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REMOVAL OF ARSENIC FROM DRINKING WATER USING MICROORGANISMS: AN EXTENSIVE REVIEW

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ABSTRACT

An extensive review work has been made on the current trends of arsenic biosorption by different microorganisms to purify it from arsenic poisoning. Literatures have suggested that arsenic biosorption may be a very useful technique for the purification of drinking water from arsenic toxicity. Among different microorganisms studies, fungi were proved to be the best biosorbents.

INTRODUCTION

Arsenic contamination is a world-wide environmental problem. It is a metalloid ,silver-gray coloured crystal comprises of about 0.00005% of earth crust and 12th in human body [1]. Arsenic compounds are released in the environment by means of different geological and anthropogenic activities. The major sources of arsenic released in the land are commercial wastes (40%),coal ash (22%),the mining industries (16%) and atmospheric fallout from the steel industries (22%) [2].The normal range of arsenic concentration in uncontaminated soil is between 0.2-40 mg/kg [3] .The ground water and oceans are contaminated with arsenic by means of soil erosion (612 X 108 gm/year) and leaching (2380 X 10^{8} gm/year) [4]. Arsenic exists in the soil in major four valence states namely: -3, 0, +3 and +5,but two forms of arsenic commonly occur in natural water: arsenite ($AsO3^{3-}$) and arsenate ($AsO4^{3-}$) referred to as As III and As V [5-16].Arsenite is 10 to 100 times more toxic than arsenate [7,8].Not only toxicity, but the solubility ,bioavailability and mobility of arsenic varies with its valence [17,18]. Though As III and As V are soluble in water ,but As III is more soluble than As V and thus has increased bioavailability and mobility compared to As V [19].According to WHO recommendation ,0.01 mg/L ha sbeen adopted as drinking water standard, but may countries have retained the earlier guide-line of WHO (i.e, 0.05 mg/L) as listed below:

Table 1: Maximum permissible limits of arsenic for drinking water

Maximum permissible limits (mg / L)	Countries
0.01	USA[9],Taiwan[10],Newzeland[11],India[12]and Vietnam[13]
0.05	China[14],Bangladesh[15],Chile[16],Mexico[17],Nepal [18] and Argentina[19]

All most 21 countries around the world are more or less affected by arsenic pollution.Among them,the largest population is at risk in Bangladesh,followed by West Bengal in India [20-24]. Arsenic removing techniques were extremely studied,but those conventional and non-conventional methods for removal of aqueous arsenic may not successful in the villages of India and Bangladesh due to their technical difficulties 25.But comparatively easier,harmless and cheep microbial techniquesmay be more applicable in those areas. Arsenic was isolated by **Albertus Magnus** in 1250 A.D [26].It is a silver-gray crystal with melting point 817 ^{o}C (at 28 atm),boiling point 613^{o}C ,molecular weight 74.9,vapour pressure 1 mmHg at 372oC and specific gravity 5.73[26].Arsenic exists in the environment in the forms of arsenic acids (H3AsO4,H3AsO4- and H3AsO42-) arsenous acids (H3AsO4,H3AsO4- and H3AsO42-) ,

arsenites (AsO33-), arsenates(AsO43-) dimethyl arsenic acid,methyl arsenic acid,arsine etc 26.As IIIbehaves as a hard acid and generally forms complexes with oxides and nitrogen,where as As V acts as soft acid and complexes with sulphides [27]. Among metalloids,arsenic is uniquely sensitive to mobilization under oxidizing and reducing conditions [28]. H2AsO4- dominates at pH less than 6.9 and under reducing conditions such as at pH≤ 9.2, H3AsO4 predominates. Long-term ingestion of arsenic contaminated water and food may cause several diseases like cancers of different organs namely: skin, lung, liver, bladder, kidney; respiratory illness, cardiovascular disease, birth defects and ultimately leads to death [30-33].Skin lesions are a typical sign of arsenic poisoning [29,34, 35].

Considering the huge problem of arsenic toxicity our present study was intended to focus on the recent trends of research on arsenic biosorption and bioremediation using different microorganisms.

RECENT TRENDS OF ARSENIC REMOVAL USING MICROORGANISMS

Though arsenic is toxic to microorganisms, it inhibits growth,but certain microorganisms can use these compounds for their respiration (such as As V) and different oxidation reactions (such as As III) [36].Thus ,several techniques are used in the field of bioremediation.For this purpose,several microbial strains of bacteria and fungus have been employed in the field of bioremediation of arsenic for last few years.Some important works in this field are summarized below:

Loukidou *et al*.(2001) claimed that biosorption is an alternative method for the removal of toxic materials from waste waters.They used dead cells of Gram-negative bacteria for the removal of penta-valent arsenic and got promising results [37].In the same year ,Visoottiviseth and Panviroj aimed to remove toxic arsenic compounds from liquid medium by introducing thirty eight fungal strains isolated from arsenic polluted areas in Ron Phibum District ,Nakhonsi Thammarat Province,Thiland which can able to grow in 700 mg /L of either arsenite or arsenate medium.Out of them fungal isolates PRMT2-401 was proved to be the most effective at removing arsenite/arsenate from potato dextrose broth.The fungal strain was identified as *Penicillum* sp . Which grew best with pH 5.0 or 7.0 at 27^{o}C .Growth reaches at stationary phase within 4 days. Arsenite/arsenate concentration above 1000 mg /L slightly affected its growth which almost unaffected by lower concentration of arsenite/arsenate (10 and 100 mg/L). Arsenic uptake reaches to its peak at stationary phase. During this phase ,arsenic also excreted from the cells.Arsenic removal was also affected by culture age and cell

viability.Dead cells have no capacity to remove arsenic [38].Hossain and Anantharaman (2006) claimed that Gram +ve bacterium *Bacillus subtilis* is also capable of absorabing arsenic(III) from aqueous solution [39].Pokhrel and Viraraghavan (2006) used *Aspergillus niger* (coated with iron oxide) for removal of arsenic from aqueous solution .This fungal biomass removed 95% As (V) and 75% As(III) at pH 6,but the surface charge did not show any significant change during arsenic biosorption [40].Cernansky *et al*. (2007) used filamentous fungus *Aspergillus clavatus* DESM for biosorption of cadmium and arsenic (ranging from 0.25 to 100 mg /L) from aqueous solutions.They claimed that the experimental biosorption of arsenic and cadmium followed Freundlich equilibrium sorption model [41].Mamisanebei *et al*.(2007) studied the efficiency of tea fungal biomass to remove arsenic (V) from a contaminated water .The pre-treated biomass with FeCl3 was found efficient to remove arsenic (V) upto 79% within 90 minutes [42].Botes *et al*.(2007) introduced two bacterial strains namely: *Stenotrophomonas maltophila* SAAnt 15 and *Serratia marcescens* SAAnt 16 which where able to grow in both arsenite and arsenate. *Stenotrophomonas maltophila* SAAnt 15 was resistant to 10 mmol/Larsenite and 20 mmol/L arsenate,where as *Serratia marcescens* SAAnt 16 grew in 15 mmol/L arsenite in upto 500 mmol/L arsenate ,making effective arsenic resistant organism.During growth ,addition of arsenite and arsenate adversely affected the biomass production.However,reduction of arsenate to arsenite may be the reason for the high arsenate tolerance of the bacteria.Therefore they claimed this hyper resistant bacteria may be use as remediation agents in arsenic contaminated areas [43].Cernasky *et al*.(2007) studied on the abilities of different heat –resistant fungi for biosorption and biovolatilization of arsenic.They recommended few filamentous fungi which are able to adsorb arsenic from aqueous solutions ,among them *Neosartorya fischeri* mycelium is most suitable [44]Aksornchu *et al*.(2008) isolated twenty four bacterial isolates from arsenic contaminated soil collected in Ronphibun District ,Nokorn Srithammarat province. Among them B-4 and B-13may be identified as genus *Streptococcus* and *Xanthomonas* (characterized based on their morphological and biochemical characterization appeared to be novel arsenic adsorbing bacteria [45].Maheswari and Murugesan(2009) isolated 5000 ppm arsenic resistant strain of *Aspergillus nidulans* from arsenic contaminated soil and reported its potential to absorb arsenic (84.35%) after 11 day at pH 4 and temperature 350C [2].Littera *et al*.(2011) introduced two fungal strains namely *: Aspergillus niger* and *Neosartorya fischeri* to evaluated their biosorption capacity of As (V) ranging from 0.2 to 5.0

mg/L at two different pH values (pH 5 and pH 7) .Arsenic biosorption capacity increased linearly with increasing initial arsenic concentration.Treatment with FeCl3 and HCl did not result any significant increase in arsenic biosorption,but treatment with ferric oxyhydroxide was found to be most effective (biosorption resulted upto 100%) [46].Srivastava *et al*.(2011) studied the efficacy of fifteen fungal strains (isolated from arsenic contaminated agricultural soils from State of West Bengal,India)on a medium supplemented with 100,500,1000,5000 and 10,000 mg/L of sodium arsenate for 30 days under laboratory conditions.*Trichoderma* sp.,sterial mycelial strain ,*Neocosmospora* sp. And *Rhizopus* sp. Showed significant efficiency in arsenic biosorption among the fifty strains studied [47].Kamsoman *et al*.(2012) carried out an experiment on biosorption of As (III) from contaminated water using palm bark (PB) biomass under various experimental conditions and reported efficient biosorption of arsenic was resulted at 25^{o}C with pH 7.5 and 90 minutes contact time [48].

Thus, from this present study, it can be recommended that though there are many directions of arsenic removal techniques from drinking water, but its removal by microorganisms especially using fungi may be useful as eco-friendly methods.

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