# Journal of Applied Sciences

ISSN 1812-5654

Journal of Applied Sciences 6 (6): 1275-1286, 2006
ISSN 1812-5654


# How Does Arsenic Contamination of Groundwater Causes Severity and Health Hazard in Bangladesh

[1]M.A.I. Chowdhury, [1]M.T.Uddin, [2]M.F. Ahmed, [2]M.A. Ali and [3]S.M. Uddin
[1]Shah Jalal University of Science and Technology, Sylhet
[2]Bangladesh University of Engineering and Technology, Dhaka
[3]City Corporation, Chittagong, Bangladesh

**Abstract:** The toxic effects of arsenic are complicated by its existence in different forms whatever be the organic and inorganic. Most cases of vertebrate toxicity have been associated with exposure to inorganic arsenic as a variety of inorganic arsenate and arsenite occur in water, soil and food. Humans appear to be most susceptible to arsenic than animals and chronic oral exposure to inorganic arsenic causes neurological and hematological toxicity on human. Obviously untreated groundwater enriched in arsenic appeared to be the major threat to drinking water that was and is being extensively used as a source of drinking and food for the decades in rural and semi-urban areas of the developing countries that results in a high incidence of arsenic with deleterious effects on humans and food chain. In Bangladesh, China, China, Chile, India, Mexico, Vietnam and other developed countries, arsenic contamination in groundwater is considered to be the key environmental health problem of the twenty first century. In Bangladesh higher levels of arsenic (exceeding the WHO standard of 0.01 mg $L^{-1}$ and Bangladesh standard of 0.05 mg $L^{-1}$) have been detected in ih groundwater of tube-wells in a vast region of the country including 61 districts out of 64. It is estimated that of the 140 million inhabitants of Bangladesh more than 100 million are at the risk of arsenic hazard, such arsenic hazards cause the a number of arsenicosis. The severity of chronic arsenic exposure via drinking water in Bangladesh and its adverse health effect on the poor people of Bangladesh, mostly living under the poverty level as well as the arsenic patient management including the risk of arsenic hazard is reflected in the study.

**Key words:** Arsenic, arsenicosis, Bangladesh, cancer, ingestion, inhalation, lesion, severity

## INTRODUCTION

Widespread arsenic contamination in groundwater has become a major concern where the water supply, particularly the rural water supply, is heavily dependent on groundwater extracted from shallow aquifers via tube-well and common trace of arsenic in drinking-water identified as a significant health risk (McNeill and Edward, 1997; Pontius *et al*., 1994; Abernathy and Ohanian, 1993; Wu *et al*., 1989) and public health is severely endangered for its high toxicity and its ability to induce skin cancer after long term ingestion (Driehaus *et al*., 1998) resulting in signs and symptom of arsenic poisoning. Classically these include cutaneous manifestations such as skin pigmentation changes, keratosis and cancers (cancers in skin, bladder, kidney, lung, liver and colon), peripheral viscular diseases like black-foot disease and Raynaud's syndrome, systematic arterial disease resulting in myocardial infarction (Rosenberg, 1973; Moran *et al*., 1977) changes in electromyographic patterns (Hindmarsh *et al*., 1977) and moderate effects in the respiratory system (Borgono *et al*., 1977) although the mutagenic and teratogenic effect of arsenic exposure in human beings are still the subject of debate (Cebrian *et al*., 1994). Thus recent studies indicate that arsenic in drinking water is a matter of great concern and is considered more dangerous than it was in the past. The occurrences of arsenic in drinking water drawn from a variety of groundwater environment has been reported in many places around the world particularly in Argentina (Smedley *et al*., 1998), Australia (Smith *et al*., 2003) Bangladesh (Karim, 2000; Nickson *et al*., 2000; Kinnibug and Smedley, 2001; McArther *et al*., 2001; Ravenscroft *et al*., 2001), Cambodia (Ahmed M.F., 2003), Chile (Ahmed, 2003; Romero *et al*., 2003), China (Smedley *et al*., 1998; Ahmed, 2003), Hungary (Ahmed, 2003), India (Battacharaya *et al*., 1997; Acharyya *et al*., 2000), Lao PDR (Ahmed, 2003), Mexico (Del Razo *et al*., 1990; Arminta *et al*., 1997), Mongolia (Ahmed, 2003), Nepal (Ahmed, 2003), Pakistan (Ahmed, 2003), Switzerland (Fabian *et al*., 2003), Taiwan (Kuo, 1968; Chen *et al*.,

**Corresponding Author:** M.A.I. Chowdhury, Shah Jalal University of Science and Technology, Sylhet, Bangladesh

1996; Guo *et al*., 1997), Thailand (Ahmed, 2003), the USA (Matisoff *et al*., 1982; Welch *et al*., 2000; Robertson, 1989; Welch and Lico, 1998; Peters *et al*., 1999; Schreiber *et al*., 2000) and Vietnam (Berg *et al*., 2001). Among them, arsenic in groundwater has been regarded as the severest natural calamity in arsenic zone of Bengal Delta including Bangladesh where more than 100 million people in 61 districts out of 64 are at the risk of severe arsenic hazard.

## LITERATURE REVIEW AND RELEVANT STUDIES ON ARSENIC EXPOSURE

**Arsenic toxicity in human body:** Symptom of arsenic poisoning on human depends on the type of arsenical involved and on the time-dose relationship of exposure. Based on the consumption of arsenic in human body, its toxicity according to the clinical manifestation can be divided into three categories: (i) acute toxicity, (ii) sub-acute toxicity and (iii) chronic toxicity.

**Acute toxicity:** Acute toxicity in human body is usually homicidal, suicidal or accidental. A fatal dose of arsenic trioxide is probably in the range of 200 to 300 mg, yet a dose of 20 mg has regarded as life-threatening and recovery from 10 mg has occurred (Schoolmeester and White, 1980). Smallest recorded fatal dose is about 125 mg and death occurs after a fatal dose in 12 to 48 h and symptom appear within half an hour.

**Sub-acute toxicity:** Sub-acute toxicity is a condition where arsenic is administered in a small dose at repeated interval. The symptoms of sub-acute toxicity of arsenic are at first dyspepsia, cough and tingling in the throat, then vomiting and purging with abdominal pain and tenesmus with foul tongue, dry and congested throat and a feeling of depression and languor. Besides bloody motion is obvious, symptoms of neuritis are pronounced in addition to the severe cramps on the muscles that are tender on pressure. Patients suffered with sub-acute toxicity of arsenic become restless cannot sleep, ultimately collapse sets in and results in death.

**Chronic toxicity:** The clinical manifestation due to chronic arsenic toxicity develop very insidiously after six months to two years or more depending on the amount of arsenic intake. Chronic arsenic toxicity is better understood in terms of the organs and systems affected. Long-term affect of chronic arsenic toxicity leads to malignancy.

Clinicopathological findings in acute and chronic arsenic poisoning (Cebrian *et al*., 1994; Gorby, 1994) are described in Table 1.

**Exposure level and arsenicosis:** Arsenic is carcinogenic in humans if exposed orally or by inhalation, but not in animals. Obviously quantitative dose-dependent data of animals should not be applied to humans to investigate arsenicosis, although quantitative dose-dependent data of animals is used to humans in many cases for disease indication phenomenon.

**Carcinogenic effects:** Arsenic induces a wide range of skin lesions including hyperpigmentation, hyperkeratosis

Table 1: Clinicopathological findings in acute and chronic arsenic poisoning

| Organ system | Acute arsenic poisoning | Chronic arsenic poisoning |
|---|---|---|
| Dermatologic | Capillary flush, contact dermayitis, folliculitis; Hair: Delayed loss (diffused or patchy hair Loss); Nails : Aldrich- Mees' lines (growth of finger nails and toenails) (4 to 6 week postingestion). | Melanosis, Bowen's disease, facial edema, actinic keratosis, Hyperkeratosis and warts or corns of palms and soles, papillomatosis, recurrent episodes of pruritic urticaria, cutaneous malignancies, desquamation, hyper pigmentation on the face, neck and back. |
| Neurologic | Hyperpyrexia, convulsions, tremor, coma, disorientation. | Encephalopathy showing symptom of persistant headache, diminished recent memory, distractibility, abnormal irritability, restless sleep, loss of libido,increased urinary urgency etc.; peripheral Polyneuropathy; axonal degeneration. |
| Gastrointestinal | Abdominal pain and cramps, dysphagia, vomiting, bloody or rice-water diarrhea, garliky odor to breath and stools, mucosal erosion, dry mouth and throat, heartburn. | Nausea, vomiting, diarrhea, anorexia, weight loss, hepatomegaly, jaundice, pancreatitis, cirrhosis, mild esophagitis, gastritis or colitis with respective upper and lower abdominal discomfort, malabsorption. |
| Renal | Crotical necrosis, tubular necrosis with partial and complete renal failure, tubular and glomerular damage, oliguria, uremia. | Proteinuria, nephritic disease. |
| Hematologic | Anemia, thrombocytopenia, granulocytopenia, pancytopenia, hemolysis with anemia, hematuria, Collapse and risk of renal failure. | Bone marrow hypolasia, normochromic normocytic anemia, leukopenia, impaired folate metabolism, basophilic stripping, karorrhexis. |
| Cardiovascular | Altered myocardial depolarization (ST-T wave abnormalities, $Qt_c$ Prolongation ), ventricular fibrillation, typical ventricular tachycardia. | Arrhythmias, pericarditis, acrocyanosis, cyanosis of fingers and toes, Raynaud's gangrene (Blackfoot disease), myocarditis. |
| Hepatic | Fatty infiltration, cholangitis, cholecystitis, yellow atrophy. | Cirrhosis, portal hypertension without cirrhosis, fatty degeneration, hepatic neopalsia, bleeding from esophageal varices, hepatic blood vessel damage, fibrosis and expansion of the portal zone. |
| Respiratory | Pulmonary edema, ARDS, bronchial pneumonia, tracheobronchitis, alveolar hemorrhages, mucosal sloughing, pharyngitis, laryngitis, stuffy nose, sore tgroat, hoarseness etc.. | Cough, pulmonary fibrosis, lung cancer. |

and various cancers. Arsenic has been found to cause cancer of the skin, bladder, liver, lung, prostate and possibly of haempoietic and lymphatic tissues. Arsenic exposure has been associated with three types of skin cancers vis-à-vis Bowen's disease, Basal cell carcinoma and Squamous cell carcinoma. These cancers are frequently multiple in occurrences and develop primarily from arsenical keratosis.

**Arsenic pollution disrupts hormones:** Arsenic interferes with the action of glucocorticoids, hormones never known before to be vulnerable to endocrine disruption by pollution. Glucocorticoids belong to the same family of steroid hormones as estrogen and testosterone. Glucocorticoids are responsible for turning on many genes that may suppress cancer and regulate blood sugar. Researchers have identified estrogens, thyroid hormones androgens and melatonin as types of hormones that pollutants can affect.

Ordinarily, hormones bind to a receptor in a cell and the hormone-receptor complex then turns on genes as shown in Fig. 1. This may be the way some other endocrine disrupters work as well, he speculates. The new finding may help explain how arsenic triggers cancer, diabetes and other chronic diseases such as hypertension,

**Stages of clinical features:** Sign and symptoms of chronic arsenicosis differ in manifestation in different countries. The clinical manifestations are categorized into following four stages (Quamrazzaman *et al*., 2003).

**Pre-clinical stage:** It includes chemical phase and sub-clinical or occult phase. In chemical phase urine shows arsenic excretion during intake of groundwater containing higher arsenic concentration, while in sub- clinical phase body tissues show high arsenic concentration with no apparent clinical symptom.

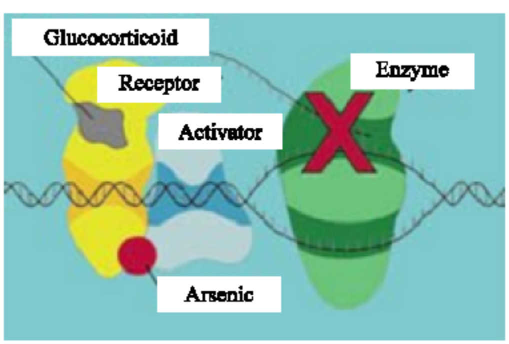


Fig. 1: Arsenic pollution disrupt hormon (Linda, 2001). Arsenic alters the hormone-receptor complex (left). This keeps an activator molecule (center) from directing an enzyme (right) to read genes. (Adapted from William Scavone, 2001)

**Clinical stage:** The presence of clinical symptoms is characterized by detection of higher arsenic concentration in nail, hair and skin-scale.

**Stage of complication:** Clinical stage is followed by different complications in the affected organs like lung, liver, muscles, eye vessels etc. where higher concentration of arsenic is involved.

**Stage of malignancy:** Malignancy affecting skin, lung, bladder or other organs develops if arsenic patients survive the stage of complication.

## MATERIALS AND METHODS

Groundwater samples were collected and subsequently tested to determine arsenic concentration in tube-well water using field kits as well as spectrophotometer, UV spectrophotometer, atomic absorption spectrophotometer etc. Blood, hair, nail, urine etc. of arsenic affected people were collected from the arsenic patients of Samta of Jessore, Rajarampur of Rajshahi and Coutpara of Kushtia of Bangladesh and subsequently diagnosticed and tested to observe the health aspect of arsenic hazard. Field kits were and are being used to determine arsenic content in groundwater of tube-wells in conducting rigorous water analysis in the field. Also relevant information and pertinent data were collected from other sources and analyzed to assess the severity of arsenic hazard throughout Bangladesh. Specific treatment for arsenicosis were applied to arsenic patients of Samta of Jessore, Rajarampur of Rajshahi and Coutpara of Kushtia and the improvement was observed subsequently. The arsenicosis case study was conducted during 2002-2004.

## ARSENIC HAZARD BECOMES SEVERE IN BANGLADESH

In groundwater of Bangladesh arsenic was first discovered in the district of Chapai Nawabgang bordering the West Bengal of India in 1993. Since then elevated levels of arsenic (exceeding the WHO standard of 0.01 mg $L^{-1}$ and Bangladesh standard of 0.05 mg $L^{-1}$) have been identified in many regions of the country (Ahmed *et al*., 1997; Khan *et al*., 1998; Talukder *et al*., 1998; Saifullah *et al*., 1998; Ahmed *et al*., 1998; Tanable *et al*., 1998). Estimates of affected population are being updated, as more data are becoming available. According to Dave (1997), about 23 million people are "at high risk" endangered by arsenic in Bangladesh. Arsenic contamination of groundwater has been detected in 41 out of 61 administrative districts and an estimated 35 million people in Bangladesh are at risk of arsenic toxicity (Khan *et al*., 1998). In accordance with survey findings of Dhaka Community Hospital (DCH) published in October 1997, 60 million people of 41 districts are "at risk of arsenic contamination" as water of tube-wells of 41 districts showed arsenic concentration above 0.05 mg $L^{-1}$ (permissible limit of arsenic in drinking water for Bangladesh). According to a study report published jointly by the School of Environmental Sciences (SOES)of Jadabpur University of India and DCH, 50 million people of 29 districts of Bangladesh is at the risk of arsenic poisoning. Field survey conducted from August 95 to February 2000 by SOES and DCH shows that 100 million people of 54 districts of area 125,133 sq. km is at risk of arsenic hazard where groundwater of 73.39% of tubewells contain arsenic above 0.01 mg $L^{-1}$ and 9.3 million people of 47 districts of area 112,407 sq km. is at risk of arsenic poisoning where groundwater of 53.47% of tubewells contain above 0.05 mg $L^{-1}$ (SOES and DCH, 2000). According to a recent estimate, 27% of shallow hand-tubewells have arsenic concentration exceeding 0.05 mg $L^{-1}$; in acute arsenic problem areas more than 75% of shallow tubewells are contaminated with arsenic. Out of 64 administrative districts of Bangladesh, arsenic contamination has so far been reported in 61 districts. Arsenic problem alone has reduced the national safe water supply coverage by about 15 to 25%.

The most arsenic contaminated part of the country lies in the southern regions covering the districts Chandpur, Comilla, Noakhali, Munshiganj, Faridpur, Madaripur, Gopalganj, Shariatpur and Satkhira. Contamination has also been found in South-west, part of North-west, North-east and North Central regions (Fig. 3). There is variability in the pattern of occurrences. In the North-west and South-west regions, contaminated and uncontaminated wells are located close to each other whereas in the South-east, particularly in Chandpur, almost all the shallow wells are contaminated. Testing of all wells using field kits conducted by BRAC, UNICEF and BAMWSP show large variations in the percentage of contaminated wells in different upazilas, e.g., almost 100% contamination in Hajiganj in Chandpur district compared to almost none contaminated in Porsha in Naogaon district (Ahmed, 2003). There is a large variability in the concentration ranges of arsenic within an area. In certain areas the concentration ranges show normal distribution pattern, whereas in other areas bimodal or polymodal distribution patterns are shown. There are variations in concentration ranges even in village scales where areas of low and high arsenic regions can occur as reported from Samta village of Sarsha thana of Jessore district (AAN, 1998).

Table 2: Administrative areas with at least one tubewell exceeding drinking water standards

| Type of administrative areas | No. of administrative areas: Bangladesh standard (50 µg $L^{-1}$) Below | Above | WHO guideline value (10 µg $L^{-1}$) Below | Above | Total |
|---|---|---|---|---|---|
| Divisions | 0 | 6 | 0 | 6 | 6 |
| Districts | 8 | 53 | 1 | 60 | 61 |
| Upazilas | 184 | 249 | 39 | 394 | 433 |

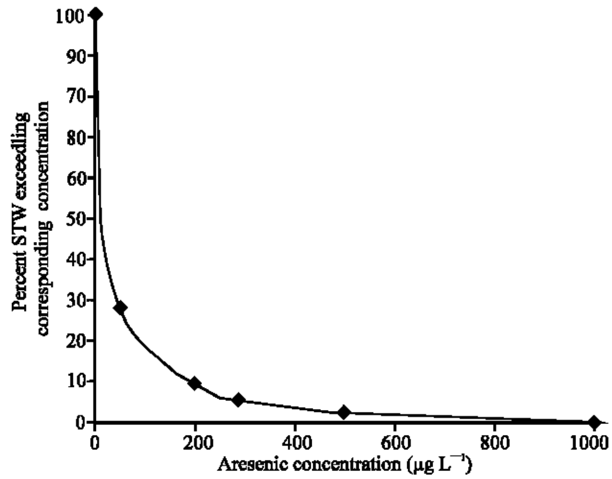


Fig. 2: Levels of arsenic content in STW water

The study conducted by British Geological Survey (BGS), Department of Public Health Engineering (DPHE) and Mott MacDonald Limited (MML) in two phases examined 3534 distributed water samples from 61 districts except 3 hilly districts (DPHE, BGS and MML, 1999) with an average of 58 samples per district and 8 samples per upazila. The study showed that arsenic concentration of 42% of all tubewell samples exceeded 10 µg $L^{-1}$ and 25% exceeded 50 µg $L^{-1}$. When only shallow tubewells are considered, 46 and 27% exceeded 10 and 50 µg $L^{-1}$, respectively. In case of deep tubewell (> 150 m ) samples, arsenic content of only 5% exceeded 10 µg $L^{-1}$ and 1% exceeded 50 µg $L^{-1}$. The number of administrative areas with at least one sample exceeding Bangladesh Drinking Water Standard and WHO guideline value are shown in Table 2.

The percentages of shallow tubewells yielding water of various concentrations of arsenic prepared on the basis of BGS/DPHE test results are shown in Fig. 2. This diagram provides information about the percentage of shallow tubewells producing water in excess of corresponding concentration.

A map showing the intensity of arsenic contamination of groundwater in different parts of Bangladesh is shown in Fig. 4. The map has been updated

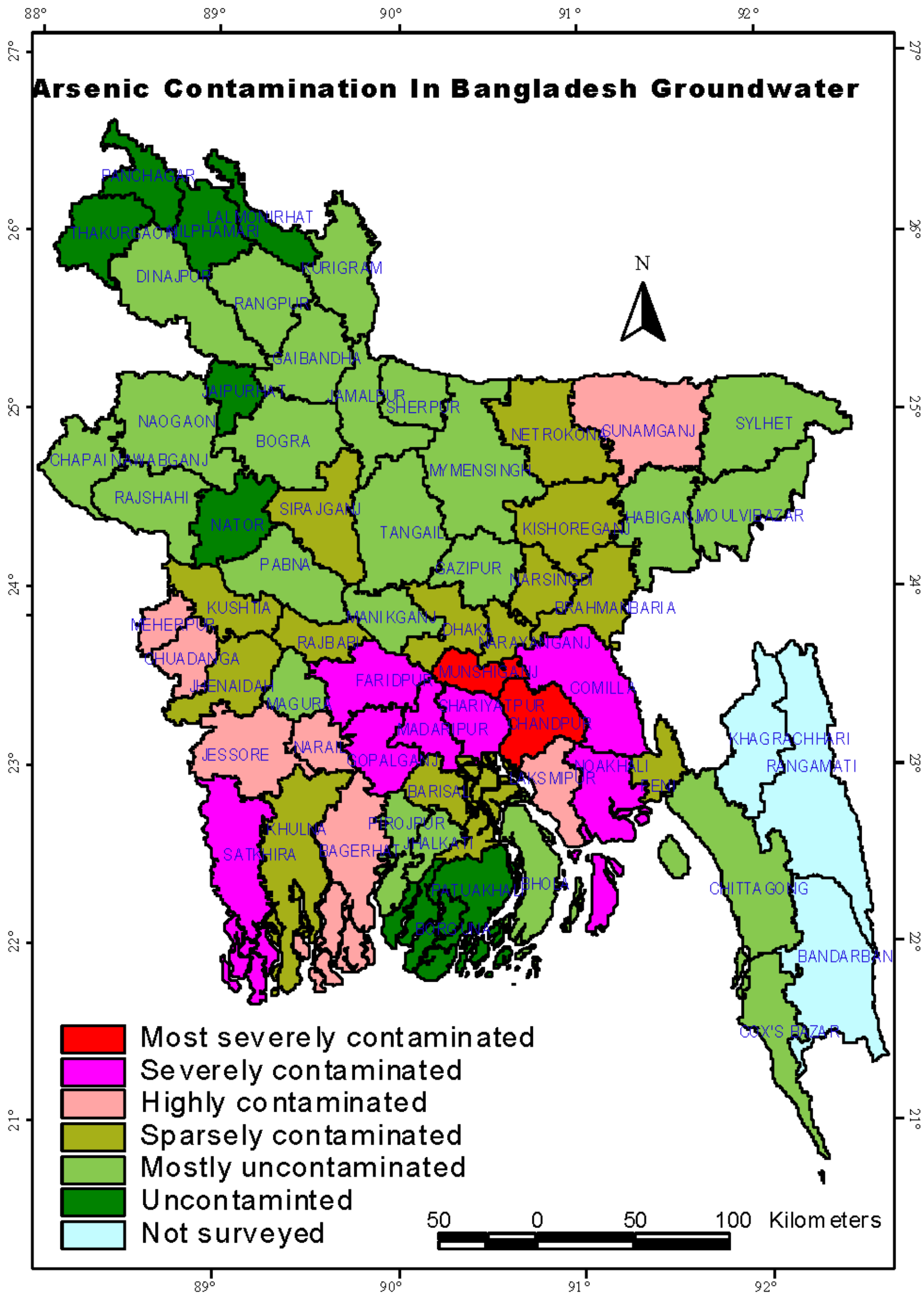


Fig. 3: Severity of arsenic contamination in groundwater of Bangladesh

on the basis of information available from arsenic analysis conducted by DPHE, BGS and MML (1999), SOES and DCH, JU (2000) and BUET. The maps produced by other organizations based on field/laboratory test data more or less provide similar pictures of arsenic contamination. It may be observed that shallow tube-wells even at the level of contamination still providing water with arsenic within the acceptable level to about 75 million people in Bangladesh. However, the safe tubewells may turn into unsafe in future.

## ARSENIC CONTAMINATION AFFECTS PUBLIC HEALTH OF BANGLADESH

Arsenic mass poisoning in groundwater of Bangladesh surpasses any incident seen before. A few

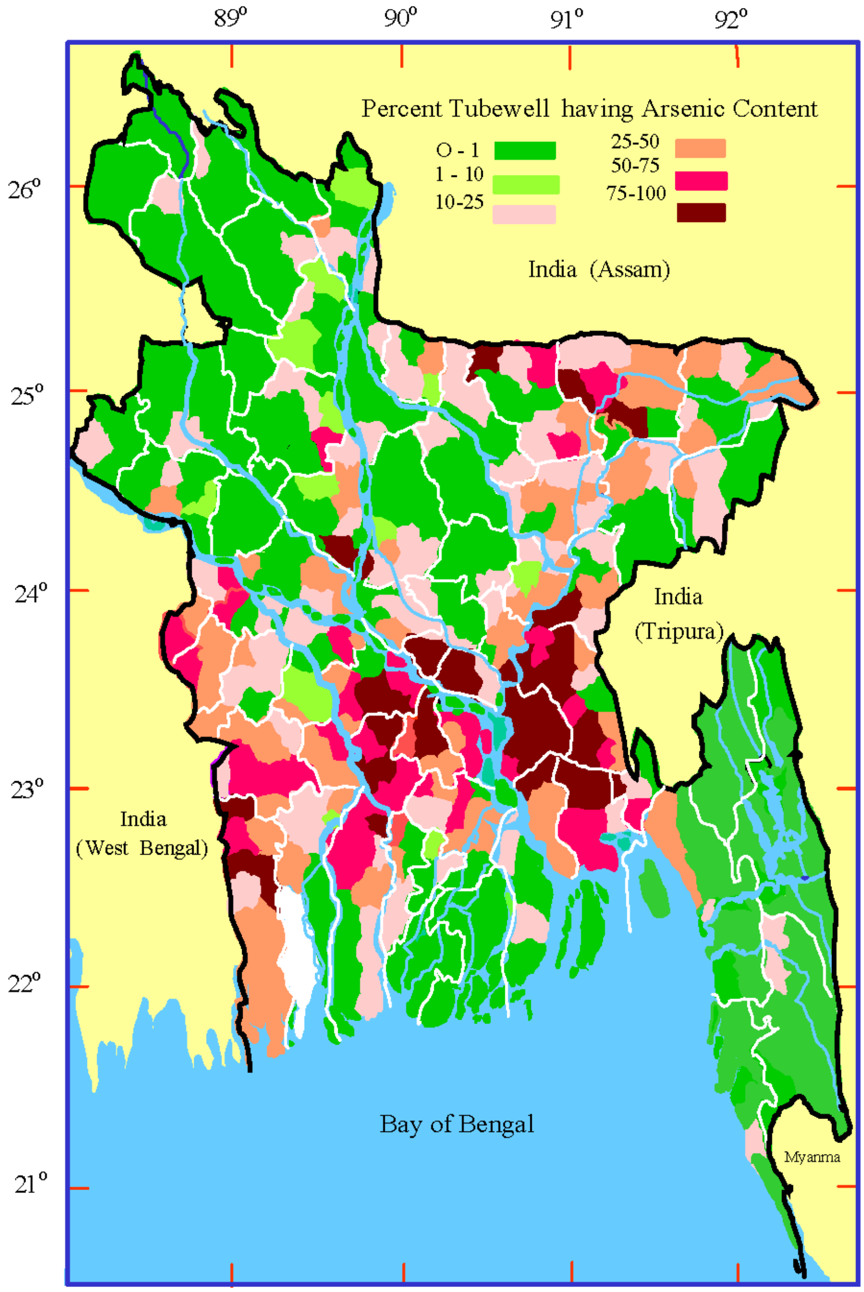


Fig. 4: Intensity of arsenic contaminated (>50 μg $L^{-1}$) tubewells in Bangladesh

clinical, large population based case-control epidermiological studies conducted by Mandal *et al.* (1996) identified a number of common arsenical manifestation and arsenic lesions such as different type of melanosis e.g., diffused melanosis, spotted melanosis, lucomelanosis, mucus membrane melanosis, different type of keratosis e.g., diffused keratosis, spotted keratosis, shyper keratosis, gangrene, squamoous cell carcinoma and hyperpigmentation in palms and soles and non-cirrhotic portal fibrosis among the population affected by arsenic in Bangladesh. In a later stage the patches might develop into cancer and foot will probably have to be amputated (Pontius *et al.*, 1994; Battacharaya *et al.*, 1997). Skin cancer, internal cancers of bladder, kidney, liver and lunges, neurological effects, hypertension, cardiovascular disease and diabetes

**Eye disease caused by arsine**

**Keratosis: hardening of sole of a Dantint's feet**

Fig. 5: Arsenicosis including eye disease and keratosis

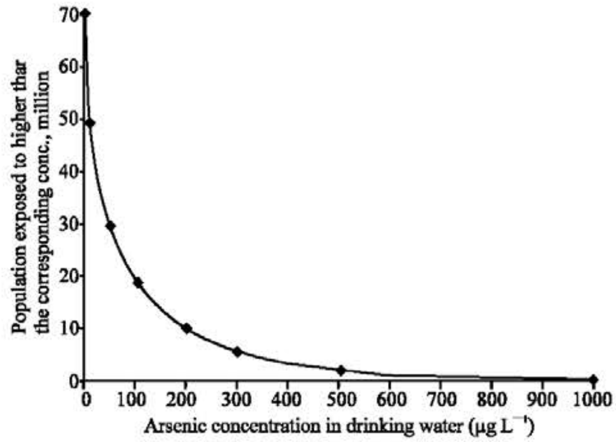


Fig. 6: Population exposed to different level of arsenic in drinking water

mellitus, pulmonary disease and peripheral vascular disease are included to long-term health effects of exposure to arsenic (WHO, 2000). A few pictorial cases of arsecinosis found in Bangladesh is shown in Fig. 5.

Chowdhury *et al.* (2000) examined 11,180 people (including children) at random; they registered 2,736 (24.47%) people with arsenical skin lesions in 27 districts of Bangladesh, who usually drink water containing above 0.30 mg $L^{-1}$ of arsenic. According to Tondel *et al.* (1999), in four villaged of Faridpur, Narayangang, Nawabgang and Jessore district, arsenic concentration in groundwater ranged from 0.01 to 2.04 mg $L^{-1}$ and the prevalence rate of arsenic lesions was 30.1 and 26.5% for males and female respectively. An estimated 20 million people are exposed to the risk of arsenic related ailment through drinking of arsenic contaminated water in Bangladesh (BGS and MML, 1999). About 7,600 arsenic affected patients have so far been identified in arsenic affected areas. The arsenic problem has emerged as a big environmental disaster and more than 50 million people are exposed to arsenic above the Bangladesh drinking water standard (SOES and DCH, 2000; DPHE and BGS, 2000). DPHE, BGS and MML studies estimated that the population exposed to arsenic contamination would lie in the range 18.5-22.7 million (DPHE, BGS and MML, 1999). However, The BGS-DPHE studies finally gave two estimates of population exposure based on projected population of 125.5 million in 1999. The estimates of total population exposed to As concentration above 50 and 10 μg $L^{-1}$ using the kriging method were 35.2 million and 56.7 million respectively. Based on upazila statistics the exposure levels to As exceeding 50 and 10 μg $L^{-1}$ were 28.1 and 46.4 million respectively. School of Environmental Studies, Jadavpur University (SOES, JU), Calcutta and Dhaka Community Hospital (DCH), Dhaka estimated that the populations exposed to above 0.01 and 0.05 mg $L^{-1}$ in 43 districts of Bangladesh were 51 and 25 million, respectively (SOES and DCH, 2000). Population exposed to different levels of arsenic from drinking water is presented in Fig. 6.

The arsenic poisoning which occurred recently in Bangladesh due to drinking of arsenic contaminated groundwater, is chronic in nature. In Bangladesh, chronic arsenic toxicity is observed in arsenic contaminated areas where arsenic problem alone has reduced the national safe water supply coverage by about 15 to 25%. Most of the time, the victims do not complain of the symptom until they are detected through active screening, possibly due to the ignorance of the arsenicosis and its dengareous effect on the health. Initial symptoms aare also difficult to identify the arsenic cases from other clinical conditions. The present experience to identify the arsenic cases are by external manifestations specially with the presentation on the skin called melanosis and keratosis with the history of consuming arsenic contaminated water. Preliminary observation of a subset study on population Arihazar, Bangladesh suggests that uptake of arsenic and duration of ingestion has positive correlation with presence of visible skin lesion of hyperpigmentation and hyperkeratosis (Hussain, 2003). Excess intake of arsenic by concentration and duration also indicate altered microscopic changes like presence of excess leokocytes and red blood cells (Hussain, 1998). In a few cases, eye disease due to arsenic exposure is also happened to a few extent. Chronic exposure to inorganic arsenic has been documented to induce the development of blackfoot disease oedema; clinically the disease starts with numbness or coldness of one or more extremities and intermittent claudication, which progress to black

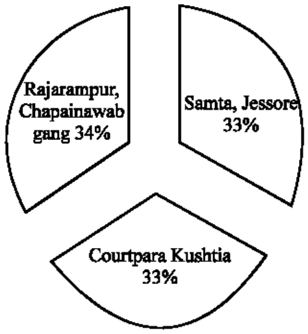


Fig. 7: Pi-diagram of arsenic patients at clinical stage

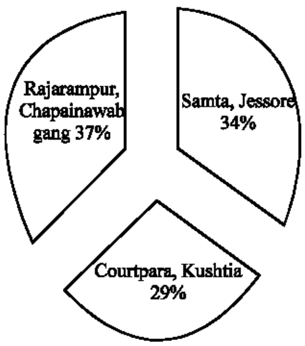


Fig. 8: Pi-diagram of arsenic patients at complication stage

discolouration, ulceration and gangrene (Hussain, 1999). In some cases, odema and blacking of the leg may start together. Thus in Bangladesh, skin menifestation are prime and common that undergoes to pre-clinical, clinical, complication and malignancy stage. In arsenic contaminated areas of Bangladesh majority of the patients are found in the clinical and complication stages. In Samta of Jessore, Courtpara of Kushtia and Rajarampur of Chapainawabgang about 43.33, 44 and 45% of arsenic patients are found in the clinical stages while about 23.33, 20 and 25% are found in complication stages in the case studies as shown in Table 3 and pie diagrams of Fig. 7 and 8.

## MANAGEMENT OF ARSENICOSIS PATIENTS

To date there is no specific treatment for arsenicosis whatever be the acute or sub-acute or chronic.

Withdrawal of further intake of arsenic contaminated water and taking arsenic free water for drinking and cooking purpose improve the cases of arsenicosis. However the following treatment may be advised for arsenic patients.

**Provision of vitamins:** Provision of antioxidant vitamins such as Vitamin A, C and E enhance the recovery of arsenicosis. Vitamin C reduces the toxicity of arsenic while deficiency of vitamin A increases sensitivity to arsenic; however excessive intake of vitamin A may produce chronic toxicity in the body such as appetite loss, dry skin, bone and joint pain, enlarged liver and spleen, abnormal skin pigmentation etc. Vitamin E is relatively non-toxic. Thus Vitmin C and E have widespread use in the clinical management of arsenicosis although there is currently small evidence that the use of Vitamin C and E have therapeutic effect to some extent.

**Nutritious diet and protein:** Proper nutritious diet from more protein and vitamin rich food like beans, peas, pulse, lentils, wheat, suyabeans, green and leafy vegetables may recover the arsenicosis.

**Chelation therapy:** Recently chelation therapy is considered for the treatment of arsenicosis to get the relief of systematic clinical manifestations and for the reduction of arsenic stored in the body. The drugs used for chelating the arsenic in acute toxicity may also be used in the chronic arsenicosis in spite of the unsatisfactory result to some extent. A few chelating agents like d-penicillamine, dimercapto succinic acid DMSA and dimercapto propane sulphonate DMPS may be used for arsenicosis. But the efficacy of such chelating agents in reating chronic arsenicosis is in the verge of the question as well as they have adverse effects to some extent. Also recent clinical trial on chelating agents in treating chronic arsenicosis conducted in West Bengal of India find no significant role of such agents in improving the condition of the arsenicosis patients.

**Indigenous medicine spirulina:** Recent success in the treatment of arsinocosis with indeginous medicine ‘Spirulina’ has demonstrated potential benefit in the

Table 3: Statistics of Menifestation of Arsenicosis in Bangladesh

| | No. of arsenic patients | | | | Arsenic patients (%) | | |
|---|---|---|---|---|---|---|---|
| Area | Clinical stage | Complication stage | Other stage | Total | Clinical stage | Complication stage | Other stage |
| Samta, Jessore | 13 | 7 | 10 | 30 | 43.33 | 23.33 | 33.34 |
| Courtpara, Kushtia | 11 | 5 | 9 | 25 | 44 | 20 | 36 |
| Rajarampur, Chapainawabgang | 9 | 5 | 7 | 20 | 45 | 25 | 30 |

Table 4: Treatment of arsenicosis with d-penicillamine

| Area | Arsenicosis patients before treatment | | Improved cases of arsienicosis after Treatment providing safe drinking water | | Percentage of improvement | |
|---|---|---|---|---|---|---|
| | Pigmentation | Keratosis | Pigmentation | Keratosis | Pigmentation | Keratosis |
| Samta, Jessore | 15 | 10 | 7 | 6 | 46.7 | 60 |
| Courtpara, Kushtia | 10 | 10 | 5 | 5 | 50 | 50 |
| Rajarampur, Chapainawabgang | 10 | 5 | 5 | 3 | 50 | 60 |

Table 5: Effect of providing safe drinking water

| Area | Arsenicosis patients before Providing safe drinking water | | Improved cases of arsienicosis after Providing safe drinking water | | Improvement (%) | |
|---|---|---|---|---|---|---|
| | Pigmentation | Keratosis | Pigmentation | Keratosis | Pigmentation | Keratosis |
| Samta, Jessore | 10 | 10 | 4 | 5 | 40 | 50 |
| Courtpara, Kushtia | 10 | 5 | 4 | 3 | 40 | 60 |
| Rajarampur, Chapainawabgang | 5 | 5 | 2 | 2 | 40 | 40 |

management of arsenic patients. Experience from such observations suggests that at least some stages of arsenicosis (melanosis) are reversible if the consumption of arsenic contaminated water is stopped (Hussain *et al.*, 2001). Result of the therapeutic trial with spirulina along with the cessation of consumption arsenic contaminated water showed significant improvement in diminishing visible skin lesions of arsenicosis patients (Dey, 2003).

**Other symptomatic treatment:** A few sympiotic treatment were applied and observed as pilot studies for the cases of arsenicosis.

- Keratolytic ointment - 20% Urea and 10 to 20% salicylic acid in cream or vaselin are locally applied to treat arsenicosis specially Keratosis of palms and soles. Treatment of associated fungal infection with ointment and medicine improves the arsenicosis cases significantly (Milton, 2003).
- As a pilot study, d-penicillamine was given in a dosage of 250 mg, 3 times a day for 15 days in a group of 15 patients (10 patients sufferings with pigmentation and the rest 5 with keratosis) in Chapainawabgang, 20 patients in Kushtia and 25 patients in Samta, Jessore in addition to providing safe drinking water. The patients were examined after a period of 2-4 years; the condition of patients with pigmentation and with keratosis was improved significantly in the level of about of 48.9 and 56.7% as shown in Table 4.
- To know the effect of providing safe water to the arsenicosis affected people, a cohort of 45 patients of chronic arsenicosis who were drinking arsenic contaminated water of 0.1 to 2 mg $L^{-1}$ for 3 to 10 years, were reexamined after drinking arsenic free water for a period 2-5 years. Parttial improvement of pigmentation and keratosis were observed at a level of about of 40 and 50% as shown in Table 5.

**Treatment of arsenicosis complications under management protocol:** In January 2002, the health session of an international workshop held in Dhaka, Bangladesh concentrated on a case of definition of arsenicosis, protocols for the management of arsenicosis patients and research needs that agreed for diagnosis of arsenicosis. Outline of such management protocol agrees with the following points (Dey, 2003; Milton, 2003).

- As the asymptotic patients won't seek any clinical intervention-it should be detected from the management protocol.
- Scientific proof is necessary to incorporate the anti-oxidants like Beta Carotene and Vitamin C and E in the recommended management protocol.
- The structure of management protocol should not contain any staging recommendation
- Add follow-up and counseling.
- Karotylytic Agents: its role is merely palliative-if given, then 5 to 20% salicylate should be used.
- The management protocol should include a footnote.

## CONCLUSIONS

Arsenic in groundwater has been detected in 61 districts out of 64. As a result, arsenic contamination of groundwater in Bangladesh has severely affected the groundwater-based drinking water supply system. Field study as well as the facts, information and results obtained from the studies carried out by different organizations have established that the water in substantial number of tube-wells of Bangladesh is arsenic contaminated in varying degrees and millions of people of Bangladesh are at risk of arsenic poisoning. The population exposed to high arsenic contents in drinking water exceeding Bangladesh Drinking Water Standards of 0.05 mg $L^{-1}$ and provisional WHO Guideline value of 0.01 mg $L^{-1}$ are about 29 million and 47 million, respectively. More than 7600 arsenicosis patient have so far been identified in Bangladesh The estimated number of excess skin cancer due to arsenic contamination of drinking water in Bangladesh is 3,75,000. Estimates of population exposed to arsenic contamination varying from about 20 million to over 50 million.

Although Bangladesh achieved a remarkable success by providing 97% of the rural population with tube-well water, recently discovered arsenic contamination of shallow aquifers in many parts of the country has made shallow tube-well water unsafe for drinking and the success achieved for years in rural water supply in Bangladesh is on the verge of collapse. The problem of arsenic contamination has been complicated by a large variability at both the local and regional scale. At the moment, only proper planning with alternative option to groundwater or low-cost arsenic removal techniques based on local raw materials can save the millions of arsenic affected people of Bangladesh. In this regard, raising public awareness, participation of the civil society, improving nutrition and fighting undernourishment, proper treatment of arsenicosis in time, taking vitaminous food, nutritious diet and protein and intra-governmental coordination should be taken into consideration to handle the biggest arsenic calamity of the world. Proper management protocol of arsenicosis treatment should be established and modified time to time to handle the uprising new hazard.

## REFERENCES

AAN, 1999. Arsenic Contamination of Groundwater in Bangladesh. Interim Report of the Research at Samta Village. Asia Arsenic Network.

Abernathy, C.O. and E.V. Ohanian, 1993. Health effects of inorganic arsenic in drinking water. Proceeding of Water Quality Control Conference, American Water Works Association, Denver, Colorado, USA.

Acharyya, S.K., S. Lahiri, B.C. Raymahashay and A. Bhowmik, 2000. Arsenic toxicity of groundwater in parts of Bengal basin in India and Bangladesh: The role of quaternary stratigraphy and holocene sea-level fluctuation. Environ. Geol., 39: 1127-1134.

Ahmed, M.F., M.D. Hossain, A.B.M. Badruzzaman, M.A. Jalil and M.A. Ali, 1997. Study on concentration of Arsenic in groundwater of north-eastern zone of Bangladesh. J. Civil Eng. Institute of Engineers, Bangladesh.

Ahmed, K.M., R. Nickson, W.G. Burgess, J.M. Macarthur, M.B. Imam, M. Alam, P. Ravenscroft and M. Rahman, 1998. On the release mechanism of Arsenic in groundwater of Bangladesh. Proceeding of the International Conference on Arsenic Pollution of Groundwater in Bangladesh: Causes, Effects and Remedies, 8-12 February, Dhaka, Bangladesh.

Ahmed, M.F., 2003. Arsenic Contamination of Groundwater in Bangladesh; In Arsenic Contamination: Bangladesh Perspective (Ed.) M. Feroze Ahmed and Published by ITN-Bangladesh.

Arminta, M.A., R. Rodriguez and O. Cruz, 1997. Arsenic content in hair of people exposed to natural Arsenic polluted groundwater at Zimapan, Mexico. Bull. Environ. Contam. Toxicol., 9: 583-589.

Battacharaya, P., D. Chatterjee and G. Jacks, 1997. Occurrence of Arsenic-contaminated groundwater in alluvial aquifers from delta plains, Eastern India: Options for safe drinking water supply. Water Resour. Develop., 13: 79-92.

Berg, M., H.C. Tran, T.C. Nguyen, H.V. Pham, R. Schertenleib and W. Giger, 2001. Arsenic contamination of groundwater and drinking water in Vietnam: A human threat. Environ. Sci. Technol., 35: 2621-2626.

BGS and MML, 1999. Groundwater Studies for Arsemic Contamination, Department of Public Health Engineering, Government of Bangladesh.

Borgono, J.M., P. Vincent, H. Venturino and A. Infante, 1977. Arsenoc in the city of Antofagasta: Epidermiological and clinical study defore and after the installation of of the treatmrnt plant. Environ. Health Perspect., 19: 103-105.

Cebrian, M.E., A. Albores, G. Garcia-Vargas, L.M. Delrazo and P. Ostrosky-Wegman, 1994. Chronic Arsenic Poisoning in Humans: The Case of Mexico In: (Ed., Nriagu, J.O.) Arsenic in the Environment-Part II: Human Health and Ecosys. Effects, pp: 93-107.

Chen, S.I., S.R. Dzeng, M.H. Yang, K.H. Chlu, G.M. Shich and C.M. Wal, 1996. Arsenic species in ground waters of the blackfoot disease areas, Taiwan. J. Environ. Sci. Technol., 28: 877-881.

Chowdhury, T.R., B.K. Manal, G. Samanta, G.K. Basu, P.P. Chowdhury, C.R. Chanda, N.K. Karan, D. Lodh, R.K. Dhar, D. Das, K.C. Saha and D. Chakraborti, 2000. Arsenic in Groundwater in Six Districts of West Bengal, India, the Biggest Arsenic Calamity in World, the Status Report up to August 1995, in Arsenic Exposure and Health Effects IV. (Ed.) Chappell, W.R., C.O. Abernathy, R.L. Calderon and Published by Elsevier Sci., Ltd., pp: 93-111.

Dave, J.M., 1997. Excerpts from Arsenic contamination of drinking water in Bangladesh. WHO Consultation on Arsenic in drinking water and resulting toxicity in India and Bangladesh, WHO New Delhi, 29th April-1st May., pp: 5.

Del Razo, L.M., M.A. Arellano and M.E. Cebrian, 1990. The oxidation state of Arsenic in well water from a chronic Arsenicism area of Northern Mexico. Environ. Pollut., 64: 143-153.

Dey, R.K., 2003. Arsenic Health Problem. In Arsenic Contamination: Bangladesh Perspective (Ed.) M. Feroze Ahmed and Published by ITN-Bangladesh.

DPHE, BGS and MML, 1999. Groundwater Studies for Arsenic Contamination in Bangladesh. Final Report (Phase-1).

DPHE and BGS, 2000. Groundwater Studies for Arsenic Contamination in Bangladesh. Draft Final Report Summary.

Driehaus, W., M. Jekel and U. Hilderbrandt, 1998. Granular ferric hydroxide-a new adsorbent for the removal of Arsenic from natural water. J. Water SRT-AQUA, 47: 30-35.

Fabian, D., Z. Zhou, B. Wehrli and G. Friedl, 2003. Diagenetic cycling of arsenic in the sediments of eutrophic Bladeggersee, Switzerland. Applied Geochem., 18: 1497-1506.

Gorby, M.S., 1994. Arsenic in Human Medicine. In: (Ed. Nriagu J. O.) Arsenic in the Environment-Part II: Human Health and Ecosystem Effects, pp: 1-60.

Guo H.R., H.S. Chiang, H. Hu, S.R. Lipsitz and R.R. Monson, 1997. Arsenic in drinking water and incidence of urinary cancers. Epidemio, 8: 545-550.

Hindmarsh, J.T., O.R. McLetchic, L.P.M. Hefferman, O.A. Hayene, H.A. Ellenberger, R.F. McCurdy and H.J. Thiebaux, 1977. Electromyographic abnormalities in chronic environmental arsenicalism. J. Anal. Toxicol., 1: 270-276.

Hussain, A.Z.M., Iftikhar, 1998. Report of the Emergency Programme for Mitigation of Arsenic Contamination of Groundwater in Bangladesh. A project funded by UNDP, Bangladesh. Ministry of Health and Family Welfare. Government of the People's Republic of Bangladesh, NIPSOM Building (Room No. 324), Mohakhali, Dhaka-1212, Bangladesh.

Hussain, A.Z.M.I., 1999. Effects of arsenic contamination of drinking wateron health and its management. Proceedings of National Conference on Co-ordinated Arsenic Mtigation, Dhaka.

Hussain, A.Z.M.I. and H. Momtaj, 2001. Effect of spirulina on Arsenicosis Patients in Bangladesh. Proceedings of International Conference on Arsenic Contamination of Groundwater, New York, USA.

Hussain, A.Z.M.I., 2003. Arsenic Hazards and Possible Public Health Management. In Arsenic Contamination: Bangladesh Perspective (Ed.) M. Feroze Ahmed and published by ITN- Bangladesh.

Karim, M., 2000. Arsenic in groundwater and health problems in Bangladesh. Water Resou., 34: 304-310.

Khan, A.A., B. Imam, S.H. Akhter, M.A. Hasan and K.M.U. Ahmed, 1998. Subsurface investigation of Arsenic contaminated areas of Rajarampur, Chanlai and Baragharia of Nawabganj district. Research Report of Geohazard Research Group, Department of Geology, University of Dhaka, Dhaka, Bangladesh.

Kinniburg, D.G. and P.L. Smedley, 2001. Arsenic Contamination of Groundwater in Bangladesh Volume 2: Final Report Published by DPHE/DFID/BGS.

Kuo, T.I., 1968. Arsenic content of artesian well water in endemic area of chronic arsenic poisoning. Report, Institute of Pathology, National Taiwan University, 20: 7-13.

Linda, W., 2001. Science News vol.159, No.11, 17 March.

Mandal, B.K., T.R. Chowdhury, G. Samanta, D.P. Mukherjee, C.R. Chanda, K.C. Saha and D. Chakraborti, 1996. Impact of safe water for drinking and cooking on five Arsenic affected families for 2 years in West Bengal, India. Sci. Total Environ., 218: 185-201.

Matisoff, G., C.J. Khourey, J.F. Hall, A.W. Varnes and W.H. Strain, 1982. The nature and source of arsenic in North-eastern Ohio groundwater. Ground Water, 20: 446-456.

McArther, J.M., P. Ravenscroft, S. Safiullah and M. Thirlwall, 2001. Arsenic in groundwater: Testing pollution mechanism for sedimentary aquifers in Bangladesh, Water Resour. Res., 37: 109-117.

McNeill, S.L. and M. Edwards, 1997. Arsenic removal during precipitative softening. J. Environ. Eng. ASCE. May, pp: 453-460.

Milton, A.H., 2003. Health Effects of Arsenic: Toxicity, Clinical Manifestation and Health Managemen. In Arsenic Contamination: Bangladesh Perspective (Ed.) M. Feroze Ahmed and Published by ITN- Bangladesh.

Moran, S., G. Mayurana, H. Rosenberg, P. Casanegra and J. Dubernet, 1977. Occlusions coronariennes liees a une intoxication arsenical chrinique. Arch Mal. Coeurvaiss., 70: 1115-1120.

Nickson, R.T., J.M. McArther, P. Ravenscroft, W.G. Burgess and K.M. Ahmed, 2000. Mechanism of arsenic release to groundwater of Bangladesh and West Bengal. Applied Geochem., 15: 403-413.

Peters, S.C., J.D. Blum, B. Klaue and M.R. Karagus, 1999. Arsenic occurrence in new hamasphire drinking water. Environ. Sci. Technol., 33: 1328-1333.

Pontius, F.W., K.G. Brown and C.J. Chen, 1994. Health implications of arsenic in drinking water. J. AWWA, 86: 52-63.

Quamruzzaman, Q., M. Rahman and K.A. Asad, 2003. Effects of Arsenic on Health. In Arsenic Contamination: Bangladesh Perspective (Ed.) M. Feroze Ahmed and published by ITN-Bangladesh.

Ravenscroft, P., J.M. McArther and B.A. Hoque, 2001. Geochemicals and Palaeohydrological Controls on Pollution of Groundwater by Arsenic. In Arsenic Exposure and Health Effects Iv. (Ed.) Chsappell, W.R., C.O. Abernathy R.L. Calderon and Published by Elsevier Science Ltd, pp: 53-79.

Robertson, F.N., 1989. Arsenic in groundwater in oxidizing conditions. South-West United States. Environ. Geochem. Health, 11: 171-186.

Romero, L., H. Alonso, P. Campano, L. Fanfani, R. Cidu, C. Dadea, T. Keegan, I. Thonton and M. Farago, 2003. Arsenic enrichment in waters and sediments of the Rio Loa (Second Region, Chile). Applied Geochem., 18: 1399-1416.

Rosenberg, H.G., 1973. Systematic arterial disease with myocardial infraction. Circulation, 47: 270-275.

Safiullah, S., A.K. Sarker, A. Zahid, M.Z. Islam and S.Z. Haider, 1998. Geochemical mapping and speciation of Arsenic in the groundwater of Faridpur Municipality. Proceeding of the International Conference on Arsenic Pollution of Groundwater in Bangladesh: Causes, Effects and Remedies, February, Dhaka, Bangladesh., pp: 8-12.

Schoolmeester, W.L. and D.R. White, 1980. Arsenic poisoning. South Med. J., 73: 198-208.

Schreiber, M.E., J.A. Simo and P.G. Freiberg, 2000. Stratigraphic and Geo-chemical controls on naturally occurring arsenic in groundwater, Eastern Wisconsin, USA. Hydrogeol. J., 8: 161-176.

Smedley, P.I., H.B. Nicolli, A.J. Barros and J.O. Tullio, 1998. Origin and mobility of arsenic in groundwater from the Pampean Plain, Argentina. Proceeding of 9th International Conference on Water-Rock Interaction, Tauipo, New Zealand, pp: 275-278.

Smith, J.V.S., J. Jankowski and J. Sammut, 2003. Vertical distribution of As (III) and AS (V) in a coastal sandy aquifer: Factors controlling the concentration and speciation of Arsenic in the stuarts point groundwater system, northern New South Wales, Australian. Applied Geochem., 18: 1479-1496.

SOES and DCH, 2000. Groundwater Arsenic contamination in Banglades. Summary of Survey Reports from August 1995 to February 2000, School of Environmental Studies, Jadabpur University, India and Dhaka Community Hospital, Bangladesh.

Talukder, S.A., A. Chatterjee, J.A. Zheng and W. Kosmus, 1998. Studies of drinking water quality from Chapai Nawabgang, Western Bangladesh. Proceeding of the International Conference on Arsenic Pollution of Groundwater in Bangladesh: Causes, Effects and Remedies, 8-12 February, Dhaka, Bangladesh.

Tanabel, K., Y. Akiyoshi, Y. Yakota and H. HIronaka *et al*., 1998. Arsenic concentration of groundwater of Samta village and the applicability of a field kit by HIronaka to quantify Arsenic. Proceeding of the International Conference on Arsenic Pollution of Groundwater in Bangladesh: Causes, Effects and Remedies, 8-12 February, Dhaka, Bangladesh.

Tondel, M., M. Rahman, A. Magnuson, I.A. Chowdhury, M.H. Faruquee and S.A. Ahmed, 1999. The relationship of arsenic levels in drinking water and the prevalence rate of skin lesions in Bangladesh. Environmental Health Perspectives, Faculty of Health Sciences, Linkopings University, 107: 727-729.

Welch, A.H. and M.S. Lico, 1998. Factors controlling As and U in shallow groundwater of the Southern Carson desert, Neveda, Applied Geochem., 13: 521-539.

Welch, A.H., D.B. Westjohn, D.R. Helsel and R.B. Wanty, 2000. Arsenic in the groundwater of the United States: Occurrence and geochemistry. Ground Water, 38: 589-604.

WHO, 2000. Bulletin of World Health Organizations, Bulletin No. 78.

Wu, M.M., T.L. Kuo, Y.H. Hwang and C.J. Chen, 1989. Dose response relation between arsenic and well water and mortality from cancer. Am. J. Epidermol., 130: 1123-1132.