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

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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 its 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 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; Pontus et al., 1994; Abernathy and Chhanian, 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 vascular 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; Kinniburgh 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 (Battarhanya et al., 1997; Acharya 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.,

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1996; Guo et al., 1997), Thailand (Ahmed, 2003), the USA (Matinoff 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 arsensal 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 in which 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 | Toxicity | Chronic arsenic poisoning |
| Dermatologic | Capillary flush, contact dermatitis, folliculitis; Hair: Delayed loss (diffused or patchy hair loss); Nails: Aldrich-Mees lines (growth of fingernails and toenails) (4 to 6 week post ingestion). | Melanosis, Bowen’s disease, facial edema, actinic keratosis, Hyperkeratosis and warts or coms of palms and soles, papillomatosis, recurrent episodes of pruritic urticaria, cutaneous malignancies, desquamation, hyper pigmentation on the face, neck and back. Encephalopathy showing symptom of persistent headache, diminished recent memory, distractibility, abnormal irritability, restless sleep, loss of libido, increased urinary urgency etc.; peripheral Polyneuropathy; axonal degeneration. |
| Neurologic | Hyperpyrexia, convulsions, tremor, coma, disorientation. | Nausea, vomiting, diarrhea, anorexia, weight loss, hepatomegaly, jaundice, pancreatitis, cirrhosis, mild esophagitis, gastritis or colitis with respect to upper and lower abdominal discomfort, malabsorption, Proteinuria, nephritic disease. |
| Gastrointestinal | Abdominal pain and cramps, dysphagia, vomiting, bloody or rice-water diarrhoea, gurky odor to breathe and stools, mucosal erosion, dry mouth and throat, heartburn. | Bone marrow hypoplasia, normochromic normocytic anemia, leucopenia, impaired folate metabolism, basophilic stripping, keratosis. Anfythiasis, pericarditis,acrocyanosis, cyanosis of fingers and toes, Raynaud’s gangrene (Blackfoot disease), myocardiitis. Carfiosis, portal hypertension without cirrhosis, fatty degeneration, hepatic neoplasia, bleeding from esophageal varices, hepatic blood vessel damage, fibrosis and expansion of the portal zone. Cough, pulmonary fibrosis, lung cancer. |
| Renal | Crotical necrosis, tubular necrosis with partial and complete renal failure, tubular and glomerular damage, oliguria, uremia. | |
| Hematologic | Anemia, thrombocytopenia, granulocytopenia, pancytopenia, hemolysis with anemia, hematuria. Collapse and risk of renal failure. | |
| Cardiovascular | Altered myocardial depolarization (ST-T wave abnormalities, QT, Prolongation), ventricular fibrillation, typical ventricular tachycardia. | |
| Hepatic | Fatty infiltration, cholangitis, cholecystitis, yellow atrophy. | |
| Respiratory | Pulmonary edema, ARDS, bronchial pneumonia, tracheobronchitis, alveolar hemorrhages, mucosal sloughing, pharyngitis, laryngitis, stuffy nose, sore throat, hoarseness etc. | |
and various cancers. Arsenic has been found to cause cancer of the skin, bladder, liver, lung, prostate and possibly of haemopoietic 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 arsenicism differ in manifestation in different countries. The clinical manifestations are categorized into following four stages (Quamruzzaman 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.

**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 Sotma of Jessore, Rajarampur of Rajshahi and Coupura of Kushtia of Bangladesh and subsequently diagnostically and tested to observe the health aspect of arsenic hazard. Field kits were used 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 arsenicism was applied to arsenic patients of Sotma of Jessore, Rajarampur of Rajshahi and Coupura of Kushtia and the improvement was observed subsequently. The arsenicism 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 Chhupi Nawabganj 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; Tabbale 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 Jadavpur 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 tube wells 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 tube wells 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 Porsa 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 Santta village of Sarsha thana of Jessore district (AAN, 1998).

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

<table>
<thead>
<tr>
<th>Type of administrative areas</th>
<th>No. of administrative areas</th>
<th>Bangladesh standard (50 µg L(^{-1}))</th>
<th>WHO guideline value (10 µg L(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Divisions</td>
<td>6</td>
<td>Below 6</td>
<td>Below 6</td>
</tr>
<tr>
<td>Districts</td>
<td>8</td>
<td>Below 53</td>
<td>Below 60</td>
</tr>
<tr>
<td>Upazilas</td>
<td>184</td>
<td>249</td>
<td>39</td>
</tr>
</tbody>
</table>

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
clinical, large population based case-control epidemiological 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, lichenoid melanosis, mucus membrane melanosis, different type of keratosis e.g., diffused keratosis, spotted keratosis, shyper keratosis, gangrene, squamous 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 lungs, neurological effects, hypertension, cardiovascular disease and diabetes
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 arsenicism 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 0.50 mg L\(^{-1}\) of arsenic. According to Tondel et al. (1999), in four villages of Faridpur, Narayangang, Nawabganj 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 arsenicism and its dangerous effect on the health. Initial symptoms are 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 leukocytes and red blood cells (Hussain, 1998). In 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
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, savyabees, 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, dimercapro succinic acid DMSA and dimercapro propane sulphonate DMPS may be used for arsenicosis. But the efficacy of such chelating agents in treating 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 arsenicosis with indigenous medicine ‘Spirulina’ has demonstrated potential benefit in the
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 symptomatic 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 Chapainawabganj, 20 patients in Kushia and 25 patients in Sama, 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. Partial 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.
- Keratolytic 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 vitamins and minerals, and infra-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 uprisings new hazard.

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