Development Of An Integrated Technology For The Removal Of Emerging Substances of Concern From Municipal Wastewaters

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INTRODUCTION

Background:

- The **consumption** of pharmaceuticals has increased dramatically around the world in recent years. For example:
  - **60.4 million** prescriptions were handed out in US pharmacies in 2012.[1]
  - Sales of prescription drugs in Canada alone escalated to **US$8 million** in a period of four years.[2]
- Recent studies have shown that traces of several pharmaceuticals have started to emerge in **Municipal Wastewaters (MWW)** and **Groundwater (GW)**. Due to inefficient conventional treatments in practice at wastewater treatment plants (WWTPs), these **emerging substances of concerns (ESOCs)** are now being detected in receiving water bodies such as rivers, streams and aquifers that serve as drinking water sources.[3]
- Long term exposure to these contaminants could be **harmful** to aquatic life and potentially to humans.
- Advancement in biological and chemical wastewater treatment technologies have shown promising aspects with some limitations as shown below.
- There is a need of more efficient and cost effective technology to remove such ESOCs from MWW.

Table 1: ESOCs Detected in Surface and Drinking Waters of Calgary [4]

Pharmaceuticals	Groups	Pharmaceuticals	Groups
Metformin	Anti-Diabetic	Sulfamethoxazole	Antibiotics
Caffeine	CNS* Stimulant	Venlafaxine	Antidepressant
Carbamazepine	Antiepileptic	Gemfibrozil	Antihyperlipidemic
Cotinine	Antidepressant	Ibuprofen	Anti-inflammatories
Fluoxetine	Antidepressant	Naproxen	Anti-inflammatories
Trimethoprim	Antibiotics	Diclofenac	Anti-inflammatories
Ethynylestradiol	Estrogens	Estrone	Estrogens

*Central Nervous System

Treatment Technologies:

Biological Treatment	Advanced Oxidation Process
Advantages	
Economical	Fast Removal
Low maintenance	Non-selective
Disadvantages	
Long Retention	Expensive
Slow Removal	By-products
Partial Removal	

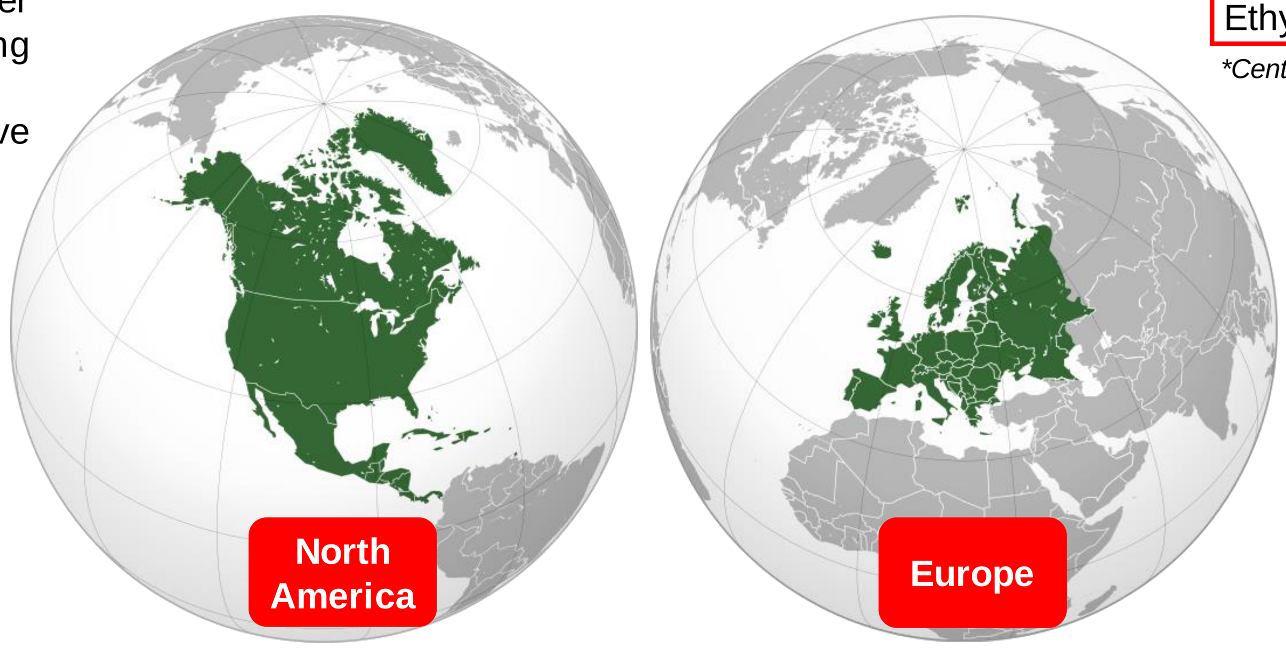


Table 2: Concentration (µg/L) of some ESOCs detected in WWTP Effluents and Surface waters [5-7]

Region	Metformin	Sulfamethoxazole	Naproxen	Carbamazepine
North America	0.02 - 47	~6.9	~4.9	~6.2
Europe	0.1 - 16	0.3 - 29	0.85 – 12.3	7.6 – 8.05

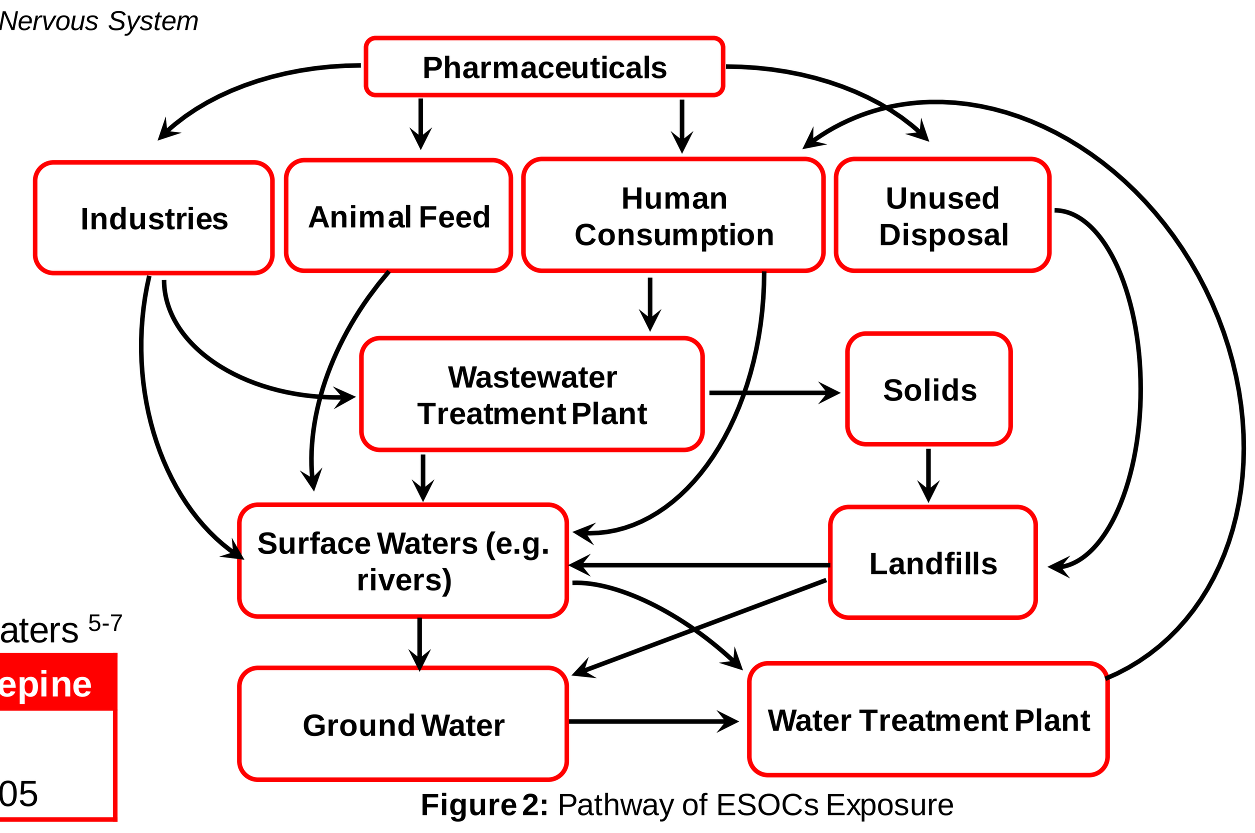


Figure 2: Pathway of ESOCs Exposure

BIOLOGICAL PROCESSES

Table 3: Advantages and Disadvantages of Biological Processes

Biological Treatment	Process	Advantages	Disadvantages
Activated Sludge	Aerobic **Suspended** growth of active biomass	Proven Technology	Large Footprint, Clarifier required, Sludge recycle
Moving Bed-Biofilm Bioreactor (MBBR)	Aerobic **Suspended** and **Attached** growth of active biomass on bio-carriers.	Can adapt to fluctuating organic loads, Recycle sludge not required	Change of bio-carriers, Odor
Aerobic Granulation	Aerobic Suspended growth where microbes are **self immobilized** into **aggregates** without the need of bio-carriers	Small Footprint, Can handle high organic loads, Clarifier not required, Recycle sludge not required	Long startup time

ADVANCED OXIDATION PROCESS (AOP)

- AOPs produce **hydroxyl radicals (•OH)** that are highly reactive oxidants able to oxidize almost all organic contaminants in wastewaters.
- AOPs use strong **oxidizing agents** separately or in combination with each other to produce •OH.
- AOPs are able to transform toxic organic compounds (e.g. pharmaceuticals, pesticides, etc.) into biodegradable compounds or to complete mineralization.

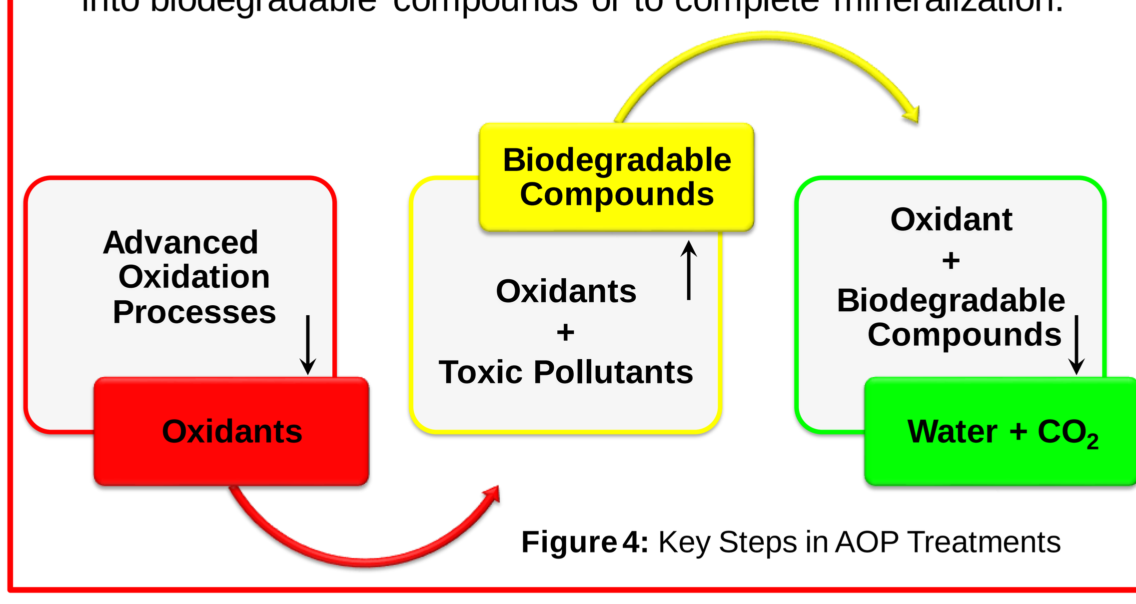


Figure 4: Key Steps in AOP Treatments

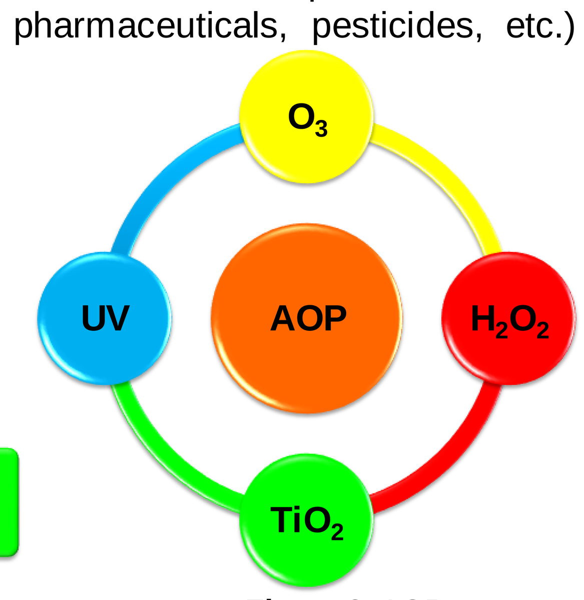


Figure 3: AOPs

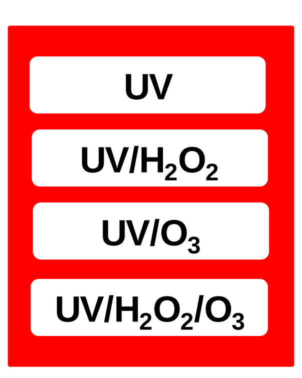
OBJECTIVES

1. To investigate the impact of biological treatment on AOP for the removal of selected ESOCs from MWW by analyzing the effects of residual nutrients, concentration of mixed liquor suspended solids (MLVSS), total organic carbon and contaminant concentration.
2. To investigate the degradation kinetics of selected ESOCs, determine the optimum conditions and extent of mineralization using biological treatment, AOP and a combination of both.
3. To study and compare three different biological treatments in combination with different AOP and determine the most efficient and cost effective integrated technology for the removal of ESOCs from MWW.
4. To investigate the impact of AOP on aerobic granulation for ESOCs removal by analyzing the effects of residual oxidant concentration, potential by-product formation and total organic carbon on the biological process.
5. To develop and optimize an integrated technology for enhanced overall removal of ESOCs from MWW.

POTENTIAL TREATMENT METHODOLOGY

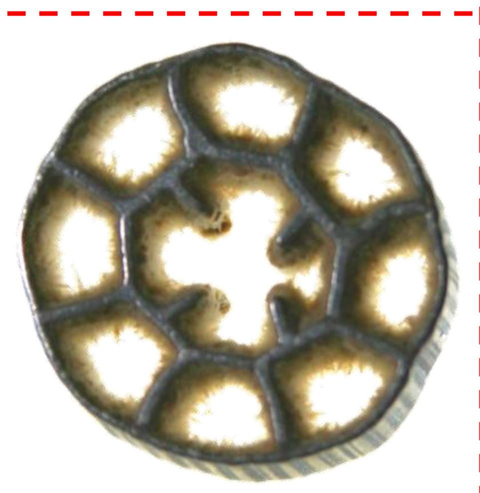
Case 1: Conventional Biological Treatment Followed by AOP

- Evaluate the Impact of Total Suspended Solids from biological process on AOP treatment on ESOCs removal from MWW.
- Evaluate the Impact of residual nutrients on performance of post AOP treatment.
- Evaluate the performance of **different AOPs**
- Optimize the combined process for effective and efficient ESOCs removal



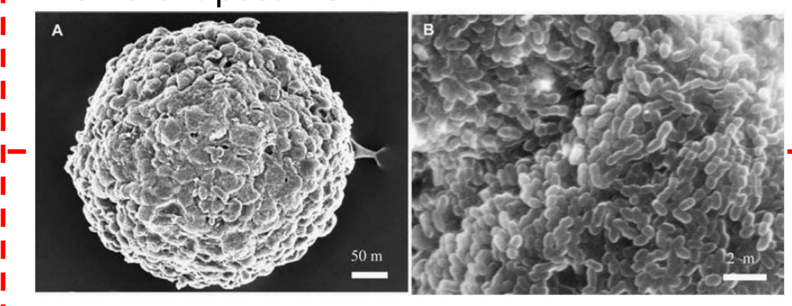
Case 2: Moving Bed-Biofilm Reactor Followed by AOP

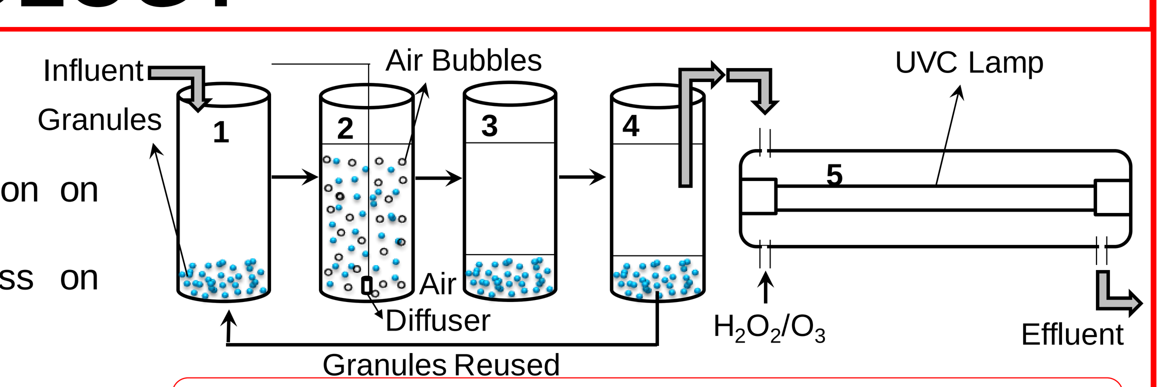
- Evaluate the Impact of bio-carriers and residual nutrients on AOP treatment in removing ESOCs from MWW.
- Evaluate the Impact of initial contaminant concentrations on treatment performance.
- Evaluate the performance of different AOP treatments after MBBR
- Optimize the combined process for effective and efficient ESOCs removal



Case 3: Aerobic Granulation Followed by AOP

- Evaluate the Impact of granule concentration on ESOCs removal.
- Evaluate the impact of granulation process on different post-AOP.



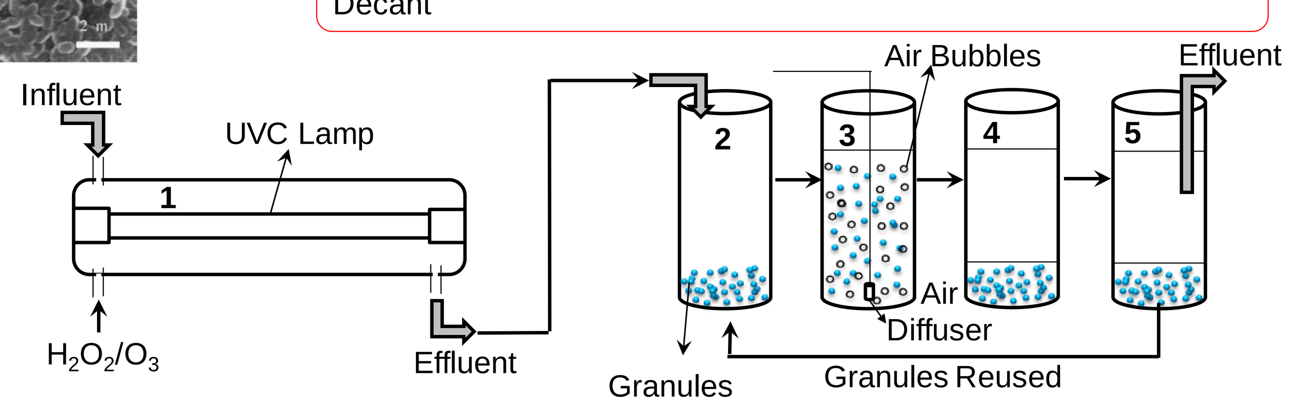


1. Influent Fill, 2. Reaction (Aeration), 3. Settling, 4. Effluent Decant, 5. AOP

1. AOP, 2. Influent Fill, 3. Reaction (Aeration), 4. Settling, 5. Effluent Decant

Case 4: AOP Followed by Aerobic Granulation

- Evaluate the Impact of residual oxidants, potential by-products on aerobic granulation process.
- Evaluate different AOPs



TECHNOLOGY APPLICATION

Case 1 and 2:

Bench scale studies will be completed in Laboratory. Determination of optimized conditions will be followed by implementation of these technologies on pilot scale at ACWA facility to remove ESOCs from MWW.

Case 3 and 4:

These case studies will be carried out on bench scale. Aerobic granulation technology has the potential to replace conventional biological treatment in practice today with less footprint and lower capital cost. Future pilot scale testing will take place at ACWA facility.

REFERENCES

1. C. Hampp, V. Borders-Hemphill, D. G. Moeny and D. K. Wysowski, *Diabetes Care*, 2014, **37**, 1367–1374.
2. IMS Health Canada, Unlocking the value of health information, www.imhealthcanada.com.
3. M. S. Fram and K. Belitz, *Sci. Total Environ.*, 2011, **409**, 3409–3417.
4. M. Chen, K. Ohman, C. Metcalfe, M. G. Ikonomou, P. L. Amatya and J. Wilson, *Water Qual. Res. J. Canada*, 2006, **41**, 351–364.
5. B. D. Blair, J. P. Crago, C. J. Hedman and R. D. Klaper, *Chemosphere*, 2013, **93**, 2116–2123.
6. T. aus der Beek, F. A. Weber, A. Bergmann, S. Hickmann, I. Ebert, A. Hein and A. K????ster, *Environ. Toxicol. Chem.*, 2016, **35**, 823–835.
7. P. M. Bradley, C. A. Journey, D. T. Button, D. M. Carlisle, J. M. Clark, B. J. Mahler, N. Nakagaki, S. L. Qi, I. R. Waite and P. C. VanMetre, *Environ. Sci. Technol. Lett.*, 2016, 243–249.