Sustainable Nanotechnology Conference 2015

Fate of Fullerenes (C_{60}) during Peracetic Acid (PAA) Post Disinfection of Treated Alum Enhanced Combined Sewer Overflow (CSO) Primary Treatment

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UNIVERSITY OF ALBERTA

MARCH 9, 2015

Outline

1. Introduction
2. Project Objectives
3. Selection of Unit Processes
4. Results and Discussion
5. Work Currently in Progress

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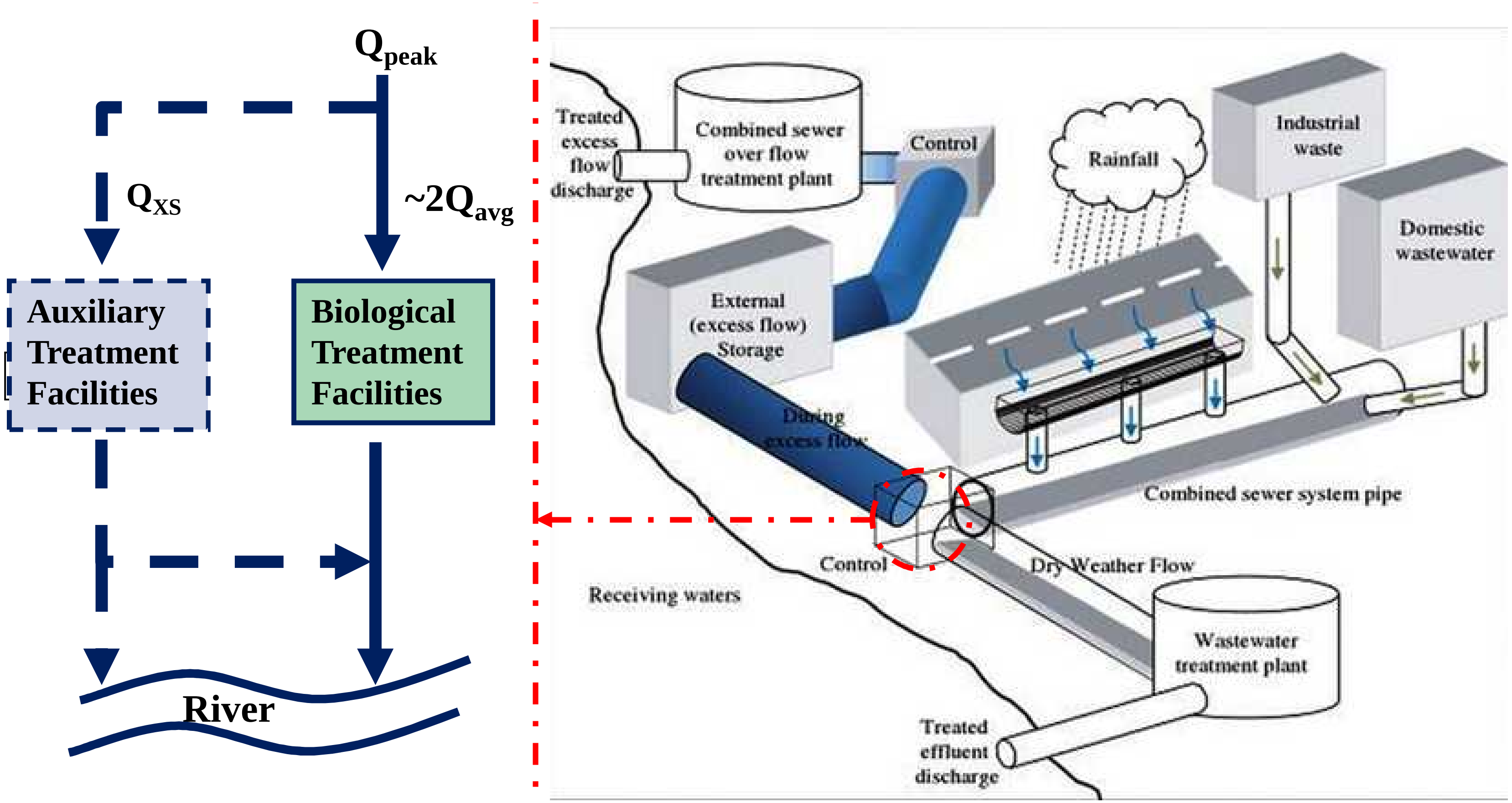
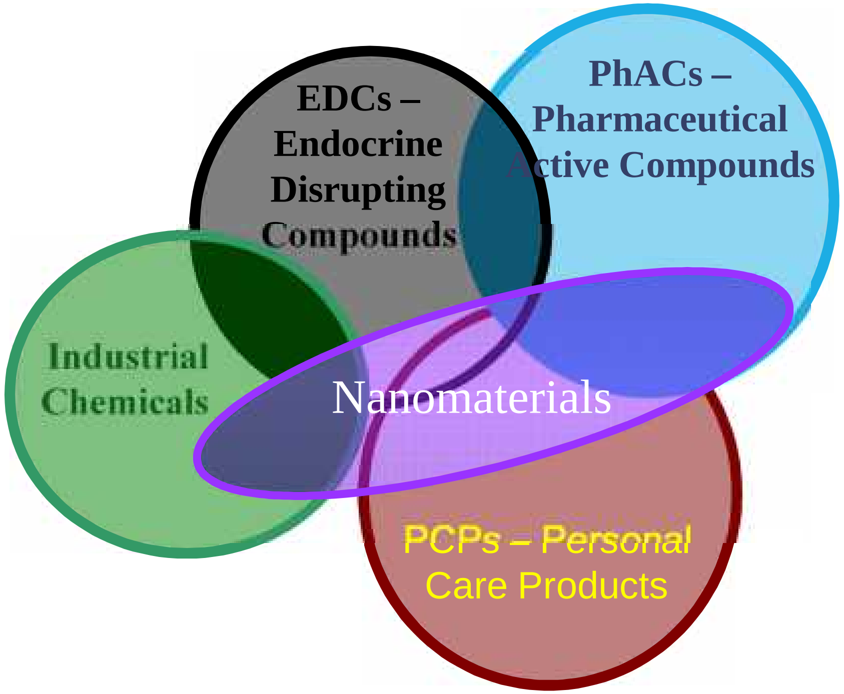
Combined Sewer Overflow System



Hung, Y.-T.; Abdul Aziz, H.; Ramli, M. H. (2012)

Emerging Contaminants
“small IS DIFFERENT”

"existing regulatory approaches and risk management strategies are appropriate for the challenges presented by nanomaterials," however, it recommended that more investment be made in strategic risk assessment research.



Council of Canadian Academies
Conseil des académies canadiennes

Council of Canadian Academics, 2008, “Small is Different: A Science Perspective on the Regulatory Challenges of the Nanoscale”

Toxicity of Fullerenes C_{60}

- **Solvation Method**

(Solvent Exchange, Ultra-Sonication, Long Stirring)

- **Surface Modification**

(Adsorption of other Materials)

- **Functionalization or Derivatization**

(Fullerol, Oxo-deravatives)

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Selection of Unit Processes

Enhanced Primary Treatment (Settling + Disinfection)

- **Coagulation/Flocculation/Sedimentation:**

Destabilization of colloidal impurities- Transferring small particles in to large aggregates – Adsorption of dissolved organic materials into the aggregates- Removal of aggregates by sedimentation

- **Disinfection:**

Kill/ Inactivate harmful organisms (bacteria and viruses) and control/ remove the odour precursors

Hypothesis

Combinations of oxidants and coagulants will transform and mineralize the target pollutants and result in the reduction or elimination of their toxicity.

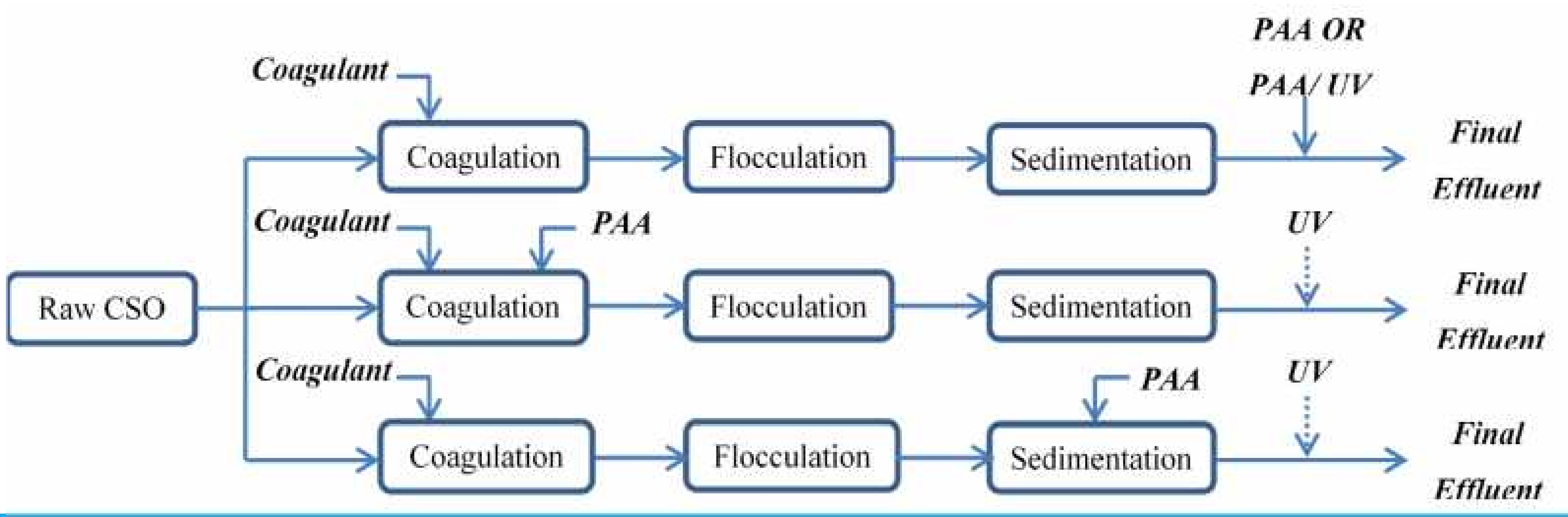
PAA Study

Coagulant

- Alum
- PACl
- $FeCl_3$

Disinfectant/ Oxidant

- PAA
- UV



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Overall Objectives

- Enhancement of primary sedimentation process for the treatment of CSOs
- Assessment of the environmental impacts and mitigation measures of some NMs of emerging concern

Short-Term Objectives

- Selection of the optimum operating conditions of the most effective chemicals and processes for CSO treatment
- Investigation of the role of using dual disinfection system
- Understanding the fundamentals of the selected processes in handling NPs
- Assessment of the effects selected coagulants and oxidants on the transformation of selected NPs.
- Investigation of the removal efficiency of the regulated parameters such as chemical oxygen demand (COD), nitrogen, phosphorus, *E. coli*, etc. with the increase of NMs.
- Toxicity reduction

Long-Term Objectives

- Scientific foundation for the sustainable and integrated management of CSO
- Assisting decision-makers to adopt sustainable development strategies based on the simulation of actual conditions and the predictions of the impact of NPs on the environment
- Protection of environment and human health

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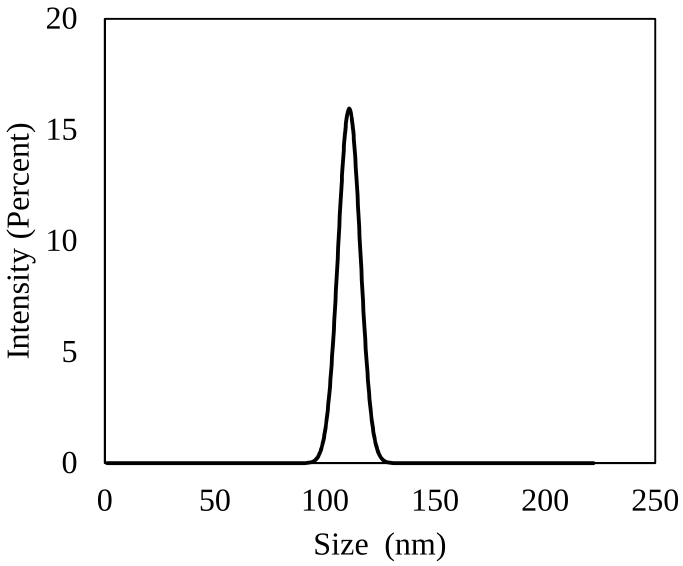
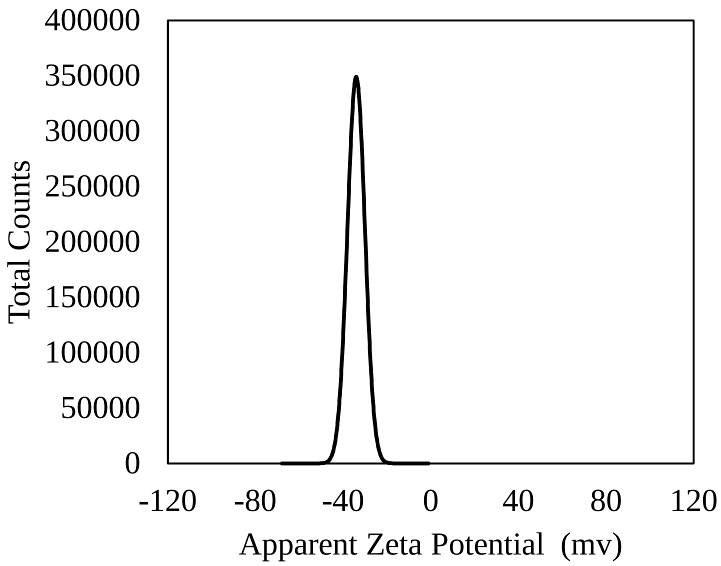
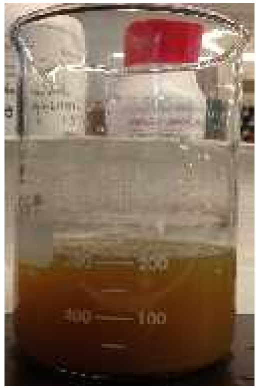
Sub Project#1: Fate of fullerenes (C_{60}) during peracetic acid (PAA) post disinfection of treated alum-enhanced combined sewer overflow (CSO) primary treatment

Preparation of nC60

➢Solvent Exchange (Toluene)

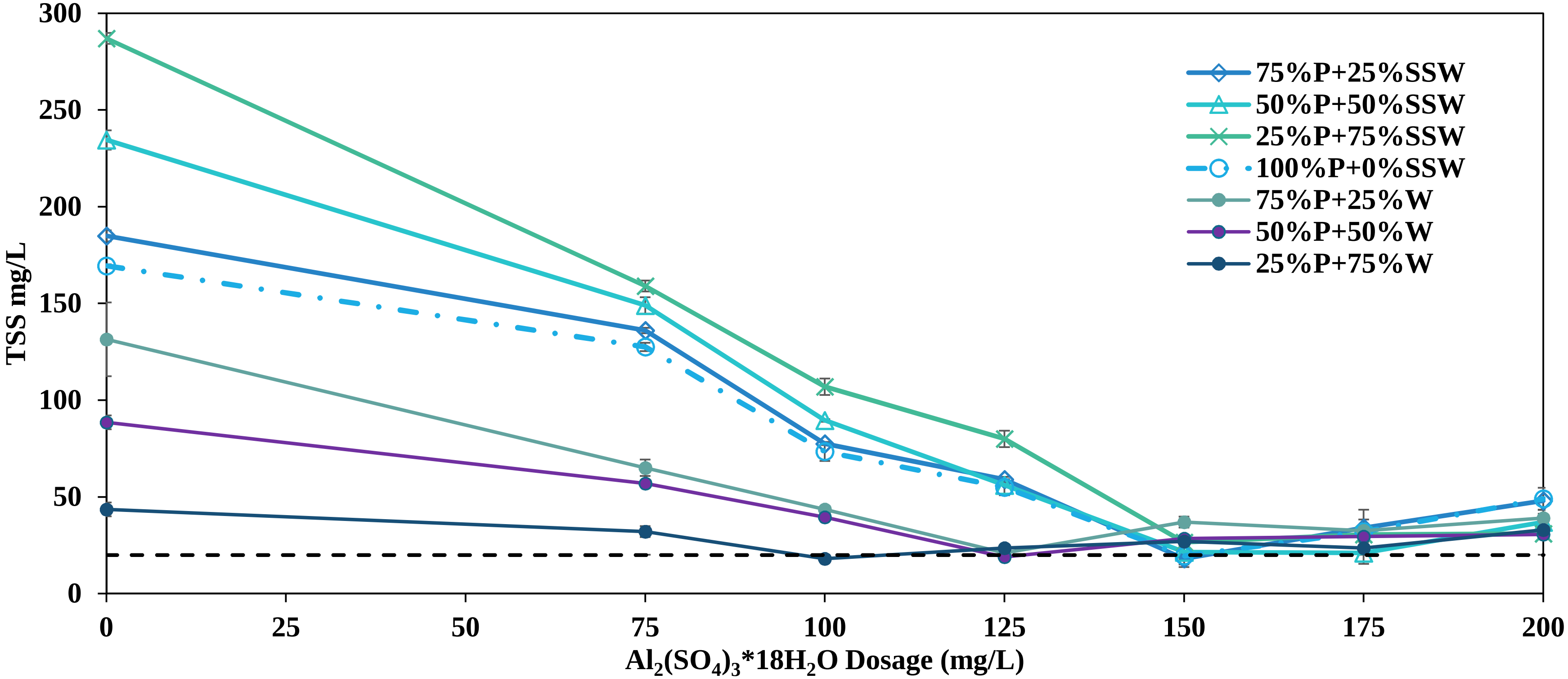






CFS- Flushes Role

Sample Type	25%P+ 75%W	50%P+ 50%W	75%P+ 25%W	100%P	75%P+ 25%SSW	50%P+ 50%SSW	25%P+ 75%SSW
Avg. TSS (mg/L)	62	127	189.5	251.5	310.5	424	534



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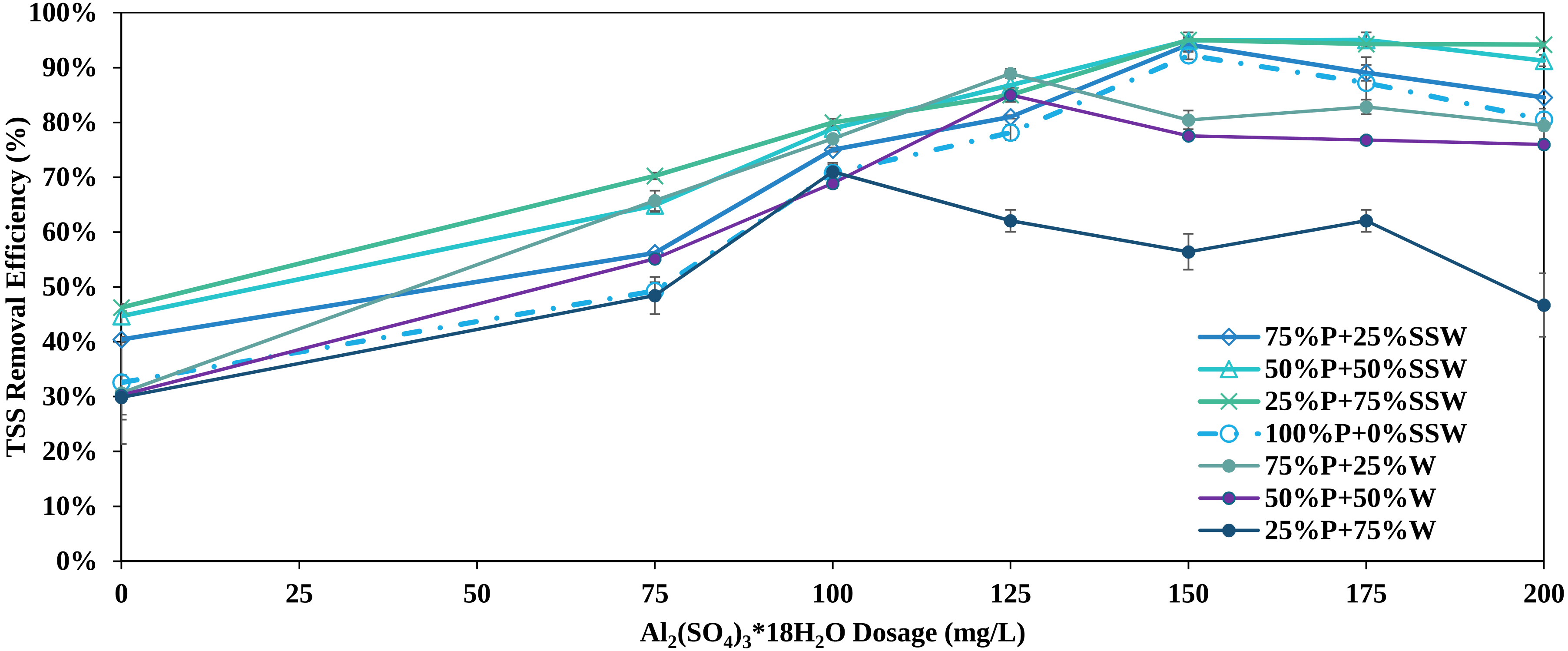
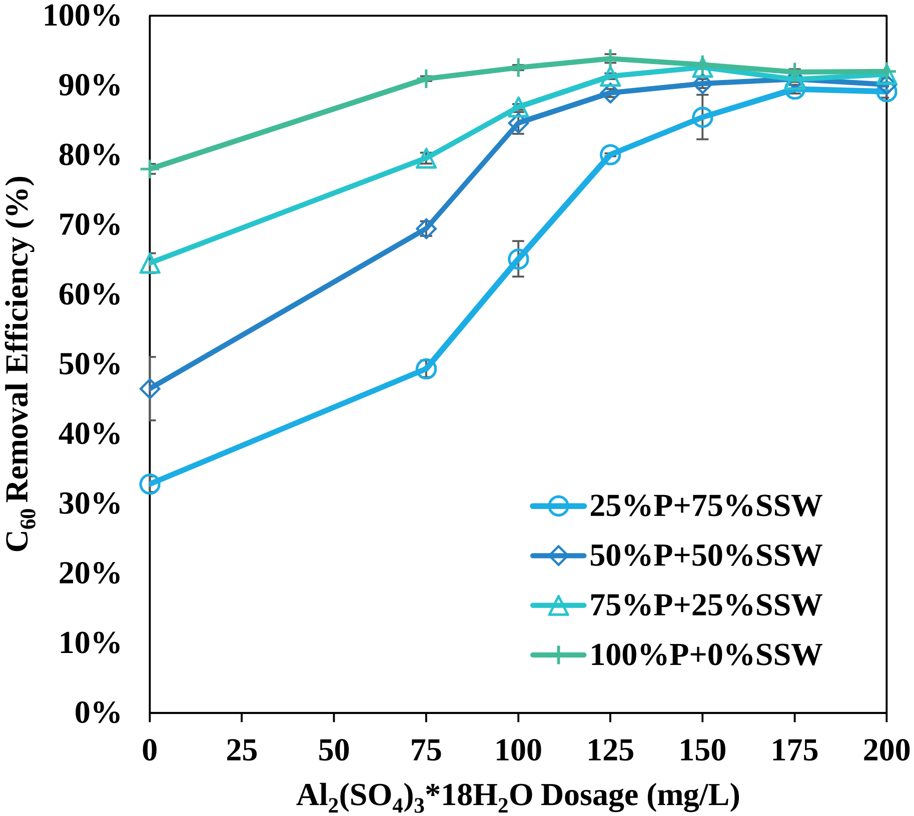
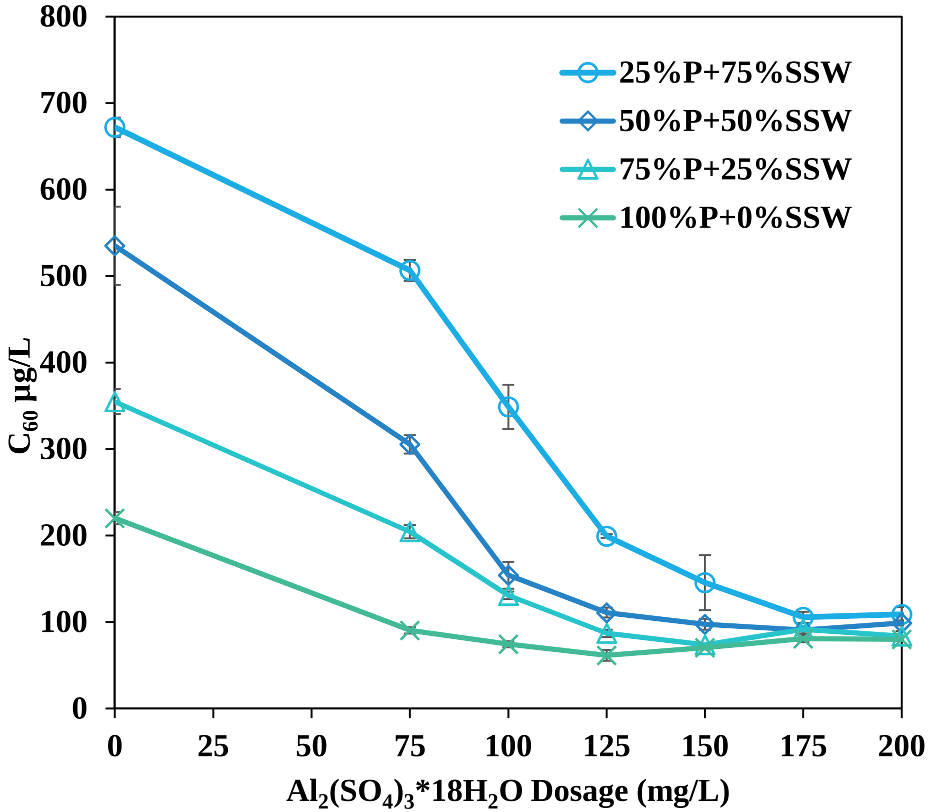


CFS- Flushes Role

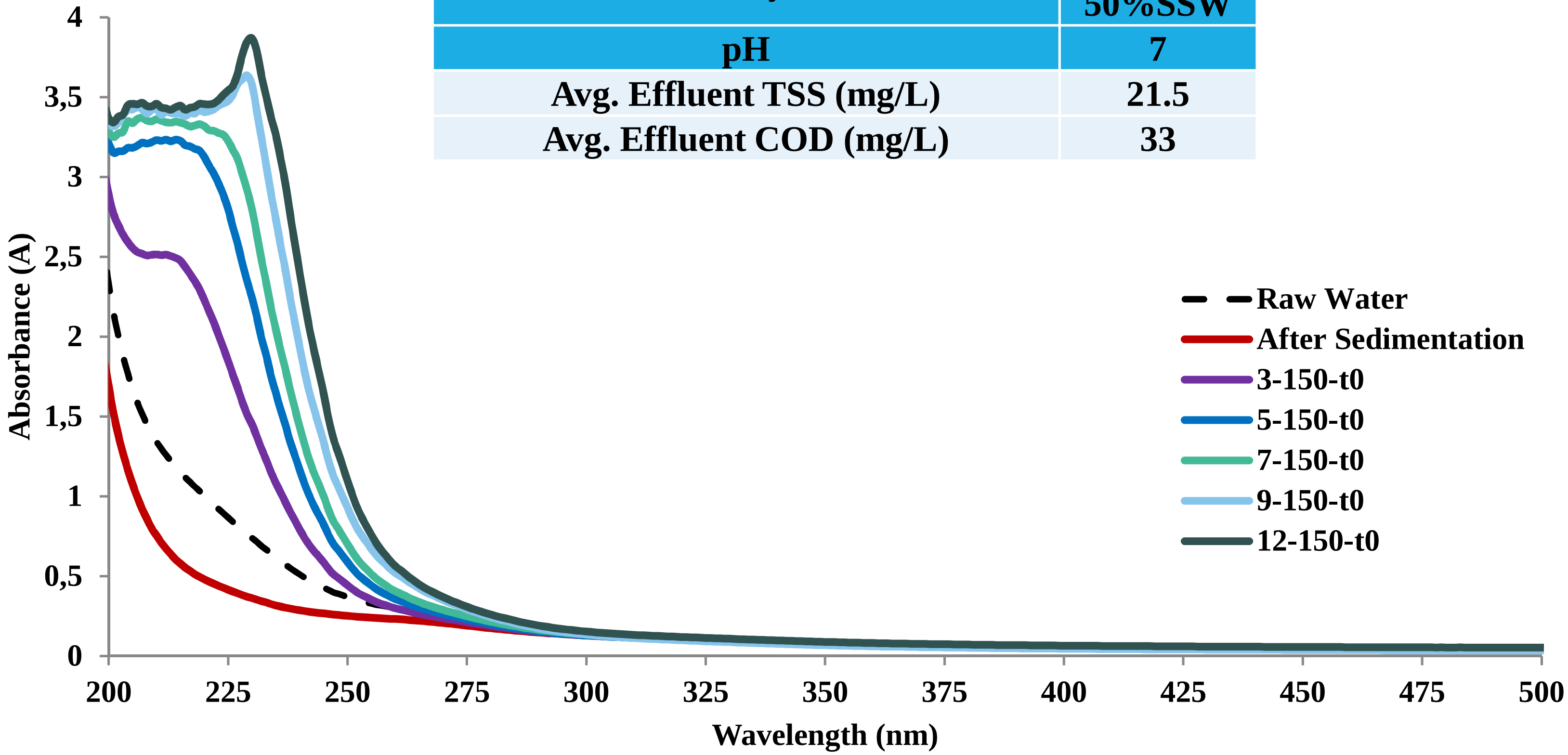
Spiked C_{60} in the Influent	1 mg/L





PAA Post Disinfection

% of Primary Influent	50%P+ 50%SSW
pH	7
Avg. Effluent TSS (mg/L)	21.5
Avg. Effluent COD (mg/L)	33



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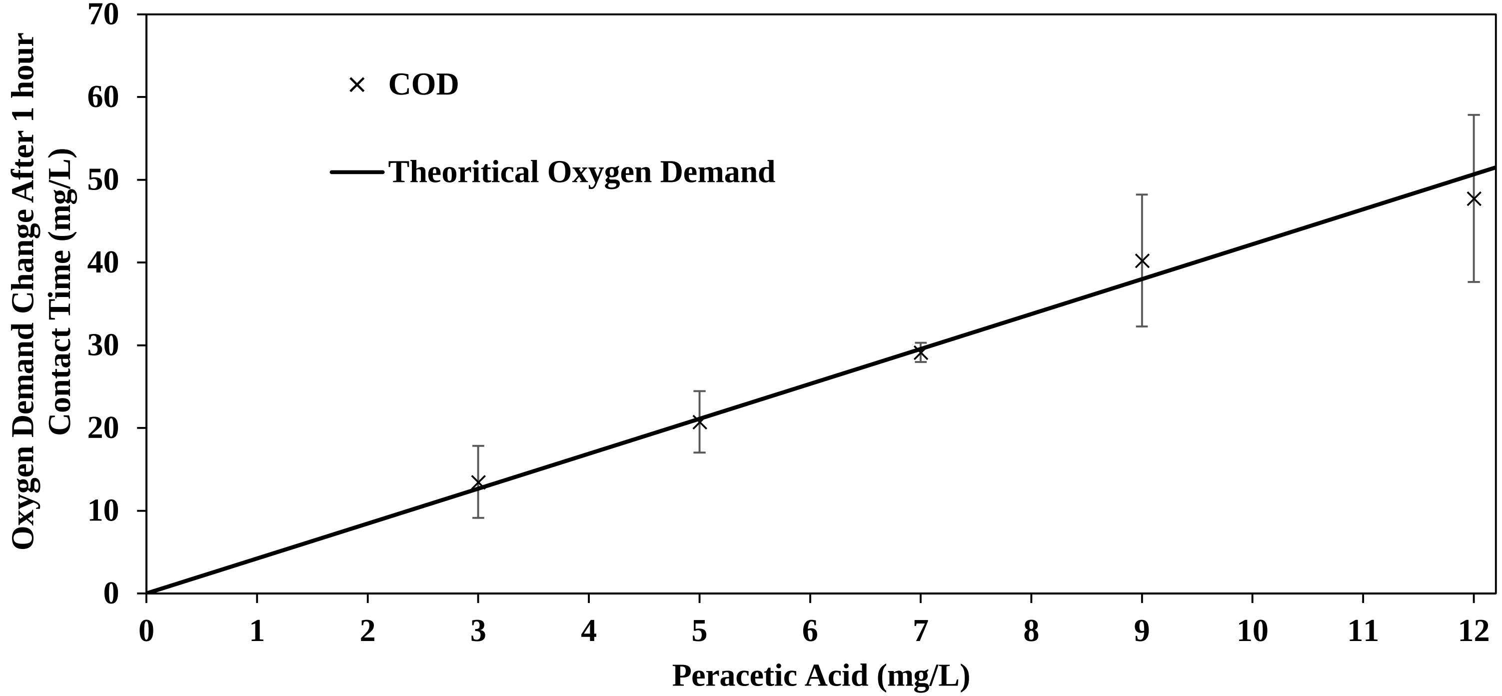

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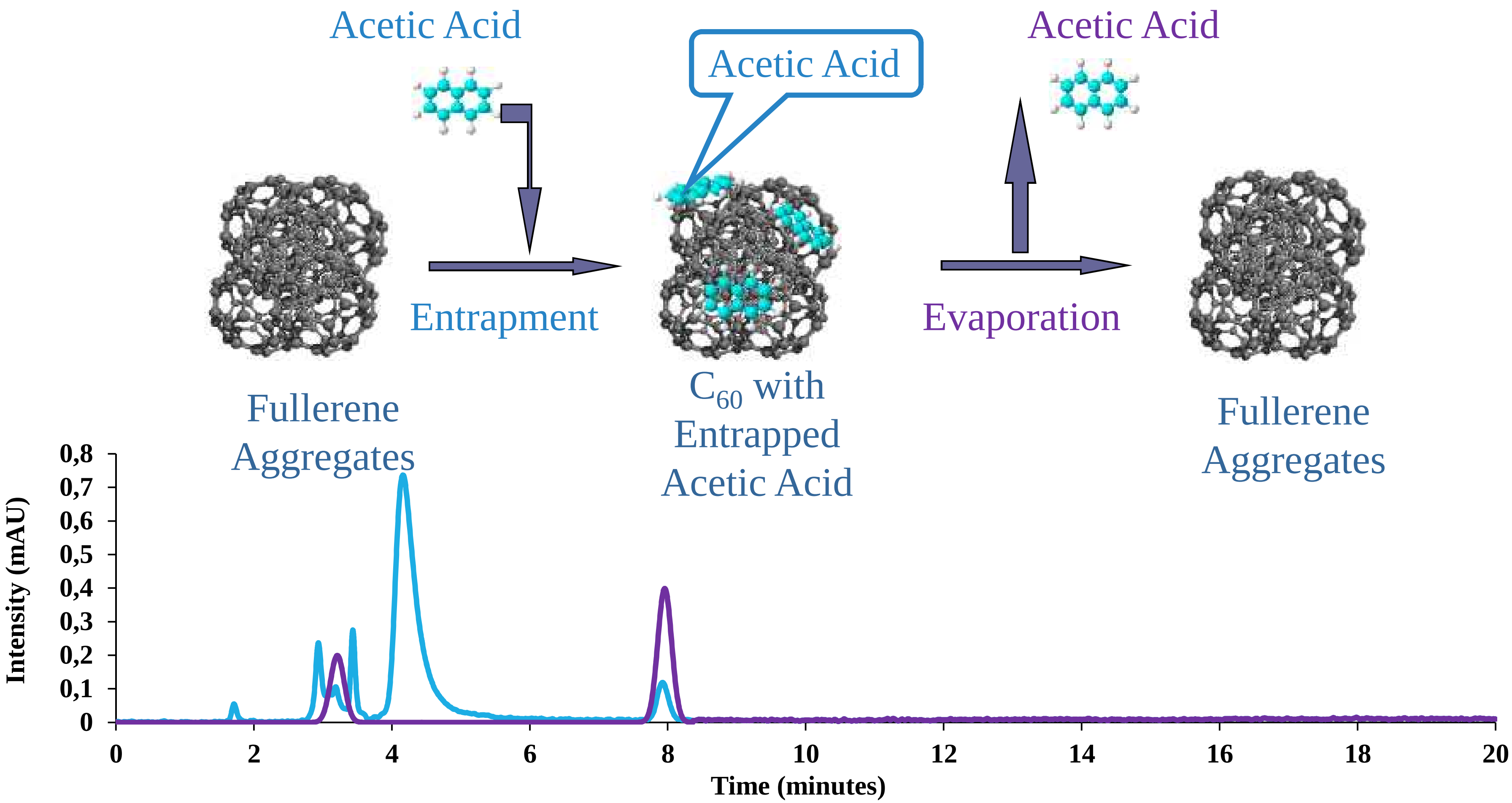

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Work Currently in Progress (May 2015)

1. Simultaneous Removal of *E.coli* and C_{60}
2. Repeat Experiments at 5^o Celsius
3. Kinetics
4. Toxicity Studies


THANK YOU
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Q & A time
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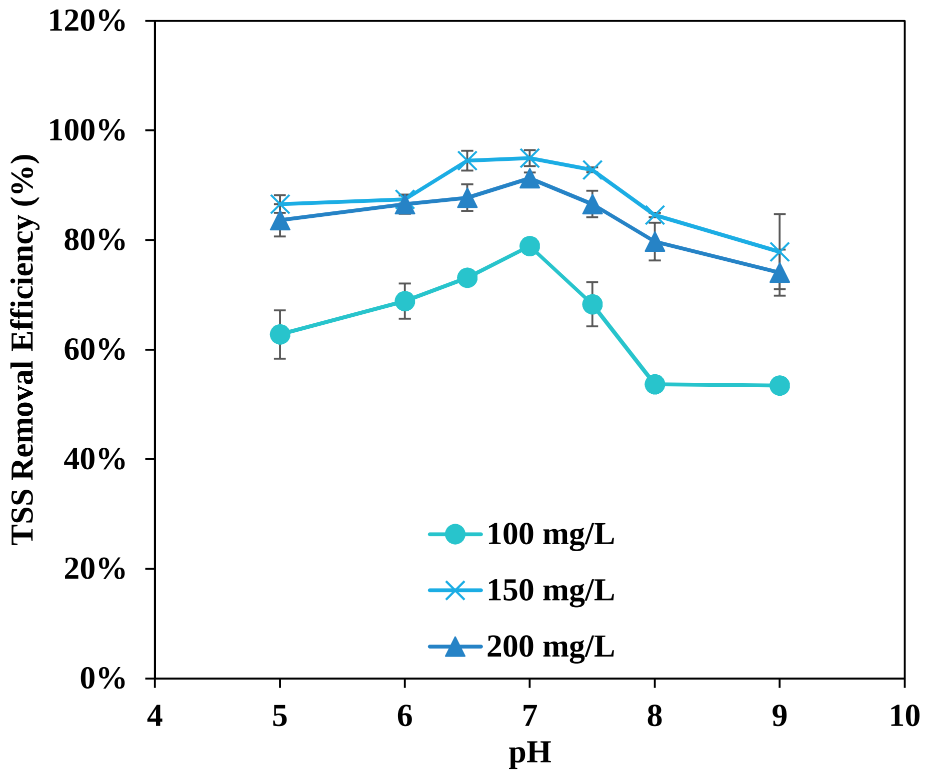
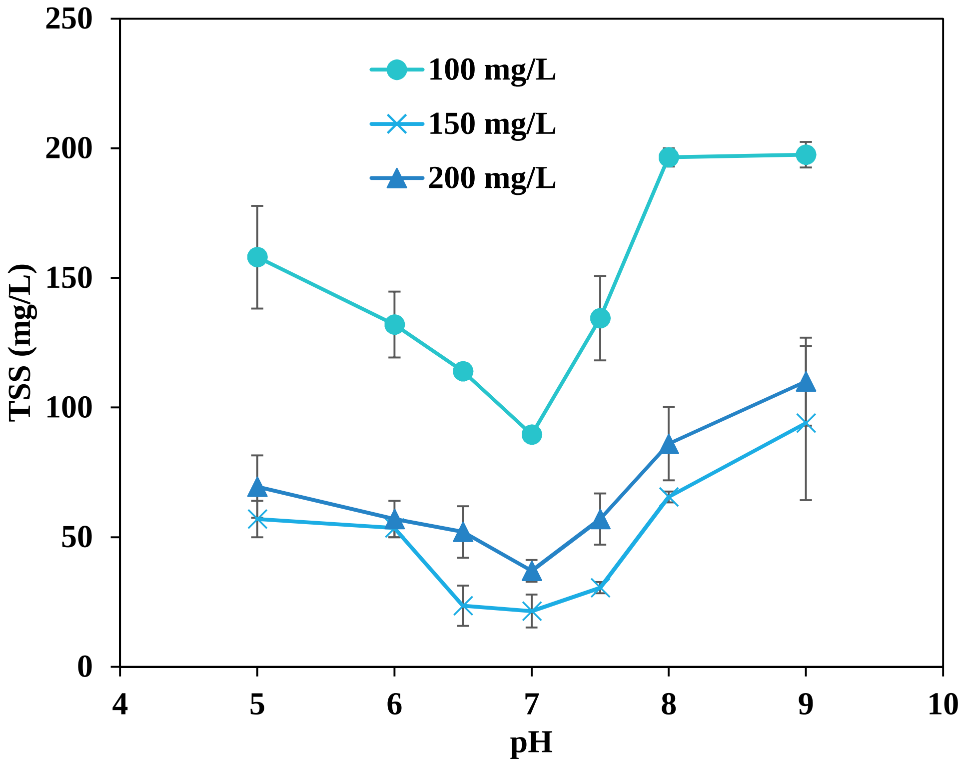
Sub Project#1: CFS- pH Role

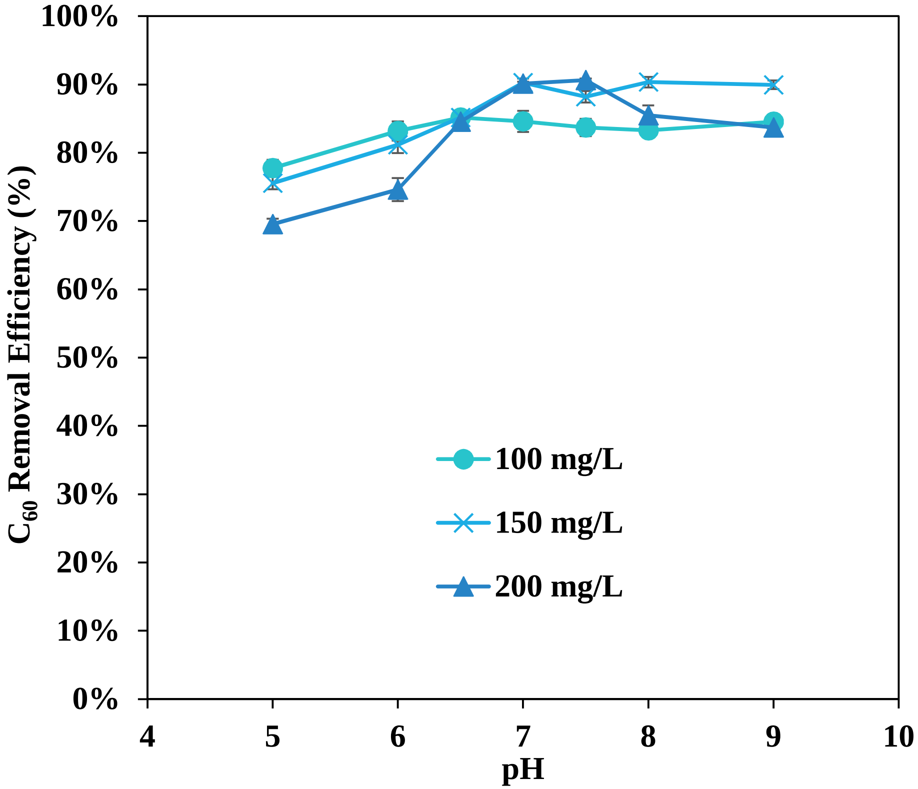
% of Primary Influent	50%
Avg. TSS (mg/L)	424

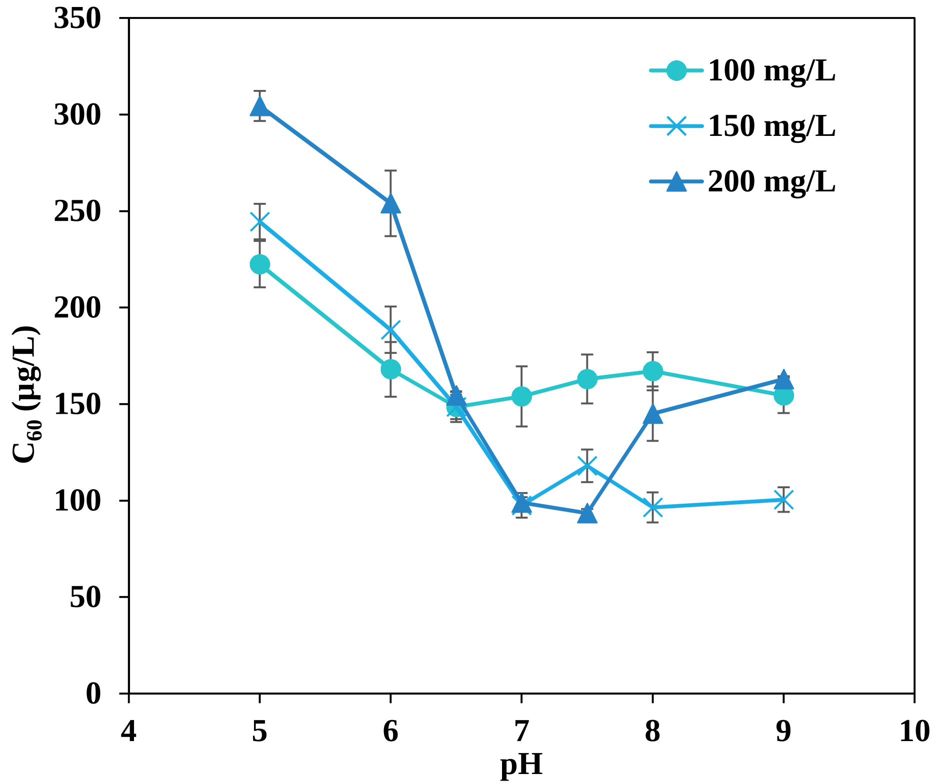




Sub Project#1: CFS- pH Role

% of Primary Influent	50%
Spiked C_{60} in the Influent (mg/L)	1





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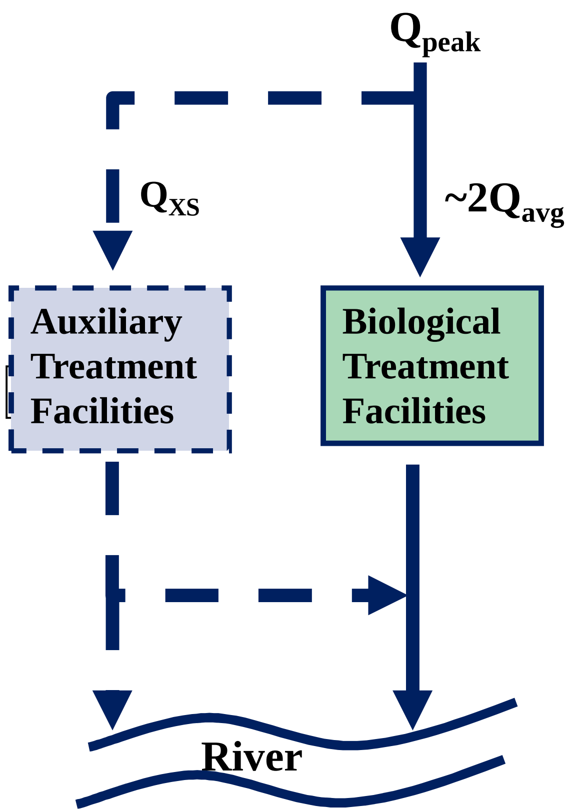

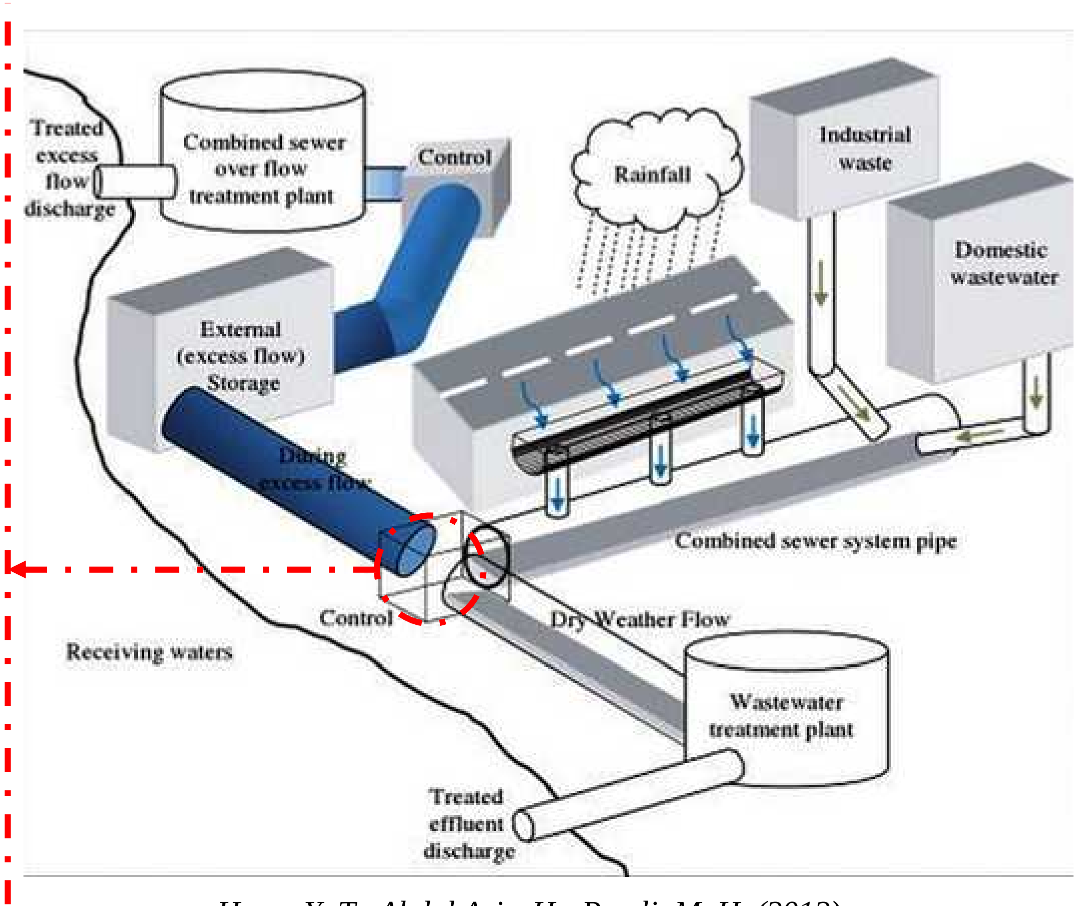

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Typical Pollutant Concentrations Found in CSOs

US EPA, 2001

Contaminant Source	BOD_5 (mg/L)	TSS (mg/L)	Total N (mg/L)	Total P (mg/L)	Fecal Coliform (cfu/100mL)
Untreated Domestic Wastewater	100—400	100—350	20— 85	4—15	10^7—10^9
Treated Wastewater - Secondary	<5—30	<5—30	15— 25	<1—5	< 200
Urban Runoff	10—250	67—101	0.4—1.0	0.7—1.7	10^3—10^7
CSO	25 —100	150—400	3—24	1–10	10^5–10^7

Yearly Flow and TSS Load to the NSR passing through Edmonton

Gyurek, L.; Lodewyk, S.; Malesevic, L., 2010

Source	Yearly flow (ML/Year)	Yearly TSS Load (Tones)
Storm water outfalls	67,000 (0.89% of NSR Yearly Flow)	8600 (82%)
Combined sewer overflows from Rat Creek outfall plus 17 smaller ones	1,500 (0.02% of NSR Yearly Flow)	760 (7%)
GBWWTP final effluent that utilized secondary treatment	94,000 (1.3% of NSR Yearly Flow)	650 (6%)
GBWWTP bypassed effluent that utilizes EPT only	3,000 (0.04% of NSR Yearly Flow)	560 (5%)

GBWWTP- Approval to Operate

Parameter	Limit	Calculation Method	Sample Type
BOD_5	20 mg/L	Monthly arithmetic mean	____
TSS	20 mg/L	Monthly arithmetic mean	Daily composite samples
Total Phosphorus	1.0 mg/L	Monthly arithmetic mean	Daily composite samples
Ammonia-Nitrogen (December 1 to May 31)	10 mg/L	Monthly arithmetic mean	Daily composite samples
Ammonia-Nitrogen (June 1 to November 30)	5.0 mg/L	Monthly arithmetic mean	Daily composite samples
E. coli counts	200units/ 100mL	Monthly geometric mean	Daily grab samples
pH	6.5 –9.5 pH unit	____	____

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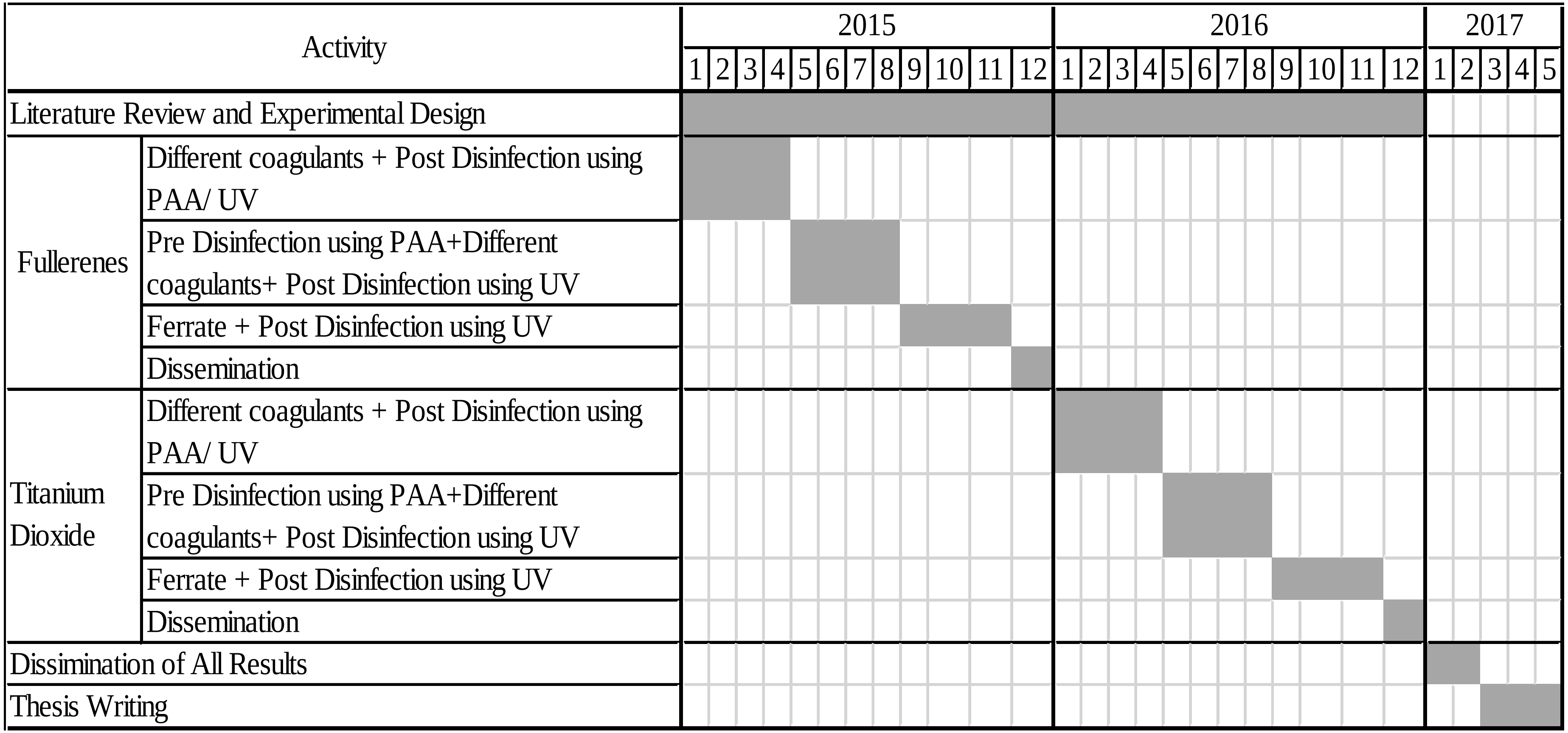
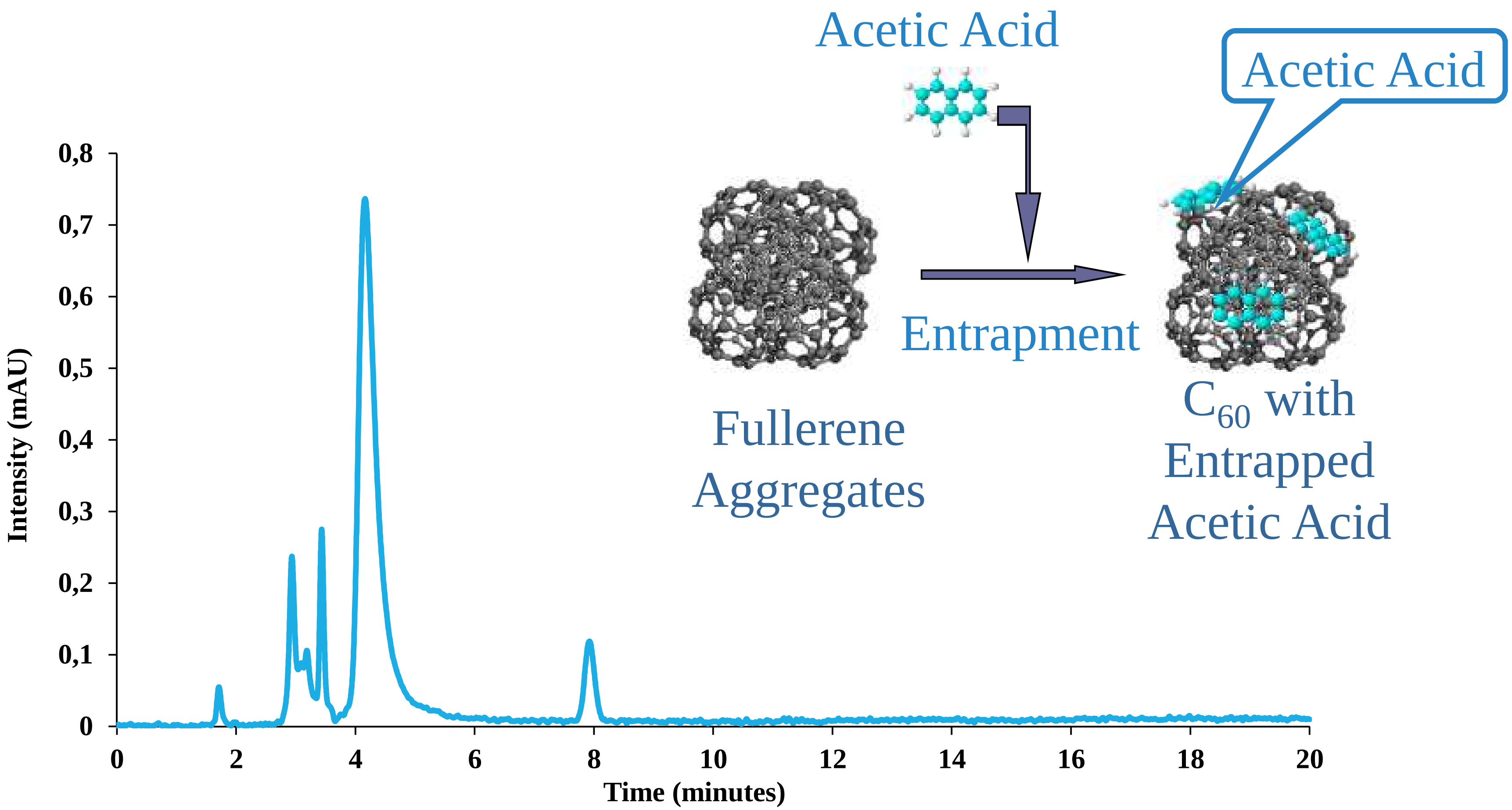
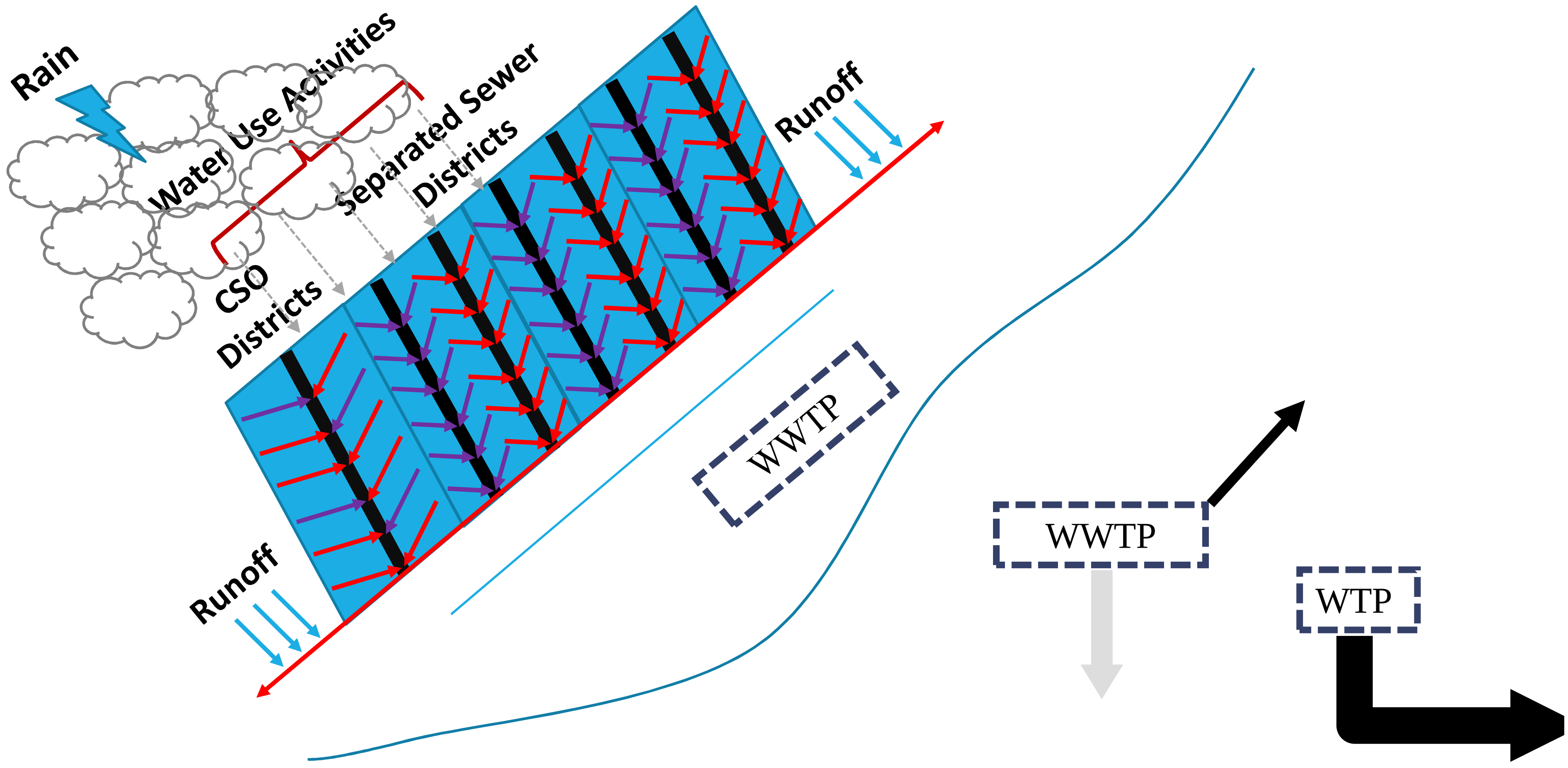
4. Ongoing Sub-projects
5. **Research Plan**

Research Plan



Sub Project#1: PAA Post Disinfection




Rain
Water Use Activities
Separated Sewer Districts
CSO Districts
Runoff
Runoff
WWTP
WWTP
WTP

Building Fugacity or Aquivilant Concentration Model

Lake/ Rivers

Primary Sedimentation Tank

Hydrologic and Limnologic Parameters
Volume of Water
Particles Present, entering, and leaving
Evaporation and Precipitation rates
Sediment Deposition and Resuspension Rates

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Mass Transfer Coefficients and diffusion variables
Although chemical dependent, a common value can be applied to all chemicals

Reaction Rate Constants (Metals= Zero unless a speciation change is considered

Partitioning Properties of the chemical between various environmental media are treated (Z values)-
Z values are dependent on both the chemical and the nature of the medium

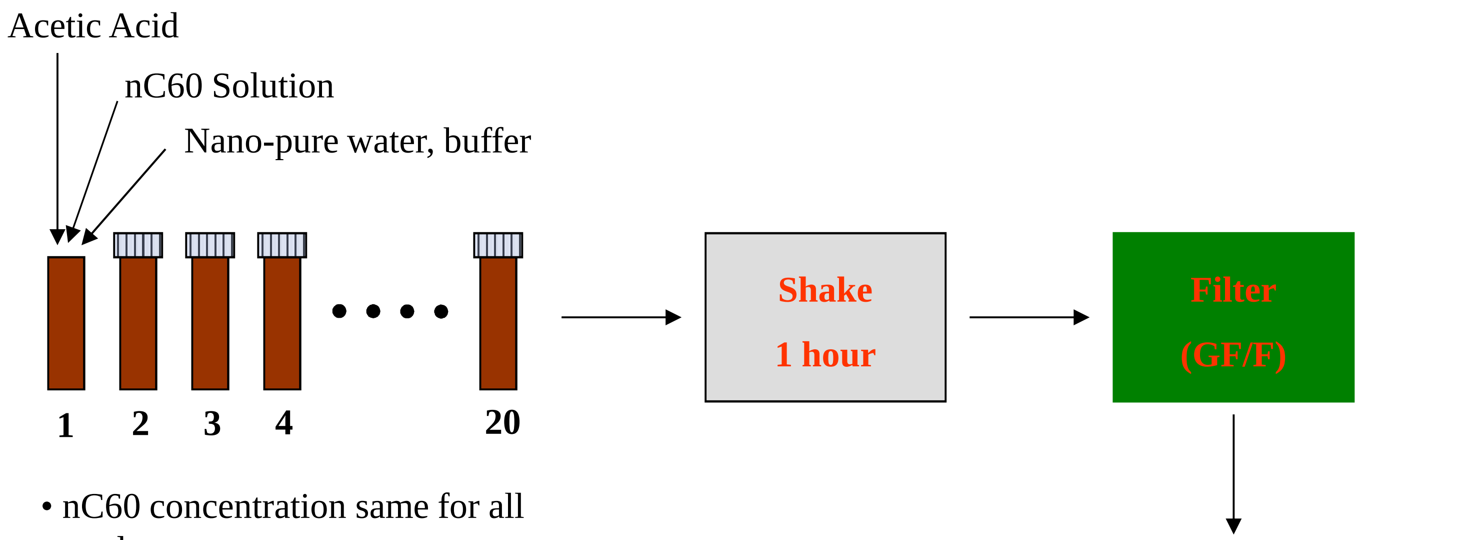
Volatile Chemicals

Involatile Chemicals

Fugacity Approach: Estimate is based on Air Phase then Partitioning Between Air and Water

Aquivalant Approach: Calculations begin with assigning the water phase Z a value of unity

Batch Sorption Procedure



- nC60 concentration same for all samples
- Vary water quality
- Vary acetic acid dosage

N-C60 measured by HPLC/UV method for down to 0.1 ug/L

Mass balance modeling at WWTP on nC60

Input Parameters

$Q = 2.3$ mgd

HRT = 2.3 hours

$\theta = 5$ days

$C_0 = 6$ mg/L

$K = 3.1$

$1/n = 1.4$

Results

Predicted effluent C60 conc = 4.7 mg/L (78%)

22% of nC60 would go to biosolids

Model estimates must be validated with lab and field measurements

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Mass balance on nanoparticles in a WWTP operating at steady state

Assume sorption to biological matter dominates over biodegradation or volatilization for engineered nanoparticles

Mass Balance Equation (mass NPs per time) at steady state:

$$QC_0 - QC - \frac{\left(KC_e^{1/n}\right)XV}{\Theta} = 0$$

Terms are common WWTP parameters: Q = water flowrate, C_0 & C_e are inlet and effluent nanoparticle concentrations, X is biomass concentration, θ is sludge retention time, V is reactor volume, K and 1/n are Freundlich isotherm parameters

Estimate K and 1/n from batch isotherms

Alkalinity Effect on Coagulation

Removal Mechanisms in CFS