



# Mechanisms of Arsenic Accumulation and Biogeochemistry in Evaporation Basins

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*Arsenic exists mainly as arsenate (oxidized form) in subsurface agricultural drainage waters but when evapoconcentrated in evaporation basins some of the arsenate is transformed into reduced forms such as arsenite and organic arsenic, especially in the reduced terminal cells of the evaporation basin. Although sinks of arsenic were identified, arsenic behaved somewhat similar to salinity, increasing with increasing evapoconcentration along the water flow pathways from Cells 1 to 10.*

Disposal of saline subsurface drainage waters from croplands into evaporation basins (ponds) occurs in the San Joaquin Valley in areas with no opportunities for disposal into the San Joaquin River. In addition to excess salts, these agricultural drainage waters contain elevated concentrations of trace elements including arsenic, a potentially high risk element with little information about its fate.

The objective of this study was to evaluate the biogeochemical conditions under which arsenic accumulates in a specific agricultural subsurface drainage disposal site. The goal was to better understand arsenic transformations and speciation, including their fate in evaporation basins.

The study site is South Evaporation Basin in the Tulare Lake Drainage District, a 726-ha facility containing 10 cells with water flowing by gravity and in series between the cells. We examined monthly water chemistry and arsenic concentration and speciation along the water flow path between cells. Additionally, we conducted comprehensive sampling within Cell 1 which was the first cell to receive the drainage water, and Cell 9, towards the terminal end of the flow path

in which the water had been subjected to substantial evapoconcentration. Cross-sectional water samples from the top and bottom layers of the water column and surface sediments within Cells 1 and 9 were comprehensively analyzed.

Evapoconcentration was evident in this drainage disposal facility, resulting in increasing salinity along the flow path from an EC of 12 dS/m to about 240 dS/m. Arsenic concentrations also increased with increasing EC along the water flow path, exhibiting a somewhat conservative behavior.

The redox condition in Cell 1 was oxidized and in Cell 9 reducing, as indicated by lower concentrations of dissolved oxygen and nitrate, and higher concentrations of ferrous and sulfide ions. Increases in reduced arsenic species, such as arsenite (As(III)), monomethylarsonic acid (MMAA) and dimethylarsinic acid (DMAA), were found towards the terminal end of the flow pathway. However, arsenate (As(V)), the dominant form of arsenic in the subsurface drainage water, remained at 50% or greater in all pond waters sampled.

Sequential extractions of the sediments indicated that carbonates played an important role in immobilizing arsenic into the sediments. However, reducing conditions can mobilize sorbed arsenic on oxyhydroxide mineral phases.

These sink mechanisms did not significantly reduce arsenic concentrations within the cells. Arsenic behaved nearly the same as salinity from the continuous inputs of arsenic-containing fresh drainage water into the system and the resulting evapoconcentration up to 20-fold in the terminal end of the flow pathway.



Preparing for spatial sampling of the water column and sediments within a cell of the evaporation basin.

### **Publications**

Gao, S., J. Ryu, K.K. Tanji, and M.J. Herbel. Arsenic Accumulation and Speciation in Evaporating Waters of Agricultural Evaporation Basins. *Chemosphere* 2007, 67:862-871.

### **Professional Presentations**

Gao, S., K.K. Tanji, and J. Ryu. Chemical Behavior of Selenium and Arsenic in a Saline Agricultural Drainage Disposal Pond Facility. International Salinity Forum, Riverside, CA, April 25-27, 2005.

Gao, S., J. Ryu, and K.K. Tanji. Arsenic Accumulation in Evaporation Basins for Agricultural Drainage Disposal, California, USA, 18<sup>th</sup> World Congress of Soil Science, Philadelphia, PA, July 9-15, 2006.

### **Collaborative Efforts**

This study was conducted in Tulare Lake Drainage District's (TLDD) South Evaporation Basin. TLDD assisted us in monitoring water flows and reading staff gauges in the cells. We also received assistance from Novalek, Inc., for spatial sampling of the water column and sediments within Cells 1 and 9. Dr. M.J. Herbel of the US Salinity Laboratory helped us interpret some of the arsenic data.

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