

## Understanding biotransformation and sorption of TOrCs in BNR treatment

Evaluating Fate Mechanisms of Contaminants of Concern in Biological Nutrient Removal Treatment Systems (U2R13/4874)

### The Central Issue

Biological nutrient removal (BNR) treatment is considered a cost-effective process for reducing nutrients such as nitrogen and phosphorus from wastewater. Yet, the indiscriminate discharge of trace organic compounds (TOrCs) remains an important issue due to their potential to cause adverse effects to aquatic life. With the recent emergence of BNR treatment, there is a need to understand the fate and removal mechanisms of these TOrCs in BNR systems. The three key knowledge gaps noted in understanding the elimination of TOrCs during BNR treatment include:

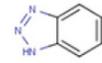
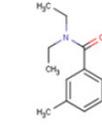
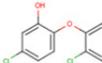
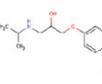
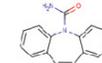
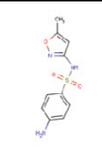
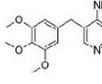
1. An understanding of the fate and transport of emerging contaminants in different redox conditions (anaerobic, anoxic, and aerobic redox zones), especially when compared to conventional activated sludge treatment (aerobic zone).
2. An understanding of the metabolic degradation pathways of emerging contaminants under varying redox conditions.
3. An understanding of the kinetics or adsorption and desorption of TOrCs with activated sludge solids, particularly under different redox conditions.

Filling these gaps is essential for optimizing current treatment processes for TOrC removal and in using mass balance models to predict TOrC fate and removal in BNR treatment systems.

### Context and Background

Seven trace organic compounds were selected for study and all meet the U.S. EPA definition of contaminants of emerging concern, e.g., they lack regulatory standards, have recently been found in the environment owing to advances in analytical instrumentation, and 3) constitute a risk for either aquatic life or human health at environmentally relevant concentrations (U.S. EPA, 2008). The research was structured into three tasks:

- Determine biotransformation rates for the select TOrCs in three different redox regimes.
- Identify biotransformation intermediates and degradation pathways of the target compounds.
- Determine equilibrium sorption distribution coefficients for select TOrCs in three differing redox regimes.

	TOrC	Category	Application
	Benzotriazole (BTA)	Corrosion Inhibitor	Household Chemical
	<i>N,N</i> -Diethyl-3-methylbenzamide (DEET)	Insect Repellent	Personal Care Products
	Triclosan (TCS)	Antimicrobial	
	Atenolol (ATN)	Beta-blocker	Pharmaceuticals
	Carbamazepine (CBZ)	Anticonvulsant	
	Sulfamethoxazole (SMX)	Antibiotic	
	Trimethoprim (TMP)	Antibiotic	

These tasks were accomplished by conducting laboratory biotransformation and sorption experiments at the University of Cincinnati and TOrC and biotransformation analysis at the Southern Nevada Water Authority. The investigators hypothesized that different operational conditions (SRT, redox conditions, and temperature) at the two treatment plants may affect the microbial diversity, which in turn could change the biodegradation rates of the target compounds. Grab samples of anaerobic, anoxic, and aerobic activated sludge were collected from the two wastewater treatment plants.

### Findings and Conclusions

This study determined first-order biotransformation rates ( $k_{bio}$ ) for seven TOrCs (atenolol, benzotriazole, carbamazepine, DEET, sulfamethoxazole, trimethoprim



and triclosan) in two BNR treatment systems and identified biotransformation intermediates for three of the TOrcs (benzotriazole, triclosan and trimethoprim) under aerobic and anoxic conditions. The sorption distribution coefficients (Kd) for the target TOrcs were also determined. This is the first study to identify biotransformation intermediates for benzotriazole, trimethoprim, and triclosan under anoxic conditions.

The BNR treatment process eliminates total nitrogen and total phosphorus from wastewater by the synergistic action of different classes of bacteria within different redox conditions. In addition to nutrient removal, BNR treatment could enhance the removal of trace organic compounds that are amenable to degradation in anaerobic and anoxic regimes. The sorption and biotransformation information determined in this study could be used to predict effluent concentrations (and biosolids concentrations) in BNR

treatment. Predicted effluent TOrc concentrations (and biosolids concentrations) could then be used for subsequent risk assessments in receiving environments.

## Management and Policy Implications

Results from this study significantly add to the current knowledge on the biotransformation and sorption of TOrcs in BNR treatment. In particular, the study provides additional insight into the fate behavior of the target TOrcs in BNR treatment systems. Results from this study could be used to adjust the operating conditions of a BNR treatment system to improve the removal of TOrcs (e.g., changing SRT when conditions change like temperature). The biotransformation rate and sorption data could be used as input parameters in mass-balance models to predict the fate and removal of the target TOrcs in BNR treatment.

Related WRF Research	
Project Title	Research Focus
<b>Pharmaceutical Fate Under Varying Redox Biological Treatment Environments (U1R09)</b>	Provides an understanding of the role that microaerobic metabolism plays on defining the fate of trace organic compounds (TOrcs), and gives insights into how decisions made in the interest of sustainability may help or hinder TOrc removal.
<b>Developing a Standardized Protocol for Assessing the Biodegradability of Trace Organic Contaminants (U3R10)</b>	Provides insight and guidelines for prioritizing future TOrc efforts and provides an analytical technique that allows for the simultaneous detection of five TOrcs under positive and negative mode ionization.
<b>Holistic Assessment of Trace Organic Compounds in Wastewater Treatment (U3R11)</b>	Summarizes performance characteristics of common biological treatment processes, filtration technologies, and disinfection technologies in reducing 12 TOrcs to evaluate alternative treatment processes to meet new NPDES discharge permit limits.
<b>Demonstrating Advanced Oxidation Coupled with Biodegradation for Removal of Carbamazepine (INFR6SG09)</b>	Evaluates the combination of ultraviolet plus hydrogen peroxide (UV-H2O2)-based advanced oxidation and biodegradation to enable carbamazepine removal.
<b>TOC Indicator Removal during Conventional Wastewater Treatment (CEC408)</b>	Identifies suitable performance indicators that allow for a rapid characterization of performance efficiency of conventional wastewater treatment facilities.
<b>Demonstrating Advanced Oxidation/Biofiltration for Pharmaceutical Removal in Wastewater (U2R11)</b>	Evaluates the efficacy of UV-based advanced oxidation processes (UV/AOPs) and UV/AOPs followed by bio-filtration to remove trace organic compounds from wastewater.

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