Pharmaceuticals in Groundwater: Fate, Transport, and Effects, Part I

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## **Overview**

- Sources of Pharmaceuticals to Groundwater
- Detection/Monitoring
- Transport
- Potential Effects
- Mitigation Strategies

#### **Routes to the Environment**



# **Specific Sources to Groundwater**

- Municipal wastewater
  - Sewage ponds/sewage farms
  - Artificial groundwater recharge
  - Irrigation
- Fertilization with liquid manure
- Manure lagoons
- Landfills

# How are they detected?

- Levels range from ng/L to µg/L (ppt to ppb)
- 1-2 L samples
- pH adjustment
- Solid phase extraction (& derivativization)
- GC-MS or LC-MS/MS

# What has been seen?

- Source: municipal wastewater
  - Clofibiric acid, lipid regulator
  - Carbamazepine, antiepileptic
  - Iopamidol, X-ray contrast
  - Sulfamethoxazole, antibiotic
- Source: wastewater for irrigation
  - Caffeine
  - Ibuprofen
  - Estrogens





# What has been seen?

- Source: lagoons/liquid manure
- Sulfa drugs
- H<sub>2</sub>N N

Tetracyclines

# What has been seen?

- Source: Landfill leachate
- Sulfa drugs and analgesics
  Grunsted landfill, Denmark
  In operation 1930-1977
  - = 22 different OM/Cs
- 22 different OWCs
  - Landfill in Oklahoma
  - In operation 1920-1985

Suggests long term persistence/transport

# **Detection summary**

- Wide range of compounds
  - Variety of structures
  - Variety of drug classes
- Maximum concentrations 1-10 ppb
- Antibiotics and estrogens of particular concern

# **Fate/Transport**

- Biodegradation is possible for some compounds, especially under aerobic conditions
- Sorption/Retardation
  - Pharmaceuticals don't fit the "standard mold"
    - Acid/base chemistry, (multiple) pK<sub>a</sub>'s
    - Variety of substituents
    - Strong interactions with mineral surfaces

# Fate/Transport



R = 1.4

# **Fate/Transport**







Figueroa et al., Environ. Sci. Technol. 2004, 38, 476

 $K_D = 200-7000$ R = 500-30,000

## **Potential Effects**

#### Public perception

- Reliability of groundwater resources
- Water reuse
  - Artificial groundwater recharge
  - River bank filtration
  - "Toilet to tap"
  - Irrigation with (treated) wastewater

#### **Antibiotic Resistance**



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#### **Resistance Genes in Groundwater**



Chee-Sanford, et al. Appl. Environ. Microbiol. 2001, v. 67 p. 1494.

# **Potential mitigation strategies**

- Improved municipal wastewater treatment
  - Membranes
  - Add-on lagoons/wetlands (mixed success)
- Improved handling of manure
  - Lined ponds
  - Elevated temperature or time to allow degradation to occur before
- Answers will affect irrigation and groundwater recharge