



# WASTEWATER IRRIGATION AND GROUNDWATER RECHARGE

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## **PROJECT SUMMARY**

Using wastewater for groundwater recharge is an attractive way for seasonal storage and additional water quality improvement through soil-aquifer treatment. The efficacy of soil-aquifer treatment for removal of organic carbon including pharmaceutically active compounds will be studied with soil columns in a greenhouse. Soil columns will also be used to study the fate of organic compounds in soil where crops are irrigated with sewage effluent. Additionally, samples of the upper groundwater below fields and urban areas (parks, golf courses, landscaping) with a long history of sewage irrigation will be taken and tested for organic agricultural compounds and pathogens.

Long-term storage of water via artificial recharge of groundwater (water banking) in times of water surplus provides a valuable source of water for use in times of water shortage. We plan to expand the potential of this technology, which is now pretty well restricted to permeable soils, to finer-textured “challenging” soils that need to be managed to minimize reductions in infiltration rates due to clogging.

## **OBJECTIVES**

1. Determine the fate of organic compounds, such as pharmaceuticals and pharmaceutically active chemicals and disinfection byproducts, in vegetated soil columns (grass and alfalfa) in a greenhouse irrigated at various efficiencies with chlorinated secondary sewage effluent. The columns will also be used to determine fate of pathogens in sewage irrigated soil under a companion project under National Program 208, Food Safety (Protecting Groundwater Quality Below Waste-Water Irrigated Fields).
2. Analyze samples of the upper groundwater below agricultural fields and urban irrigated areas (golf courses, parks, landscaping) with a long history of sewage irrigation for pharmaceuticals, disinfection byproducts and other chemicals to evaluate effects of sewage irrigation on groundwater quality. The samples will also be analyzed for pathogens under a companion project.
3. Carry out field and laboratory research to develop optimum management procedures for basins that infiltrate secondary or tertiary sewage effluent for recharge of groundwater and water quality improvement through soil-aquifer treatment. Focus will be on relatively fine-textured soils where clogging, crusting, and fine-particle movement can seriously reduce infiltration rates, and hence, recharge capacities.

## **NEED FOR RESEARCH**

*Description of the Problem to be Solved*

Increasing populations and finite water resources necessitate more water reuse (Asano, 1998; Bouwer, 1993 and 1999). Also, increasingly stringent treatment requirements for discharge of sewage effluent into surface water make water reuse more attractive. The present focus in the U.S. is on sustainability of irrigation with sewage effluent and of soil-aquifer treatment, particularly the long-term fate of synthetic organic compounds (including pharmaceutically active chemicals and disinfection byproducts) in the underground environment (Lim et al., 2000; Bouwer, 2000; Drewes and Shore, 2001). The fate of pathogens and nitrogen also needs to be better understood. In Third World countries, simple, low-tech methods must be used to treat sewage for reuse. These methods include lagooning, groundwater recharge, and intermittent sand filtration (Bouwer, 1993). While most standards or guidelines for irrigation with sewage effluent focus on indicator organisms and pathogens, other water quality aspects must also be considered (Bouwer and Idelovitch, 1987).

Long-term effects of irrigation with sewage effluent on soil and underlying groundwater must be better understood so that future problems of soil and groundwater contamination can be avoided. Potential problems include accumulation of phosphate, metals, and strongly adsorbed organic compounds to the soil matrix, and of salts, nitrate, toxic refractory organic compounds, and pathogenic microorganisms in groundwater. Water reuse for irrigation is a good practice, however, care should be taken to prevent deterioration of groundwater quality (Bouwer et al., 1999; Bouwer, 2000). Typical concentrations of some potentially endocrine disrupting chemicals in sewage effluent are shown in Table 1, taken from Lim et al., (2000). Other pharmaceuticals such as lipid regulators, antiepileptics, analgesic/anti-inflammatory drugs, and antibiotics can also be present. The microbiological safety of water reuse is also an important issue, particularly when wastewater is used for the irrigation of fruits and vegetables that are eaten raw or brought raw into the kitchen, as discussed in a companion project under National Program 108. It is of utmost importance to understand the risks associated with wastewater used for irrigation and the factors affecting the deterioration of wastewater effluent after it leaves the treatment plant. There is growing concern about the potential for microbial regrowth in the conveyance /distribution systems where the effluent is transported over long distances to the irrigated areas (mostly with pipelines). The aim of this research is to develop technology for optimum water reuse, to evaluate the role that groundwater recharge and soil-aquifer treatment can play in the potable and nonpotable use of sewage effluent (Bouwer, 1985) and to determine the safety of tertiary effluent used for irrigation of foods, particularly where effluent is transported for relatively long distances in pipes or open channels where regrowth of pathogens and other processes can occur.

#### *Relevance to ARS National Program Action Plan*

This research directly addresses national and global problems dealing with safety of food produced in fields that have been irrigated with sewage effluent or with effluent contaminated water. It also addresses water conservation and integrated water management through water reuse. These issues occur or emerge in many parts of the U.S. and the rest of the world wherever there is not enough water to meet all demands for municipal, industrial, and agricultural (irrigation) purposes. All objectives fall under National Program 201, Water Quality and

Management. Objectives 1 and 2 fall under Problem Area 2.5 (Waste Water Reuse), Goal 2.5.3 (Waste Water Standards). They address water conservation and integrated water management through water reuse. Objective 3 addresses Problem Area 2.3 (Water Conservation Management), Goal 2.3.1 (Water Conservation Technologies).

Table 1. Typical concentrations of some EDCs in treated sewage effluent (Lim et al., 2000).

Compound	Secondary Treatment	Tertiary treatment
Estrogen (ng/L)	38	3
Testosterone (ng/L)	50	2
Estrone (ng/L)	1.4 - 76	1.8 - 3.6
17 $\beta$ -estradiol (ng/L)	<5 - 10	2.7 - 6.3
Estriol (ng/L)	<10 - 37	
Ethyinylestradiol (ng/L)	<0.2	<0.2
Nonyl-phenol ( $\mu$ g/L)	<0.02 - 330	
2,4-dichlorophenol ( $\mu$ g/L)	0.061 - 0.16	
Alkylphenols (total)( $\mu$ g/L)	27 - 98	
Bisphenol A ( $\mu$ g/L)	0.02 - 0.05	
Arsenic ( $\mu$ g/L)	1.3 - 23	
Cadmium ( $\mu$ g/L)	<0.02 - 150	
Lead ( $\mu$ g/L)	0.1 - 44	

Sources: Shore et al. 1993a, Desbrow et al. 1998, Lee & Peart 1998, Blackburn & Waldock 1995, Rudel et al. 1998, Johns & McConchie 1995, Feigin et al. 1991, Bahri 1998.

### *Potential Benefits*

Benefits from attaining the objectives include safe reuse of sewage effluents for irrigation from the standpoint of food safety and groundwater quality protection. Control measures and actions or activities that can be used to prevent, reduce, or eliminate the microbial and chemical food safety hazard will be developed. Water reuse will be more common and the practices will be safer for public health. Such reuse will help in production of adequate food and fiber for growing populations.

### *Anticipated Products*

1. Improved techniques of sewage treatment and system management for safe and sustainable water reuse with minimum adverse effects and in environmentally acceptable ways.
2. New guidelines for irrigation with wastewater to protect groundwater and surface water quality.
3. New procedures for managing groundwater recharge basins to improve their effectiveness, especially where soils are relatively fine-textured.

### *Customers*

Customers of the research include the public, farmers and farm workers, water planners and managers, government regulators, consulting engineers, water districts and municipalities, wastewater treatment plant operators and managers, and the turf, landscape, and golf-course industries.

**SCIENTIFIC BACKGROUND:** Refer to 2002 Annual Report

**APPROACH AND RESEARCH PROCEDURES:** Refer to 2002 Annual Reportg

**PHYSICAL AND HUMAN RESOURCES:** Refer to 2002 Annual Report

### **MILESTONES AND EXPECTED OUTCOMES**

Milestone Time Line: Publication and presentation of results as significant outcomes arise. Demonstration and training programs will be held with potential users as required (Table follows).

Information should be available on the underground fate of sewage chemicals like synthetic and natural organic compounds below sewage irrigated fields and their potential effect on groundwater below sewage irrigated fields or infiltration basins used for artificial recharge of groundwater with sewage effluent. Depending on the results, these outcomes should have a significant effect on water reuse practices around the world, either giving them the green light or a warning about potential adverse effects on human health and underlying groundwater. If the latter is true, best management practices will be developed and tested. The pathogen aspects will be the responsibility of the microbiologist on a related project. The organic chemical aspects of recharge and soil-aquifer treatment systems, as well as principles and practices of water reuse and groundwater recharge in general will be the responsibility of the engineer and chemist.

Since the research addresses practical and real-world problems, it should not be difficult to translate the results into useful concepts. Additional investigations are needed and will be added to the project as funds become available.

Milestone timeline:

<b>Research Study Components</b>	<b>end of year 1</b>	<b>end of year 2</b>	<b>end of year 3</b>	<b>end of year 4</b>	
Greenhouse soil columns	operation, management and sampling for irrigation and groundwater recharge procedures, chemical analyses, program completed	operation, continued results of chemical analysis interpreted changes in column management as indicated, consider applying animal manure and analyze inflow and outflow for pharmaceuticals	operation continued, manuscripts prepared, spiking infiltration water with tracers and specific chemicals	final reports and manuscript prepared, plan and perform future studies	fin m pl fu
Field reconnaissance	select sites of wastewater irrigated fields and urban areas and sample water and groundwater for wastewater chemicals	include more sites in other parts of the U.S.	expand sampling program to other countries	prepare final reports for presentation and publication of papers, plan and perform future studies	pr pr pu pl st
Clogging research	set up laboratory and field studies for soil clogging and mitigation in recharge basins, study crusting and fine particle movement	continue laboratory and field studies for maximizing infiltration rates in fine-textured soils	continue laboratory and field studies for maximizing infiltration rates in fine-textured soils	write papers on best management practices, plan and perform future studies	w m pl st

## **PROGRESS:**

A new scientist was hired on this project during FY03. Field lysimeters were installed in six locations where sewage effluent is used for irrigation. Drainage collected from the lysimeters will be analyzed for various organic and inorganic contaminants to determine the environmental impacts and sustainability of using reclaimed sewage effluent for irrigation. Data collection continued for the column studies where sewage effluent is used for irrigation at various efficiencies.

### Subordinate Projects

Constructed wetlands are potentially an important means of treating sewage effluent before release to surface water bodies. The Trés Rios constructed wetland at the Phoenix Arizona 91st Avenue Sewage treatment plant experienced a failure of the bulrush population in the wetland. The Bureau of Reclamation has funded a study to evaluate chemical and biological conditions that may have lead to the decline of the plant population of the wetland. This project was initiated in July of 2003.

A set of preliminary values of oxidation-reduction potentials of areas in which bulrush survived and where it died out was collected. The wetland was then drained and the pond bottom reshaped in portions of the pond. Samples were taken from the experimental areas and are currently being analyzed. The wetland was refilled and then replanted. The site will be released by the contractor to the City of Phoenix in August of 2003. At that time the monitoring of redox will be resumed.

A Ph.D level graduate student in the Ag. and Bio Engineering department has been recruited to conduct chemical, biological, and operational evaluations of the wetland to isolate the cause of the decline of the bulrush population.

FY04 - Field lysimeters will be characterized for flow dynamics and sportive properties. Leachate will also be collected for water quality analysis, including organic and inorganic contaminants. Studies will also be initiated in cooperation with the Weber Basin Water Conservancy District and the South Davis Sewer District to determine suitability and best management practices in reusing reclaimed sewage effluent in municipal secondary irrigation systems.

FY05 - Continue data collection from the field lysimeters. Collect data from secondary irrigation system and investigate various management practices that will provide for the safe use of reclaimed sewage effluent in a municipal setting.

FY06 - Continue data collection from the field lysimeters and secondary irrigation system. Investigate the fate and transport of organic contaminants found in sewage effluent and publish results.