Water Reuse Research at EPA: Current and Emerging Drivers

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Goals of Presentation

- Provide general overview of EPA’s Office of Research and Development (ORD) Research Programs Relevant to Workshop Goals
- Describe research drivers
- Highlight ORD’s research relevant to water reuse
  - Context
  - Opportunities
    - Technological and Scientific advances
    - Integrated water resource management
      - Decentralized/distributed systems
      - Water reuse, “Gray water” and “Green infrastructure
      - Capacity to tailor water availability/quality to water use
    - Ecosystem services
      - Decision support tools
      - Valuation of services that impact or are impacted by water availability and quality (e.g. fisheries, recreation, green spaces)
ORD’s Research Programs relevant to Water Reuse

- **ORD’s Mission:** Produce credible, relevant and timely research results and technical support that inform EPA policy decisions

- **Overarching Agency Goals relevant to reuse:**
  - Clean and Safe Water
    - Drinking Water Research
    - Water Quality Research
  - Safe Communities and Healthy Ecosystems
    - Human Health and Ecosystem Services
    - Environmental Contaminants:
      - Endocrine Disrupting Chemicals, Pesticides & Toxics,
      - Nanotechnology
    - Global Change
  - Homeland Security
  - Land: Waste management, Remediation
  - Stewardship: Sustainability
Current and emerging research drivers

- **Water quality**
  - Public health protection—pathogens, contaminants, byproducts
  - Environmental protection, aquatic habitats, recreational waters, ecosystem services

- **Water availability**
  - Augment/replenish water supplies (surface and ground water)
  - Locally available “drought-resistant” water supply

- **Energy—water nexus**
  - Carbon footprint of water production, conveyance, and reclamation
  - Water footprint of energy production

- **Climate change**
  - Role of water in greenhouse gas mitigation strategies
    - Geologic sequestration
    - Biofuels
  - Adaptation strategies; sustainable water infrastructure
Legislative Authorities

- Clean Water Act
- Safe Drinking Water Act
- Other Legislative Authorities
  - Resource Conservation and Recovery Act (RCRA),
  - Comprehensive Environmental Response, Compensation and Liability Act (CERCLA),
  - Toxic Substances Control Act (TSCA).
  - Emergency Planning and Community Right-to-Know Act (EPCRA)
  - Homeland Security Act (HSA)
  - Coastal Zone Act Reauthorization Amendments (CZARA)
  - National Invasive Species Act (NISA)
  - Endangered Species Act
  - BEACH Act
  - Energy Independence and Security Act

Emerging and pending issues
- Water Efficiency
- Process water, water quality, water research
Water Resource Management Challenges

- Need to balance water availability, water allocation and use, and replenishment of surface and subsurface water resources

- Changing patterns of water use
  - Increasing urbanization
  - Energy and industrial water use
  - Changing irrigation practices—less land area, more intensive agriculture; competition with local uses
  - Climate: rainfall patterns; drought; snowpack depletion

- Water quality management
  - Salts
  - Nutrients
  - Pathogens
  - Toxins
  - Trace contaminants
  - Process residuals
  - Unknown/future issues
Overview of Water Reuse

- **Drivers for water reuse:**
  - Augment water supply
    - Dry areas: Lack of water sources
    - Locally available drought resistant resource
  - Environmental protection
    - Reduce discharges to environmentally sensitive receiving waters
    - Control release of waterborne contaminants

- **Non potable reuse applications**
  - Industrial cooling and process water
  - Irrigation: agriculture and landscape
  - Urban settings: In-building applications
  - Restore hydrologic balance
    - Aquifer storage and recovery systems
    - Groundwater recharge
    - In-stream flows
    - Wetlands and surface water augmentation

- **Indirect potable reuse**
  - How do we know reclaimed water is safe for its intended uses—microbiologically and chemically
Advantages to Reuse

- Preservation of higher quality water sources.
- Produced in close proximity to water needs.
- Infrastructure and treatment are already in place (sanitation, environmental protection).
- Treatment can be tailored to meet needs of users.
- Energy-carbon footprint benefits.
- Replenishment of natural hydrologic cycles.
**Industrial Water Systems**

**Sources of water for industrial use**
- Local surface or groundwater supplies—depending on water rights/permits/availability
- Municipal water systems
- Municipal reuse systems
- On-site reuse systems

**Goals:**
- Water for: Production, Cooling, Cleaning, and other Needs
- Effluent
- Treatment
- Water Reclamation, Reuse, and Recycling

**Water availability/quality issues**
- Competing water needs (public water systems, aquatic habitats, irrigation, energy)
- Unregulated contaminants—safeguards for public health protection, environmental issues
- Sustainability

**Goal:**
Zero Liquid Discharge
Strategic Use of Technology to Tailor Water Quality for Intended Uses

- Salinity reduction (RO, Distil.)
- Hardness reduction (NF, EDR)
- No salinity reduction

Tertiary Treatment
- Irrigation of food crops
- Landscape irrigation
- Industrial uses

Secondary Treatment
- Irrigation of fodder, orchards, etc.

Primary Treatment

Water sources, Rain water

Water Treatment

Drinking Water

Municipal & Industrial Use

Stormwater

Wastewater

Water Reclamation and Reuse

Quality of Water (No scale)

Time Sequence (No scale)
Characteristics of reclaimed water

Monitored routinely (permits or regulatory requirements)
- BOD
- Suspended Solids
- Bacterial indicators
- Nutrients
- Chlorine residual

Monitored infrequently
- Metals
- Priority pollutants
- Disinfection byproducts
- Emerging contaminants

Limited information:
- Pathogens
- Organics
  - Characterization
  - Health effects
- Trace contaminants
  - Endocrine disruptors
  - Trace pharmaceuticals
    - Antibiotics
    - Antibiotic resistance
  - Personal care products
- Biomarkers of exposure
Knowledge gaps related to reclaimed water quality and water reuse

- Pathogen control and assessment
- Trace contaminants—fate and transformation
- Tools for assessing effectiveness of treatment
- Distribution system design and operation
- Process control
- Salt accumulation
- Water quality changes due to distribution and storage
- Real-time monitoring
- Security/vulnerability
- Risk assessment
- Cost/pricing
ORD’s “Direct” and “Indirect” Research activities relevant to water reuse

- Wastewater derived contaminants
  - Characterization and monitoring
  - Health risks
  - Environmental protection
  - Recreational water

- Public health protection
  - Exposure
  - Health effects
  - Risk management

- Source water protection

- Technologies and Treatment system reliability

- Infrastructure

- Water balance and Water Resources Adaptation
  - Water availability forecasting methodologies
  - Riparian and wetland restoration
  - Conservation and protection of resources to maintain water quality and water availability
  - Assessment and management of aquifer recharge to address water availability issues
Water Quality Concerns

- Microbiological health and environmental risks
  - Viruses, bacteria, protozoa
  - Algae and cyanobacteria
  - Antibiotic resistance
- Chemical health risks
  - Fuel components and byproducts
  - PPCPs (Pharmaceuticals and Personal Care Products)
  - Endocrine disrupting compounds
  - Metals
  - Surfactants and dyes
  - Volatile constituents
  - Treatment process byproducts and residuals
- Nutrients (Nitrogen, Phosphorus)
- Salts
MALDI-MS was used to create a mass spectral fingerprint (3000 m/z -30,000 m/z) for each strain/isolate studied. The mass values observed were used to differentiate between the species of *Aeromonas* as well as other related genera (*Vibrio* and *Plesiomonas*). This comparison is possible because different species of bacteria express different proteins. Below is an example of the spectra observed for different microorganisms.
Water technology applications

- **Water quality monitoring**
  - Safety, Security, Regulatory compliance
    - Health risks
    - System reliability
  - Habitat protection/restoration
    - Nutrients, pH, temp, salinity, and turbidity
    - Biota

- **Treatment efficacy, performance, and efficiency**

- **Water Infrastructure: integrity, condition assessment, operations, and health risks**

- **Water management**
  - Surface water, underground sources of water
  - Water use efficiency
  - Source water protection, replenishment, and rehabilitation
  - Water-energy interdependencies—
    - carbon “footprint” of water; water demand of energy
Underground Sources of Drinking Water

Modeling

- Modeling studies to develop user-friendly software for use by regulators for permit evaluations

Experimental Studies

- Experimental studies to examine underground injection and recharge:
  - Potential for metals release and other impacts
  - Water quality changes

Field Studies

- Field investigations:
  - Potential leakage from abandoned wells
  - Aquifer characterization and monitoring
  - Water-rock interactions
Experimental studies

- Fate and transport of recalcitrant contaminants and micronutrients in water treatment, transport, and beneficial reuse processes
  - Pesticide and herbicide (e.g., aldicarb, atrazine), pharmaceuticals (e.g., ibuprofen), neurostimulants (e.g., caffeine), macronutrients (e.g., N, P)
  - Biological contaminants (cryptosporidium)
- Microbial risk characterization
On site water management: Demonstration Projects

- Installing in heavily-used parking lot
- Measuring (among other things) relative infiltration changes with time (use)
- Measuring the performance of each surface under similar climatic conditions and operation

Side-by-side demonstration of 3 permeable pavement systems
- Paving Stones
- Porous Concrete
- Porous Asphalt
The use of reclaimed water as alternative water resource

Quality and quantity: interrelated
Water resources and infrastructure analytical tools

National water reuse need analysis

Water reuse experimental testing

Low-pressure MBR development for water reuse

- No precipitation in April, 5-yr MA polygon area (km²)
  - 6.0e+4
  - 9.0e+4
  - 1.2e+5
  - 1.5e+5

- April 1985 precipitation (cm)
  - 0
  - 0 – 10.7
  - 10.7 – 21.5
  - 21.5 – 32.2
  - 32.2 – 43.0
  - 43.0 – 53.7

- National water reuse need analysis
  - Great Plains
  - Great Basin and Ranges
  - Nevada
  - Sierra Nevada

- Secondary Activated Sludge Treatment
- Advanced treatment process
- Reclaimed Water Distribution Station
- Soil Columns for Fate and Transport Studies

- National Water Reuse Need Assessment
- Where it is needed?
- What and how much emerging contaminants in reclaimed water?
- How can we control?
- Do microbes grow or re-grow in transportation?
- What are the impacts of residual contaminants in reuse?

- Sierra Nevada
- Great Basin and Ranges
- Great Plains

- Water reuse experimental testing

- Secondary treatment: activated sludge systems
- Soil column for irrigation simulations
Water Availability Forecasting

- Methodology and techniques
- GIS and wavelet modeling, RCM calibration, and remote-sensing based Water Availability Index (WAI) techniques in an integrated platform
- Support long-term planning and short-term operations

Yang et al. (2008), Yang & Goodrich (2008), Chang et al. (2008)
Integrated research approach

Historical hydrologic data mining

Remote sensing and satellite imagery

Monitoring and modeling

Emerging contaminants

Water treatment

Water infrastructure adaptation

Water demand changes
(demographic change, economic activities, etc)

Long-term water availability
(Climate change, heuristic prediction, watershed hydrologic changes)

Sustainable climate mitigation measures
(alternative energy, carbon sequestration)

Water reuse

Adaptation water
Resource engineering

Water demand prediction

Population and economic data mining and synthesis

Integrated modeling and simulation

Potential groundwater impacts in carbon sequestration and storage

Wastewater treatment & reuse

Water requirement & water impact in alternative energy (ethanol, butanol) production

Atmospheric modeling

GCM, RCM

Stream flow robust statistics

Isotopic tracing and hydrosources

Earthquake and volcanisms

Geophysics
Summary and Conclusions

- **Transitions at EPA**
  - Increasing concerns about emerging contaminants
  - Increasing interest in water efficiency, water-energy nexus, climate, environmental justice

- **Evolving directions of ORD’s water-relevant research programs**
  - More integration—less fragmentation
  - “Greening” of research
    - Infrastructure
    - Technology
    - Integration of reuse in research “waterscape”
    - Water availability-quality interdependencies
    - New dimensions to research on contaminants
    - Incorporate ecosystems services into paradigms for water resources management
  - Increased collaboration
  - Become more “nimble” and more multi-disciplinary
ORD Laboratories and Centers

- Laboratories
  - National Exposure Research Laboratory (NERL)
  - National Health and Environmental Effects Research Laboratory (NHEERL)
  - National Risk Management Research Laboratory (NRMRL)

- Centers
  - National Center for Computational Toxicology (NCCT)
  - National Center for Environmental Research (NCER)
  - National Center for Exposure Assessment (NCEA)
  - National Homeland Security Research Center (NHSRC)
ORD Laboratories and Centers

ORD Lab and Office Locations

- Newport, OR
- Corvallis, OR
- Las Vegas, NV
- Duluth, MN
- Grosse Ile, MI
- Cincinnati, OH
- Ada, OK
- Narragansett, RI
- Edison, NJ
- Washington, DC
- RTP, NC
- Athens, GA
- Gulf Breeze, FL
Additional Information

ORD’s Research Programs and Laboratories
http://www.epa.gov/ORD

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