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Arsenic in Food Web: An Alert for Public Health

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ABSTRACT: Arsenic in groundwater and its contamination in food stuff are found severely in India. Groundwater resources are quite rich in both bank of river Ganges and a major part of the groundwater is arsenic contaminated and used for drinking, agricultural and industrial purposes. The concentration of arsenic (As) in groundwater exceeds the guideline concentration set internationally and nationally at 10 µg L^{-1}. Contaminated ground water is also used for irrigation and this makes it possible for arsenic to enter the human food chain through locally grown food, fodder, forage crops and vegetables. Some cases of arsenic also found in the poultry bird, cow, milk, fish and shellfish; ultimately As comes in food web and causes many health disorder. Rice and root vegetables absorb more amount of Arsenic and they act as a major source of exposure. Agricultural produces transport arsenic affected areas to non affected area resulting arsenic exposure in surroundings. This reviewed article discusses the exposure of arsenic in soil, water, field crops, foods, humans and its possible remediation measures.

Keywords: Arsenic exposure, agricultural crops, foodstuffs, health effect.

INTRODUCTION

Arsenic contamination in foodstuffs is common phenomena in arsenic prone areas. Adverse effect of arsenic in humans as well as animals is severe in arsenic affected area and its indirect adverse effects in non affected area of arsenic. The major sources of As exposure to human beings include water and food items; especially rice (Upadhay *et al.,* 2020). In arsenic affected areas summer rice cultivation is common and its cultivation is large e.g. West Bengal, Assam, Bihar, Jharkhand, Uttar Pradesh, Punjab and Haryana. Besides rice, all kinds of vegetables more contaminated with arsenic. Hence, rice and vegetables are more exposure to arsenic than other agricultural crops. Leading production of rice and vegetables this state, locally grown agricultural food export to non arsenic affected state. Peoples of non arsenic affected areas indirectly consume arsenic contaminated foods more or less. More than a dozen districts of West Bengal including 111 blocks with 10 million people from approximately 3500 villages have been identified where groundwater contains arsenic above 50 µg L^{-1} (Rahaman *et al*., 2007). The concentration of arsenic (As) in groundwater exceeds the guideline concentration set internationally and nationally at 10 µg L^{-1} (WHO, 2013). Long term exposure of arsenic through water and foods with high concentration results in adverse effect in human body. Arsenic toxicity is commonly termed arsenicosis. It also causes "arsenolysis" wherein As anions can substitute for phosphate in many reactions inside the cell resulting in the features of thiamine deficiency. Symptoms of arsenicosis are primarily manifested in the form of different types of skin disorders, cardiovascular diseases, diabetes, melanosis and cancer (Shikawat *et al*., 2019)**.** Various agronomic management strategies i.e. deficit irrigation, alternate wetting and drying, sprinkler irrigation, use of pond water, nutrient management (Phosphorus, nitrogen, iron, and selenium), biological approaches (algal, fungal and bacterial) has been taken up to reduce arsenic load in food chain (Li *et al*., 2019; Chauhan *et al*., 2017; Yu *et al*., 2017; Awasthi *et al*., 2018; Srivastava *et al*., 2019). Rain water harvesting, use of surface water, less cultivation of boro rice, application of soil amendments, and maintenance of field capacity, growing marigold and arum plant reduce chance of As transfer in food chain. Such groundwater is also used for irrigation and this makes it possible for As to enter the human food chain through locally grown food crops and vegetables (Meharg *et al.,* 2003; Das *et al.,* 2004). Arsenic load in food items is coming through different concentration; it depends upon the food grains, fruits, vegetables, milk, meat and its byproducts. This article discusses the aspects of agricultural crops, human exposure, and its possible remediation measures in foodstuffs.

A. Arsenic in Food Sources and its Transportation

The World Health Organization's Guidelines for drinking-water quality (WHO, 2005), set a provisional level for As in drinking water of 10 µg L^{-1}. Arsenic is found in many types of food. High concentrations of As also occur in rice, mushrooms, poultry, root crops such as arum, carrots, onions and potatoes are most vulnerable. As poisoning from food and beverages, wine, beer and cider causing fatalities among consumers have been reported from France, England, Japan and US in the early twentieth century. Total arsenic in food composites collected from Murshidabad District, West Bengal; the results revealed that potato skin; leaf of vegetables, arum leaf, papaya, rice, wheat, cumin, turmeric powder, cereals and bakery goods, vegetables, and spices contained the highest mean arsenic (Roychowdhury *et al.*, 2002) (Fig. 1).

Several experiment revealed that in each food items having As concentrations in which correlation with irrigation water (Alam *et al.*, 2003). Rice, the staple food in Bangladesh and West Bengal, is an important dietary source of arsenic (Bae *et al.*, 2002; Sengupta *et al.*, 2006). The actual amount of As in cooked rice could be either increased or decreased depending on the water. There have been some reports on As in paddy rice related to dietary exposure (Williams *et al*., 2005) and As content in cooked rice (Ackerman *et al.*, 2005). There was a positive relationship between As levels in rice and groundwater. Cooked rice had approximately twice the levels of As in raw rice probably due to parboiling rice in As contaminated water (Duxbury *et al*., 2003).

This emphasizes the need to further monitor the food web and develop appropriate management options since continued use of As contaminated irrigation water is likely to increase the probability and magnitude of dietary arsenic intake. In potato tuber, stem and leaf also having significant amount of arsenic which are cultivated in the soils having As level of 1.50 mg kg^{-1} As level. In rice growing soils under submerged condition (Adak *et al.*, 2002) As content in soil was 2.37 mg kg^{-1}) and low levels of As (3.84–6.15 mg kg^{-1}) decreased the microbial biomass and their activities (Bhattacharyya *et al*., 2003).

Agricultural product transports from arsenic affected areas to non affected area resulting arsenic exposure in surroundings areas and it may export in other districts, states and foreign countries. Import and export system facilitates to more prone to arsenic exposure. While it is generally agreed that rice is the predominant source of inorganic As from food sources, vegetables grown with As contaminated groundwater could significantly increase As exposure in As-affected than non affected areas.

B. Arsenic Contamination in Rice

Rice is the predominant source of As from food sources. Rice grown with arsenic contaminated water the increase the As exposure in arsenic prone areas. Rice absorb the As and create a pathway of As enter into the food chain. To study As level in the whole rice plant it has been found that in the root of rice plant (98-100 ppm) highest amount of arsenic present, stem (6.55-7.06 ppm), husk (0.5- 0.6 ppm) and grain (0.3-0.7 ppm) also show the presence of arsenic (Ghosh *et al.*, 2004; Liu *et al*., 2007). Higher concentration of arsenic in root, stem and leaf of rice plants also reported irrigation with high arsenic content. Both As (III) and MMA are phytotoxic to rice plants grown on nutrient solutions and the degree of arsenic uptake by rice followed as As (III)>MMA>As(V)>DMA (Basu *et al.*, 2014). A number of studies have shown that there was reduced growth of plants when grown in soil containing high arsenic or when irrigated with water containing high concentration of arsenic (Norra *et al.*, 2005). Rice was the main contributor of arsenic compared to other food composites in the arsenic-affected areas (Andrew *et al.*, 2003). As concentration in whole rice plant ranges from 100-110 ppm and in vegetable ranges from 448.5 - 1143.4 µg kg^{-1} (Farid *et al.*, 2003). In As affected areas, As exposure from food i.e. cooked rice, vegetables could be comparable to that from contaminated drinking water (Fig. 1).

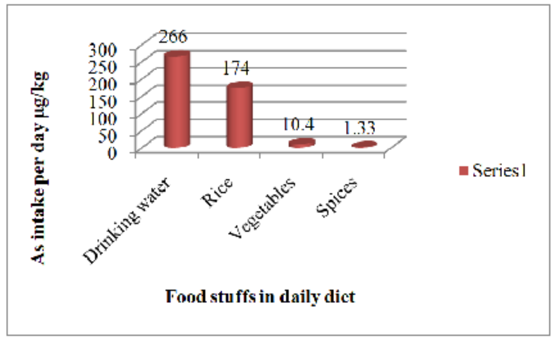

Fig. 1. Average daily dietary intake of As in affected area.

C. Arsenic Contamination in Vegetables and Fodder Crops

Arsenic existence in raw vegetables is much more than food grains also behave as a source of As. The vegetables can be classified in to three categories such as root and tuber vegetable, leafy vegetable and non leafy and fruiting vegetable. Among the three categories of vegetable root vegetable comprises highest amount of arsenic (Table 1, 2 and Fig. 2).

Table 1: Arsenic concentration in leafy vegetable and fodder crops.

Food stuff	Arsenic content in (µg/kg)
Amaranth leaf	458.2
Arum leaf	1134.3
Halancha leaf	674.3
Jute leaf	632.3
Kalmi leaf	111.5
Potato leaf	705.0
Pumpkin leaf	784.6
Indian spinach	771.2
Berseem	635.4
Cowpea	597.5
Lucerne	658.4
Oats	756.5
Straw	496.4
Husk	178.8
Mustard oil cake	319.3

Table 2: Arsenic concentration in root and tuber vegetable.

Food stuff	Arsenic content in (µg/kg)
Arum lati	**1143.4**
Arum root	**1130.9**
Raddish	932.6
Potato	448.5

Leafy vegetable is a very important food source for human being when it content As then it transfer to human through consumption green as well as cooked (Roychowdhury *et al.*, 2002). Important aspects of fodder crops (Berseem, lucerne, cowpea and oats) which are grown in arsenic affected areas and fed by milch animal and milk and milk product is being transported to new areas where arsenic not reported earlier but peoples are also taking high concentration of arsenic (Table 1). Some important and major fodder crops and food stuff having arsenic load which is fed by animals (Hedayetullah *et al.,* 2011).

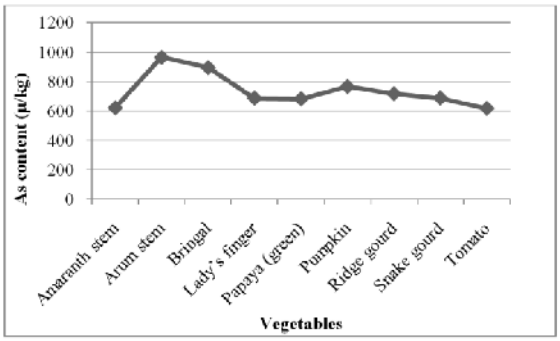

Fig. 2. Arsenic concentration in non leafy and fruiting vegetable.

D. Health Effect on Human

Health effect of arsenic depends on the numbers of factors i.e. age, gender, nutrition and long term exposure (Jovanovic and Rasic-Milutinovic, 2017). Arsenic toxicity is commonly termed arsenicosis. It also causes "arsenolysis" wherein As anions can substitute for phosphate in many reactions inside the cell resulting in the features of thiamine deficiency. Symptoms of arsenicosis are primarily manifested in the form of different types of skin disorders such as skin lesions, hyperkeratosis and melanosis (Shikawat *et al.,* 2019). Exposure of low levels of arsenic can cause nausea and vomiting, decreased production of red and white blood cells, abnormal heart rhythm and damage to blood vessels and sensation (Hasim *et al.,* 2013). Exposure of low levels of inorganic arsenic for a long time can cause darkening of the skin. Wide exposure of arsenic drinking water has different health hazards i.e. skin, liver, lungs, heart, peripheral vascular system, bone marrow, nervous system. Long term taking of arsenic through drinking water can also cause of cancers in the human body. Arsenic in drinking water may cause of pulmonary effects, and also found mortality in young adults from both malignant and nonmalignant lung disease. WHO (2011) proposed Benchmark Dose Lower Limit (BMDL) value is 0.5 and also suggested a 0.5% increased incidence of different human organ cancer for As. The BMDL0.5 values for lung cancer, bladder cancer and skin lesion were set as 3µg day^{-1} kg^{-1} body weight, 5.2µg day^{-1} kg^{-1} body weight and 5.4 µg day^{-1} kg^{-1} body weight respectively (WHO, 2011; JFCFA, 2011).

E. Arsenic Remediation

There are several methods available for removal of As from contaminated water, both at the community and household level. Coagulation, adsorption, ion exchange and membrane filtration techniques are employed for the purification of arsenic contaminated water. However, phytoremediation has the potential to become an environmentally friendly and low-cost alternative remediation technique. It is well documented that some tropical and sub-tropical plant species can tolerate and uptake various inorganic and organic forms of arsenic (Hedayetullah *et al.*, 2011).

Arsenic load in food web can minimize through farming practice. These farming practice are dug well, rain water harvesting, deep tube well. Cultivate the crop through harvested rain water, growing boro rice in deficit irrigation (Basu *et al.,* 2014), changing the cropping pattern such as growing maize under deficit water, as an alternative crop in case of boro rice; mitigate arsenic status in soil through organic amendments, proper water management practice also reduces the absorption of As by plant parts. Arsenic is a public issue. So, Govt. also set up the mitigation strategy for arsenic. Develop National and State level As policy, build As free water source plant in arsenic prone area, increase the scope of research and provide proper medical facility for As affected people.

CONCLUSION

The studies discussed in the review point to expand the problem of As in food, fodder, vegetables and its transportation from production areas to non-production areas or import zones. However, it must be observed that most of the available studies were conducted only for arsenic soil, water and foods. The present study emphasizes the distribution of As contaminated foods which is affects human health. Adoption of agronomic management in situ for crop production is to mitigate the arsenic load in food chain. Current focus of "National As Policy" and "Implementation Plan on providing safe foods and drinking water should be more emphasize. There have an ample scope of future research of arsenic in food web and its adverse effect in human health.

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