

Adverse Health Effects of Arsenic Toxicity

Jhumi Jain¹, Sakshi Bajpai² and Pammi Gauba³

^{1,2}Student at JIIT University, Noida

³JIIT University, Noida

E-mail: ¹jhumi.jj@gmail.com, ²sakshibajpai.5@gmail.com, ³pammi.gauba@jiit.ac.in

Abstract—Arsenic is a ubiquitous heavy metal derived from the natural environment. It is considered as the “king of poisons”, which leads to a global health problem by affecting millions of people all over the world by getting chronically exposed to elevated doses of arsenic from food, water and soil. There are various sources through which arsenic toxicity occurs like, mining, smelting or agricultural resources (pesticides or biofertilizers) and geological sources, by which arsenic gains its entry into the food chain. But, the major cause of arsenic toxicity is considered through the drinking water/underground water leading to adverse health effects. Therefore, leading to various health disorders like dermatological changes; diarrhea, vomiting; cardiovascular diseases; breathing related problems, which further leads to chronic diseases like skin cancer; gastrointestinal effects; hematological effects and lung cancer, respectively. In this 21st century, it is considered as one of the major silent epidemic of environmental metal toxicity, affecting countries like USA, Thailand, Taiwan, Canada, Mexico, India and Bangladesh, the most. There are also various parts of India like Bihar, West Bengal and Jharkhand, which are highly affected by arsenic toxicity and its adverse health effects.

Keywords: Arsenic toxicity, drinking water contamination, health disorders.

1. INTRODUCTION

Arsenic is a ubiquitous heavy metal derived from the natural environment and is considered as the king of the poisons, which has influenced the human population more than any other b arsenic contamination via air, soil, food and the most important, water. Arsenic compounds are mainly widely present in the earth-crust in the forms of oxides or sulphides and are well known for their toxicity leading to various disorders and carcinogenicity. Arsenic toxicity has become a major threat for not only the human population but plants and animals systems. Human are predominantly exposed to arsenic through direct intake, inhalation of contaminated air or by dermal contact. Spoliation of ground water with high concentration of inorganic arsenic has become a global problem and countries like Bangladesh, India, China, Taiwan, Thailand, Chili, Romania are worst affected. In India, several states are acutely affected due to the arsenic contamination of water including Uttar Pradesh, West Bengal, Bihar, Orissa, Jharkhand and Chhattisgarh. Different parts of the world, such as Bangladesh, Chile, Japan, Thailand, Mexico, USA, Chile,

Taiwan and Canada have also reported water contamination with arsenic. In certain parts of India, like Jharkhand, West Bengal, Bihar, the ground water of several districts has arsenic contamination above the present day permissible limit laid down by both World Health Organization and U.S. Environmental Protection Agency [1]. Hence, the present scenario in parts of India is being regarded as the greatest arsenic calamity in the world.

2. ARSENIC IN ENVIRONMENT

Arsenic is naturally present in the environment as a result of geological factors as well as from anthropogenic sources. It is a highly mobilized element and primarily cycled by water in the environment. Intake of arsenic contaminated water, foods, drugs, smoke of cigarette and fossil fuels are the main routes of arsenic exposure to the population. In occupational exposure, workers are exposed to airborne arsenic from the industries involved in smelting and refining of metals, producing and using arsenic-containing chemicals, manufacturing of glass, semiconductors and different pharmaceutical substances [graph 1]. In medicinal exposure to arsenic, certain drugs containing different forms of arsenic are currently being used to treat diseases like syphilis, asthma, cough and itching.

3. ARSENIC CONTAMINATION OF WATER

Ground water is a major source of drinking water, and high concentration of arsenic in ground water is one of the major sources of human exposure to inorganic arsenic and is considered one of the most noteworthy environmental causes of cancer in the world [4]. Thus, since 1963, the World Health Organization has recommended limits for the maximum arsenic concentrations in drinking water. At that time, their recommendation was of 50 µg/L, but with fresh evidence linking low concentration of arsenic to cancer, their recommendation was reduced to 10 µg/L in 1992[1]. Many countries, specifically developing countries, still use the 50 µg/L values as standard because of lack of adequate analytical techniques for quantifying arsenic concentrations in water. Arsenic is reportedly introduced into groundwater through the reductive dissolutions of arsenic-rich Fe (III) oxyhydroxides

or Al-hydroxides were widely accepted to be the main mechanism of direct arsenic mobilization[2].

4. METABOLISM OF ARSENIC

Once arsenic compounds are absorbed, they are processed by the liver's metabolic pathway, and converted into various organic and inorganic compounds including arsenite (As^{3+}), dimethylarsinate (DMA), arsenate (As^{5+}), and monomethylarsonate (MMA)[2]. Inorganic and organic arsenic are absorbed into the blood and circulated to the gastrointestinal tract. Organic arsenic species do not pose health hazard since they are poorly absorbed into cells. Inorganic arsenic species are highly reactive and affect multiple intracellular reactions. Eventually, arsenic metabolites in the body are excreted with urine, which is the crucial excretion pathway for the elimination of arsenic species from the body. Each form of arsenic has different bioactive and physiological characteristics, hence it is necessary to quantify and identify every chemical form of arsenic to analyze their distinctive effects on human health. The toxicity of arsenic is strongly dependent on the chemical form in which it is present in the body. It is generally recognized that inorganic arsenic is more toxic than organic arsenic.

5. HUMAN EXPOSURE TO ARSENIC

The International Agency for Research on Cancer (IARC) has classified arsenic and its compounds in Group 1, which is associated with cancer in humans. Arsenic has also been classified as Group A (human carcinogen) by the US EPA. Inorganic arsenic, especially the trivalent methylated species, is more toxic to human health than the organic form[3].

Chronic ingestion of inorganic arsenic is responsible for multisystem health damage. High dose of arsenic in drinking water causes characteristic skin manifestation, neurological effects, vascular disease, cardiovascular disease, renal disease, cardiovascular disease, chronic lung disease, cerebrovascular disease, reproductive effects and cancers of kidney, skin, liver, lungs and bladder.

5.1. Toxicity

Arsenic toxicity, being a global health problem, affects various cell enzymes, which are involved in cellular energy pathways and DNA replication and repair. Arsenic can penetrate into the body through the skin or the lungs but arsenic mainly enters through drinking water or food that has been ingested [3]. Most Arsenic compounds are soluble in water to some extent; this water solubility also helps to remove some of the arsenic via the urine and the excrement. Unfortunately, a certain portion of the ingested Arsenic is absorbed by various tissues in the body and is retained for an extended period.

5.2 Exposure and Related Symptoms

Arsenic in little amounts is required for the body, but, larger doses are considered to be fatal. According to various studies that enters into the body is excreted rapidly but a fraction of it accumulates in various organs, including even the hair, nails and other organs[see table 1]. The fraction of Arsenic that is present in the body, thus leading to various physiological damages, depending on the mode of entering the body. Depending on the quantity consumed, there are various symptoms like one may start having problems with his urinary track and stomach, and thus, leading to problems like severe pain in the abdomen, mainly in the bowel area leading loose bowel movement and intestinal disorders in urination associated with pain as well as nausea and vomiting. It is also seen that bad odor from the stomach comes along with green or yellow vomit, also sometimes with blood, occurs as the Arsenic exposure increases. Epidemiological studies indicate that in various parts of India like Bihar, Jharkhand and West Bengal more than 300,000 people show symptoms of arsenic toxicity. An extreme relationship between arsenic level in water with the widespread presence of hyper pigmentation and keratosis in the exposed individuals has been reported earlier [3]. Prolonged exposure to arsenic-contaminated water causes various kinds of adverse health effects, including conjunctivitis in the eyes, skin pigmentations, keratosis, vascular diseases, neuropathy, lung diseases and skin cancer and different internal organs.

5.3 Dermatological Changes

Various skin changes occur with long term exposure. It is seen that dermatological changes are among the various common features and the initial clinical diagnosis is often based on these changes like, solar keratosis, hyper pigmentation and palmar. The keratosis occurrence is considered as discrete nodules or as uniform thickening. It is emphasized that both palmar *and* solar keratosis are a significant diagnostic criterion. Hyperpigmentation occurs as diffuse dark brown spots, or less discrete diffuse darkening of the skin, and known for its characteristic "rain drop" appearance. The latent period after exposure is considered as long as 60 years and has been reported in patients treated with Fowler's solution, in different types of workers like , sheep dip workers, in vineyard workers using pesticides related arsenic compounds, and from drinking contaminated wine. Also, another manifestation occurs due to the arsenic deposition in keratin rich areas which are prominent transverse white lines in the fingernails and toenails, called Mee's lines [5].

Epidemiological studies indicate that in various parts of India like Bihar, Jharkhand and West Bengal more than 300,000 people show symptoms of arsenic toxicity.

5.4. Effects on Gastrointestinal System

Though diarrhea is a major and early onset symptom in arsenic poisoning, it occurs in recurrent bouts and can be

associated with vomiting. Suspicion of arsenic ingestion should be aroused if other manifestations such as skin changes, a neuropathy burning lips, painful swallowing, thirst, nausea and several abdominal colic are present.

In a study comprising 248 patients with evidence of chronic arsenic toxicity from West Bengal, India who consumed arsenic contaminated drinking water for one to 12 years, hepatomegaly occurred in 76.6%, and of the 69 who were biopsied, among them 63 showed non-cirrhotic portal fibrosis [5].

In another study, arsenic was considered the aetiological agent in five patients with incomplete septal cirrhosis, an inactive form of macronodular cirrhosis, characterised by small, incomplete septa that demarcate insignificant nodules, and an unusually high incidence of variceal bleeding.

5.5. Effects on Cardiovascular System

Increased risk of cardiovascular disease is reported in smelter workers due to arsenic exposure, it is seen that arsenic might affect thrombocytes, [6] which play an important role in cardiovascular diseases. Exposure to trivalent arsenite, in the presence of thrombin, increases the agglutination of thrombocytes.

5.6. Lung Disorders

Various reports suggest there is a significant increase in lung cancer-related deaths with arsenic intake. Also, numerous studies have concluded that the dose-dependent relationship between arsenic ingestion and lung cancer incidence, thus, making lung cancer the most well-known cancer related with arsenic exposure.

Epidemiological studies have shown that the incidence of lung cancer is consistently prominent in groups exposed to arsenic than it is among the general population or a control group. Also another study concluded in Bihar which showed about the eminent mortality rate and standardized mortality ratio of lung cancer, which was observed among patients who consumed high-arsenic concentrated drinking water for the past 50 years.

5.7 Hematological Effects

The hematopoietic system is the most affected system by arsenic toxicity. It is seen that the anemia and leucopenia are common effects of arsenic toxicity. These effects are considered due to a direct hemolytic or cytotoxic effect on the blood cells and a suppression of erythropoies. Also, the malnutrition is a major cause of anaemia is developing countries like India and Bangladesh. In a recent study, it is seen that a high concentration of arsine (>5 ppm) causes death within hours due to red blood cell haemolysis and low levels of arsenic (0.5-5.0 ppm)[7] bring about the following effects in some days, and an average concentration of 0.5 mg/l (0.2mg/m³) is considered acceptable in the work place.

5.8. Epigenetic changes

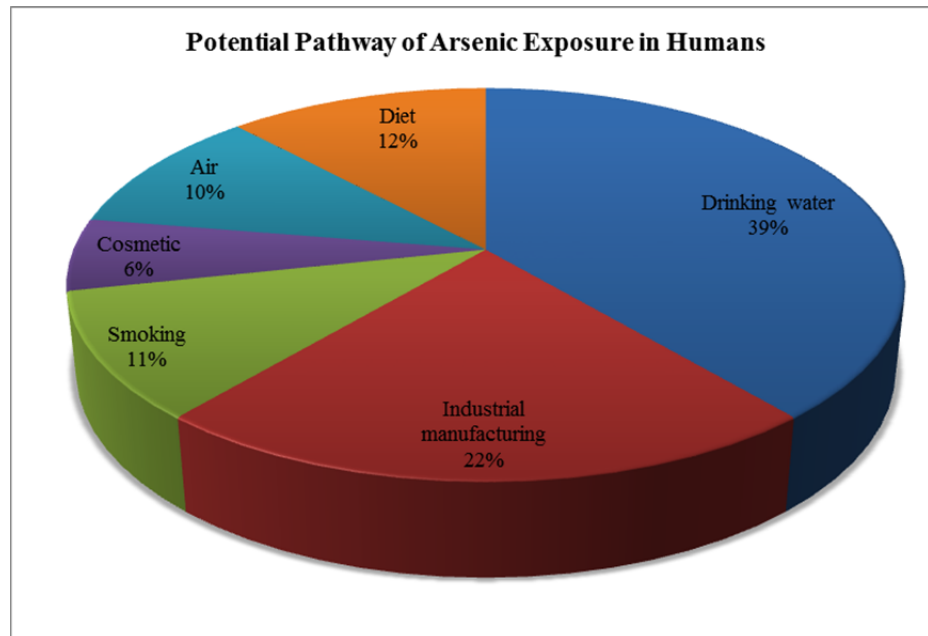
Various mutations associated with genes, DNA and biochemical pathways. It involves mutations which includes the induction of DNA damage and a variety of genetic alterations. Some of these changes may lead to genetic damage, which is transmissible to subsequent generations, and/or some may cause cancer or other problems in the exposed generation [2].

Arsenic has also been known to cause chromosomal damage. The chromosomal damage leads to genetic damage by inhibiting DNA repair. Also, arsenical compounds are known to inhibit a number of important enzymes in both animals and humans. For example, Phenylarsine oxide (PAO), an inhibitor which blocks glucose transport activity by inhibiting insulin activation of glucose uptake. Thus, it induces fluctuation in blood glucose levels in the body, causing diabetes. [See table 2]

6. CONCLUSION

Arsenic toxicity has had a major impact on lives across the world. Studies are being conducted to evaluate and find solutions to the problem of high arsenic levels in soil, air and water. Various Government organizations are working in the direction of improving quality of water by constantly monitoring quality of drinking water supply; reforming water supply and sanitation sector; and ensuring participation of communities in schemes involving drinking water supply and sanitation.

Given its toxicity, arsenic exposure is an important issue in public health, and more research is warranted. To determine the level of arsenic exposure and its associated health effects in the arsenic prone areas, biological monitoring data that can objectively assess human exposure. However, data on the total arsenic exposure level and that by arsenic compounds are lacking in the population; therefore, further research of this kind is needed to support productive public health management.



Graph 1: Various sources for the exposure of high levels of arsenic toxicity. [6]

Table 1 : Occupational exposures of arsenic in various parts of human body. [1,2, 3,]

| Occupation | Accumulation in body (mg/l) | Disease |
|-----------------------------------|---------------------------------------|---|
| Smokers | Blood (0.5), Urine (0.4), Hair(0.5) | Leucopenia, lung cancer |
| Non smokers | Blood (0.1), Hair (0.2), Urine(0.1) | Gastrointestinal disorders |
| Industrial workers | Blood (0.3), Urine (0.4), Hair (0.2) | Skin cancer and respiratory disorder |
| Farmers | Nail(0.3), Urine (0.2) | Skin lesions, lung cancer |
| Population consuming ground water | Hair (0.3), Nail (0.4), Urine (0.1) | Gastrointestinal disorder, epigenetic changes |

Table 2 : Impact of Arsenic toxicity in different Indian states [3,5,7,8]

| State | Source | Accumulation (mg/l) | Disease | Reference |
|---------------|-------------------------------------|----------------------------|--|---|
| Bihar | Ground water, mining, smoking | >0.01 | Hyperkeratosis leading to skin cancer, Cardiovascular disease. | Arsenic contaminated aquifer, A.K.Ghosh, |
| Orissa | Drinking water, mining, sea food. | >0.08 | Anaemia and leucopenia | A review of arsenic poisoning and its effects on human health, J.C.Saha |
| West Bengal | Ground water, Sea food, agriculture | >0.05 | Lung and Bladder cancer | Arsenic contaminated aquifer, A.K.Ghosh, |
| Jharkhand | Ground water, smoking, pesticide | >0.64 | Gastrointestinal diseases, Lung cancer | Acute and chronic arsenic toxicity, R.N Ratnaik. |
| Chhattisgarh | Underground and drinking water | >0.055 | Skin lesions, hyper pigmentation, leucopenia | Effect of arsenic contamination in water, A.Kumar |
| Uttar Pradesh | Ground water, smoking, pesticide | >0.1 | Lung cancer, cardiovascular disease | Effect of arsenic contamination in water, A.Kumar |

REFERENCES

- [1] Allan H Smith, "*Cancer risks from arsenic in drinking water*"; Arsenic exposure and health effects, Elsevier science 1999
- [2] Pritha Ghosh, "*Cytogenetic damage and genetic variance in individual susceptible to arsenic induced cancer*"; Int J Cancer 118, Willey-Liss 2005.
- [3] Jayesh Saha, "*A review of arsenic poisoning and its effects on human health*", IIT-Kharagpur.
- [4] Ashish Kumar, "*Effects of arsenic contamination in portable water and its removal technique*", International journal of water and wastewater treatment, June 2015.
- [5] David J Thomas, "*Health effects and risk assessment of arsenic*", Research triangle park, NC 27711.
- [6] Young Saeoung Hong, "*Health effects of chronic arsenic exposure*", Journal of preventive medicine and public health, jpmph. 14.035.
- [7] Rakesh N Ratnaik, "*Acute and chronic arsenic toxicity*", published by group.barj.com, August 8, 2016.
- [8] Nupur Bose, "*Arsenic contaminated aquifers: Study of Ganga level zone in India*", Royal Geographical Society, London, August, 2007.