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Review Article

GROUND WATER ARSENIC CONTAMINATION AND HEALTH EFFECT IN WEST BENGAL, INDIA -A STUDY REPORT OF 36 YEARS

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A B S T R A C T

Though various states of India were affected with health effects due to ground water arsenic contamination, West Bengal had been affected most. The present report is based on studies on the problem since detected in the state.

Chronic arsenic exposure was associated with skin lesions of pigmentation and keratosis and systemic manifestations like lung disease, liver fibrosis, polyneuropathy, hypertension, limb swelling and weakness and cancer of the skin. Arsenic exposure was found to increases risk of stillbirth in pregnant women and decrement of intellectual function in children. A wide range of psycho-social consequences were observed due to arsenicosis in the society. Deficiencies of micronutrients, vitamins and protein were found to increase the risk of arsenical skin lesions.

Over and above drinking water, arsenic exposure occurred through diet in arsenic endemic region. Significant elevation of arsenic level in biomarkers like urine and hair was associated with elevated arsenic intake through water and diet in people living in arsenic affected region.

For the treatment of arsenicosis, chelating agent DMSA was not found to be effective, but DMPS caused significant decrease of arsenical symptoms. Prolonged drinking of arsenic safe water was associated with clearance of arsenical skin lesion in significant number of cases.

INTRODUCTION

People of various states like West Bengal, Jharkhand, Bihar, Uttar Pradesh Assam and Manipur in eastern India and Chhattisgarh state in central India have been chronically exposed to ground water arsenic contamination above permissible limit.[1] Though various states of India have been affected with the arsenic problem, West Bengal has been affected most and the calamity has been reported as early as 1984[2,3]. Groundwater arsenic contamination has far-reaching consequences. Various disease manifestations result from drinking Arsenic contaminated water over a long period of timeand the condition is known as Arsenicosis. Further various social disorders, and socioeconomic dissolution develop due severe morbidity and mortality resulting from prolonged drinking of arsenic contaminated water. The current report is based on review of various studies done on human health related to drinking of arsenic contaminated water and intake through Food-chain carried out through hospital based clinical studies and field based epidemiological studies during the period of 1984 to 2020, all of which have been reported in the literature.

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Initial Experience

Groundwater arsenic contamination was first reported in India in 1976 in Chandigarh and in different villages of the Punjab and Haryana states, India and incriminated as a cause of liver disease known as non-cirrhotic portal hypertension (NCPH)[4,5]. However, the significance of this information went unnoticed at the time. First report of cases suffering from Keratomelanosis associated with drinking of arsenic contaminated tube well water was made in 1984[2,3]based on studies of patients attending School of Tropical Medicine, Kolkata from districts of 24 Parganas, Burdwan, Nadia and Murshidabad of West Bengal. Subsequently household survey was carried out during 1984-1987 for case detection among 786 persons living in 127 households belonging to four arsenic affected villages in the districts identified earlier. A total of 197 (25.12%) cases of arsenicosis with typical pigmentation and keratosis were detected among the population surveyed. The liver was found to be enlarged in 68 (34.5%) cases while ascites was present in 11(5.6%) patients. One patient had skin cancer. Mean arsenic content of 31 water samples collected from tube well (34-46 meters deep) water of arsenic affected families was 0.64mg/L. Lowest concentration of arsenic in

water producing skin lesion was found to be 0.2mg/L[6].Another epidemiological study was carried out among 166 villagers living in two hamlets of Ramnagar village situated 40 km south of Kolkata in the Ganges delta region, far away from industrial areas in South 24 Parganas during the same period. Evidence of chronic arsenical dermatosis and hepatomegaly was noticed among 62 (92.5%) out of 67 members of families drinking arsenic contaminated (arsenic level, 0.2-2 mg/L) water while hepatomegaly was noted in 6 (6.25%) subjects and no skin lesion was noted among 96 persons living in the same village but drinking water with arsenic level <0.05 mg/L[7].

Arsenic and liver disease

Hepatic damage caused by chronic arsenic exposure has been reported earlier[4-,5]. Further study on liver affection associated with arsenic exposure was carried out in thirteen patients (8 male, 5 female) from six families who lived in Ramnagar village and who exhibited signs of chronic arsenical dermatosis. These patients were investigated in details for assessing nature of liver affection including liver biopsy at Institute of Post-Graduate Medical Education and Research (IPGME&R), Kolkata. All the 13 patients with arsenical skin lesion and hepatomegaly, who were studied in details, five had splenomegaly. Results of routine liver function tests were normal, but the prothrombin time for one patient was elevated, while the bromsulphthalein retention tests of three patients were abnormal (13.8%, 13.1 %, and 15.3%). Oesophageal varices were noted in three patients in whom splenomegaly was identified. Splenoportal venography indicated that four of the five patients with splenomegaly had increased intra-splenic pressure (30-36 cm saline) and evidence of intrahepatic portal vein obstruction. The intra-splenic pressure in the other nine patients studied was normal (16-20 cm saline).Biopsy of samples of liver from 12 out of 13 subjects showed features suggestive of the diagnosis of non-cirrhotic portal fibrosis (NCPF).Arsenic content of liver tissue obtained by biopsy, was found to vary between 0.5 mg/Kg to 6mg/Kg dry weight in 11 out of 13 cases tested by Neutron Activation analysis. [Control value-0.16±0.04mg/Kg Dry weight,(n-5)][7].

Environmental pollution and chronic arsenicosis in South Calcutta

During the period July-September 1989, some residents of an area in South West Calcutta, attended IPGME&R and were found to have signs of chronic arsenic toxicity. The locality was close to the boundary wall of a chemicals factory which had been producing the insecticide Paris-green (copper acetoarsenite) for the last 20 years. The factory's effluent was connected to a drain and a canal about 400 m away. Out of the 45 shallow tube wells analyzed, 17 contained arsenic in a safe level and 28 had arsenic concentrations of 0.1-58 mg/L. Out of the 30 nearby houses visited, members of nine of the 17 families, who were drinking shallow tube well water contaminated with high arsenic, were found to have cases of arsenical dermatoses; out of the 79 members of these families, 53 (67%) were affected. Although the remaining 21 houses were also close to the factory, the occupants had been using safe water from deep tube well or tap water and none of them were affected with arsenical skin lesion[8].

Further Studies

Studies during subsequent period showed chronic arsenic toxicity in the people drinking arsenic contaminated water in eight districts of West Bengal, namely, Malda, Murshidabad, Nadia, North and South 24 Parganas, Burdwan, Hooghly and Howrah (Fig 1). On the basis of hospital based studies done at (IPGME&R) Kolkata, since 1984, the clinical characteristics of chronic arsenic toxicity have been delineated[9].

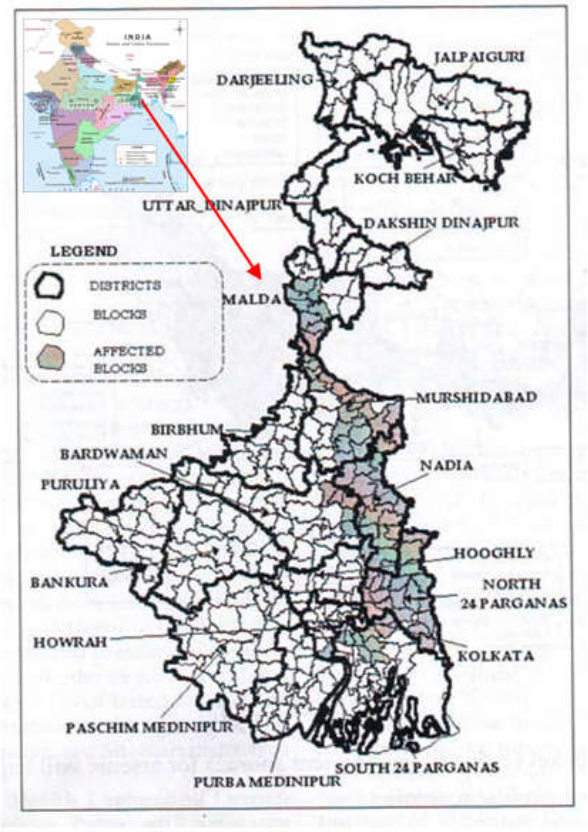

Fig 1 Location Map of West Bengal in relation of India with arsenic affected districts marked in shade

Results of hospital based study

A total of 248 patients, mostly coming from rural areas of the 8 districts of West Bengal, were studied clinically and by relevant investigations at IPGME & R, Kolkata. The arsenic contaminated water (0.05 to 3.4 mg/L) which they were drinking was drawn from subsoil water by hand pump from varying depths (20-80 m). The patient population also included 20 cases from South Calcutta drinking water containing higher quantity of arsenic (5.05 to 14.2 mg/L) in subsoil water due to contamination by factory effluent of manufacturing Paris green (copper acctoarsenite). Duration of intake of contaminated water usually varied from 1 to 15 years, but in some cases it was lifelong. The inclusion criteria were as follows: (1) typical raindrop pigmentation and/or depigmentation and/or keratosis of skin of body and limbs, and (2) arsenic level in drinking water above 0.05 mg/L (permissible limit of arsenic in India at that time) consumed by these people.

The 248 patients included 193 men, with mean (SD) age 32.5 (13.4) years. The clinical manifestations in these cases are given in Table 1. Pigmentation and keratosis were seen in 94.4 and 65.3% of cases respectively while skin cancer was detected in 5 cases.

The arsenic levels in hair and nails of the patients were found to be 16.29±3.75 and 42.72±5.92 mg/kg (control values 0.15±0.35 and 0.34±0.24 mg/kg) ($P < 0.001$, $P < 0.001$) respectively.

Table 1 Clinical features of 248 arsenic exposed cases (arsenicosis) studied in a hospital in West Bengal

Presenting Features	No. of Patients	Percentage
1. Rain-drop pigmentation	234	94.4
2. Keratosis (sole & palm)	162	65.3
3. Weakness	163	65.7
4. Dyspepsia	165	66.5
5. Cough (± Expectoration)	154	62.1
6. Burning sensation of eyes	74	29.8
7. Anemia	109	44.0
8. Hepatomegaly	190	76.6
9. Splenomegaly	73	29.4
10. Varices (out of 73 cases)	5	6.85
11. Ascites	5	2.0
12. Chronic Bronchitis	75	30.2
13. Polyneuropathy	74	29.83
14. Pedal oedema (non-pitting)	23	9.3
15. Peripheral vascular disease (Gangrene of toes)	3	1.2
16. Skin cancer	5	2.0

There was no correlation between the quantity of arsenic taken through water and the level of arsenic in hair, and nails[9].

Further Epidemiological study

An epidemiological study was conducted between 1995 and 1996 to investigate arsenic-associated skin lesions in South 24 Parganas district, West Bengal, India, and to determine their relationship to arsenic levels in water. In all, 7683 participants were examined and interviewed, by house to house survey, and the arsenic level in their drinking water were measured. Highest level of arsenic in drinking water was found to be 3.4mg/L. However more than 80% of participants were drinking water containing arsenic <0.5mg/L. The age-adjusted prevalence of keratosis was strongly related to water arsenic levels, rising from 0.2 per 100 in the lowest exposure category to 10.7 per 100 for males in the highest exposure level (> 0.8mg/L) and increasing from zero in the lowest exposure level (<0.05mg/L) to 8.3 per 100 for females drinking water containing >0.8mg/L. Similar findings were observed for hyper pigmentation, with strong dose-response relationship. Men were found to have roughly two to three times the prevalence of both keratosis and hyperpigmentation compared to women apparently taking the same dose of arsenic from drinking water when calculated by dose per body weight. Persons who were below 80% of the standard body weight for their age and sex were found to have a 1.6 fold increase in the prevalence of keratosis, and this suggested that malnutrition may play a small role in increasing susceptibility[10].

Arsenic and lung disease

Out of the population studied in South 24 Parganas, 6864 participants who were non-smokers were subsequently assessed for respiratory symptoms. Among both sexes, the prevalence of cough, shortness of breath, and chest sounds (crepitation and/or rhonchi) in the lungswere found to increase with increasing arsenic concentrations in drinking water. These respiratory symptoms were found to be pronounced in individuals with high arsenic water concentrations who also had skin lesions. Prevalence odds ratio (POR) estimates were markedly increased for participants with arsenic-induced skin lesions who also had high levels of arsenic in their current drinking water source (>or=0.5mg/L) compared with individuals who had normal skin and were exposed to low levels of arsenic (<0.05 mg/L)[11].

Further, during 1998 – 2000,a case control study was done in relation to lung function, respiratory symptoms and exposure to arsenic (<0.5 mg/L) in drinking water in 287 participants, including 132(cases) who had arsenic-caused skin lesions and remaining 155 control subjects (without skin lesion), in the above mentioned study population of South 24 Parganas. In men with skin lesions the average forced expiratory volume in 1 second (FEV_1) adjusted for age, height and smoking was reduced by 256 ml (95 percent CI: 114, 398; *p* value: <0.001), and the average adjusted forced vital capacity (FVC) by 288 ml (135, 441; *p* value: <0.001), compared to men without skin lesions. An increase of 0.1mg/L arsenic was associated with a decrease in FEV_1 of 45 ml (6.2, 83.9; *p* value: 0.02) and in FVC of 41.4 ml (0.7, 83.5; *p* value 0.053) in men. Risks of developing arsenic-caused skin lesions was lower in women compared to men and showed little evidence of respiratory effects and altered lung functions. Thus respiratory symptoms and reduced pulmonary function were found predominantly in men, especially among those who have developed arsenic related skin lesions following drinking of arsenic contaminated water[12].

Further study on pulmonary changes caused by arsenic was done on 108 subjects (arsenic exposure <0.4mg/L) with arsenic-caused skin lesions and 150 subjects (arsenic exposure <0.05/L) without lesions from a populationsurvey, as above, in the arsenic-exposed region of South 24 Parganas. High-resolution computed tomography (CT) was done on thirty-eight study participants who reported at least 2 years of chronic cough. Bronchiectasis severity score was 3.4 (± 3.6) in the 27 participants with skin lesions and 0.9 (± 1.6) in the 11 subjects who had no skin lesion. In subjects who reported chronic cough, CT evidence of bronchiectasis was found in 18 (67%) participants who complained chronic cough and had skin lesions and in 3 (27%) participants without skin lesions. A 10-fold increased prevalence of bronchiectasis was observed in participants with arsenical skin lesion compared to those who had no such lesions[13]

In another hospital based study carried out on 29 cases of chronic arsenic toxicity with non-malignant lung disease in Kolkata, obstructive lung disease was diagnosed in 17(58.6%), interstitial lung disease in 9 (31.2%) and bronchiectasis in 3(10%) cases[14].

Arsenic and Pulmonary artery dilatation

A cross sectional study was carried out in Nadia and Hooghly, the two adjacent districts having demographically similar populations with or without evidence of chronic arsenic exposure respectively. High Resolution Computerized Tomography (HRCT) of Chest was done to participants in both the groups with chronic respiratory symptoms. Clinical assessment of lung disease was followed by evaluation of HRCT of chest in194 and 196 subjects from the arsenic exposed and unexposed people; the former had a higher prevalence of cough and shortness of breath respectively. Higher score for bronchiectasis, pulmonary artery branch dilatation (PAD) [2.48 ± 2.33 vs. 0.78 ± 1.56, (P <0.001)] and pulmonary trunk dilatation [0.26 ± 0.45 vs. nil] were observed in arsenic exposed individuals compared to unexposed subjects. Age-adjusted prevalence odds ratio (POR) for Pulmonary Artery Dilatation found in HRCT comparing those exposed to arsenic (Group 1) to unexposed participants (Group 2) was found to be 6.98 (CI: 2.26–16.48). There was a strong

dose– response relationship observed between the PAD and cumulative arsenic exposure[15].

Arsenic and Pregnancy outcome

A retrospective study was carried out among 202 married women selected from the source population of 7,683 having wide range of arsenic exposure through drinking water in the district of South24 Parganasto ascertain pregnancy outcomes and infant mortality. Reproductive histories were ascertained over and above assessment of arsenical skin lesions from the participants. Exposure of arsenic during each pregnancy was assessed based on all water sources used and measurements of arsenic level from a total of 409 wells. Using logistic regression models odds ratios (OR) for spontaneous abortions, stillbirth, neonatal and infant mortality were estimated. Though average exposure of arsenic through drinking water during pregnancy was 0.098 mg/L, 17.5 percent of participants were exposed to arsenic ≥0.2 mg/L.A six-fold increased risk for stillbirth was observed in participants having arsenic exposure of ≥0.2mg/L during pregnancy after adjusting for potential confounders (OR: 6.23; 95% confidence interval (CI): 2.13, 18.3, p<0.001). Arsenic-related skin lesions were found in twelve women who had a substantially increased risk of having stillbirths (13.1; 3.2, 53.9, p<0.001). The odds ratio estimate for neonatal deaths was 2.28 but with a wide confidence interval (0.62,8.38). No association was found between arsenic exposure and spontaneous abortion (OR:0.94; 95%CI 0.34,2.63) or overall infant mortality (1.13; 0.35, 3.62)[16].

Another field based study was carried out in Murshidabad district on pregnancy outcome on 17 women exposed to drinking water with arsenic level 0.284mg/L to1.414mg/L and 7 control women drinking water with arsenic level <0.03mg/L. In comparison to control Group, arsenic exposed group showed increasing trends in spontaneous abortion, preterm birth, and low birth weight rates[17]

Arsenic and Children's Intellectual function

A cross-sectional study was conducted among 351 children age 5 to 15 years who were selected from the source population of 7683 people of South 24 Parganas in 2001–2003. Intellectual function was assessed with 6 subtests from the Wechsler Intelligence Scale for Children as well as with the Total Sentence Recall test, the Coloured Progressive Matrices test, and a pegboard test. Arsenic in urine and lifetime water sources (including during the pregnancy period) were assessed using measurements of samples from 409 wells. Intellectual function was tested on 156 children with arsenic exposure and 195 control children (5-15 yrs). Reduction in intellectual function scores, particularly vocabulary and picture completion test scores were associated with increased urine arsenic concentrations[18].

Arsenic and Neurological affection

To ascertain neurological affection occurring in arsenic affected people a detailed study was carried out on 249 subjects out of 4813 cases registered with arsenical skin lesions in Murshidabad, one of the eight arsenic-affected districts in West Bengal. Neuropathies from arsenic toxicity were identified in 127 (51%) cases; of these, 107 (43%) had sensory neuropathy and 20 (8%) had additional motor components (sensorimotor neuropathy). The majority of the patients presented with sensory manifestations of distal paresthesia (41.7%), limb pain (12%), and distal hypoesthesia (34.5%), outnumbering motor features of distal limb weakness or atrophy (15.3%), localized to feet. In more severe cases, all modalities are affected in a stocking–glove distribution. There may be tenderness of calves. A total of 34.5% of patients in Murshidabad had reduced sensations (hypoesthesia) in the distal parts of the extremities.

Other associated relevant features in the patients included neuropathic tremor of distal limbs (7.2%), headache (2%), decreased libido (1.6%), vertigo (1.6%), and somnolence (0.4%)[17].

Arsenic and Hypertension

A study was done to assess the likelihood of occurrence of hypertension (HTN) in individuals resident in an area of high arsenic contamination in ground water (Nadia district) compared to those from a non-contaminated area (Hoogly district) in West Bengal. Two hundred and eight study participants with clinical evidence of arsenicosis (Group 1) were recruited from a cross-sectional study of six villages in the Nadia district and 100 controls (Group 2) without any skin lesion were recruited from a village in the Hoogly district. The two groups were evenly matched in regard to age and sex. Increased association of hypertension in individuals resident in arsenic endemic region compared to those from a non-endemic region was observed in this study. Increased odds ratio for hypertension[Adjusted Odds Ratio, OR, 2.87 (95 %CI = 1.26–4.83)] was observed in Group- 1 participants compared to Group- 2 people. Dose-effect relationship was observed with increasing cumulative arsenic exposure and arsenic level in hair and hypertension in participants living in arsenic endemic region.[19]

Report of systemic manifestations observed in epidemiological studies done in two districts of West Bengal

Systemic manifestations were assessed in the epidemiological study carried out in South 24 Parganas in 1995 in which 7683 participants were examined.[8] Arsenic level in current drinking water source was found to be low,<0.05 mg/L (maximum permissible limit of As in India during the period of study) in3467 people while high,≥ 0.05 (Maximum value: 3.40mg/L) in4216 people. The clinical manifestations of the study population giving the incidence of pigmentation, keratosis, weakness, hepatomegaly, chronic lung disease, dyspepsia and neuropathy among both the groups are given in Table 2.

Table 2 Incidence of various clinical manifestations in a population with and without arsenic exposure

Symptoms	As level <0.05 mg/L (n = 3467) Percent (n)	As level ≥0.0 5 mg/L (n = 4216) Percent (n)	P Value
Pigmentation	0.34 (12)	8.82 (372)	< 0.001
Keratosis	0.11 (4)	3.64 (154)	< 0.001
Hepatomegaly	2.99 (104)	10.21 (431)	< 0.001
Weakness	1.37 (48)	4.99 (211)	< 0.001
Pain abdomen	31.81(1103)	27.84 (1174)	NS
Nausea	0.31 (11)	0.74 (31)	< 0.02
Lung disease	7.74 (269)	11.68 (493)	< 0.001
Neuropathy	2.73 (95)	4.70 (198)	< 0.001

It could be seen that over and above pigmentation and keratosis, all the clinical features excluding pain abdomen were found to be significantly more in arsenic exposed population compared to those drinking arsenic safe water[9].

It need to be mentioned that a few cases of pigmentation and keratosis occurred in people drinking water with arsenic content <0.05mg/L because of the fact that water samples were collected from current drinking water sources in that study. When lifetime arsenic exposure data was ascertained in the same study population, the lowest level of peak arsenic ingested by a confirmed case of arsenicosiswas found to be 0.115 mg/L. The average latency for skin lesions was 23 years from first exposure[20]. Another epidemiological study was carried out in the district of Nadia during 2006-07. A total number of 10469 participants were examined from 37 arsenic affected villages belonging to all the 17 blocks of the district. Out of the participants examined, 1,616 (15.43%) patients had features of arsenical skin lesion (cases), while 8853 participants did not have any such lesion (controls). Highest level of arsenic in drinking water sources was found to be 1.362 mg/L. Arsenic exposure data, age and sex distribution and features of systemic manifestations in relation to cases and controls are presented in Table 3.Aged males with higher arsenic exposure were significantly more among cases. Except anaemia all other systemic manifestations noted (Chronic lung disease, dyspepsia, chronic diarrhoea, hepatomegaly, pedal edema, and peripheral neuropathy) were found to be significantly more in cases compared to controls.[21].

Table 3 Arsenic exposure data and clinical features in an arsenic exposed population in a cross sectional study in Nadia district, West Bengal, India.

Parameter	2006-07 Population based study in Nadia in Arsenic Endemic Region (N = 10469)				p-Value
	(Cases: n -1616) (Mean ± S.D.)		(Control:n-8853) (Mean ± S.D.)		
Water Arsenic(mg/L)	0.10±0.15		0.07± 0.15		<0.001
Age (yr)	53±15		33± 15		<0.001
Sex :	n	%	n	%	
Male	934	57.80	3213	36.29	<0.001
Female	682	42.20	5640	63.71	<0.001
Disease Symptoms :					
1.Chronic Cough	127	7.86	52	0.59	<0.001
2. Breatlessness (COPD)	146	9.03	39	0.44	<0.001
3. Pain abdomen(Dyspepsia)	67	4.15	77	0.87	<0.001
4.Ch.Diarrhoea	19	1.18	15	0.17	<0.001
5. Liver Palpable	5	0.31	0	0.00	<0.001
6. Ascities	3	0.19	1	0.01	<0.05
7.Pallor(Anaemia)	1	0.06	7	0.08	>0.05
8.Limb Swelling (Solid Oedema)	4	0.25	2	0.02	<0.01
9. Per Neuritis	257	15.90	136	1.54	<0.001

Arsenic and Cancer

A total number of 212 (4.35%) cases of skin cancer and 38 (0.78%) internal cancer were detected among 4865 cases of arsenicosis studied among the participants attending the health camps organized by the investigator in arsenic affected villages in different districts of West Bengal[22].In an epidemiological study carried out during 2015-17, a total of 68 cases (1.27%) of skin cancer was detected among a population of 5355 participants living in 2013 households in 7 arsenic affected Blocks of district of Malda.[23]Arsenical skin lesion was found to be present in 446 (8.4%) cases in the study population.In another epidemiological study, done during 2017-20, skin cancer was found to be present in 44 cases(0.61%) out of a population of 7162 residing in 2233 household in 17 arsenic affected blocks of Nadia district. Arsenical skin lesion was found to be present in 264 cases (3.68%) cases in this study population. Death due to cancer was found to occur in 121 (11.6%) subjects out of which death due to skin cancer was found to occur in 6 (4.96%) subjects [24].

Arsenic and Psychosocial, Behavioral and Economic Issues

Information on psychosocial, behavioral and economic issues were assessed amongst surveyed population during epidemiological study carried out in 7 arsenic affected blocks of Malda during 2015-17. Out of 357arsenicosis cases who responded to the query, whether they were aware of their arsenical illness (out of 446 cases of arsenicosisidentified in Malda district), a total of 136 (38.1%) participants were not aware of their disease. All the remaining 221 participants felt embarrassed due their illness. Forty seven patients felt badly, 68 patients felt depressed, 59 patients felt pain and uneasiness, 77 felt tired and 76 felt anxiety and tension. Only 3 (1.6%) patients out of 187 arsenicosis cases, who responded, felt that their status had been changed within the family. However, 175 (93.6%) patients felt that their status had been changed within the community. When enquired about any marital problem, 6 (3.1%) out of 192 arsenicosis cases, who responded, said that they had encountered marital problem due to arsenicosis. In one case the prospective partner thought that his partner was unsuitable, while in 5 cases they confided weakness during physical relation. Regarding disability, majority (239, 92%) of 269 arsenicosis cases who responded complained that their ability to work was affected due to the arsenical illness. These patients narrated various reasons; often multiple by a single patient, like can't work as earlier, felt lethargic, weak to work. Out of these 171(71.5%) patients had to change their previous occupation. Termination of job occurred in 161(67%) cases[25].

Knowledge and perception among surveyed population

A total of 111 (8.7%) persons, out of 1272 participants who responded amongst 5355 villagers surveyed in Malda, considered arsenicosis to be a communicable disease. Out of these 35 (31.5%) subjects felt tension and anxiety for fear of contacting the disease by contact with an arsenicosis case. Regarding social exclusion, majority (1084, 88%) of 1232 participants, who responded, had no bad feelings (empathy) towards arsenicosis cases. But 127 (10.3%) persons expressed some fear about the diseased cases. Only 17 participants (1.4%) wanted to avoid to mix with arsenicosis patients (1.4%) and 4 participant did not allow their children to mix with the diseased persons. [25]

Nutritional Factors and Arsenic Caused Skin Lesion

During 2001-02 a case–control study was carried out on the study population of 1995 cross-sectional survey of South 24 Parganas. Cases had arsenic-induced skin lesions having exposure of arsenic >0.5mg/L in their drinking water source. For each case, an age- and sex-matched control (without of skin lesion) was selected from participants, whose drinking water at that time also contained >0.5mg/L arsenic. Nutritional assessment was based on a 24-hr recall for major dietary constituents and a 1-week recall for less common constituents. Conditional logistic regression suggested that the strongest associations of cases with arsenical skin lesion were with low calcium, low animal protein, low folate, and low fiber intake. Nutrient intake was not related to arsenic exposure[26].

Similar nutritional study was carried on a population of Nadia district during 2008-2012.The study was composed of two

groups – Group 1 (cases, n 108) exhibiting skin lesions and Group 2 (exposed controls, n 100) not exhibiting skin lesions – age- and sex-matched and having similar arsenic exposure through drinking water and similar level of arsenic in urine and hair. Energy intake was below the recommended 'Daily Allowance' (set by the Indian Council of Medical Research) in males and females in both groups. Increased risk of arsenical skin lesions was found for those in the lowest quintile of protein intake. Significantly lower intakes of energy, protein, thiamine, niacin, Mg, Zn and choline were observed in both males and females of exposed cases compared to exposed controls. Significantly lower intakes of carbohydrate, riboflavin, niacin and Cu were also observed in female cases with skin lesions compared with non-cases. [27].

Arsenic in Food Chain and Human Effect

There is increasing evidence of elevated rice grain arsenic level in regions of West Bengal where paddy fields are irrigated with arsenic-rich water[28]. Few reports are available that characterize daily arsenic exposure through water and diet among people living in regions having groundwater arsenic contamination and correlate it with arsenic in biomarkers. A study was carried out to assess the total individual arsenic exposure and arsenic level in urine and hair of an arsenic-exposed population living in areas (Nadia district) where paddy fields are irrigated with arsenic-rich water and compare the same in arsenic unaffected region (Hooghly district)in West Bengal. There was no difference in age, sex and occupation among the 167 (Group-1) study participants living in regions with groundwater arsenic contamination and the 69 (Group-2) study participants living in the region without such contamination in West Bengal. Arsenic intake through water and diet were ascertained from each participant during the study period. Quantities of various food items consumed by each participant were assessed in each cohort by taking help of a dietician working with the research group. Duplicate diet samples were collected and analyzed for arsenic content from each participant. Collection of urine and hair samples were also made from each participant for estimation ofarsenic level. Biological samples were analyzed for arsenic after proper digestion, using AAS with hydride generation system. Correlation of the data with arsenic exposure through water and food were carried out with arsenic level in the biomarkers like urine and hair.

Mean arsenic level in current drinking water source for the 167 Group-1 participants was0.054 mg/L, (range: BDL- 0.326 mg/L) while that of the 69 Group-2 participants was below the detection limit (BDL).Total daily arsenic intake fromdiet for each participant was 0.165 (range 0.020–0.479) mg/day in Group-1 while 0.036 (range:0.012–0.12) mg/day in Group-2 participants (P<0.001).The mean arsenic level in urine of these participants was 0.124±0.10mg/L, and 0.016 ±0.010 mg/L and in hair was 1.02, and 0.17 mg/Kg, respectively. This study showed that significant elevation of arsenic level in urine and hair was associated with elevated arsenic intake through water and diet in people living in arsenic endemic region (group-1) while these values were low in people in non-endemic region (group-2). Those with skin lesions were found to have higher arsenic in urine and hair compared to those without skin lesion with similar arsenic intake through water and diet[29].

Further analysis of data showed that, even when people were using arsenic-safe water (<0.05mg/L, permissible limit in India during study) for drinking and cooking purposes, daily doses of arsenic intake from both water and diet were significantly positively associated with urinary arsenic level in people living in an arsenic endemic region of Nadia. When the arsenic level in drinking water was further reduced to <0.01 mg /L (WHO safe limit), the dose of arsenic exposure from diet was still found to be associated with significant urinary arsenic excretion; but no significant association was found with arsenic dose from water in this group. The study suggested that dietary arsenic intake was a potential pathway of arsenic exposure even where arsenic intake through water was reduced significantly in arsenic endemic region in West Bengal [30,31].

Study on Treatment of Chronic Arsenic Toxicity

As information on satisfactory therapy for chronic arsenic toxicity was scanty, evaluation of effective therapy for chronic arsenicosis was done by a research group. Chelation therapy for removal of arsenic from body was considered specific for amelioration of symptoms of arsenic toxicity and prevention of its sequelae including cancer.

Chelating Agents

Study with DMSA (Dimercapto- Succinic Acid)

A placebo controlled trial was carried out with DMSA, a chelating agent, among arsenicosis cases to assess its efficacy. Twenty one consecutive patients suffering from chronic arsenicosis were randomized into two groups. In the drug group, 11 patients (10 males, age 25.5±8 yrs.) received DMSA (1400 mg/day in the first week and 1050 mg/day during next two weeks); the same dose sequence being repeated after 3 weeks period without the drug. In the placebo group, ten patients (all male age 32.2±9.9 yrs.)were given placebo capsules (resembling DMSA) in the same schedule. The clinical features were evaluated by an objective scoring system before and after treatment. Routine investigations including liver function tests, arsenic level in urine, and skin biopsy evaluation were also made similarly.

Though there was improvement in clinical score in DMSA treated patients, similar improvement was also observed in the placebo treated group who were given only arsenic free water and high protein hospital based diet. There was no statistical significant difference in clinical score between the two groups both at the beginning and at the end of treatment.(Table 4) Similarly no difference of other parameters investigated were found among the DMSA treated and control group. The study demonstrated that though there was some improvement of symptom score in DMSA treated group, similar improvement was observe among control group managed by arsenic safe water and high protein hospital diet. Thus DMSA was not found to be effective in the treatment of arsenicosis..[32]

Table 4 Clinical scores of patients before and after therapy with DMSA and Placebo

	Before	After	*P* value
DMSA (*n* = 11)	9.33 ± 3.33	6.2 ± 2.11	0.017
Control (*n* = 10)	10.6 ± 3.20	6.7 ± 1.70	0.003

Study with DMPS (2,3 Dimercapto-1-Propanesulfonate)

DMPS, a chelating agent, had been found to increase excretion of arsenic in urine several folds above pre-chelation levels[33]. However, therapeutic efficacy of DMPS in the management of

chronic arsenic toxicity was not yet been properly evaluated. Clinical use of DMPS in arsenicosis patients were studied at IPGME&R, Calcutta. Twenty one consecutive patients with chronic arsenic exposure were individually randomized into two groups; 11 patients (9 males, 2 females, Age 30.63±11.4 years) received DMPS 100 mg capsules four times a day for one week and repeated on 3rd, 5th and 7th week with no drug during the intervening period. The 10 control patients (5 males and 5 females, age 34.4±14.41 years) were given placebo capsules (resembling DMPS) in the same schedule. The patients were blinded about the nature of treatment given.

Therapy with DMPS was found to cause significant improvement of clinical condition of chronic arsencosis patients as evident by significant reduction of individual symptom score and total clinical scores from 8.90±2.84 to 3.27±1.73; $p < 0.0001$. (Table 5) Total urinary excretion of DMPS treated cases was found to increase significantly following drug therapy, while no such increase was noticed in placebo treated cases. Increased urinary excretion of arsenic during the period of therapy was the possible cause of this improvement. This was the first time that a cheating agent (DMPS) treatment was demonstrated to cause significant improvement of symptoms of chronic arsenic toxicity. It is to be noted that significant reduction of total symptom score was also noted in the placebo treated group also in this study[34].

Table 5 Clinical scores of patients before and after therapy

Clinical features	Drug	Before	After	*P* value
Pigmentation	DMPS	1.45 ± 0.52	0.90 ± 0.54	0.02
	Placebo	1.60 ± 0.84	1.10 ± 0.87	0.20
Keratosis	DMPS	1.54 ± 0.68	1.09 ± 0.70	0.14
	Placebo	1.40 ± 0.96	1.11 ± 0.87	0.47
Weakness	DMPS	0.91 ± 0.30	0.00 ± 0.00	0.00031
	Placebo	0.80 ± 0.42	0.40 ± 0.52	0.07
Hepatomegaly	DMPS	0.82 ± 0.40	0.45 ± 0.52	0.08
	Placebo	0.70 ± 0.67	0.50 ± 0.53	0.46
Neuropathy	DMPS	0.27 ± 0.46	0.09 ± 0.30	0.29
	Placebo	0.50 ± 0.70	0.40 ± 0.51	0.72
Lung disease	DMPS	1.82 ± 1.33	0.36 ± 0.80	0.005
	Placebo	1.50 ± 1.43	1.10 ± 0.87	0.46
Total scoring	DMPS	8.90 ± 2.84	3.27 ± 1.73	0.0017
	Placebo	8.50 ± 1.96	5.40 ± 2.12	0.003

Initial study with DMPS, though found to be satisfactory, this agent could not be recommended for large scale use. Further, follow-up study of the cases treated needs to be carried out to assess the efficacy of this initial improvement of clinical symptoms in altering the natural history of chronic arsenic toxicity.

Natural History of Arsenicosis Following Intake of Arsenic Safe Water

As natural history of arsenic related skin lesion following intake of safe water is scanty, a study was carried out to assess the outcome in regard to skin lesion following supply of arsenic free safe water by PHED, Govt. of West Bengal through spot sources and surface water supply through pipe line system in a study district in West Bengal. Afollow up study was carried out on a cohort population of 7162 having arsenical skin lesion during 2017-2020, out of 8206 persons studied previously during 2006-07,in arsenic affected district of Nadia. Water samples were collected from drinking water sources from households studied currently and analyzed for arsenic level**.** Arsenic exposure data of all available past and present study subjects were used for exposure assessment.

Out of the population of 7162 studied, a total of 843 arsenicosis cases had skin lesion in the past, the lesions persisted in 249 (29.5%) cases while cleared in 594 (70.5%) subjects during current study. Further, 15 (0.21%) cases with new skin lesion were seen currently. Arsenical pigmentation was found to be present in 823 (11.49%) cases and keratosis in 236 (3.3%) cases in the past subjects studied. Pigmentation and keratosis was found to be present during past and present study in 220 (3%) cases and 57(0.8%) cases respectively. Thus clearance of skin lesion of pigmentation and keratosis was found to occur in 603(73%) and 179 (75.8%) patients respectively following a gap of 10 years out of the population studied. Arsenic exposure data of past and current patients showed that 36.3% of individuals were drinking water with arsenic level ≥0.01mg/L previously, but currently taking safe water (As<0.01mg/L). Arsenic safe water could not prevent occurrence of new lesion in 11 cases.[35]

Total Arsenicsis Disease Burden in the State

Prevalence of arsenicosis varied widely in different district of West Bengal. Prevalence data noted in three major arsenic affected districts of the of West Bengal, namely, South 24 Parganas[10],North 24 Parganas[36] and Murshidabad[17], were found to vary from 4.6 to 19 percent. Further cross sectional study done in Nadia[21] and Malda[25] showed prevalence of arsenicosis as15.43% and 8.3% respectively in the two districts. Extrapolating the prevalence data on the reported exposed population in the five major arsenic affected districts of West Bengal[37], an estimated total disease burden of arsenicosis cases appear to be 457,484 of people in the state. (Table 6).

Table 6 Estimated population exposed to arsenic contaminated water ≥0.05 mg/L in the surveyed affected blocks of the 5 main arsenic affected districts of West Bengal and estimated number of arsenicosis patients.

Districts	Total population of Affected blocks[37]	Estimated no. of people Exposed to As ≥0.0 5 mg/L[37]	% of people affected with arsenicosis	Estimated no. of People suffering from Arsenicosis
North 24 Parganas	4290233	959377	6.8[36]	65237
South 24 Parganas	2577369	524922	4.6[10]	24146
Murshidabad	5249116	1208863	19[17]	229683
Nadia	3855122	589810	15.43[21]	91007
Malda	2751151	571224	8.3[25]	47411
Total	18,722,991	3,854,196		457,484

CONCLUSION

Chronic arsenic exposure was associated with pigmentation and keratosis of skin and systemic manifestations including cancer in West Bengal. Daily arsenic intake from both water and diet are significantly positively associated with urinary arsenic levels in arsenic-endemic region. Chelation therapy for arsenicosis has limitations. Proper supply of arsenic safe water need to be adopted for mitigation of arsenic problem as arsenic safe water was found to cause clearance of arsenical skin lesion in significant number of cases in a population.

References

1. Groundwater Arsenic Contamination in India - Central GroundWater...cgwb.gov.in/documents/papers/

incidpapers/Paper%208%20-%20Ghosh.pdf. consulted on 25.4.19.
2. Saha K C. 1984. Melanokeratosis from arsenic contaminated tube well water. *Ind. J. Dermatology*., 29(4): 37-46.
3. Garai R. Chakraborty A, Dey S, SahaKC. 1984. Chronic arsenic poisoning from tube-well water.*J. Indian. Med. Assoc*.,82: 34–35.
4. Datta D, Kaul M. 1976. Arsenic content of drinking water in villages in Northern India: A concept of arsenicosis. *J. Assoc. Phys. India*., 24: 599–604.
5. Datta DV. 1976. Arsenic and non-cirrhotic portal hypertension. *Lancet.*,307:433.
6. Chakraborty AK, Saha K C. 1987. Arsenical dermatosis from tube well water in West Bengal. *Indian.J. Med.Res.,* 85: 326-334.
7. GuhaMazumder DN, Chakraborty AK, Ghosh A, Gupta JD, Chakraborty DP, Dey SB, Chattopadhyay N. 1988. Chronic arsenic toxicity from drinking tube well water in rural West Bengal. *Bull. World. Hlth.Orgn*.,66: 499-506.
8. GuhaMazumder DN, Das Gupta J, Chakraborty AK, Chatterjee A, Das D, Chakraborti D. 1992. Environmental pollution and chronic arsenicosis in south Calcutta. *Bull. World. Hlth. Orgn.,* 70(4):481-5.
9. GuhaMazumder DN. 2003. Chronic Arsenic toxicity: Clinical features, epidemiology and treatment: Experience in West Bengal. *J. of Envn. Sc. and Hlth.,*Part A., 38(1):141-163
10. GuhaMazumder DN, Haque R, Ghosh N, De BK, Santra A, Chakraborty D, Smith AH. 1998. Arsenic levels in drinking water and the prevalence of skin lesions in West Bengal, India. *Int. J.Epidemiol*., 27(5):871-7.
11. GuhaMazumder DN, Haque R, Ghosh N, De BK, Santra A, Chakraborti D, Smith AH 2000.Arsenic in drinking water and the prevalence of respiratory effects in West Bengal, India. *Int. J .Epidemiol*., 29(6):1047-52.
12. von Ehrenstein O S, GuhaMazumder DN, Yuan Y, Samanta S, Balmes J, Sil A, Ghosh N, Smith MH, Haque R, Purushothamam R, Lahiri S, Das S, Smith AH. 2005. Decrements in Lung Function Related to Arsenic in Drinking Water in West Bengal, India. *Am. J. Epidemiol*.,16: 533-541.
13. GuhaMazumder DN, Craig S, Bhattacharya P, von Ehrenstein O, Ghosh N, Gotway M, Sil A, Balmes JR, Haque R, Hira-Smith MM, Smith AH.2005. Bronchiectasis in persons with skin lesions resulting from Arsenic in Drinking Water. *Epidemiology.,* 16: 760-765.
14. De, B.K. Majumdar, D., Sen, S., Guru, S. and Kundu, S. 2004. Pulmonary Involvement in Chronic Arsenic Poisoning from Drinking Contaminated Ground-water. *J. Assoc. of Physcn.India*., 52:395-400.
15. Bhattacharya P, Sen P, Ghosh A, Saha C, Bhattacharya PP, Das A, Majumder KK, GuhaMazumder DN, 2014.Chronic lung disease and detection of pulmonary artery dilatation in high resolution computerized tomography of chest in chronic arsenic exposure. *J. of Environ. Sci. and Hlth*., *Part A.,*49: 1453–1461.
16. von Ehrenstein OS, GuhaMazumder DN , Hira-Smith M, Ghosh N, Yuan Y, Windham G, Ghosh A , Haque R, Lahiri S, Kalman D, Das S, Smith AH. 2006. Pregnancy outcomes, infant mortality and arsenic in drinking water in West Bengal, India. *Am. J.Epidemiol*.,163: 662-9.
17. Mukherjee S C, Saha C, Pati S, Dutta RN, Rahman, MM, Sengupta MK, Ahamed S, Lodh D, Das B, Hossain M. A, Nayak B, Mukherjee A, Chakraborti D, Dutta SK, Palit S K, Kaies I, Barua AK, and Asad KA.2005. Murshidabad-One of the Nine Groundwater Arsenic-Affected Districts of West Bengal, India. Part II: Dermatological, Neurological, and Obstetric Findings. *Clinical. Toxicol.,* 43:835–848.
18. von Ehrenstein OS, Poddar S, Yuan, Y ; GuhaMazumder DN, Eskanazi B, Basu A, Hira-Smith M, Ghosh N, Lahiri, S, Haque R, Ghosh A, Kalman D, Das S, Smith AH. 2007. Children's Intellectual Function in Relation to Arsenic Exposure. *Epidemiology.,* 18: 44-51.
19. GuhaMazumder DN, Kar-PurkayasthaI.Ghose A, Mistry G, Saha C, Nandy AK, Das A, and Majumder KK.2012. Hypertension in chronic arsenic exposure: A case control study in West Bengal. *J.Env. Sc. and Health*. Part A.,47: 1514–1520.
20. Haque R, GuhaMazumder DN, Samanta S, Ghosh N, Kalman D, Smith M.M., Mitra S, Santra A, Lahiri S, Das S, De BK & Smith AH. 2003. Arsenic in Drinking Water and Skin Lesions: Dose-Response Data from West Bengal, India. *Int. J.Epidemiol*., 14: 174-182 .
21. GuhaMazumder DN, Ghosh A, Majumdar KK, Ghosh N, Saha C, GuhaMazumder RN. 2010.Arsenic contamination of Ground Water and its Health Impact on Population of District of Nadia, West Bengal, India. *Ind. J, of Comm. Med*., 35: 331-338.
22. Saha KC. 2003. Saha'sGrading of Arsenicosis, Progression and Treatment. In: W.R. Chappell C.O. Abernathy, R.L. Calderon and D.J Thomas, eds. Arsenic Exposure and health effects V, Oxford, UK: Elsevier Science: 391-414.
23. GuhaMazumder DN, Ghosh AK, Majumder KK, Majumder PK, Mukherjee S. 2020. Ground water arsenic contamination in Malda, West Bengal, India: Epidemiology and efficacy of mitigation measures. *Int. J. of Med. and Pub. Hlth*., 10(1):34-37.
24. GuhaMazumder DN, Majumdar KK, Ghosh P, Ghosh AK. 2020. Prevalence and Mortality of Skin Cancer in an Arsenic Exposed Population in District of Nadia, West Bengal, India. *ClinOncol*., 5: 1-5.
25. Majumdar KK, Ghosh AK, Majumder PK, Mukherjee S, GuhaMazumder DN. 2018. Arsenical Disease Burden and Psychosocial, Behavioural & Economic Issues Associated with Chronic Arsenic Exposure: A Study in Malda District, West Bengal. *Int. J. of Res. & Rev*., 5 (12): 156-165.
26. Mitra S, GuhaMazumder DN, Basu A, Block G, Haque R, Samanta S, Ghosh N, Smith M H, Ehrenstein OSV, and Smith AH. 2004. Nutritional Factors and susceptibility to arsenic-caused skin lesions in West Bengal, India.*Envl. Health. Presp.*, 112:1104-09.
27. Deb D, Biswas A, Ghose A, Das A, Majumdar KK, GuhaMazumder DN. 2013. Nutritional deficiency and arsenical manifestations: a perspective study in an arsenic-endemic region of West Bengal, India.*Pub. Hlth. Nutrn.,* 16(09):1644-55.

28. Halder, D. and Bhowmick, S. and Biswas, A. and Chatterjee, D. and Nriagu, J. and GuhaMazumder, D.N. and Å lejkovec, Z. and Jacks, G. and Bhattacharya, P. 2013. Risk of arsenic exposure from drinking water and dietary components: Implications for risk management in rural Bengal. *Environ. Sc. and Technology*. 47(2): 1120-1127
29. GuhaMazumder DN, Deb D, Biswas A, Saha C, Nandy A, Ganguly B, Ghosh A, Bhattacharya K, Majumdar K. 2013. Evaluation of dietary arsenic exposure and its biomarkers: A case study of West Bengal, India.*J. of Env. Sc. and Hlth*., *Part A.,*48:896-904.
30. GuhaMazumder DN, Deb D, Biswas A, SahaC, Nandy A, Das A, Ghosh A, Bhattacharya K, Majumdar K. 2014. Dietary arsenic exposure with low level of arsenic in drinking water and biomarker: A study in West Bengal.*J. of Env. Sc. and Hlth*., *PART A*. 49: 555–564.
31. Biswas A, Deb D, Ghosh A, Laing G, Neve J, Santra S. C, GuhaMazumder D.N.2014. Dietary arsenic consumption and urine arsenic in an endemic population: response to improvement of drinking water quality in a 2-year consecutive study. *Env. Sc. and Poll. Res.*, 21(1):609-19.
32. GuhaMazumder DN, Ghoshal UC, Saha J, Santra A, De BK, Chatterjee A, Dutta S, Angle CR, Centeno JA. 1998. Randomized placebo-controlled trial of 2,3-dimercaptosuccinic acid in therapy of chronic arsenicosis due to drinking arsenic-contaminated subsoil water. *J. Toxicol. Clin. Toxicol*., 36:683-690.
33. Aposhian HV, Alex Arroyo M.E, Cebrian L, Del Razo LM.1997. DMPS-arsenic challenge test. I. Increased urinary excretion of monomethylarsonic acid in humans given dimercaptopropane sulfonate. *J. Pharmacol. and Exp. Therapeutics*., 282:192–200
34. GuhaMazumder DN, De BK, Santra A, Ghosh N, Das S, Lahiri S, Das T. 2001. Randomized placebo-controlled trial of 2, 3-dimercapto-1-propane-sulfonate (DMPS) in therapy of chronic arsenicosis due to drinking arsenic contaminated water. *J. Toxicol. Clin. Toxicol*., 39 (7): 665-674.
35. GuhaMazumder DN, Ghosh P, Majumdar KK and Ghosh AK. 2020. Natural history of chronic arsenic toxicity following intervention to reduce arsenic exposure, a study from West Bengal, India. *Int. J. Curr. Adv. Res*., 9 (08): 22980-22985.
36. Rahaman MM, Mondal BK, Roy Chowdhury T, Sengupta MK, Chowdhury UK, Lodh D, Chanda CR, Basu GK, Mukherjee SC, Saha KC and Chakraborti D. 2003. Arsenic Groundwater Contamination and Sufferings of People in North 24-Parganas, One of the Nine Arsenic Affected Districts of West Bengal, India. *J. Env. Sci. and Hlth*., *Part A* ., 38 (1): 25-59.
37. Chakraborti D, Das , Mohammad MR, Chowdhury U K, Biswas B, Goswami AB, Nayak B, Pal A, Sengupta MK, Ahamed S, Hossain A, Basu G, Roychowdhury T and Das D. 2009.Status of groundwater arsenic contamination in the state of West Bengal, India: A 20-year study report. *Mol. Nutr. Food Res*., 53: 542–551.

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