Dealing with Emerging Contaminants from Air, Land and Sea

Dan Woltering
WERF Director of Research

2012 ACWA Annual Conference
July 25-27
Outline

- WERF
- WERF’s “emerging contaminants” research program
  - strategy and highlights
- Most recent “air, land and sea” projects
- What’s next
Emerging Contaminants  *aka* Microconstituents, *Trace Organics*, PPCPs ...

Residual (trace) amounts of organic compounds that have been analyzed for and found following conventional wastewater treatment
Biosolids Land Application

Wastewater Treatment & Receiving Water

Aerial Turf Irrigation
Who is WERF

• Not-for-profit research foundation
• ~$8 million / year of research
• Subscriber driven
• Volunteer Board, Research Council and Technical Advisory Committees for each program / project
• Peer-reviewed research to advance science and engineering to find solutions for wastewater, stormwater and water quality issues
• Deliver results that subscribers can use
Leveraging Investments

$1 Subscriber = $4 WERF Research
Oregon Subscribers

- City of Albany
- Clean Water Services
- City of Gresham
- City of Lake Oswego
- Oak Lodge Sanitary District
- City of Portland
- Water Environment Services
  - Oregon City
- Numerous Engineering Firms
Research Drivers

- Improve water quality
- Protect human & environmental health
- Gain efficiencies & reduce costs
- Achieve sustainable water resource mgmt
- Inform regulations & policy
- Implement best practices
- Accelerate adoption of new technologies
Which research topics are the most important for your organization?

The percentage of total respondents selecting that topic
Questions about CECs / PPCPs

- What’s in WWTP influent?
- Does treatment remove them and what is their fate in effluent and in sludges?
- What analytical methods are reliable?
- Are there likely adverse health or ecological effects? “Is their presence a problem”?
- What are the sources and what are possible source control options?
- What are the regulatory implications?
- What can I tell my customers with certainty?
WERF Advisory Committee

- Wastewater Utilities
- State agencies
- EPA, USGS
- Consultants
- Industry
- Academics
- Equipment Mfg
Knowledge Area: Trace Organics

Our Objective

WERF will provide the tools and data that facility and industry managers need to evaluate public health and environmental impacts, to determine treatment effectiveness, and to support optimization decisions and risk communications with their constituents for trace organic compounds in treated effluents, receiving waters, and in water for reuse.

Latest News

Brief Overview: WERF project U2R11
A year of research has been completed under WERF INFRSG09, investigating bench scale use of UV disinfection with an advanced oxidation processes (UV-AOP) in wastewater effluents demonstrating the effectiveness of UV-AOP on carbamazepine (CEZ) and discovering the impact of native wastewater nitrate in enhancing the oxidative decay of CBZ even in the absence of hydrogen peroxide.
**WERF Trace Organics Research**

This chart lists completed reports and ongoing research efforts for WERF’s Trace Organics program. The timeframe is primarily from the past seven years. To search for older trace organics reports, go to [www.werf.org/search](http://www.werf.org/search) and enter “trace organics” or another related topic, or just enter a project or report number if you know it.

<table>
<thead>
<tr>
<th>Completed Projects</th>
<th>Number</th>
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<td>Diagnostic Tools to Evaluate Impacts of Trace Organic Compounds: Prioritization Framework for Trace Organic Compounds</td>
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<td>Development of Diagnostic Tools for Trace Organic Compounds and Multiple Stressors</td>
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<tr>
<td>Testing Diagnostic Tools for Trace Organic Compounds and Multiple Stressors: Case Studies</td>
<td>CEC5R08c</td>
<td>2010</td>
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<td><strong>Solids (Sludge) Treatment</strong></td>
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<tr>
<td>Gathering Unpublished Data for Chemicals Detected in Biosolids</td>
<td>TOBI1T11</td>
<td>2012</td>
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<tr>
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<td>Removal of Endocrine Disrupting Compounds in Water Reclamation Processes</td>
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<td>Technical Brief, Endocrine Disrupting Compounds and Implications for Wastewater Treatment</td>
<td>04-WEM-6</td>
<td>2005</td>
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<td><strong>Fate and Transport</strong></td>
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<td>Attenuation of PPCP/EDCs through Golf Courses using Reuse Water</td>
<td>WERF1C08</td>
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<td>Fate of Estrogenic Compounds During Municipal Sludge Stabilization and Dewatering</td>
<td>04-HHE-6</td>
<td>2010</td>
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<tr>
<td>Fate of Pharmaceuticals and Personal Care Products Through Municipal Wastewater Treatment Processes</td>
<td>03-CTS-22UR</td>
<td>2007</td>
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<td>Technical Brief, Endocrine Disrupting Compounds and Implications for Wastewater Treatment</td>
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<td><strong>Occurrence</strong></td>
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<td>Contributions of Household Chemicals to Sewage and Their Relevance to Municipal Wastewater Systems and the Environment</td>
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<td>2009</td>
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<td>Technical Brief: Trace Organics Compounds and Implications for Wastewater Treatment</td>
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<td>2008</td>
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<td>Technical Brief, Endocrine Disrupting Compounds and Implications for Wastewater Treatment</td>
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<td>2005</td>
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<td><strong>Analytical</strong></td>
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<td>Technical Brief: Trace Organics Compounds and Implications for Wastewater Treatment</td>
<td>CEC3R07</td>
<td>2008</td>
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Occurrence and Potential for Human Health Impacts of Pharmaceuticals in the Water System

Detected pharmaceuticals in water systems raise understandable concerns about the potential implications for public health. Research organizations around the world including members of the Global Water Research Coalition (GWRC), are exploring these implications and assessing the risks through a number of extensive peer-reviewed research projects.

This paper is a synthesis of nine recently published reports that address the occurrence and potential for human health impacts of pharmaceuticals in the water system. Synopses of these reports are attached. They are principally review documents that summarize previously published research.

Although the nine reports were commissioned for various purposes, they present consistent findings across the topics of occurrence and health impacts. It can be concluded from these reports that, to date, no definitive link has been reported or established between human exposure to pharmaceutical exposure in drinking water and human health risk. Put another way, there is no known impact on human health.

Even though the trace levels of detected pharmaceuticals present a very low health risk (there is no “zero risk” in today’s environment), the water sector continues to investigate the issues and invest in treatment technologies to safeguard the quality of drinking water today and for the future.

Detects pharmaceuticals in water systems are not new

As long as humans use prescription medicines and over-the-counter drugs, we will find trace amounts in wastewater, surface water, groundwater and drinking water. Scientists first

Today's methods can detect concentrations as low as one part per trillion of many compounds, and even lower concentrations in some cases. We hear more reports about the presence of
<table>
<thead>
<tr>
<th>Project Code</th>
<th>Project Title</th>
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<tr>
<td>01-HHE-20T</td>
<td>Removal of Endocrine Disrupting Compounds in Water Reclamation Systems</td>
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<td>01-HHE-21T</td>
<td>Innovative DNA Array Technology for Detection of Pharmaceuticals in Reclaimed Water</td>
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<td>03-CTS-21UR</td>
<td>Contributions of Household Chemicals to Sewage &amp; Their Relevance to Municipal Wastewater Systems &amp; the Environment</td>
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<td>03-CTS-22UR</td>
<td>Fate of Pharmaceuticals and Personal Care Products Through Municipal Wastewater Treatment Processes</td>
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<td>03-HHE-4T</td>
<td>Tools for Analyzing Estrogenicity in Environmental Waters</td>
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<td>04-HHE-1CO</td>
<td>Development of Indicators and Surrogates for Chemical Contaminant Removal During Wastewater Treatment and Reclamation</td>
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<td>04-WEM-6</td>
<td>Technical Brief: Endocrine Disrupting Compounds and Implications for Wastewater Treatment</td>
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<td>04-HHE-6</td>
<td>Fate of Estrogenic Compounds During Municipal Sludge Stabilization and Dewatering</td>
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<td>DEC14U06</td>
<td>Performance Dynamics of Trace Organics in Onsite Treatment Units and Systems</td>
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<td>U2R07</td>
<td>Evaluation of QSPR Techniques for Wastewater Treatment Processes</td>
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<td>Technical Brief: Trace Organic Compounds and Implications for Wastewater Treatment</td>
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<td>CEC2C08</td>
<td>Communication Principles and Practices, Public Perception, and Message Effectiveness</td>
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</table>
Removal of Estrogenic Activity and EDCs during Activated Sludge Treatment

Drewes et al. 2005, WERF
Removal of PPCPs during Chlorination

**Operational Conditions:**
sec./tert. treated effluent; 1 mg of Cl/mg of C; 24-h contact time; pH 8

<table>
<thead>
<tr>
<th>Good Removal (&gt;90%)</th>
<th>Intermediate Removal (90%&lt;90%)</th>
<th>Poor Removal (&lt;25%)</th>
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<tr>
<td>Acetaminophen</td>
<td>Gemfibrozil</td>
<td>Acetyl cedrene&lt;sup&gt;hi&lt;/sup&gt;</td>
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<tr>
<td>Atorvastatin (&lt;hydroxy)&lt;sup&gt;i&lt;/sup&gt;</td>
<td>Musk ketone</td>
<td>Atenolol</td>
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<tr>
<td>Alorvastatin (&lt;hydroxy)&lt;sup&gt;i&lt;/sup&gt;</td>
<td>Raeroxalide</td>
<td>Benzyl acetate&lt;sup&gt;j&lt;/sup&gt;</td>
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<tr>
<td>Alorvastatin&lt;sup&gt;2&lt;/sup&gt;</td>
<td>Ibuprofen</td>
<td>Bucinal&lt;sup&gt;j&lt;/sup&gt;</td>
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<tr>
<td>Benzyl salicylate&lt;sup&gt;i&lt;/sup&gt;</td>
<td>Tonalide&lt;sup&gt;k&lt;/sup&gt;</td>
<td>Caffeine</td>
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<tr>
<td>Bisphenol A</td>
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<td>Carbamsazepine</td>
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<tr>
<td>Butylated hydroxyanisole&lt;sup&gt;i&lt;/sup&gt;</td>
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<td>Chloroform</td>
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<td>Ciprofloxacin</td>
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<td>DEET</td>
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<td>Diclofenac</td>
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<td>Dichlorprop&lt;sup&gt;j&lt;/sup&gt;</td>
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<td>Erythromycin&lt;sup&gt;5&lt;/sup&gt;H&lt;sub&gt;2&lt;/sub&gt;O</td>
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<td>Estradiol</td>
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<td>Estrone</td>
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<td>Flutaxine</td>
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<td>Hexyl salicylate&lt;sup&gt;k&lt;/sup&gt;</td>
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<td>Hexylcinnamaldehyde&lt;sup&gt;j&lt;/sup&gt;</td>
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<td>Hydrocodone</td>
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<td>Indolobutyric acid&lt;sup&gt;j&lt;/sup&gt;</td>
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<td>Isobutylparaben&lt;sup&gt;i&lt;/sup&gt;</td>
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<td>Iopromide</td>
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<tr>
<td>Methyl salicylate&lt;sup&gt;i&lt;/sup&gt;</td>
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<td>Isobornyl acetate&lt;sup&gt;j&lt;/sup&gt;</td>
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<td>Naproxen</td>
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<td>Ketoprofen</td>
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<td>Nonylphenol</td>
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<td>Mecoprop&lt;sup&gt;j&lt;/sup&gt;</td>
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<tr>
<td>Phenylphenol&lt;sup&gt;i&lt;/sup&gt;</td>
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<td>Meprobamate</td>
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<tr>
<td>Propranolol&lt;sup&gt;k&lt;/sup&gt;</td>
<td></td>
<td>Methyl dihydrojasmonate&lt;sup&gt;h&lt;/sup&gt;</td>
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<tr>
<td>Propylparaben&lt;sup&gt;i&lt;/sup&gt;</td>
<td></td>
<td>Methyl ionine&lt;sup&gt;j&lt;/sup&gt;</td>
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<td>Salicylic acid&lt;sup&gt;i&lt;/sup&gt;</td>
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<td>Metoprolol</td>
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<td>Sulfamethoxazole</td>
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<td>Musk xylene</td>
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<tr>
<td>Triclocarban&lt;sup&gt;i&lt;/sup&gt;</td>
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<td>NDMA</td>
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<td>Triclosan</td>
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<td>Ofloxacin</td>
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<td></td>
<td></td>
<td>OTNE&lt;sup&gt;j&lt;/sup&gt;</td>
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<td></td>
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<td>Primidone</td>
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<td></td>
<td></td>
<td>Simvastatin hydroxy acid&lt;sup&gt;j&lt;/sup&gt;</td>
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<td>TDCPP&lt;sup&gt;j&lt;/sup&gt;</td>
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<td></td>
<td></td>
<td>Terpineol&lt;sup&gt;j&lt;/sup&gt;</td>
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Drewes et al. 2008, WRF
Partial List of Workshop Participants

- Water Reuse Foundation
- American Water Works Association
- Global Water Research Coalition
- United States Environmental Protection Agency
- EMEA
- Clean Water
- ASI WPCA
- Environment Agency
- Water Environment Federation
- Pharma
- U.S. Fish & Wildlife Service
- California Urban Water Agencies
- NACWA
- AWWA Research Foundation
- NWRI - USA National Water Research Institute
- USGS
- WERF
## Table 8. Ongoing Research Efforts and Web Links.

<table>
<thead>
<tr>
<th>Organization / Topic</th>
<th>Link</th>
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<tr>
<td><strong>Analytical</strong></td>
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<tr>
<td>CRC: Tools for analyzing estrogenicity in environmental waters</td>
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<tr>
<td>GWRC: Tools for analyzing estrogenicity in environmental waters</td>
<td><a href="http://www.globalwaterresearchcoalition.net/activities.htm">http://www.globalwaterresearchcoalition.net/activities.htm</a></td>
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<td>TZW: Tools for analyzing estrogenicity in environmental waters</td>
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<td>WRC: GWRC EDC Toolbox project</td>
<td><a href="http://www.werf.org/AM/Template.cfm?Section=Home&amp;TEMPLATE=/CM/ContentDisplay.cfm&amp;CONTENTID=4918">http://www.werf.org/AM/Template.cfm?Section=Home&amp;TEMPLATE=/CM/ContentDisplay.cfm&amp;CONTENTID=4918</a></td>
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<td>CRC: Expansion of the bio-analytical toolbox concept used for estrogens to a wider range of health-related endpoints (e.g., cytotoxicity, neurotoxicity, genotoxicity, etc.)</td>
<td><a href="http://www.werf.org/AM/Template.cfm?Section=Home&amp;TEMPLATE=/CM/ContentDisplay.cfm&amp;CONTENTID=4918">http://www.werf.org/AM/Template.cfm?Section=Home&amp;TEMPLATE=/CM/ContentDisplay.cfm&amp;CONTENTID=4918</a></td>
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<td>Kiwa: Development of toxicological tests and methods to assess human health effects</td>
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<td>USEPA: Developing tools to characterize and minimize exposures to EDCs</td>
<td><a href="http://epa.gov/osp/myp/edc.pdf">http://epa.gov/osp/myp/edc.pdf</a></td>
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<tr>
<td>WERF: Improving analytical tools (bioassays) for detecting and monitoring estrogenic activity in various environmental waters</td>
<td><a href="http://www.werf.org/AM/Template.cfm?Section=Home&amp;TEMPLATE=/CM/ContentDisplay.cfm&amp;CONTENTID=4918">http://www.werf.org/AM/Template.cfm?Section=Home&amp;TEMPLATE=/CM/ContentDisplay.cfm&amp;CONTENTID=4918</a></td>
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<td>WRC: EDC activity of identified veterinary compounds in surface and ground water - mainly around cattle feedlots</td>
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<td>WRC: New detection methods for EDCs</td>
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<td>WRC: The use of chemical and biological assays and sentinel species to determine EDC pollution</td>
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<td>PWRI: Evaluating the biological effects of trace organic compounds by gene expression</td>
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<td>SRA: Advancing the use of non-animal testing in the safety and environmental sciences</td>
<td><a href="http://www.cleaning101.com/about/background.cfm">http://www.cleaning101.com/about/background.cfm</a></td>
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</table>
WERF Strategy

- Finding solutions to trace organics issue is huge effort; much bigger than WERF

- Major Topics
  - * Source/source control
  - □ Analytical
    - # Occurrence / monitoring
    - △ Fate and transport
    - △ Treatment - if not WERF then who!
  - ✗ Ecological & health effects - presence = problem?
  - ☺ Communication/Outreach - essential

- Lead on some, leverage where possible, track all
Focus Areas of WERF Research

- Treatment
- Ecological Effects
- Communication
WERF Treatability Research Plan

Objective
Establish a practical set of tools and guidance for measuring and/or predicting the removal of representative chemicals under a wide range of treatment processes and operational variables. A utility could select and optimize treatment to remove these chemicals.

Strategy
- Develop a short-list of representative chemicals that are high priority and analytically feasible to track
- Focus on conventional wastewater treatment processes and advanced unit operations that are widely deployed

Research team
Carollo Engineering, Colorado School of Mines, Southern Nevada Water Authority, University of New South Wales, Syracuse Research Corporation; plus WWTP utility test sites in UT, NV, WA, CO, WI and VA
Focus Areas of WERF Research

- Treatment
- Ecological Effects
- Communication
WERF Ecological Effects Research Plan

Objective
To provide on-site tools and guidance to assess aquatic impacts of trace organics in surface waters that receive treated wastewater. Are the chemicals in my effluent likely to cause impact? Is my receiving water particularly sensitive to trace organic chemicals?

Strategy
- Develop a short-list of representative chemicals that are high priority
- Focus on population and community level effects
- Utilize available chemical and biological monitoring data
- Field test the tools and guidance

Research team
Tetra Tech, U Brunswick, Condatis, E2 and FTN
- Collaborators (on right) plus Canadian Water Network, Great Lakes Env Program, SCCWRP
Areas of WERF Research

- Treatment Processes
- Ecological Effects
- Communication
Communication Principles and Practices, Public Perception, and Message Effectiveness

Objective
Guidance/answers on effective communication practices for trace organics issues

Product
A framework to help utilities as they present and monitor the effectiveness of communication strategies and materials

Research Team
Malcolm Pirnie, CH2MHiIl and U Oregon
Biosolids Land Application

Wastewater Treatment & Receiving Water

Aerial Turf Irrigation
WERF Recent Research Efforts

Fate and transport of representative trace organics in treated wastewater used to irrigate turfgrass
  ▪ How effectively removed; is shallow groundwater at risk?

Wastewater treatment efficiency and optimization
  ▪ Predict removal of “indicator chemicals” and provide best options to improve removal in conventional treatment

Trace organics in land-applied biosolids
  ▪ Data to inform health and environmental risk assessment
Aerial Turf Irrigation ("air")
Q. How much water used annually on a golf course?
A. 300 acre feet or ~ 100 million gallons
   June – Sept
   From City of Bend WWTP

Q. How much is saved by using recycled water?
A. Almost half the cost of drinking water
Attenuation of PPCPs Through Turfgrass Using Recycled Water
Project Objectives

- Investigate the fate and transport of representative PPCPs in treated wastewater used to irrigate turfgrass
  - Do these 15 representative compounds reach and accumulate in shallow groundwater systems?
  - Is the matted layer of grass debris and soil organic matter near the surface (“root zone”) acting as a biofilter?
  - What roles do degradation and sorption play in the attenuation?
Research Team

- Mike McCullough – Northern California Golf Association
- Dr. Michael Young – Desert Research Institute
- Dr. Dale Devitt – University of Nevada, Las Vegas
- Drs. Robert Green & Jay Gan – UC Riverside
- Dr. Shane Snyder & Brett Vanderford – Southern Nevada Water Authority
## Project Co-funders - $700,000

<table>
<thead>
<tr>
<th>California Golf Course Owners Association</th>
<th>Monterey Regional Water Pollution Control Agency</th>
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<tr>
<td>California Golf Course Superintendents Assn</td>
<td>PhARMA (California)</td>
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<tr>
<td>Coachella Valley Water District</td>
<td>San Francisco Public Utilities Commission</td>
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<td>City of Santa Rosa</td>
<td>Santa Clara Valley Water District</td>
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<td>Denver Water</td>
<td>State Water Resources Control Board (CA)</td>
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<td>Environmental Institute for Golf</td>
<td>South Bay Recycling</td>
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<td>Inland Empire Utility Agency</td>
<td>Sonoma County Water Agency</td>
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<tr>
<td>Monterey County Water Resource Agency</td>
<td>WaterReuse Foundation</td>
</tr>
<tr>
<td>Toro Foundation</td>
<td>Delta Diablo Sanitation District</td>
</tr>
<tr>
<td>Reedy Creek FL (Disney)</td>
<td>Florida Utility Council</td>
</tr>
<tr>
<td></td>
<td></td>
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</tbody>
</table>
### List of PPCPs Studied

<table>
<thead>
<tr>
<th>PPCPs Studied</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trimethoprim</td>
<td>Antibiotic</td>
</tr>
<tr>
<td>Sulfamethoxazole</td>
<td>Antibiotic</td>
</tr>
<tr>
<td>Triclosan</td>
<td>Antibiotic</td>
</tr>
<tr>
<td>Carbamazepine</td>
<td>Anticonvulsant</td>
</tr>
<tr>
<td>Primidone</td>
<td>Anticonvulsant and seizure treatment</td>
</tr>
<tr>
<td>Dilantin</td>
<td>Anticonvulsants and seizure treatment</td>
</tr>
<tr>
<td>Diazepam</td>
<td>Sedative and anticonvulsant</td>
</tr>
<tr>
<td>Meprobamate</td>
<td>Tranquilizer</td>
</tr>
<tr>
<td>Naproxen</td>
<td>Anti-inflammatory</td>
</tr>
<tr>
<td>Diclofenac</td>
<td>Anti-inflammatory</td>
</tr>
<tr>
<td>Ibuprofen</td>
<td>Anti-inflammatory</td>
</tr>
<tr>
<td>Atorvastatin</td>
<td>Lower blood pressure</td>
</tr>
<tr>
<td>Gemfibrozil</td>
<td>Lower lipid levels</td>
</tr>
<tr>
<td>Atenolol</td>
<td>β-Blocker; cardiovascular disease and hypertension</td>
</tr>
<tr>
<td>Fluoxetine</td>
<td>Antidepressant (Prozac)</td>
</tr>
</tbody>
</table>
Lysimeter & Field Plot Studies – UNLV and UC Riverside

Storage tank

Post UV water
Field Methods

Wildhorse Golf Course, NV

Datalogger
Concentration in drainage water (~3 ft depth) as a function of soil type, leaching fraction and surface cover.

Concentrations in Drainage of Loamy Sand Lysimeters After 14 Months of Imposed Treatments

Leaching Fraction and Surface Cover

Concentrations in Drainage of Loam Lysimeters After 14 Months of Imposed Treatments

Leaching Fraction and Surface Cover
<table>
<thead>
<tr>
<th>Field Plots</th>
<th>Lysimeter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>LF</td>
</tr>
<tr>
<td>Atenolol</td>
<td>X</td>
</tr>
<tr>
<td>Atorvastatin</td>
<td>X</td>
</tr>
<tr>
<td>Carbamazepine</td>
<td>X</td>
</tr>
<tr>
<td>Diazepam</td>
<td>X</td>
</tr>
<tr>
<td>Diclofenac</td>
<td>X</td>
</tr>
<tr>
<td>Dilantin</td>
<td>X</td>
</tr>
<tr>
<td>Fluoxetine</td>
<td>X</td>
</tr>
<tr>
<td>Gemfibrozil</td>
<td>X</td>
</tr>
<tr>
<td>Ibuprofen</td>
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<td>Meprobamate</td>
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<td>Primidone</td>
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</tr>
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<td>Sulfamethoxazole</td>
<td>X</td>
</tr>
<tr>
<td>Triclosan</td>
<td>X</td>
</tr>
<tr>
<td>Trimethoprim</td>
<td>X</td>
</tr>
</tbody>
</table>

Green cell - 98% or more compound attenuation
Yellow cell – 85 - 98% compound attenuation
Red – 84-80% compound attenuation
Not measured
Agreement between lysimeter, field plot & golf courses

After >1year irrigation on range of soil/cover types
  • The mass of 10 of 15 chemicals was removed >98%
  • 5 detected in drainage water at 3-4 foot depth
  • 3 removed >85%; 2 removed >80% (high rate, sandy soil)
  • “release rates” ranged from 5-120 mg/acre/year
    • for context, aspirin tablet is 325 mg

Results support the use of recycled water for irrigation purposes as long as sound irrigation management practices are implemented
  • Pay attention to soil type and over-irrigating
Wastewater Treatment ("sea")
Trace Organic Compounds in Wastewater Treatment: How Close are We to Predicting Removal?

Research Team

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University of Arizona

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Clark County Water Reclamation District

Jorg Drewes
Eric Dickenson
Chris Higgins
Katherine Hyland
Southern Nevada Water Authority

Utility Test Sites in CA, CO, IL, NV, UT, VA, WA, WI
Questions Driving the Industry

• How well are trace organics removed during conventional wastewater treatment?
• What compounds should be best monitored to assess treatment performance?
• How does process operation effect trace organic chemical removal?
• Can we predict trace organic chemical removal at a WWTP?
Study Approach

1) Identify Suitable Indicator Chemicals

2) Mass Balance Eval. and Operational Factors at WWTPs

3) Removal Mechanisms: Fate Parameter Measurements in Lab

4) Model / Predict Chemical Removal
Trace Organic Indicator Compound Selection

Candidate Selection Criteria

- Occurrence
- Analytical amenability
- Bio-physicochemical properties
- Toxicological relevance
# Indicator Candidate List

## Pharmaceuticals
- Sulfamethoxazole: Antibiotic
- Trimethoprim: Antibiotic
- Gemfibrozil: Lipid Regulator
- Atenolol: Beta Blocker
- Primidone: Anticonvulsant
- Carbamazepine: Anti-epileptic Drug
- Naproxen: Anti-inflammatory Drug
- Ibuprofen: Pain Killer
- Acetaminophen: Pain Killer
- Fluoxetine: Antidepressant
- Cimetidine: Antihistamine
- Diphenhydramine: Antihistamine
- Meprobamate: Tranquilizer
- Iopromide: X-ray Contrast Agent

## Food Additives
- Caffeine: Stimulant
- Sucralose: Artificial Sweetener
- BHA: Food Additive

## Personal Care Products
- Benzophenone: UV-Blocker
- Musk Ketone: Fragrance
- DEET: Insect Repellent
- Triclocarban: Anti-Bacterial / Antifungal
- Triclosan: Anti-Bacterial / Antifungal

## Industrial Chemicals
- Bisphenol A: Plasticizer
- TCPP: Flame Retardant
- TCEP: Flame Retardant
Analytical Methods

- Established methods for 25
- Round robin tested
- $500-3,000 per sample
- Over 10 contract labs in U.S.

Liquid:
1. Isotope dilution
2. Solid phase extraction
3. Concentration

Solids:
1. Filtration/isotope dilution
2. Accelerated solvent extraction
3. Solid phase extraction

Analysis:
- LC / MS – MS
Study Approach

1) Identify Suitable Indicator Chemicals

2) Mass Balance Eval and Operational Factors at WWTPs

3) Removal Mechanisms: Fate Parameter Measurements in Lab

4) Model / Predict Chemical Removal
Study Focus – Secondary Treatment

- Full-scale testing: 8 municipal treatment plants
  - Process
    - Level of treatment
  - Operation
    - Solid retention time
    - Hydraulic retention time
    - Mixed liquor concentration
  - Geographical location
    - Indicator occurrence
    - Temperature
  - Capacity and Flow
Sampling Points in Anaerobic Digestion
Indicator Occurrence

- Detection of 23/25 compounds at all facilities
- Influent concentrations typically similar between sites
  (exception: DEET, Caffeine, Iopromide)
Removal as Function of SRT

- Acetaminophen
- DEET
- Atenolol
- Triclocarbon
- Caffeine
- Ibuprofen
- Diphenhydramine
- Cimetidine
- Gemfibrozil
- Naproxen
- Bisphenol A
- DEET
- Sulfamethoxazole

Removal as a function of SRT for various compounds.
Indicator Review –
Strong Candidates for Removal Prediction Using Plant Condition and Fate Criteria

<table>
<thead>
<tr>
<th>Recalcitrant</th>
<th>Degradable / Low Sorption</th>
<th>Sorbable / Slow degradation</th>
<th>Sorbable / Degradable</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low SRT/HRT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sucralose Carbamazepine TCEP</td>
<td>Ibuprofen Naproxen Acetaminophen Caffeine</td>
<td>DEET Atenolol Trimethoprim</td>
<td>Triclocarban TCPP</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fluoxetine Meprobamate Gemfibrozil Triclosan</td>
</tr>
</tbody>
</table>
Findings:

- Indicator compounds can be used to predict removal in conventional secondary treatment.

- Processes can be modified to improve removal; 80+% is achievable for many compounds; solids retention and hydraulic retention times are key.

- Some biodegradation occurs but also sorption to wasted solids from secondary treatment. And some not further removed during anaerobic digestion. So finding “concentrated” ppm levels in biosolids is not surprising.

- Carbamazepine is example of a recalcitrant compound
Findings (continued)

- One of the facilities was also testing activated powdered carbon (wood based) to get enhanced nutrient removal.
- Able to achieve 75+% removal of the AS recalcitrant compounds (including carbamazepine).
- More research needed on trace organic compound removal during enhanced nutrient removal.
  - A win-win for facilities upgrading to meet tougher nutrient standards.
Product

- Excel database of 22 indicator compounds
- Removal efficiency in relation to AS treatment configuration and operational conditions, plus a seasonal factor
  - 9 bin categories showing like compounds (sorption and biodegradation) beyond the 22
  - e.g., threshold SRTs at >80% removal
<table>
<thead>
<tr>
<th>Ongoing Projects</th>
<th>Number</th>
<th>Expected Completion</th>
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<tbody>
<tr>
<td><strong>Wastewater Treatment</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Understanding Microaerobic Metabolism in a Sustainable World</strong> (Univ. Michigan)</td>
<td>U1R09</td>
<td>2012</td>
</tr>
<tr>
<td><strong>Developing a Standardized Protocol for Assessing the Biodegradability of Trace Organic Contaminants</strong> (Hazen and Sawyer)</td>
<td>U3R10</td>
<td>2013</td>
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<tr>
<td><strong>Demonstrating Advanced Oxidation/Biofiltration for Pharmaceutical Removal in Wastewater</strong> (Univ. Colorado)</td>
<td>U2R11</td>
<td>2013</td>
</tr>
<tr>
<td><strong>Holistic Assessment of Trace Organic Compounds in Wastewater Treatment</strong> (Metro Sacramento)</td>
<td>U3R11</td>
<td>2013</td>
</tr>
</tbody>
</table>
Understanding Microaerobic Metabolism in a Sustainable World (Univ. Michigan)

- Examine the fate of trace levels of pharmaceuticals using bioreactors to achieve nitrogen removal under various redox states.
  - Anoxic/aerobic
  - Microaerobic with nitrate limitation or not
  - Aerobic
Developing a Standardized Protocol for Assessing the Biodegradability of Trace Organics (Hazen and Sawyer)

- RO and advanced oxidation good but expensive
- To optimize biological treatment requires a standardized method for in-plant evaluation
  - Develop a standard assay for on-site use
Advanced Oxidation/Biofiltration for Pharmaceutical Removal in Wastewater
(Univ. Colorado & Univ. Michigan)

• Bench, pilot and full scale to see if UV-AOP followed by biofiltration will remove recalcitrant trace organics like carbamazepine

• Achieving high level of mineralization in the lab so far
Holistic Assessment of Trace Organics in Wastewater Treatment (Metro Sacramento)

• Look at trace organic removal as part of the utilities testing of selected BNR, filtration and disinfection treatment technologies being considered for $2 billion upgrade to meet new permit requirements
  – No trace organic limits in new permit but CA looking at these compounds
Biosolids Land Application
- Wastewater solids concentrate chemicals
- 2009 EPA sludge survey
  - 74 WWTP, 145 PPCPs
  - many found; >1 ppm
- No risk context provided
- Exposure to crops, animals, soil microbes, groundwater, people
- Uncertainty !!!
WERF Research Program

- Predict fate and effects of trace organics in land applied biosolids to inform environmental risk assessment
- Coordinate with EPA and chemical manufacturers
- Expert input on EPA Prioritization Tool
- Use Tool to id representative chemicals and parameters
- Develop the data to fill key data gaps
- Use research findings to inform risk assessment and support risk management decisions
Trace Organic Chemicals in Biosolids Amended Soils – State of the Science Review
State of the Science Review

- Compilation of published biosolids occurrence data for 105 trace organic chemicals
- Published data for physical, chemical, and biological parameters
- Discussion of processes affecting fate, transport, bioavailability, and toxicity in biosolids-amended soils
- Identify chemicals of “high interest” and data gaps
- Risk assessment methods and minimum data set for ecological and human risk assessment modeling
EPA 503 Rule Pathways of Exposure

- Inhalation of aerosols
- Consumption of groundwater
- Incidental ingestion of biosolids in soil
- Ingestion of plants grown on biosolids-amended fields
- Consumption of surface water

<table>
<thead>
<tr>
<th>Chemical Class</th>
<th>Occurrence</th>
<th>Mobility</th>
<th>Persistence</th>
<th>Bio-availability</th>
<th>Toxicity Human</th>
<th>Toxicity Ecological</th>
<th>Microbial Impacts</th>
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<tbody>
<tr>
<td>Brominated Flame Retardants (BFRs)</td>
<td>Tier 3</td>
<td>Tier 1</td>
<td>Tier 1</td>
<td>Tier 2</td>
<td>Tier 0</td>
<td>Tier 0</td>
<td>Tier 0</td>
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<tr>
<td>Perfluorocarbons (PFCs) and PFC Precursors</td>
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<td>Tier 2</td>
<td>Tier 1</td>
<td>Tier 0</td>
<td>Tier 0</td>
<td>Tier 0</td>
<td>Tier 0</td>
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<td>Tier 2</td>
<td>Tier 3</td>
<td>Tier 1</td>
<td>Tier 0</td>
<td>Tier 0</td>
<td>Tier 1</td>
</tr>
<tr>
<td>PPCPs: Antibiotics</td>
<td>Tier 3</td>
<td>Tier 2</td>
<td>Tier 1</td>
<td>Tier 0</td>
<td>Tier 2</td>
<td>Tier 0</td>
<td>Tier 1</td>
</tr>
<tr>
<td>PPCPs: Musks</td>
<td>Tier 3</td>
<td>Tier 2</td>
<td>Tier 3</td>
<td>Tier 2</td>
<td>Tier 1</td>
<td>Tier 0</td>
<td>Tier 0</td>
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<tr>
<td>PPCPs: Other</td>
<td>Tier 3</td>
<td>Tier 0</td>
<td>Tier 0</td>
<td>Tier 0</td>
<td>Tier 2</td>
<td>Tier 0</td>
<td>Tier 0</td>
</tr>
<tr>
<td>Plasticizers</td>
<td>Tier 3</td>
<td>Tier 2</td>
<td>Tier 1</td>
<td>Tier 1</td>
<td>Tier 1</td>
<td>Tier 0</td>
<td>Tier 0</td>
</tr>
<tr>
<td>Steroidal Chemicals</td>
<td>Tier 3</td>
<td>Tier 2</td>
<td>Tier 2</td>
<td>Tier 1</td>
<td>Tier 2</td>
<td>Tier 0</td>
<td>Tier 0</td>
</tr>
<tr>
<td>Surfactants</td>
<td>Tier 3</td>
<td>Tier 2</td>
<td>Tier 0</td>
<td>Tier 1</td>
<td>Tier 0</td>
<td>Tier 0</td>
<td>Tier 0</td>
</tr>
</tbody>
</table>

Generic Interpretation of Data Availability:

| Tier 0 | Essentially no data were available of this type for this class or subclass of TORCs, including data that could be used for modeling. |
|Tier 1  | For the majority of TORCs in this class or subclass, some data were available, but available data are likely of limited utility or are limited to modeled systems only (i.e., not directly derived from experimental studies). |
|Tier 2  | Useful data from experimental systems are available for a majority of TORCs in this class or subclass, but most of the data are not directly applicable to biosolids-amended soils. |
|Tier 3  | Substantial data of this type directly relevant for biosolids-amended soils are available, though some gaps in data may exist for specific TORCs. For this class or subclass of TORCs, data are available that have been measured in real world systems with biosolids-borne TORCs and reasonable biosolids application rates, and/or in long-term field-based studies with appropriate attention to study design and QA/QC. |
Steps in the Research Program

- Gather published data 145
- Screen for health & environmental risks ↓
- Gather unpublished data 60
- Screen for risks ↓
- Prioritize remaining compounds 31
- Develop data to fill key gaps ↓
- Screen for risks ??
~60 Compounds with Data Gaps

- Brominated flame retardants
- Antimicrobials (triclocarban)
- Antibiotics (15)
- Synthetic hormones (10)
- Steroids (10)
- Surfactants (alcohol ethoxylates)

- Pharmaceuticals (6)
- Musk Ketone
- Galaxolide
- Tonalide
- Organotins (3)
- Polydimethylsiloxane
- Polyorganosiloxane

WERF biosolids research 2012
Trace Organics in Biosolids Web Seminar

Wednesday, May 23, 2012

 Archived: visit www.werf.org and click on “Register for Events”
Trace Organics in Biosolids

**Next Steps** –

- Expert feedback / input on EPA Prioritization Tool
- RFP (in 2012) that will
  - Apply the Tool to identify priority, representative chemicals and key parameters needing data
  - Develop the data in partnership with utilities, manufacturers and EPA
- Use research findings to inform risk assessment and support risk management decisions
A Strategic Risk Communications Process for Biosolids Land Applications

- Long term viability and sustainability of biosolids land application requires community confidence, trust & support
- Adaptation of a proven strategic risk communications process
- Two case studies to test the process
- Guidance includes
  - A Primer for Biosolids Professionals
Investigation of Complaints/Symptoms of Illness Reported by Neighbors of Biosolids Land Application and other Soil Amendments [08HHE5PP]

Purpose
Pilot test a 5-step investigation protocol for neighbors of land application sites complaining of health effects to doctors, local health officials, biosolids generators, biosolids appliers, state EPA/DEP/DEQ.

Research Team
Franklin County Board of Health
Ohio State University
Ohio EPA

Published 2012
THANK YOU

For more information:

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www.werf.org
Technology Evaluation & Implementation

- New initiative in collaboration with WEF
  - Establish best practices and metrics for R&D
  - Evaluate new processes and technologies
  - Promote knowledge sharing & rapid implementation

- Leaders Innovation Forum for Technology (LIFT)

- Facility owners/operators as decision makers
Technology Evaluation & Implementation

- 6 step process for technology evaluation
  - Identify technology needs
  - Screen technologies to match needs
  - Select technologies to evaluate
  - Assemble technology evaluation partnerships
  - Conduct evaluations
  - Disseminate and implement findings
New Research Challenges
(Embrace a New View of Wastewater as a Resource)

- Energy Production & Efficiency
- Nutrient Recovery
- Sustainable Integrated Water Management
- Linking Contaminant Sources to Receiving Water Impacts – Nutrient site-specific WQC
- Sensor Integration & Guidance
- Trace Organics in Biosolids
WERF Research Challenges

- Pathogen Health Risks and Biosolids
- Pathogen Health Risks in Receiving Waters
- Nutrient Removal – Technology
- Strategic Asset Management
- Stormwater - BMPs and Water Quality
- Operations Optimization including Energy
- Trace Organics – Treatment and Receiving Waters
- Climate Change – Mitigation and Adaptation