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EXECUTIVE SUMMARY

AGRICULTURAL DRAINAGE TREATMENT TECHNOLOGY REVIEW

July 1990

Prepared under Contract
for the
San Joaquin Valley Drainage Program

This report presents the results of a study conducted for the Federal-State Interagency San Joaquin Valley Drainage Program. The purpose of the report is to provide the Drainage Program agencies with information for consideration in developing alternatives for agricultural drainage-water management. Publication of any findings or recommendations in this report should not be construed as representing the concurrence of the Program agencies. Also, mention of trade names or commercial products does not constitute agency endorsement or recommendation.

The San Joaquin Valley Drainage Program was established in mid-1984 as a cooperative effort of the U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, U.S. Geological Survey, California Department of Fish and Game, and California Department of Water Resources. The purposes of the Program are to investigate the problems associated with the drainage of irrigated agricultural lands in the San Joaquin Valley and to formulate, evaluate, and recommend alternatives for the immediate and long-term management of those problems. Consistent with these purposes, Program objectives address the following key areas: (1) Public health, (2) surface- and ground-water resources, (3) agricultural productivity, and (4) fish and wildlife resources.

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EXECUTIVE SUMMARY

Inadequate subsurface drainage coupled with increasing salt accumulations on the west side of the San Joaquin Valley threaten the productivity of over one million acres of irrigated farmland. In 1983, it was discovered that concentrations of selenium, a trace element found naturally in westside soils, was being leached out in drainwater conveyed to the Kesterson Wildlife Refuge, and was accumulating there in sufficient concentrations to pose a toxic threat to portions of the wildlife population.

Following this disclosure, and the subsequent plugging of the drains to the Kesterson area, a stepped-up research effort was instituted to manage the selenium problem, attacking it from many directions, including the treatment facet. Research efforts were directed at selenium removal from both agricultural drainage and selenium-laden soils, in which evaporation coupled with biologic conversion contribute to elevated selenium levels. Both biological and physicochemical removal systems were explored. Several contracts were let by the San Joaquin Valley Drainage Program (SJVDP) along with others to research the subject with the objectives of applying state-of-the-art water and soil treatment technologies, or developing new technologies to solve the problem.

This report is a review of the major treatment research efforts undertaken. It addresses to the extent possible both the technical and economic feasibility of each process, and attempts to evaluate research efforts and findings with regard

to process feasibility, short-range and long-range applicability, and relative costs.

Research in treatment technology has emphasized the removal of selenium, primarily because it is reported to be the major cause of the biological damages at Kesterson Reservoir and at several evaporation ponds in the valley. The current status of selenium removal treatment technology reflects research conducted in various progressive stages: bench-scale, field pilot plant, and prototype plant. The Los Banos Demonstration Desalting Facility operated by DWR is the single attempt at testing a treatment technology in a prototype plant.

The biological drainage treatment schemes generally utilize anaerobic/anoxic processes and result in the reduction of soluble selenate to selenite and elemental selenium, which are then removed by proven solids separation technologies. All of the biological processes require amendments of carbon and nutrients to support the biological activity. In one anaerobic research effort carried to pilot plant level by EPOC AG, methanol was utilized as the carbon source; while in an algal-bacterial pilot plant operated by UC Berkeley researchers, algae were grown and harvested to provide the carbon source for the subsequent anaerobic bacterial selenium reduction step. In another study, the kinetics of facultative-bacterial selenate reduction were investigated using bench-scale batch reactors in which selenium removal was demonstrated to be influenced by nutrients, oxygen supply, and temperature. Oxygen stimulated the bacterial growth, but selenium reduction was most effective at low oxygen concentrations. In another variation of the selenium reduction process, a submerged soil column experiment developed an anoxic biomass on the soil surface which removed both nitrate and selenate as water moved through the column. The projected scale-up of this system would involve growing and harvesting pond biomass to provide the carbon feed, similar to the algal-bacterial process use of algae for carbon feed.

In most of the biological studies, nitrate was identified as an inhibitor to selenate reduction, and a denitrification step would be included in most biological treatment scheme. A major cost item in biological processes is the carbon required, especially for biological denitrification. While methanol may be relatively expensive, the use of alternative "free" carbon sources such as sugarbeet waste may be more costly in the long-run due to the variable carbon content of the feed.

Substantial selenium removals have been achieved with the biological reduction processes, and further exploration involving process design to improve the system efficiency appears to be warranted. In a more recent anaerobic/anoxic reduction study, a sequential batch reactor system was studied at bench-scale, and field studies are now proposed.

A research program to remove selenium from soils by a microbial volatilization process has been developed in the laboratory and field tested on Kesterson area pond sediments, and on San Luis Drain sediments. The process requires application of soil amendments for the carbon source, and a number of these consisting mostly of natural waste products were tested. Results showed a decrease in the soil selenium inventory of from about 17 to 25 percent in a ten-month testing period. Calculated half-life values, representing the time required to convert half of the residual soil selenium into dimethylselenide (DMSe), range from 2.48 to 12.55 years, with a large number of the soil amendments producing half-life values at the lower end of the scale. The relatively long time required to reach selenium target levels may be considered disadvantageous; however, the process volatilizes selenium from the system leaving no high-selenium sludges requiring costly disposal.

Another application of this process to evaporation pond sediments is currently being supported by the State Water Resources Control Board. Process application to soil sediments containing high concentrations of selenium appears meritorious; evaporation ponds with soil selenium concentrations approaching allowable limits can be recycled for continued use.

Microbial volatilization was also found to occur from pond waters. Field experiments with water columns containing a casein amendment volatilized up to 28 times the selenium evolved from unamended control columns. However, practical application of this technique is questionable because the required amendment addition would undoubtedly result in pond eutrophication.

The physicochemical processes investigated for selenium removal include attenuation in irrigated soils; adsorption of selenium on iron filings; chemical reduction of selenium (the ferrous hydroxide/selenate reaction); ion exchange; and reverse osmosis. Selenium attenuation in irrigated soils was explored using test columns with simulated agricultural drainwater containing various amendments. Carbon amendments facilitated the transformation of selenate to "organically associated selenium species", suggesting a biological mechanism in the process. The research did not address selenium attenuation under field conditions using actual drainwater.

A patented heavy metal removal process using iron filings is being researched for application in irrigation drainage treatment. Heavy metals and selenium are removed from solution, purportedly by their adsorption on activated iron filing surfaces. The process mechanism(s) are not defined. Further, bed solidification adversely affects permeability and adsorption rates. Currently, the project is being field-tested at the Panoche Drainage District where work is continuing to address the factors related to assessing process feasibility.

Selenium removal by chemical reduction with ferrous hydroxide was researched in the USBR Denver laboratory, and briefly field tested in the Valley. Selenium removal rates for the field test were slower than expected; attributed to inhibiting substances in the drainwater. The inhibitors, mainly oxygen and nitrate, must also be reduced, thus affecting the technical feasibility and cost effectiveness of the process.

Ion exchange research involved resin identification with preferential selectivity for selenate over sulfate based on relative ion size. Further resin formulation and development will be necessary for ion exchange to be a competitive selenium treatment process.

Reverse osmosis was field tested for selenium removal, and removals of over 97 percent were reported. Drainwater pretreatment is necessary to remove membrane fouling substances. The process is very expensive, but it does generate a water low in TDS. The boron content, however, may remain relatively high. The market value of the treated water for agricultural use will depend on the amount of boron left in solution. If the RO process removes some 50 percent of the boron, the remaining level of some 7-8 ppm or greater would still reduce significantly the resale value of the treated water.

Inhibitory impacts of various drainage constituents can affect the design of treatment processes. Several inhibiting substances to the various processes have been identified. In the biological processes, optimal selenium reduction is associated with conditions of low nitrate and dissolved oxygen. Bicarbonates were also identified as a problem in chemical reduction with ferrous hydroxide. In ion exchange technology, sulfate competes with selenate for available resin sites.

Waste disposal is a major component of treatment strategies. It is necessary to identify the composition of treatment wastestreams and to quantify the volumes produced by various treatment processes. This is especially important if the wastestream is deemed hazardous, since hazardous waste treatment and disposal constitutes a difficult and expensive problem that must be addressed more thoroughly.

Salt recovery was investigated in the EPOC AG study; but insufficient data were reported to substantiate their claim of recovering salts of marketable high purity. Salt recovery may possibly be a viable option, but additional work is required to develop effective salt recovery methods. The market value and demand for recovered salts also require further evaluation.

The feasibility of discharging treated drainage is largely governed by geographic location. In the San Joaquin River Basin, treated effluent may be discharged to the San Joaquin River provided that water quality objectives for the river are not exceeded. Under adequate freshwater flows, the assimilating capacity of the river may result in realistically attainable treatment goals. However, in the Tulare Lake Basin, drainage is of necessity discharged to evaporation ponds. If such ponds are to provide safe wildlife habitat, then the treated drainage discharge must not contain more than 3 ppb selenium, according to new standards contemplated by the California Department of Fish and Game and the U. S. Fish and Wildlife Service. None of the selenium removal technologies tested under field conditions have been consistently capable of producing effluents with less than 10 ppb selenium.

In the future, large reductions in drainage volume may be expected as irrigation management practices improve water use efficiency. Further substantial reductions may occur through agroforestry programs. The resulting drainage volume reductions will concomitantly result in lower overall treatment costs.

Capital costs and operating and maintenance costs were estimated in a few of the project reports. Wastestream treatment and disposal costs were estimated only in the reverse osmosis feasibility study by CH2M Hill. Other shortcomings of the reports providing cost information were the selection of different cost parameters (i.e., interest rate and design period) and insufficient information to provide a common basis of cost calculation for comparisons. There is a need for developing a set of uniform cost parameters to be applied in future treatment cost analyses. In addition to estimating drainage treatment costs in a uniform manner, there is a need to conduct economic analyses of how drainage treatment costs compare to the costs of other management strategies, and in particular, what constitutes afforadable drainage treatment.

Recommendations are presented for specific project research, wastestream characterizations, integrated treatment, expansion of research scope to other substances of concern, quality control, and economic analysis. It is recommended that an "Expert System" approach be developed to assist in decision making regarding the application of specific treatment processes or combinations of processes to meet specific conditions.

Selenium is presently the primary contaminant of concern. However, future research will, in all probability, consider drainage issues other than selenium removal. In particular, the problem of salt accumulation must be considered. Improved irrigation management will reduce salt import into the valley, but will not achieve a salt balance. Currently the scope of salt-management options has been limited by policy decision to consider only in-valley solutions to the drainage problem. However, the continuing salt accumulation in the valley will have to be addressed, ostensibly as a mass-balance problem based on establishing acceptable salt tolerance levels compatible with land use objectives. For example, if agricultural productivity is to be sustained, an economically and politically feasible salt export system will have be developed to remove excess salt from westside soils.

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