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Remediation Measures for Arsenic Pollution of Soil

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Abstract

Arsenic contamination is turning out to be a major problem these days with its increasing area coverage and the number of people affected directly or indirectly. Now, the level of the contaminant has spread over the soil and sediments from groundwater and other natural sources. Arsenic poisoning in groundwater events is familiar to the world, but the consequences of soil contamination are still unrevealed to the community. Long-term use of arsenic contaminated groundwater to irrigate crops, especially paddy (*Oryza sativa* L.) has resulted in elevated soil arsenic levels. Now the time is right to take into account the soil contamination of Arsenic and to devise cost effective remedial measures to correct this problem. This article deals with some of the remediation technologies included within broad category of physical, chemical and a few biological methods.

Introduction

Arsenic (As) is ubiquitous in the environment and highly toxic to all forms of the life. It is a crystalline “metalloid”, a natural element with features intermediate between metals and non-metals. Arsenic ranks as the 20th most occurring trace element in the earth’s crust, 14th in seawater and 12th in the human body. Contamination of terrestrial and aquatic ecosystems by arsenic (As) is a very sensitive environmental issue due to its adverse impact on human health. Although not anthropogenic in origin, the problem of As contamination in West Bengal has been considered of calamitous proportion because significant segment of the population is at high risk, with untold numbers already suffering from irreversible effects of As poisoning. The utilization of these groundwater sources for irrigation and for drinking affected the various forms of life including humans, cattle, and crops, even causing death.

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 main focus of attention, until recently, has been exclusively on arsenic concentration in groundwater-derived drinking water. However, since groundwater is also used extensively (to the tune of 85–90 %) for crop irrigation, the possibility of a build-up of arsenic concentration in agricultural soils and agronomic produce is expected. Indeed, arsenic uptake by crop plants grown in soils contaminated with a high concentration of arsenic, and irrigated with such arsenic contaminated groundwater has been reported by several workers (Sanyal *et al.*, 2015).

Generally, As concentrations in uncontaminated soils seldom exceed 10 mg kg^{-1} . However, anthropogenic sources of As have elevated the background concentration of As in soils. Depending on the nature of the geogenic and anthropogenic sources, As concentration in soils can range from <1 to $250,000 \text{ mg kg}^{-1}$. However, there is a large fluctuation among countries due to variation in soil parent material. According to the U.S. Environmental Protection Agency, the permissible limit of arsenic in soil is 24 mg kg^{-1} . The major sources of its contamination in soil are identified to include many anthropogenic activities e.g. the use of insecticides, herbicides and phosphate fertilizers, mining and smelting, industrial processes, coal combustion, timber preservatives etc.

Remediation of Arsenic Contamination in Soil

Remediation measures can be categorized into three broad categories as has been outlined by Mahimairaja *et al.* (2003).

1. Physical Remediation

Major physical in situ treatment technologies to remediate metalloid-contaminated sites include capping, soil mixing, soil washing, and solidification. The simplest technique for reducing the toxic concentration of As in soils is mixing the contaminated soil with uncontaminated soil. This results in the dilution of As to acceptable levels. Another dilution technique, especially in cultivated soils, relies on deep ploughing, during which the vertical mixing of the contaminated surface soil with less contaminated subsoil reduces the surface contamination, thereby minimizing the potential for As uptake by plants and ingestion of As by grazing animals. However, in this method the total concentration of As in soil will remain the same.

Soil washing or extraction has also been used widely for the remediation of metalloid-contaminated soils and may be applicable for As-contaminated soils to some extent. The success of soil washing largely depends on speciation of As present in the contaminated soils, as it is based on the desorption or dissolution of As from the soil inorganic and organic matrix during washing with acids and chelating agents. Although soil washing is suitable for off-site treatment of soil, it can also be used for on-site remediation using mobile equipment. However, the high cost of chelating agents and choice of extractant may restrict their usage to only small-scale operations.

Arsenic-contaminated soil may be bound into a solid mass by using materials such as cement, gypsum, or asphalt. Capping the contaminated sites with clean soil is used to isolate contaminated sites as it is less expensive than other remedial options. Such covers should obviously prevent upward

migration of contaminants through the capillary movement of soil water. The depth of such cover or "cap" required for contaminated sites should be assessed carefully.

2. Chemical Remediation

Remediation, based on chemical reactions, is becoming increasingly popular largely because of a high rate of success. A number of methods have been developed mainly involving adsorption, immobilization, precipitation, and complexation reactions. However, such methods are often expensive for the remediation of large areas. Two approaches are often used in the chemical remediation of metalloid-contaminated soils: (i) immobilization of metalloids using inorganic and organic soil amendments in order to reduce their bioavailability; and (ii) mobilization of metalloids and their subsequent removal through plant uptake (phytoremediation) or soil washing. Chemical immobilization is achieved mainly through adsorption/precipitation of As in contaminated sites through the addition of soil amendments. Immobilization of As may be achieved by (a) changing the physical properties of the soil so that As is more tightly bound and therefore becomes less bioavailable; (b) chemically immobilizing As either by sorption onto a mineral surface or by precipitation as a discrete insoluble compound; and/or (c) mixing the contaminated soil with uncontaminated soil, thereby increasing the number of As-binding sites.

Liming is increasingly being used as an important soil management practice in reducing the toxicity of certain metalloids in soils. In addition to the traditional agricultural lime, a large number of studies have examined the potential value of other liming materials as immobilizing agents in reducing the bioavailability of a range of metalloids in soils. However, the effect of liming soils on As mobility has been rather inconsistent. Lime addition to As-contaminated soil induces the formation of $\text{CaH}(\text{AsO}_4)_2$, thereby reducing the soluble As in the soil solution for plant uptake and leaching. However, the solubility product of this compound is greater than that for Fe and Al arsenates, which are readily formed in most soils. For this reason, liming is not practiced widely to overcome As toxicity in soils, although liming has been reported to increase the immobilization of and to decrease the plant uptake of As (Jiang and Singh, 1994).

3. Biological Remediation

Bioremediation of soils contaminated with organic compounds such as pesticides and hydrocarbons is widely accepted in which native or introduced microorganisms and/or biological materials, such as compost, animal manures, and plant residues, are used to detoxify or transform contaminants. Although it has several limitations, this technology holds continuing interest because of its cost effectiveness. The unique aspect in bioremediation is that it

relies mainly on natural processes and does not necessarily require the addition of chemical amendments other than microbial cultures and biological wastes.

Existing and developing in situ bioremediation technologies may be grouped into the following two broad categories.

a) Intrinsic bioremediation is where the essential materials required to sustain microbial activity exist in sufficient concentrations that naturally occurring microbial communities are able to degrade the target contaminants without the need for human intervention. This technique is better suited for remediation of soils with low levels of As over an extensive area.

b) Engineered bioremediation relies on various approaches to accelerate in situ microbial degradation rates. This is accomplished by optimizing the environmental conditions by adding nutrients and/or an electron donor/ acceptor, thus promoting the proliferation and activity of existing microbial consortia. It is favored for highly contaminated localized sites. Three approaches could be used in the bioremediation of As-contaminated soils: (i) As could be immobilized into microbial cells through biosorption (bioaccumulation), (ii) toxic As (III) could be oxidized to less toxic As (V), and (iii) As compounds could be removed from the soil by volatilization.

(i) Bioaccumulation

Microorganisms exhibit a strong ability to accumulate As from a substrate containing very low concentrations of this element. Bioaccumulation is activated by two processes, namely biosorption of As by microbial biomass and its byproducts and physiological uptake of As by microorganisms through metabolically active and passive processes. Factors such as soil pH, moisture and aeration, temperature, concentration and speciation of As, soil amendments, and rhizosphere are known to influence the process of bioaccumulation of As in microbial cells. While a number of bacterial and fungal species have been known to bioaccumulate As, some algal species (*Fucus gardneri* and *Chlorella vulgaris*) are also known to accumulate As.

(ii) Microbial Redox Reactions

Heterotrophic bacteria have been found to oxidize toxic As (III) in soils and sediments to less toxic As (V) and thus could play an important role in the remediation of contaminated environment. Because As (V) is strongly adsorbed onto inorganic soil components, microbial oxidation could result in the immobilization of As.

(iii) Methylation of As

A variety of microbes could transform inorganic As into its metallic hydride or methylated forms. Due to their low boiling point and/or high vapor pressure, these compounds are susceptible for volatilization and could easily be lost to the atmosphere. Methylation is considered a major biological transformation through which As is volatilized and

lost. Biomethylation of As in soils and aquatic systems is well documented, as it is important in controlling the mobilization and subsequent distribution of arsenicals in the environment.

Phytoremediation

Phytoremediation is considered a subset of bioremediation that employs plants and their associated root-bound microbial communities to remove, contain, degrade, or render environmental contaminants harmless. This terminology applies to all plant-influenced biological, chemical, and physical processes that aid in the remediation of contaminated medium. It involves soil-plant systems in which metal(loid)s-accumulating plants are grown in contaminated sites. It is considered an economically feasible and environmentally viable technology for remediating metalloid-contaminated systems. The effectiveness of this technology is, however, variable and highly site dependent.

The various mechanisms of phyto-remediation are given below:

Phytoextraction

Few species of plants, while growing on contaminated sediments, accumulate metal arsenic into their roots and translocate them to the surface.

Phytostabilization

Some plants decrease the volume of water percolating through the sediment matrix and thus act as a barrier, preventing contamination of soil. Phytostabilization can also occur through sorption, complexation, or metal valence reduction and serves as a useful tool in mining land areas.

Rhizofiltration

While capillary water is being absorbed through the root xylem, the heavy metals, if present in the water, are also being taken up. This process is called rhizofiltration. Rhizofiltration mainly functions in remediation of extracted groundwater, subsurface or surface water, and wastewater with low concentrations of contaminant.

Phytovolatilization

Plants take up the contaminants from groundwater through their roots, pass them through xylem vessels and volatilize them, and release them during transpiration. This process is called phytovolatilization.

Conclusion

Arsenic (As), is one of the toxic metalloid present in soil in inorganic and organic forms has been acknowledged to pose a very high risk to large human populations. The sources of As are largely geogenic but anthropogenic activities are also contributing to a large extent causing rise in the background levels of As in soil. Although, As is present

in inorganic and organic forms and the inorganic forms are present predominantly in As (V) and As (III) forms, the toxicity does not depend upon the oxidation state of As. Large number of remedial Measures are being used for rectifying the As contaminated soil i.e. physical, chemical and biological. Out of these remedies only biological method is cost effective and can be used *in situ* for the correction of contaminated soils. Also, this method is eco-friendly and can be used in high polluted soils for their correction.

References

Jiang, Q.Q., Singh, B.R., 1994. Effect of different forms and sources of arsenic on crop yield and arsenic concentration. *Wat. Air Soil Pollut.* 74: 321-343.

Mahimairaja, S., Bolan, N.S., Adriano, D.C., Robinson, B., 2005. "Arsenic contamination and its risk management in complex environmental settings." *Advances in Agronomy.* 86: 1– 82.

Sanyal, S.K., Gupta, S.K., Kukal, S.S., Rao, J.K., 2015. Soil degradation, pollution and amelioration. In *State of Indian Agriculture-Soil* (eds. H. Pathak, S. K. Sanyal, and P. N. Takkar), pp. 234-266. National Academy of Agricultural Sciences, New Delhi.