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National Webinar
on
Arsenic Mitigation: A Nexus Approach

May 29, 2020

Proceedings

Editors

Bishun Deo Prasad
Jajati Mandal
Sunil Kumar
R. K. Sohane

Organized by
Bihar Agricultural University
Sabour, Bhagalpur - 813210 (Bihar)

Proceedings-cum-Abstract book

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(AMANA-2018)

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Foreword

Arsenic (As) menace is a great environmental concern because of its cycling in water-soil-plant-human/animal continuum. It is a toxic trace element, which has been affecting many countries including India, specially the areas of Ganga delta basin.The widespread arsenic contamination of groundwater in different parts of Bihar has been found to be distributed over several blocks, located primarily in 18 districts adjoining the river Ganga, which is severe in districts of Bhagalpur, Khagaria, Munger, Begusarai, Lakhisarai, Samastipur, Patna, Vaishali, Saran, Bhojpur, Buxar, and Katihar. Arsenic pollution in majority of cases is geogenic in nature and over exploitation of ground water for drinking and irrigation has been implicated as a main cause of its pollution. Hence, now soil also has been a major sink as well source of As in polluted areas.

Hence we should look forward to investigate to comprehend suitable mitigation options to reduce the As contamination in both the drinking water as well as the food crops. In this regard several research groups are working very hard in different fields to achieve a suitable and sustainable mitigation/remediation approach that will be prolific in arresting this hazard.

On this context of arsenic contamination in the environment and for the quest of an appropriate mitigation strategy this unique National Webinar on, "Arsenic Mitigation: A Nexus Approach" is an excellent platform to exchange concepts and opinions. I'm delighted that all the experts as well as the participants of this webinar were agreed in utilizing multidisciplinary approaches to mitigate arsenic poisoning. The webinar was attended by more than four hundred participants across the India and from different countries. All presentations were followed by in-depth discussions. I am particularly happy to congratulate the organizing team for this which leads to exchange views and share experiences with other high level professors, colleagues and friends, representing many well-known Universities and Research Institutes together with the students of different universities. I hope proceeding-cum-Abstract book of this webinar will be quite useful for scientific communities, education stakeholders and policymakers aimed at arsenic mitigation. I congratulate all for commitment and active participation and wish you all the success.

(Ajoy Kumar Singh)

Contents

Thematic Area: I
Arsenic in Agriculture

Thematic Area II
Biotechnological intervention in arsenic management in crop plants

Thematic area III
Risk assessment of arsenic contamination

Thematic Area IV

Analytical techniques for measurement of arsenic

About the webinar

Environmental contamination with arsenic (As) is a global environmental, agricultural and health issue due to its high toxicity and carcinogenic nature of As. Arsenic contamination in soil and irrigated water in Southeast Asia including India is a major catastrophe, the consequences of which exceed most other man-made disasters. Apart of drinking arsenic contaminated water consumption of food are the major sources of its intake in human. Use of contaminated groundwater for crop irrigation may result in the accumulation of As in agricultural soils, eventually resulting in decreased crop yields and impaired human health. Several individual remediation techniques for arsenic mitigation has resulted in limited success. Also in long term conditions some of the remedies further results in secondary environmental pollution, which marked the major disadvantages. Therefore, development of nexus approach for a quick removal of Arsenic complexes from contaminated soil and drinking water resources are much awaited.

The webinar was conducted under following thematic areas.

- **Arsenic in Agriculture**
- **Analytical techniques for measurement of arsenic**
- **Techniques for sustainable mitigation and management of arsenic**
- **Biotechnological intervention in arsenic management in crop plant**
- **Risk assessment of arsenic contamination**

This proceedings-cum-abstract book contains the summary of keynote lectures delivered by eminent speakers and participant's abstract submitted during National Webinar held on 29th May 2020. The outcome of this webinar in a form of proceedings has been included at the end of this book.

Keynote addresses

Arsenic Contamination of Groundwater in Parts of West Bengal (India) Build-up in Soil-Crop Systems & Mitigation

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Even though the widespread arsenic (As) contamination of groundwater in West Bengal (India) and Bangladesh has remained mostly confined to the Bengal delta basin, bound by the rivers Bhagirathi and Padma-Brahmaputra-Meghna, the spread (detection) of such groundwater arsenic contamination has been reported from several states of India, as well as certain other parts of the World. The safe limit for arsenic in drinking water has been prescribed by the World Health Organization (WHO) to be 10 μg As. L^{-1} and yet, arsenic contamination in the groundwater to the tune of 50 to 3700 μg As. L^{-1} has been reported from the states of West Bengal, Assam, Bihar, Uttar Pradesh, Madhya Pradesh, Manipur, Jharkhand, Chhattisgarh, Punjab, Tripura and Nagaland in India. The source of such arsenic contamination in groundwater is believed to be of geogenic origin. The primary attention so far has been directed towards solving the problem of contaminated groundwater-based drinking water, notwithstanding the fact that the groundwater in the affected belt (in India) is extensively used in the agricultural sector rather than for drinking purpose. The number and extent of well-planned systematic studies conducted world over so far to examine the influence of arsenic in groundwater, used as irrigation source, on soil-plant-human continuum are only limited. Indeed, much more research work remains to be done in this field, not only in the Bengal delta basin but also, and especially in other parts of the affected belt in India mentioned above. This issue assumes particular significance in view of the fact that what remains essentially a point-source of contamination, as in the case of drinking water, becomes a diffuse-source of contamination of uncertain extent and spread, when arsenic finds its way into the human-food-web through the use of such contaminated groundwater for agricultural irrigation, coupled with the possibility of bio-magnification up in the food-chain.

Suggested Remedial Measures to Contain Arsenic in the Food-Chain

- Adoption of optimum conjunctive use of ground and surface water (e.g. harvested rainwater), to reduce the use of contaminated groundwater for irrigation during the lean period, and recharge of groundwater resource with harvested rainwater, free of arsenic.
- Development/identification of low arsenic-accumulating, less water-intensive high yielding crop varieties and cropping sequences suitable for arsenic-contaminated areas, especially for the lean period of January to May (e.g. cropping sequences, Elephant foot yam-mustard-sesame, Green gram-rice-mustard, etc., in place of, for instance, Olitorius jute-rice-rice and Green manure-rice-rice).
- Irrigation with pond-stored contaminated groundwater in which partial decontamination is facilitated by sedimentation-cum-dilution with rainwater.
- Enhancement of the water use efficiency (through optimum water management practices) for groundwater irrigation, especially for the summer (Baro) paddy (e.g. by having recourse to judicious intermittent ponding of summer paddy during the vegetative growth period, followed by continuous ponding during the subsequent reproductive phase, which does not compromise the yield significantly while cutting down the contaminated groundwater use considerably.
- Increased use of FYM, Vermicompost, Oil cakes and other organic manures + green manure crops, as well as the application of appropriate inorganic amendments (zinc/iron/silicon salts as and wherever applicable).
- Identification/development of varieties/crops which accumulate less arsenic in the consumable parts, and where the ratio of inorganic to organic forms of arsenic is low.

- Development of cost-effective phyto- and bio-remediation options.
- Creation of general awareness through mass campaigning, holding of farmers' day, field demonstrations, taking due cognizance of the socioeconomic factors.
- Ensuring people's participatory approach in the creation of mass-awareness about the menace as well as adopting and popularizing the remedial measures to address the problem at the local level.

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Arsenic Poisoning – Problems and Solutions

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Abstract

Arsenic poisoning through groundwater has become a major health challenge in the recent times. Severe health hazards have been observed in the population drinking arsenic contaminated water. Areas predicted to have high arsenic concentrations in groundwater exist on all continents, with most being located in Central, South, and Southeast Asia; parts of Africa; and North and South America.

In India, the entire Ganga Meghna Brahmaputra basin is the hotbed of arsenic contamination in ground water and about 200 million population is affected by arsenic poisoning. In Bihar, an estimated 10 million population is affected with arsenic poisoning. The control of the disease burden has become a major challenge for health practioners. The major source of inorganic arsenic in the human body is through arsenic contaminated water, although ingestion through food, particularly rice, wheat and potato represents another important route of exposure as reported by my research group.

Problems: The exposed population exhibit the typical skin manifestations like hyperkeratosis in palm and sole, melanosis in palm and sole, blackening of tongue, skin irritation, anaemia, gastritis, constipation, loss of appetite, bronchitis & cough etc. These symptoms were also observed in children of age between 8-14 years. Arsenicosis with cancer disease is also now reported from the arsenic hit area and recently,

incidences of Gall bladder cancer from arsenic hot spots has been reported from the state.

Solutions: Groundwater is an integral part of the livelihoods of rural communities in the Gangetic region, women's inclusion, panchayats, contact with different stakeholders and assemblage of their perspectives is essential for the effective implementation of any decision-making process. The combination of spatial and social vulnerability may be useful to prevent people from arsenic exposure, while awareness campaigns enable people to move/migrate to potentially healthier, arsenic free handpumps, as a low-cost solution. Many technologies have been introduced to mitigate arsenic but most of them have failed due to lack of ownership, community participation and mechanism for long term operation and maintenance. The Bihar state Government has allocated INR 30.91 million in current budget for arsenic mitigation. The Bihar State Health Society is preparing database for persons with arsenic poisoning. Recently, with the support from CSIR-CGCRI, Water Aid and Bihar State Pollution Control Board, ceramic based arsenic filters were installed in Buxar (Badka Rajpur village) and Saran district (Sabalpur Village).The units are being operated through community participation successfully.

Visible symptoms of arsenic poisoning is increasing in arsenic exposed population of Bihar due to lack of area specific mitigation strategy and malnutrition. There is urgent need for intensive arsenic mapping and ensure supply of arsenic free water as early as possible in arsenic hot spots. Identifying arsenic safe aquifers in Bihar is another priority.

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Arsenic and rice: Development of crop varieties safer for farming in arsenic-contaminated environments

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Arsenic (As) contamination of the environment has emerged as a serious problem. Consequently, there is an urge to understand plants' responses to As. One of the findings was that partitioning of arsenic in rice grains showed major variation in diverse germplasm of rice. The molecular basis for phenotypic divergence (As accumulation in grains and other tissue of rice) in the different or contrasting genotypes is still unclear. Several QTLs for variations in the As accumulation in different rice tissues have been already mapped in rice genome. However, they are failed to elucidate the mechanism related to the variability in As accumulation among different rice genotypes and limiting molecular breeding program. Transgenic technology is being widely enforced for improving heavy metal tolerance in plants. We have also identified several candidate genes that are involved in arsenic metabolism in rice and generated several transgenic rice plants that accumulate less arsenic in their grains. To restrict As in the rice roots as a detoxification mechanism, a transgenic approach has been followed through the expression of phytochelatin synthase from *Ceratophyllum demersum (CdPCS1*), an aquatic plant. Transgenic lines showed enhanced accumulation of As in root and shoot but less in grains. We also describe a glutaredoxins (Grx) family protein designated as OsGrx_C7, and investigate the mechanism of glutaredoxin mediated arsenic tolerance and accumulation in rice grains. Overexpression of OsGrx_C7 conferred a markedly enhanced tolerance to arsenite and reduces arsenite accumulation in seeds and shoots of rice. Recently, we reported for the first time the role of rice class III peroxidase in As tolerance and low As accumulation. They over-expressed the class III peroxidase of rice (OsPRX38) in Arabidopsis thaliana and showed that OsPRX38 transgenic lines were tolerant to As stress.Transgenic lines also accounted for a low amount of As due to lignin formation by OsPRX38 in the apoplastic region, which acts as a barrier for As entry via roots. Another potential strategy is to generation of genetically engineer plants with arsenic methyltransferase gene capable of methylating and volatilizing arsenic. Arsenic methyltransferase (*WaarsM*) gene from *Westerdykella aurantiaca* was cloned and demonstrated to confer arsenic resistance *in vivo* when expressed in the arsenic-sensitive *Escherichia coli* strain AW3110 (Δ*ars*). Recently, we constructed transgenic rice with *WaarsM* gene from *Westerdykella aurantiaca* and demonstrated that the resulting transgenic plant acquired the potential for methylating inorganic arsenic to a variety of innocuous organic species, including volatile arsenicals, providing a potential strategy for potent transgenic rice capable of low arsenic accumulation not only in grain but also in straw, feed for livestock.

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Sustainable Remediation of Arsenic for Nutritious Rice-Based Systems in South Asia

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Arsenic contamination in soil, plant and irrigated water in Southeast Asia including India is a major devastation, the consequences of which severely affected the human wellbeing. A gamete of research articles and newspaper link human health is at high risk due to intake of arsenic. Apart of drinking arsenic contaminated water consumption of food are the major sources of its intake in human. Application of in insecticides, rodenticides has further worsened the arsenic contamination. Use of contaminated groundwater for crop irrigation may result in the accumulation of As in agricultural soils, eventually resulting in decreased crop yields and impaired human health (Brammer and Ravenscroft, 2009). The threat of As to humans is usually exacerbated in countries that have high population densities, use groundwater as their primary drinking water source, and rely heavily on large quantities of irrigation for agriculture, such as those within South and Southeast Asia.

Rice is the staple food of more than half of the world's population more than 3.5 billion people depend on rice for more than 20% of their daily calories. Asia accounts for 90% of global rice consumption, and total rice demand there continues to rise. As per consumption statistics, rice is a major contributor to As intake in humans, because rice is mainly cultivated in anaerobic paddy soil, where arsenite [As(III)] is more available. The four main As species are found in rice grains are As(III), arsenate [As(V)], monomethylarsonic acid (MMA), and dimethylarsinic acid (DMA) (Williams et al., 2006). Different species of As showed different spectrum of As absorption in human (Kuramata et al., 2013). DMA in rice is poorly absorbed *in vivo* after oral administration, resulting in a low bioavailability in the human body. Conversely, iAs in rice are much more bioavailable than DMA, indicating a high potential risk to human health (Mostafalou and Abdollahi, 2017). Accumulation of As in rice varies according to the genotype of the plant (Norton et al, 2010) and its mobilization and intake is controlled by different factors such as As speciation, soil texture, pH and organic matter present (Mitra et al, 2017). The root characteristics also play a major role in As accumulation, which includes the root aeration, porosity (Wu et al, 2011), rhizosphere interactions (Dasgupta et al, 2004) and Fe-plaque formation on the root surfaces (Liu et al, 2004). Screening and selection of rice local land races and cultivated rice varieties of rice with low As and managing soil properties is an effective approach for reducing the As contamination in rice. Moreover, decreasing As uptake and translocation in rice plants by augmenting mineral nutrients in soils that competes with As uptake. In addition, better agronomic management interventions i.e. water management, Si fertilization, growing hyperaccumulator (native hygrophyte) plants, biostimulation with organic matter amendment (rice straw recycling) and crop establishment method showed promising results in reducing the uptake of iAs from soil to straw and grain. Based on site specific and extent/magnitude of contamination, varietal selection and agronomic management should be geared to achieve sustainable rice production system. Additionally, it is important that the finding of the research reach the end users i.e. farmers using various tools and dissemination channels. Translating the scientific outcomes to actionable advice and reaching the beneficiaries using ICT tools can help in overcoming the issue.

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Arsenic Exposure from food and health risks

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Arsenic exposure from drinking water and food continues to pose an important environmental public health challenge especially in south-east Asia where millions are affected. While arsenic exposure from drinking water is recognised as a significant health risk the same for food hasn't drawn much attention. Mondal and Polya (2008), noted that not only rice was found to be the most important exposure route for some areas of West Bengal, India but also its relative importance might increase as effective drinking water remediation technologies are put in place and at the same time as the arsenic content of arsenic-bearing groundwater irrigated paddy fields increases. While, estimated risk of arsenic exposure from rice intake are widely available, limited studies have reported direct evidence of health impact from arsenic in rice. In our study from West Bengal, India, Banerjee et al. (2013) reported elevated genotoxic effects, measured as by micronuclei frequency in urothelial cells, associated with the staple consumption of cooked rice with arsenic more than 200 μg/kg. The relative contributions of drinking water, rice and cooking of rice to human exposure in three contrasting areas of West Bengal, India with different overall levels of exposure to arsenic, viz. high (Bhawangola-I Block, Murshidabad District), moderate (Chakdha Block, Nadia District) and low (Khejuri-I Block, Midnapur District) indicated water to be the dominant exposure route in Murshidabad, both water and rice were major exposure routes in Nadia, whereas rice was the dominant exposure route in Midnapur (Mondal et al., 2010) indicating rice risk to be of importance when arsenic in drinking water is low. While appropriate cooking methods, typically with excess water represents a relatively inexpensive way of making small but widespread reductions in arsenic exposure, a significant loss of essential elements (potassium (50%), nickel

(44.6%), molybdenum (38.5%), magnesium (22.4%), cobalt (21.2%), manganese (16.5%), calcium (14.5%), selenium (12%),iron (8.2%), zinc (7.7%), and copper (0.2%)) incurred when rice was cooked using rice-to-water ratio of 1:6 as often followed in rural areas in India (Mwale et al., 2018). Hence, in poverty-stricken arsenic affected rural areas where cooked rice is the staple, there needs to be a balance between risk and benefit of cooking rice with excess water. More importantly factors associated with rice consumption behaviour, cooking practices, knowledge of arsenic and perception associated with exposure to arsenic in rice need to be determined (Mondal et al., 2019). Another important aspect to determine is the arsenic exposure from other staples like wheat. Consumption of wheat is next to rice in India but has greater annual global consumption than rice. Fortunately, unlike rice, wheat is not an arsenic accumulator but in a study from rural Bihar, India (Suman et al., 2020) concentrations in wheat flour was found to be high enough to cause excess lifetime cancer risk of 1.23 x 10-4, which was higher than the 10-4-10-6 range, typically used by the USEPA as a threshold to guide regulatory values, indicating widespread arsenic exposure from wheat intake in the studied population.

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Arsenic management options in soil-plant-food chain

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Introduction

The menace of arsenic pollution has by large affected a large number of countries through soil-plant-food chain continuum. In terms of global coverage, Bangladesh and India (adjoining the Indo-Gangetic plains) are among the fore-runners (Amini *et al*., 2008). The geogenic source of arsenic in the Bengal Delta Basin has been attributed to three different processes, of which fluvial sediment deposition from the Himalayas (McArthur *et al*., 2004) is given special consideration. The widespread arsenic contamination in groundwater in different parts of West Bengal has been detected to be distributed over 111 blocks, covering 12 districts and affecting more than 50 million people (*http://www.soesju.org*). Among the different sources of water, groundwater arsenic concentration is alarmingly high. Groundwater abstraction by shallow tube-wells especially for *boro* rice cultivation contributes to arsenic in soil (Sanyal and Nasar, 2002). The inorganic arsenic (iAs) load in rice grain in China, Bangladesh and India are much higher than maximum limit of 0.2 mg/kg iAs, set by Codex (Sun *et al*., 2008; Signes-Pastor *et al*., 2008). The higher value of arsenic in paddy as well as boiled rice suggests even cooking cannot curb the arsenic load. Even in case of vegetables, the arsenic offloads in cabbage, chilli, potato, brinjal etc were much higher than the maximum limit of 0.5 mg/kg tAs (WHO-BCKV, 2008).

Total As is not a reliable index for assessment of the risk of dietary exposure, necessitating species level study (inorganic/organic As). Inorganic As (arsenite > arsenate) is more toxic than organic As (MMA, DMA, AsB). Rice grain with maximum arsenite content and straw with arsenate offloads (Sinha and Bhattacharyya, 2014) pose much graver arsenic uptake situation. A transfer factor of 10.20 and 2.70% was obtained in rice straw and grain from the same study. The additional food sources such as cow milk, goat meat, poultry egg and meat, fish can also accumulate arsenic and manifest the wrath through food chain (Datta *et al*., 2010; Chowdhury and Samanta, 2012). The diet and water mediated uptake of arsenic is found to be correlated with its elevated level in urine and arsenicosis skin lesions (Halder *et al*., 2013; Guhamazumder *et al*., 2014). The consumption of a composite diet of water, rice, vegetables etc. through their individual contributions often render the intake levels much higher than the WHO prescribed provisional tolerable daily intake value of 2.1 μg day^{-1} kg^{-1} BW (Halder *et al*., 2013). In this pursuit of addressing the global peril, suitable management strategies are to be delved into.

Management options of arsenic contamination:

Different strategies have been brought under the research purview for combating the soil-plant-food chain mediated arsenic transfer. They include- (a) soil management; (b) water management; (c) low water requiring crops; (d) low arsenic accumulating varieties; (e) microbiological tools of remediation; (f) genetic modification to reduce arsenic accumulation and (h) clinical and therapeutical measures.

A large number of studies explore the mitigation potential of soil amendments such as the application of inorganic fertilizer or organic manure which can immobilize, adsorb, bind or co-precipitate arsenic *in situ*. Different organic amendments like farm yard manure, compost, vermicompost, oil cakes etc, have been attempted where vermicompost has been found to be the most successful to curb As load. Better and highly stable metal-humate complexes (Sinha and Bhattacharyya, 2011), competition for available adsorption sites, formation of aqueous complex, changing in the redox potential of arsenic and surface of NOM may be the possible reason for such.

Inorganic amendments like application of phosphorus, zinc and iron have also been found to reduce As bioaccumulation. In the soil system, P addition facilitated desorption and bioavailability of As, however, the net effect of P on As phytoavailability in soils depends on the extent of P-induced As mobilization in soils and P-induced competition for As uptake by roots (Bolan *et al*., 2013). The study of Giri *et al*. (2011) illustrated how zinc and iron can reduce the arsenic uptake in rice and mustard. Enhanced iron (Fe^{2+}) and/or zinc (Zn^{2+}) in the soil solution due to soil application reduce extractable As through sorption/coprecipitation as insoluble Fe/Zn-As complexes.

In this pretext, our research group has initiated an attempt to club these organic and inorganic amendments. We have prepared Zn and Fe enriched vermicompost of different concentration and applied to soil in different doses. Interestingly the first year results suggest even half of the recommended dose of usual vermicompost had similar or even better arsenic curbing potential. The possible mechanisms and characterization are yet to be deciphered.

In another study, the integrative approach of deficit irrigation and organic amendment (vermicomost) was found to significantly offload (even 46%) arsenic in rice grain among ten NFSM/BGREI recommended rice varieties. We further validated the study in three districts of Bengal using local popular varieties where again the integrative approach emerged victorious.

A similar study in vegetables (cauliflower, tomato, spinach) revealed the use of surface water and organic amendments in conjunction can better alleviate arsenic load in edibles.

Adopting cultivation of low As accumulating crops (potato, pumpkin, sesame), low As accumulating cultivars like UP-262 (Wheat), BT-893 (Sesame), Kufri Chandramukhi (Potato), Khitish, Rasi, Choli 60, Palman (Rice) and non-food crops (flowers, fibres etc.) can be the alternatives of combating As toxicity (DNGM Research Foundation, 2012).

In another study using microbiological remediation, twelve bacterial isolates were screened as As-oxidizing bacteria, of which *Geobacillus stearothermophilus* HWB2 and *Bacillus megaterium* strain 14 emerged most successful in 32 and 52% As oxidation (Majumder *et al*., 2013). In a present study *Burkholderia cepacia* and *Burkholderia metallica* emerged even better in such remediation.

In another study of genetic modification, SSR markers linked with QTL located at chromosomal regions responsible for arsenic uptake by rice grain and husk have been identified and favourable alleles of Zinzibarene Synthease (ZIS) and Multidrug and Toxic Compound Extrusion transporter (MATE) gene of Gobindabhog has been tried to be incorporated into the high yielding photo-insensitive cultivars for developing low arsenic accumulating rice genotypes (Debnath *et al*., 2016).

A current study has been initiated to find the permissible limit of arsenic in soil & irrigation water with reference to edible grains through Tobit censored regression models. It can enable us to ascertain at what levels of As in soil or irrigation water, the cultivation of rice cannot be environmentally safeguarded.

In another ensuing study we have developed a prototype filter using bamboo, laterite soil, graphite, graphene oxide and their doped counterparts. An astounding 85% reduction of As in drinking water was observed. It is currently further being validated and characterized for their sorption behaviour.

The therapeutic measures of As in human, cattle, ruminants, etc has been researched and indigenous drugs like curcumin and folic acid, sodium thiosulfate, zinc oxide and sodium selenite, mushroom lectin with ascorbic acid emerged successful options.

Conclusion

Different singular strategies have been developed and further numerous strategies are underway for breaking the chain of soil-plant-food chain mediated contaminant transfer. However an integrative approach through enactment of a model village where PHED, CGWB, SWID (Aquifer assessment, Low cost filters), Doctors (Risk assessment, Clinical correlation therapeutic measures), Animal, Fisheries experts (Risk assessment, managed rearing, Therapeutic measures) and State Agricultural Universities (Risk assessment, Non-food crops, engineered low As taking varieties, soil amendment, water management) can work together may be a more holistic and viable alternative. Further addressing the crux of the problem through preventive means rather than curative one must be initiated as long-term problems needs long-term solutions (Brammer and Ravenscroft, 2009). A study of isotope hydrology of groundwater for characterization and mitigation of arsenic in groundwater may be initiated in this regard to develop a hydrogeological model of the groundwater aquifers substantiated with environmental isotope database. The problem being imminent strategic wayouts can only bring forward ways by which we can all strive against the carcinogenic toxin 'Arsenic'.

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Isolation and molecular characterization of arsenite tolerant bacteria

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Arsenic is a highly toxic metalloid that considerably threatens the environment and human health. The most striking example is the epidemic of arsenic poisoning observed in Bangladesh and West Bengal, where arsenic contaminates the drinking water through geological sources and thereby affects millions of people (Nordstrom, 2002). The World Health Organization recommends "As" guideline values of 10g/l (WHO Report, 2000), but development of industrial corporations in Gujarat has led to an alarming increase in amount of "As". Report of National Knowledge Commission (2005) has shown presence of 150µg/l of "As" in Gujarat. Arsenic can find its way into the grains of plants, such as rice and wheat, and into vegetables and fruit plants through irrigation with As-contaminated water. Its chronic exposure causes cardiovascular diseases, neurological disorders, and liver injury and is associated with cancers of the skin, bladder, liver, and lung. All organisms have been exposed to toxic agents since the origin of life, and tolerance mechanisms arose early during evolution. Arsenic can exist in multiple oxidation states, the toxicity order of arsenicals is As III > MMAO III > DMA IIIGS> DMA V > MMA V > As V (Vega et al., 2001). As V (arsenate) is an analogue of phosphate, and its toxicity is due to the disruption of critical cellular functions or synthesis of essential building blocks. These include uncoupling of ATP phosphorylation that would directly impact energy flow, as well as nucleic acid and phospholipid synthesis. As III (arsenite) toxicity is thought to be predominantly due to its ability to covalently bind protein sulfhydryl groups. Several remediation techniques for arsenic removal have been applied, e.g., ion exchange, adsorption with activated alumina and activated carbon, ultrafiltration, reverse osmosis, and complexation with metal ions followed by coagulation. These methods require large amount of chemical reagents, for example, adsorption and ion exchange are expensive when used in the event of high concentration of heavy metal ions. Furthermore, the treated sludge may be contaminated with treatment reagents resulting in secondary environmental pollution. Due to this apparent disadvantage of the above listed physico-chemical treatments, novel techniques for the reduction of contaminant toxicity in concerted with minimizing cost have been proposed. Biological remediation techniques, either using living/dead cells or biosynthesized molecules have been examined (Katsoyiannis et al., 2002). Studies have shown that both plant and microorganism are able to accumulate metal ions via processes such as transportation across the cell membrane, biosorption onto cell wall, entrapment in extracellular capsule, precipitation, oxidation-reduction reaction and biosorption to extracellular polysaccharides. Hyperaccumulating plant species, such as *Pityrogramma calomelanos* and *Pteris vitta*, were shown to accumulate arsenic in the form of arsenate at the leaf section (Visoottiviseth et al., 2002). Studies have reported the ability of algae, fungi and bacteria to transform arsenite to arsenate and vice versa during their growth (Visoottiviseth and Panviroj, 2001). During the long history of exposure to arsenic, a large number of microorganisms have evolved several kinds of mechanisms to reduce the harmful effects of arsenite. Microorganisms cope up with the toxic effects of arsenic by: (i) minimizing the uptake of arsenate through the system for phosphate uptake, (ii) increasing the level of antioxidants to reduce the effect of reactive oxygen species (ROS), and (iii) using the best characterized microbial arsenic detoxification pathway involving the ars operon.

Two arsenite tolerant bacteria, one from marine and other from non-marine environment, were isolated by enrichment culture method at 28°C in aerobic conditions. Marine isolate, designated as strain ALANG-4 can tolerate 27mM As III (arsenite) and non-marine industrial isolate, GIDC-5 can tolerate 54mM As III , in rich medium. Based on 16S rDNA analysis, strain ALANG-4 was identified as *Halomonas* sp. and strain GIDC-5 as *Alishewanella* sp. Both strains were also able to oxidize As III to As V by the action of arsenite oxidase. As III oxidase activity (localized in membrane fraction) was 88.43µM/min/mg protein and 75.04µM/min/mg protein, in presence of 1mM As III, in ALANG-4 and GIDC-5 respectively. Arsenite oxidase gene, aoxB and arsenite transporter genes, arsB and ACR3, were amplified in DNA samples of both strains, using specific degenerate primers for each gene. Specific activities of antioxidant enzymes like CAT, APX, SOD and GST were increased with increasing amount of As III in medium. GR activity was inversely proportional to concentration of arsenite in the medium. When 10mM As III was present in medium, 75% and 94% inhibition in activity of PDH, and 85% and 94% inhibition in alpha-KGDH activity was observed in ALANG-4 and GIDC-5, respectively. *Halomonas* sp. strain ALANG-4 overcomes the toxic effect of As III by action of efficient eflux system, PYC and GST. Also, its TCA cycle operates at low pace. In case of *Alishewanella* sp. strain GIDC-5, GDH and MDH activities were increased proportionate to As III concentration; suggesting ED pathway and Glyoxylate cycle were operating in this strain in arsenite stress condition. The results of present study suggest the mode of action of arsenite and on-going metabolic processes in *Halomonas* sp. strain ALANG-4 and *Alishewanella* sp. strain GIDC-5 to combat the harmful effects of As III.

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Risk assessment of arsenic contaminated soils using predictability model

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Introduction

Arsenic (As) pollution in agricultural land is increasing day by day due to over exploitation of groundwater. As a results, transfer of As from soil to food-chain *via* crops is also increasing day by day. Therefore, there is an urgent need of risk assessment of As contaminated soils with the ultimate aim of judging the suitability of soil for safe cultivation of crops. Moreover, there is no safe limit of extractable As in soil in relation to soil properties and human health. On the other hand, total As content ranging from 10 to 20 mg kg^{-1} in soil has been used as a simple index of As hazard in different countries (Golui *et al.,* 2017). However, total As content in soil does not take into account as to how its availability is modified by important soil properties. Therefore, an attempt has been made to prescribe a safe limit of extractable As in soil, based on (i) solubility of As in soil as affected by important soil properties, (ii) transfer of As to human food-chain, and (iii) health hazard associated with dietary intake of As by human.

Risk assessment

Risk assessment is the determination of quantitative or qualitative value of risk related to a concrete situation and a recognized threat. For assessing risk due to As toxicity, knowledge about the routes of entry of As into human body is required. Prolonged exposure to As can cause deleterious health effects in human like arsenical skin lesions (pigmentation and keratosis), chronic respiratory disease, peripheral neuropathy, liver fibrosis, peripheral vascular disease, conjunctivitis, cardiovascular diseases, gangrene and skin cancer, pre-malignant skin lesions, bladder and lung cancer (Guha Mazumder, 2003). Arsenic may enter the human body through consumption of drinking water, direct ingestion of soil, and consumption of food plants grown in As-contaminated soil. Recent development in the area of risk assessment to human health for the intake of As through consumption of foods grown on contaminated soil can be listed as: i) based on total As content in soil (10-20 mg kg^{-1}) and drinking water (10 µg kg^{-1}), ii) based on As content in edible portion of rice grain (1 mg kg^{-1}), iii) based on hazard quotient (HQ=0.5) for As intake, iv) based on integrated approach using predictive model.

Integrated solubility and free ion activity model: Arsenic content in rice grain could be predicted by the integrated solubility-free ion activity model without actually measuring the free ion activity in soil solution (Meena *et al.,* 2016; Golui *et al.,* 2017; Mandal *et al.,* 2019a; 2019b). Free ion activity model (FIAM) suggests that uptake may be controlled by metalloid ion activity in the soil pore water. The equation for prediction of As uptake by plant can be written as follows:

$$\mathrm{p}[\mathrm{M}_{\mathrm{Plant}}] = C + \beta_1 p[M_C] + \beta_2 pH$$

Where, $C = \frac{k_1}{n_F} - logTF$, $\beta_1 = \frac{1}{n_F}$, and $\beta_1 = \frac{k_2}{n_F}$; C, β_1 *and* β_2 are empirical As and plant-specific coefficient. Model equation can be parameterized by non-linear error minimization using the “SOLVER” facilities in Microsoft Excel.

Risk to human health for intake of As through consumption of rice grown on As contaminated soils is computed in terms of hazard quotient (HQ), following the US Environmental Protection Agency (USEPA) protocol (IRIS, 2020) and can be expressed as:

$$\mathrm{HQ} = \frac{\mathrm{M}_{\mathrm{Plant}} \times \mathrm{W}}{\mathrm{RfD} \times 68}$$

Where, M_{plant} is As content (mg kg^{-1}) in the grain of rice grown in As contaminated soils; W is the daily intake of grain of rice, while the body weight of the individual consuming such contaminated rice is 68 kg. For fixing the safe limit of extractable As in soil at a particular pH and organic carbon content, critical value of HQ used is taken as 0.5 under modeling framework. Hence, a ready reckoner is developed to compute the permissible limit of extractable As in soils, based on pH and organic carbon content. These permissible limits are based on the predicted HQ by solubility-FIAM.

***Case study*:** Chronic arsenic toxicity due to exposure of arsenic and its health impact on population has been studied in Malda district of West Bengal (Golui *et al.,* 2017). To ascertain these, a scientific epidemiological study was carried out in four blocks of the district. Epidemiological study was carried out by house-to-house survey for the selection of the participants. A total number of 66 households of 10 arsenic affected villages were surveyed in the district. Out of 182 participants examined, 80 (43.9%) patients showed clinical features of arsenicosis (cases), characterized by arsenical skin lesion (pigmentation and keratosis), while 102 participants did not have any such lesion (control). Out of total number of cases having arsenical skin disease, 96.3 % had pigmentation (mild-62.5%, moderate-30.0%, severe-3.75%), whereas 52.5% had only keratosis (mild-37.5%, modeeate-12.5%, and severe-2.50%). Both pigmentation and keratosis were found in 47.5% of the patients, majority being males. However, insufficient education, poverty, lack of awareness and effective health-care support system are the major contributory factors to the malady of the severely arsenic affected people. Permissible limit of extractable As in soil for rice in relation to soil properties and human health hazard, associated with consumption of rice grain by human, was also established in the study area. Analysis of experimental soils collected from participants own field showed the mean Olsen extractable and total arsenic concentration of 0.206 and 6.70 mg kg^{-1}, respectively. Arsenic concentration in rice grain ranged from 2.00 to 1260 μg kg^{-1} with the mean value of 146 μg kg^{-1}. The hazard quotient (HQ) for intake of As by human through consumption of rice varied from 0.03 to 3.52. As high as 77.6% variation in As content in rice grain could be explained by the solubility-free ion activity model. Permissible limit of extractable As in soil for rice in relation to soil properties and human health hazard, associated with consumption of rice grain by human, was established as 0.43 mg kg^{-1}, if soil pH and organic carbon content were 7.5 and 0.50%, respectively. The conceptual framework of fixing the toxic limit of arsenic in soils with respect to soil properties and human health under modeling-framework was established.

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Exploitation of PGPR for arsenic mitigation and plant growth-promoting traits

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Arsenic contamination of underground water and soil poses a serious risk to plants and animals. It is widely distributed in soils and natural waters, both released from natural and anthropogenic sources, from the weathering of rocks, by mining industries and agricultural practices. The widespread contamination of arsenic in groundwater in North-East India and Gujarat reflects arsenic as a potent environmental toxic metal. Arsenic, a metalloid that primarily exists in two redox states: the reduced form, arsenite (AsIII), and the oxidized form, arsenate (AsV). AsIII is more toxic to most of the organisms, as it is more soluble and mobile than arsenate. Arsenic V is an analogue of phosphate (PO_4) as its interference in the aerobic metabolism of plant and animals.

In arsenic contaminated soil and water, a large number of microorganisms have evolved with several kinds of mechanisms to reduce the harmful effects of arsenic. One of the effective strategies to identify arsenic tolerant microorganism having arsenite (AsIII) to arsenate reduction potential. However, this conversion may leads to the higher accumulation of AsV. Since the AsV and PO_4 has same chemistry as well as same transporter for its absorption through plant's root may lead to higher accumulation of AsV. The microorganism having PO4 solubilizing activity along with arsenic mitigating properties will be quite effective in mitigating arsenic as it accumulate more amount PO_4 instead of AsV. Therefore, identification of microorganism having bioremediation potential along with multi-trait PGPR (plant growth-promoting rhizobacteria) activities will be quite beneficial.

In recent years, PGPRs have been exploited for potential bioagents. *Pseudomonas* spp. have been shown to trigger systemic resistance in plants, often referred to as induced systemic resistance (ISR) (Van Loon *et al*. 1998; Pieterse *et al.* 2000, 2014; Bakker *et al.* 2007). Nine pseudomonad isolates were characterized for ammonification property, HCN (Cyanide), IAA (Indole acetic acid) and phosphorus solubilisation activities (Kumar et al., 2018). Among the nine isolates, pseudomonad isolates PGPR-WS were best in exhibiting multiple PGPR traits like ammonification, HCN production, IAA production (26.08 mgl^{-1}), and phosphate solubilization (306.51 mgl^{-1}) as well as best in antagonistic activity against *F. oxysporum* f.sp. *ciceri,* showed 75.00% inhibition of growth of mycelia over control and caused total lysis of mycelia in advanced stages of antagonism (Kumar et al., 2018).

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Signal transduction pathway in host-pathogen interaction

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In this study, the ability to hyper accumulate heavy metals from contaminated site by water hyacinth (*Eichhornia crassipes*) was assessed, gene functionalized, mechanism decoded and its future prospective unfolded. The heavy metal contaminated habitat was validated by X-ray diffraction and energy dispersive X-ray elemental spectrometry analysis of the soil samples. Heavy metal contamination in soil and water; accumulation in foliar, root and bulb tissue samples were determined by atomic absorption spectroscopy and were monitored as a function of accumulation in different tissues. Significant differences were recorded in the bioaccumulation capability of heavy metals by different tissue. Discrete variation in protein profile of leaves and high expression of alcohol dehydrogenase (ADH), peroxidase (POX) and altered regulation of esterase (EST) in root tissue was observed in contaminated site grown *Eichhornia*.

The detoxification of heavy metals frequently involves conjugation to glutathione prior to compartmentalization and eflux in higher plants. So, a heavy metal stress responsive (*Echmr*) gene was cloned from water hyacinth, which conferred tolerance to Cd sensitive *Escherichia coli* Δgsh mutants against heavy metals and abiotic stresses. The recombinant *E. coli* Δgsh mutant cells showed better growth recovery and survival than control cells under Cd (200 mM), Pb (200 mM), heat shock (50°C), cold stress at 4°C for 4 h, and UV-B (20 min) exposure. The enhanced expression of *Echmr* gene revealed by northern analysis during above stresses further advocates its role in multi-stress tolerance. Heterologous expression of EcHMR from

Eichhornia rescued Cd^{2+} sensitive *E. coli* mutants from Cd^{2+} toxicity and induced better recovery post abiotic stresses. This suggests a possible role of *Echmr* in Cd (II) and desiccation tolerance in plants for enhanced stress response.

The bioinformatic analysis revealed the presence of various STREs viz., DRE, ABRE, HSE and Calmudilin binding element, and HM binding motifs in EcHMR, which suggests its possible role in abiotic stress tolerance. The analysis hypothesize that EcHMR protein has predicted molecular and biological function of metal ion transmembrane transporter activity with predicted binding site of EcHMR closest to crystal structure of the CorA Mg^{2+} transporter and Ca^{2+} ATPase pump crystal structure with its predicted location at cell periphery or intrinsic to membrane.

Hence, further investigations on functional validation of *Echmr* gene in Cd^{2+} sensitive yeast Δycf1 mutant and FY3 cells complemented the cells to survive in the excess Cd^{2+} and *invitro* condition of 4% polyethylene glycol. This suggests that the *Echmr* also enhances Cd (II) and desiccation tolerance in yeast ΔYcf1 mutant and FY3 cells through the possible mechanisms of cation transport. The subcellular localization of the EcHMR was studied in *Arabidopsis* protoplast which revealed its localization within the plasma membrane or intrinsic to membrane and cytosol as predicted by the bioinformatics tools. The localization results possibly support the hypothesis of EcHMR having transmembrane transporter activity and this implies that the regulation of EcHMR and its integrated functions may have crucial role in the stress tolerance responses of plants in hostile environments. The present endeavour has revealed that *Echmr* gene from *Eichhornia* possess the potential to deliver tolerance against HM and other abiotic stresses and when harnessed properly may be instrumental in genetic engineering-based strategies to develop heavy metal tolerant crop plants for remediation of polluted soils. The high metal accumulation efficiency of water hyacinth due to the biomass production suggests this species as reliable organic biomarker for heavy metal contamination.

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Role of Microbes in Bioremediation of Arsenic

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Introduction

The pandemic of arsenic poisoning due to contaminated groundwater and soil of Southeast Asia including India is a major catastrophe, the consequences of which exceed most other man-made disasters. A plethora of research articles and newspaper link human health is at high risk due to intake of arsenic. Awareness and Government initiation should some impact on drinking of pure water in arsenic affected area. Apart of drinking arsenic contaminated water consumption of food are the major sources of its intake in human. Use of contaminated groundwater for crop irrigation may result in the accumulation of As in agricultural soils, eventually resulting in decreased crop yields and impaired human health. Application of in insecticides, rodenticides has further worsen the arsenic contamination. The four main As species are found in rice grains are As (III), arsenate [As(V)], monomethylarsonic acid (MMA), and dimethylarsinic acid (DMA). Different species of As showed different spectrum of As absorption in human. Dimethylarsenic acid (DMA) is poorly absorbed in vivo after oral administration, resulting in a low bioavailability in the human body. Conversely, iAs concentration are much more bioavailable than DMA, indicating a high potential risk to human health. Several remediation techniques for arsenic removal have been applied e.g., ion exchange, adsorption with activated alumina and activated carbon, ultrafiltration, reverse osmosis, and complexation with metal ions followed by coagulation, however many of the treatments are reported to be expensive and time consuming. Also in long term conditions some of the remedies further results in secondary environmental pollution, which marked the major disadvantages. Further, some physicochemical treatments like co-precipitaion need to be preceded by oxidation of As (III) to As (V) for enhancing quick removal of Arsenic complexes from drinking water resources. One of the effective approach is bioremediation using microorganisms that has the capability to convert highly toxic form of As to its less toxic form.

Bioremediation

Bioremediation is the use of biological interventions of biodiversity for mitigation (and wherever possible, complete elimination) of the noxious effects caused by environmental pollutants in a given site. It has been successfully applied for cleanup of soil, surface water, groundwater, sediments and ecosystem restoration. It is generally considered to include natural attenuation, bio-stimulation or bio-augmentation, the deliberate addition of natural or engineered micro-organisms to accelerate the desired catalytic capabilities. Thus bioremediation, phytoremediation and rhizoremediation contribute significantly to the fate of hazardous waste and can be used to remove these unwanted compounds from the biosphere. Traditionally, the efficacy of bioremediation could be determined by measuring changes in total pollutant concentrations by analytical tools (chromatographic and spectroscopic techniques etc.). The specific mechanisms that are emphasized in an application depend on the mobility, solubility, degradability, and bioavailability of the contaminant(s) of concern. Phytoremediation involves the use of certain plants to clean-up soil and water contaminated with inorganics and/or organics. The use and transformation of over thousands of individual compounds whose current locations are largely unknown have resulted in the establishment of new fields of research, which have one thing in common: they link ecological, physiological, and chemical/analytical lines. This complex system of interactions and interrelations requires intensified efforts to provide integrated information on the status and development of environmental quality (Markert et al., 2008; Prasad, 2008). Biotechnology and systems biology approaches are also implicated in bioremediation and are gaining considerable importance in fostering bioremediation (De Lorenzo, 2008; Van Aken, 2009). It is strongly believed that an integral approach of multidiscipline may work out to overcome such contamination. A long-term monitoring plan will have to be carried out to ensure continuing effectiveness.

Arsenic contamination of underground water and soil poses a serious risk to plants, animals including human being. It is widely distributed in soils and natural waters, both released from natural and anthropogenic sources, from the weathering of rocks or by mining industries and agricultural practices. The widespread contamination of arsenic in groundwater in North-East India reflects arsenic as a potent environmental toxic metal. Arsenic, a metalloid that primarily exists in two redox states: the reduced form, arsenite (AsIII), and the oxidized form, arsenate (AsV). AsIII is more toxic to most of the organisms, as it is more soluble and mobile than arsenate. AsV is an analogue of phosphate (PO_4) that interfere in the aerobic metabolism of plant and animals. Inorganic arsenic species are classified as potent human carcinogens. Exposure of Arsenic through inhalation or drinking water causes various types of skin lesions such as melanosis, leucomelanosis, and keratosis. Other effects are neurological disorder, high blood pressure, diabetes mellitus, diseases of the respiratory system and of blood vessels including cardiovascular, and cancers typically involving the skin, lung, and kidney are also reported. Several remediation techniques for arsenic removal have been applied e.g., ion exchange, adsorption with activated alumina and activated carbon, ultrafiltration, reverse osmosis, and complexation with metal ions followed by coagulation, however many of the treatments are reported to be expensive and time consuming. Also in long term conditions some of the remedies further results in secondary environmental pollution, which marked the major disadvantages. Further, some physico-chemical treatments like co-precipitaion need to be preceded by oxidation of As (III) to As (V) for enhancing quick removal of Arsenic complexes from drinking water resources.

Conclusion

Therefore, developing a new enhancing technique for a quick removal of Arsenic complexes from contaminated soil and drinking water resources and having less negative impact to the environment is must. There are organisms in both terrestrial and aquatic environments that could accumulate or change the form of As, including several species of bacteria that reduce As(III) to the less toxic As (V), could be coupled with adsorption or coagulation technique they may produce a good alternative remediation technique.

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Arsenic Contamination in Soil, Plant and Groundwater -Its impact on animal and human health

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Natural arsenic contamination of groundwater resources is posing a serious threat to the health of millions of people. Its high toxicity and increased appearance in the biosphere have triggered public and societal concern. The main focus of attention, until recently, has been exclusively on arsenic contamination in groundwater-derived drinking water at levels beyond the WHO-permissible and safe levels of 0.05 and 0.01As mgL^{-1}, respectively. Indeed, arsenic uptake by crop plants grown in soils contaminated with high concentration of arsenic and irrigated with such arsenic contaminated groundwater has been reported by several workers (ICAR, 2001, Abedin *et al*., 2002, Adak *et al*., 2002, Ghosh *et al*., 2003). Such findings call for an immediate attention, since what remains essentially a point and fixed source of arsenic contamination as for drinking water may well become a diffuse and uncertain source of contamination when arsenic finds its way into the food web, accompanied with possible biomagnifications up in the food chain.

Arsenic in groundwater is generally present as dissolved, deprotonated/protonated oxyanions, namely arsenites ($As^{III}O_3^{3-}$, $H_n As^{III}O_3^{(3-n)-}$, with n = 1,2) or arsenate ($As^{V}O_4^{3-}$, $H_nAs^{V}O_4^{(3-n)-}$, with n = 1,2), or both, besides the organic forms. The toxicity of arsenic compounds in ground water/soil environment depends largely on its oxidation state, and hence on redox status and pH, as well as whether arsenic is present in organic combinations. The toxicity follows the order: arsine [AsH_3; valence state of arsenic (As): -3]> organo-arsine compounds > arsenites (As^{3+}form) and oxides (As^{3+} form)> arsenates (As^{5+} form)> arsonium metals (+1)> native arsenic metal (0). The arsenites are much more soluble, mobile and toxic than arsenates in aquatic and soil environments. At pH 6-8, in most aquatic systems, both $H_2As^VO_4^-$ and $HAs^VO_4^{2-}$ ions (pentavalent arsenic forms) occur in considerable proportions in an oxidized environment (redox potential, E_h= 0.2-0.5V), while the arsenous acid, $H_3As^{III}O_3$, is the predominant species (trivalent arsenic form) under reduced conditions (E_h = 0-0.1V) (Sadiq, 1997). Reduction of As (V) to As (III) would be accompanied by mobilization of arsenic in aquatic system.

The soil matrices act as arsenic sinks, thereby reduce the availability of the toxicant to the crop, but continuous accumulation of arsenic in soil for years together through the use of polluted groundwater irrigation is the probable reason for elevated level of arsenic in the crops. The accumulation and translocation of this toxin is to harvested and edible parts largely depend on soil and climatic factors, plant genotype, arsenic concentration in groundwater and agronomic management practices. Furthermore, the emerging concern for arsenic toxicity to human through food chain adds new dimension to the age-old global issues of arsenic contamination through drinking water. The growing threat of entry of the toxin to the non-endemic regions through the food chain has indeed necessitated a thorough investigation of arsenic build-up in the agricultural produce of diverse types. As mentioned earlier, soil acts as an effective sink of arsenic present in the contaminated groundwater used for irrigating the crops.

The soil organic fractions, including humic acid (HA) and fulvic acid (FA), behave as effective accumulators of toxic heavy metals, following the formation of metal- humate complexes (chelates) with different degrees of stability. Besides, soil clays, aluminum oxides and iron oxides, especially the amorphous iron and aluminum oxides in soil, also, influence the arsenic retention by soils, minerals and sediments.

The stability constant (log K) of the complexes formed by the soil HA/FA with arsenic is quite stable even in the presence of competing oxyanions such as phosphate and nitrate. Stability constant values in respect of the humic /fulvic acid fractions of selected organic manures with arsenates in aqueous phases dependence on the nature and properties of the humic polymers, which, in turn, would affect the retention and release of arsenates in soil. Indeed, these are expected to have considerable bearing on the ability of the native soil organic fractions, as well as the incorporated organic manures to sorb arsenates, thereby moderating its toxicity in the soil organic matter stock in the arsenic-affected soils. Sanyal et al. (2012) indicated the use of crop residue, green manure poultry manure, FYM, compost, vermicompost has improved organic matter content of soil and quite effective in minimizing the available arsenic pool in soil and crop intake of arsenic.

With the priorities of understanding the behaviour of arsenic in soil, water and principal crops, quantifying the net toxicities and bio-availabilities of arsenic in soil-water-plant with regard to species-level information of the toxic metalloid, assessing risks of dietary exposures and exploring for possible mitigation options is need of the time and necessary for sustainable agriculture under safe environment.

Visual symptoms of arsenic poisoning

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Addition of organic amendments can reduce arsenic uptake in wheat and maize

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Introduction

Arsenic (As) menace is a great environmental concern because of its cycling in water-soil-plant-human/animal continuum. It is a trace toxic element, which has been affecting more than 66 countries including India, specially the areas of Ganga delta basin (Sanyal et al., 2015). In human, prolonged consumption of As contaminated food and drinking water causes arsenicosis, whose symptoms include mottled dark brown pigmentation on trunk and limb and diffuse bilateral thickening of palm (keratosis). Although, drinking water has been considered as the most potent source for As exposure to human, there are other sources like As contaminated food materials. Indeed, accretion of As in rice grain has been considered as a catastrophe, which is the staple food of the South East Asia (Meharg and Rahman, 2003). Recently, Golui et al. (2017) reported As concentration in rice grain ranging from 2.00 to 1260 mg kg^{-1} with a mean value of 146 mg kg^{-1} in As affected areas of Malda district of West Bengal. Similar elevated levels of As in As contaminated areas of Maner block of the Patna District, Bihar were reported (Singh et al., 2014). Apart from rice, wheat contributes significantly to the cereal basket of India and also one of the prime cereals grown in Ganga Delta Basin. In order to reduce the uptake of As by rice, several agronomic practices including application of amendments (both inorganic and organic) have been tried from time to time. Scanty information is available on use of organic amendments for immobilization of As in contaminated soils under maize and wheat crop particularly in Ganga Delat Basin. In this context, few research findings are presented in the following section.

Research Findings

In view of limited information, a laboratory experiment was conducted by (Mandal etal, 2019a) to study the stability of organo-As complexes as affected by competing anions i.e. phosphate, nitrate and sulphate. For this purpose, humic acid (HA) and fulvic acid (FA) were extracted from farmyard manure (FYM), vermicompost (VC), sugarcane bagasse (SB) and soil. A pot experiment was also conducted with 4 levels each of As (10, 20, 30 and 40 mg kg^{-1}) and amendments (no amendment, FYM, VC and SB at the rate of 10 t ha^{-1} each). Results indicate that stability of FA extracted from sugarcane bagasse have the highest stability constant (log K) as 9.77 and the corresponding mole ratio (x) value of 1.51. The phosphate was the most effective in replacing As from organo-As complexes followed by sulphate and nitrate. Under pot culture study, As content in wheat grain was the lowest in sugarcane bagasse amended soil followed by FYM and VC at all levels of As application.

In another study, a field experiment was conducted to evaluate the efficacy of organic amendments in reducing the availability of As in contaminated soils, followed by its uptake by wheat and maize (Mandal et al., 2019b). Accumulation of total As in wheat and maize grains varied from 0.02 to 0.11 mg kg^{-1} and from 0.23 to 0.29 mg kg^{-1}, respectively, whereas available As in post-harvest soil varied from 1.07 to 1.33 mg kg^{-1} for wheat and from 1.10 to 1.24 mg kg^{-1} for maize. The organic amendments reduced the As accumulation in wheat grain to the extent of 84% (sugarcane bagasse (SB)), 50% (rice straw) and 40% (paddy husk (PH)) compared with control. Similarly, As content in maize grain was the lowest in SB treated soil followed by rice straw and PH.

Conclusion

Higher value of log K for complexation of As with FA extracted from sugarcane baggase suggests that the latter could be a potential complexing agent for As as observed from equilibrium study. This is reflected in the field experiment of bioavailability of As using wheat and maize crops. Highest reduction in uptake of As by wheat and maize was recorded for sugarcane baggase, followed by paddy husk and rice straw. Intervention of organic amendments in As-contaminated soils proved to be effective in reducing the content of As in edible portion of crops.

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Thematic Area: I

Arsenic in Agriculture

Arsenic Residue Toxicity to Vegetable Crops

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Abstract

The subsistence of very high satisfied of arsenic excessive international enactment consecrated for irrigation water can able to the prime factor for the concern of the amount of arsenic found in the soil and different vegetable crops of different countries in Asia such as India and Bangladesh especially. Irrigating in horticultural fields with the harmful arsenic defiled water produces the procurement of arsenic in soil and subsequently an increment of concentration of arsenic in different vegetable crops. In Asia around 100 million rural people are manifested to arsenic polluted drinking waters, agricultural and horticultural products. The prime objectives of the present study were to observe the various levels of arsenic in different vegetable species which were planted on arsenic polluted soil and evaluate the health risks of human being after consumption of the contaminated vegetable. Each of the edible portions of vegetables was detached for entire arsenic to examine the outcome of organic matter on transfer of the venomous elements into the vegetable crops. Important distinction were find out in the concentrations of total and inorganic arsenic in the main edible parts of the different vegetables raised on the contaminated soil, which were usually in the subsequent order: leafy vegetables > stem vegetables > root vegetables > melon and fruit vegetables. A fulfilling single-year study of various leafy vegetables like lettuce, arugula, spinach, and collards transpired a lucrative outcome of compost in decrement of arsenic concentrations in leafy vegetables. Compare to all the surveyed vegetable concentrations to international health-based standards apprise that tomatoes can be grown except obsessive standards also in substantially arsenic contaminated soils.

Green leafy vegetables may also overcome health-based standards in fields where soil arsenic is squatted, having an especially potential aptitude to amassed arsenic.

Keywords: Arsenic, vegetable, soil contamination, health risk assessment

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Arsenic uses in agriculture and veterinary science

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Abstract

Arsenic is a compound component with the image As and nuclear number 33. Arsenic happens in numerous minerals, for the most part in blend with sulfur and metals, yet in addition as an unadulterated essential precious stone. Arsenic is a metalloid. It has different allotropes, yet just the dark structure, which has a metallic appearance, is essential to agricultural chemical industry especially for pesticides and herbicides. Arsenic was additionally utilized in different rural bug sprays and toxic substances. For instance, lead hydrogen arsenate was a typical bug spray on natural product trees, however contact with the compound once in a while brought about mind harm among those working the sprayers. In the second 50% of the twentieth century used to monosodium methyl arsenate (MSMA) and disodium methyl arsenate (DSMA) less harmful natural types of arsenic supplanted lead arsenate in agricultural farming. The biogeochemistry of arsenic is mind boggling and incorporates different adsorption and desorption forms. The harmfulness of arsenic is associated with its solvency and is influenced by pH.Arsenite (AsO3−3) is more solvent than arsenate (AsO3−4) and is increasingly harmful; be that as it may, at a lower pH, arsenate turns out to be progressively portable and poisonous. It was discovered that expansion of sulfur,

phosphorus, and iron oxides to high arsenite soils enormously decreases arsenic phytotoxicity. Arsenic is utilized as a feed added substance in poultry and pig creation, specifically in the U.S. to build weight gain, improve feed productivity, and to forestall malady. A model is roxarsone, which had been utilized as an oven starter by about 70% of U.S. oven cultivators. The Poison Free Poultry Act of 2009 proposed to boycott the utilization of roxarsone in modern pig and poultry creation. Alpharma, an auxiliary of Pfizer Inc., which produces roxarsone, deliberately suspended deals of the medication in light of studies indicating raised degrees of inorganic arsenic, a cancer-causing agent, in rewarded chickens. A replacement to Alpharma, Zoetis, keeps on selling nitarsone, essentially for use in turkeys. And also small amounts of arsenic are a basic dietary component in rodents, hamsters, goats, chickens and probably different species.

Keywords: Arsenic, arsenic uses, agriculture, veterinary science

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Arsenic in agriculture

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Abstract

The problem of arsenic pollution of groundwater used for domestic water supplies is now well recognised in Bangladesh, India and some other countries of South and South-east Asia. However, it has recently become apparent that arsenic-polluted water used for irrigation is adding sufficient arsenic to soils and rice to pose serious threats to sustainable agricultural production in those countries and to the health and livelihoods of affected people. This paper reviews the nature of those threats, taking into account the natural sources of arsenic pollution, areas affected, factors influencing arsenic uptake by soils and plants, toxicity levels and the dietary risk to people consuming arsenic-contaminated rice.

Keywords: Arsenic, Bangladesh, India, Irrigation, Rice soils, Groundwater

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Effects of Arsenic contaminated irrigation water on Plants

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Abstract

Arsenic (As) in groundwater is a major health concern in Bihar and the risks from using shallow tube-wells for drinking-water are well-known. Through irrigation water As entering in the food chain, affecting food safety. This poses a potential dietary risk to human health in addition to the risk from drinking contaminated groundwater. Continuous build-up of As in the soil from As-contaminated irrigation water may reduce crop yields, thus affecting the nutritional status and incomes of rural farming communities.The form and behavior of As vary greatly between flooded soils, such as paddy fields, and non-flooded soils. The most important As species are arsenate (AsV) under non-flooded conditions and arsenite (AsIII) under flooded conditions. AsIII has a higher solubility than AsV, resulting in a higher mobility of As in flooded soils. Long-term use of As-contaminated irrigation water could result in As accumulation in the soil. If absorbed by the crops, this may add substantially to the dietary As intake, thus posing additional human health risks. Over time, As accumulation in the soil could reach soil concentrations toxic to crops, thus reducing yields. As taken by plant tissues causes severe damage to metabolic process in mitochondria and important cellular components, such as lipids, protein, DNA and RNA. In Canola: As causes stunted growth, chlorosis and wilting. In Rice: As reduces seed germination, decrease in seedling height, reduces leaf area and dry matter production. In Tomato: As reduces fruit yield, decreases the leaf fresh weight. Symptoms of As toxicity in plants include

leaf wilting, purpling and root discoloration. It should be noted that the symptoms of arsenic poisoning are similar to those of phosphorus deficiency.

Keywords: Arsenic, Arsenate, Arsenite, Dietary risk, Accumulation, Deficiency, flooded soils, Shallow tube-wells

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The inherent and efficient defense mechanism to combat arsenic induced oxidative damage

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Abstract

Arsenic (As), a metalloid commonly known as "king of poisons" or "inheritance dust" and its lethal potential has been known for millennia that can undergo different ranges of biochemical and physiological interactions in plants. The problem of As has two aspects, it's a menace to sustainable crop production by creating stress as well as human health hazard due to incorporation of As in the food chain. Arsenic is known to induce toxic reactive oxygen species (ROS) which are generated in the cell wall region as well as inside the cell during the process, which affects electron transport chain, membrane permeability, enzyme activity, metabolic pool, ion homeostasis that leads to decrease in plant biomass, leaf chlorosis and necrosis. Usually, Plant roots are first tissue that exposed to As, that inhibits root extension and proliferation as well as compromising plant reproductive capacity through losses in fertility, yield, and fruit production. Between the two inorganic forms, the highly oxidized pentavalent arsenate (AsV) is prevalent in the aerobic environment, while the highly reduced trivalent arsenite (AsIII) is the predominant form in an anaerobic environment. Arsenate reduced to arsenite in plant tissue, does not normally have enough cytoplasmic concentrations to exert

toxicity. Arsenite reacts with—SH group of enzymes and proteins due to suppression of cellular function and death. Plants have innate and efficient defense system to counter attack the toxic effects of As that penetrate into the cytosol. To protect from the sudden increase in intracellular levels of ROS, plant cells contain both enzymatic antioxidants, superoxide dismutase (SOD), catalase (CAT), ascorbate peroxidase (APX), Guaiacol peroxidase (GPOX), monodehydroascorbatereductase (MDHAR), dehydroascorbatereductase (DHAR) and glutathione reductase (GR) as well as nonenzymatic antioxidants, such as ascorbate and γ-Glu-Cys-Gly-tripeptide glutathione (GSH); and accumulation of anthocyanin in the leaves have been found to be very important.Tolerance in plants is achieved by the production of phytochelatin following As exposure which is derived from GSH. The first enzyme that initiates under As induced oxidative damage is SOD which reduce the superoxide radicals into H_2O_2 and O_2. The neutralization of H_2O_2 then carried out by ascorbate- glutathione cycle and catalase (CAT) converts H_2O_2 into H_2O and O_2. This cycle involves two enzymes APX and GR. The levels of SOD, APX, and GR increased with increase in As for scavenging and controlling ROS levels adaptation of plants for oxidative stress. Glutathione (GSH) is one of the major nonprotein sources which has been reported as part of the antioxidant barrier as it is oxidized by ROS and prevents excessive oxidation of sensitive cellular entities. During degradation of H2O2, the ratio of reduced GSH changes to the oxidized GSSG from serving as an indication of cellular redox balance. Glutathione also acts as a precursor for the synthesis of heavy-metal-binding peptides known as phytochelatins (PCs). Thus, GSH is extensively involved in the maintenance of the cellular ionic homeostasis and detoxification mechanisms of heavy metals. Scientists are involved in the research regarding the metabolism, reduction, detoxification and sequestration process of As that can be a basis of overcoming As poisoning.

Keywords: Arsenic, Antioxidative Enzyme, Glutathione, Phytochelatins, Reactive Oxygen Species

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Arsenic contamination in indian agro-ecosystem

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Abstract

Arsenic (As) is a naturally occurring toxic metalloid and occurs mainly in its inorganic forms (Arsenate As V and Arsenite As III) which are more toxic than its organic forms. The chemical is carcinogenic and is naturally found in water supplies and soil, particularly in parts of North-East India. The presence of high concentrations of arsenic in the agricultural system has led to a serious problem. There are two sources of arsenic in agriculture, namely, arsenic coming from deep wells from sites that due to its geological characteristics contain heavy metals and arsenic coming from agro-chemicals and industrial wastes. The contaminated water used in agriculture for irrigation is moving arsenic to soil and crops, which is currently the major source of this element in agriculture. The arsenic adsorbed by crops from contaminated water depends on several factors such as pH, temperature, oxidation state of arsenic, type of soil and crop. It is known that bio-accumulation of arsenic in some crops leads to biomass and yield reduction. Additionally, the agricultural soil is accumulating arsenic from contaminated irrigation water. The bio-accumulation and adsorption of arsenic in soil is affected by its properties such as the content of oxalic, citric and malic acids. The long term use of arsenic contaminated groundwater for irrigation of agricultural soils may lead to excessive accumulation of arsenic in the soil which, in turn, may exert land degradation in terms of loss of yield i.e. decline in crop production and disease. It is highly warranted to initiate monitoring and assessment programmes for arsenic contamination into irrigation groundwater sources, agricultural fields being irrigated using those sources and the crops grown in those fields.

Keywords: Arsenic, contamination, agriculture, soil, toxicity

Arsenic Toxicity in Maize Crop

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Abstract

Arsenic (As) is a metalloid representing an environmental threat due to high toxicity pertaining to its inorganic forms. It has been classified as a human carcinogen by U.S. Environmental Protection Agency. The arsenic concentration in the top soil available to the crop plants increases with the use of arsenic contaminated irrigation water. A high As level in farming affects plant development and adds a risk to human health through consumption. Maize plants essentially take up arsenic through soil, groundwater irrigation or arsenic contaminated additives. As (V) is the major chemical form absorbed by corn plant. Arsenic present in the oxidized form As (V) is reduced within the maize root system to As (III) through phytochelinates and stored in cell vacuoles as an As (III) tristhiolate complex. High As in the above ground parts of the plant provides an exposure passage for humans through food chain. The As concentration has been reported to vary from 0.01 to 0.65 mg kg-1 and from 0.01 to 0.17 mg kg-1 in the shoot and grain of corn plant, respectively. High As level reduces phosphate uptake by plant, leads to oxidative stress and interacts with the sulfydryl and andthiol groups of proteins. Due to As toxicity there in change in the Mg, K and Ca content in maize plant; while Mg and Ca concentration increases K concentration decreases. Its level in maize crop can be indirectly affected by the rhizospheremicroorganisms viz. mycorrhiza that alters the nutritional status of Fe and P. There is lack of information about As species distribution (arsenate, arsenite, arsenic, arsine) in corn grain and food derivatives and the assessment of their bioavailability which is a critical parameter for estimating exposure through consumption of corn based foods.

Keywords: Arsenic, corn, phytochelinates and mycorrhiza

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Arsenic in Rice: its accumulation and probable mitigation

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Abstract

According to recent reports, millions of people across the globe are suffering from arsenic (As) toxicity. Arsenic is present in different oxidative states in the environment and enters in the food chain through soil and water. In the agricultural field, irrigation with arsenic contaminated water, that is, having a higher level of arsenic contamination on the top soil, which may affects the quality of crop production. The major crop like rice (*Oryzasativa* L.) requires a considerable amount of water to complete its lifecycle. Rice plants potentially accumulate arsenic, particularly inorganic arsenic (iAs) from the field, in different body parts including grains. Researchers and practitioners are trying their level best to mitigate the problem of As contamination in rice. However, the solution strategies vary considerably with various factors, such as cultural practices, soil, water, and environmental/economic conditions, etc. The contemporary work on rice to explain arsenic uptake, transport, and metabolism processes at rhizosphere, may help to formulate better plans. Common agronomical practices like rain water harvesting for crop irrigation, use of natural components that help in arsenic methylation, and biotechnological approaches may explore how to reduce arsenic uptake by food crops.

Keywords: Arsenic, rice, soil, uptake, environment

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Arsenic contamination in plant system

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Abstract

Now -a- days, arsenic pollution through food-chain contamination is a major health concern throughout the world. It is widely spread in the soil, water, air and all living systems. Threshold limit of arsenic in irrigation water leading to crop damage is 0.1 mg/l. The drinking water is not the only source of consumption of arsenic in human diet. Irrigating agricultural fields with arsenic contaminated water produces accumulation of arsenic in soil and subsequently an increases of arsenic concentration in crops. International standards of arsenic for drinking water is 0.05 by United States Public Health Standards and World Health Organization. Solubility, mobility, bioavailability and hence toxicity of arsenic depends on its oxidation state and its form (organic or inorganic). Arsenate can compete with phosphate within the plant cells disturbing the energy flow in the cell. Arsenite reacts with a number of enzymes and tissue proteins that can cause inhibition of cellular function and finally death. The reduced arsenite (As^{3+}) form is much more toxic than arsenate (As^{5+}) and organic forms of arsenic (e.g., MMA and DMA). Arsenate is taken up by plants via phosphate uptake system, whereas arsenite is taken up through water channels or aquaporins in the roots. Arsenic is then transported from root to leaves through xylem. Concentration of arsenic in crops depends of many factors, for example, type of crop, arsenic concentration of soil and water, soil type, among others. Different crop plants have exhibited varying tendencies to accumulate arsenic in different plant parts in the following order, root > stem > leaf > economic produce. Plants can combat with arsenic accumulation either by formation of antioxidant enzyme system or by chelating the toxin with certain ligands (e.g. metallothioneins, phytochelatins) or by sequestering them in sub- or extra-cellular organelles and thus prevents the normal metabolic process from the

interference of arsenic. Early symptoms of arsenic poisoning- skin disorders, weakness, anorexia, nausea, vomiting etc. while long term symptoms include acute diarrhoea, edema, enlargement of liver, skin cancer etc.

Keywords: Arsenic, Contamination, Phytochelatins, Sequestration, Toxicity

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Effect of arsenic in agriculture and its remediation

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Abstract

Arsenic is an ordinarily happening part that is extensively dispersed in soils and minerals. Arsenic tarnishing of drinking water is a real and vast issue that sabotages human prosperity and nature. The World Health Organization (WHO) recommends a biggest measure of arsenic of 10 $\mu g\ L^{-1}$ in drinking water. Human activities, which may begin from mechanical waste or conceivably cultivating use of arsenical pesticides. Excess present in groundwater may be a trademark contaminant and it is correct now a troublesome that impacts various districts far and wide. The effect of arsenic contamination in rustic soil and water, impacts crops, decreasing the gather yield and thusly enters to the regular hierarchy. There was a comfortable association between the enacted iron and the amassed arsenic, in all actuality the iron accepts a huge activity for arsenic arrangement. Accumulated arsenic in plants impact the creating frameworks and hence the yield of harvests, similarly as the total of arsenic in yields may influence on adequacy of living animals. Various Studies have indicated

that Arsenic (V) uses a comparable pathway than phosphate to be devoured by the establishment of rice from soil. Guideline kind of arsenic in high-sway soils is arsenic (V), this structure presents various compound comparable qualities of phosphate and get in to plant root tissue through the part of phosphate transporters. A couple of remediation strategies for arsenic from water and soil have been proposed. To lessen arsenic gathering of green soil; the boss can be proposed, for instance, adsorption, precipitation, inverse osmosis and phytoremediation. The phytoremediation of degraded soils with arsenic has been seen as feasible and naturally all around arranged strategy. It is commonly real in the Bengal Delta territory of Bangladesh and West Bengal, India where the groundwater has been extensively advanced to effortlessly drinking and water framework water.

Keywords: Arsenical pesticides, contamination, amassed arsenic, inverse osmosis and phytoremediation.

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Arsenic Contamination of Ground water: Transfer of Arsenic into Food materials and Health risk

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Abstract

Arsenic contamination of groundwater in several parts of the world is a major outcome of natural and/or anthropogenic sources, which is resulting in adverse effects on human health and ecosystem. In India seven states namely West Bengal, Bihar, Jharkhand, Uttar Pradesh within the flood plain of the Ganga River. Assam and Manipur in the flood plain of the Brahamaputra and Imphal rivers and Rajnandgaon village in Chhattisgarh state have so far been reported affected by Arsenic contamination in

groundwater above the permissible limit of 10 μ g/L. People in these affected states have been exposed to drinking Arsenic contaminated hand tube-wells water. Millions of people from the different countries are mainly dependent on ground water containing elevated level of As for the drinking purpose. Arsenic contamination in groundwater has been far reaching results including its ingestion through the food chain, which are in the form of social disorders, health hazards and socioeconomic dissolution besides its sprawling with movement, and exploitation of groundwater. The food crops which are grown using arsenic contaminated water are sold off to other places, including uncontaminated regions where the inhabitants may consume arsenic from the contaminated food. This may give rise to a new danger. Excessive and prolonged exposure of inorganic As within drinking water causing arsenicosis, a deteriorating and the disabling disease majorly characterized by skin lesions and pigmentation of the skin, patches on palm of the hands and soles of the feet. Arsenic poisoning culminates in to potentially fatal diseases like skin and internal cancers. Arsenicosis causes extremely serious consequences for the livelihood, family life, and earning capability when individuals fall victim. Elevated As contamination may resulting in societal stress, disability in individuals, poverty, and decreased market value of potentially contaminated agricultural products resulting in low income to affected farmers. Proper management of As contamination in groundwater in several different parts of the world, followed by detailed outlook in epidemiology and toxicity mechanisms of As in animals and humans. In order to combat arsenic problem, various remediation methods based on conventional, modern, and hybrid technologies for removal of As in several parts of the world have been critically reviewed. The implementations of mitigation options are often facilitated by setting proper guidelines and to control implementation at appropriate intervals. The awareness of the population is deemed equally important in maintaining and selecting mitigation. The risk of dietary exposure to inorganic arsenic through rice, the staple food in rural Bengal, has been noted to pose as great a threat to human health. Organic amendments and augmented phosphate as well as selective micronutrient e.g. zinc and/or iron salts wherever appropriate fertilization showed considerable promise in reducing total and inorganic arsenic accumulation in rice and the consequent dietary risk.

Keywords: Arsenic contamination, groundwater, Health risk, toxicity, Arsenicosis, Arsenic mitigation.

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The negative effect of arsenic in agriculture: Irrigation water, soil and crops, state of the art

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Abstract

The existence of high content of arsenic exceeding international regulations established for irrigation water can be the main factor for the relationship of arsenic content found in soil and crops of many countries around the world such as Bangladesh, Mexico and Spain. The drinking water is not the only source of consumption of arsenic in human diet. Irrigating agricultural fields with arsenic contaminated water produces accumulation of arsenic in soil and subsequently an increase of arsenic concentration in crops. Concentration of arsenic in crops depends of many factors, for example, type of crop, arsenic concentration of soil and water, soil type, among others. In this paper, data from several studies are presented to show that arsenic in irrigation water tends to accumulate in agricultural soil and through several mechanisms is absorbed by crops. The problem of arsenic in agriculture requires more research that allows to know the actual situation and to propose solutions in order to solve some cases and avoid others.

Keywords: Accumulation, concentration, absorption, agriculture, impact

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Negative impact of arsenic in agriculture and its mitigation

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Abstract

Arsenic is a chemical element and is a natural component of the Earth's crust and is widely distributed throughout the environment in the air, water and land. Excess presence of arsenic in the groundwater may lose a problem in drinking as well as irrigation water. Arsenic accumulation in the plants results in the nagative effect of its growth as well as its yield besides it's accumulation in the plants. The amount of arsenic absorbed is influenced by the chemistry of the aqueous phase, including arsenic speciation, the presence and concentration of different kinds of competition for arsenic and pH. The germination of seed decreased considerably due to arsenic toxicity. Higher arsenic concentration can inhibit growth because of interference with plant metabolic processes that often leads to death. Under toxic metal stress, plant organs show a wide-range of secondary stresses; water or osmotic stresses are common among them. Different forms and concentration of As application were recorded to slow down net photosynthesis. Several reports indicated a huge decline in crop yield under As toxicity. Arsenic mitigation technique can be one in 2 different ways- ex-situ technique and in-situ arsenic technique. Ex-situ focus to lower the concentration of As after the water is extracted from the aquifers. Precipitation processes includes coagulation or filtration, direct filtration, coagulation assisted microfiltration, enhanced coagulation,lime softening and enhance lime softening. Adsorption processes it involve the passage of water through a contact bed where arsenic is removed by surface chemical reaction. Membrane processes: this include nanofiltration ultrafiltration, reverse osmosis and electro-dialysis which uses synthetic membrane for removal of many contaminants including arsenic. In situ remediation refers to the technique that makes arsenic immobilization possible within the acquifer itself. Arsenic is mobilized in groundwater

under reducing conditions it is also possible to immobilize the arsenic by creating oxidised condition in the subsurface such as use of atmospheric O_2 for iron and arsenic rich water. Use of atmospheric O_2 and ferrous chloride for low iron and arsenic rich water. Additional remedies for agricultural soil are precipitation, inverse osmosis and phytoremediation. The presence of high Concentration of arsenic in the agricultural system of water soil crop has led to a serious problem and therefore to dimension and solve this problem considerable research has been done around the world and need to be continued.

Keywords: Arsenic, acquifer, groundwater, precipitation, adsorption

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Arsenic behaviour in Soil-Plant-Human Continuum: Impact on agriculture and food safety

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Abstract

Arsenic (As) is a naturally occurring toxic metalloid classified as group 1 carcinogen. It occurs mainly in its inorganic forms (arsenate AsV and arsenite AsIII) which are more toxic than its organic forms. The main reason for As contamination is the biogeochemical weathering of rocks and the release of bound As into groundwater. Human interventions through intensive agricultural practices and excessive groundwater consumption have contributed greatly to the prevailing As contamination. The uptake of arsenic depends on various factors like variety of crop, crop-growing condition (aerobic or anaerobic), water requirement, etc. Within the soil plant system, there's a unquestionable difference in behaviour of As under flooded conditions, where arsenite (AsIII) predominates, and under non-flooded conditions, where arsenate

(AsV) predominates. The former is regarded as most toxic to humans and plants. The long term use of arsenic contaminated groundwater for irrigation of agricultural soils may lead to excessive accumulation of arsenic in the soil as well as in crop grains posing a threat to agricultura sustainability and food safety. A good correlation between arsenic uptake in plants/crops and total arsenic content in soils is not always found. It is revealed that soil total arsenic content isn't likely a true predictor of arsenic uptake and toxicity under different soil types and micro-climatic conditions. It is the bioavailable fragments of total arsenic in specific soil condition, which is potentially causing a threat to the crops/plants. It is not yet possible to predict As uptake and toxicity in plants rely on soil parameters. It is unknown under what conditions and in what time-frame As is build up within the soil. Representative phytotoxicity data necessary to assess current and future soil concentrations aren't yet available. It is necessary to sufficiently understand and quantify the factors determining soil arsenic accumulation, its bioavailability and toxicity to crops in the fields. Identification of geographic areas either presently contaminated with arsenic or vulnerable to its contamination, is a crucial step for risk assessment and developing remediation strategies. The mapping of arsenic content which is being transported from soil or irrigation water to edible plant part, is important for protecting against human arsenic exposure through arsenic contamination of the food chain. Estimation of soil arsenic bioavailability may greatly support the scope of remediation required at contaminated sites. It is concluded that future research and development is to be focused on speciation, transformation and bioavailability of arsenic in soil and associated soil properties to reveal tangible latent risk of soil arsenic contamination to agriculture and related food-chain links.

Keywords: Arsenic contamination, food-chain, toxicity, bioavailability

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Study the irrigation water quality collected from difference sources at Uluberia, West Bengal

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Abstract

Uluberia is situated on the bank of River Hooghly. The problem is erosion of Hooghly River and encroachment in the main land. Thirty six (36.0) water samples were collected from difference sources like, Deep tube well, Shallow tube well, Pond and River water in before monsoon (April-May) and after monsoon (September-October) in year 2011.The same practice fallow for the collection of water samples in next year 2012. The farmers of these areas use difference sources for irrigation. After the analysis of the water sampleswere compared with irrigation water quality chart. Surface water source pond water then river water was found good quality of water for the irrigation purpose in before monsoon were found classes between C1S1-C2S1 and after monsoon were found class C1S1 in 2011 and 2012.They have contain less soluble salt and safe for the irrigation use for any crops. The ground water like deep tube well and shallow tube well water were found high saline water before monsoon in classes between C2S1-C3S1 in both years. Salinity of water high due to the high temperature, low water table, evaporation of soil moisture and accumulation of salt. Irrigation quality of the water after the monsoon (C2S1) improve due to the rain fall and its result infiltrate water in ground and improve water table and quality also. Pond water is most suitable for the irrigation than river water in surface water sources. In ground water regarding deep tub well water were found better compare to the shallow tube well. Shallow tube well water was found highly saline water in both season and both year compare to all water resource use by farmers.

Keywords: irrigation water, Pond water, Soluble salt, Deep tube well

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The negative effect of arsenic in agriculrure

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Abstract

Arsenic is widely distributed in soil, water, air and all living matters. Presently Arsenic pollution through food chain contamination is a major health concern worldwide. The Drinking water is not the only source of consumption of Arsenic in human diet. Irrigating Agricultural fields with Arsenic contaminated water produces accumulation of Arsenic in soil and subsequently an increase in Arsenic concentration in crops. Concentration of Arsenic in crops depends upon many factors, for example- Type of crops, Arsenic concentration of soil and water, soil type etc. Arsenic may occur in both Organic and Inorganic forms. Arsenate can compete with phosphate within the plant cells disturbing the energy flow in the cells. Arsenite reacts with a number of enzymes and tissue proteins that can cause inhibition of cellular function and finally death. Arsenate is taken up by plants via phosphate uptake system, while Arsenite is taken up through water channels or aquaporins in the roots. Arsenic is then transported from root to leaves through xylem. However, different forms of arsenic have different translocation efficiencies. Different crop plants have exhibited varying tendencies to accumulate arsenic in different plant parts in the following order, Root > Stem > Leaf. Economic produce. Plants can combat with arsenic accumulation either by formation of antioxidant enzyme system or by chelating the toxin with certain ligands or by sequestering them in sub- or extra-cellular organelles and thus prevents the normal metabolic process from the interference of arsenic.

Keywords: Arsenic pollution, Food chain, Health hazards, Aquaporins, ligands

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Arsenic compounds: a cause of adverse effects on health

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Abstract

From the time of historical Roman Empire Arsenic compounds is considered as "King of poisons" as well as "poison of kings" because of it's odourless, tasteless qualities, so telling arsenic compounds as "perfect position" will not exaggeration.Usually when concentration of arsenic cross the limit of 8-10 µg/ liter, is known as arsenic contaminated stuff whether it is soil, water, food etc. This concentration exceed the limit declared by world Health Organization, 2003. This concentration of arsenic depends on various factors like type of soil, crop species, water used so on.According to The National Centre for Biotechnology Information (NCBI), Organic fertilizers contain very low amount of Arsenic compared to inorganic (chemical) materials. NCBI collected 226 samples of fertilizers and 273 samples of different pesticides and do atomic analysis on them relation to arsenic concentration. Highest Arsenic amount was in Triple super phosphate, around 31 mg/kg. This arsenic concentration in pesticides ranges from 0.18 mg/kg to 2.53 mg/kg, Glyphosate contains average 1.9 mg/kg arsenic. Their research reveals that agrochemicals especially phosphate fertilizers are major source of arsenic. Arsenic, metals cause many severe disease like chronic kidney disease, improper metabolism, diarrhea, and intestinal infection etc., even cancer also. So as now all of you know how much arsenic Compounds are dangerous to health, that's why for it's mitigation now we have to take some steps ahead. We know that it's sources which are mainly agrochemical. Controlling the use of agrochemical will be a

landmark to mitigate arsenic and other heavy metal and now this thing is possible because now we've lots of substitute also available.

Keywords: Mitigation, Agrochemicals, NCBI, Severe diseases

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Existence of arsenic in agriculture

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Abstract

Access to safe supply of water is fundamental to a country's development and a basic human right worldwide. But the increasing contamination of arsenic in drinking water and soil as well is an important concerning area. Arsenic excess present in groundwater may be a natural contaminant and it is currently a problem that impact many sites around the world, for example India, Spain, Peru, Argentina and Mexico are among the countries where have detected concentration above of 10 ug/L of this pollutant, this concentration exceeds the permissible limit according to WHO, 2003. Arsenic occurs in the earth's crust as the 20 th most abundant element and is mobilized through natural processes such as mineral weathering , biologically aided mineralisation and volcanic emissions as well as through a range of anthropogenic activities and as a result arsenic occurs in all kinds of natural waters. The existence of high content of arsenic exceeding international regulations established for irrigation water can be the main factor for the relationship of arsenic content found in soil and crops of many countries around the world. The drinking water is not the only source of consumption of arsenic in human diet. Irrigating agricultural fields with arsenic contaminated water produces accumulation of arsenic in soil and subsequently an increase of arsenic concentration in crops. Concentration of arsenic in crops depends on many factors such as type of

crop, arsenic concentration of soil and water, soil type etc. There are many studies about the mobilization and accumulation of arsenic in soil, as well as the effect of oxalic, citric and malic acids on this mobilization. Arsenic mobility increases as dose of oxalic acid increases. In other hand, there was a close relationship between the mobilized iron and the mobilized arsenic. In fact the iron play an important role for arsenic mobilization. There are several options to eliminate or reduce arsenic concentration of agriculture soil; the principals can be suggested such as adsorption, precipitation, inverse osmosis and phytoremediation. The phytoremediation of contaminated soils with arsenic has been considered feasible and environment friendly technique. The problem of arsenic in agriculture requires more research that allows to know the actual situation and to propose solutions in order to solve some cases and avoid others.

Keywords: Arsenic, iron, phytoremediation

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Plant breeding: a potential approach to mitigate arsenic contamination

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Abstract

Presence of arsenic in soil is a worldwide problem which is carcinogenic and naturally found in water in supplies and soil particularly in part of north east India, Bangladesh and also present in some other countries like Pakistan, Nepal, Chile, Spain and Argentina. Arsenic is a naturally occurring element that is widely distributed in soil and minerals. The main source of arsenic in agriculture is the irrigation of field crop with arsenic contaminated water i.e. underground water. This arsenic contamination leads to the accumulation of arsenic in soil and finally absorbed by plant /crops which are harmful for humans as well as animals. Arsenate is the most abundant form of arsenic and is structurally similar to phosphate. Therefore it is easily incorporated in to the plant cells through phosphate uptake pathway - the process of the root absorbing nutrients. When plant absorbs arsenic it can be translocated into the edible part of the plants. We can also mitigate arsenic by using plant breeding approaches like use of molecular genetic techniques such as alteration of gene expression characteristics, gene editing to alter target specificity or alternatively, using traditional plant breeding techniques. Phytoremediation and detoxification of arsenic with some novel bacteria is also a very effective way of reducing arsenic toxicity in soil and water.

Keywords: Arsenic, Remediation, Phytoremediation.

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Effect of Arsenic on Soil-Water-Plant Systems

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Abstract

Millions of people across the globe are suffering from arsenic (As) toxicity. Arsenic is present in various oxidative states in the environment and enters in the food chain through soil and water. In the agricultural field when irrigated with arsenic-contaminated water, that is, having a higher level of arsenic contamination on the top soil, which may affect the quality of crop production. The widespread arsenic (As) contamination of groundwater in West Bengal (India) and Bangladesh has remained mostly confined to the Bengal delta basin, bound by the rivers Bhagirathi and Padma,

the spread (detection) of such groundwater arsenic contamination has been reported from several states of India (Assam, Bihar, Uttar Pradesh, Madhya Pradesh, Manipur, Jharkhand, Chhattisgarh, Punjab, Tripura and Nagaland), as well as certain other parts of the Indian subcontinent. The safe limit for arsenic in drinking water has been prescribed by the World Health Organization (WHO) to be 10 µg As./l. The source of such arsenic contamination in groundwater is believed to be of geogenic origin. The primary attention so far has been directed towards solving the problem of contaminated groundwater-based drinking water, notwithstanding the fact that the groundwater in the affected belt is extensively used in the agricultural sector rather than for drinking purpose. The number and extent of well-planned systematic studies conducted so far to examine the influence of arsenic in groundwater, used as irrigation source, on soil-plant-human continuum are only limited. This issue assumes particular significance in view of the fact that what remains essentially a point-source of contamination, as in the case of drinking water, becomes a diffuse-source of contamination of uncertain extent and spread, when arsenic finds its way into the human-food-web through the use of such contaminated groundwater for agricultural irrigation, coupled with the possibility of biomagnification in the food-chain.

Key words: Arsenic contamination, Groundwater, Biomagnification

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Arsenic Contamination in Food and Food Products

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Abstract

Arsenic, an element with atomic number 33 and chemically a metalloid, is one among the 10 metal contaminants specified by the Food Safety and Standards Authority of

India (FSSAI) in the Food Safety and Standards (Contaminants, Toxins and Residues) Regulations, 2011, which came into effect on 5th August, 2011. The single biggest source of arsenic poisoning in countries like India is through contaminated ground water containing arsenic. Arsenic contamination usually takes place in crops because of contaminated sub-surface and ground water used in irrigation. One of the agricultural crops which is prone to arsenic contamination is rice because of the use of large quantity of ground water which may be contaminated with arsenic. One of the recent cases has been seen in case of boro rice cultivation in West Bengal. In prepared food products it can come either through contaminated raw materials or through water used in its preparation or through utensils washed with contaminated water. Fish, shellfish, meat, poultry, dairy products and cereals can also be dietary sources of arsenic, although exposure from these foods is generally much lower compared to exposure through contaminated groundwater. Tobacco plants can pick up arsenic from soil naturally, so the risk of inorganic arsenic poisoning in people consuming tobacco is also high. In seafood, arsenic is mainly found in its less toxic organic form. The FSSAI regulation sets permissible limit of arsenic to be present in different types of food in PPM by weight. The limit is 0.1 in milk and different categories of fats and oils in ppm by weight while it is 0.01 mg/L in natural mineral water. At the international level, The Food and Agriculture Organization/World Health Organization (FAO/WHO) has given a provisional tolerable weekly intake (PTWI) value of 2.1 µg/kg body weight/day.The highest limit is set for molluscs (86 ppm) and fish and crustaceans (76 ppm). It has been reported that inorganic arsenic is more toxic than organic arsenic. In humans it is known to be carcinogen, and affects skin, vascular and nervous system. Symptoms of arsenic poisoning begin with headaches, confusion, severe diarrhoea, and drowsiness which may lead to coma and even death. The commonly used analytical method to estimate arsenic content is using Atomic Absorption Spectroscopy (AAS) and Inductively Coupled Plasma-Mass Spectrophotometer (ICP-MS). As far as prevention and control is concerned, WHO suggests that the most important action in affected communities is the prevention of further exposure to arsenic by the provision of a safe water supply for drinking, food preparation and irrigation of food crops. The 2030 agenda of the United Nations (UN) for sustainable development includes indicator of "safely managed drinking water services" drinking water which aims at pure drinking water accessibility free of chemical contaminants, including arsenic.

Keywords: Arsenic, Contamination, FSSAI, WHO, FAO, UN, Poisoning, AAS, ICP-MS

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Arsenic - a heavy metal

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Abstract

Concentration of arsenic in crops depends on many factors, for example, type of crop, arsenic concentration of soil & water, soil type, among others. Arsenic content found in soil & crops of many countries around the world such as Bangladesh, Mexico & Spain. The drinking water is not only the source of consumption of arsenic in human diet, irrigating or application of arsenic to the agricultural crops also the sorce. For example rice wants arsenic in their life cycle. So rice contains arsenic in that grains. So we have to boil more & eat rice, otherwise arsenic will entering into our body. In India mostly people preferring rice as their favourite food. Heavy consumption of arsenic becomes diarrhea, vomiting, cramping muscles, hair loss & stomach pain. So we have to apply arsenic to agricultural crops critically.

Keywords: Arsenic, Rice, Agricultural crops

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Arsenic contamination in agriculture and some preventive measures

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Abstract

It has been reported that arsenic (As) contamination of groundwater in the Ganga-Brahmaputra plains in India, it's subsequent accumulation in the food chain through the intake of As contaminated food and water, and it's consequences to human health is one of the significant natural calamities to the mankind. Prolonged intake of As contaminated food and water may lead to symptoms such as arsenic poisoning, with cancer of skin, bladder, kidney or lung. Other visible symptoms include change in the skin colour and hard patches on palms and soles. World Health Organization prescribed the permissible limit of arsenic in drinking water 0.01 mg/l. But in various parts of affected areas, values of arsenic in water is much higher than the permissible value. A number of hypotheses suggest that the root of the contamination may lie in the intensive use of groundwater for drinking as well as agricultural practices. The geochemical reactions that are conducive for the dissolution of arsenic in the aquifers can be a potential source of contamination. The worst effected states due to arsenic contamination are - West Bengal, Jharkhand, Bihar, Uttar Pradesh in the flood plain of river Ganga; Assam and Manipur in the flood plain of Brahmaputra and Imphal rivers, Chattisgarh. According to the Food and Agriculture Organization, the bio-magnification of arsenic in the food chain due to the use of arsenic contaminated water for irrigation of staple food crops, is a matter of concern. The drastic increase in the symptoms of arsenic poisoning, among the population residing in the affected areas, are creating an alarming situation demanding immediate measures. Arsenic is naturally present in the aquifers and occurs in both organic and inorganic forms, it's toxicity being largely dependent on its chemical structure and oxidation states. Generally the inorganic form of arsenic in soil is taken up by the plants and transported through food

chain to the higher organisms and is therefore more toxic. Intensive use of arsenic contaminated water for irrigation purpose can be impactful in reducing the productivity due to toxicity in the food grains. The build-up of As in the soil also renders the soil unsuitable for further cultivation. Therefore, increased value of As in soil and groundwater hampers the food safety and security exposing humans and animals to its toxic effects. A few management strategies can be undertaken, like, growing rice in aerobic conditions where As is absorbed in the oxidised Fe surfaces. Arsenate uptake can be suppressed by phosphate and arsenite in the flooded soil can be taken up by aquaporins. Use of deep groundwater for irrigating the crops and identification of arsenic tolerant varieties over conventional varieties can serves as some of the effective safety measures.

Keywords: Arsenic, agriculture, water, food chain

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Arsenic contamination in rice crop

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Abstract

Around 40 percent districts of Bihar have reported arsenic in its groundwater. This comprises more than 67 blocks from 15 districts and covering more than 1600 habitations across the state where arsenic contamination in groundwater exceeds the Bureau of Indian Standard(BIS) limits for safe drinking water of 50 parts per billion

(ppb) and more. If we consider the WHO limits of 10 ppb, the coverage area will be much more and the population which is facing the danger of arsenic hazard will be more than the BIS standard limit. It is estimated that more than 13.85 million people could be under the threat of contamination level above 10 ppb/l, out of which more than 6.96 million people could be above 50 ppb/l, against the total population of these area is around 50 million. Arsenic is a heavy metal and regarded as a toxic element. The primary sources of As are thought to be eroding coal seam and rocks containing sulfide minerals within the Himalayas whose weathering and transport leads to downstream deposition of As in Gangetic plains. The minerals contained within these deposits are oxidized when exposed to the atmosphere, and much of their As content is transferred to secondary phases including iron (Fe) hydroxides, oxyhydroxides, and oxides, collectively referred to as Fe oxides. As is released from Fe oxides into groundwater through microbial processes. Hence, As has been found to be distributed in widespread areas of Gangetic plains of, Bihar. Large areas of paddy soils are contaminated by As due to irrigation with As-tainted groundwater. Rice is one of the most severely affected crop plants with Arsenic contamination as compared to other crop plants like wheat and maize. The reason being the cultivation method of rice that is flooded as compared to non-flooded for wheat. This leads to the development of reducing conditions in soils that in turn result in predominance of As(III) over As(V). Further, rice is one of the most efficient silica accumulators among all crop plants and As(III) too enters through silicic acid transporters in rice. These factors contribute to As accumulation in rice grains in quantities greater than recommended safe limits. The situation becomes of even grave concern considering the very high rice consumption rate in Arsenic contaminated South east Asian countries ranging from 250 to 650 g of rice per day per person. It is imperative to understand the mechanisms of Arsenic uptake and translocation by rice.

Keywords: Arsenic, Rice, Bihar

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Impact of Arsenic to Agriculture in India

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Natural arsenic pollution of drinking water supplies is now known to occur in over 70 countries, affects an estimated 150 million people worldwide .Presence of arsenic in soil is a worldwide problem. The chemical is carcinogenic and is naturally found in water supplies and soil, particularly in parts of North-East India. Arsenate is the most abundant form of arsenic and is structurally similar to phosphate uptake pathway- the process of roots absorbing nutrients. However, when a plant absorbs arsenic it can translocate it up to the edible part of the plant-ultimately arsenic enters food chain. Plants have an inherent capacity to cope with arsenic stress b producing metal chelating peptides called Phytochelatins (PCs). PCs detoxify the arsenic and restrict the movement of arsenic in roots, which in turn helps to reduce the root-to-shoot translocation the arsenic absorbed by the plant in the roots. However, it has recently become apparent that arsenic polluted water used for irrigation is adding sufficient arsenic to soils to pose serious threats to sustainable agriculture production in those countries and to the health and livelihoods of affected people.

Keywords: Arsenic, drinking water, phytochelatins

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Thematic Area II

Biotechnological intervention in arsenic management in crop plants

Biotechnological approaches to mitigate Arsenic contamination through phytoremediation

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Abstract

Arsenic toxicity in soil and water is an increasing menace across the world and it is causing significant health damage to people living in developing and third world countries. Rising arsenic concentrations in groundwater are alarming due to the health risk to plants, animals, and human's health. Many countries around the world including India have reported extensive arsenic groundwater contamination. Use of such contaminated water for irrigation of crops may lead to arsenic contamination of agricultural soils. Plant Growth Promoting Microorganisms have many plant growth promoting traits and minimize the toxic effects of abiotic and biotic stress including heavy metals. Microbes possessing both as resistance and plant growth promoting properties provide tolerance to the plants through several mechanisms that can be direct or indirect. The lead taken by Bihar Agricultural University in order to mitigate the effect of arsenic in groundwater and in rice grain is appreciable, through which the people suffering with it and whole farming community will get benefited with this technology. Phytoremediation may be another sustainable option for developing countries. Many plant species especially aquatic macrophytes and some wetland plants have shown promising ability to uptake arsenic from contaminated environments. Free metal ions in the soil solution are absorbed by plants and are reduced as metal chelates using specific high-affinity ligands (like oxygen-donor ligands, sulfur-donor ligands, and nitrogen-donor ligands). Bioaccumulation in stems and leaves along

phytovolatilization have been shown to be possible tolerance mechanisms by plants against arsenic contamination. Phytoremediation of arsenic-contaminated areas requires the development of new plant varieties with enhanced uptake and accumulation of this metalloid in order to remove as much arsenic as possible from the environment. Next-generation "omic" approaches are paving the way to increase plant tolerance and extraction of arsenic, holding promising results for phytoremediation. Importantly, the next-generation gene-editing CRISPR/Cas9 technology is nowadays an emerging tool to obtain improved crops. This technology is target-specific and allows targeting multiple genes in the genome with high efficiency and specificity. Thereby, this system opens up the possibility to obtain precisely edited crops with enhanced arsenic extraction and accumulation. For example, engineering the aquatic plant Lemna with CRISPR/Cas9 for point mutations in the As(V)/phosphate transporters and As(III)-PCs vacuolar transporters at the same time would be a feasible strategy for cleaning arsenic-contaminated waters.

Keywords: Aresenic, Biotechnology, Omics, CRISPR/Cas9

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Recent advancements in biotechnological intervention to reduce grain arsenic in rice

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Abstract

Inorganic form of Arsenic (As) is considered a potent carcinogen, and its ingestion through foods like rice presents a major risk to human health. It is considered a highly

toxic metalloid which is classified as a non-threshold class-1 carcinogen. Further, millions of people around the world suffer from As toxicity because of the consumption of As-contaminated water and food. Arsenic exposure in plants leads to the alteration of the physiochemical and biological properties and further, loss of crop yield. Naturally plants control quantity of arsenic they accumulate by first chemically converting arsenate into arsenite, which is then returned through the roots back to the soil. Genetic manipulation for arsenic accumulation may offer an efficient approach to scale back its accumulation in rice grains. Target genes have been identified for genetic engineering to reduce As accumulation in grains. The main processes that controls arsenic in grains include As uptake, arsenite (AsIII) efflux, arsenate (AsV) reduction, AsIII sequestration, As methylation and volatilization. Recent advancements has led to characterization of AsV uptake transporter OsPT8, AsV reductase OsHAC1;1 and OsHAC1;2, rice glutaredoxins, and rice ABC transporter OsABCC1, which creates immense possibilities to develop low-arsenic content rice. There are bundles of genes and proteins that are involved in As detoxification, especially the glutathione (GSH) biosynthesis pathway, arsenic methyltransferase and phytochelatin (PC) synthesis which provides an excellent pathways which can be utilized for the low As in rice grains. Furthermore, the other specific approaches such as bio-remediation, bio-augmentation practices and molecular breeding, which have great potential to reduce As uptake from soil to rice grains can also work like wonders.

Keywords: Arsenic, rice, carcinogen, genes, transporters

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Feasible Approach of Arsenic Phytoremediation

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Abstract

Arsenic is a carcinogenic found in the atmosphere, soils, natural waters, and organisms. Arsenic contamination of underground water poses a serious risk to plants and animals including human being. Exposure of arsenic through inhalation or drinking water causes various types of skin lesions such as melanosis, leucomelanosis, and keratosis. While other effect like neurological disorder, high blood pressure, diabetes mellitus, diseases of the respiratory system and of blood vessels including cardiovascular, and cancers typically involving the skin, lung, and kidney are also reported. Mainly, arsenic, a metalloid that generally exists in two redox states: the reduced form, arsenite (AsIII), and the oxidized form, arsenate (AsV). Conventionally applied techniques to remove arsenic species show low removal efficiency, high operational costs, and high-energy requirements. The biological methods, especially phytoremediation, could be cost-effective for protecting human health and the environment from toxic metal contamination. Plants, as sessile organisms, have developed an extraordinary capacity to tolerate arsenic through three main strategies: uptake repression, sequestration into the vacuole, or extrusion. Therefore, arsenic perception and tolerance require a coordinated response that involves arsenic transporters, extrusion pumps, vacuole transporters, and the activation of the phytochelatin biosynthetic pathway. For phytoremediation to become a feasible strategy for arsenic removal from contaminated sites, it is essential to completely understand the molecular mechanisms of arsenic uptake, extrusion, and sequestration, as well as how this response is coordinated. The new genome-wide technologies provide a unique opportunity to understand the molecular mechanisms underlying arsenic perception and accumulation in plants that

will open up new possibilities for phytoremediation of arsenic-contaminated waters and soils.

Keywords: Arsenic, Arsenite, Arsenate, Phytoremediation

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Nano Drugs are new approaches, to alleviate the acute encephalitis syndrome by herbal formulations

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Abstract

Infectious diseases are the 6th leading cause of premature deaths in the world. Emerging and re-emerging infectious diseases continue to impose a constant threat on human population. Among several infectious diseases, viral infections in particular, caused by a range of new and old infectious viruses, challenge survival of mankind on this planet. Acute encephalitis syndrome (AES) is a serious public health problem, caused mainly by viruses. It is claiming thousands of life. The average incidence is between 3.5 and 7.4/100,000 patient-years. AES is defined as a person of any age at any time of year but being higher in children, with the acute onset of fever and a change in mental statuses such as confusion, disorientation, delirium, coma, or inability to talk and/or new onset of seizures. The actual contribution of viruses to AES is not entirely known because of problems associated with laboratory diagnosis and many disorders of central nervous system (CNS) mimicking AES. The majority of cases of viral acute encephalitis syndrome (~90%) have no specific treatment (AES). Specific anti-viral drug for AES is not available till date and cases are managed symptomatically. It is estimated that 70-80% of people worldwide rely on traditional medicine to meet their primary health care needs and also for income generation and livelihood improvement. Herbal plants, plant preparations and phytoconstituents have proved

useful in attenuating infectious conditions and were the only remedies available, till the advent of antibiotics. Herbal sources provides enormous scope to explore and bring out viable alternatives against viral diseases, considering non-availability of suitable drug candidates and increasing resistance to existing drug molecules for many emerging and re-emerging viral diseases. Medicinal plants and natural compounds, such as *Centella asiatica*, *Withania somnifera*, Ginseng, curcumin, resveratrol, *Baccopa monnieri*, Ginkgo biloba and Wolfberry have been applied to prevent or alleviate neurological diseases and relief of neurological symptoms reported in in vivo or in clinical trials. Natural compounds in nanosize range as a therapeutic agent possess the same activity as in native state. Nano drug delivery helps to increase the bioavailability of the drug and thereby specifically target cells and tissues. Nanoparticles, polymeric nanomicelles, complex polymers nanocrystal and nanofibers are used to carry the medicinal plants for drug delivery system in the treatment of neurodegenerative diseases.

Keywords: Acute encephalitis syndrome (AES)

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Genetic Manipulation in Arsenic Transporter genes in Rice to Reduce Arsenic

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Abstract

Rice (*Oryza sativa* L.) grown on arsenic contaminated water and soil gives negative impact to yield, deteriorate grain quality and pose a significant global health risk. Genetic manipulation an important effective approach to reduce arsenic (As) accumulation in rice grains. Genetic engineering in gene that targeted for uptake and reduction in arsenic accumulation in grains have been identified in plant. Major transporter of As in rice roots includes aqua glyceroporins and phosphate trasporter assimilated both organic As [DMA (V) and MMA (V)] and inorganic [As(III) and As(V)] from the rice rhizosphere. A number of key controlling metabolic pathway controlling As uptake in grains include, arsenite (AsIII) efflux, arsenate (AsV) reduction and AsIII sequestration, and As methylation and volatilization. Genectic manipulated recently characterized transporter includes rice ABC transporter OsABCC1, AsV reductase *OsHAC1*;1 and *OsHAC1*;2, rice glutaredoxins, AsV uptake transporter *OsPT8* make insight possibilities to develop low arsenic rice.

Keywords: *Oryza sativa*, arsenic uptake, arsenate reduction, arsenite efflux, methylation

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Thematic area III

Risk assessment of arsenic contamination

Effect of arsenic contamination on human health and its remedies: A case study

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Abstract

In the current senecio, arsenic contamination is becoming a major problem with its direct or indirect effects on the human society. The level of the contaminant has spread over the soil due to contaminated groundwater and other natural sources. But the future consequences of soil contamination are still unknown the most of community, especially in developing countries. Arsenic is a serious instantaneous concern for the people and other life forms regarding the poisoning through crops and vegetables. Contaminated water used for drinking, food preparation and irrigation of food crops are the main cause posing the greatest threat to public health from arsenic. The immediate symptoms of arsenic poisoning include vomiting, abdominal pain and diarrhoea while long term symptoms are usually observed in the skin, and include pigmentation changes, skin lesions and hard patches on the palms, soles of the feet and cancers of the bladder and lungs. Many remediations include physical, chemical, and a few biological methods have been developed and checked. It has suggested that physical and chemical methods are often not as much capable as but limited to applicable for aqueous systems. Although, bio-remedies are most efficient method for restoring the water quality as biological organisms have the ability to degrade, detoxify the contamination. The provision of a safe water supply for drinking, food preparation and irrigation of food crops can reduce the consequences of arsenic contaminations in the affected areas.

Keywords: Arsenic contamination, physical method, chemical method, bio-remedies

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Arsenic contamination in Gujarat

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Abstract

Over the past two or three decades, the arsenic contamination in water is more recognized. The amalgamation of overexploitation of groundwater with over reliance on chemical pesticides and fertilisers helped spreading the contamination of arsenic in normal soils and underground water and relatively in the arsenic free regions. In general, arsenic contamination is more common in the coasted region. Arsenic contamination is not confined to the one or two states of India. Gujarat state with longest coastal line among the states of India is no exception for arsenic groundwater contamination. Arsenic contamination in Gujarat is not confined to the coastal areas but the contamination can be linked to the industrial activities, agricultural activities and associated agro-climatic region and patent material of soil. The Arsenic is geogenic in origin and predominantly found as in sulphide minerals of rocks and soil in nature with average soil abundance from 5.5 to 13 ppm. As reported in 2018, In Gujarat, groundwater of more than 12 districts are affected with arsenic contamination with presence of arsenic over 1 mg/L. In ground water inorganic arsenic is present commonly as arsenate (As V) and arsenite (As III), inter-conversion of which takes place by oxidation-reduction. As (III) is ten times more mobile than As (V). The chemical form of arsenic depends in its source inorganic or organic. Distribution of different forms of arsenic in soil is complex phenomenon. However, the predominant form between pH 3 and pH 7 is H_2AsO^{4-}; between pH 7 to pH 11 is $HAsO^{4-}$; and under reduced condition it is $HAsO_2$ (aq) or H_3AsO_3. The Food and Agriculture Organization's recommended maximum level of As for irrigation water is 100 µg/L. As per BIS 2012 (IS 10500:2012) as well as WHO, the acceptable limit of Arsenic is

0.01 mg/l. The Indian standard IS: 2490-1982 suggests the 0.2 mg/L as maximum limit for sewage effluent discharge or its use for irrigation. It has been observed that higher arsenic levels in sediments were recorded in the summer followed by monsoon and winter seasons. Human system is more sensitive to arsenic compared to animal system. Adverse health hazard of arsenic depend on the dose and duration of exposure. Infants and children might be at greater risk from arsenic toxicity due to higher water consumption on a body-weight basis. In the present context, it is necessary to create awareness and concerted efforts to minimise the exposure to the arsenic contamination by concerted research and management efforts especially in the high arsenic risk areas.

Keywords: Arsenic, Gujarat, transformation, standard

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Arsenic: A Major threat to cause disease in human

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Abstract

Most of the people are suffering many diseases which are caused by the different forms of arsenic contamination. Arsenic plays a major role to cause diseases in humans such as cancers, skin diseases, and hair diseases due to the production of toxic compounds. The people of rural areas are directly consuming the arsenic through in the form of contaminated water or foods which are infested with arsenic. These peoples are unable to go for medical treatment of such disease for example skin, hair, and nails, bringing about different clinical symptoms, like hyperpigmentation and keratosis because it takes a lot of many for the treatment. In starting these diseases not show a major effect on the human body but after some time it may be converted the form of permanent diseases such as lung cancers infect interior organs and it also may be changed in

cardiovascular diseases. Arsenic is one of the most harmful compounds which are present in the environment and continuous up taking of these compounds poisonousness for our body causes the disease called arsenicosis. The early symptoms of arsenicosis are very difficult to analyze that's why it converted into a permanent disease and the cure of this disease is also very difficult. Medication is one of the ways for the cure of arsenicosis has been seen as unacceptable by rehashed application and experience.

Keywords: Arsenic, Human disease, Cancer, Arsenicosis

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Determination of safe limit of Arsenic in irrigation water

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Abstract

A greenhouse pot experiment was conducted to evaluate the impact of arsenic-contaminated irrigation water in rice. There were altogether 10 treatments of arsenate contaminated irrigation water from 0 to 15 mg L-1 and 2 soil types (alluvial and red). Use of arsenate containing irrigation water significantly reduced the plant height, SPAD, tiller number and yield of rice. The arsenic content in the plant parts followed the order root>stem>leaf>grain. Application of 0.25 ppm of irrigation water throughout the crop growth period is safe for both alluvial and red soil when the maximum limit of arsenic content is considered at 0.2 mg kg-1 as per the recommendation of Codex Alimentarius Commission a Joint FAO/WHO Food

Standards Programme, 2014. However as per the Hazard Quotient (HQ) quantified from the solubility free ion activity model (FIAM) up to 1.0 ppm of arsenic loaded irrigation water is safe for application in both alluvial and red soil. The different fractions of arsenic in soil also controls the grain arsenic content as revealed from the regression equation.

Keywords: Arsenate, SPAD, FIAM, Hazard Quotient

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Effects of Arsenic toxicity on growth, yield and quality of seeds of chickpea (*Cicer arietinum* L.)

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Abstract

The concentration of arsenic in the edible parts of a plant depends on the availability of soil availability of soil arsenic and on a plant's capacity for accumulation and translocation. In general, As (V) is taken up and metabolized by plants through the transport channels for phosphate. Because of their chemical similarity, arsenic competes with phosphate for root uptake and interferes with metabolic process like ATP synthesis and oxidative phosphorylation. Arsenate is taken up by phosphate transporter in plants grown on aerobic soils. Plants generally have a low efficiency of arsenic translocation from roots to shoots, may be due to the formation of complexes of arsenite, less toxic organic compounds and thiol compounds and subsequent sequestration in the root vacuoles, or because of the strong efflux of arsenite to the

external medium .At a higher concentration, arsenic is toxic to most plants. It interferes with metabolic processes and inhibits plant growth and development through arsenic induced phytotoxicity. When plants are exposed to excess arsenic either in soil or in solution culture, they exhibit toxicity symptoms such as inhibition of seed germination; decrease in plant height; reduction in root growth; decrease in shoot growth; lower fruit and grain yield and sometimes, leads to death. However, visible injuries and significant changes in growth inhibition and poor yield become apparent only after the plants are exposed to relatively high levels of pollutants or after a certain growth period. Seed is one of the vital components of the world's diet. The uptake, distribution, and effects on growth, yield, and quality of seeds of chickpea in arsenic (As)–contaminated soils revealed that roots accumulated the greatest arsenic (As), followed by stem, leaves, and seeds. Arsenic inhibited the growth of the roots and shoots (as dry weight) by 65% and 60%. The seed yield (g) and number of pods plant−1 decreased by 66 and 53%, respectively. A marked increase in membrane damage coupled with reduction in chlorophyll and relative leaf water content occurred in As-treated plants. The contaminated plants showed 34% and 25% decrease in sucrose content in their leaves and seeds, respectively. The accumulation of seed reserves such as starch, proteins, sugars, and minerals was inhibited significantly due to As-treated plants. Storage proteins such as albumins, globulins, glutelins and prolamins decreased significantly with larger effect on glutelins. The contents of minerals such as calcium (Ca), phosphorus (P), and iron (Fe) declined greatly in the seeds of As-treated plants. The accumulation of amino acids such as lysine, methionine + cystine, phenylalanine + tyrosine, proline, threonine, tryptophan, and valine was inhibited significantly in the seeds of As-applied plants compared to the control. The findings indicated that arsenic application markedly reduced the quality of the chickpea seeds, especially in terms of proteins and minerals.

Keywords: Arsenic, chickpea, yield, storage proteins

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Determination of suitable extractant and risk assessment of Arsenic in Rice

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Abstract

A study was conducted to assess the suitability of the extractants for determination of soil available Arsenic (As) and risk assessment by solubility Free Ion Activity Model (FIAM) under rice (variety: SushkSamrat), for this purpose soil in bulk was collected from six locations of Indo-Gangetic Plain of Bihar, India, varying in physicochemical properties to conduct the pot experiment using five doses of As 0, 10, 20, 40 and 80 mg kg−1. Six extractants namely 0.2 (M) NH4-Oxalate, 0.05 (N) HCl+0.025 (N) H2SO4, 0.5 (M) KH2PO4, 0.5 (N) NH4F, 0.5 (M) NaHCO3 and 0.5 (M) EDTA were used and the results revealed that 0.5 (M) KH2PO4 gave the best correlation with the soil properties and crop uptake and hence proved to be the suitable extractant. The predictability of solubility FIAM in terms of Hazard Quotient (HQ) revealed that 94% variation of As content in rice grain can be explained when 0.5 (M) KH2PO4 is being used as an extractant for determination of soil available As.

Keywords: Arsenic, correlation studies, extractant, Free Ion Activity Model, Hazard Quotient

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Arsenic poisoning: menacing consequences in environment

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Abstract

Arsenic is widely occurring natural element in earth crust having properties of both metal and non-metal, called as metalloid. Arsenic may enters in environment through either volcanic eruption, ground water, soil, wind blow, landform, leaching or food. The concentration of arsenic in natural surface and groundwater is generally about 1(1 ppb), but may exceed 1,000 ppb in contaminated areas or where arsenic levels in soil are high. Arsenic toxicity mediated through enzymatic reaction in metabolism, because of this, it affects almost all kind of living system in the environment. Living organism including human, plant and other land and water living creature showed wide range of sensitivity towards exposure time, exposure concentration and different form of Arsenic (organic and inorganic). Inorganic form is more hazardous than organic form of Arsenic due to their physiological path. Further, Arsenite have more deleterious effect than Arsenate, as it bind to the sulfhydryl group found in protein affecting protein synthesis, while, Arsenate affects key energy producing process (respiration) in cell. In plants, the deleterious effects include inhibition of photosynthesis, respiration, reproduction, reduction in growth and ultimately death. Arsenic-contaminated environments are characterized by limited species abundance and diversity. If levels of arsenate are high enough, only species, which exhibit resistance, may be present. In animal including human, arsenic mainly entered through gastrointestinal tract and methylation and reduction of Arsenic takes place. Long-term exposure to arsenic in drinking-water is causally related to increased risks of cancer in the skin, lungs, bladder and kidney, as well as other skin changes such as hyperkeratosis and pigmentation

changes. Increased risks of lung and bladder cancer and of arsenic-associated skin lesions have been reported to be associated with ingestion of drinking-water at concentrations 50 µg arsenic/litre. The maximum limit or arsenic in complete feed for animals as set by European Union is 2 mg/ kg for all animals and 10 mg/ kg for fish and fur animals. In animal's arsenic consumption above recommended levels may get retained in blood, urine, faeces, hair and tissues which directly or indirectly are consumed by humans and become a source of major health hazard in addition to contaminated milk, meat and eggs. Urine and dung from animals may be a potent source of arsenic exposure to soil which further contributes arsenic exposure to animal and humans through food chain. Chronic exposure or arsenicosis may cause enlargement and stiffness of hock and other joints resulting in paresis, reduced body weight and coffee colored urine with polyuria. While acute or subacute exposure may result in hyperpnoea, diarrhea, stiff gait, paresis, tremor, convulsions and finally death. However, there are some intervention including correction of ground water, limited use of Arsenic contaminated water for Agricultural use, phytoremediation to harvest Arsenic accumulated from shoot and dispose, which can help to reduced health hazards and deleterious effect on plants and environments. In environments where phosphate concentrations are high, arsenate toxicity to biota generally reduced. As arsenate is a phosphate analogue, organisms living in elevated arsenate environments must acquire the nutrient phosphorous yet avoid arsenic toxicity.

Keywords: Arsenic, poisoning, environment, consequences

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Arsenic hazards round the world

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Abstract

This review deals with environmental origin, occurrence, episodes, and impact on human health of arsenic. Arsenic, a metalloid occurs naturally, being the 20th most abundant element in the earth's crust, and is a component of more than 245 minerals. These are mostly ores containing sulfide, along with copper, nickel, lead, cobalt, or other metals. Weathering of rocks converts arsenic sulfides to arsenic trioxide, which enters the arsenic cycle as dust or by dissolution in rain, rivers, or groundwater. So, groundwater contamination by arsenic is a serious threat to mankind all over the world. It can also enter food chain causing wide spread distribution throughout the plant and animal kingdoms. Humans are exposed to this toxic arsenic primarily from air, food, and water. Thousands and thousands of people are suffering from the toxic effects of arsenicals in many countries all over the world due to natural groundwater contamination as well as industrial effluent and drainage problems. Arsenic, being a normal component of human body is transported by the blood to different organs in the body, mainly in the form of MMA after ingestion. It causes a variety of adverse health effects to humans after acute and chronic exposures such as dermal changes (pigmentation, hyperkeratoses, and ulceration), respiratory, pulmonary, cardiovascular, gastrointestinal, hematological, hepatic, renal, neurological, developmental, reproductive, immunologic, genotoxic, mutagenetic, and carcinogenic effects. Key research studies are needed for improving arsenic risk assessment at low exposure levels urgently among all the arsenic research groups.

Keywords: Asrenic, Hyperkeratoses, Genotoxic, carcinogenic effect

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Effect of arsenic contamination in Indo Gangetic zones of Bihar

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Abstract

The presence of high concentration of arsenic in groundwater contamination has emerged as a significant challenge for the human civilization. As we know ground water plays important role in India to meet out water demands in various uses. At present over 80% human population dependence on groundwater for drinking, particularly in the rural areas of India. Deterioration of ground water quality by different contaminants particularly by arsenic is the major problem in many states, mainly in the Ganga-Brahmaputra-Barak fluvial plains. In Bihar, the areas of 15 districts (Begusarai, Bhagalpur, Bhojpur, Buxar, Darbhanga, Katihar, Khagaria, Kishanganj, Lakhisarai, Munger, Patna, Purnea, Samastipur, Saran and Vaishali).located in the vicinity of river Ganga are partially affected by high concentration of Arsenic in ground water. In order to mitigate the arsenic problem and provide safe and quality drinking water to the peoples, government and non-governmental agencies have started several initiatives. The new interventions can be categorized under one of the following approaches, like, treatment of contaminated water; supply of groundwater with acceptable level of arsenic; surface water supply; and rainwater harvesting. Among the different arsenic mitigation interventions in India from these different sustainable approaches, it has been proposed that rainwater harvesting offers the most promising way forward for sustainable arsenic mitigation.

Keywords: Arsenic, Groundwater, Ganga, Rainwater Harvesting

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Mitigation of Arsenic in Soil-Plant (Cauliflower) System through Water Harvesting and

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Field experiment was conducted with a common winter vegetable (cauliflower) at geogenically arsenic contaminated Ghentugachi village of Chakdah block in Nadia, West Bengal, India (23°02'N, 88°34'E, 9.75 masl) for two consecutive years to study arsenic accumulation in the edible head. Water harvesting techniques (through pond water) and organic amendments (Mustard Cake @ 1 t/ha, Vermicompost @ 3 t/ha and FYM @ 10 t/ha) as suitable management strategies have been explored in reducing arsenic contamination in soil-plant system. Results revealed arsenic accumulations to the tune of 0.154-0.168 mgkg-1 in cauliflower head under conventional cultivation practices. Organic amendments and pond water irrigation separately and in combination reduced arsenic contamination in soil-plant system over shallow tube well (STW) drafted underground water irrigated and no manure situation. The use of surface pond water curtails arsenic load by 38.71% over STW. Vermicompost remained most successful among the organic amendments used with arsenic offloading of 81.25% over no manure situation. Conjunctive use of surface (pond) and underground (shallow tube well drafted) water also significantly reduced arsenic contamination in soil-plant system to a tune of 21.51%. The risk of dietary exposure to arsenic was assessed through computation of Provisional Tolerable Weekly Intake (PTWI), Hazard Quotient (HQ) and Target Cancer Risk (TCR). Consumption of cauliflower head was critical in all dietary risk measures especially when associated with other dietary components, and our interventions curtailed their hazard. To employ for theoretical considerations

in areas where cultivation is difficult, solubility FIAM was adopted and considerable relationship was observed among predicted and actual As load.

Keywords: Arsenic, irrigation sources and organic amendments, cauliflower, Solubility- free ion activity model, Risk assessment

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Methods to tackle Arsenic contamination in ground water

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Abstract

Recently, Central Ground Water Board (CGWB) released its report on Groundwater Arsenic Contamination in India. According to their report, 21 states across the country have pockets with arsenic levels higher than the Bureau of Indian Standards (BIS) stipulated permissible limit of 0.01 milligram per litre (mg/l). The states along the Ganga-Brahmaputra-Meghna (GBM) river basin i.e. Uttar Pradesh, Bihar, Jharkhand, West Bengal and Assam are the worst affected. Arsenic contamination in groundwater has penetrated the food chain. Regular extraction of ground water for irrigation deposits arsenic in soil and consequently its uptake by the crops. Also, paddy farms flooded with contaminated water eventually causes accumulation of arsenic in the food crops. Rice husk used as fodder for livestock exposes them to impacts of arsenic contamination. This leads to potential risk for humans also when they consume cattle-based food products. The entry of arsenic into the food chain, in addition to drinking water increases possibilities of biomagnification. Drinking of arsenic-rich water results in skin cancer, cancers of the bladder, kidney and lung, diseases of the blood vessels (Blackfoot disease) and reproductive disorders. Treatment technologies based on oxidation, co-precipitation, adsorption, ion exchange and membrane exchange processes have been developed for removal of arsenic from contaminated water.

Among the various removal technologies, lime softening and iron co-precipitation have been reported to be the most effective. Lime softening is a water treatment process that uses calcium hydroxide, or limewater. Iron co-precipitation implies that arsenic is precipitated using an Iron based substrate. Innovative technologies, such as permeable reactive barriers, phytoremediation, biological treatment and electro kinetic treatment are also being used to treat arsenic contaminated water and soil. Rainwater harvesting and recharging of ground water table can also done to avoid fall in groundwater level and check leaching of metals into groundwater. The available arsenic removal technologies require refinement and operated through a public-private partnership to make them suitable and sustainable for their large scale effective uses.

Keywords: Biomagnification, iron co-precipitation, lime softening

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Cover Crops: A sustainable way of mitigation of Arsenic Contamination in Soil

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Heavy metals problems are increasing day to day in the soil plant continuum as change of land use pattern due to population pressure. Especially problem of arsenic in the soil most of area of world. Several studies reviled that problem of Arsenic is major among heavy metals in the soil. There is need to adopt such approach which should be sustainable for long time. Cover crops are very favourable to mitigate problem of arsenic contamination in the soil. Cover crops are having mechanisms for enhancing organic matter and microbial activities in the soil. Cover crops usually have a dense with the different depth root systems, grow faster and can cover the soil fast compared

to other crop types. Some cover crops can produce chemical compounds that help crops to uptake the heavy metals and compart them into root or/and shoot. A cover crop is a crop of a specific plant that is grown primarily for the benefit of the soil rather than the crop yield. Cover crops are commonly used to suppress weeds, manage soil erosion, help build and improve soil fertility and quality, control diseases and pests, and promote biodiversity. With their characteristics, the use of cover crops as phytoremediation plants was thought to be more efficient and effective to reduce heavy metals content in the soil as well as can improve soil fertility and productivity simultaneously. According to the previous studies, several non-edible plants that can be used as cover crops are potential for phytoremediation process of heavy metals contaminated soils. The inclusions of cover crops in the cropping system is the sustainable way and will reduce contamination of arsenic in the soil.

Keywords: Heavy metals, Arsenic and cover crops

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Safeguarding rice and groundwater from Arsenic contamination

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Abstract

Over the previous years, the degree and level of arsenic pollution of India's groundwater has been developing in colossal extents. Be that as it may, there has not been any incorporated and encompassing methodologies, or any solid activity taken to combat the issues and dangers of arsenic sullying, explicitly by the Indian Government. Over the top and delayed presentation of inorganic As with drinking water is causing

arsenicosis, a falling apart and incapacitating infection portrayed by skin injuries and pigmentation of the skin, fixes on palm of the hands and bottoms of the feet. Arsenic poisoning comes full circle into possibly deadly illnesses like skin and inward malignant growths. Human exposure to As through rice utilization is an overall wellbeing concern. There is a dire need to either remediate As tainted paddy soils, or to screen for low As aggregating rice varities, accordingly restricting the development of As in their grains. The supplementation of redox-sensitive elements (i.e. Fe and Mn) and the incorporation of biochar (BC) may also immobilize As in the paddy environment. Inoculation of microorganisms is another in-situ technique to decrease As in rice grains. Accumulation of Asin rice grains can also be largely reduced through altering the expression of genes in rice plants. Nonetheless, applicability of potential As alleviation approaches is subject to the biogeochemical properties of the paddy agroecosystems, water management practices, accessibility of sources and cost. The best in class information as the option for As free drinking water and different advances (oxidation, coagulation flocculation, adsorption, and microbial) can be utilized for mitigation of the problem of As contamination of groundwater.

Keywords: Arsenic poisioning, groundwater, Contamination, Arsenicosis

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Using Micro flora: Feasible approach for Arsenic Mitigation

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Abstract

Throughout the world Arsenic (As) contamination is a serious issue for plant, animals and environment. Arsenic exposure to plants for long time inhibits their growth and development, leading to either death of plants or to poor yield and quality of crops.

Among major crops, Rice plants potentially accumulate arsenic, particularly inorganic As from the field, in different parts of plant like grains, leaves and stem. Through rice consumption, As enters in our food chain and its concentration is more than the safe limit. As is a carcinogen for human and causes several diseases like skin cancer, liver and kidney problem. A number of mitigation approaches have been tried to control arsenic accumulation in plants. Use of Micro flora like bacteria, algae and fungi in soil could be an approach to decelerate the accumulation of As in different crops. Arsenic poisoning can be minimized through biological immobilization and stabilization using a range of organic compounds, such as biochar. Microbes could play a great role in the natural bioremediation of As polluted geo-aqua ecosystem by forming bio-minerals, such as Arsenic-lollingite. Some of the strain of microorganisms like Bacillus Flexus and *Acinetobacter junii* has a great potential to survive in the As contaminated plot through absorbing the excess As on the cell surface. Some bacteria are used As as a substrate for energy requirement. The specific strains of bacteria performs peculiar function i.e. microbial methylation, biotransformation may generate less toxic forms of As, and thus can be used in the clean-up of As-contaminated sites. Recent studies have suggested that microbial mats are formed by the autotrophic and heterotrophic bacteria like bacillus, coccus, filamentous and rod along with photosynthetic algae that could be responsible for selectively accumulate heavy metal (i.e. Arsenic) and metalloids as having their own niche in the geo aqua ecosystem.

Keywords: Bioremediation, Micro flora, Microbial mats

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Role and Opportunities of Nano Technology for Mitigation of Arsenic Contamination in Bihar

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Abstract

Arsenic is one of the most dangerous heavy metal contaminating ground water and further leading to contamination of soil and food chain as secondary and tertiary contamination over about forty percent districts of Bihar. Long term uptake of arsenic contaminated water or food for causes skin, bladder, kidney and lung cancer, disease of leg & feet blood vessels with reproductive disorders as well as (WHO 2010). About 67 out of 534 blocks in Bihar are facing severe arsenic contamination as per BIS standards (less than 50 ppb), And as per WHO standards (less than 10 ppb) more than 13 million peoples are affected with direct or indirect arsenic contamination. With the development of nanotechnology, research scientists used modified nano particles for treatment of arsenic contaminated water and mitigation of arsenic effected soils. According to Liang and Zhao, starch stabilized magnetite nanoparticles are found to be effective for enhancing sorption and immobilization of arsenate As(V). Results shown that amount of water leachable As(V) was significantly decreased under in situ soil conditions. Amorphous zirconium oxide nano particles and zero valent iron (ZVI) nano particles are also found to be effective in mitigation of arsenic in soil system. Nanotechnology also offers extremely efficient, less expensive methods for water treatment, which may be adopted without using high cost, large infrastructures to overcame the currently faced water purification problems. Still there is a huge opportunities for research and adaptability for use of nanotechnology in arsenic mitigation. Residual effects of ZVI or nanoparticles is still unknown, which is limiting use of nanoparticles for Arsenic mitigation.

Keywords: Arsenic, Nanotechnology, Nanoparticles, ZVI, Water purification, Arsenic mitigation

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Bioremediation for mitigating arsenic content in seeds

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Abstract

Arsenic (As), a potent carcinogen, can cause malignant arsenical skin lesions, respiratory disease, gastrointestinal disorder, liver malfunction, severe cardiovascular malfunction and cancer in human. Vegetables and crops grown in arsenic contaminated groundwater can add many fold daily arsenic intake through human food apart from drinking water. Once released into the environment, arsenic compounds reach water sources, such as rivers and groundwater systems, and subsequently food sources. Arsenic-contaminated soil, sediment, and sludge are the major sources of arsenic in the food chain, surface water, groundwater, and drinking water. The use of arsenic-containing irrigation water can lead to both long-term soil contamination with arsenic and a supply of arsenic to the crop. Rice accumulates a higher amount of arsenic than any other grain crops, largely because of the high availability of arsenic to plants under reduced soil conditions. Other crops like wheat, maize, Indian mustard are grown aerobically leading to abundance arsenate [As(V)] in field. And, the uptake and transport of As(V) occurs through phosphate transporters that is subjected to strong competition with phosphate. Nevertheless, other crop plants (wheat, maize) and

vegetables (tuber, leaf, fruit) also act as sources of As. The highest arsenic accumulation in potato, brinjal, arum, amaranth, radish, lady's finger, cauliflower was observed whereas lower level of arsenic accumulation was observed in beans, green chilli, tomato, bitter guard, lemon, turmeric. Arsenic estimation in seeds is thus more important in order to develop a strategy to reduce arsenic contamination in food chain. Several microorganisms have the capability to mitigate the arsenic content. Plant growth promoting microorganisms (PGPMs) constitute a diverse group of microorganisms including bacteria, fungi and microalgae. These are associated with the rhizospheric zone of plants. They improve plant growth through different mechanisms like increase of nutrients level in plants, improved soil quality, siderophore and hormone production, changes in biochemical properties of plants etc. Another important assistance imparted by PGPMs is the altered speciation of As in the soil through methylation and subsequent change in the bioavailability of As to the plants. Further, a change in As speciation also affects As uptake and transport in plants and arsenic accumulation in seeds.

Keywords: Arsenic, Seed, PGPM

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Spatial mitigation planning with GIS and public participation

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Abstract

A PPGIS (Public Participatory Geographical Information System) has recently been developed in combination with PRA (Participatory Rural Appraisal) and GIS (Geographical Information Systems) methodologies to utilise GIS in the context of the needs of communities that are involved with, and affected by development

programmes. The impact of arsenic poisoning in some areas of India is 'tragic and painful' on patients' health and their social life what was described as the 'worse mass poisoning in human history' in a WHO report. Deep tube well is said to be a source of arsenic-free safe drinking water and people are mainly interested in deep tube well water rather than rainwater harvesting, dug-wells, and pond-sand-filters (PSF). This mainly explores the application and suitability of GIS with local community participation in deep tube well planning for arsenic mitigation. The relevant data for this study were collected from the field survey. The PRA methods were used to obtain social and resource information; while a GIS was used to organise, analyse, and display the information. Participants from three different focus-groups were asked to determine their 'own priorities' for spatial planning of deep tube well for arsenic-free water. The study results valuable community perspectives on deep tube well planning and reveals the suitability of PPGIS in spatial planning for arsenic mitigation with local community mapping overlay. The process of dialogue and preparation of mental mapping within each focus-group participants lead to enhance information about community needs of deep tube well in the study area.

Keywords: Arsenic, Health hazard, GIS, PPGIS, Participatory mental mapping

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Optimal integrated approach to safe rice

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Abstract

Arsenic (As) is a naturally occurring toxic metalloid that occurs in many minerals, as it is the most serious pollution in Southeast Asia, including some Indian states. The primary sources of As are believed to be the eroding of coal seams and rocks containing

sulfide minerals in the Himalayas whose weathering and transport leads to the deposition of As in Gangetic plains downstream. As has been found to be distributed across Uttar Pradesh, Bihar and West Bengal in widespread areas of Gangetic plains. A few potential strategies available that might be used to achieve the goal of decreasing Arsenic (As) in rice grains. However, in future, the design of an "Integrated Optimum Approach" will require the contrasting responses and pros and cons of these strategies. Agronomic practices to regulate the availability of rice plants: Water management, fertilizer modifications, mycorrhizal and microbial treatments are notable examples of agronomic practices. Altering the expression of transporters involved in the absorption, transportation and sequestration of As: As(V) and As(III) absorption and vacuolar sequestration has been targeted leading to decrease in As accumulation in rice shooting and grains. However, altered expression of As transporters, which are basically the transporters of essential elements such as phosphate, silica, boron and water-like compounds, is doubtful given potential effects on the homeostasis of essential elements and compounds. The increased vacuolar sequestration needs to be studied in light of the influence of other essential elements such as Zn on homeostasis, which PCs can also complex. Therefore, the transgenics for multiple nutrient elements need to be analysed. Targeting the mobility of As by enhancing chelator synthesis and by changing its speciation: The approach of methylation and volatilization of As in the atmosphere to reduce As in rice grains is debatable as this may be toxic to farmers working in the field and local residents living in the area.

Keywords: Water management, transporters, methylation, volatilization

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Identification of Low Arsenic Accumulating Genotypes in Vegetable Crops: A Bio-Remediation Approach towards Arsenic Mitigation

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Abstract

Vegetable forms an important part of human diet and is consumed habitually throughout India and abroad. Vegetables differ extensively in their habit and degree of uptake and accumulation of arsenic. This variability is found even amongst cultivars and varieties falling under the same species. Still further, even different edible parts of vegetables vary significant in their concentrations of total and inorganic arsenic. Generally leafy vegetables have greater content than stem vegetables and root vegetables. Melon and fruit vegetables have shown comparatively lower absorption and accumulation. Arsenic easily builds up in the tillage layer from the outside into the soil, and is absorbed by the crops and vegetables which ultimately make way to human body by way of consumption. Excessive amount of arsenic is reported to cause acute and chronic poisoning and promotes cancer development in vital organs in humans besides many other fatal diseases. Hence meticulous strategies are required for its mitigation. In this situation, phyto or bio-remediation may possibly be exploited as a potential solution to deal with the problem of arsenic contamination of soil crop system. Here green plants degrade, assimilate, metabolise or detoxify inorganic and organic chemicals present in the soils to the safe limit of consumption. Bio-remediation is not only cost effective; it has its own aesthetic importance. Identification or development of genotypes of vegetable crop species which uptake and accumulate less arsenic from the soil and where ratio of organic and inorganic form of arsenic is high can undoubtedly be one of the potential remedial options aimed at reducing the toxic effect of arsenic in agricultural systems.

Keywords: Arsenic, Vegetable Crops, Arsenic Mitigation

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Role of organic amendment in arsenic mitigation

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Arsenic (As) is a non-threshold carcinogenic and causes some diseases. Arsenic contamination in groundwater has recently received significant attention. It is a trace toxic element which is of great environmental concern due to its presence in soil, water, plant, animal and human continuum. Geogenic and Anthropogenic sources contribute to the world wide occurrence of as contamination. Release of arsenic from soil and sediments into the soil solution may be enhanced by application of organic amendments. But the main influencing mechanism include competition for available adsorption sites, formation of aqueous complexes and or change in the redox potential of site surface. Organic matter also serve as binding agent and chelation agent which reduce Asmiobility. Organic fraction including humic acid (HA) and fulvic acid (FA) as aeffective accumulator of toxic heavy metal by forming metal humate complexes (chelate) with different degree of stability (Sanyal et al.,2015) and these organo-arsenic complexes were quite stable, even in the presence of competiting oxyanion such as phosphate and nitrate. Organic amendment like FYM, Vermicompost, Muncipal sludge, mustard cake, were formed a stable arseno-humic/fulvic complexes formed in organic manure treated contaminated soil (Ghosh et al., 2012). Thus application of the organic amendment in contaminated soil will facilitate As retention in the affected soil.

Keywords: Amendment, Mitigation, arseno-organic complex, chelate

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Technologies for sustainable mitigation and management of arsenic in West Bengal

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Abstract

The huge amount of rural water supplies in West Bengal (India) and Bangladesh are obtained from groundwater and it is now clear that much of this ground-water contains dangerously high levels of arsenic. This contamination results in the human health hazard of rural people and a rapid solution in this regard is mandatory. People are suffering from water- borne diseases, Skin and systemic manifestations57% of the exposure of chronic arsenic toxicity, Dyspepsia one of the most dominated (38.4%) gastrointestinal syndrome for chronic arsenic toxicity,47.4% total population of west bengal suffered from peripheral neuropathy,4.35% of skin cancer and 0.78% of internal cancers and 50% anemia were caused in the Arsenic contamination is often associated with water that has high iron content which tastes metallic. Sustainable technologies are Two Bucket Treatment Unit consists of two 20-liter plastic buckets stacked vertically, connected with a plastic tube. It removes arsenic by co-precipitation, where by the combined action of alum, a coagulant, and potassium permanganate, anoxidizer, removes arsenic from the contaminated water, and binds it to flocs that are then filtered out by a sand layer in the bottom bucket, three kalshi filter unit is based on a traditional water filter and comprises three clay pitchers, or kalshi, stacked vertically in a frame, the top kalshi contains a layer of iron filings and a layer of coarse sand, the middle kalshi contains a layer of charcoal and a layer of fine sand, and the bottom kalshi collects the filtered water ,Rama Krishna Mission filter unit comprises two clay pitchers (one of them containing a 'tripura' candle filter14) and a plastic bucket. Like the two bucket treatment unit, it uses co-precipitation to remove arsenic, with a pinch of powdered 'ferric alum'15 as the coagulant, and a few drops of bleaching powder

solution as the oxidant. The 'tripura' candle filter ensures that the arsenic-rich flocs are retained in the top kalshi, The Amal unit comprises a conventional two-chamber domestic candle filter body, with a layer of activated alumina granules in the top chamber(in place of a ceramic candle filter). The activated alumina media is a granulated form of aluminum oxide that has a strong affinity for dissolved arsenic, and removes it from solution by adsorbing arsenic molecules onto its surface. The media has a finite adsorption capacity, but can be regenerated by flushing with sodium hydroxide and acid, The simplest approach to household arsenic removal is passive sedimentation, whereby water is aerated (by pouring into a bucket, or by stirring) and then left to settle for 12 hours or so another is arsenic removal by adsorption etc Some tests are for arsenic measurement like GPL Field Test Kit, Merck Field Test Kit, arsenator etc. These are all the technologies are adopted for creating healthy and hygienic environment for the people and by the people. It is vital that public,private and NGOs must work together to mitigate the arsenic hazard for the wellbeing of the people sustainably.

Keywords: Arsenic, mitigation, sustainable, healthy, filter

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Recent development for remediation of arsenic contaminated soils

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Abstract

Arsenic (As) has caused the largest mass poisoning in the history of Universe, where more than 178 million people from 66 countries are potentially exposed to As from all sources. Several chemical, physical, biological remediation technologies are being implemented for removal of As from time to time. For example, soil washing with inorganic acids (e.g. HCl, H3PO4 etc.) and bases (e.g. NaOH), humic substances,

chelants (e.g. Na_2EDTA, [S, S]-EDDS etc.) and recent biosurfactants like saponin, tannic acid etc. were extensively used by several researchers to remove As from soil. Apart from this, use of inorganic phosphate like 0.1 M KH_2PO_4 can remove As by 63% in contaminated soil. Use of organic sources like extracted dissolved organic carbon with high binding capacity results in 88% removal of As from contaminated sites. Recent research on remediation of As contaminated soil has mainly been focused on cost effective and easy to operate immobilization techniques of As in soil. For example, Fe oxides, steel slag, municipal solid waste compost, biochar, nano zero valent iron are commonly used as immobilization agents for As in soil. Phytoextraction by Chinese Brake Fern (*Pteris vittata* L.) along with DAP as phosphate fertilizer can reduce soil As concentration by 18-34%. Two strains viz. AMO-10 and AGH -02 of *Geobacillus stearothermophillus* can oxidize the toxic form i.e. As (III) to non-toxic form i.e. As (V). Penicillium sp. is also able to produce volatile As species and can be effectively used in microbial bioremediation. However, further study on stability of immobilized or sequestered As in soil is required to judge the success of remedial measures in long-run.

Keywords: Arsenic, chelants, biosurfactants, nano zero valent iron, phytoextraction, bioremediation

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Influence of sulphur supply on Arsenic toxicity in rice: A review

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Abstract

Arsenic (As) is a non-essential element whose entry into rice grains is an issue of public concern. The need, therefore, exists to understand the regulatory mechanisms of As accumulation and distribution patterns in plants. Many studies analysed the effect of sulphur (S) supply on As accumulation and distribution in rice plants. Sulphur is an

essential element for plant growth. It plays a crucial role in As regulation through complication of As by S-containing ligands glutathione and phytochelatins which form complexes with As. By means of decreasing As translocation from root to shoot or by efflux of As from root to the growing medium, As complexation plays an important role in As mobility. For the detoxification of As, S assimilation pathway has central importance in plants. Sulphur metabolism synthesize S rich low molecular weight nonproteinthiols (Cys, GSH, phytochelatin) which play an important role in the detoxification of As. When a paddy field is submerged, the redox potential leads to the reduction of sulphate ions to sulphide ions which may form complexes with As ions. The most reduced forms of S, such as sulphides and sulfhydryl groups (thiols), have a high affinity for binding As (III). In the process of As detoxification, the As-thiol complexes are formed which are subsequently transported to vacuoles thus reduce As content in grain. It was observed that As concentrations in shoots decreased with increasing doses of S sources (SO_4^{2-} or S0). This was ascribed to S induced formation of iron plaque, which has been suggested to act as a barrier to As entry into roots through As sequestration.

Keywords: Sulphur, Arsenic, Glutathione and Phytochelatins, Sulphides and sulfhydryl groups (thiols)

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Arsenic Mitigation techniques for soil, waste and water

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Abstract

In India, the current situation containing arsenic contaminant in soil waste and water and that can be difficult to treat and may cause a variety of adverse effect on human

health. Arsenic contamination of soil and water are due to many industrial raw materials, products Arsenic readily changes valence state and reacts to form species with varying toxicity and mobility, effective treatment of arsenic can be difficult. The maximum contaminant level (MCL) of arsenic contaminated drinking water from 0.050 to 0.010 mg L-1 will impact technology selection and application for drinking water treatment, and could result in lower treatment goals for remediation of arsenic-contaminated sites. Different techniques like solidification/ stabilization, vitrification, soil washing/acid extraction, precipitation/ coprecipitation, membrane filtration, phytoremediation and biological treatment are used for decontamination or treat arsenic contaminated water and wide range of influent to the revised MCL for arsenic.

Keyword: Arsenic, maximum contaminant level

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Impact of Addition of Organic Matter on Biovailbility of Arsenic in Rice

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Arsenic is a toxic metalloid which exists in soil environments predominantly as two inorganic species which are arsenite [As(III)] and arsenate [As(V)]. Arsenic (III) has greater toxicity than As(V), and the methylated As is much less toxic than inorganic ones. The contamination of As is more evident and common in rice, which is staple food for Asian countries. This is because As easily solubilizes under water-flooded conditions like paddy soils, through the reductive dissolution of As-bearing Fe oxides and the redox transformation of As(V) to soluble As(III) . Because of this paddy or rice accumulates much more As than upland crops. Therefore rice becomes a significant dietary source of inorganic As for the population in Asian countries. Thus there is need for reduction of contamination of rice by As which can be achieved by reducing the

solubility of As under standing water condition. Addition of organic matter can be one such was. But the effect of organic matter on bioavailability of As is of contrasting nature, studies have found it both to be beneficial and harmful. It can be beneficial because organic matter potentially insolubilizes As through several mechanisms, such as binding of As with phenolic OH, carboxylate, and sulfhydryl groups with/ without ternary complex (cation bridging). The decrease in sodium hydrogen carbonate-extractable As during submerged soil incubation with a well-decomposed farm yard manure and vermicompost. The application of OAs, and their combination, significantly decreased the As load of rice plants. On the other hand, organic matter induces chemical reduction in soil substances, competes for sorption sites with As, and forms soluble complexes with As. This combination results in a potential increase in As solubility and bioavailability. As mobility has been reported to increase in soil following compost or organic amendments. The addition of compost extract to two calcareous soils (compacted in a column bed) led to an increase in bioavailable As concentration in the leachate, although it varied depending on other properties of both soils. Previous reports indicated that in soils and sediments (mine spoils), possessing low or no organic matter, compost addition increased the dissolved organic matter in soil solution, thus raised the leachable amount of As possibly due to competition for adsorption sites on the mineral components. Thus more experiments are required in various soils in order to determine potential impact of organic matter on bioavailability of As.

Keywords: Arsenic, Rice, Organic Matter, Bioavailbility

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Arsenic decontamination through phytoremediation

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Abstract

Arsenic, a class-1 carcinogen is found in the atmosphere, soils, natural waters and organisms. Unlike organic compounds it is not degraded and thus its contamination in the environment is a global concern due to its high toxicity to living organisms. The long-term consumption of arsenic contaminated water and plants from agricultural source poses a serious risk of chronic poisoning among the local population causing diseases such as skin melanoma, cancer and high blood pressure. Plants have developed an extraordinary capacity to tolerate arsenic through uptake repression, sequestration into the vacuole and extrusion. Some of the plants species reported to be suitable for phytoremediation of arsenic are brake ferns, silverback fern, marsh fern, asparagus fern, water hyacinth, duckweeds, water spinach, water ferns, water cabbage, Hydrilla, watercress (Dryopteris), herbs such as Blumea Mikania and Ageratum, shrubs such as Clerodendrum and Ricinus, floating plants such as Eichhornia and Spirodela, common wetland weed (Monochoria) etc. Phytoremediation includes phytoextraction, phytoming, phytostabilization, rhizofiltration and phytovolatilization. The modern technologies may be deployed for arsenic sequestration in the root, hyperaccumulation of arsenic in aboveground tissues and phytovolatilization. Key mechanisms include arsenate reduction, arsenic sequestration in vacuoles of root or shoot, arsenic loading to the xylem, and volatilization through the leaves. There is an awful need to develop cost effective technologies for reducing arsenic from 50 ppb to 10 ppb or for its removal. Conclusively, phytoremediation could be cost-effective for protecting human health and the environment from arsenic contamination.

Keywords: Arsenic, Ferns, Phytoremediation, Phytoextraction, Phytostabilization, phytovolatilization

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Phytoremediation: Green technology for sustainable mitigation of arsenic pollution

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Toxic and carcinogenic nature of arsenic (As) raises global concern with respect to environment, agriculture and subsequently health issues. Anthropogenic activities such as mining, smelting, coal combustion, wood preservation, leather tanning operations and use of As-based pesticides in agriculture have further aggravated the problem and led to elevated concentrations of As in soil. Bangladesh and west Bengal (India) are globally worst affected area because of much higher As concentration (3200 µg/L) in ground water. Those ground water when irrigated in arable crop land cause build-up of As in soil and subsequently through soil and water it enters to the food chain inviting various health problems. Therefore, remediation and restoration of As-contaminated soils is imperative for providing safe food and healthy soils. Among various remediation methods, phytoremediation is a green technology which implies treatment of environmental problems (bioremediation) through the use of plants that mitigate the environmental problem without the need to excavate the contaminant material and dispose of it elsewhere. Phytoremediation has become an effective and affordable technological solution used to extract or remove inactive metals and metal pollutants from contaminated soil. Phytoremediation includes includes phytostabilisation, phytoextraction, phytovolatilisation, rhizofilteration etc. Phytoextraction basically

means to hyperaccumulate heavy metals in plant biomass. Phytostabilization indicates immobilisation of heavy metals in the soil or ground water through absorption or accumulation by roots, whereas rhizofilteration means dsorption/absorption of contaminant into plant roots present in solution surrounding root. Generally for a plant to be used in phytoremediation, it should be metal tolerant; but in extreme forms plants exhibit hyper-tolerance and often accumulates exceptionally high concentrations of those metals or metalloid (in case of As) and are termed as hyperaccumulator. Some of the ferns including *Pteris vittata* L. has been studied extensively as As hyperaccumulator for its potential in producing greater biomass and efficiency in As uptake and also marketed by some agencies. The studies are still carried out on identification of various other genotypes to be used as As hyperaccumulator at various other agro-ecological region around the world. But uptake mechanism of plants depend upon various other mechanisms such as: plant species, properties of the medium, root zone, environmental condition, chemical properties of the contaminant, bio-availability of element, chelating agent etc. Phytoremediation is aesthetically pleasing, less disruptive when compared with other physical and chemical methods, effective in reducing contaminant, less costly, environment friendly and acceptable by the general public. Besides the multiple advantages, the technique also comes with number of limitations such as greater time involved, sensitivity of plant to higher concentration, age of the plant, impact of contaminated vegetation and the problem of disposal. Though the technology is environmentally sound, economically feasible and socially acceptable, it needs long term research to overcome the limitations.

Keywords: Phytoremediation, Arsenic, Green technology

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Remediation of arsenic contamination for agriculture sustainability

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Now-a-days natural pollution and contamination of ground water is known to occur worldwide. Approximately, 30 million people in India live at a risk due to toxicity of heavy metals in drinking water. The presence of high concentrations of arsenic in the agricultural system of water-soil-crop has led to a serious problem. Therefore, to alleviate this problem, considerable research is being done around the world. Two major sources of arsenic in agriculture are: deep wells from sites that contain heavy metals due to its geological characteristics and agrochemicals as well as industrial wastes. The contaminated water used in agriculture for irrigation is moving arsenic to soil and crops, which is currently the major origin of this element in agriculture. Amount of arsenic accumulated in crops depends on many factors viz. type of crop, arsenic concentration of soil and water and soil type. High toxicity and bioavailability of arsenic makes it necessary to conduct research on various aspects viz. knowing the mechanisms by which this element moves through the system water-soil-plant, concentrations affecting yield of crops and health of living beings, geographical distribution and propose economically and technically viable solutions to this problem. Amount of arsenic adsorbed by crops from contaminated water depends on various factors i.e. pH, temperature, oxidation state of arsenic, type of soil and crop. It is known that bioaccumulation of arsenic in some crops leads to biomass and yield reduction. In crops, arsenic concentration is highest at the root, followed by stem, leaf and lowest in grain or fruit. Accumulation of arsenic in the soil is a threat to sustainable agriculture and yet this problem is not widely recognised. Cutting off the main source of arsenic is the only way to deal with arsenic dynamics in agronomic systems. Re-establishing the water levels of groundwater, good irrigation practices and efficient irrigation

technologies can be considered as some promising solutions. Removal technologies to alleviate arsenic from water and soil may also help to deal with this issue. Technologies such as inverse osmosis, precipitation, adsorption and phytoremediation are proposed. Phytoremediation is more eco-friendly and is easier to adopt than its other alternatives. Other technologies including oxidation, coagulation, adsorption, reverse osmosis and ion exchange are introduced for purifying drinking water but are too costly to be incorporated in daily agricultural practices as large volumes of water is required in agriculture. The most crucial need is to estimate the scale of the problem precisely, so that suitable mitigation strategies can be planned out.

Keywords: agrochemicals, geological, mitigation, phytoremediation, precipitation

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Mitigation approach to alleviate Arsenic levels in Agriculture

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Arsenic contamination in the crop lands has been a serious concern because of the high health risk involved as it gets transferred via soil-food chain. High concentration of arsenic in groundwater is a global threat for all living organisms. Naturally, this carcinogenic agent may be reported in aquifers, geological surroundings such as polluted bodies. Arsenic based pesticides and herbicides is the largest anthropogenic input to agricultural soils. Arsenic can harm immune system, kidney, lungs, liver and can even cause bladder cancer. Due to these major health risks, World Health Organization has established a standard value of maximum arsenic contaminant level for drinking water i.e. 10 µg/L. Arsenic is associated with several diseases such as cerebrovascular, cardiac and pulmonary disease. Chronic arsenic ingestion from drinking water can cause skin cancer. Arsenic enters in our body through two pathways; directly through drinking water and indirectly via cultivated foods and crops. Irrigating crops with arsenic contaminated groundwater is leading to elevation in arsenic levels in rice, wheat, vegetables and other agricultural products. Arsenic uptake by crop can be mitigated by water management, using amendments and balanced fertilization. Flooded conditions mobilize soil-bound arsenic through dissolution of Fe oxides. Intermittent flooding and improving drainage are the most promising management techniques to reduce arsenic levels and to produce higher grain yield. Soil amendments also possess the potential of reducing arsenic uptake by plants. Developing those crops that accumulate high levels of arsenic, while preventing arsenic from reaching the edible grain is a great strategy for reducing human exposure to arsenic. Balanced fertilization is an effective way for mitigating arsenic accumulation in food chain and improving fertilizer use efficiency should be a common practice in farming. Biological oxidation, a new treatment technique for arsenic removal, remediates metals in soil and groundwater using certain plants and micro-organisms.

Keywords: Aquifers, anthropogenic, cerebrovascular, intermittent flooding, micro-organisms

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Remediation of Arsenic contamination for Agriculture Sustainability

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Abstract

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heavy metals in drinking water. The presence of high concentrations of arsenic in the agricultural system of water-soil-crop has led to a serious problem. Therefore, to alleviate this problem, considerable research is being done around the world. Two major sources of arsenic in agriculture are: deep wells from sites that contain heavy metals due to its geological characteristics and agrochemicals as well as industrial wastes. The contaminated water used in agriculture for irrigation is moving arsenic to soil and crops, which is currently the major origin of this element in agriculture. Amount of arsenic accumulated in crops depends on many factors viz. type of crop, arsenic concentration of soil and water and soil type. High toxicity and bioavailability of arsenic makes it necessary to conduct research on various aspects viz. knowing the mechanisms by which this element moves through the system water-soil-plant, concentrations affecting yield of crops and health of living beings, geographical distribution and propose economically and technically viable solutions to this problem. Amount of arsenic adsorbed by crops from contaminated water depends on various factors i.e. pH, temperature, oxidation state of arsenic, type of soil and crop. It is known that bioaccumulation of arsenic in some crops leads to biomass and yield reduction. In crops, arsenic concentration is highest at the root, followed by stem, leaf and lowest in grain or fruit. Accumulation of arsenic in the soil is a threat to sustainable agriculture and yet this problem is not widely recognised. Cutting off the main source of arsenic is the only way to deal with arsenic dynamics in agronomic systems. Re-establishing the water levels of groundwater, good irrigation practices and efficient irrigation technologies can be considered as some promising solutions. Removal technologies to alleviate arsenic from water and soil may also help to deal with this issue. Technologies such as inverse osmosis, precipitation, adsorption and phytoremediation are proposed. Phytoremediation is more eco-friendly and is easier to adopt than its other alternatives. Other technologies including oxidation, coagulation, adsorption, reverse osmosis and ion exchange are introduced for purifying drinking water but are too costly to be incorporated in daily agricultural practices as large volumes of water is required in

agriculture. The most crucial need is to estimate the scale of the problem precisely, so that suitable mitigation strategies can be planned out.

Keywords: agrochemicals, geological, mitigation, phytoremediation, precipitation

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Integrated approaches for remediation of arsenic from soil

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Arsenic is one of the toxic metalloids that exists in more than 200 different mineral forms, where 60% of them are normally arsenates; 20% are sulphosalts and sulphides; and the remaining 20% are arsenite, oxides, arsenide, silicates, and elemental arsenic. The intrusion of orogenesis and granitic magma have resulted in the formation of arsenopyrite. Arsenic was first discovered by Albertus Magnus in the year 1250. Under natural condition, arsenic normally cycled at the earth surface where the breakdown of rocks has converted arsenic sulfides into arsenic trioxide. Arsenic (As) causing mutagenic and genotoxic effects on humans, and it has been associated with increased risk of skin, kidney, lung, and bladder cancers. Thus, there is an urgent need to efficiently remove As from contaminated soil and water. During recent years, many treatment options like physical, i.e., soil replacement, soil isolation and vitrification technologies, chemical, i.e., encapsulation, stabilization/solidification and soil washing technologies and biological, i.e., biosorption and metal uptake by plants and microorganism. Despite the success of these processes, they do face certain disadvantages like efficiency, cost and failure during large scale implementation, etc. However, these can be overcome by upgrading them as integrated processes, which has various advantages, such as effectiveness, economic feasibility, short duration,

versatile, eco-friendliness, on-site adaptability, and large scale treatment options etc. Correlating to these factors, combined or integrated treatment processes were reported to be more effective by many researchers worldwide. But, integration of two different processes needs careful understanding and the purpose of the processes. Two processes should to be integrated in such a way that, they should be experimentally feasible even under large scale applications, economically viable and relatively efficient than the individual processes. Owing to these outcomes, integrated processes are gaining popularity toward arsenic removal from various environmental matrices.

Keywords: Integrated approaches, arsenic.

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Microorganisms: A promising eco-safe tool for arsenic mitigation

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Abstract

Arsenic is a potent carcinogenic element which is having a toll on not only humans and animals but also plants. The use of plants, algae, bacteria, and fungi are innovative and potential tools for remediation and mitigation of Arsenic (As) contamination in water and foodstuffs. Microbial mechanisms for As remediation include (hyper) accumulation into vacuoles, sorption (mainly by molecules containing cysteine), methylation to less toxic organic As-species as well their volatilization. Microorganisms are isolated for understanding their specific influence on As bio-volatilization. Isolation of fungi to be applied in bioremediation is a promising tool. Fungi are potential tools for soil remediation because i) they can solubilize, transform

(e.g., methylation and highly contaminated by potentially toxic elements such as cadmium, lead and As. Also, fungi can promote nutrient uptake, redox reactions) and/or absorb potentially toxic elements; ii) they are important biomass producers with known high adsorption capability (living or dead) and, iii) they are frequently found in soils mineralization of organic compounds, resistance to plant diseases and to potentially toxic elements, soil stability, and other important functions. Microbes are proven to mitigate As contaminations are Aspergillus sp. and Penicillium sp. There is a need for the development, optimization, and application of methods/techniques useful to investigate the As biogeochemical cycle and which take into account selected variables such as the type of microorganism, growth conditions, incubation time, and As species. Hence, microorganisms can be an eco-friendly and sustainable answer to the arsenic problem.

Keywords: Arsenic, carcinogenic, bio-volatillization, bioremediation

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Thematic Area IV

Analytical techniques for measurement of arsenic

Effect of Soil pH on adsorption of Arsenic

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Arsenic is a silver-gray or white metallic solid element found in nature. Arsenic combines with other elements to form organic and inorganic compounds. Inorganic arsenic compounds are thought to be more toxic than organic arsenic compounds. Arsenic, a metalloid, exhibits complex chemistry and can be present in several oxidation states (-III, O, III, V). In aerobic environments, As (V) is dominant, usually in the form of arsenate (AsO43-), H3AsO4, H2AsO4 -, HAsO42- and AsO43-. Arsenate and other anionic forms of arsenic behave as chelates and can precipitate when metal cations are present. Metal arsenate complexes are stable only under certain conditions. As (V) can also coprecipitate with or adsorb onto iron ox hydroxides under acidic and moderately reducing conditions. Co precipitates are immobile under these conditions, but arsenic mobility increases as PH increases. Under reducing conditions As (III) dominates, existing as arsenite (AsO3 3-), and its protonated forms H3AsO3, H2AsO3- and HAsO32-. Arsenite can adsorb or coprecipitate with metal sulfides and has a high affinity for other sulfur compounds. Elemental arsenic and arsine, AsH3, may be present under extreme reducing conditions. Biotransformation (via methylation) of arsenic creates methylated derivatives of arsine, such as dimethyl arsine HAs(CH3)2and trimethylarsine As(CH3)3 which are highly volatile. Since arsenic is often present in anionic form, it does not form complexes with simple anions such as CI- and SO42-. Arsenic speciation also includes organometallic forms such as methylarsinic acid (CH3)AsO_2H_2 and dimethylarsinic acid $(CH3)_2AsO_2H$. Many As compounds adsorb strongly to soils and are therefore transported only over short distances in ground water and surface water. Arsenic is associated with skin damage, increased risk of cancer, and problems with circulatory system.

Keywords: Arsenic, soil pH, adsorption

Use of mehlich-3, a multinutrient extractant for extraction of arsenic in soils

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Bioavailable As in soil is the labile fraction that can be taken up by plants and soil organisms. Continuous intake of As leads to its accumulation in the human body, thereby affecting the body system (integumentary, nervous, respiratory, cardiovascular, hematopoietic, immune, endocrine, hepatic, renal, and reproductive) through multiple pathways. It is well known that the mobility and bioavailability of As in the environment is affected by various factors such as pH, redox condition, dissolved organic carbon (DOC), clay content, and iron/manganese/aluminum-metal oxides. A common approach to predict arsenic bioavailability is to correlate extractable fraction with plant concentrations. The most commonly used soil extractants include water, ammonium sulfate [0.05M $(NH_4)2SO_4$], ammonium phosphate (0.05M NH_4H2PO_4), and Mehlich 3 (0.2 M CH_3COOH, 0.25 M NH_4NO_3, 15 mM NH_4F, 13 mM HNO_3 and 1 mM EDTA). These extractions target different As fractions in soils. Mehlich 3, a dilute acid solution at pH 2.5 consisting of a mixture of several chemicals, removes As bound to Fe/Al minerals along with dissolved and adsorbed forms of As. EDTA included in the Mehlich 3 solution targets organically-bound As fraction but may dissolve a considerable proportion (up to 20%) of Fe/Al from amorphous hydrous oxides. Mehlich 3 solution has been widely used to predict nutrient availability for crops. A significant fraction of the As (III) was oxidized to As (V) during mineral acid and alkaline extraction and extraction efficiency also varied with the concentration of the acid and alkali solution.

Keywords: Arsenic, extractants, mehilich-3 and bioavailability

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Key recommendations

The widespread arsenic contamination of groundwater in different parts of Bihar has been found to be distributed over several blocks, located primarily in 18 districts adjoining the river Ganga severe in districts of Bhagalpur, Khagaria, Munger, Begusarai, Lakhisarai, Samastipur, Patna, Vaishali, Saran, Bhojpur, Buxar, and Katihar is of great concern.

On this context of arsenic contamination in the environment and for the quest of an appropriate mitigation strategy webinar on, "Arsenic mitigation a nexus approach" was organized by Bihar Agricultural University which proved to be an excellent platform to exchange concepts and opinions. Renowned and eminent scientists/researchers like Dr. S. K. Sanyal, Ex- Vice Chancellor, BCKV, Mohanpur, Nadia, WB, Dr. Ashok Ghosh, Professor & HoD Research, Mahavir Cancer Institute and Research Center, Patna, Dr. Debasis Chakrabarty, Principal Scientist CSIR-NBRI, Lucknow, Dr. Debapriya Mondal, University of Salford, UK, Dr. Mohammad Mahmudur Rahman, Scientist, University of Newcastle, Australia, Dr. Sheetal Sharma, Scientist II, Soil Scientist-Nutrient Management, IRRI, Dr. Sanjay Jha, Associate Professor, NAU, Navsari, Dr. Sangita Sahni, Scientist, RPCAU, Pusa (Samastipur), Dr. G. Thapa, Department of Biological Sciences, University of Limerick, IRELAND and others have presented their research on Arsenic mitigation strategies. The outcomes/recommendation of the webinar are as follows:

- Arsenic pollution in majority of cases is geogenic in nature and over exploitation of ground water for drinking and irrigation has been implicated as a main cause of its pollution. Hence, now soil also has been a major sink as well source of As in polluted areas.
- Merely determining the total arsenic concentration is insufficient for accurate risk assessment so speciation of As in soil and plant is need of the hour.

- The use of different techniques for separation of arsenic species like ion-exchange, ICP-MS and by octapole collision reaction system and also by microwave-assisted extraction (MAE) is an option for extracting As species from soil.
- Optimum conjunctive use of ground water in the contaminated areas and to increase the use surface water (ponds, lakes, rivers etc.) and recharge of groundwater resources.
- Irrigation of crops should be done with pond-stored groundwater.
- Cultural practices like moderate wetting and drying of rice field should be followed to reduce arsenic absorbance in rice.
- Prefer low-water requiring farmer-attractive cropping sequences (especially for the lean period).
- Increased use of FYM, Vermicompost, Sugarcane bagasse and other manures + green manure crops, inclusion of pulses/other legumes as well as application of appropriate amendments Zn/ Fe/Si salts as and where applicable). Efficiency Order: $FeSO_4 > ZnSO_4 > CaSiO_3$ irrespective of growth stages of crops.
- Identification/development of varieties /crops which accumulate less arsenic in the consumable parts & where ratio of inorganic to organic forms of arsenic is low.
- Cost-effective phyto and bio-remediation options, identification of suitable microbes that can mitigate As in the agroecosystem.

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