Selenium Removal from Agricultural Drainage Water by Selenate-Reducing Bacteria

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Executive Summary:
The deformity of fish and waterfowl in wetlands and evaporation ponds is caused by the bioaccumulation of selenium (Se) from agricultural drainage water. Concerns for the safety of these waterfowl production areas make it very important for scientists and wetland managers to find ways to remove Se from drainage water before it is disposed into the wetlands.

Microbial reduction of Se[VI] to Se[0] is one of the most important biogeochemical processes in the aquatic systems. Because Se[0] can precipitate at bottom of the facilities used for drainage water treatment, this process is considered to be a useful technique for bioremediation. In the aquatic system, Se oxyanions can serve as electron acceptors for microbial respiration. The free energies for Se[VI] reduction to Se[IV] and Se[IV] reduction to Se[0] coupled to H_2 oxidation are -15.53 and -8.93 kcal/mol, respectively. When acetate and lactate are used as the electron donors, Se[VI] reduction to Se[IV] is energetically favorable, yielding -172 kJ/mol with acetate and -343 kJ/mol with lactate. Therefore, addition of an efficient organic material in a treatment system can enhance Se removal from drainage water through Se[VI] reduction to Se[0].

Many bacteria have been found to be capable of reducing Se[VI] to Se[0]. For efficient removal of Se from water, most bacteria need a nutrient-rich environment. In many cases, chemical nutrients, i.e. acetate, phosphorus, lactate, and glucose, added to water for bacteria growth can exacerbate nutrient contamination in treated water. Also, the high costs of purchasing these chemicals make it less practical to use these chemicals as electron donors, carbon sources and nutrients for microorganisms to reduce Se[VI] to Se[0] in field conditions. Therefore, it is important to search for alternative economic organic materials that provide electron donors, carbon sources and nutrients for microorganisms to reduce Se[VI] to Se[0], and serve as materials for the attachment of microorganisms with precipitation of formed red Se[0].

In a preliminary study on the removal of Se from the drainage water by rice straw, we found that Se[VI] reduction proceeded rapidly. At day 7, about 80-90% of the Se[VI] was reduced to Se[0]. Also in the study, we isolated a bacterium that can utilize rice straw as a carbon source and reduce Se[VI] to Se[0]. This finding suggests that rice straw may be a superior choice as a remediation agent that can be used in the field to remove Se from the drainage water because microorganisms attach to the rice straw utilizing the organic materials as electron donors, natural nutrients, and carbon sources to reduce Se[VI] to Se[0]. Also, rice straw is much cheaper than other chemicals tested for Se[VI] reduction in other studies, and is easily obtained from the San Joaquin Valley, CA.

We propose to investigate the removal of Se from drainage water by determining the optimum conditions for maximum Se[VI] reduction to Se[0] in the presence of rice straw. This is a two-year study. In the first year, a series of the batch experiments will be performed in the laboratory to determine the rates of Se[VI] reduction to

Se[0] and the effect of added Se[VI]-reducing bacteria on Se[VI] reduction to Se[0] in both sterile and non-sterile rice straw samples under both aerobic and anaerobic conditions. The effects of pH, nitrate (NO_3^-) as a competitive electron acceptor and sulfate (SO_4^{-2}) as a dominant anion in the drainage water on Se[VI] reduction will also be determined. The mineralization of organic materials from the rice straw will be monitored during the experiments. Mechanisms for removing Se from the drainage water by the rice straw will be determined by analyzing Se speciation in the drainage water at two-day intervals. Once the optimum conditions for maximum Se[VI] reduction to Se[0] in the presence of rice straw are obtained from a series of the batch experiments, we will apply this technology to a flow system in the second year. The flow system will be built to mimic a field channel and a treatment system to maximally remove Se from drainage through Se[VI] reduction to Se[0]. After we complete all the experiments described above, we will provide the drainage water managers and scientists with an effective technology (flow-through channel system) to remove Se from drainage water in the San Joaquin Valley, California.