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Arsenic Contamination in Rice - Health Implications and Sustainable Mitigation Strategies

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ABSTRACT

Arsenic (As) is a toxic environmental pollutant that occurs naturally in soil and groundwater as inorganic and organic forms. The global dietary preference and high grain As accumulation potential in rice, proclaims rice as one of the chief source of As entry in food chain. Among all the cultivated crops rice has more than 10-fold tendency to accumulate carcinogenic arsenic. Rice is majorly grown under reduced state which favors inorganic arsenic (As+3) availability in soil, its uptake and accumulation in grains. However, this problem is becoming worse as most of the places in India are affected by severe arsenic contamination and Chhattisgarh state is one of them. Persistent consumption of arsenic can cause severe health issues like chronic cancer and various neurological disorders. Effective measures must be taken to reduce and mitigate this concern for As-safe rice. Most of the approaches on reducing accumulation of arsenic in

rice utilizes agronomic, and biotechnological approaches but undermining natural variation can be the most economical way to mitigate this concern. This article comprehensively summarizes different ways to reduce arsenic in rice grains.

INTRODUCTION

Arsenic (As) is a toxic metalloid present ubiquitously both in inorganic and organic form. Its inorganic form is most hazardous to human as it exists naturally or anthropogenically in ground water as well as soil. It has been classified as Type I carcinogen by International Agency for Research on Cancer (IARC). Some regions like Ambagarh chowki, Kaudikasa, Dongargaon and Mohla in Chhattisgarh severely prone to arsenic contaminated soil and are high producer of rice crops. Rice is mainly cultivated in reduced condition, favoring inorganic As-availability in soil and its accumulation in rice grains. Major reason for As-contamination was reported due to the uranium exploration done by the Bodal underground mine in 1976. Even though the central government put an end to the operations a decade later, much damage was already done to the groundwater. One of the main sources of arsenic exposure for people in the region has been identified as the consumption of local rice that was cultivated in soil contaminated with arsenic. Arsenic accumulation in rice grains grown in areas with elevated arsenic in groundwater and soil has been documented in several studies. Rice was found to be the primary source for heavy metal exposure in humans. Though the concentration of arsenic consumed is in trace amount, persistent consumption can lead to various types of cancer, vascular diseases, hypertension, Heart disease, Type 2 diabetes, Impaired concentration, learning and memory, reduced intelligence, and social competence. To assess the risks to human health, knowledge regarding the levels of heavy metals in food and dietary consumption is crucial. As the region that has been part of the study belongs to the demography that is not economically stable. Consumption of brown rice among the population is common in the area. According to the Codex Alimentarius committee, the concentration of permissible arsenic limit in polished rice must be 0.2 mg/kg and 0.3 mg/kg for brown rice. And more than that could produce some serious health problems. Mitigating strategies must be used for reducing the gain As-content for developing safe-rice deprived of arsenic.

Figure 1. Contamination of Arsenic in groundwater and its affect

SOURCES OF ARSENIC IN CONTAMINATED AREA

Major source of arsenic contamination is erosion of acid volcanic rocks, granites, industrial processes, arsenic is used in the production of antifungal wood preservatives, incinerating wood products that have been treated with chromate copper arsenate, agricultural and industrial waste.

Major reason for As-contamination was reported due to the uranium exploration done by the Bodal underground mine in 1976. Due to this contamination of groundwater of regions like Kaudikasa and Ambagarh chowki region was documented in 1999. Arsenic levels in tube well water was found to be up to 520 μg L^{-1}, which was more than ten times the World Health Organization (WHO) guidelines.

MITIGATION STRATEGIES FOR REDUCING ARSENIC ACCUMULATION

Water management: Arsenic accumulation can be reduced by changing water management techniques like alternate wetting and drying technique as arsenic availability is favored by reduced condition.

Bioremediation: Using natural arsenic chelators.

Seed priming: Seed priming techniques can be used for limiting arsenic accumulation.

Inoculation: Microorganisms like arsenic oxidizing and reducing bacteria, fungi (Trichoderma sp. and archaebacteria can be used for reducing arsenic in rice grains.

Soil amendments: Adding phosphorus, silicon sources can aid to low arsenic uptake.

Biochar: Biochar can be incorporated into the paddy environment to immobilize arsenic.

Redox-sensitive elements: Iron and manganese supplements can be used to limit the arsenic accumulation.

Undermining germplasm: Diverse rice accessions and land-races could be utilized for screening of potential genotype, with the aim to develop low-arsenic accumulating rice, either through breeding or genetic engineering. This provides the most economical and promising way in utilizing broad genetic base having genes which could withstand As-stress with low arsenic accumulation.

Gene editing: Using biotechnological tools can aid to development of new gene edited lines which might accumulate low arsenic without affecting its natural characteristics.

Post-harvesting: Polished rice must be used for reduce arsenic content in cooked rice.

Cooking practices: Cook rice in percolating water or use excess water for cooking to reduce arsenic content.

Thiourea supplementation: Foliar supplementation of thiourea can be done to reduce arsenic accumulation in grains.

CONCLUSION

Arsenic toxicity in rice poses a significant threat to human health, food security, and sustainable agriculture, particularly in regions reliant on rice as a staple food. The accumulation of arsenic in rice grains, primarily due to contaminated irrigation water and soil, underscores the need for urgent intervention. Mitigation strategies such as the development of arsenic-tolerant rice varieties, improved irrigation practices like alternate wetting and drying, and soil amendments to reduce arsenic bioavailability are essential. Additionally, educating farmers on safe agricultural practices and enhancing water quality monitoring systems can further reduce risks. Collaborative efforts among policymakers, scientists, and local communities are crucial for implementing sustainable solutions to mitigate arsenic exposure and ensure the safety of rice production systems.

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