Biological Treatment of Irrigation Drainage for Selenium Removal

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RESEARCH OBJECTIVES

Much of the subsurface agricultural drainage in the western San Joaquin Valley (SJV) is contaminated with selenate (50–1,200 mg/L as Se) and nitrate (20–120 mg/L as N), in addition to high total dissolved solids (TDS) and boron. This water is currently either discharged to sloughs that drain into the San Joaquin River and then to the San Joaquin Delta, or it is evaporated in terminal ponds. These means of disposal are problematic because selenium is a teratogen that bioaccumulates in the aquatic food web, and because nitrate contaminates groundwater supplies and promotes eutrophication of surface waters. Nitrate also interferes with the reduction and removal of selenate, SeO_4^{-2}, the most abundant form of selenium found in western SJV drainage. Our objective is to develop reliable and economical treatment methods to remove these contaminants.

APPROACH

From Pilot Plant to Prototype Facility

We have developed the algal-bacterial selenium removal (ABSR) process to remove nitrate and selenium from irrigation drainage. A 75 m^3/day pilot-scale ABSR Facility has been used to study the mechanisms and rates of selenium and nitrate removal. Based on the success of the pilot facility, a 10-fold scale-up intermediate-scale ABSR Facility may be implemented. In the ABSR process, subsurface drainage is dosed with a carbonaceous energy source for bacteria (usually animal feed-grade molasses) and then injected into a baffled and covered anoxic reduction pond. In the reduction pond, bacteria denitrify nitrate and reduce selenate to selenite, elemental selenium, and bacterial-associated organic selenium. Much of the reduced selenium settles in the pond. Settled bacterial biomass in the reduction pond undergoes anaerobic decomposition, so the volume of solid residues increases very slowly. Removal of the selenium-containing solids should not be required for many years, possibly decades. The effluent water from the reduction pond is coagulated, clarified, and filtered to remove suspended bacteria and selenium-containing suspended solids.

ACCOMPLISHMENTS

Selenium Removal

Over two years, the pilot-scale ABSR Facility at the Panoche Drainage District has removed 95% of the influent nitrate-nitrogen load and 80% of the influent soluble selenium load. Addition of physical-chemical treatment processes, including dissolved air flotation and filtration processes to remove particulate selenium, has increased total selenium removal to 87%. Dozens of bacterial species have been isolated from the ABSR Facility and identified by 16S rRNA sequencing, including the prevalent *Acinetobacter Johnsonii*/genospecies 7, *Pseudomonas mendocina*, and *Xanthomonas maltophilia*. Pure cultures of several of these bacteria have been proven to reduce selenite in the laboratory.

Brine Treatment

Planned "zero discharge" drainage management in the SJV will create brines that require treatment. The high salt concentration of brines may inhibit bacterial selenium reduction, thereby increasing the cost of irrigation drainage treatment. We have found that denitrification and selenate reduction are unaffected by NaCl concentrations augmented up to 22 g/L. Above 22 g/L, however, reduction is substantially inhibited. This information is important in the planning and design of proposed integrated-reverse-osmosis and biological-drainage treatment processes.

SIGNIFICANCE OF FINDINGS

With the ABSR Facility at the Panoche Drainage District, we have demonstrated a promising, cost-effective process that will be used in planning full-scale facilities to remove nitrate and selenium from irrigation drainage.

RELATED PUBLICATIONS

Green, F.B., T.J. Lundquist, N.W.T. Quinn, M.A. Zárate, I.X. Zubieta, and W.J. Oswald, Selenium and nitrate removal from agricultural drainage using the AIWPS® Technology. Water Science and Technology, 48 (2): 299–305, 2003. Berkeley Lab Report LBNL-55205.

Sudame A., S. Lee, H. Lee, T. Lundquist, P. Muller, K. Hida, H. Ng, P. F. Strom, and T. Leighton, Selenite-reducing bacteria of Panoche Algal Bacterial Selenium Removal (ABSR) Facility, California. In: Proceedings of 34th Mid-Atlantic Industrial and Hazardous Waste Conference, 159–172, September 2002.

Quinn, N.W.T., T.J. Lundquist, F.B. Green, M.A. Zárate, W.J. Oswald, and T.J. Leighton, Algal-bacterial treatment facility removes selenium from drainage water, California Agriculture, 54 (6), 50–56, 2000. Berkeley Lab Report LBNL-50318.

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