An Algal-Bacterial Treatment System for Drainage Selenium Removal

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Research Objectives

Selenium drainage water treatment has been an active area of research for more than a decade since the discovery of selenium toxicosis at Kesterson Reservoir in the western San Joaquin Valley of California. The Grassland Bypass Project established monthly and annual selenium load targets for tile drainage from agricultural water districts within the Grassland Basin—exceeding these could lead to fines of up to $500,000 per year. This has proved a powerful incentive for investment in irrigation source control and drainage reduction technology. These monthly and annual load-based targets have helped to change the economics of drainage treatment—no longer are expensive unit processes required to achieve the 5 ppb effluent standard. Hence, technologies such as the Algal-Bacterial Selenium Removal System (ABSR), developed by Professor Oswald and his co-workers at the Applied Algae Research Group (AARG) at the University of California, Berkeley, are well suited for this application. The primary goal of this project is to demonstrate the technical and economic feasibility of the ABSR system at a larger scale, up to 20,000 gallons per day.

Approach

The current collaborative demonstration project involves scientists in LBNL's Earth Sciences Division, the AARG and the departments of Cell Biology and Plant Biology at UC Berkeley.

The ABSR system was constructed in July 1996 and consists of two parallel systems, each having a reduction pond (RP), a paddle-wheel mixed algal high rate pond (HRP) and an algae settling pond (ASP); see Figure 1. By operating two systems simultaneously, the operational parameters of one system can be varied while the other system is operated as a control.

The basic concept of the ABSR system is to grow microalgae on drainage water and to utilize the algal biomass as a carbon source for native bacteria such as Acinetobacter and Psuedomonas, which reduce nitrate to nitrogen gas and selenate to selenite. Selenite combines with metal ions and precipitates or is further reduced to insoluble elemental selenium. The insoluble forms of selenium are then separated from the effluent by sedimentation in the ponds followed by dissolved air flotation and sand filtration. Past and current studies show a clear need to reduce dissolved oxygen and nitrate to low levels before selenate can be reduced to selenite. Oxygen is eliminated from the drainage water by the respiration of microorganisms. Nitrate is removed by reduction to nitrogen gas during denitrification, or in another flow scheme, by assimilation into algal biomass in addition to denitrification. Selenium removed from the water column accumulates in the algal-bacterial biomass and inert materials in the bottom of the RPs. Because the biomass is continuously decomposing, the volume of solid residues increases very slowly. Removal and disposal of the solids in a landfill should be required only after many years of accumulation.

Figure 1. The Algal-Bacterial Selenium Removal System (ABSR).

The 0.1-acre RPs were designed to promote the growth of nitrate- and selenate-reducing bacteria. Floating covers on the RPs were installed to reduce wind-induced mixing. The 0.1-acre paddle-wheel-mixed HRPs were designed to cultivate microalgae in high concentrations and at high productivities. The low speed mixing of HRPs enhances the selection of algal species that bioflocculate and settle in quiescent algae settling ponds.

Carbon dioxide supplementation to the algae is provided by sparging the gas into a carbonation sump near the paddle wheel in each HRP. A baffle in the carbonation sump forces the flow of water downward. Against this downward current, the carbon dioxide bubbles are held in suspension as they dissolve into the water. ASPs provide a quiescent zone for the algae grown in the high rate ponds to settle. The launders in the ASPs improve algae sedimentation by removing supernatant from the surface of the pond at a very low overflow velocity. A sloped floor and internal sump in each ASP enables the harvesting of the algal biomass using a diaphragm pump.

Two flow modes are possible in the ABSR facility in the Panoche Drainage District, each having its advantages in terms of the economics of the system. In Mode 1 (South ABSR system), drainage water is brought into a HRP where 15 to 30 mg/L of nitrate-nitrogen can be removed through assimilation by algal cells. The remaining nitrate is removed in the RP via heterotrophic denitrification to nitrogen gas. By removing some nitrate through assimilation, less algal biomass is required as a carbon source for the denitrifying bacteria. The disadvantage of this mode is that car-