A Standardized Protocol for Assessing the Biodegradability of Trace Organic Compounds

WERF U3R10

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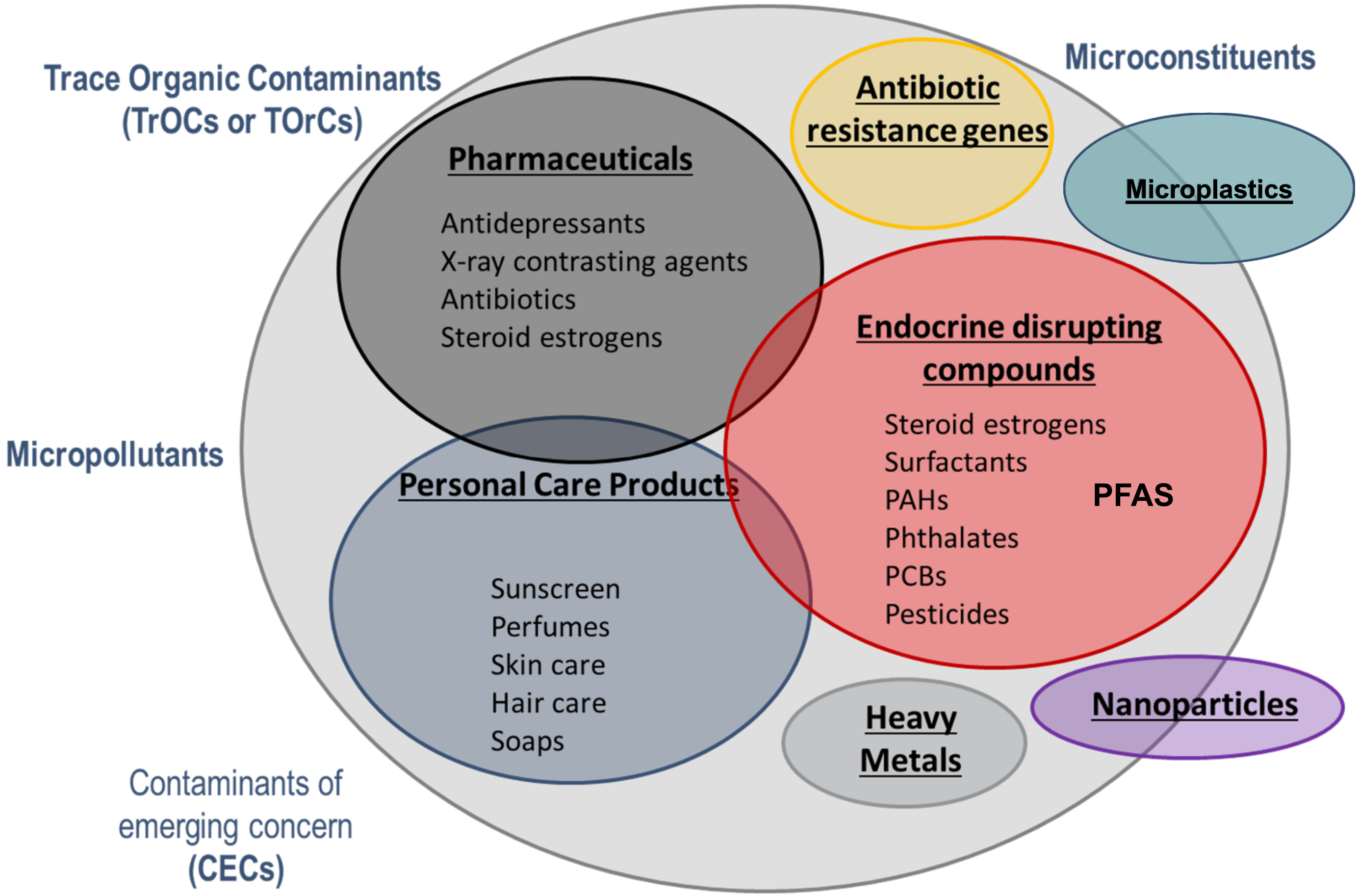
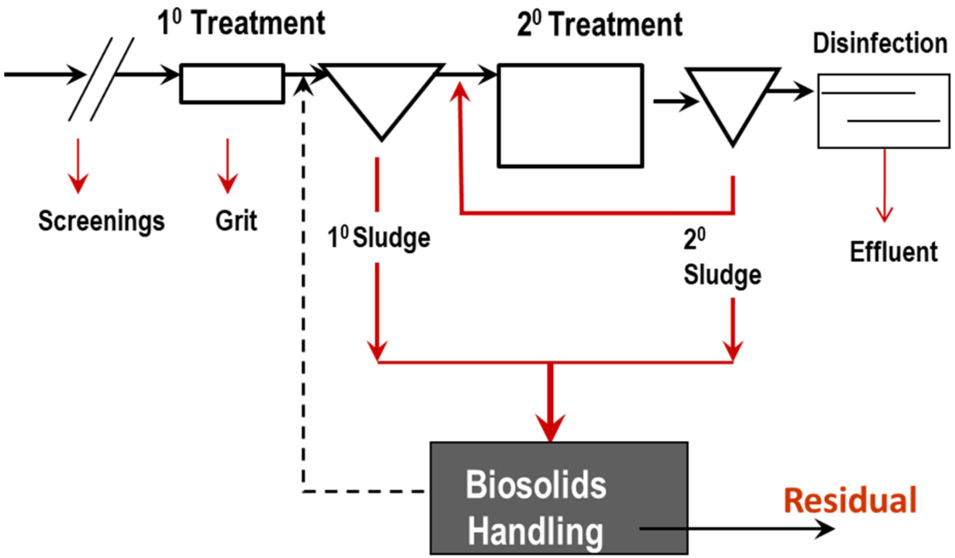
Background



Trace Organic Contaminants
(TrOCs or TOrCs)
Microconstituents
Micropollutants
Contaminants of
emerging concern
(CECs)
Pharmaceuticals
Antidepressants
X-ray contrasting agents
Antibiotics
Steroid estrogens
Antibiotic
resistance genes
Microplastics
Endocrine disrupting
compounds
Steroid estrogens
Surfactants
PAHs
Phthalates
PCBs
Pesticides
PFAS
Personal Care Products
Sunscreen
Perfumes
Skin care
Hair care
Soaps
Heavy
Metals
Nanoparticles

Background

- WRRFs first line of defense
- WRRFs designed for bulk carbon and pathogen reduction
- More recently, there has been a focus on biological nutrient removal
- > 84% of WRRFs facilities in USA have some form of biological treatment



Background

Extending biological treatment to include bulk carbon, nutrient, pathogen AND TOrC reduction/removal can help reduce overall energy requirements for WRRFs of the future

	Average kWh/MG treated
Activated sludge	**1000 to 2200[1]**
Ozone	**100 to 500[2]**
GAC	**400 to 600[2]**
UV-H_2O_2	**400 to 600[2]**

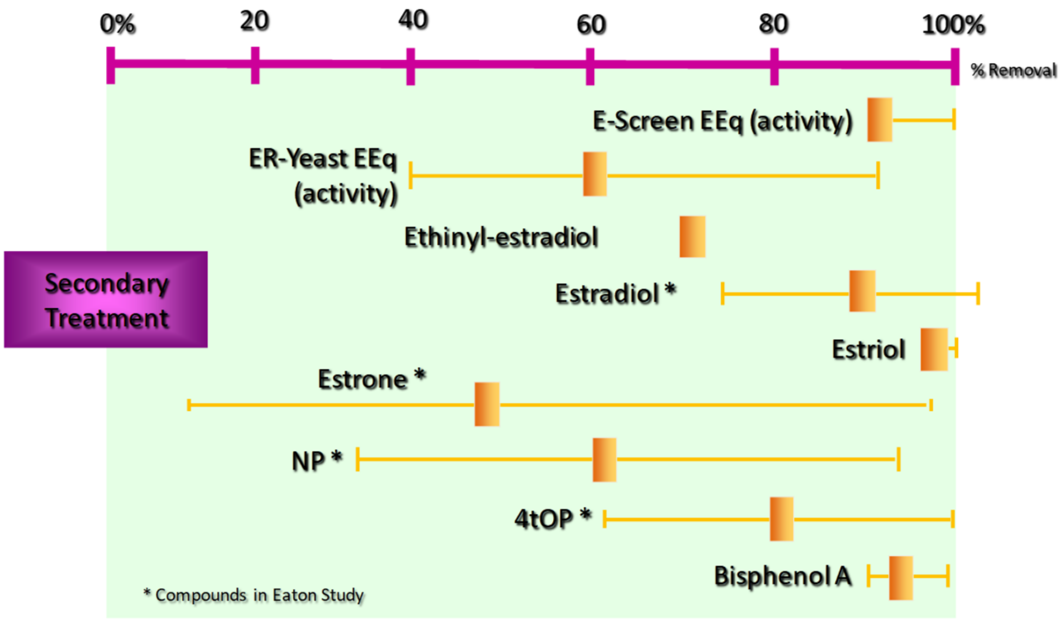
[1]From Energy Conservation in Water and Wastewater Treatment Facilities, WEF Manual of Practice No. 32; McGraw-Hill, Inc., New York, NY.

[2]Adapted from Use of Ozone in Water Reclamation for Contaminant Oxidation, WateReuse Foundation

Background

EDC removal ranges from 20-100%

Cannot use this information to accurately predict removal



WERF 2006, Removal of Endocrine Disrupting Compounds in Water Reclamation Processes

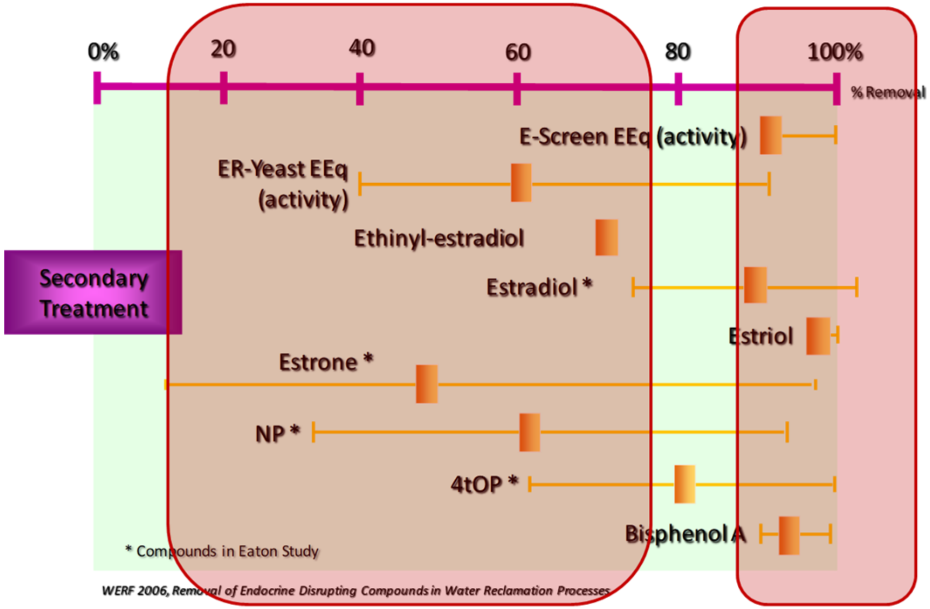
Background

Variability in TOrC removal results can be magnified if consistent test procedures are not followed

Is this variability due to differences in technology?

OR

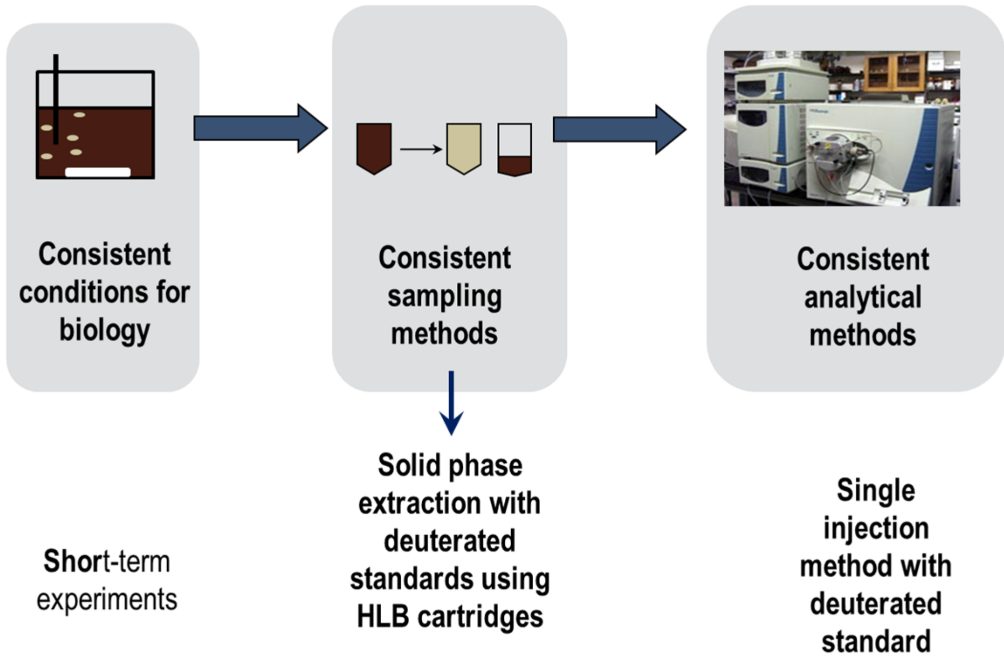
Is this variability a reflection of multiple testing conditions?



WERF 2006, Removal of Endocrine Disrupting Compounds in Water Reclamation Processes

Goals and Objectives

Developed and employed a method for standardizing analysis of biotransformation potential of various TOrCs



Methodology

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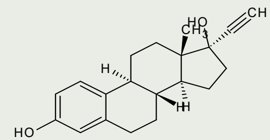
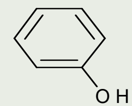
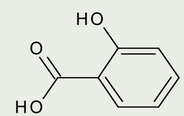
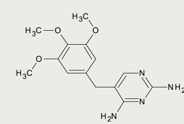
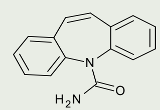
Trace Organic Compounds

Chemical	Structure	Use
17α-ethinylestradiol (EE2) $C_{20}H_{24}O_2$		Synthetic estrogen
Nonylphenol (NP) $C_{15}H_{24}O$		Surfactant
Salicylic Acid (SA) $C_7H_6O_3$		Analgesic and Antimicrobial
Trimethoprim (TMP) $C_{14}H_{18}N_4O_3$		Antibiotic
Carbamazepine (CBZ) $C_{15}H_{12}N_2O$		Antiepileptic

Selected based on prior fate studies and collaborator interest

Standardized Protocol

Bioreactor redox conditions	Representative biomass	No change in cell condition (3-6 hrs)
Non-toxic initial substrate concentrations	Fast, direct measure of removal	Inexpensive sample preparation

Ideal test should incorporate all of the above

Experimental

Standard methodology employed on:

- Lab-Scale Batch Experiments
- Full-Scale Sampling Campaign
- Full-Scale Batch Experiments

Results from Lab-Scale Experiments

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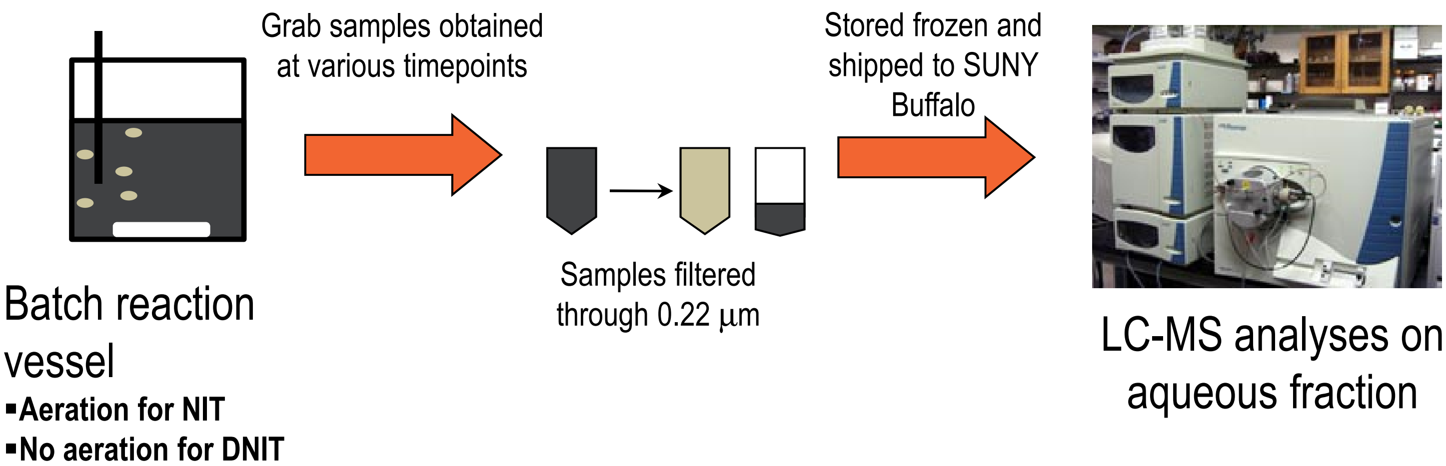
Lab-Scale Objectives

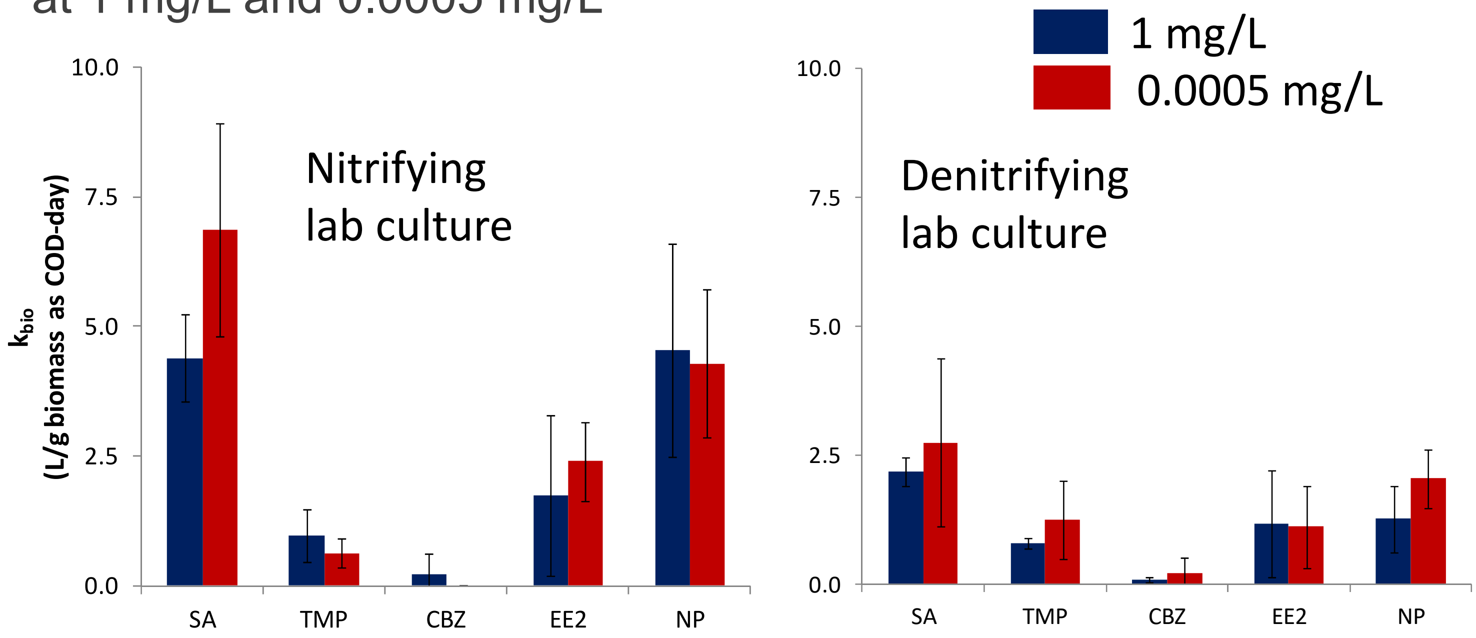
Two fundamental questions:

1. Does the initial TOrC concentration to biomass ratio (S0/X0) have an impact on the estimated pseudo-first order kinetic parameters?
2. Does the presence of readily biodegradable substrate (rbCOD) impact the estimated pseudo-first order kinetic parameters



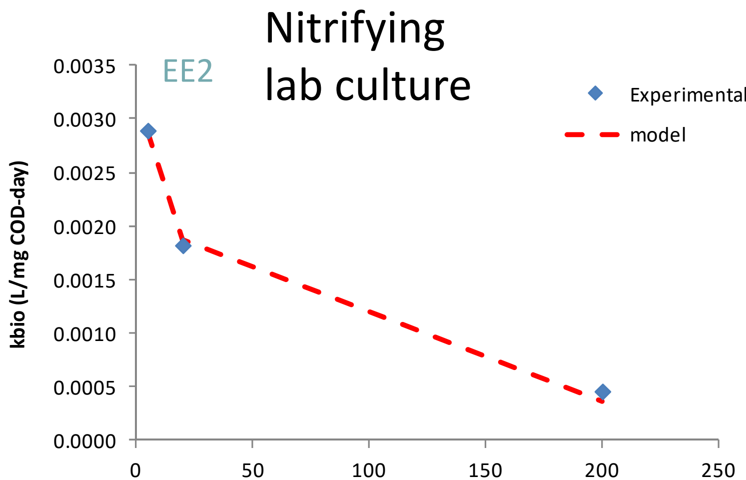
Lab-Scale TOrC Biotransformation

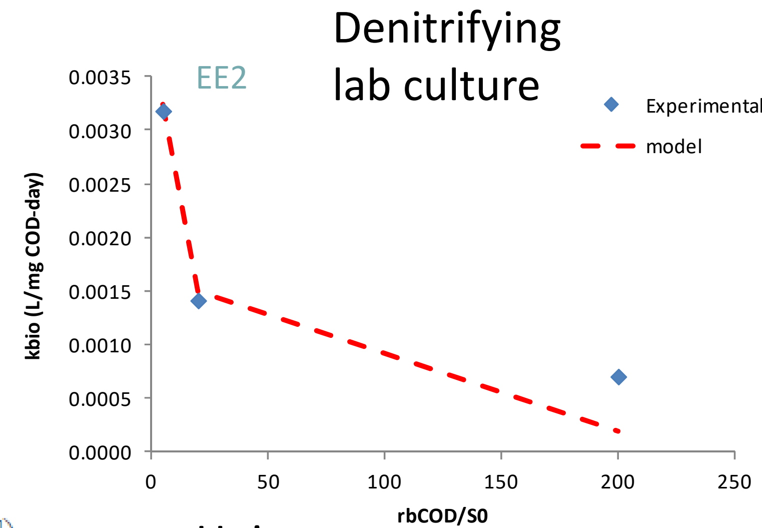
- SA, EE2 and NP more readily bio-transformed under aerobic conditions
- No statistical difference existed in estimated parameters between tests at 1 mg/L and 0.0005 mg/L



Lab-Scale TOrC Biotransformation

Readily biodegradable substrates can "suppress" rbTOrC biotransformation





$$kb_{io,TOrC} = k_{bio,TOrC_{max}} \left(1 - \left[\frac{\left(\frac{rbCOD}{S}\right)}{\left(\left(\frac{rbCOD}{S}\right) + K_{TOrC}\right)}\right]\right)$$

Unique parameters that need to be estimated

Lab-Scale TOrC Biotransformation

Findings from lab-scale results suggests that biotransformation of TOrC is linked to sorption

k_{bio} (L/g biomass as COD-day): > 1.5 | 0.5 to 1.5 | < 0.5

Biodegradability

Log K_D: > 3.0 | 2.5 to 3.0 | < 2.5

Sorption potential

Sorption potential	High	Medium	Low
High	EE2, NP		
Medium	SA	TMP	
Low			CBZ
	"readily" biotransformable TOrC	"moderately" biotransformable TOrC	"slowly" biotransformable TOrC

Lab-Scale Key Takeaways

- No statistical difference between tests at 1 mg/L and 0.0005 mg/L
- Presence of rbCOD will impact TOrC parameter
- Biotransformation of SA, EE2 and NP under aerobic conditions is more rapid than under anoxic conditions
- Extended process model shows promise for describing C, N, P and TOrC fate

Results from Full-Scale Experiments

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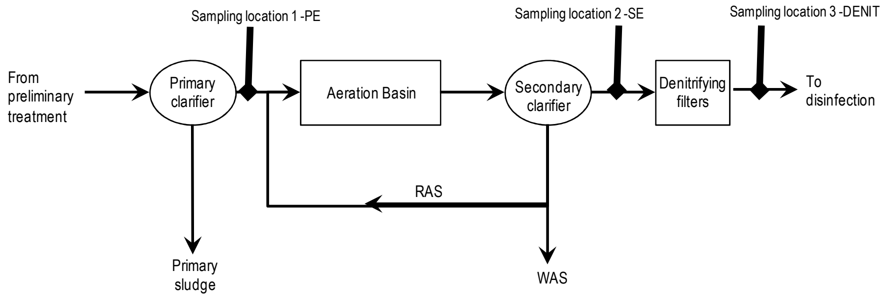
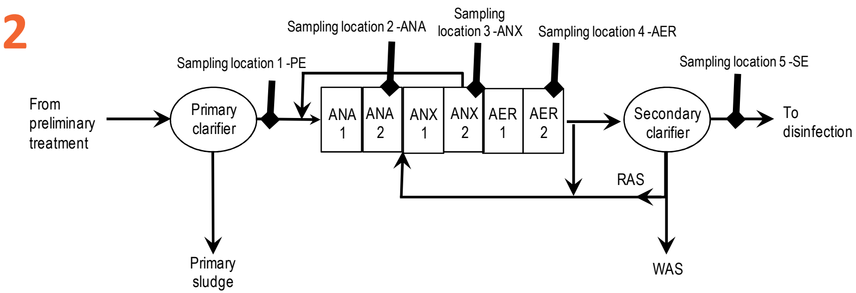
Full-Scale Sampling

Plant 1



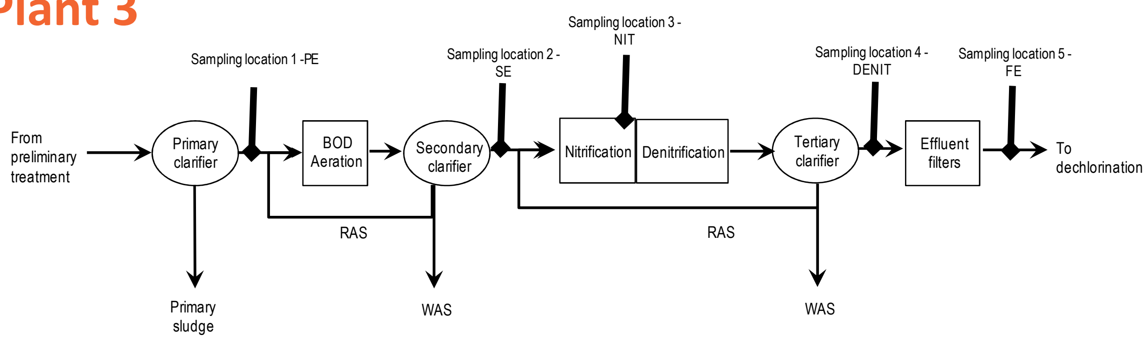
Nitrogen removal

Plant 2



Bio-Nitrogen and Bio-phosphorus removal

Plant 3



Bio-Nitrogen and chemical P removal

Key Takeaways from Full-Scale Experiments

- SA and EE2 were biotransformed most rapidly under carbon limited aerobic conditions followed by anoxic and then anaerobic conditions
- TMP biotransformation rates were variable and showed no preference for anaerobic, anoxic or aerobic conditions
- NP biotransformation was more rapid in the anaerobic zone than the anoxic or aerobic zones.
- Strategies that aim to enhance attenuation of rbCOD should focus on maximizing the reaction time under carbon limited conditions ($HRT_{carbonlimit}$)
- Process models can accurately predict TOrC fate. The impact of sorption and desorption is significant and needs to be accurately quantified.

Conclusions

Key Conclusions

- TOrC removal in biological reactors can be effectively described using short-term batch experiments
- Batch tests should be performed in the presence and at the incident concentration of the in-situ rbCOD to gauge accurate TOrC removal kinetics
- Strategies that aim to enhance attenuation of SA, EE2, and NP should focus on maximizing the reaction time under carbon limited conditions ($HRT_{Carbonlimit}$)
- Process models can accurately predict TOrC fate. The impact of sorption and desorption is significant and needs to be accurately quantified.

Questions and Contact Information

WERF U3R10

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