Water Environment Research Foundation
Collaboration. Innovation. Results.

UPDATE ON WERF BIOSOLIDS RESEARCH

2011 Residuals and Biosolids Conference, Sacramento, CA – May 22 – 25, 2011

Recently Published Research Reports

Evaluation of Processes to Reduce Activated Sludge Solids Generation and Disposal (05CTS3)

- Literature search of technologies known to reduce activated sludge solids
- Analysis of these technologies at full-scale installations
- Validate processes and performance expectations
- Final report published December 2010

Energy Efficiency in Wastewater Treatment in North America: A Compendium of Best Practices and Case Studies of Novel Approaches (OWSO4R07e)

- Incremental improvements in energy efficiency through optimization of existing assets and operations
- More substantial improvements in energy efficiency from the adoption of novel (but proven at full scale) technologies
- Develop a Compendium of best practice (worldwide) in the energy-efficient design and operation of water industry assets. For this project, WERF is serving the role of North America wastewater practice coordinator.
- Final Report published May 2010

Energy Efficiency in the Water Industry: A Compendium of Best Practices and Case Studies Global Report (OWSO9C09)

- Best-in-class wastewater utilities strive to improve efficiency in all aspects of operations, particularly energy optimization
- Documentation of global case studies of Energy Optimization/Energy Recovery Technologies and/or Practices considered novel and full-scale proven in at least one installation
- Examples of novel technologies/approaches case studies documented under this project include the use of renewable energy sources related to anaerobic digestion optimization and cogeneration with the resulting biogas, and the treatment of domestic wastewater with anaerobic processes among others
- Final report published February 2011

State of the Science on Biogas: Treatment, Co-Generation, and Utilization in High Temperature Fuel Cells and as a Vehicle Fuel (OWSO10C10a)

- A suite of 4 affiliate reports prepared by Suez and contributed to WERF as part of the ongoing research into siloxanes in biogas. Reports reflect the European experience in :
    - Evaluation of Biogas Treatment Efficiency for the Elimination of Siloxanes – State of the Art on Biogas Treatment
    - State of the Art on co-generation using biogas

    - State of the Art on high temperature fuel cells using biogas
    - State of the Art on biogas utilization as a vehicle fuel
- Final report published April 2011

Ongoing Projects

Field Testing of Protocol for the Timely Investigation of Reported Health Incidents Associated with Biosolids Applied to Land (08-HHE-5PP)

- Top ranked priority from Biosolids Research Summit
- Draft protocol (Stock no. 06HHE5PP) published January 2008
    - Health questionnaire (local or state health department)
    - Site identification (permitting authority)
    - Biosolids generator questionnaire (wastewater utility)
    - Biosolids applier questionnaire (land applier)
    - Report of on-site inspection (investigation team)
- Applicable to all soil amendments, including commercial fertilizers and animal manures
- Most likely users are local and state health agencies
- Field testing conducted by Franklin County (OH) Board of Health
- Final Protocol will be completed May 2011

A Strategic Risk Communications Process for Outreach and Dialogue on Biosolids and Land Application (SRSK2R08)

- Facilitate dialogue of biosolids land application practices making them generally available to users at the local level
- Develop an integrated methodology for risk communications methodology to be applied simultaneously starting with problem formulation
- Expected completion date May 2011

Site Specific Risk Assessment Tools for Land Applied Biosolids (SRSK3R08)

- Describe the integration of knowledge to assess microbial risks from the land application of biosolids.
- This knowledge has been incorporated into an environmental dispersion, exposure, and risk model, known as the Spreadsheet Microbial Assessment of Risk: Tool for Biosolids ("SMART Biosolids"). The SMART Biosolids model enables wastewater utilities, land applicators, and regulators, to estimate microbial risk from biosolids land application under a variety of scenarios and thereby gain insight into effective management practices. In addition, this project conducted field monitoring to assess the fate and transport of microbes from land application during wet weather events.
- Compiles knowledge from a wide variety of sources into a documented tool for regulators and land applicators to perform site-specific assessments of microbial risk, including estimates of the effect of different setback requirements on microbial risk, the relative risks associated with different pathogens and exposure pathways, and the correspondence between indicator organisms and pathogens.
- Fills data gaps related to the fate and transport of microbes from land application during wet weather events.
- Expected completion date July 2011

Wastewater Treatment Plant Design and Operations Modifications to Improve Management of Biosolids Odors and Sudden Increases in Indicator Organisms (SRSK4T08)

- Start-up June 2009
- Evaluate effect of biosolids processing and upstream parameters on odors, SI, and regrowth to develop new approaches and insights
- Upstream processes: SRT, reactor configuration, iron addition
- Advanced digestion: dual digestion, EEH, TPAD, thermal hydrolysis
- Additives: Targeted compounds to attack mechanisms: enzymes, metals, anti-oxidants, and mixtures to address multiple mechanisms
- Identify and formulate solutions to odor, SI, and regrowth developed from Phase I results
- Field-test new approaches and solutions at plant-scale
- To be completed by end of 2011; interim results published during course of the project, including completed workshop at WEFTEC 2010 in New Orleans, LA.

Co-Digestion of Organic Waste with Wastewater Solids (OWSO5R07)

- Co-digestion of organic wastes with wastewater solids is being used to treat industrial, agricultural and commercial organic wastes.
- There has been an observed increase in biogas production, reduced electrical and natural gas demand, extended landfill life, reduced greenhouse gas production and a new revenue source from waste tipping fees.
- Anaerobic digester performance and operations is based on indirect measurements that include volatile solids reduction and loading rates. These indirect measurements work for wastewater solids because of the extent of empirical data on the treatment of wastewater solids.
- The development of operational data for organic waste sources is essential to make co-digestion an efficient process to be implemented by municipalities.
- Expected completion date December 2012

Characterization of Volatile Organic Compounds (VOCs) Emitted from Biosolids Composting (WERF2C10)

- Characterize volatile organic compounds (VOCs) emitted from biosolids composting to determine to what degree these VOCs are reactive and thus could contribute to ground level ozone.
- There are proposed rules in California on this subject and it is expected that other parts of the country will face similar rules. The two test sites are in California.
- The use of a wind tunnel will collect gas emission samples from the test compost piles. The wind tunnel will be equipped with a chemiosorbant -and- activated-carbon filter to clean the air being pulled into the chamber. The use of a wind tunnel provides a relatively large surface area, a defined flow direction and air exchange rates or air speed in the tunnel which may be more representative of natural conditions.
- Scores of compounds fall under the definition of "volatile organic compounds" that can contribute to ozone formation in the atmosphere. There is no single approach to measure the full range of compounds. Keeping this in mind, multiple techniques are being employed in order to obtain the widest possible profile of VOC emissions from compost sources. Alcohols, which constitute a major fraction of compost emissions, are being measured. Physico-chemical properties are being studied along with VOC measurements.

- Mobile Ozone Chamber Assays are being conducted for direct on-site measurement of ozone.
- Expected completion date June 2011

Wastewater Treatment Anaerobic Digester Foaming Prevention and Control Methods (INFR1SG10)

- Anaerobic digester foaming can be a common problem in wastewater treatment plants (WWTPs), with many cited causes, and a variety of prevention/control methods. However, much of the reported technical information is based on single plant specific cause-effects-control investigations.
- Foaming problems are still prevalent, persistent, and being experienced by more WWTPs than in the past. Implementation of longer SRT processes such as biological nutrient removal (BNR) and MBR (membrane bioreactor) processes might increase the incidence of digester foaming. Regardless of the causes, the result of digester foaming has been significant reduction in performance, capacity, and/or operational difficulties in the liquid and solids processing trains. Anaerobic digestion is also the primary energy production method from organic matter in wastewater, and it is the key to the overall energy sustainability of WWTPs.
- The goal of this project is investigate anaerobic digestion foaming at multiple full scale plants in a systematic method to determine the multiple causes, the contribution of each cause to foaming, mechanisms of foaming, prevention methods and control practices to obtain solutions for most, if not all, digester foaming causes.
- This project will synthesize the current state of knowledge in the USA and abroad, investigate additional methods and practices from full-scale facilities, with an end goal of producing and disseminating a systematic guidance document on anaerobic digester foaming and control for the WWTP industry. The outcome will help improve anaerobic digestion for enhanced energy recovery and make WWTPs more self-sustaining in terms of energy management.
- Expected completion date December 2012

Full-Plant Deammonification for Energy-Positive Nitrogen Removal (INFR6R11)

- Deammonification requires significantly less oxygen to remove nitrogen and so less energy is needed for aeration. Aeration energy demand for deammonification is in the range of 1.2 kilowatt-hours per kilogram of nitrogen removed, compared to about 5.0 for conventional nitrogen removal.
- Deammonification requires significantly less organic carbon to remove nitrogen, reducing the need to purchase external carbon, such as methanol.
- Energy recovery from wastewater is maximized. Organic carbon in wastewater contains energy that can be recovered through anaerobic digestion and methane capture. Process flowsheets using mainstream deammonification maximize energy recovery by diverting more particulate organic carbon away from the nitrogen removal process and directing it toward anaerobic treatment from which methane can be captured.
- Expected completion date January 2014

Fate of Engineered Nanomaterials in Wastewater Biosolids, Land Application and Incineration (U1R10)

Goal: To develop tools to quantify and understand how engineered nanomaterials accumulate in biosolids, undergo biosolids treatment and are disposed of and accumulate in the environment. We will include both model ENMs and ENMs in consumer products to improve our knowledge into their material life cycles, final disposition in the environment, and exposures to ENM by biota in rivers and soils. Specific research questions include:

- What levels of ENMs occur in biosolids?
- What factors affect ENM interaction with biosolids?
- What analytical tools are capable of monitoring ENMs in biosolids?
- How are ENMs in biosolids altered during digestion or incineration?
- Are ENMs currently present in biosolids that have been land applied?
- Do ENMs affect basic soil microbial processes?
- Expected completion date December 2012

Developing Better Indicators for Pathogen Presence in Sewage Sludge's (U1R08)

- Report provides information about the concentrations of an extensive selection of raw sewage-associated organisms across warm and cool seasons and from locations across the United States.
- Identification of sewage-related indicator organisms suitable for wastewater screening
- Identification of indicator organisms suitable for screening temperature-based wastewater treatment processes
- Information on the time-temperature relationships of indicator organisms and microbial pathogens
- Information can be used to assess pathogen kill predictions for temperature-based treatment technologies
- Expected completion date June 2011

Use of Nanoparticles for Reduction of Odorant Production and Improvements in Dewaterability of Biosolids (U3R08)

- Demonstration that nanoscale particles can improve polymer-aided dewatering and reduce odor production from biosolids.
- Characterization of the performance of a number of different nanoadditives with varying size, charges, chemistry, and structure.
- Characterization of the performance of nanoadditives during dewatering with polymers of different charge densities, molecular weight and configuration.
- Illustrates the performance of nanoadditives during dewatering under various shear conditions.
- Provides preliminary concepts on the role of nanoscale additives on dewatering and odor control.
- Expected completion date June 2011

Research Programs

Optimization of Wastewater and Solids Operations

Goal: Develop and demonstrate economical and environmentally responsible processes that improve wastewater and solids treatment operations efficiencies and cost by at least 20%

- Final Reports

    - Energy Efficiency in North America: A compendium of Best Practices (OWSO4R07e)
    - Energy Efficiency in the Water Industry: Global Report (OWSO9C09)
    - State of the Science on Biogas: Treatment, Co-Generation, and Utilization in High Temperature Fuel Cells and as a Vehicle Fuel (OWSO10C10a)

- Ongoing Activities
    - Test Life Cycle Assessment Manager Energy Recovery (LCAMER) for anaerobic digestion (updated version underway)
    - Co-digestion organic waste & wastewater solids (2012)
    - Decision support system sustainable energy management (summer 2011)
    - Life-cycle tool for green energy options (summer 2011)
    - Optimization tool (CHEApet - Summer 2011)
    - Treatment to Remove Siloxanes in Biogas (2012)
    - Identification of and strategy to overcome barriers to expanded use of Anaerobic digestion and CHP (Fall 2011)
    - Demonstration of energy management at subscriber facilities (Summer 2011)

Climate Change
Goal: WERF will evaluate the likely effects of climate change on wastewater services, and will assess processes and technologies to cost-effectively mitigate and adapt to the potential impacts.

- *Ongoing Activities*
    - Greenhouse nitrogen emissions from wastewater treatment (U4R07 Final Report expected Fall 2011)
    - Greenhouse gas emissions (methane from various wastewater treatment and some solids management options (U2R08 reports - Fall 2011)
- *Complete*
    - GHG generation and emission from septic systems (DEC1R09)

Biosolids Trace Organics (new research program)
Goal: Determine the fate and transport of trace organics/emerging contaminants in biosolids and develop the data to support risk management.

- In 2010, WERF subscribers requested that we consider ways to initiate research on biosolids trace organics to provide them with information on whether there is a cause for concern from trace organics in biosolids-amended soils
- EPA also released its Targeted National Sewage Sludge Survey which found many trace organics present in biosolids at higher concentrations than previously anticipated
- WERF developed a State of the Science report (SRSK5T09) to identify the gaps in the data needed to evaluate the human and ecological exposure to trace organics in biosolids-amended soils
- WERF has contacted utilities and researchers with ongoing activities regarding biosolids trace organics; all have indicated an interest in participating in a coordinated program
- WERF has receiving funding and data commitments from various stakeholders for an initial phase that will identify, collect and summarize all the available but unpublished data on a short-list of chemicals that are found in biosolids. This work will be conducted by a contractor in 2011. In 2012, WERF will undertake a next phase to fill remaining

data gaps. Partners include wastewater utilities, industry subscribers and associations, and the US EPA. This final phase is likely to be a multi-year research effort.

For more information contact:

Dan Woltering, Ph.D
Director of Research
571-384-2095
dwoltering@werf.org

Amit Pramanik, PhD, BCEEM
Senior Program Director
571-384-2101
apramanik@werf.org

Lola Olabode, MPH
Program Director
571-384-2109
lolabode@werf.org

Lauren Fillmore, M.S.
Program Director
571-384-2107
lfillmore@werf.org

WERF Research on the Treatment and Management of Residuals and Biosolids

Highlights:

- **Almost a third of WERF's research projects have focused on the treatment and management of residuals and biosolids. This research is valued at over $20 million.**
- **Two of the six program areas in WERF's new PDR (Program Directed Research) process which was launched in 2005 will continue work in this area – they include Solids Treatment, Residuals & Reuse and Wastewater Treatment & Reuse.**
- **Key Subscriber challenges are related to residuals and biosolids, including Operations Optimization Challenge.**
- **Biosolids TCR (Targeted Collaborative Research) program set up by WERF to fund research on key biosolids related issues that were identified in the WERF-EPA Biosolids Research Summit (2003) and by the TCR funding partners. Biosolids TCR funding partners currently include 12 WERF Subscribers, each contributing between $5,000 to $50,000 per year for 5 years.**

Starting on July 1, 2009, WERF will have an open access policy for research reports which are over two years old. These reports will be free to the public as downloads from the WERF web site www.werf.org under "Search Publications and Tools." These "open access" reports are marked in blue.

Publication Year	Project Number and Project Title	Principal Investigator and Contracting Organization	Research Objectives
1992	90-4, (No Longer Available) Innovative Process Assessment: Sludge Processing, Disposal, and Reuse	Richard Kuchenrither, Ph.D., P.E. Black & Veatch Kansas City, MO	Provides an assessment of diverse research/ development projects regarding the treatment and disposal of biosolids.
1999	91-ISP-1, Evaluating and Measuring Biosolids Incinerator Emissions (Product No. D93006)	John Stukenberg, Ph.D., P.E. Black & Veatch Kansas City, MO	Developed a database on incinerator emission characteristics; users determine performance evaluation for various airborne contaminant control options (including hydrocarbons).
1993	91-ISP-4, Document Long Term Experience of Biosolids Land Application Programs (Product No. D0015)	John R. Stukenberg, Ph.D. Black & Veatch Kansas City, MO	Provides information on the beneficial use of biosolids in land application programs.
1993	91-ISP-5, Polymer Characterization and Control in Biosolids Management (Product No. D43007)	Steven Dentel, Ph.D., P.E. University of Delaware Newark, DE	Provides information on optimal usage of chemical conditioners for biosolids dewatering. Assesses automatic polymer feed equipment. Provides a formal protocol for making decisions on selecting polymers and estimating dosing rates.
1995	91-ISP-5A, Guidance Manual for Polymer Selection in Wastewater Treatment Plants (Companion report to project above) (Product No. D0013)	Steven Dentel, Ph.D., P.E. University of Delaware Newark, DE	Aids wastewater chemists, managers, and operators in the selection of polymers. Systematic processes for polymer selection are divided into modules for each type of polymer application with step-by-step guidance.

1996	92-PUM-1C0,(Not available from WERF) Long-Term Fate of Land Applied Wastewater Materials	New York State Energy Research and Development Authority (cooperative project www.nyserda.org)	A collaborative program project that examines the long term effects of land application of biosolids products and evaluates the effects of using various forms of materials on land sites, including compost, pelletized products and liquid applications.
1997	94-REM-1, Defining Biosolids Stability: A Basis for Public and Regulatory Acceptance (Product No. D72002)	Michael S. Switzenbaum, Ph.D. Univ. of Massachusetts Amherst, MA	Provides information on biosolids stability criteria and recommends definitions for stability for various biosolids processes and products.
2000	94-REM-2, Analysis and Fate of Polymers in Wastewater Treatment (Product No. D00301)	Steven Dentel, Ph.D., P.E., DEE University of Delaware Newark, DE	Addresses the impact and fate of polymers used as flocculant agents in wastewater treatment. Evaluates when polymer release to the environment may be harmful. Examines analytical methods to detect polymer.
2004	95-REM-2 Producing Class A Biosolids with Low Cost, Low Technology Treatment Processes	Perry Schafer, P.E. Brown & Caldwell	Describes low tech treatment processes for producing Class A Biosolids. Class A biosolids have been and are now being produced by low-cost, low-technology biosolids treatment processes including lagoon storage, air drying, and cake storage. This project reviewed the available literature and municipal agency data about these processes.
1999	95-REM-3, Understanding Fate, Transport, Bioavailability and Cycling of Metals (Molybdenum) in Land Applied Biosolids (Product No. D93017)	George O'Connor, Ph.D. University of Florida Gainesville, FL	Improves understanding of risks and the pathways associated with metal uptake (focusing on molybdenum) in grazing animals. Enhances scientific knowledge base and provides information relative to EPA's Part 503 regulations on molybdenum.
1997	96-CTS-5, Benchmarking Wastewater Treatment Plant Operations – Collection, Treatment, and Biosolids Management (Product No. D73001)	Roger Patrick Water Research Center (WRC)	Derives performance standards for wastewater treatment operators to help focus their efforts, improve operations, and reduce costs. Highlights approaches, processes, and results that have been used by others to accomplish these objectives.
1998	96-REM-1, Biosolids Management: Assessment of Innovative Processes (Product No. D83004)	Albert Pincince, Ph.D., P.E. Camp, Dresser & McKee Cambridge, MA	Identifies and reports on the development, status and cost effectiveness more than 110 innovative biosolids processing and management technologies.
1999	96-REM-2, Watershed Effects of Biosolids Land Application: Literature Review (Product No. D93003)	Kathryn Draeger Environmental Ground, Inc., St. Paul, MN	Assesses available information (more than 1400 references spanning 100 years) on the uses and impacts of biosolids in watersheds.

2004	97-REM-2, Pathogen Destruction Efficiency in High Temperature Digestion	Donald Gabb, Ph.D., P.E. East Bay Municipal Utility District Oakland, CA	Compiles information available worldwide on high temperature digestion studies. Will develop practical and economical high temperature (mesophilic/thermophilic) digestion protocols to yield Class A biosolids products and augment existing processes to further reduce pathogens.
2000	97-REM-3, Estimating Plant-Available Nitrogen in Biosolids (Product No. D00307)	John Gilmour, Ph.D. University of Arkansas Fayetteville, AR	Practical guidance for biosolids managers and regulatory agencies in using biosolids to benefit crop growth, and in minimizing the potential for nitrogen to migrate to groundwater or cause surface water pollution.
2000	97-REM-4, Investigating the Effects of Electrical Arc Pretreatment of Biosolids (Product No. D00314)	Steven Dentel, Ph.D., P.E., DEE University of Delaware Newark, DE	Investigates the feasibility of electrical arc pretreatment of biosolids as a potential innovative biosolids dewatering process prior to chemical conditioning and dewatering. Addresses fundamental and applied aspects of its operation.
2003	97-REM-5, Assessing Bioavailability of Metals in Biosolid-Amended Soils: Root Exudates and their Effects on Solubility of Metals	Andrew Chang, Ph.D., P.E. University of California, Riverside Riverside, CA	Exploring phenomena that control the fate of metals in biosolids and soil mixtures, and impacts on ecological and human health. Will improve technical basis of 503 Rule, thereby enhancing its acceptability within the scientific community and improving public confidence.
2003	98-REM-1 (Phase 1), A Dynamic Model to Assess Microbial Health Risks Associated with Beneficial Uses of Biosolids	Jack Colford, M.D., Ph.D. University of California, Berkeley	The first phase developed an assessment framework for microbial exposures associated with beneficial biosolids reuse, and a streamlined protocol to assess risks from various exposure pathways.
2006	98-REM1a Application of a Dynamic Model to Assess Microbial Health Risks Associated with Beneficial Uses of Biosolids and Research Digest	Joseph Eisenberg, Ph.D. University of Michigan	The second phase applies the framework developed in Phase I to characterize risk associated with real-world biosolid application scenarios. Risk assessment framework provides a mechanism to discuss biosolids management microbial risk using a common metric for comparison of treatment methods, management alternatives, and to set risk-based standards for microbial contaminants in biosolids. Biosolids producers can use this research to interpret the results and potential health implications of biosolids monitoring data. Treatment plant engineers can evaluate the potential risk-based benefits of making operational changes to existing treatment and/or adding additional treatment processes, and environmental managers can use it to evaluate capital improvements and/or land application site placement issues from a health-based perspective.
2006	98REM1b Research Digest	Joseph Eisenberg, Ph.D. University of Michigan	Research Digest aimed at a more general audience to emphasize the practical aspects of the findings.

2002	99-PUM-1, Evaluating Risks and Benefits of Soil Amendments Used in Agriculture 99PUM1RD research digest also available	Lynne H. Moss, P.E. Camp, Dresser, & McKee Austin, TX	Determines the risks and benefits, advantages and potential disadvantages associated with the use of a variety of soil amendments in comparison to chemical fertilizers. Provides information in determining which soil amendment can be used in or for a specific soil, crop, or climatic condition.
2002	99-PUM-2T, Characterizing the Forms, Solubilities, Bioavailabilities and Mineralization Rates of Phosphorus in Biosolids, Commercial Fertilizers and Animal Manures (Phase 1) (PDF available)	George O'Connor, Ph.D. University of Florida Gainesville, FL	Phase I characterized the forms and solubilities of phosphorus in a variety of biosolids products and in biosolids-soils matrices. Phase II will further define this work
2006	99-PUM-2T (Phase II), Characterizing the Forms, Solubilities, Bioavailabilities and Mineralization Rates of Phosphorus in Biosolids, Commercial Fertilizers and Animal Manures	George O'Connor, Ph.D. University of Florida Gainesville, FL	Phase II research will confirm and expand Phase I findings on the fate of phosphorus added to soil from biosolids and manures and will improve our ability to use these amendments for environmentally sound crop production.
2002	99-PUM-3, Developing Protocols for Measuring Biosolids Stability	Michael S. Switzenbaum, Ph.D. Univ. of Massachusetts Amherst, MA	Develops standard, detailed protocols for conducting tests that are commonly used to assess stability in the associated biosolids/products.
NA	99-PUM-5T, Manual of Good Practice for Biosolids (Product available from the NBP website: http://biosolids.policy.net/emsguide/manual/goodpractmanual.vtml))	Mark Lang, P.E. Sear Brown Group Rochester, NY	A targeted collaborative project that developed an online resource document on the issues to be considered when designing and implementing a biosolids management program. [Managed by WERF for the National Biosolids Partnership.]
2000	99-PUM-6-ET, Evaluating the Use of Near-Infrared Spectroscopy for the Analysis of Biosolids Constituents (Product No. D00306)	Diane F. Malley, Ph.D. PDK Projects, Canada	An emerging technology project that evaluated the feasibility of applying near-infrared spectroscopy (NIRS), widely used in commercial and industrial applications, to analyze nutrient and heavy metal concentrations in biosolids and receiving soils.
2002	98-REM-3, Thickening and Dewatering Processes: How to Evaluate and Implement an Automation Package (Product No. D13006)	Robert Gillette, P.E., DEE Carollo Engineers	Evaluates state of current practices, screens and field tests selected automation processes. Provides information to improve dewatering operations to cut the cost of dewatering biosolids in POTWs and in downstream operations.

2003	00-CTS-8, Membrane Technology: Feasibility of Solid/Liquid Separation in Wastewater Treatment (Subscriber Tool)	Glen Daigger, Ph.D., P.E. George Crawford, P.E. CH2M-Hill	Provides a comprehensive assessment of membrane applications and identifies a method to evaluate the use of membrane technologies for specific treatment applications. Results from this research will allow for a direct comparison of membrane technologies with more conventional methods of solid/liquid separation.
2004	00-CTS-10T, Minimizing Biomass Production from Biological Treatment	David H. Stensel, Ph.D., P.E. University of Washington Seattle	Will identify and evaluate methods to reduce biological solids in aerated biological reactors. It will determine whether cost savings can practically be realized by reducing the ultimate amount of waste requiring treatment and disposal.
2004	00-HHE-5C (Phase I) Identifying and Controlling Municipal Wastewater Odor Environment – Literature Review	Gregory M. Adams, P.E. Los Angeles County Sanitation District, and Jay Witherspoon, Ph.D., P.E. CH2M-Hill	The primary objective is to evaluate the state of knowledge and science about odors and odor control for all stages of treatment and disposal of wastewater and residuals. It provides a basis from which to begin a multi-phase process to develop efficient, effective odor control technologies at all stages of wastewater treatment and disposal. Phase 1 involves critical reviews and syntheses of published information (includes conventional and grey literature), findings from recent and upcoming odors-related workshops, as well as electronic databases.
2004	00-HHE-5T (Phase II), Identifying and Controlling Odor in the Municipal Wastewater Environment Phase II: Impacts of In-Plant Parameters on Biosolids Odor Quality	Gregory M. Adams, P.E. Los Angeles County Sanitation District, and Jay Witherspoon, Ph.D., P.E. CH2M-Hill	Phase 2 collects objective data to demonstrate the influence of anaerobic digestion system design and operating parameters on the odor quality of the final product. Biosolids odor emissions measured before and after anaerobic digestion and operations and treatment parameters measured to determine the influence of these parameters on biosolids odor quality. A total of 10 POTWS were involved in the Phase 2 research effort.
2004	00-HHE-5T (HEA), Identifying and Controlling Municipal Wastewater Odor Environment – Health Effects Addendum	William Cain, Ph.D. Gregory M. Adams, P.E. Los Angeles County Sanitation District, and Jay Witherspoon, Ph.D., P.E. CH2M-Hill	The overall objective was to identify the research gaps and needs through a review of appropriate literature and to prioritize the future direction of research on health effects associated with POTW biosolids odors.
2004	00-PUM-5, Biosolids: Understanding Public Perception and Participation	Ned Beecher New England Biosolids & Residuals Association, Tamworth, NH	Lessons learned from successful and unsuccessful biosolids recycling programs will be shared to provide guidance in incorporating stakeholder priorities.
2003	00-PUM-7, Development of a Cost Determination Protocol for Use in Benchmarking Biosolids Management Programs	Eliot Epstein, Ph.D. E&A Environmental Consultants, Inc.	Developed a protocol to identify and quantify direct and indirect costs associated with management of biosolids for all reuse and disposal options. The protocol was tested and refined at several sites that represent wide range of biosolids management options in diverse geographic areas. Should help utility managers evaluate the cost of biosolids management programs on a consistent basis with other agencies.

2004	01-CTS-32-ET, A New Tool for Measuring Biosolids Floc Strength	Mohammad Abu-Orf, Ph.D. US Filter NATC / Vivendi Water	Established a standard method and set of procedures for measuring floc strength. Will aid in understanding fundamentals of conditioning and enhance full scale dewatering
2010	02-CTS-8-P Advanced Biosolids Flow-Through Thermophilic Treatment (BFT3) Demonstration Project	Billy Turner and Cliff Arnett Columbus Water Works, GA John Willis, Brown & Caldwell Mike Aitken & Mark Sobsey, University of North Carolina – Chapel Hill	Evaluated the BFT3 process for retrofitting existing digestion systems to upgrade them from Class B to Class A. WERF provided peer review of the protocols definition, experimental testing for health risk assessment of microbial contaminants, and full-scale start-up.
2004	02-HHE-1-CO, Analytical Method for Endocrine Disruptors in Sewage Sludge	Cooperative Project with UKWIR Contractor: WRc	Will solidify methods for extracting steroidal hormones from biosolids.
2004	03-HHE-1, WERF/EPA Biosolids Research Summit	WERF & Consensus Building Institute	Multi-stakeholder workshop that developed a research agenda to address scientific issues related to the land application of biosolids.
2006	00-PUM-6, Development of a Metals Toxicity Protocol for Biosoliuds	Katherine M. Banks, Ph.D. Purdue University	A series of toxicity bioassay tests that will provide practitioners with a way to address citizen concerns regarding the human health and environmental impacts of biosolids reuse.
2006	01-CTS-1, Understanding Factors Affecting Polymer Demand for Conditioning and Dewatering	Matthew J. Higgins, Ph.D. Bucknell University	Improves understanding of the nature of flocs and the specific chemical interactions that alter floc properties. Results could lead to better selection of conditioning chemicals, help to reduce chemical costs and/or lead to improved dewatering techniques.
2006	03-CTS-13T, Examination of Reactivation of Fecal Coliforms in Anaerobically Digested Biosolids	Matthew J. Higgins, PhD, P.E. Bucknell University Sudhir Murthy, Ph.D., P.E. DC Water & Sewer Authority	A look at the phenomenon of reactivation of pathogens through the digestion process. Demonstrates that pathogens exist in a viable-but-non-culturable state through the digestion process but are induced to become culturable due to the presence of a substrate in the dewatering process, which allows for rapid growth in the final cake material.
2006	99-HHE-3, Control of Human Parasites in Municipal Biosolids	Christine L. Bean University of New Hampshire Durham, NH	Screens, identifies, and selects an appropriate surrogate human parasite(s), in lieu of helminth ova, and develops protocols to recover, detect, and measure surrogate organism(s) for municipal wastewater biosolids.
2009	01-CTS-18-UR, An Assessment Tool for Managing Cost-effective Energy Recovery from Anaerobically Digested Wastewater Solids	Hugh Monteith, Ph.D. Hydromantis, Inc.	Identifies cost-effective alternatives for energy recovery from solids treatment (anaerobic) based on key factors such as energy costs, regulatory conditions, plant capacity, social values, and more. Information on development of LCAMER model.

2008	01-CTS-19-UR, Effects of Biosolids Properties on Membrane Bioreactors (MBRs) and Solids Processing	Slav Hermanowicz, Ph.D., P.E. University of California Berkeley	Will investigate the effects of biosolids characteristics on membrane performance and solids processing. This will help define the operating limits of MBRs in municipal wastewater treatment and improve understanding of the behavior of solids to be processed.
2007	01-HHE-3, Assessing the Fate of Emerging Pathogens in Biosolids	Scott Yates, Ph.D. University of California-Riverside	Will detect and follow the fate of emerging pathogens in biosolids from the treatment process through land application until they are undetectable. Will help address public health concerns regarding land application of biosolids.
2007	02-CTS-3, Innovative Technologies to Reduce Water Content of Dewatered Sludges	Sarah Miller CSIRO Manufacturing & Infrastructure Technology	Evaluates methods to improve water removal from dewatered cakes, including innovative equipment, new additives, additive or conditioning agent combinations, physical modifications, or a combination of these or other approaches.
2007	02-HHE-2, Biosolids Sample Processing for Analyses of Pathogens	Morteza Abbaszadegan, PhD Arizona State University	Addresses concerns raised by NRC's recent report on biosolids. Will develop sample preparation methods for use with molecular detection techniques such as microarray analysis, quantitative PCR, fiber-optic biosensors, and other new technologies. Will help address public concern over land-applied biosolids by measuring the presence and fate of pathogens.
2007	02-PUM-1, Quantification of Airborne Biological Contaminants Associated with Land Applied Biosolids	Jordan Peccia, PhD Arizona State University	Addresses concerns raised by NRC's recent report on biosolids. Provide fundamental data to assess the potential release and exposure to airborne biological contaminants from land application of Class B biosolids by analyzing current health-impact literature. Data produced will provide basis for a comprehensive, full-scale analytical investigation.
2008	03-CTS-9, Biosolids Processing Modifications for Cake Odor Reduction	Gregory M. Adams, P.E. Los Angeles County Sanitation District, and Jay Witherspoon, Ph.D., P.E. CH2M-Hill	Builds on and enhance an existing process, anaerobic biosolids digestion, to produce lower-odor biosolids. Equipment or process vendors may be invited to demonstrate their processes full-scale at one or two plants, while researchers collect and analyze data and compares results. Builds upon work conducted in Identifying and Controlling Municipal Wastewater Odors (00-HHE-5T).
2009	03-HHE-2, Pathogen Risk Indicators for Wastewater and Biosolids	Judy Blackbeard CRC Water Quality and Treatment Australia	Compares the accuracy, advantages, and disadvantages of existing indicator organisms with proposed indicators in wastewater and biosolids. If successful, alternative organisms will provide better indicators of public health impacts, more accurate tools for setting appropriate standards, and more effective monitoring of water and biosolids, leading to increased confidence in the quality of effluent and residuals.

2008	04-CTS-3T, Fecal and Pathogen Regrowth/ Reactivation From Centrifugation of Anaerobically Digested Sludges	Matthew J. Higgins, PhD, P.E. Bucknell University Sudhir Murthy, Ph.D., P.E. DC Water & Sewer Authority	This project determined the extent that reactivation / regrowth of microbes in digested and dewatered biosolids, which has been the focus of 03CTS13T, is occurring for both indicator organisms and pathogens. Special attention was given to the effect that variability of microbe measurements may be having on observed results, and the best analytical methods to use to assess this observed phenomenon.
2007	06-HHE-5PP, Epidemiologic Surveillance and Investigation of Illness Reported by Neighbors of Biosolids Land Application Sites – Phase I	Steve Wing, Ph.D. University of North Carolina	This project was the highest ranked priority at the 2003 Biosolids Research Summit The first phase of the project developed a protocol to be used in conjunction with established public health investigation procedures and implemented through the existing network of public health organizations.
2007	04-CTS-2, An Economic Framework for Evaluating the Benefits and Costs of Biosolids Management Options	Robert S. Raucher, Ph.D. Stratus Consulting, Inc.	Developed a method for evaluating the costs and benefits of various sludge/biosolids disposal and beneficial use options that provides utility and industry managers with the information necessary to make a decision on which option to use. This information can also be shared with the general public to help explain the disposal or beneficial use options made by the utilities.
2009	04-CTS-7T, Minimizing Mercury Emissions from Biosolids Incinerators	Carl E. Hensman, Ph.D. Frontier Geosciences, Inc.	Quantified mercury emissions from representative biosolids incinerators located in the United States. Established test protocols that POTWs that practice incineration can use to accurately determine the fate of the mercury that enters their plants. Identified practices and control technologies to cost-effectively reduce mercury emissions from biosolids incinerators.
2010	04-HHE-6, Fate of Estrogenic Compounds During Municipal Sludge Stabilization and Dewatering	Kathleen Esposito, P.E. & Beverly Stinson, Ph.D., P.E. *AECOM, Inc.* Ed Furlong, Ph.D. *U.S. Geological Survey* David Quanrud, *University of Arizona*	Investigated the fate of known estrogenic compounds and total estrogenic activity in solids derived from wastewater treatment, in processes commonly used to stabilize, disinfect and dewater municipal wastewater treatment sludges.
2009	04-HHE-7, An Investigation into Biosolids Sampling and Handling Methods for USEPA-Approved Microbial Detection Techniques	Sharon C. Long, Ph.D. University of Massachusetts – Amherst (now with University of Wisconsin- Madison	Developed scientifically defensible methods for collecting and handling representative samples for microbial analysis from biosolids matrices with the greatest potential impact to public health (liquid, cake, compost).
2010	05-CTS-3, Evaluation of Processes to Reduce Activated Sludge Solids Generation and Disposal	Julian Sandino CH2M-Hill	Develop and demonstrate an evaluation methodology that will be used to independently assess the effectiveness of at least one selected commercially available process. This tool can be used by industrial and municipal wastewater treatment facility owners and operators to technically and economically evaluate processes that can reduce waste activated sludge quantities

2010	05-CTS-2T, Evaluation of BMPs for Sustainable Groundwater Protection at Biosolids land application Sites	Mike McFarland, Ph.D. Utah State University	Developed a protocol to evaluate the effectiveness of best management practices to mitigate the potential risk of groundwater contamination at biosolids land application sites. Describe the range of groundwater protection BMPs currently in practice at land application sites.
2011	SRSK2R08 A Strategic Risk Communications Process for Outreach and Dialogue on Biosolids Land Application	Sara Eggers, PhD. Decision Partners	Provide wastewater utilities, land appliers, regulatory agencies and public administrators' state-of-the-science, practical, locally applicable pathogen risk assessment and communication approaches, with methodologies tailored to a variety of conditions. Appropriate risk assessment methodologies will accommodate varying levels of expertise and resources.
Ongoing	SRSK3R08 Site Specific Risk Assessment Tools for Land Applied Biosolids	Patrick Gurian, Ph.D. Drexel University	Provide wastewater utilities, land appliers, regulatory agencies and public administrators' state-of-the-science, practical, locally applicable pathogen risk assessment and communication approaches, with methodologies tailored to a variety of conditions. Appropriate risk assessment methodologies will accommodate varying levels of expertise and resources.
2010	03CTS9a Evaluation of Aluminum and Iron Addition During Conditioning and Dewatering for Odor Control	Matthew J. Higgins, PhD, P.E. Bucknell University	Investigate factors impacting the effectiveness of metal salts in reducing the production of volatile organic sulfur compounds in biosolids, and develop recommendations for applying metal salt addition for odor reduction.
2010	03CTS9b Effect of Aluminum and Iron on Odors, Digestion Efficiency and Dewatering Properties	John T. Novak, PhD, P.E. Virginia Tech University	Investigate the impact of iron and aluminum addition in determining odor generation from dewatered sludge cakes. Iron and aluminum addition to activated sludge for phosphorus removal and directly to anaerobic digestion were studied. Data on sludge dewatering properties also was collected.
2010	03CTS9c Biosolids Odor Reduction - Development of Web-Based Decision Tool	Zeynep Erdal, P.E./Robert Forbes, P.E. Ch2M-Hill	Web-based roadmap to integrate the findings of all four phases of the biosolids-odor-reduction research and encompass real solutions to enhancing biosolids odor quality, beyond the use of odor-scrubbing or masking agents. Incorporates a cradle-to-grave approach from early treatment processes to the biosolids end use or disposal point.

Ongoing	INFR1SG10 Wastewater Treatment Anaerobic Digester Foaming Prevention and Control Methods	Krishna Pagilla, Ph.D. Illinois Institute of Technology	Anaerobic digester foaming can be a common problem in wastewater treatment plants (WWTPs), with many cited causes, and a variety of prevention/control methods. However, much of the reported technical information is based on single plant specific cause-effects-control investigations. Foaming problems are still prevalent, persistent, and being experienced by more WWTPs than in the past. Implementation of longer SRT processes such as biological nutrient removal (BNR) and MBR (membrane bioreactor) processes might increase the incidence of digester foaming. Regardless of the causes, the result of digester foaming has been significant reduction in performance, capacity, and/or operational difficulties in the liquid and solids processing trains. Anaerobic digestion is also the primary energy production method from organic matter in wastewater, and it is the key to the overall energy sustainability of WWTPs.
Ongoing	INFR6R11 Full-Plant Deammonification for Energy-Positive Nitrogen Removal	Maureen O'Shaughnessy O'Shaughnessy Water Consulting, LLC	The successful application of full-plant deammonification could save wastewater utilities hundreds of millions of dollars in aeration and external carbon costs in the life cycle. For municipalities, wastewater treatment plants (WWTP) are frequently the largest point requirement of energy with significant energy used to provide aeration to oxidize organic carbon and ammonia. This research will demonstrate energy-neutral or even energy-positive wastewater treatment and reduction of external carbon for denitrification by applying a more efficient alternative biological pathway. This innovative technology is compatible with existing wastewater infrastructure, often with minimal modifications.The 1990s discovery of a plantomycete-like ANaerobic AMMonium-OXidizing "anammox" bacteria allowed the development of wastewater treatment concepts that apply advantageous metabolic pathways unique to this microorganism. "Deammonification" is a two-step biological process. In the first step, ammonia-oxidizing bacteria (AOB) aerobically convert half of the ammonia to nitrite. In the second step, anammox bacteria oxidize the ammonia using nitrite to produce nitrogen gas without the organic carbon substrate required for conventional heterotrophic denitrification. The implications of deammonification for sustainable, cost effective and energy positive wastewater treatment are extraordinary
2008	OWSO3R07 State of the Science Report Energy and Resource Recovery from Sludge	Hugh Monteith, P. Eng, Hydromantis, Inc.	A Global Water Research Coalition report on the state of the science for recovering energy and resources, such as nutrients, from wastewater sludge. A triple bottom line approach was applied to identify suitable options.
Ongoing	OWSO5R07 Assessment of Operational and Performance Parameters for Co-Digestion	David Parry, Ph.D. P.E. CDM	A practical procedure developed to assess the potential impacts of a particular organic waste as a co-digestion feedstock in anaerobic digestion. The project provides access to empirical data necessary to support digester design and operational stability parameters. Will result in an economic model to assess the viability of co-digestion.

Ongoing	SRSK4T08 Wastewater Treatment Plant Design Operation and Modification to Improve Management of Biosolids Odors and Sudden Increases in Indicator Organisms	Matthew J. Higgins, PhD, P.E. Bucknell University Sudhir Murthy, Ph.D., P.E. DC Water & Sewer Authority	Provide wastewater treatment personnel and their consultants with practical design and operational procedures that holistically address biosolids odors and sudden increases in indicator organisms.
2010	SRSK5T09 State-of-the-Science Review of Occurrence and Physical, Chemical and Biological processes Affecting Biosolids-borne Trace Organic Chemicals in Soils	Christopher Higgins, PhD Colorado School of Mines	Identifies the TOrCs of potential greatest concern for the land application of biosolids and prioritized them based on occurrence data and readily available data on bioaccumulation and toxicity. Provides a detailed overview of what is currently known about the physical, chemical, and biological processes affecting TOrC fate, transport, bioavailability, and toxicity in biosolids-amended soils for the targeted TOrCs.
2011	U1R08 Developing Better Indicators for Pathogen Presence in Sewage Sludges	Suresh D. Pillai, Ph.D. Texas A&M University	Report provides information about the concentrations of an extensive selection of raw sewage-associated organisms across warm and cool seasons and from locations across the United States. Identification of sewage-related indicator organisms suitable for wastewater screening Identification of indicator organisms suitable for screening temperature-based wastewater treatment processes. Information on the time-temperature relationships of indicator organisms and microbial pathogens Information can be used to assess pathogen kill predictions for temperature-based treatment technologies.
Ongoing	U1R10 Fate of Engineered Nanomaterials in Wastewater Biosolids, Land Application and Incineration	Paul Westerhoff, Ph.D. Arizona State University	The goal of this project is to develop tools to quantify and understand how engineered nanomaterials accumulate in biosolids, undergo biosolids treatment and are disposed of and accumulate in the environment. We will include both model ENMs and ENMs in consumer products to improve our knowledge into their material life cycles, final disposition in the environment, and exposures to ENM by biota in rivers and soils. Specific research questions include: 1) What levels of ENMs occur in biosolids? 2) What factors affect ENM interaction with biosolids? 3) What analytical tools are capable of monitoring ENMs in biosolids? 4) How are ENMs in biosolids altered during digestion or incineration? 5) Are ENMs currently present in biosolids that have been land applied? 6) Do ENMs affect basic soil microbial processes?

2011	U3R08 Use of Nanoparticles for Reduction of Odorant Production and Improvements in Dewaterability of Biosolids	Matthew J. Higgins, Ph.D. Bucknell University	Demonstration that nanoscale particles can improve polymer-aided dewatering and reduce odor production from biosolids. Characterization of the performance of a number of different nanoadditives with varying size, charges, chemistry, and structure. Characterization of the performance of nanoadditives during dewatering with polymers of different charge densities, molecular weight and configuration. Illustrates the performance of nanoadditives during dewatering under various shear conditions. Provides preliminary concepts on the role of nanoscale additives on dewatering and odor control.
Ongoing	WERF2C10 Characterization of Volatile Organic Compounds (VOCs) Emitted from Biosolids Composting	Greg Kester California Association of Sanitation Agencies (CASA)	The purpose of the project is to characterize volatile organic compounds (VOCs) emitted from biosolids composting to determine to what degree these VOCs are reactive and thus could contribute to ground level ozone. It is known that not all VOCs are reactive, but biosolids have not been studied. There are proposed rules in California on this subject and it is expected that other parts of the country will face similar rules. The two test sites are in California, but the intent is that the findings would be applicable to other parts of the country. A wind tunnel will be used collect gas emission samples from the test compost piles. The wind tunnel will be equipped with a chemiosorbant -and- activated-carbon filter to clean the air being pulled into the chamber. The use of a wind tunnel provides a relatively large surface area, a defined flow direction and air exchange rates or air speed in the tunnel which may be more representative of natural conditions. Scores of compounds fall under the definition of "volatile organic compounds" that can contribute to ozone formation in the atmosphere. There is no single approach to measure the full range of compounds. Keeping this in mind, multiple techniques are being employed in order to obtain the widest possible profile of VOC emissions from compost sources. Alcohols, which constitute a major fraction of compost emissions, are being measured. Physico-chemical properties are being studied along with VOC measurements. Mobile Ozone Chamber Assays are being conducted for direct on-site measurement of ozone.

Information current as of April, 2011