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Biological Wastes the Tool for Biosorption of Arsenic

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Abstract

Arsenic is now a recognized hazard of water, particularly in the groundwater. The problem of naturally occurring Arsenic in the groundwater is more or less a global reporting. Direct consumption of Arsenic contaminated water is extremely harmful. Thus, a lobby of scientists is engaged in the search of proper, efficient and an economical remedial measure for Arsenic contaminated water. In light of the above, the problem was taken into consideration to study the efficacy of the biological tools in removing the arsenic. On the ground of the literary reports many biological wastes, particularly the agrowastes were found to be potential enough; and they can be employed for biosorption of Arsenic.

Keywords: Arsenic; Biosorption; Agrowaste; Phytoremediation; Toxins

Introduction

Arsenic is a naturally occurring element and forms about 1.5 ppm (parts per million) of the Earth's crust. Arsenic is highly toxic in inorganic form. It is also present in sedimentary, igneous and metamorphic rocks. It is present in more than 150 different minerals such as arsenides, sulfoarsenides and arsenites. Natural processes such as weathering of rocks and volcanic emissions eads to mobilization of arsenic into ground and marine water [1,2]. It is also introduced to organic world through various anthropogenic sources such as gold mining, nonferrous smelting, petroleum refining, combustion of fossil fuel in power plants, and the use of pesticides and herbicides containing arsenic [3,4]. Arsenic is listed as WHO's 10 chemicals of major public health concern. The threshold limit of arsenic in drinking-water is 10 µg/litre, as recommended by World Health Organization (WHO). A recent survey revealed that the ground water of several parts of eastern Uttar Pradesh and Bihar contain far higher levels of arsenic than is considered safe for human consumption [5]. Acute exposure to arsenic poisoning include severe stomach pain, nausea, headaches and diarrhea, whereas chronic exposure to arsenic includes pigmentation changes, Blackfoot disease, skin lesions and hard patches on the palms and soles of the feet (hyperkeratosis) and neurotoxicity, conjunctivitis, diabetes, enlarged liver, bone marrow depression, destruction of erythrocytes, high blood pressure and cardiovascular disease, infertility, spontaneous abortion, still birth and preterm birth, DNA damage and cancer of skin, bladder and lungs [6].

Arsenic remediation is a matter of global concern. Several conventional techniques are being used for arsenic remediation, such as oxidation, reduction, precipitation, ion exchange, adsorption, lime treatment, solid-liquid separation, physical exclusion, biological removal processes and reverse osmosis, distillation, coagulation with metal salts, iron or manganese removal method, Iron oxide coated sand method, sulphur modified iron method, Granular ferric hydroxide method, Iron filing and photo oxidation method, Acid washing method, Solidification and stabilization method, capping and Soil removal (excavation) method [5,7]. Conventional technologies for remediation of arsenic contamination are expensive and tedious, hazardous to workers and the disposal of their byproducts not safe environmentally. At this juncture there is urgent need of an economical, eco-friendly alternative for arsenic remediation.

Biosorption

Biosorption is the passive uptake of heavy metals by natural material or dead biomass. Biosorption is an innovative technology which offers best alternative for removal of toxic metals from polluted streams. It involves the use of natural materials such as agricultural residues [8], forestry waste products [9], microorganisms [10], casein [11] and sugar-beet pulp [12]. Natural materials offer high capacity for heavy metals decontamination. Metal entrapment property of these residues are attributed due to the presence of carboxylic, phosphate, sulfate, amino, amide and hydroxyl groups, which are most commonly found in cell wall [13,14]. Biosorption is affected by several factors such as pH, simultaneous presence of other metals, kind of biosorbent material and many more. Metal ion uptake by biosorption depends upon substrate and involves complexation, coordination, chelation, ion exchange, adsorption and inorganic micro precipitation [15]. It is well known that many biomolecules, proteins, polysaccharides and extracellular polymers containing SO_4^{2-}, $RCOO^-$, PO_4^{3-}groups are responsible for the bioaccumulation of heavy metals [16-18]. Biosorption capacity for living plants is observed to be a two-stage process, the first phase is rapid, and second phase is slow. Adsorption by plant materials follows three steps: surface adsorption (physical and chemical), diffusion into particles and adsorption and fixation.

Biosorption mechanisms are of two types:

1. Metabolism Dependent, i.e., transport across cell membrane and intracellular precipitation and accumulation.
2. Metabolism Independent, i.e., precipitation, physical and chemical adsorption, ion exchange, and complexation [14].

Biosorption mechanisms are not dependent on cell metabolism and are rapidly reversible [19-21]. It is reported that dead biomass has higher metal uptake capacity, and the process is nutrient independent [22].

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Researches in biosorption of Arsenic

Some promising arsenic biosorbents were inactive, dead biological biomass, such as algae [23,24], vascular plants [25], fungi [26-29], and bacterial materials [19]. Some biochars were recently focused for arsenic immobilisation from soils and adsorptive removal in aqueous media [30-32] stated that the phosphorylation of biosorbent results into higher binding of arsenates to the cell wall. Arsenic removal from solution is also possible through formation of complexes on cell surface [33]. Plants [20] their parts or their dried, seized, and chemically treated seeds [25,34,35], and also the industrial or agricultural residue of vascular plants such as rice polish and orange wastes [32,36] were evaluated as biosorbent material for arsenic removal [25] reported chelation of As (III) with the –OH groups for different fresh parts of the biomass of *Momordica charantia* following Langmuir and Freundlich sorption models. The nature of sorption were evaluated from Dubinin–Radushkevich (D–R) sorption isotherms and used to explain the heterogeneity of surface energies [25]. Fibres, lignins, cellulose, and other cell walls binding substance, such as phenols, cutin, suberins and waxes have also been suggested as a prominent tool for the purpose [37]. Lignin and pectin, are supposed to be connected with the sorption of metal ions [38-41]. Plant fibres are spacious for sorption of metal ions and have been evaluated for water purification [38]. Alginate, the outer cell wall component of brown algae, Prokaryotes cell walls, is made up of polysaccharides, proteins, and lipids (holds abundant metal-binding functional groups, such as carboxylate, hydroxyl, sulphate, phosphate, and amino groups) and mushrooms, filamentous fungi, chitin, chitosan, and other fungi have been studied for arsenic retention [23,27,28,33,42]. However, not much attention has been given to understand the mechanisms behind these bio-sorption processes [43] reported that bark, chitosan, xanthate, zeolite, clay, peat moss, seaweed, dead biomass are potentially low-cost sorbent and they offers highest heavy metal adsorption capacity [44] observed that **Paecilomyces** sp. is a promising biomaterial for removal or recovery of Arsenic (III) from aqueous solution of arsenic. Biomasss of *Sargassum* sp., brown seaweed can probably perform biosorption process, contributing through ion-exchange reactions. The modified biomass of *Aspergillus niger* suggests their potential applications for the removal of metals from contaminated water [45] Modified biomass of *P. chrysogenum* showed promising results in effective removal of As(V) [28]. Byproduct chars from bio-oil production can be explored as cost effective adsorbents for arsenic removal from contaminated water system [46]. $FeCl_3$ pretreated tea fungus, a waste produced during black tea fermentation are effective bio-sorbent for As(III) and As(V) [42]. Rice polish, an agrowaste proved efficient biosorbent material for arsenic removal from aqueous solution, as according to [36]. Biowaste from fruit juice processing industry are effective biosorbent for removing of toxic metal ions from metal contaminated aqueous solution [41]. Waste biomass of high fiber and protein content are effective to sorb arsenic [14,47] reported that biosorption of As(V) by crab shell based chitosan is a promising technique to treat the arsenic contamination. Pyrolysed sludge from sewage is an effective low cost sorbent material and is able to remove arsenic from water [48].

Conclusion

The applicability of biomass material by biosorption can be explored, as it is easy, economical and eco-friendly. Substantial progress has been made towards an understanding of Arsenic transformation processes in soils [49,50]. The waste products can be utilized again for the removal purpose and then can be disposed of without any harm to the environment. Biosorption provides a potential source to recycle waste products as well as to adsorb and degrade arsenic from contaminated system which is not possible from chemical adsorbent. It acts as easily handled decontamination method. More studies are needed to the better understanding of biosorption, actual arsenic binding mechanism to the biosorbents, metal desorption and biosorbent regeneration, formulation of new biosorbent materials. Commercial interest is also needed for exploitation of new biosorption technology.

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