Project Number

WRF-05-004

USBR AGREEMENT: # 04-FC-81-1047

Development of Surrogates to Determine the Efficacy of Soil Aquifer Treatment Systems for the Removal of Organic Chemicals

Principal Investigators: Jörg E. Drewes and Eric Dickenson, *Colorado School of Mines*; Shane Snyder, *Southern Nevada Water Authority*

Cash Contributors (in addition to the Bureau of Reclamation): State Water Resources Control Board (CA); Southwest Florida Water Management District

Objectives:

The objectives of this project were: (a) to identify potential surrogates and indicators for the removal of wastewater-derived chemical contaminants in groundwater recharge projects employing soil-aquifer treatment (SAT) and high-pressure membrane treatment, (b) to validate the ability of chosen surrogates and indicators to predict the removal of wastewater-derived contaminants in groundwater recharge projects, and (c) to develop recommendations for the water industry regarding suitable surrogates for groundwater recharge systems using reclaimed water.

Summary of Findings:

Based on findings derived from conducting field monitoring efforts at five different field sites, redox conditions and feed water types did not seem to impact the removal of indicator chemicals during SAT. The results indicate that removals for biodegradable indicator chemicals are similar across sites for similar travel times despite differences in the extent of vadose zones, which supports the robustness and reliability of SAT operations regarding the removal of biodegradable trace organic chemicals. Removal of indicator chemicals was correlated with removal of surrogate parameters, such as TOC, TOX and UVA. In general, select indicator chemicals, with the exception of benzophenone, exhibited a significant correlation with both TOC and TOX. As demonstrated in previous studies, the vast majority of indicator chemicals are efficiently rejected by RO membranes exceeding 90 percent removal. Chemicals that are nonionic (neutral) and small can exhibit a partial removal, as observed for nitrosamines, such as NDMA, or 1,4-dioxane. Indicator compounds that are small but exhibit hydrophobic properties can adsorb to the polymeric structure of thin-film composite membranes and partition through the active layer of the membrane into the permeate (e.g., chloroform). The highly efficient rejection of wastewater-derived contaminants by RO membranes limits the number of available indicator chemicals representing intermediate removal to a few. None of the indicator chemicals considered in this study exhibited poor removal (<25%).

Recommendations:

- Future research should evaluate the use and precision of appropriate analytical methods to quantify indicator chemicals in these water reuse applications. These methods should be validated through Round Robin efforts.
- To increase the use of surrogate parameters rather than favoring the measurement of individual chemicals, additional or suggested surrogate parameter should be explored that can be measured in real time.
- A better relationship should be developed between removal of indicator chemicals and travel time during SAT operations, preferably resulting in rate constants for biotransformation. These rate constants could be used for contaminant transport models that can assist in design and operation of managed aquifer recharge facilities.
- A better understanding of pathways of biotransformation can also assist in a better classification of indicator compounds that are not solely based on observed removal efficiencies but molecular fragments that are subject to a biological attack. The relationships can guide in the development of quantitative structure property relationship models that coupled with contaminant transport models could provide an *a priori* assessment of emerging chemicals that haven't been studied or monitored for before.
- Methods how to quantify suggested surrogate parameters, such as BDOC, fluorescence, should be standardized.