Rapid Removal of Selenium from Agricultural Drainage Water in a Biotreatment System

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Executive Summary

Irrigation in certain parts of the San Joaquin Valley, California has produced high selenium (Se) drainage water causing deformities in aquatic waterfowl. In the aquatic system, selenate [Se(VI)] can be used in microbial respiration as a terminal electron acceptor for growth and metabolism. Because of the insolubility of elemental Se [Se(0)] in aquatic systems, bacterial reduction of Se(VI) to Se(0) is considered to be a useful technique for removing Se from agricultural drainage water. An economically feasible biotreatment method should consider two criteria: (i) use an effective and low cost organic carbon source used by Se(VI)-reducing bacteria to reduce Se(VI) to selenite [Se(IV)], and then to insoluble Se(0); (ii) minimize the formation of the most bioavailable organic Se during the maximum removal of Se(VI) from agricultural drainage water through reduction of Se(VI) to insoluble Se(0).

Soluble redox mediators have been successfully used to enhance bacterial reduction of Se(VI) to Se(0). Although the dosage levels of the redox mediators can be relatively low, continuous dosing in a flow-through system would increase cost for Se bioremediation. Non-soluble redox mediators have been used to enhance reductive reaction of decolololorization of azo dyes. Therefore, non-soluble redox mediators with relatively lower redox potentials such as anthraquinone may be better materials that can be used in Se bioremediation because they can be repeatedly used, thus reducing cost. One problem using redox mediators in the reduction of Se(VI) to Se(0) is that redox mediators purchased from chemical companies are normally in an oxidation state. An extra amount of organic carbon is needed for bacteria to reduce the oxidative redox mediators to their reduced forms prior to their function as electron donors to enhance bacterial Se(VI) reduction, thus increasing cost for organic carbon. Inexpensive zero-valent iron (ZVI) can

be used to overcome this problem. Zero-valent iron as an inexpensive and moderately strong reducing agent has been used to remove Se(VI) from water through reductive and adsorptive processes during its corrosion to Fe oxyhydroxides. Although removal of Se by only using ZVI was limited in drainage water due to its high salt contents, it can be used in Se bioremediation to rapidly reduce oxidative redox mediators to their reduced forms for bacteria to enhance Se(VI) reduction to Se(0), thus reducing the usage of organic carbon and then limiting the formation of organic Se.

Activated carbon is commonly used in the removal of environmental contaminants from water due to its strong adsorptive ability. It has been used to trap Se(0). Activated carbon as a carrier of redox mediators has been used to accelerate the degradation of azo dye. It also can serve as a support for the Se(VI) reducing bacteria attachment due to its high surface area. Therefore, a mixture of non-soluble redox mediators, ZVI, and activated carbon may be a better system used in Se bioremediation.

We propose to use non-soluble redox mediators, ZVI, and activated carbon in a biotreatment system in which Se(VI)-reducing bacteria use inexpensive molasses or sucrose to reduce Se(VI) to Se(0) in agricultural drainage water and at the same time accelerate the Se(VI) reduction to Se(0) through redox mediator electron transfer assisted by ZVI. Through a series of batch experiments, we will obtain an optimal condition with activated carbon, a non-soluble redox mediator, and ZVI for rapid bacterial reduction of Se(VI) to Se(0). Then, we will build a flow-through bioreactor filled with a mixture of activated carbon, a non-soluble redox mediator, and ZVI for bacterial reduction of Se(VI) to Se(0). The changes in Se chemistry in the bioreactor will be monitored by analysis of Se species in the drainage water samples. After completing the proposed study, we will design a pilot-scale bioreactor to remediate Se-contaminated agricultural drainage water in field.