Executive Summary

Understanding the role that microaerobic metabolism plays on the removal of trace organic compounds

Pharmaceutical Fate Under Varying Redox Biological Treatment Environments (U1R09)

The Central Issue

Lower dissolved oxygen (DO) levels are becoming increasingly common in the more fully optimized water resource recovery facilities. This research sought to evaluate whether low DO treatment environments are also effective in removing trace concentrations of pharmaceuticals in wastewater relative to environments created by fully aerobic or anoxic/aerobic treatment. It also helped understand the comparative energy demand and environmental impacts associated with these systems.

The study found that depending on the compound, the removal and/or transformation of the different pharmaceuticals at environmentally relevant concentrations can be either enhanced or slowed under similar redox environments. It determined that the life-cycle energy requirements of microaerobic systems are comparable to fully aerobic systems.

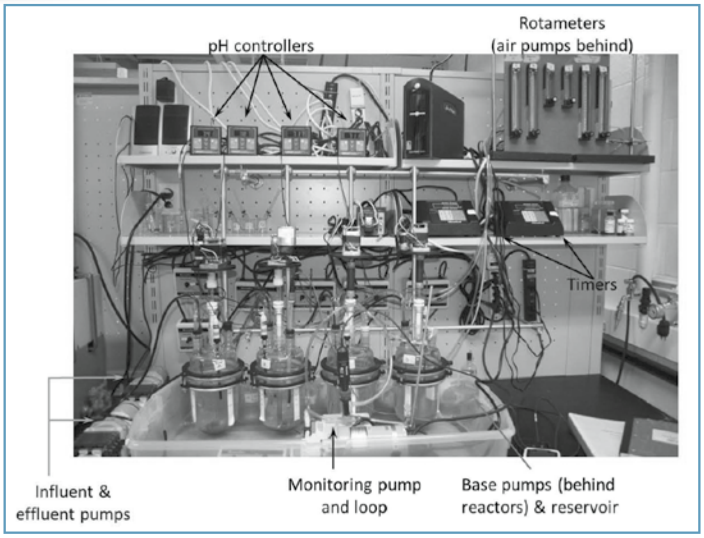
Context and Background

As Water Resource Recovery Facilities (WRRFs) continue to seek optimization of treatment, consider longer-term issues of sustainability, and face the high costs of designing, building, and operating these facilities, they will likely implement greater controls on aeration, thus affecting levels of dissolved oxygen. Some facilities operating at lower DO levels have shown better longer-term performance and enhanced nutrient removal. A limited number are also considering implementing anaerobic mainstream and sidestream nitrogen removal processes which often involve low DO phases to control ammonia oxidation while preventing nitrite oxidation. WERF sought to determine other implications of lower DO treatment as they relate to WERF's body of research on trace organic compounds (TOrC).

This research provided further understanding of the role that microaerobic metabolism plays on defining the fate of TOrC. It also complements WERF's ongoing research to understand the fate of TOrCs in treatment processes, the environment, and process optimization.

Findings and Conclusions

In addition to showing that the redox environment influenced the removal and/or transformation of certain concentrations of pharmaceuticals, this research found that for some compounds, for example ATE (atenolol), are degraded more rapidly under aerobic conditions. While other compounds, SMX (sulfamethoxazole) for example, are degraded more rapidly under microaerobic conditions.



Sequencing batch reactor laboratory setup.

The study showed that transformations occur for both the parent and conjugated forms of pharmaceuticals under the redox conditions studied, and that both are important to track. The study also demonstrated that nitrogen removal can occur under fully microaerobic conditions to a greater extent than fully aerobic conditions, yet less than under sequential anoxic/aerobic conditions.

Finally, the research determined that the life-cycle energy requirements of microaerobic systems are comparable to fully aerobic systems. Yet, the requirements are lower than MLE (Modified Lidzack-Ettinger) systems due to the energy demands from recirculation in the latter.

Management and Policy Implications

These results indicate that systems that employ microaerobic treatment without excessive pumping may be beneficial from an energy balance, environmental impact, and pharmaceutical biotransformation perspective. For example, recent efforts to develop low energy footprint mainstream nitrogen treatment technologies that use anaerobic and low DO environments may enhance transformation of these pharmaceuticals while also achieving low energy demanding nitrogen removal. Mainstream deammonification uses either low DO or cycling transient anoxia to achieve partial nitration (conversion of ammonia to nitrite while preventing nitrite oxidation). Pharmaceutical fate in these environments warrants further investigation, especially as deammonification moves toward full-scale application.

Trace Organic Compounds Under Investigation

Atenolol (ATE)	Desvenlafaxine-glucuronide (DVF-glu)
Trimethoprim (TMP)	Venlafaxine (VLF)
Sulfamethoxazole (SMX)	Phenytoin (Dilantin) (DLT)
Desvenlafaxine (DVF)	Ibuprofen (IBU)

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WERF

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Related WERF Research

Project Title	Research Focus
Fate of Pharmaceuticals and Personal Care Products Through Municipal Wastewater Treatment Processes (03CTS22UR)	Surveyed a list of 20 pharmaceuticals and personal care products (PPCPs) and assessed their removal through secondary treatment. The study data examined if the removal of these compounds is influenced by the solids retention time (SRT) – the master variable in the operation of activated sludge secondary treatment. PPCP removal through subsequent tertiary media filtration, disinfection, and membrane bioreactor processes were also evaluated.
Diagnostic Tools to Evaluate Impacts of Trace Organic Compounds (CEC5R08a, CEC5R08b, CEC5R08c)	Developed diagnostic tools for water quality managers to assess and monitor trace organics in their treatment processes and watersheds. Companion parts of this project include a trace organics prioritization method, a report on diagnostic approaches and types of analyses in aquatic systems used to identify causes of ecological impairments, seven case studies, and web-based database to help users search and evaluate trace organic data.
Evaluation of QSPR Techniques for Wastewater Treatment Processing (U2R07)	Evaluated Quantitative Structure Property Relationship (QSPR) techniques for predicting key wastewater treatment processes – sludge sorption, activated-sludge biological, and chlorine oxidation transformation. QSPR are potentially powerful tools that utilities can use to screen the fate of trace organics during wastewater treatment processes. Study findings were used as input in WERF's CEC4R08 report, which provides reliable mass balance modeling tools that describe and predict removal efficiencies for a wide range of trace organics.
Demonstrating Advanced Oxidation/ Biofiltration for Pharmaceutical Removal in Wastewater (U2R11)	Develops and demonstrates design criteria for UV/H_2O_2 advanced oxidation process (AOP) followed by downstream biofilm-based treatment for removing biologically recalcitrant pharmaceuticals like carbamazepine from wastewater effluents. It builds on WERF study *Demonstrating Advanced Oxidation Coupled with Biodegradation for Removal of Carbamazepine* (INFR6SG09) which demonstrates that UV light in combination with hydrogen peroxide produces breakdown products that could be completely biodegraded. It also established analytical methods.
Developing a Standardized Protocol for Assessing the Biodegradability of Trace Organic Compounds (U3R10)	Establishes a standardized approach for site-specific evaluations of trace organics removal and a protocol that outlines how to perform biodegradation tests under conditions that closely match the system being considered – biological technologies.
Holistic Assessment of Trace Organic Compounds in Wastewater Treatment (U3R11)	Sacramento Regional Sewer District is designing an upgraded $2 billion treatment facility to comply with a new discharge permit. This WERF study of trace organic treatment performance will demonstrate testing of biological nutrient removal (BNR), filtration, and disinfection treatment technologies. The project outcomes will provide a roadmap for agencies considering upgrading for nutrient removal now and trace organics reduction later.

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