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Arsenic, A Threat to People Consuming Food-Crops Cultivated in Contaminated Soil and Its Phytoremediation

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Introduction:

Arsenic (As) is a redox-active, toxic metalloid, ubiquitous in soil and ground water contaminating every form of life including plants, animals and human beings. In agriculture, most of the crops are heavily depended on ground water for its irrigation and this ground water is very much prone to arsenic contamination in present days due to rapid industrialization and globalisation. Arsenic is predominantly found in two forms *i.e.* arsenate (As V) and arsenite (As III). Arsenate is structurally similar to phosphate which is a major nutrient needed for various bio-chemical reactions such as oxidative phosphorylation and ATP synthesis. Therefore, plants mistakenly absorb arsenic in place of phosphate and hampering its biological processes. Arsenite tends to bind sulfhydryl group and consequently interfering protein synthesis. Human are suffering with different skin problems, cancer and other health issues due to arsenic contamination in water bodies, soil and food chain system across the different parts of world. Being so toxic in nature, International Agency of Research on Cancer (IARC) has put it in class I category of carcinogen (Cohen *et al.*, 2019) and also ranked as first among the most hazardous substance list (ATSDR, 2019). Different parts of India and Bangladesh are facing its excess limit of 2000 µg/L in groundwater and its continuously increasing. Arsenic finds its way to grain and straw in rice and wheat, vegetables and fruits. Numerous studies have been done to acquire knowledge regarding arsenic speciation, transportation from soil to root, root to shoot and shoot to grain and above all the mechanisms and ways of arsenic tolerance. Reduction of arsenic transport to grain is the basis of minimizing arsenic toxicity.

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Different sources of Arsenic and its distribution:

The most common form of arsenic detected in contaminated water is the one that is naturally prevalent in aquifers around the world is the natural world. Several studies have been conducted over the last few decades to track elements that influence arsenic mobilisation ending up groundwater contamination. One of the well accepted concepts is that As is released when Fe Oxides are reductively dissolved, which is a common phenomenon in sedimentary environments (Eiche *et al.*, 2008).

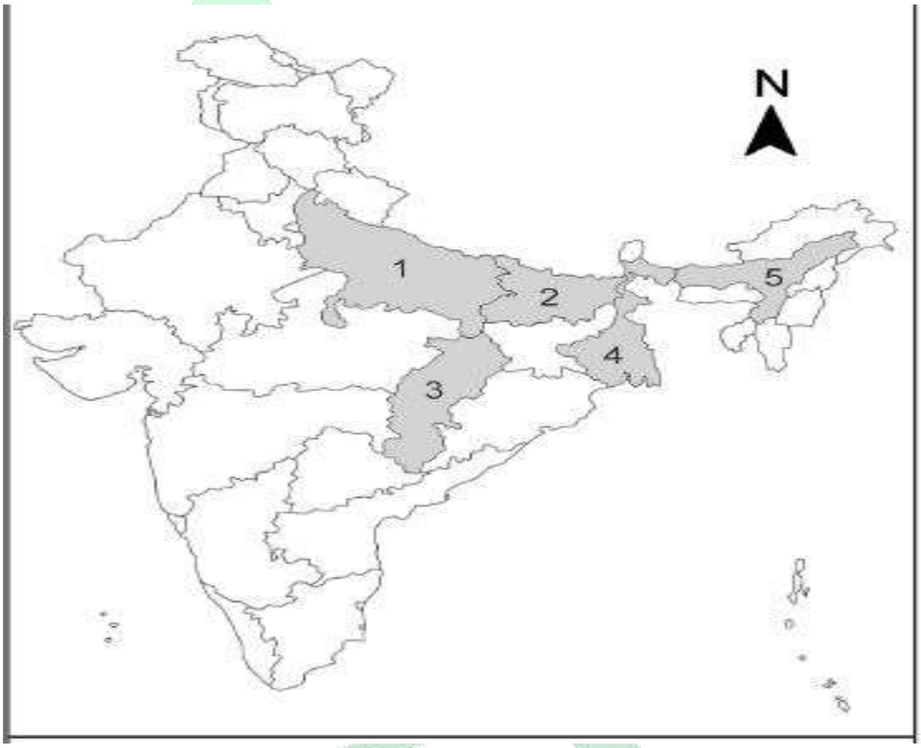

Figure 1. Different states of India exposed to arsenic contamination in ground water 1. Uttar Pradesh 2. Bihar 3. Chattisgarh4.West Bengal 5. Assam (Shrivastava *et al.*, 2015)

Arsenic enters into food chain through dissolution into water from as enriched minerals through natural factors and anthropogenic factors such as application of insecticide, herbicide, phosphate fertilisers, mining, smelting, coal combustion, timber preservation. According to WHO, the safe permissible limit of as in drinking water is 10 µg/L of whereas, the value is 50 µg/L in absence of alternate source. However, the concentration of arsenic in groundwater is found to be 50–3200 µg/L across the delta region of India (West Bengal, Bihar, Uttar Pradesh, Chattisgarh, Assam). That means a portion of people are facing health hazards due to consumption of As-contaminated drinking water or food-crops grown in As-contaminated soil.

In the case of soil and sediments, areas of numerous Indian states have been designated as As polluted. Arsenic mobilisation in the Bengal Basin can occur through the oxidation of arsenic-containing pyrite, the displacement of anions of as present in aquifer sedimentary minerals by phosphate anions used in fertilisers applied to the soil surface, and the discharge of arsenic in anoxic conditions through the reduction of iron oxy hydroxide during sediment burial.

Variation of arsenic accumulation among different crops and its phytoremediation:

Arsenic accumulation in edible parts of plants depends on arsenic concentration in soil and its translocation ability of plant followed by sequestration into vacuole. Several As-transporter proteins and xylems are involved in arsenic translocation to aerial part of plant. Xylem prefers arsenate accumulation more than arsenite in plants (Pickering *et al*., 2000). Several studies have reported the accumulation rate of as in different crops (Table 1) reported in different countries. Cultivation of arsenic hyper accumulator plants could be a cost effective and eco-friendly bioremediation process. The Chinese brake fern (*Pteris vittata*) was discovered to be a hyper accumulator of arsenic (Ma *et al*., 2001). *Pteris vitella*, accumulating up to 20 mg As/dry weight, reduces As accumulation in rice field significantly. However, keeping rice field for phytoremediation can be a challenging and unacceptable task for farmers. Milled and polished rice is reported to be arsenic free. But in the era of nutritious whole grain diet, it is not advisable to consume polished grain.

Several vegetables such as tomato, potato, radish, cauliflower, cabbage, garlic, spinach, lettuce etc. absorb arsenic to some extent. Naturally, the food chain is getting contaminated by arsenic heavily. Another potential phytoremediation technique is to cultivate vetiver grass (*Chrysopogon zizanioides*) in arsenic contaminated soil. However, vetiver can tolerate arsenic to a level of 225 mg/Kg of soil.

Table 1. Accumulation of arsenic in crops and other plants

Crops	Total arsenic (mg/Kg dry weight)	Place	References
Rice	0.08-2.05	Bangladesh, China, Taiwan, United States, Vietnam, West	Islam *et al*., 2004

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		Bengal, India, Europe	
Wheat	0.74	West Bengal, India	Norra *et al.*,2005
Potato, sweet potato, carrot, radish, onion, garlic, cauliflower, broccoli, tomato, celery cucumber, spinach, lettuce, cabbage, ginger	0.029-0.217	China	Zhao *et al.*, 2008
Snake gourd, green papaya, elephant foot	0.33-0.48	Bangladesh	Alam *et al.*, 2003
Wheat flour, turmeric powder, bean	0.08-0.33	West Bengal, India	Roy Chowdhury *et al.*, 2002

Techniques to minimise arsenic exposure:

Long-term measures from mining, metal smelting and refining, burning of low-grade coal, pesticide use, and forest treatment are needed to control the impacts of arsenic. Action is needed to reduce the intake of arsenic from food and drink. This may include providing safe drinking water, routine monitoring of the level of arsenic in groundwater, raising awareness among dependents, designing and developing arsenic removal technologies, and differentiating between high and low-arsenic water sources by painting hand pumps in different colours (e.g., red and green). Additionally, keep an eye out for early indications of arsenic poisoning, such as skin problems and other impacts, in high-risk populations.

Conclusion:

Arsenic is becoming a serious threat to human being as it is contaminating ground water table heavily day by day. Therefore, people consuming groundwater or cultivating different arsenic accumulating crops using contaminated water are exposed to arsenic hazards. Farming of Chinese bake fern in As-contaminated rice field and vetiver in other crop field could be the answer for the people. Awareness program by different NGOs, technical personnel, researchers about the potential threat of As and how to minimize the as exposure are going to be a big deal for mitigating the problem.

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References:

Alam, M., Alam, M.M., Curray, J.R., Chowdhury, M.L.R. and Gani, M.R. (2003) An Overview of the Sedimentary Geology of the Bengal Basin in Relation to the Regional Tectonic Framework and Basin-Fill History. Sedimentary Geology, 155, 179-208.

Cohen, S. M., Boobis, A. R., Dellarco, V. L., Doe, J. E., Fenner-Crisp, P. A., Moretto, A., ... and Wolf, D. C. (2019). Chemical carcinogenicity revisited 3: Risk assessment of carcinogenic potential based on the current state of knowledge of carcinogenesis in humans. Regulatory Toxicology and Pharmacology, *103*, 100-105.

Eiche, E., Neumann, T., Berg, M., Weinman, B., van Geen, A., Norra, S. and Stüben, D. (2008). Geochemical processes underlying a sharp contrast in groundwater arsenic concentrations in a village on the Red River delta, Vietnam. Applied Geochemistry, *23*(11), 3143-3154.

Islam, F. S., Gault, A. G., Boothman, C., Polya, D. A., Charnock, J. M., Chatterjee, D., and Lloyd, J. R. (2004). Role of metal-reducing bacteria in arsenic release from Bengal delta sediments. Nature, *430*(6995), 68-71.

Ma, L. Q., Komar, K. M., Tu, C., Zhang, W., Cai, Y., and Kennelley, E. D. (2001). A fern that hyperaccumulates arsenic. Nature, *409*(6820), 579-579.

Norra, S., Berner, Z. A., Agarwala, P., Wagner, F., Chandrasekharam, D. and Stüben, D. (2005). Impact of irrigation with As rich groundwater on soil and crops: a geochemical case study in West Bengal Delta Plain, India. Applied geochemistry, *20*(10), 1890-1906.

Pickering, I. J., Prince, R. C., George, M. J., Smith, R. D., George, G. N. and Salt, D. E. (2000). Reduction and coordination of arsenic in Indian mustard. Plant physiology, *122*(4), 1171-1178.

Roychowdhury, T., Uchino, T., Tokunaga, H., and Ando, M. (2002). Survey of arsenic in food composites from an arsenic-affected area of West Bengal, India. Food and Chemical Toxicology, *40*(11), 1611-1621.

Shrivastava, A., Ghosh, D., Dash, A., and Bose, S. (2015). Arsenic contamination in soil and sediment in India: sources, effects, and remediation. Current Pollution Reports, *1*, 35-46.

Zhao, F. J., Ma, J. F., Meharg, A. A., and McGrath, S. P. (2009). Arsenic uptake and metabolism in plants. New Phytologist, *181*(4), 777-794.