Bio-remediation for Selenium

Making it Work for Agriculture
THE PROBLEM

- Selenium is being added to natural waterways in areas where agriculture provides return water after irrigation.
- Selenium at the concentrations reported in certain waterways has been determined to be harmful to waterfowl, fish, and potentially to humans.
- Federal authorities may assign irrigators some responsibility for reducing the selenium concentrations in the return water.
The Regional Problem

- The total load of selenium entering the Colorado River from three reaches of the Umcompahgre and Gunnison Rivers creates concentrations that have been determined to be environmentally toxic.
- Agriculture may be required to share the responsibility for reducing the Se load.
- Agriculture in the region depends upon irrigation and drainage.
- Any solution for Se discharges from farms will need to be farm friendly and agriculturally compatible.
If agriculture is required to participate in reducing selenium, how should we develop a solution?

- Localize the problem
- Review the literature
- Consolidate the available information
- Develop a model remediation program that addresses the site-specific need
AGRARIAN’S DESIGN PROCESS

DATA REVIEW

UNDERSTANDING THE PROBLEM
POLITICAL
ECONOMIC
ECOLOGICAL

INITIAL CONCEPT
THOUGHT EXPERIMENTS
METHODS
TECHNOLOGIES
INFRASTRUCTURE

DESIGN

DEMONSTRATION PROJECT
PROOF OF CONCEPT

EMPIRICAL EVALUATION

ACCEPT ELIMINATE MODIFY EXPAND

SCIENTIFIC INQUIRY ON PROCESS

RECOMMENDED ACTIONS
What the Science Says

- Selenium is a trace metal, and can be removed in a desalination plant
- Se can change forms, and some forms are more soluble and/or more toxic than others
- Se can be taken up in some quantity by certain plants under certain conditions
- Selenium can be volatilized under certain conditions
- Certain biological processes produce insoluble forms of selenium, which are removed from the water.
- Insoluble forms of Se remain in sediment and are generally less bio-available
Project Development for Selenium Removal in California’s Central Valley: Broadview Water District

Characteristics of the project:
- 10,000 acre irrigation and drainage district
- Seleniferous soils in the west side of the San Joaquin Valley
- Active network of open and tile drains
- Regulatory pressure for reduction of selenium in discharged drain water
- Project funding from federal (BOR) source, including in-kind cost sharing
Agrarian’s Goals for Broadview

- Reduce the Se load leaving Broadview: current annual load target is 852 lbs.
- Focus on “hot spots”, i.e. the few sumps that produce most of the selenium
- Minimize impacts to wildlife by restricting access to the project
- Minimize long-term costs
- Develop a project that is compatible with the agricultural setting
Important Concepts Utilized

- Selenium volatilization can take place in wetland settings
- Selenium reduction can also take place if the environment is low in oxygen
- The volatilization and the reduction take place in the plant roots, probably via bacteria that live in the root environment
- Optimal bacterial action will take place if the bacteria are well fed AND in maximum contact with the selenium in the water
A Flow-through Wetland

Water flows through the hay bale with the plants, contacting the root mass with the bacteria on them. Selenium transformation takes place in the roots. This is a true flow-through wetland.
The water on our project must flow THROUGH the root mass on the plants in the straw bales
Channel pattern for Se removal project

There are 11 channels in a treatment, and they form a block that is a total of 3300 feet long. Water moves from the intake to the discharge, through the meanders, with a residency time of 21-50 days, depending on the season.
Channels used in Broadview Project

Schematic in cross section of the dimensions of the channels used in the selenium reduction project at Broadview Water District.
Broadview’s Selenium Treatment Facility
Metering inflows to the system
Change in Selenium in Control and in Treatment

![Graph showing change in Selenium in Control and in Treatment](image_url)
Discharge of Selenium in Control and in Treatment

Ratio: \((\text{Discharge} + \text{Pool})/\text{Input}\)

T1 Selenium and T3 Selenium

<table>
<thead>
<tr>
<th>Date</th>
<th>T1 Selenium Ratio</th>
<th>T3 Selenium Ratio</th>
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<td></td>
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<tr>
<td>Jan</td>
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Percent discharge

Date

Aug | Sep | Oct | Nov | Dec | Jan

T1 Selenium Ratio

T3 Selenium Ratio
## Change in Se and NO$_3$ Concentrations in the Project

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<tr>
<th></th>
<th>pH</th>
<th>EC (umhos/cm)</th>
<th>B (ppm)</th>
<th>Se (ppm)</th>
<th>NO3-N (ppm)</th>
<th>SO4 (ppm)</th>
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<tbody>
<tr>
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<td>SL 2</td>
<td>SL 3</td>
<td>SL 1</td>
<td>SL 2</td>
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<td>14000</td>
<td>18200</td>
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The Design Spiral

Stages:
- Model
- Prototype
- Pre-implementation
- Implementation

- Effectiveness
- Technical feasibility
- Cost effectiveness
- Efficiency
- Acceptability
- Sustainability
- Risk
- Consensus
STAGES of the Design Spiral

MODEL
Small scale, inexpensive, testing basic concepts, highly adaptable

PROTOTYPE
Larger scale, testing for efficiency and cost effectiveness, more process-oriented

PRE-IMPLEMENTATION
Approaches scale for a full project, involves optimization and risk analysis

IMPLEMENTATION
A full-scale project that meets all criteria for regional applicability
Agrarian uses the design spiral as a tool for project development.

<table>
<thead>
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<th>Project Type</th>
<th>Size (acres)</th>
<th>Cost (dollars)</th>
<th>Criteria evaluated</th>
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<td>Implementation</td>
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<td>3,000,000</td>
<td>as above, and regional consensus for long-term implementation</td>
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CRITERIA EVALUATED in the Design Spiral

Effectiveness: does it work?
Feasibility: is it practical?
Sustainability: will it last?
Efficiency: does it work well?
Life cycle cost: is it affordable?
Acceptability: is it reasonable?
Risk assessment: is it reliable and safe?
Consensus: can we all agree on it?
Selenium removal in a farm setting: a *model scale* project

Testing effectiveness, feasibility, and sustainability
Agrarian’s Mission Statement

To develop solutions to land and water management problems that will be:

• effective
• technologically feasible
• sustainable
• lowest in life cycle cost
We believe that small, passionately interested teams with high capacity and creativity can solve problems with unique effectiveness. Such a team can:

- internalize the design process
- move fast
- take calculated risks
- make our mistakes quickly
- maximize gains
What it means for Agriculture

Solving problems is a team approach. The players are:

• government agencies with vision, resources, and a sense of ownership in the problem
• farmers or irrigation districts with the capacity to explore options
• consultants with information and commitment to the project
The Task Force is an important first step in building an effective team. Keep it

FOCUSED
ON TARGET
ACTIVE
CONTINUALLY EDUCATED
INTERACTIVE
REALISTIC

and you are well on your way to developing solutions