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TECHNOLOGIES FOR BIOLOGICAL TREATMENT OF WATER CONTAINING SELENIUM: A REVIEW

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Abstract
Selenium (Se) is an important trace element for many organisms, including humans, but is bioaccumulative and toxic at higher levels than homeostatic. Selenium deficiency and toxicity are problems worldwide. The mines, coal-fired power plants, oil refineries and agriculture are important examples of anthropogenic sources, generation of polluted water and wastewater. Due to the harmfulness to the human health and ecotoxicity, the concentration of selenium in drinking water and wastewater must be controlled. This paper provides an overview of biological treatment technologies for the removal of selenium from water.

Keywords: *Selenium bioreduction, Bioreactors, Selenium pollution, Selenium wastewaters*

1. INTRODUCTION

The biological treatment technologies such as: biological reduction using microorganisms, usage of the UASB bioreactors (up-flow anaerobic sludge blanket bioreactor), GE's ABMet (Advanced Biological Metals Removal) technology and others have proven to be attractive and economical methods [1,19]. The choice of method depends on the specific situation and required quality of purified water (Se and other parameters). It is also important that during water treatment, not only selenium but also other parameters must be in accordance with increasingly strict legislation. This is generally achieved by combining the different treatment techniques and phases, which includes the pre-treatment as needed.

2. TECHNOLOGIES OF BIOLOGICAL TREATMENT

Biological reduction by microorganisms has emerged as a relevant and economical method, which can provide the purified water with a few mg of L^{-1} selenium. Bacteria used to reduce selenates and selenites are the terminal electron acceptors during cellular respiration. These methods are based on the natural ability of bacteria, fungi and algae for the methylation process of Se, and its conversion into gaseous forms. These methods are attractive, cheap and environmentally friendly, because few chemicals are used in the treatment. The advantages of these methods are the low price of maintenance costs, and possibility of in-situ application, and disadvantages are: adjustment of environmental parameters (pH, temperature and co-factors); it is necessary to provide the excess of nutrients; it is necessary to separate the plant species and water; long residence time of wastewater; insufficient efficiency of selenium removal [2,3].

The chemical and physical similarity between selenium (Se) and sulfur (S) shows that these two elements have common metabolic pathways in plants. The presence of compounds Se and S indicates that these elements take part in the biochemical processes that affect the uptake, transfer and assimilation during plant development. However, based on small but crucial differences in reactivity and other metabolic interactions, it is concluded that some biochemical processes involving Se may be excluded from those related to S. The such approaches may help in the future application of genetically engineered on the plants with ability for Se accumulation regarding to the environmental protection [4].

Indian mustard (*Brassica juncea L.*) accumulates high concentrations of Se in the plant tissues and Se volatilizes in relatively non-toxic forms, such as dimethyl-selenide. Research has shown that the presence of bacteria in a rhizosphere of Indian mustard is necessary to achieve the best rates of accumulation and volatilization of selenate from the plants [5]. The advantages of these technologies are low costs, the possibility of in-situ application, minimum need for process monitoring, possibility for treatment the large amounts of solution. The disadvantages of these processes are the long average process time and large space requirement.

A significant number of studies have focused on the identification of new bacterial species with high tolerance and reduction capacity for Se removal. It has been observed that many bacterial groups have shown great potential for selenium removal, even under aerobic conditions, e.g., *Pseudomonas moraviensis* that rapidly reduces selenite to Se (0) in aerobic media [6]. The strain was ineffective against selenate, but selenite was removed by more than 95% at 2 days at high selenite concentration.

In the case of mine wastewater, the reduction of Se by bacteria can be inhibited by increased nitrate concentrations. To overcome this problem, a combination of several strains of bacteria (*Pseudomonas*-, *Lisinibacillus*- and *Thauera*-related species) was examined to simultaneously reduce selenates and nitrates from natural wetland sediment that were affected by mine water [7]. This combination can potentially treat wastewater that contains both pollutants at the same time.

Experimental studies of bioreactors use different communities of microorganisms to treat selenium-contaminated wastewater. Biological treatments can be divided into: passive biological treatment [8], sequencing batch reactor [9], electro biochemical reactor- EBR [10], fluidized bed reactor [11], hydrogen-based membrane biofilm reactor [12], ABMet® system [19], Up-flow anaerobic sludge blanket reactor [13], combined process of zero-valent iron and selenate reducing bacterium [14], combined process of activated alumina and bioreactor [15], fungal bioreactor [16].

The UASB (up-flow anaerobic sludge blanket reactor) bioreactors work in the anaerobic conditions and it is necessary to provide nutrients for the microbiological reduction of selenite and selenate to the elemental selenium. The end product of biological reduction is the elemental selenium, a fine precipitate, slightly toxic, which is easily removed from the aqueous phase by the precipitation or reverse rinsing [17,18]. This system requires a source of carbon (such as molasses) and macronutrients necessary to maintain a healthy biomass. Biological reduction in an anaerobic reactor with a charged bed showed the most consistent results. The realized laboratory experiments with bioreactors for selenium removal from the industrial wastewater from refinery have showed that after preconditioning of these water (adjustment the pH to 7, adjustment the salinity and addition of carbon sources), the initial Se concentration that was from 1.5 to 3.6 mg L^{-1} dropped to 0.1 mg L^{-1}, 15 days after the UASB treatment [18].

The GE's ABMet (Advanced Biological Metals Removal) technology is a patented treatment system, based on the bioreduction in active filters that reduces the concentrations of nitrates, selenium and toxic metals. This technology was chosen for the wastewater treatment from the metal recycling plants, coal mines and power plants (after flue gas desulphurization) [19]. The pre-treatment, such as solids, may be required selenium removal.

The biological treatment in a wetland is an integrated system of water, plants, animals, microorganisms and the environment (soil, sun and air), where pollutants are removed by the biological reduction [3]. Clearly, the first advantages of wetlands are low capital costs, maintenance and operation costs [20]. However, several aspects limit their application: a large area land is required; a long period of time to get good results after starting work; the performances affected by different environmental conditions; monitoring the need to maintain an ecologically healthy system; uncertainty about the consistency of the results; risk of groundwater pollution; periodic disposal of accumulated material; possible impact on the reproduction of avocets that feed and nest in the wetlands [3, 20].

3. CONCLUSION

Several conventional bioreactor systems can be used to remove selenates and selenites from wastewater in the form of elemental selenium. Biological treatment has emerged as a "best practice" for Se-containing wastewater due to its advantages such as low operation costs and easier operation system, the ability to adjust capacity as needed, no problems with chemical sludge disposal, the ability to recover Se regarding to reduce the total concentration of Se ions in wastewater. One of the main advantages of microbiological decreasing of selenium is the production of biogenic selenium which has a technical application. The bioreduction of selenium oxyions by various microorganisms that occur in natural and projected environments under different operating conditions has been relatively well researched. It is also necessary to take into account the actual parameters of wastewater such as pH, temperature and volume.

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