Issues in Recharge of Contaminated Surface Waters in Conjunctive Use Projects

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Presented at National Groundwater Association Conference Session on Conjunctive Use, San Francisco, CA, February (2000)

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Abstract

With increased attention being given to conjunctive use of surface and groundwaters, there is increased recharge of contaminated surface waters in conjunctive use projects. Often, limited attention is being given to the potential impacts of the chemical constituents present in the recharged surface waters on the quality of the groundwater recovered in a conjunctive use project. It is frequently assumed that the aquifer system will "treat" the recharged surface waters to remove pollutants present in those waters. While aquifer systems have the ability to treat/remove some constituents in recharged surface waters, there are constituents that are not removed that can pollute recovered groundwater and/or build up within the aquifer. Frequently, little or no attention is given to the potential for constituents in the recharged surface waters to affect the physical and chemical characteristics of the aquifer. Failing to properly consider the characteristics of the recharged surface waters on groundwater and aquifer quality can cause significant problems, including the failure of conjunctive use projects. This paper presents a discussion of pre-operation and operational monitoring/evaluation programs that should be conducted in conjunctive use projects to protect groundwater quality and the aquifer.

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Abstract (continued)

All conjunctive use projects should be prec3edwed by a comprehensive monitoring/evaluation program that characterizes the physical, chemical, and biological characteristics of the surface waters that are proposed to be recharged to the aquifer. This monitoring/evaluation program needs to be more comprehensive than typically used in conjunctive use projects. Also, the physical and chemical characteristics of the aquifer should be evaluated. This information should be used to predict whether the characteristics of the surface waters that are proposed to be recharged in a conjunctive use project could lead to impairment of groundwater or aquifer quality.

Once the conjunctive use project is operational, a detailed monitoring program of the recharged and recovered groundwaters, as well as the waters within the aquifer, should be conducted. Further, information on the potential build-up of pollutants within the aquifer system should be evaluated through examination of the fate of the recharged chemical constituents. This evaluation is essential to ensure that the build-up of hazardous chemicals within the aquifer does not ultimately lead to a "Superfund" site-type situation that will require remediation of the contaminated aquifer.

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Examples are provided of potential problem areas that have occurred in conjunctive use projects that have led to impaired recovered groundwaters and an impaired aquifer. An update of the authors' previous publications on these issues is provided. Guidance is provided on the pre-operation and operation monitoring/evaluation programs that should be conducted in conjunctive use projects.

References:

Lee, G.F., and Jones-Lee, A., 1993, *"Water Quality Aspects of Incidental and Enhanced Groundwater Recharge of Domestic and Industrial Wastewaters – An Overview,"* Proc. Symposium on Effluent Use Management, TPS-93-3, American Water Resources Association, Bethesda, MD, pp. 111-120.

Lee, G.F., and Jones-Lee, A., 1995, *"Public Health and Environmental Safety of Reclaimed Wastewater Reuse,"* Proc. Seventh Symposium on Artificial Recharge of Groundwater, University of Arizona Water Resources Research Center, Tucson, AZ, pp. 113-128.

Lee, G.F., and Jones-Lee, A., 1996, *"Appropriate Degree of Domestic Wastewater Treatment before Groundwater Recharge and for Shrubbery Irrigation,"* Proc. AWWA, WEF 1966 Water Reuse Conference, American Water Works Association, Denver, CO. pp. 929-939.

Importance of Groundwater Quality Protection

- Groundwater Provides 50% of US Domestic Water Supply
- Superfund Studies Show That Once Contaminated, Groundwater Difficult, If Not Impossible, to Clean Up
  - Cannot Develop Surface Water Supply Sources
- Future Water Supply Development Must Be Directed toward Groundwater and Aquifer Use
- Conjunctive Use of Surface and Groundwaters
  - Enhanced Recharge and Recovery
  - Aquifer Must Be “Clean”

Inadequate Regulation of Groundwater Quality Protection

- Surface Waters – 1972 Water Quality Act
  - Goal: Zero Pollutant Discharge
- Groundwater – No National Legislative Protection of Groundwater Quality
- Groundwaters Need Greater Protection Than Surface Water
  - Cannot Be Cleaned Up
  - More Vulnerable to Pollution by Some Chemicals
    - Limited Dilution
- Most States Cannot Protect Groundwater Quality
  - Politics Prevent Development of Effective Legislation

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Inadequate Regulation of Groundwater Quality Protection (continued)

- Need for National Legislation
  - Zero Pollutant Discharge in All Groundwater Recharge Waters
- **Contaminant** – Chemical Added to Water
- **Pollutant** – Contaminant That Impairs Beneficial Uses
- Must Recognize Difference or Will Over-Regulate Discharges and Waste Public and Private Funds

Types of Pollutants

- Conventional Pollutants
  - Fe, Mn, $S^{=}$, TDS, Cl^{-}, $SO_4^{=}$, NO_3^{-}, etc.
- Priority Pollutants
  - Hazardous Chemicals – e.g., DDT, TCE, Benzene, PCB’s
- Non-Conventional Pollutants
  - Organics of Undefined Composition and Characteristics Seen by Difference between TOC and Identified Organics
  - 95% of Organics in Many Wastewaters and Stormwater Runoff of Unknown Characteristics and Hazard
  - Could Contain Next “Dioxin”

- **Cannot Assume That Because There Is No Exceedance of an MCL, a Water That Has Received Non-Conventional Pollutants Is Safe to Drink**

- **Prudent Public Health Policy to Assume That Any Water Contaminated by Non-Conventional Pollutants Is Unsafe to Drink**

Areas of Concern

- Agricultural-Use Fertilizers
- Nitrogen Fertilizers Used without Regulation
  - Fertilizer-by-the-Glass
- Agricultural and Industrial Use of Pesticides and Herbicides
  - Allow Use until Groundwater Pollution Occurs
  - No Regulation of Ag In-Field Fertilizer Use
  - Widespread Nitrate Pollution of Groundwater

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Areas of Concern (continued)

- Municipal and Industrial Wastewater Discharges to Surface Waters That Recharge Groundwaters without Regard to Incidental Recharge That Could Impair Uses of Groundwater
- No Regulation of Non-Point Source Runoff from Urban and Rural Areas
- Sand and Gravel Mining Activities

Inappropriate Regulatory Approaches
Over-Regulation

- Establish Drinking Water MCL as the Effluent Discharge Limit for a Periodic Discharge during Stormwater Runoff Events That Enters an Ephemeral Stream, That Flows into a River, That Recharges Groundwater about 20 mi Downstream
  - e.g., Benzene 0.3 μg/L
- No Allowance for Dilution, Volatilization, Transformation, etc.

Current Approaches to Groundwater Quality Protection

- **Reactive – After Groundwater Water Well Polluted**
  - Abandon Use of Groundwater Water Well
  - Start Clean-up Activities
- **ProActive – Before Problem Occurs**
  - Evaluate Potential Sources of Contaminants in Recharge Waters to Determine If Water Is "Safe" to Discharge to Surface Waters
    - For All Point and Non-Point Sources of Contaminants

Overview of Water Quality Issues

- For All Recharge Waters, Evaluate Whether Contaminants Could:
  - Pollute Aquifer to Impair Use for Domestic Water Supply
  - Pollute Recharge-Recovered Water by Contaminants in Aquifer That Prevent Its Use for Water Supply
    - Radon, As, Fe, $S^{=}$, etc.
  - Limit Ability to Recharge and Recover Water from Aquifer
    - Impair Hydraulic Characteristics – Plug Aquifer by Precipitates, Biological Growths, Ion Exchange Shrink/Swell Characteristics

Regulatory Approach

- Current Water Quality Regulatory Approach Focuses on Protection of Aquatic Life and Use of Surface Waters for Drinking Water
- Need to Also Regulate Contaminants from Controllable Sources That Can Impair Groundwater Uses
- Many Situations Where Contaminants Can Be Discharged to Surface Water without Adversely Impacting Groundwater Quality
- To Avoid Over-Regulation, Essential to Conduct Site-Specific Hazard Assessments to Establish Allowable Contaminant Discharges
- Burden of Funding Studies to Define Allowed Discharge Loads Must Be on Dischargers

Overall Suggested Approach

- Point Source Dischargers and Those Responsible for Lands from Which Non-Point Runoff Occurs Should Be Required to Demonstrate That Contaminants Discharged Will Not Pollute Groundwater
- Hydrology
  - Requires Evaluation of Potential for Contaminant Discharges to Enter a Groundwater Aquifer System
- Contaminant Fate
  - Determine Composition of Discharges/Runoff
  - Evaluate Aquatic Chemistry (Fate) in Receiving Waters to Point of Potential Recharge

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Overall Suggested Approach (continued)

- Conduct Water Quality Hazard Assessment
  - Determine Concentrations of Contaminants at Entry into Aquifer
  - Determine Fate of Contaminants in Aquifer
    - Will Concentration of Any Contaminant in Saturated Part of Aquifer Exceed a Drinking Water MCL?
- Monitor Aquifer to Determine Reliability of Hazard Assessment
- Cooperative Monitoring of Aquifer by All Sources of Contaminants
- If a Source of Contaminants Will Not Conduct/Fund Studies, Apply Plausible Worst-Case Scenario as Effluent Standard

Conclusions

- Inadequate Attention Being Given to Protection of Groundwater Quality from Point and Non-Point-Source Discharges and Runoff-Associated Contaminants
- Because of Their Importance and Vulnerability, Groundwaters Deserve More Regulatory Attention for Protection of Water Quality Than Surface Waters
- All Point and Non-Point-Source Discharges and Sources of Runoff Should Be Regulated to Protect Groundwater Quality
- Regulatory Program Should Be Developed, Adequately Funded and Enforced to Manage Contaminants That Could Impair Uses of Groundwaters
- To Avoid Over-Regulation, Water Quality Hazard Assessment Should Be Allowed to Define Mass Loads of Contaminants That Can Be Discharged without Adverse Impact to Groundwater Quality via Enhanced and Incidental Recharge of Surface Waters

Use of Reclaimed Domestic Wastewaters

- Municipal Water Supply
  - Direct – Pipe to Pipe
  - Indirect – Environmental Transport Component through Surface or Groundwaters
  - Dual Plumbing Systems
- Irrigation
  - Crops – Edible and Non-Edible
  - Ornamental Shrubbery – Parks, Highways, Golf Courses
- Water Supply for Recreational Lakes
  - Contact Recreation?
- Wildlife Habitat
  - Duck & Shore Bird Habitat
- Industrial Water Supply
  - Cooling Lakes and Towers
  - Other

Groundwater Recharge with Reclaimed Wastewater

- What Is Appropriate Degree of Treatment for Domestic Wastewater before Reuse?
  - Secondary Wastewater Treatment + Aquifer to "Treat" Residual Pathogens and Chemicals?
    - Allowed in California
    - Not Allowed in Other Areas
  - Treat to Drinking Water Quality, Then Recharge
- Reliance on Soil Aquifer Treatment, Ill-Advised
  - Inadequate Treatment
  - Overload System
  - Create Future Superfund Site

Causes of Concern about Public Health & Environmental Safety of Domestic Wastewater Reuse

- Pathogenic Organisms
  - Bacteria – Enteric
  - Enteroviruses
  - Parasitic Cyst-Forming Protozoans (e.g., *Cryptosporidium*, *Giardia*
  - Helminths
- Chemical Constituents
  - Hazardous Regulated Chemicals – Priority Pollutants
  - Conventional Pollutants
  - Non-Conventional Pollutants – Unregulated Organics
    - 95% of the Organics – Unknown Hazard

Epidemiological Detection of Disease Caused by Reclaimed Domestic Wastewater

"No Reported Disease (Body Count), So Reuse of Reclaimed Wastewater Must Be Safe"

- Ignores That Epidemiology Can Only Reliably Detect Major Disease Incidence
- Would Not Expect to See Major Disease Epidemic (Body Count) Due to Inadequately Treated Reclaimed Domestic Wastewater
- Because of Inadequate Standards for Evaluating Safety of Treated Domestic Water Supplies
  - About 1,000 People/yr Die
  - A Million People/yr Become Ill

Categories of Contaminants/Pollutants
Unregulated Chemicals

Non-Conventional Contaminants/Pollutants

- Organics of Undefined Composition and Characteristics Seen by Difference between TOC and Identified Organics
- 95% of Organics in Many Wastewaters, Municipal Landfill Leachates, Stormwater Runoff Waters, etc. Are of Unknown Characteristics and Hazard
  - Could Contain the Next “Dioxin”
  - 65,000 Chemicals in Use; 1,000 New Chemicals Each Year

Key Issue: Degree of Treatment of Domestic Wastewater Prior to Reuse

- Treatment Cost vs. “Safety”
  - Err on Side of Saving Money at Expense of “Safety”

    OR

  - Protect Public Health and Environment – Surface and Groundwater Quality
- How Expensive Is It (¢/person/day) to Err on Side of Protection of Public Health and Environmental & Groundwater Quality?
  - Typically about 5 to 10¢/person/day for Those Who Generate or Use Wastewaters – Very High Degree of Protection

Suggested Approach

- Assume Plausible Worst-Case Problem/Failure Scenario
- Err on Side of Protection of Public health & Environmental Quality Rather Than Cost-Savings
  - ¢/person/day in Cost of Reclaimed Wastewater Treatment & Monitoring
- Failure to Plan for Such Scenario Could Cause Loss of Public Support for Reclaimed Wastewater Reuse Projects

Aquifer / Soil Treatment

- Unsaturated Part (Vadose Zone) and Saturated Part of Aquifer
  - Used to Remove Contaminants from Recharged Waters
  - Have Limited Capacity to Remove Many Types of Contaminants from Recharged Waters
  - When Capacity Exceeded, Excessive Concentrations of Contaminants Can Be Present in Water Recovered from Aquifer

Recharge Projects
Potential Future "Superfund" Sites

- Current Approach Relies on "Black Box" Soil Aquifer Treatment
  - Precarious Approach
  - Can Lead to Very Expensive Consequences
    - Long-Term Loss of Groundwater & Aquifer Use
    - Clean-Up – Future "Superfund" Site
- Reliable, Long-Term Protection of Groundwater and Aquifer Should Be High Priority for All Recharge Projects
  - More Important Than Contributing to Satisfying Short-Term Needs for Additional Water Supply

Conclusions

- Groundwater Recharge Projects Have Significant Potential to Cause Adverse Impacts on Water Quality and Aquifer Quality
- Insufficient Attention Given in Recharge Project Development to Potential Problems
- Pro-Active Monitoring and Studies Needed ***before*** Operation, ***during*** Operation, and ***after*** Operation to Define System Reactions, and Fate and Impacts of Contaminants Added to Aquifer
  - Can Be Highly Cost-Effective in Achieving a Successful Recharge Project with Reduced Long-Term Liabilities

Overall Recommended Approach

- Provide Very High Degree of Appropriate Treatment for Recharge Water to Reliably Reduce Contaminants, Including Non-Conventional Pollutants, to Protect against Deterioration of Aquifer & Groundwater Quality, & Reduce Long-Term Liabilities
- Avoid Reliance on “Black Box” Soil/Aquifer Treatment Approach of Putting Contaminants into Aquifer until Problems Are Recognized
  - Treat Recharge Waters to Remove Contaminants to the Maximum Extent Readily Possible
  - Take Pro-Active – Protective – Approach; Err on Side of Public Health Protection
- Initially Somewhat More Expensive; Likely Much Less Costly in the Long Term

References

Lee, G.F. and Jones-Lee, A., "Water Quality Aspects of Groundwater Recharge: Chemical Characteristics of Recharge Waters and Long-Term Liabilities of Recharge Projects," In: *Artificial Recharge of Ground Water, II*, Proc. Second International Symposium on Artificial Recharge of Ground Water, American Society of Civil Engineers, NY, pp. 502-511, (1995).

Lee, G.F. and Jones-Lee, A., "Total Dissolved Solids and Groundwater Quality Protection," In: *Artificial Recharge of Ground Water, II,* Proc. International Symposium on Artificial Recharge of Ground Water, American Society of Civil Engineers, NY, pp. 612-618 (1995).

Lee, G.F. and Jones-Lee, A., "Water Quality Aspects of Incidental and Enhanced Groundwater Recharge of Domestic and Industrial Wastewaters - An Overview," Proc. Symposium on Effluent Use Management, TPS-93-3, pp. 111-120, American Water Resources Association, Bethesda, MD (1993).

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Lee, G.F. and Jones-Lee, A., "Appropriate Degree of Domestic Wastewater Treatment Before Groundwater Recharge and for Shrubbery Irrigation," *AWWA, WEF 1996 Water Reuse Conference Proceedings,* American Water Works Association, Denver, CO, pp.929-939 February (1996).

Lee, G.F. and Jones-Lee, A., "Groundwater Quality Protection: A Suggested Approach for Water Utilities," Report to the CA/NV AWWA Section Source Water Quality Committee, 8pp, August (1993).

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References (continued)

Lee, G.F. and Jones-Lee, A., "Public Health and Environmental Safety of Reclaimed Wastewater Reuse," In: Proc. Seventh Symposium on Artificial Recharge of Groundwater, University of Arizona Water Resources Research Center, Tucson, AZ, pp. 113-128, May (1995).

Lee, G.F. and Jones-Lee, A., "Monitoring Reclaimed Domestic Wastewater Usage on Public Parkland Vegetation to Reduce Risks," *Water Engineering & Management*, 142:28-29,37 (1995).

Lee, G.F. and Jones, R.A., "Regulating Drinking Water Quality at the Source," Proc. University of California Water Resources Center Conference: Protecting Water Supply Water Quality at the Source, Sacramento, CA, 39pp, April (1991). Part of this paper has been published in the proceedings as:

Lee, G.F. and Jones-Lee, A., "Public Health Significance of Waterborne Pathogens in Domestic Water Supplies and Reclaimed Water," Report to state of California Environmental Protection Agency Comparative Risk Project, Berkeley, CA, 27pp., December (1993).

Lee, G.F. and Jones-Lee, A., "Drinking Water Protection: Insights from Comparative Risk Analysis, Part 1, Carcinogens," and "Part 2, Priority Pollutants, Unregulated Chemicals and Pathogens," Report of G. Fred Lee & Associates, El Macero, CA, November (1994).