not know where water could be tested.

Under Arsenic Mitigation programme, arsenic free tube wells are constructed in endemic areas in order to reduce the consumption of arsenic contaminated water. The success of this programme largely depends on community knowledge about the arsenic free tube wells in the area. Only 24% of the water sources in these villages were safe. Two third of the people were willing to use alternative water sources, a large proportion of people did not know which tube wells in the area are safe. As a result, majority of the population was still consuming water from arsenic contaminated wells and only one fourth changes their water sources recently. In Bangladesh where arsenicosis is a public health problem, safe tube wells are marked as green and unsafe as red. [18] UNICEF and School of environmental studies have also suggested a similar strategy in West Bengal.[19, 24] This strategy not only helps increasing community awareness about disease but also gives an option to people to choose a safe source, especially those who are having positive attitude towards changing the water source.

In the surveyed villages, knowledge about source of arsenic, its symptoms, treatment options as well as place for water testing was inadequate. Generating community awareness on these issues is an important component of arsenic mitigation programme in West Bengal. IEC campaigns conducted as a part of arsenic mitigation programmes in Bangladesh played a significant role in creating a context for raising awareness about arsenic poisoning in endemic areas and reduced the misconceptions about the mode of transmission and consequences of arsenic poisoning.[20,21] The community became

more aware about the benefits of increased consumption of fresh vegetables and the use of arsenic-free water, and seeking curative measures if needed.[22] The IEC component of the mitigation programme in the district however appears weak as only 15% of the respondents told that Panchyat or local NGOs organized programmes for generating awareness.

Arsenic clinics are established in all the community health centers in the district. Besides supportive treatment, cases of arsenicosis are advised about using arsenic free water and improved nutrition. Reducing further intake of arsenic in diagnosed cases during earlier stage of illness could significantly reduce the progression of disease.[22] The early stage of the disease is characterized by skin pigmentation, keratosis is middle stage while rough dry skin with nodules on hands, feet or legs is considered as advanced stage. This could further lead to the formation of gangrene and development of cancer.[22,] In our study, most (72%) of the case patients were in early or middle stage. Further progression to carcinoma can only be prevented with immediate and appropriate intervention with arsenic free water and improved nutrition. A large proportion of individuals however were not aware about arsenic clinics in the district as well as did not believed in the treatment offered at these clinics are effective.

The overall prevalence of arsenicosis in our study was 9.6%. Higher prevalence observed among males is consistent with other studies conducted in the state as well as Bangladesh.[23] The reasons for such higher prevalence are however not known. There was no case below five years of age. Development of arsenicosis primarily depends on arsenic content of water and duration of consumption. The fact that 4% of children aged

5-14 years had symptoms of arsenicosis indicates severity of arsenic problem in this area. A study conducted elsewhere in Nadia in 1999 also reported a high prevalence of arsenicosis among young children.[18] It is therefore necessary to strengthen the mitigation programme in the district.

There were many ponds of different sizes in all the study villages. People however did not use pond water for drinking purposes. Arsenic is present in the ground water and surface water is usually arsenic free. Surface water was the main source of drinking water in West Bengal up to early 20th century. [19] Presently, most of the surface water in these villages is bacteriologically unsafe. Treating some of the ponds in the villages against bacterial contamination and motivating people to use water from these sources could also be considered as an option for safe water.

Our study had certain limitations. First, we used WHO recommended clinical criteria for diagnosis of arsenicosis. The prevalence calculated in the study was based on medical history and clinical examination. We did not estimate arsenic level in nail and hair, which is often used for identifying the sub-clinical cases. Second, because of the logistical constraints, we tested only 18% of tube wells in the villages. Results obtained from our study however indicate that widespread arsenic contamination of ground water in these villages and arsenic concentration might be even higher in other sources.

In conclusion, arsenicosis was endemic in Nadia district. Majority of the cases identified were in early or middle stage of disease. Lack of awareness about arsenic, arsenicosis and arsenic free water sources restrained people to use safe water sources. This

incomplete knowledge was on account of poor IEC activities conducted under arsenic mitigation programme. Based on these findings, we propose following recommendations. For providing arsenic free drinking water (1) it is necessary to mark arsenic free tube-wells as green and contaminated wells as red, (2) PHED also need to periodically check all the tube-wells for arsenic contamination at least once in a year, (3) identify few ponds in affected villages as a source of drinking water and motivate community to use after adequate treatment of bacterial contamination and (4) communicate the Panchyat to procure domestic arsenic filter and distribute it by social marketing at subsidized rate by the Self Help Group. Community needs to be made aware about arsenic, arsenicosis, its symptoms, management and place for testing arsenic content of water by strengthening IEC component of arsenic mitigation programme.

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Table: 1 **Description of study population (N=533), Nadia, West Bengal, India, 2008**

Demographic characteristics		#	(%)
Age	< 5 year	21	3.9
	5-14 year	72	13.5
	15-29 year	176	33.0
	30-49 year	176	33.0
	50 year +	88	16.5
Sex	Male	272	51.0
	Female	261	49.0
Literacy >5 years	Illiterate	123	23.1
	≤ Secondary	350	65.7
	>Secondary	32	6.0
Occupation	Farmer	75	14.1
	Laborer	109	20.5
	Dependent	167	31.3
	House maker	164	30.8
	Others	18	3.4
Drinking water source	Tube well	533	100

Table: 2 Prevalence of arsenicosis by age and sex, (N=533) District Nadia, West Bengal, India, 2008

Demographic characteristics		Cases	2008 population	Prevalence (%)
Age	< 5 year	0	21	0.0
	5-14 year	3	72	4.1
	15-29 year	14	176	7.9
	30-49 year	18	176	10.2
	50 year +	16	88	18.1
Sex	Male	29	272	10.6
	Female	22	261	8.4
Total		51	533	9.5

Table: 3 Knowledge, attitude and practice about arsenicosis (N=412), Nadia, West Bengal, India, 2008.

Characteristics		#	(%)
Knowledge			
Arsenic and it's source:	Heard about arsenic	305	74.0
	Arsenic persists in water/soil/food	211	51.2
	Water is the chief source of arsenic	186	45.1
	Surface water is safer	140	34.0
	Knows about arsenic from Panchyat or NGO (IEC)	61	14.8
Mode of transmission:	Arsenic enter in our body through water	184	44.7
Development of arsenicosis:	Excess arsenic in environment cause arsenicosis	242	58.7
	Prolong ingestion through water cause arsenicosis	184	44.7
Sign/symptom of arsenicosis:	Know arsenicosis cause skin sore	207	50.2
	Know arsenicosis cause loose motion	10	2.4

Table: 3 Knowledge, attitude and practice about arsenicosis (N=412), Nadia, West Bengal, India, 2008- (cont.)

Characteristics		#	(%)
Prevention & treatment:	Know there are treatment for arsenicosis patients	240	58.2
	Know there is a arsenic clinic in block Rural Hospital	121	29.4
	Arsenicosis can be prevented by arsenic free water	156	37.9
	Arsenicosis is not a contagious disease	208	50.5
Water test:	Know water should be tested for arsenic	239	58.0
	Know water should be tested every year	112	27.2
	Knows where water can be tested	49	11.9
Safe water option:	Knows his water source is safe	105	25.5
	Knows water source is not safe	97	23.5
	Do not know the status of water source	210	50.9
	Owner tested and found safe	40	9.7
	Government people tested and told safe	65	15.8
	Knows about arsenic free tube well in the locality	140	34.0
	Know the surface water is safer	140	34.0

Table: 3 Knowledge, attitude and practice about arsenicosis (N=412), Nadia, West Bengal, India, 2008 - (cont.)

Characteristics		#	(%)
Attitude			
About water sources:	Will look for alternative source if present one is found contaminated	275	66.7
	Will continue to use the present source	137	33.3
	Continue to use as providing alternative is Govt. responsibility	14	3.4
	Continue to use as it makes no difference	2	0.5
	Continue to use as never thought of the issue	121	29.4
About disease and patient:	Think that arsenicosis is a curse	22	8.3
	Think that case of arsenicosis should be ostracized	10	2.4
About treatment:	Think that treatment offered by the block RH is effective	123	29.9
	Will recommend cases to block RH for treatment	232	56.3
Practice	Water tested for arsenic	105	25.5
	Family member received treatment at RH for arsenicosis	26	6.3
	Changed water source because of contamination	97	23.5
	Attend any awareness programme	35	8.5

***Table: 4* Prevalence of arsenicosis according to selected characteristics, cross sectional study, Nadia, West Bengal, India, 2008.**

	Frequency of exposure						Prevalence odds ratio	95% CI	"P" value
	Among ill			Among non-ill					
	#	Total	%	#	Total	%			
Low family incomefamily (BPL)[1]	39	51	76.5	269	482	55.8	2.6	1.3-5.0	0.0019
Illiteracy	22	51	43.1	101	454	82.1	2.6	1.5-4.8	0.0017
Farmer	14	51	27.5	61	482	12.7	2.6	1.3-5-1	0.0074
Drinking water from present source≥6yrs	48	51	94.1	322	482	66.8	7.9	2.4-25.9	0.0001
Distance of arsenic free tube-well > 100 m	42	46	91.3	277	366	86.8	3.4	1.2-9.7	0.0276

[1] Monthly family income≤2000 (INR)

Table: 5 Multivariate analyses of factors associated with arsenicosis, Nadia district. West Bengal, India 2008

Chractaristics	Odds Ratio	95% C.I.	P-Value
Low family income	0.6	0.3-1.3	0.1929
Illiteracy	3.1	1.6-5.8	0.0005
Farmer	2.4	1.1-4.8	0.0187
Drinking water from present source ≥6 years	8.8	2.1-36.9	0.0031

Table: 6 Increasing prevalence of arsenicosis according to duration of taking water from the present source, district Nadia, West Bengal, India , 2008

Characteristics	Frequency of exposure				
	Among ill		Among non-ill		
Duration of taking water in year	#	%	#	%	Odds ratio*
≥6	2	1.2	161	98.8	1.0
7-14	17	8.8	182	91.2	7.8
15-22	15	13.6	81	86.4	12.7
23+	17	22.7	58	77.3	23.6

*** Chi-square for trend = 30.0, "P" value = 0.0000**

Table: 7 Land area and water sources in three villages in Nadia, West Bengal, India, 2008

Name of the village	Total area km^2	Water sources					
		Tube-well			Ponds		
		Private	Government	Total	Big ponds	Small ponds	Total
Dasdia	2.98	239	17	256	22	7	29
Mitrapur	2.84	219	20	239	5	20	25
Ganguria	2.14	206	18	224	13	11	24
Total	7.96		55	719	40	38	78

Fig: 1 Clinical characteristics of arsenicosis case patients (N=51), Nadia, West Bengal, India, 2008

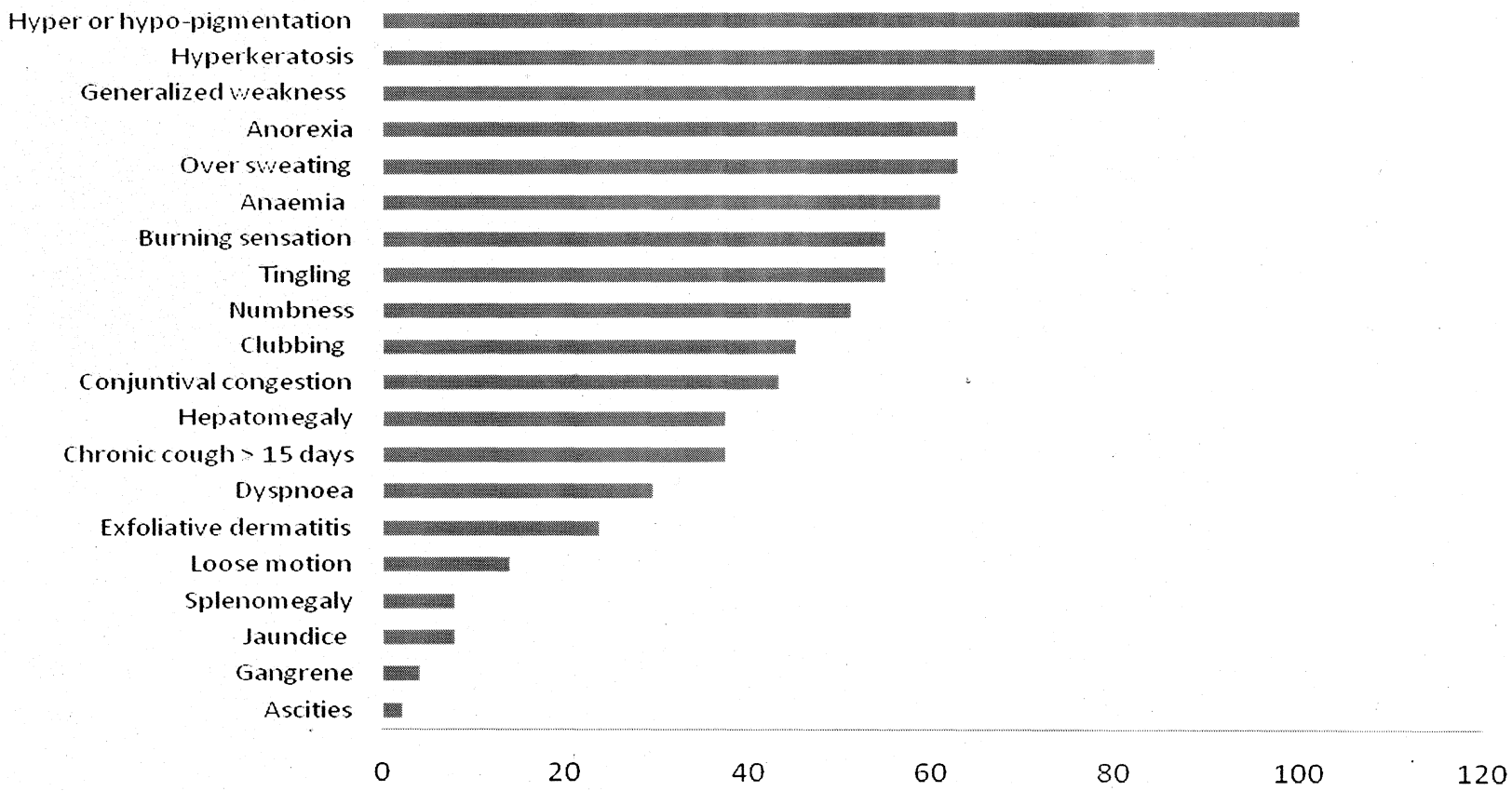
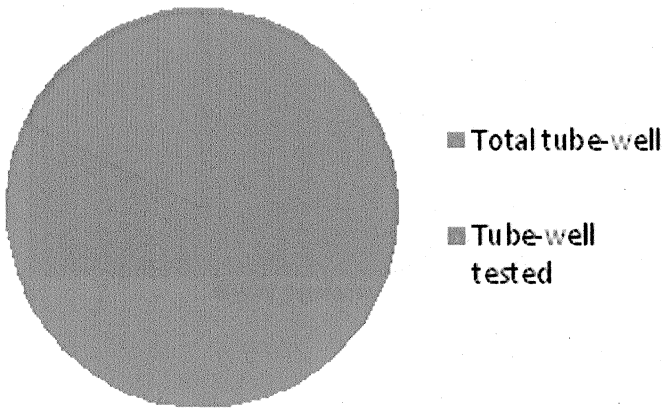
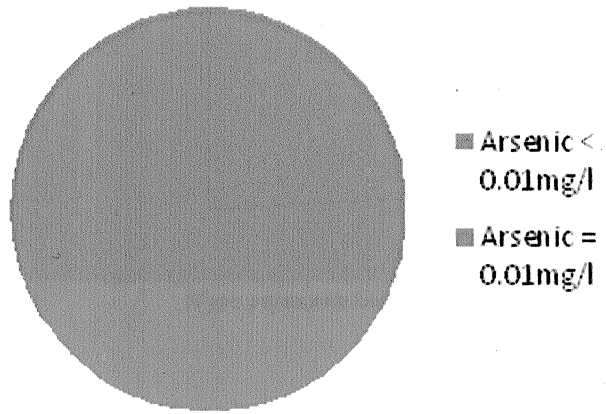


Fig: 2 Arsenic concentrations in ground water in three villages, Nadia, West Bengal, India, 2008



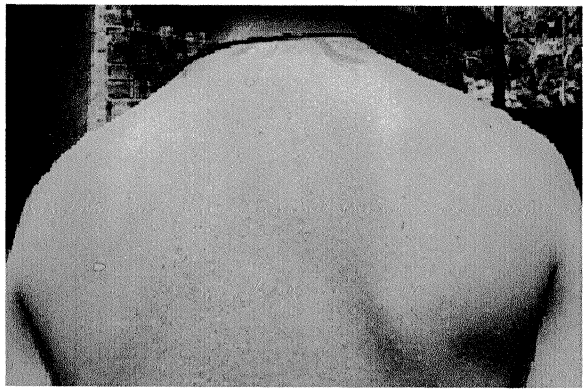
Water tested for arsenic



Arsenic level of water sample

Arsenic concentration ranges from below detection level to 0.238mg/l

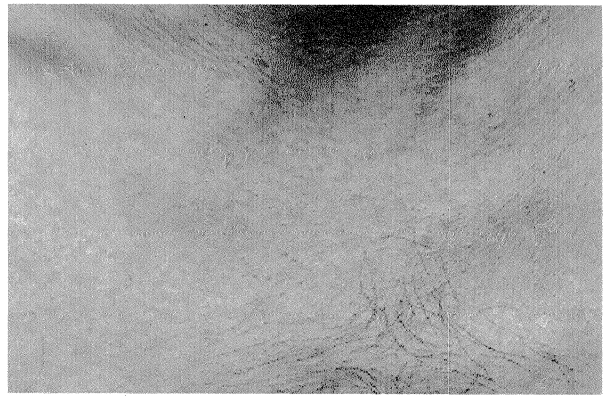
Fig: 3 Case patients of arsenicosis, District Nadia, West Bengal, India, 2008



Hyper pigmentation

Hypo pigmentation

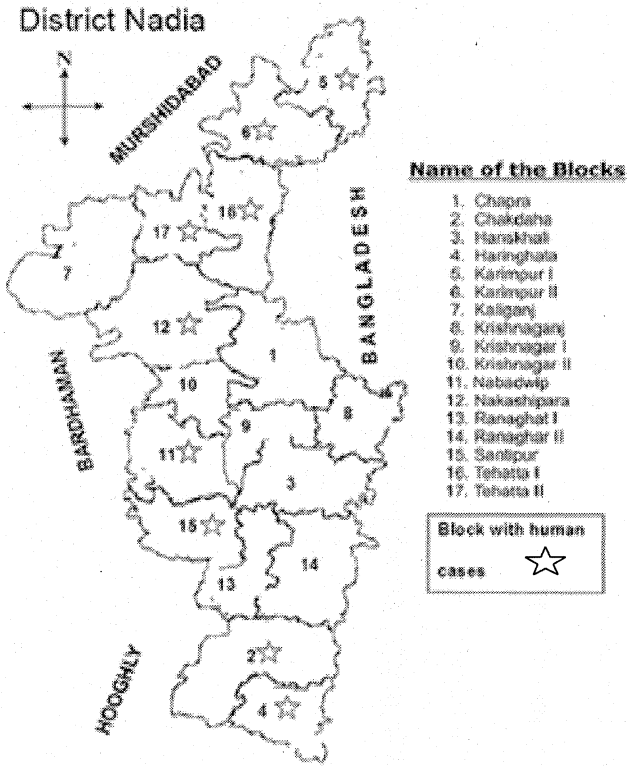
Rain Crop pigmentation



Hypo pigmentation

Appendix

Appendix 1: Map showing the study villages in district Nadia, West Bengal, India.



Appendix 2: Patient information sheet

Name of the principal investigator: Dr. Tapan Kumar Saha

Name of the organization: Directorate oh Health Services, Government of West Bengal and National Institute of Epidemiology, Chennai, India

Greetings

I, ..., a colleague of Dr. Tapan Kumar Saha, from the department of Health and Family Welfare, Government of West Bengal, with my team, comprising Medical Officer, Public Health Nurse, Health Supervisor and Multipurpose Health workers, would like to determine the knowledge, attitude and practice of people about contamination of water sources from arsenic in three affected villages of Nadia district. We would also like to determine the number of water sources contaminated and number of people affected by arsenic contamination of water sources.

We will ask you some questions and our Medical Officer will examine you if you have any arsenic related health problem. Taking part in the survey is voluntary. You can choose not to participate. You can choose not to answer a specific question or can stop answering the questions at any time without giving any reason or can choose not to be examined. This will not affect your right to routine health facilities offered by the department of health and family welfare. However, taking part in the survey eventually benefit you and your community.

We will also request you to provide water samples used by you for drinking and cooking purposes to test the arsenic content. We will inform you the result, whatever it may be as and when we receive it from the laboratory. Examination of water sample does not necessarily mean the source is contaminated. Further, drinking contaminated water does not mean you have the disease.

Arsenic related health problem could be easily prevented if you drink safe water. Arsenic related health problem can be treated free of cost in government hospitals. If the medical officer suspects that you may have arsenic related health problem, we will refer you to arsenic clinic at Rural hospital, Haringhata (block) or District Hospital, Nadia. Treatment and investigations will be done free of cost, the only thing you have to do is to reach the arsenic clinic at your own cost. We are not in a position to offer you compensation for loss of pay on account of your attendance at the arsenic clinic for this purpose.

If you wish more about the survey you may contact with the following persons personally or over telephone:

1. Dr. Tapan Kumar Saha # 9434222058
2. Dr. Chandra shekher Das #9903859221
   Block medical officer, Haringhata

Thanking you. .....

Dated: (Signature)

Place: Nadia.

Appendix 3: Informed consent forms-A and B

A) Informed consent form for adults

Serial Number: Date:

Patient's identification number:

Name of investigator:

I ... have read the foregoing information / it has been read to me on .....

The information is about the house-to-house survey to determine the knowledge, attitude and practice about arsenic, arsenic related health problem and contamination of water sources by arsenic.

I have been told the purpose of the survey and also told that if suspected to have arsenic related health problem, I would be examined by a medical officer for diagnosis.

I have been told about that I have had the opportunity to ask questions about it and any questions I have asked have been answered to my satisfaction. I consent voluntarily to participate as a subject in this survey and understand that I have the right to withdraw from the study at anytime without in any way it affecting my further medical care.

I do not claim money or compensation of wages for participating in the survey and to attend arsenic clinics when required.

Dated: (Signature)

OR

(Signature of a literate witness) (Left thumb impression)

Date: (Countersignature of the investigator)

B) Informed consent form for children

Serial number: Dated:

Patient's identification number:

Name of investigator:

My minor son / daughter named ..... aged ..... has been invited to participate in the house to house surveyto determine the arsenic related health problems, contamination of water sources by arsenic and awareness about arsenic related health problems and its prevention. I have been told the purpose of the survey and also told that if my son / daughter is suspected to have arsenic related health problem, he / she would be examined by a medical officer for diagnosis. I have been told about that I have had the opportunity to ask questions about it and any questions I have asked have been answered to my satisfaction. I consent voluntarily to allow my son / daughter to participate as a subject in this survey and understand that I have the right to withdraw him / her from the study at anytime without in any way it affecting his / her further medical care. I do not claim money or compensation of wages for participating of my ward in the survey and to attend arsenic clinics when required.

Dated: (Signature)

OR

(Signature of a literate witness) (Left thumb impression)

Dated: (Counter signature of investigator)

Appendix 4: Identifiers' collection form

Form: A (To ensure confidentiality, identifiers' will not be collected in the paper questionnaires)

Household ID:		Name of the chief of the household:			
Household address: Household number: Name of the village:					
ID1 name:		ID5 name:		ID9 name:	
ID2 name:		ID6 name:		ID10 name:	
ID3 name:		ID7 name:		ID11 name:	
ID4 name:		ID8 name:		ID12 name:	

Appendix 5: Household data collection form-for each household member

Form: B

Household ID:	Individual ID:	Team No:
Number of the persons to be interviewed (to be tallied with Form A):		

Socio-demographic characteristics:

Questionnaires items	Options		Coding
1. Age (complete years)			
2. Sex	1. Male	2. Female	
3. Literacy level (>5 yrs)	1. Illiterate 2. Primary 3. Secondary	4. Higher secondary 5. Graduate & postgraduate	
4. Occupation	1. Farmer 2. Laborer 3. Business	4. Service 5. House maker 6. Dependent	
5. Monthly family income (INR)	1. Up to 2000	2. >2000	
6. Duration of residence		(In completed year)	

Anthropometry:

7. Weight		(In kilogram)	
8. Height		(In centimeter)	

Water Consumption history:

Sources of drinking water:			
9. What is the main source of your drinking water	1. Tubewell	2. Pipeline	
	3. pond	4. Dug well	
	5.Others (specify)		
10. Duration of water intake from the source	.....	Years	
Amount of consumption of water:			
11. Daily water intake Glasses[2]	.....		

Physical examination:

Items	Options		Coding
General:			
12. Anaemia	1. Present	2. Absent	
13. Jaundice	1. Present	2. Absent	
14. Clubbing of nails	1. Present	2. Absent	
15. Generalized weakness[3]	1. Present	2. Absent	
16. Over-sweating without any exertion	1. Present	2. Absent	
Dermatological and nail examination:			
17. Hyperkeratosis[4]	1. Present	2. Absent	
18. Hyper or hypo-pigmentation[5]	1. Present	2. Absent	

[2] one full glass contains approximately 250 milliliter

[3] Feeling fatigued all the time, below 60 years age group.

[4] Diffuse bilateral thickening of palms / soles with or without nodules of various shapes and sizes.

[5] (Rain-drop shaped discolored spots with or without diffuse darkening of the skin in trunks and limbs.

19. Exfoliative dermatitis (Red scaly lesions)	1. Present	2. Absent	
20. Gangrene (Fulminating ulcer with bad odor)	1. Present	2. Absent	
21. Mee's line[6]	1. Present	2. Absent	
Examination of eyes:			
22. Conjuntival congestion (Redness of the eye)	1. Present	2. Absent	
Respiratory system:			
23. Chronic cough (Excessive cough persists > 15 days)	1. Present	2. Absent	
24. Dyspnoea	1. Present	2. Absent	
Cardiovascular system:			
25. Pain in finger tips on exposure to cold	1. Present	2. Absent	
26. Cold and calm extremities	1. Present	2. Absent	
27. Peripheral pulsation	1. Present	2. Absent	
28. Blackening of toes and fingers	1. Present	2. Absent	
Nervous system:			
29. Tingling (Needle pricking sensation)	1. Present	2. Absent	
30. Burning sensation	1. Present	2. Absent	
31. Numbness[7]	1. Present	2. Absent	
Gastrointestinal system:			
32. Anorexia for more than 15 days in last 6 months (Chronic loss of appetite)	1. Present	2. Absent	
33. frequent loose motions in last 6 months or more	1. Present	2. Absent	
Hepatobilliary system:			
34. Hepatomegaly [8]	1. Present	2. Absent	
35. Splenomegaly[9]	1. Present	2. Absent	

[6] Transverse white straie of finger nails.
[7] Loss of sensation and feeling of heaviness in the affected part.
[8] Enlargement of liver, i.e., 1 or >1finger palpable below the right costal margin

36. Ascities	1. Present	2. Absent	

History of present illness:

37. Malnutrition[10]	1. Present	2. Absent	
38. Known diabetic	1. Yes	2. No	

Knowledge: (18 years and above)

About arsenic:		
39. Have you ever heard about arsenic?	1. Yes 2. No	
40. Excess amount of arsenic in environment can enter in our body and may cause ill health	1. Yes 2. No 3. Do not know	
41. What is the main source of arsenic in environment	1. Water 2. Soil 3. Air 4. Food 5. Do not know 6. Others (specify)	
42. Arsenic can enter in our body through	1. Water 2. Soil 3. Air 4. Food	

[9] Enlargement of spleen, i.e., 1 or >1 finger palpable in the left costal margin.
[10] Malnutrition measured by weight per height below 18 years and BMI 18 years and above.

	5. Do not know 6. Others (specify)	
43. Water (drinking and others) is the chief source of arsenic	1. Yes 2. No 3. Do not know	
44. Panchyat people ever told you about arsenic and its ill effect.	1. Yes 2. No	
45. Do you know water source should be tested for arsenic content	1. Yes 2. No 3. Do not know	
46. Do you think water once tested safe for arsenic will remain safe for ever	1. Yes 2. No 3. Do not know	
47. If no, how frequent it should be tested	1. Monthly 2. Yearly 3. Once in every 5 yrs	
48. Do you know excessive ground water lifting cause increase level of arsenic in ground water:	1. Yes 2. No 3. Do not know	
49. Is the water; you are using, safe for arsenic?	1. Yes 2. No 3. Do not know	
50. If yes how do you know it?	1. You tested the water sample. 2. Govt. official told you 3. you heard it from other people 4. your assumption	

51. If tested, who arranged for the test	1. yourself 2. Govt. 3. not tested	
52. If not safe, do you have any alternative safe source of water	1. Yes 2. No 3. Do not know 4. Not applicable	
53. Do you know where water can be tested for arsenic	1. Yes 2. No 3. Do not Know	
54. Do you have any arsenic free tubewell in your locality	1. Yes 2. No 3. Do not Know	
55. If yes, what is the distance of that tubewell from your residence	1. Less than 100 meter 2. 100–500 meter 3. More than 500 meter	
56. Do you know surface water (pond, river) is comparatively safe for arsenic	1. Yes 2. No 3. Do not know	
About Arsenicosis (Shiko bish):		
57. Have you heard about arsenicosis? (effect of sheko bish)	1. Yes 2. No 3. Do not know	
58. If yes, what are the symptoms of arsenicosis?	1. Skin lesion 2. Loose motions 3. Others(specify) 4. Do not know 5. 1 & 2	

59. Do you know what cause arsenicosis	1. Arsenic 2. Bacteria 3. Virus 4. Do not know	
60. Arsenicosis is a contagious disease	1. Yes 2. No 3. Do not know	
61. Is it essential to seek care if one suffers from arsenicosis?	1. Yes 2. No 3. Do not know	
62. Do you know there is a arsenic clinic in the block Rural Hospital (Haringhata)	1. Yes 2. No 3. Do not know	
63. Do you know prolong ingestion of arsenic through contaminated drinking water cause arsenicosis	1. Yes 2. No 3. Do not know	
64. Have you attended any awareness programme on arsenic If yes, specify	1. Yes 2. No	

Attitude on Arsenic and Arsenicosis:

65. Do you think Water should be routinely tested for arsenic	1. Yes 2. No 3. Do not know	
66. Why (if the answer is yes or no) (Open)		
67. How often do you think drinking water needs to be tested for arsenic (open)	1. Once only	

	2. Every year 3. Every 5 yrs.	
68. If the water source you are presently using is found to be arsenic contaminated, what will you do?	1. Search for alternative 2. Continue to use the same 3. Do not know	
69. Why? (Open Question)		
70. Can you use water contaminated with arsenic for cooking	1. yes 2. No 3. Do not know	
71. Do you think that water used for irrigation should be tested for arsenic?	1. Yes 2. No 3. Do not know	
72. Do you think arsenicosis can be prevented by arsenic free water	1. Yes 2. No 3. Do not know	
73. If one suspects symptoms of arsenicosis, then what is to be done?	1. Wait and watch 2. Attend the arsenic clinic 3. Go for traditional treatment 4. Do not know	
74. DO you believe that treatment offered at the arsenic clinic in Block RH?[11] Is effective	1. Yes 2. No.	
75. Will you recommend anyone to take treatment for suspected arsenicosis from arsenic clinic in Block RH?	1. Yes 2. No	
76. If no, why (Open question)		
77. Do you think arsenicosis is a curse?	1. Yes 2. No	

[11] RH-Rural hospital

78. If one develops symptoms of arsenicosis he / she should not be ostracized?	1. Yes 2. No 3. Can not decided	

Practice on Arsenic and Arsenicosis:

79. Have you ever tested the arsenic level of the water source you are consuming?	1. Yes 2. No	
80. If yes, how frequently you test your water	1. Once only 2. Every year 3. Every 5 yrs. 4. Never	
81. Do you test the water used for irrigation	1. Yes 2. No 3. Not applicable[12]	
82. Have anyone from your family received treatment for suspected arsenicosis from arsenic clinic in Block RH?	1. Yes 2. No	
83. Have you changed the water source on account of arsenic contamination of earlier source	1. Yes 2. No 3. never organized	
84. If no. Why (open question)	1.°Yes 2. No	

[12] Not applicable because the respondent is not a farmer.

Section-II
Literature review

Literature review

Arsenic

Arsenic is a chemical element that has the symbol As and atomic number 33. This is a poisonous metalloid. Three forms of arsenic with different crystal structures are found free in nature (the minerals arsenic sensus stricto, pararsenolamprite and the much rarer arsenolamprite), but it is more commonly found as arsenide and arsenate compounds. Several hundred such mineral species are known.[1]

History

The word arsenic is borrowed from the Persian word Zarnikh meaning "yellow orpiment". Zarnikh was borrowed by Greek as arsenikon, which means masculine or potent. Arsenic has been known and used in Persia and elsewhere since ancient times.[2] During the Bronze Age, arsenic was often included in bronze, which made the alloy harder (so-called "arsenical bronze").[3] In the 8th century A.D, arsenic was first isolated by Geber (721-815), an Arabian alchemist.[4] As the symptoms of arsenic poisoning were somewhat ill-defined, it was frequently used for murder until the advent of the Marsh test, a sensitive chemical test for its presence. Due to its use by the ruling class to murder one another and its potency and discreetness, arsenic has been called the Poison of Kings and the King of Poisons. In ancient Korea, and particularly in Joseon Dynasty, arsenic-sulfur compounds have been used as a major ingredient of "sayak" which was a poison cocktail used in capital punishment of high-profile political figures and members of the royal family.[5]

There is a theory that Napoleon Bonaparte (1769 – 1821) suffered and died from arsenic poisoning during his imprisonment on the island of Saint Helena. The accidental use of arsenic in the adulteration of foodstuffs led to the Bradford sweet poisoning in 1858, which resulted in approximately 20 deaths and 200 people taken ill with arsenic poisoning.[6]

Physical and chemical Properties

Arsenic is very similar chemically to its predecessor, phosphorus. Like phosphorus, it forms colourless, odorless, crystalline oxides As_2O_3 and As_2O_5 which are hygroscopic and readily soluble in water to form acidic solutions. Arsenic (V) acid, like phosphorous acid, is a weak acid. When heated in air it oxidizes to arsenic trioxide; the fumes from this reaction have an odor resembling garlic. Arsenic (and some arsenic compounds) sublimes upon heating at atmospheric pressure, converting directly to a gaseous form without an intervening liquid state. The liquid state appears at 20 atmospheres and above, which explains why the melting point is higher than the boiling point.[7,8] Arsenic is an excellent example of an element that exhibits allotropy. Its various allotropes have strikingly different properties. The three most common allotropes are *metallic grey*, *yellow* and *black arsenic*.[9]

Arsenic in environment

Arsenic is a natural element which behaves like a metal. It is present in the environment both naturally and due to certain human activities.

Natural geological process: About one third of the arsenic in the atmosphere comes from natural sources. Inorganic or organic arsenic is found in the natural environment in some abundance in the Earth's crust and in small quantities in rock, soil, water and air. It is present in many different minerals. Human activity like burning of fossil fuels is responsible for releasing 80.000 tones of arsenic in the environment per year.[10] Due to natural geological contamination; high levels of arsenic can be found in drinking water that has come from deep drilled wells. This is particularly true for Bangladesh and West Bengal.[11] The mechanism of arsenic accumulation in Bengal Delta Plain is thought to have occurred during the late quaternary age (Holocene age) with arsenic containing alluvial sediment deposited by the Ganga, Brahmaputra, Meghna and other rivers that flow across into the Bay of Bengal. Here the arsenic is absorbed as arsenic oxyanions into oxyhydroxites of iron, aluminum and manganese and then mobilized in the alluvial aquifers where, due to the reducing environment, the hydroxides are dissolved by biochemical process, releasing the arsenic into the ground water. [12, 13]

Arsenic in the form of pyrites and sulphides and are being generally considered more toxic.[14, 15, 16] The air in non-urban and non industrial area contains very low level of arsenic, generally < 0.01 $\mu g/m^3$. If combines with hydrogen, arsenic, forms a very toxic arsine gas.[17, 18]

Most of the foods contain minute amount of arsenic, averaging 0.02 ppm. Arsenic is also a normal constituent of human body. Both organic and inorganic form of arsenic can be detected in natural water system. A number of microorganisms have the capacity to methylate inorganic arsenic (biomethylation) to the much less toxic

compounds like monomethyle arsenic acid (MMAA) and dimethyle arsonic acid (DMAA), the later is readily converted in soil to the volatile methyle arsines. Drinking-water from surface sources does not normally contain high concentrations of arsenic, unless those supplies come from arsenic-contaminated irrigation groundwater. Exposure to inorganic arsenic through the food chain is limited, although absorption by crops irrigated with water highly contaminated with arsenic warrants further research. Absorption of arsenic through the skin is minimal and thus, for example, washing hands or clothes and bathing in water containing arsenic or working in paddy fields with arsenic-contaminated waters do not pose risks to human health.[19]

Industrial processes: Such as mining, smelting and coal-fired power plants all contribute to the presence of arsenic in air, water and soil. Environmental contamination also occurs because it is used in agricultural pesticides and in chemicals for timber preservation. The arsenic is produced mostly during mining operations, for example the production from Peru comes mostly from copper mining and the production in China is due to gold mining.

Arsenic in different forms is transported between different parts of the environment where it may change its form. Arsenic in weathered rock or soil can be picked up and moved by the wind and water. Many arsenic compounds bind to soil and only move short distances when water percolates down through the soil. If arsenic is released into the atmosphere by industrial processes or volcanic activity, it attaches to particles that are dispersed by the wind and fall back to the ground. Microbes in soil and sediment

also release substances containing arsenic into the atmosphere. These are then converted to other arsenic compounds that settle back onto the ground.[20]

Uses of arsenic

Use as wood preservative: The toxicity of arsenic to insects, bacteria and fungi makes it an ideal component for the preservation of wood. World wide the treatment with Chromated copper arsenate, also known as CCA or Tanalith was the largest consumer of arsenic since the introduction of the process in the 1950s. Due to the environmental problems caused by the arsenic most countries banned the use of chromated copper arsenate on consumer products. The direct or indirect ingestion of wood ash from burnt CCA lumber has caused fatalities in animals and serious poisonings in humans; the lethal human dose is approximately 20 grams of ash. [21, 22]

Medical use: During the 18th, 19th, and 20th centuries, a number of arsenic compounds have been used as medicines, including arsphenamine (by Paul Ehrlich) and arsenic trioxide (by Thomas Fowler). Arsphenamine as well as Neosalvarsan was indicated for syphilis and trypanosomiasis, now substituted by modern antibiotics. Arsenic trioxide has been used in a variety of ways over the past 200 years, but most commonly in the treatment of cancer. The US Food and Drug Administration in 2000 approved this compound for the treatment of patients with acute promyelocytic leukemia that is resistant to ATRA.[23] It was also used as Fowler's solution in psoriasis.[24] Recently new research has been done in locating tumours using arsenic-74 (a positron emitter). The advantages of using this isotope instead of the previously used iodine-124 is that

the signal in the PET scan is clearer as the iodine tends to transport iodine to the thyroid gland producing a lot of noise.[25]

Use as pigments: Copper acetoarsenite was used as a green pigment known under many different names, including 'Paris Green' and 'Emerald Green'. It caused numerous arsenic_poisonings. Scheele's Green, a copper arsenate, was used in the 19th century as a coloring agent in sweets.[26]

Other uses: During the Vietnam War the United States used Agent Blue a mixture of Na cacodylate and dimethyl arsinic acid (cacodylic acid) as one of the rainbow herbicides to deprive the Vietnamese of valuable crops.[27] Arsenic was used as agricultural insecticides, termination and poisons, in animal feed as a method of disease prevention and growth stimulation. For example Lead hydrogen_arsenate was used well into the 20th century as an insecticide on fruit trees.[28,29,30] Its use sometimes resulted in brain damage to those working the sprayers. In the last half century, monosodium methyl arsenate (MSMA), a less toxic organic form of arsenic, has replaced lead arsenate's role in agriculture. Up to 2% of arsenic is used in lead alloys for lead shots and bullets[31] Arsenic was recovered mostly during mining operations. In 2005, China was the top producer of white arsenic with almost 50% world share, followed by Chile, Peru and Morocco, reports the British Geological Survey and the United States Geological Survey.[32, 33]

Arsenic in human body

Humans are exposed to arsenic (As) primarily from water, food and air. However, elevated inorganic arsenic in drinking water is the major cause of arsenic toxicity. Following exposure to arsenic, it enters the blood and subsequently is found mainly in liver and muscles, kidneys, spleen and skin. Smaller quantities are also found in the brain, heart, uterus, thyroid and pancreas, as well as hair and nails. Arsenic is eliminated from the body by the rapid urinary excretion. When inorganic arsenicals are ingested, urine forms the main route of elimination and the metabolites of inorganic arsenicals are predominant species in the urine.° The level at which overloading of detoxification system occurs may be lowered by a protein deficient diet. [34,35,36,37] When small amount of arsenic (>0.5mg/day) for a prolonged period of time or a large quantity is taken within a very short span of time, detoxification mechanism fails to eliminate the overload and arsenic starts exerting its toxic effect in the body. Arsenic is believed to exert most of its effects by inhibiting sulfhydryl (-SH) enzyme system essential to cellular metabolism. Thus the net effect is the blocking of fat and carbohydrate metabolism and cellular respiration.[38,39,40] The toxicity of arsenic compounds depends on the chemical and physical form of the compound, the route by which it enters the body, the dose and duration of exposure, dietary levels of interacting elements, and the age and sex of the exposed individuals. Arsine is considered to be the most toxic form followed by arsenites (AsIII), arsenates (ASV) and organic arsenic compounds (MMA, DMAA).[41, 42]

Acute arsenic poisoning

Arsenic dissolved in water is acutely toxic and can lead to a number of health problems. Acute symptoms develop within 30 minutes to 2 hours in the form of sudden and explosive gastro enteritis. Common symptoms include: nausea, vomiting, paralysis of the throat muscles, abdominal pain, rice-watery diarrhoea turning into dysentery, progressive generalized weakness and severe dehydration leading to collapse and heart failure. The sequelae of acute poisoning include loss of hair and brittle finger nails with white horizontal striae (Mee's lines). Peripheral nervous disturbances, primarily of sensory type, are frequently encountered in individuals surviving poisoning.[40]

Chronic arsenic poisoning (arsenicosis)

Arsenicosis, or arsenic toxicity, develops after two to five years of exposure to arsenic contaminated drinking water, depending on the amount of water consumption and arsenic concentration in water. Long-term exposure to arsenic in drinking-water causes increased risks of cancer in the skin, lungs, bladder and kidney. It also leads to other skin-related problems such hyperkeratosis and changes in pigmentation. Consumption of arsenic also leads to disturbance of the cardiovascular and nervous system functions and eventually leads to death. These health effects – sometimes collectively referred to as arsenicosis. Increased risks of lung and bladder cancer and of arsenic-associated skin lesions have been reported from consumption water contaminated with arsenic more than 50 parts per billion (or microgram per liter).[43] Initially, the skin begins to darken (called diffuse melanosis). This happens first in the palms. Diffuse melanosis

leads to spotted melanosis, when darkened spots begin to appear on the chest, back and limbs, although the latter is what is usual among people, and so is taken to be an early symptom. At a later stage, leucomelanosis sets in: the body begins to show black and white spots. 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. Diffuse or nodular keratosis on the palm of the hand or sole of the foot is a sign of moderately severe toxicity. Rough dry skin, often with palpable nodules on hands, feet and legs means severe toxicity. This can lead to the formation of gangrene, and cancer. Arsenic poisoning brings with it other complications: liver and spleen enlargement and cirrhosis of the liver; myocardial degeneration and cardiac failure; peripheral neuropathy affecting primary sensory functions; diabetes mellitus and goiter; and skin cancers. Three types of skin cancers are observed: Bowen's disease (form of squamous cell carcinoma); basal cell carcinoma and squamous cell carcinoma. These cancers develop primarily from keratosis.[44]

Operational definition of chronic arsenicosis

According to WHO – SEARO definition Arsenicosis is defined as chronic health condition arising from prolonged ingestion (not less than six months) of arsenic above a safe dose, usually manifested by characteristic skin lesion with or without involvement of internal organs.[45]

Diagnosis of chronic arsenicosis

Although chronic arsenicosis toxicity produces varied non malignant manifestations as well as cancer of skin and different internal organs, dermal manifestations such as hyperpigmentation and hyperkeratosis are diagnostic of chronic arsenicosis. Other manifestations are weakness, anaemia, peripheral neuropathy, hepatomegaly with portal zone fibrosis (with/without portal hypertension), chronic lung disease and peripheral vascular disease. The pigmentation of chronic arsenic poisoning commonly appears in a finely freckled, "raindrop" pattern of pigmentation or depigmentation that is particularly pronounced on the trunk and extremities and has a bilateral symmetrical distribution. Arsenical hyperkeratosis appears predominantly on the palms and the plantar aspect of the feet, although involvement of the dorsum of the extremities and the trunk have also been described.[46] In a nut shell diagnosis of chronic arsenicosis is made by history of exposure to arsenic, clinical manifestations and measuring arsenic content in hair, nail, urine and other body tissues like liver. Levels between 0.1 to 0.5 mg/kg on a hair sample indicate chronic poisoning. Normal range of excreted arsenic will be 40.00 – 93.75 micro gm / 1.5 liters/ day.[47, 48, 49]

Estimation of arsenic in water sample

Spectrophotometric/calorimetric procedure, Atomic absorption spectrometry, Neutron activation analysis, X-ray florescence, Inductively coupled plasma-atomic emission spectrometry, Anodic striipping voltametry, Differential pulse polarography, Hydride generation-atomic absorption spectrometry (HG-ASS), Graphyte furnace atomic absorption spectrometry are different methods available in water sample. In the arsenic

mitigation programme, in West Bengal, Water samples are examined to estimate arsenic levels using silver diethyl dithio carbamate method.[47]

Guide line value for arsenic stipulated by various regulatory agencies[50]

Country/Organization	Acceptable limit (mg/l)
W.H.O	0.01
India	0.01
US-EPA	0.05
Canada	0.03
Australia	0.007
European community	0.05
United Kingdom	0.05
Ireland	0.05
Denmark	0.05

Epidemiology of Arsenicosis

Global scenario: Before the onset of twenty first century, twenty groundwater arsenic contamination incidents from different parts of the world were known and out of these five major incidents are from Asia. In order of severity of occurrence, this includes Bangladesh, West Bengal-India, Inner Mongolia, Xin-Xiang provinces of P.R. China and Taiwan. In recent years, new arsenic groundwater contamination incidents are being reported from other Asian countries including new sites in China, Lao People Democratic Republic, Cambodia, Myanmar and Pakistan. Groundwater arsenic contamination has also been reported from the Terai area of Nepal during 2001.[50]

Arsenicosis in India: Arsenic crisis in India dates back to as early as 1976 when a preliminary survey on arsenic in dug wells, hand pumps and spring water from Chandigarh and different villages of Punjab, Patiala, Haryana and Himachal Pradesh in northern India was reported. In 2003 groundwater water arsenic contamination was reported in Bihar state of India in Middle Ganga Plain. Recently contamination has also been reported in Uttar Pradesh and Jharkhand states in Gangatic plain of India. Combining the first report of groundwater arsenic contamination reported in 1976 from Chandigarh and a few villages of Punjab, Patiala in northern India of upper Ganga plain with Uttar Pradesh, Bihar, Jharkhand and West Bengal states of India and that of Bangladesh, it appears that a good portion of Ganga-Meghna-Brahmaputra (GMB) plain of an area 569749 km2 and population over 500 million may be at risk from groundwater arsenic contamination.[51]

Arsenicosis in West Bengal: In July 1983, the first suspected cases from the village Gangapur, district 24 Parganas, attended the skin outpatient department of School of Tropical Medicine, Kolkata.[52] In 1984, Garai et al published a report of 16 cases of chronic arsenicosis having hyper and hypopigmentation.[53] In 1987 Chakravarty and Saha identified 14 villages in five districts of 24 Parganas, Bardhaman, Nadia, Malda and Murshidabad, having arsenic contaminated ground water. In his study overall prevalence of arsenical dermatitis was 25.1% [52]. From 1988-91, a joint study was carried out by Public Health Engineering Directorate, Government of West Bengal, All India Institute of Hygiene and Public Health, Centre for study of Man and Environment, School of Tropical Medicine, State Water Investigation Directorate and Central Ground Water Board. They observed that arsenic above permissible limit is confined within meander belt zone of upper delta plain comprising late quaternary sediments. The water of the intermediate (second) aquifer was also polluted. The ground water of arsenic infested zone was characterized by high iron, arsenic, calcium, magnesium and bicarbonate. The pH was always >7.[54] Workshop on ground water arsenic contamination for the paramedical', held in 1996-97 and organized by Public Health Branch of Directorate of Health Services and UNICEF identified 1,65,309 cases of arsenic related skin diseases and 3.933 million population residing in arsenic contaminated areas.[55] Mandal et al analysed 20,000 tube wells water for arsenic and found 45% of them to have arsenic content above permissible limit.[48]

Presently in West Bengal 12 districts were identified as arsenic contaminated. They are: Malda, Murshidabad, Bardhaman, Nadia, Hooghly, 24 Paraganas North, Haora, Kolkata, 24 Paraganas South, North Dinajpur, South Dinajpur and Coochbihar. To

asses the arsenic contamination of ground water, The school of Environmental studies, Jadavpur, Kolkata, analyzed 1, 40,150 hand tube-wells water for arsenic in all 19 districts covering 241 of 341 blocks from West Bengal. Out of 1, 40,150 samples analyzed, 48.1% had arsenic above 10µg/L (the WHO guide line value), 23.8% above 50µg/L and 3.3% of the analyzed tube-wells had arsenic concentrations above 300µg/L. Therefore total 75.2% tube-well water was contaminated with arsenic and was not safe for consumption[56]

Arsenicosis in Nadia district: According to recent survey conducted by the School of Environmental Studies, Jadavpur, Kolkata, the groundwater of entire 17 blocks contains arsenic above WHO guideline value of arsenic in drinking water (10µg/l). Arsenic level above 1000µg/L was found in 13 tube-wells; the maximum arsenic contamination level found in this district was 3200µg/L in the Tehatta-I block.[57]

Ground water contamination and arsenical skin lesions: In a large study it was found that 56% people in Bangladesh and 52% people in West Bengal had arsenical skin lesions with ground water contamination with arsenic above10µm/l. Another study conducted by the school of environmental studies Jadavpur, Kolkata, in nine affected district of West Bengal, indicates that and 14% have been identified with skin lesions.[58] The time of onset depends on the concentration of arsenic in the drinking water, volume of intake, and the health and nutritional status of individuals. Arsenical skin lesions have been reported to occur in West Bengal after drinking arsenic contaminated water for one year or even less. In Taiwan, the youngest patient drinking arsenic contaminated water who developed hyperpigmentation was 3 years old. Among the population

exposed to arsenic in drinking water in the Antofagasta region of Chile, cases of cutaneous arsenicosis, including both hyperpigmentation and hyperkeratosis, have been described in children as young as 2 years of age.[46] A survey conducted in one of the affected village of West Bengal showed that 10% of the children below the age of 11 were affected.[58] Higher prevalence rate of arsenic skin lesions were observed among males (male to female ratio was 1.2:1).[59]

Duration of arsenic exposure and development of skin lesions: Dr Michael Kosnett of USA describe that if a person ingests more than 0.04 mg/kg body weight/day for six months to three years, then there is a chance to develop hyper pigmentation. On the other hand, if the dose of arsenic is reduced to 0.01 mg/kg body weight/day and ingested by a person for 5 to 15 years, then hyper pigmentation will develop. Peripheral vascular disease, non cirrhotic portal hypertension, respiratory symptoms and peripheral neuropathy develop following ingestion of arsenic for years at a dose of more than 0.01 mg/kg body weight/day.[60] There is also evidence that people with poor nutrition levels are more affected by arsenic contamination than healthy people.[61]

Clinical feature other than skin lesions

Dr Mazumder presented the country report of India entitled, "Case definition of arsenicosis". He analyzed 25 publications on arsenicosis where he showed 96 per cent of the reported cases were skin lesion (spotty pigmentation and diffuse keratosis). Sixty-four per cent of the reported cases were bronchitis. Forty-four per cent cases had peripheral neuritis. Forty-eight per cent of the reported cases showed the development of cancer. He also discussed the diagnostic criteria of arsenicosis.[60]Treatment of

chronic arsenicosis: The treatment of most importance is to supply arsenic-free drinking-water. There are no well-designed studies to show whether cessation of exposure leads to improvement in skin keratosis. Thus far, anecdotal interviews of patients suggest that mild to moderate keratosis do improve with cessation of exposure. Some physicians have been giving chelating therapy to arsenic patients in West Bengal and Bangladesh. Chelating therapy was widely used in the idea that it will relieve systemic clinical manifestation and reduce arsenic stores in the body diminishing subsequent risk of cancer. Chelating agents like d-penicillamine, dimercaptosuccinic acid (DMSA), dimer captopropane sulphonate (DMPS), antioxidants (spirulina, selenium, zinc and vitamins A, C and E), retinoids (etrotinate), are empirically used.[59,60] The objective of chelation therapy is to provide the patient with a chemical to which arsenic binds strongly, and is then excreted in urine. Providing such treatment could remove large stores of arsenic from the body in a matter of hours.[62] This idea has some plausibility but its effectiveness has not been established. The problem with chelation therapy is the lack of any clinical trials that found evidence of its effectiveness.[63] Arsenic dermatitis is treated with 10% salicylic acid in 10 – 20 % urea based preparation and topical tretinoic acid and 5-flurоucil.

Since evidence from Taiwan suggests that some nutritional factors may modify cancer risks associated with arsenic. It has been proposed that providing vitamins and improving nutrition may be of benefit to patients. In particular, vitamin A is known to be beneficial in the differentiation of various tissues, particularly the skin. If the doses given are not excessive, there are other nutritional benefits to providing vitamins, particularly in populations that may have inadequate levels of micronutrients. For these reasons, it

is recommended that all patients with skin lesions be provided multivitamin tablets and that research projects be undertaken to establish whether or not they are effective for patients with arsenicosis.[64] There is no known effective medical treatment for those suffering from chronic toxicity. For people with early or mild arsenical skin lesions, clean water and nutritious food are the only way to bring about recovery.[64]

Arsenic mitigation

The mitigation options that is provision of alternative safe water, being considered under the arsenic mitigation programme include: [65] Piped water supply schemes based on either river or wide diameter deep tube wells, construction of deep tube wells to tap water from safe aquifers, arsenic removal plants attached to tube wells, horizontal Roughing Filters or Slow Sand Filters to treat traditional surface water, namely pond or lake water, development and distribution of affordable and user-friendly arsenic removal domestic filter, sharing safe sources of water in the community and rain water harvesting both for individual households and communities.

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