Suspended Fiber Biofiltration for the Treatment of Landfill Leachate. Year II. Incorporation of Advanced Oxidation and Phosphorous Removal in a Single Unit

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Xenobiotic, Organic, Phosphorous and Iron Removal from Landfill Leachate

- Fewer Restrictions
- Municipal Solid Waste (MSW)
- Protein (0.5% of Dry MSW)
- Iron Issues of Northwest Florida

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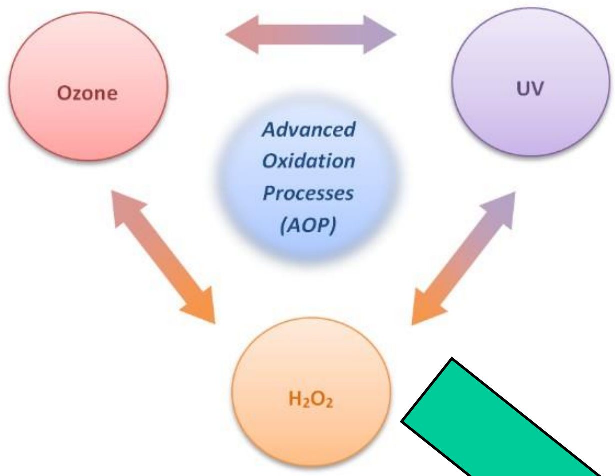
Research Question

Advanced Oxidation Combined with Suspended Fiber Biofiltration for the Treatment of Landfill Leachate



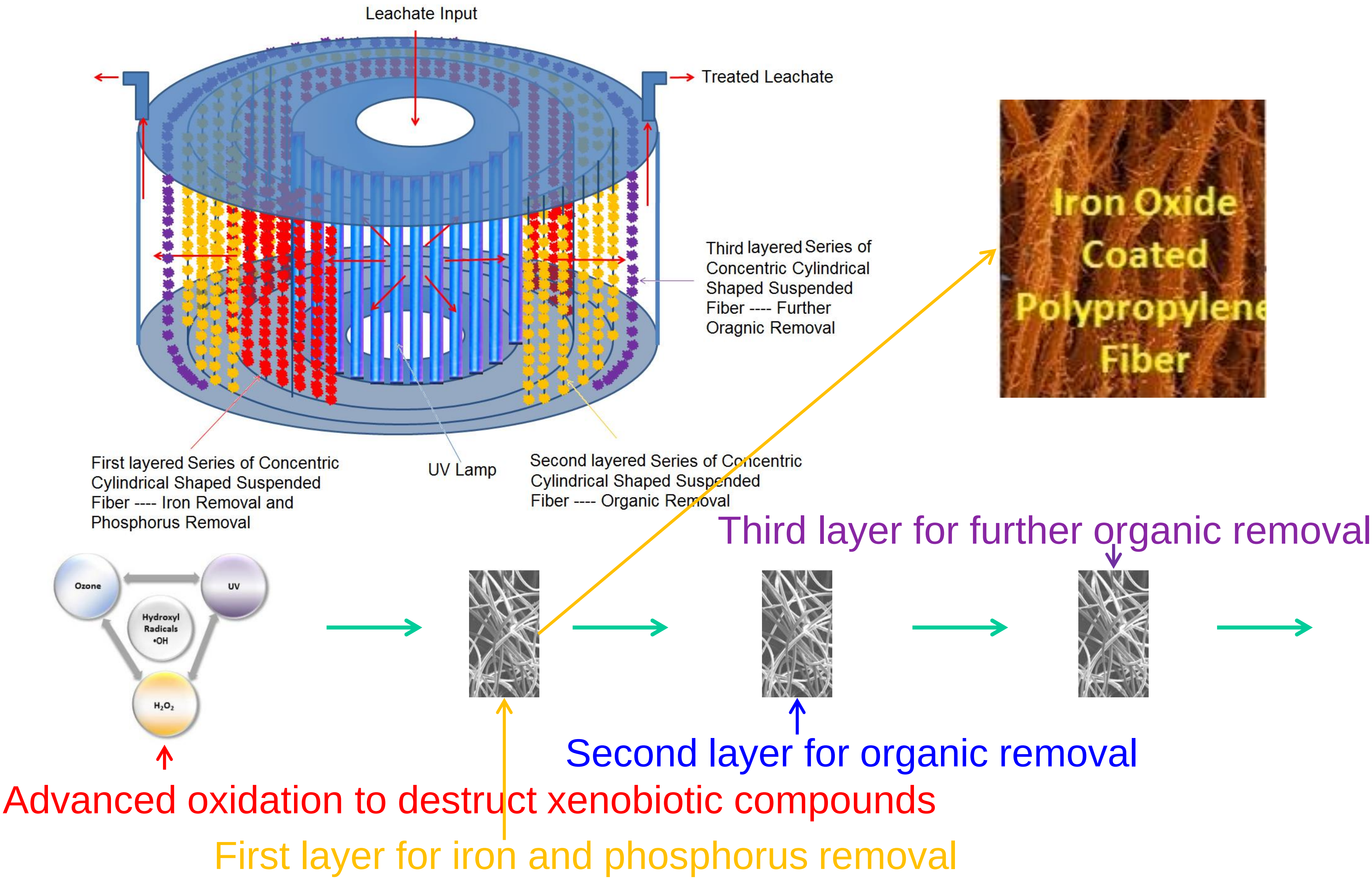
- Xenobiotic compound degradation
- Phosphorous removal
- Enhanced iron removal and organic degradation

Objectives

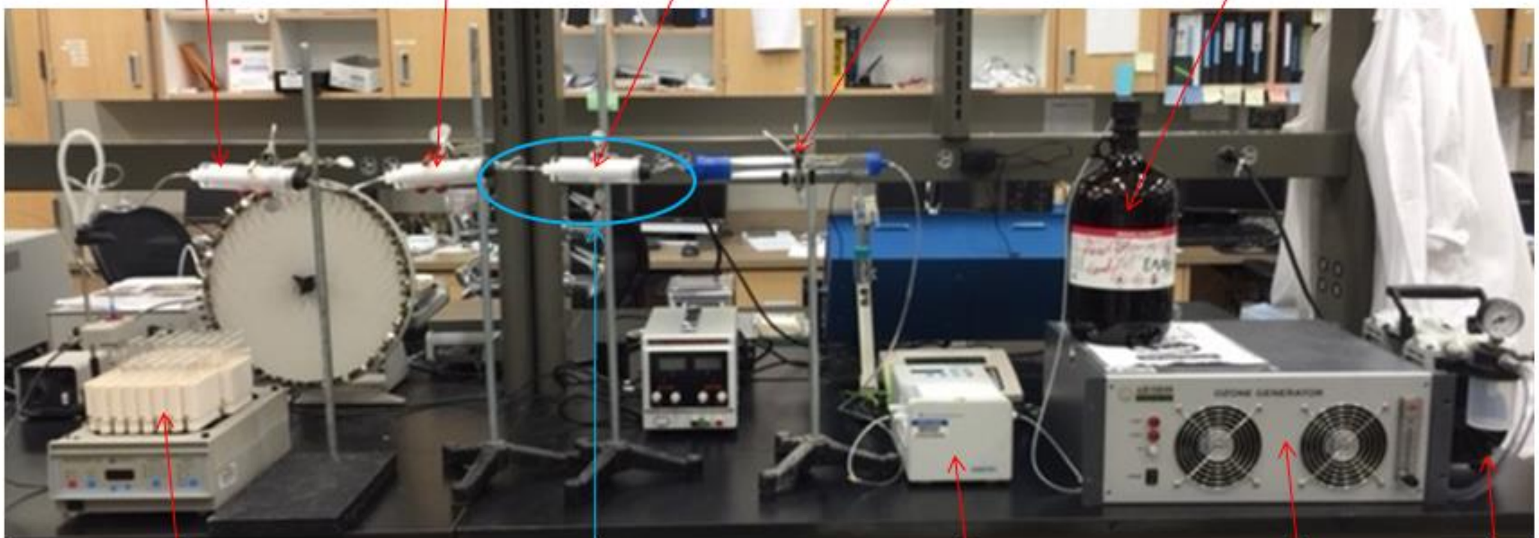
Advanced oxidizing processes will be introduced to the leachate treatment for xenobiotic destruction. The suspended fiber biofiltration will be configured to enhance iron and phosphorous removal in addition to organic degradation.

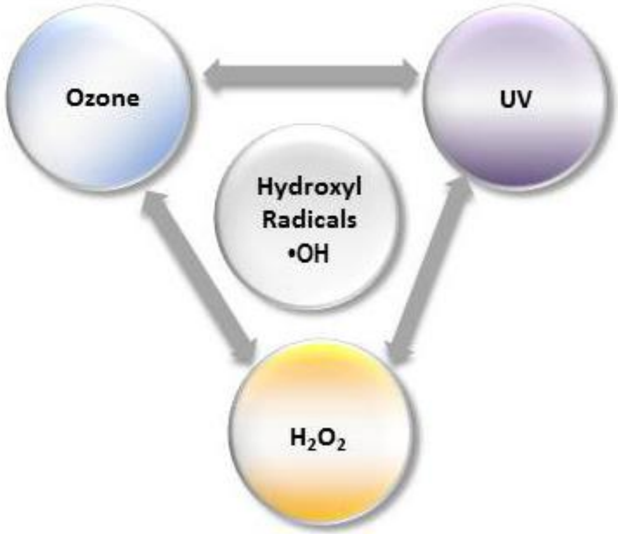
- 1. Reactor Design, Setup and Parameter Characterization – Advanced Oxidation and Suspended Fiber Biofiltration to Be Arranged in Single Unit
- 2. Reactor Operation – Combined UV, Ozone and Hydrogen Peroxide for Xenobiotic Destruction; Suspended Fiber Biofiltration for Iron and Phosphorous removal and Organic Degradation
- 3. System Optimization and Cost Analysis

Proposed Research Setup



Laboratory Setup





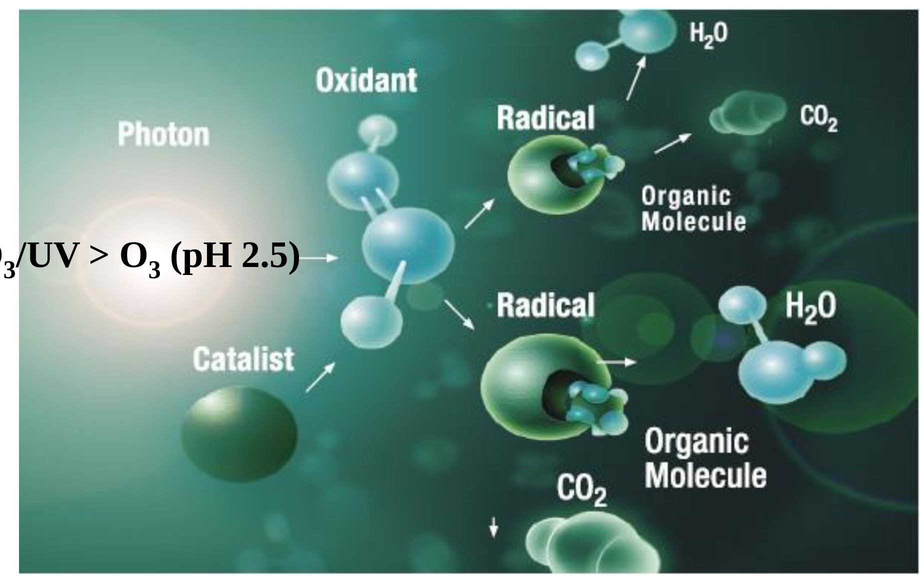
Oxidant	Standard Oxidation Potential (Volts)	Relative Strength (Oxygen = 1)
Hydroxyl Radical	2.3	1.92
Ozone	2.1	1.75
Sodium Persulfate	2.0	1.67
Hydrogen Peroxide	1.8	1.50
Oxygen	1.2	1.0

System	Molecules of O_3/Mole $^\cdot$OH	Moles of UV Photons, Einsteins/Mole $^\cdot$OH	Moles of H_2O_2/Mole $^\cdot$OH
O_3/H_2O_2	1.5	0	1.0
O_3/UV	0.5	0.5	0
H_2O_2/UV	0	0.67	0.67
O_3/H_2O_2/UV	1.0	0.58	0.83

4-chlorophenol: **UV/H_2O_2/Fe^{2+} > UV/O_3 > UV/H_2O_2**

PAHs: **O_3/H_2O_2 = O_3 > O_3/UV > O_3/H_2O_2/UV > UV**

Nitrophenols: **O_3/H_2O_2/UV > O_3 (pH 9.5) > O_3/H_2O_2 > O_3/UV > O_3 (pH 2.5)**



Advanced Oxidation

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Advanced Oxidation Types

- Ozone + hydrogen peroxide (O_3/H_2O_2)

$$H_2O_2 \rightarrow HO_2^- + H^+$$

$$HO_2^- + O_3 \rightarrow HO_2^\bullet + O_3^{\bullet-}$$

$$2O_3 + H_2O_2 \rightarrow 2^\bullet OH + 3O_2$$

- Ozone-UV radiation (O_3/UV)

$$O_3 + h\nu \rightarrow O_2 + O(^1D)$$

$$O(^1D) + H_2O \rightarrow H_2O_2 \rightarrow 2^\bullet OH$$

- Hydrogen peroxide-UV radiation (H_2O_2/UV)

$$H_2O_2 \xrightarrow{h\nu} 2^\bullet OH$$

$$H_2O_2 \Leftrightarrow HO_2^- + H^+$$

$$HO_2^- \xrightarrow{h\nu} {}^\bullet OH + O^{\bullet-}$$

- Ozone-hydrogen peroxide-UV radiation (O_3/H_2O_2/UV)

The addition of H_2O_2 to the O_3/UV process accelerates the decomposition of ozone, which results in an increased rate of $^\bullet$OH generation.

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Advanced Oxidation Application Dosage

- **O_3/H_2O_2**

  O_3 2 to 6 mg/L and H_2O_2 1 to 5 mg/L

- **O_3/UV**

  O_3 2 to 6 mg/L and UV 10 to 100 mJ/cm^2 (by varying the exposure time from 0 to 15 min)

- **H_2O_2/UV**

  H_2O_2 1 to 5 mg/L and UV 10 to 100 mJ/cm^2

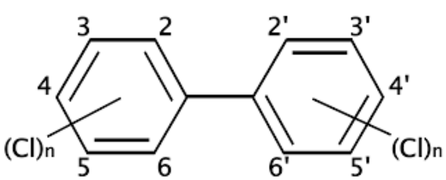
- **O_3/H_2O_2/UV**

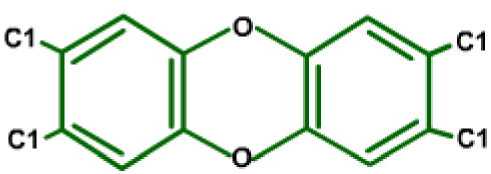
  O_3 1 to 3 mg/L, H_2O_2 1 to 2.5 mg/L, and UV 10 to 50 mJ/cm^2

Impact Factors

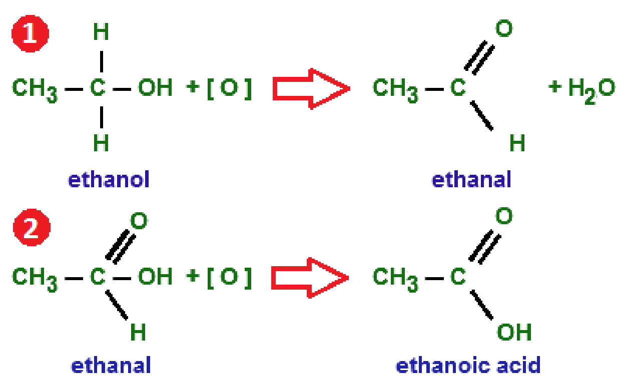
- **Reaction time** 0, 1, 5, 10 and 15 min
- **pH** 4, 5, 6, 7, 8, 9 and 10
- **Alkalinity** 100, 200, 300, 400, 500 and 600 mg/L as $CaCO_3$

Xenobiotic Destruction | **Organic Decomposition** | **Iron Removal**





2,3,7,8-TCDD -
the most toxic dioxin



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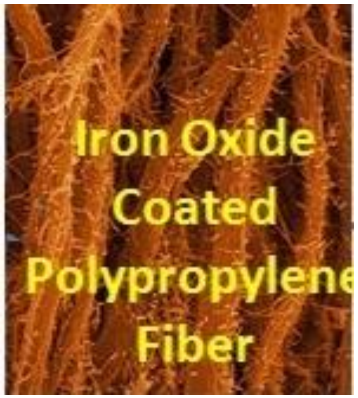
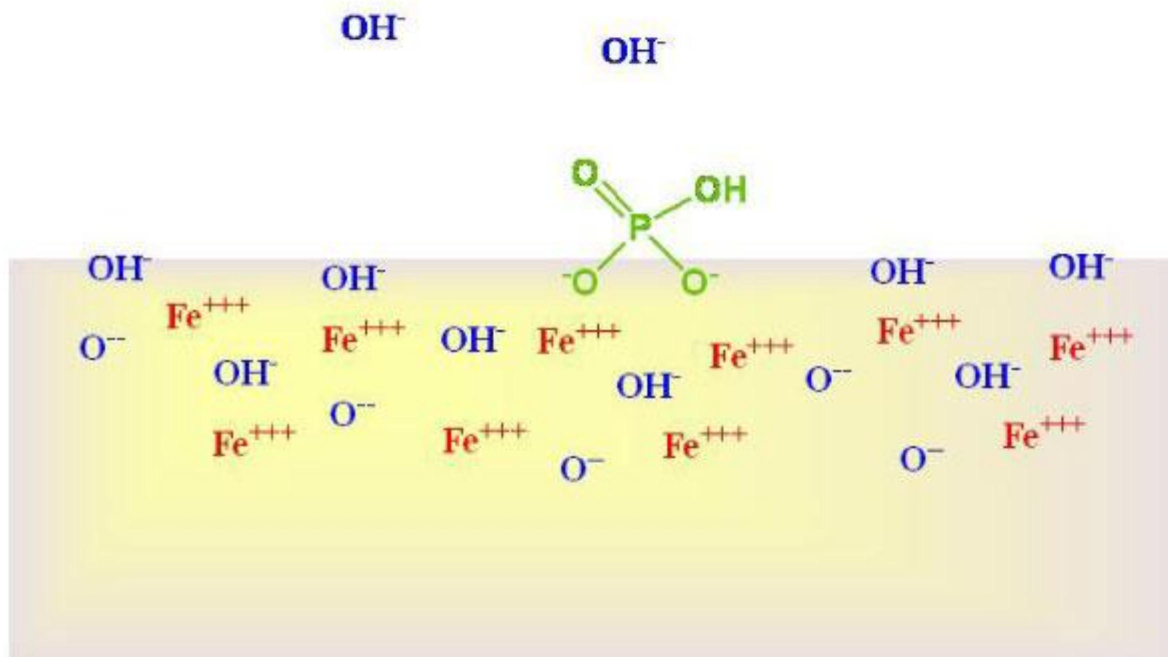
Phosphorous Adsorption on Iron Coated Fiber





Low pH preferred for phosphorous adsorption

- Alkalinity of 100, 200, 300, 400, 500 and 600 mg/L as $CaCO_3$
- pH of 5, 6, 7, 8, 9 and 10

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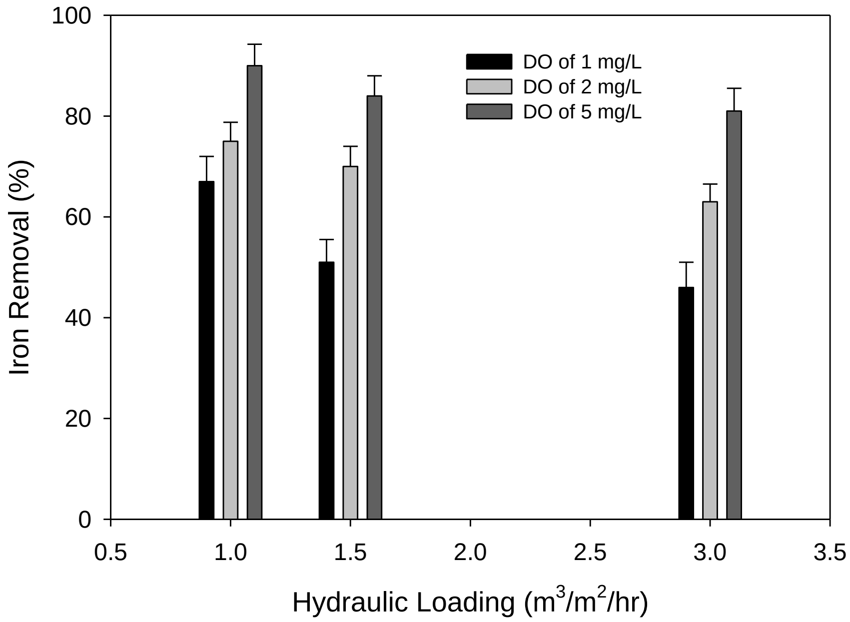
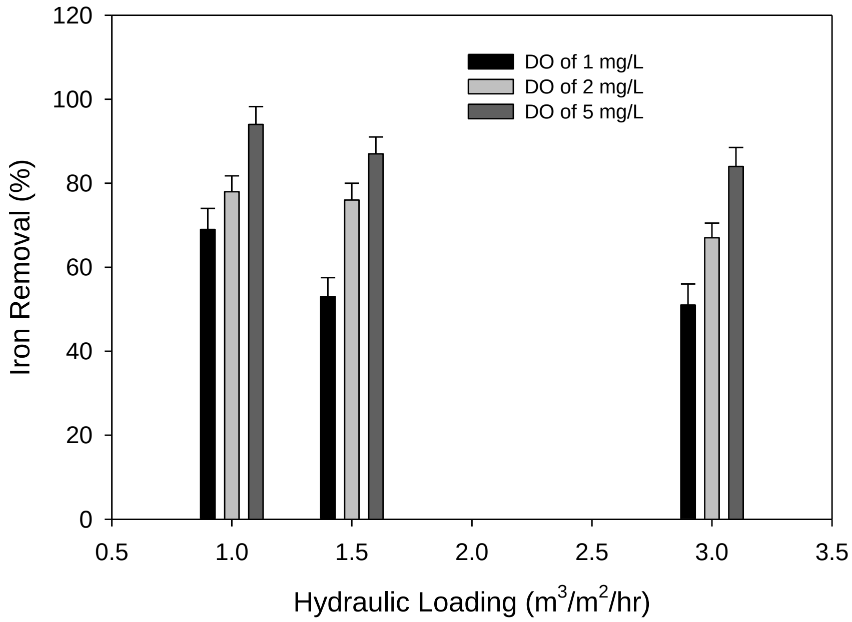
Iron Removal as a Function of Oxidation





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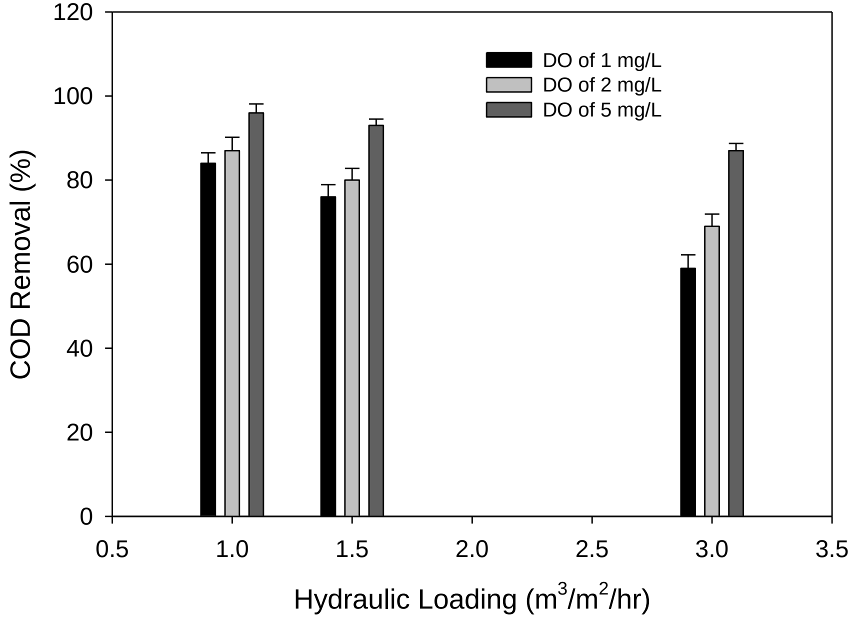
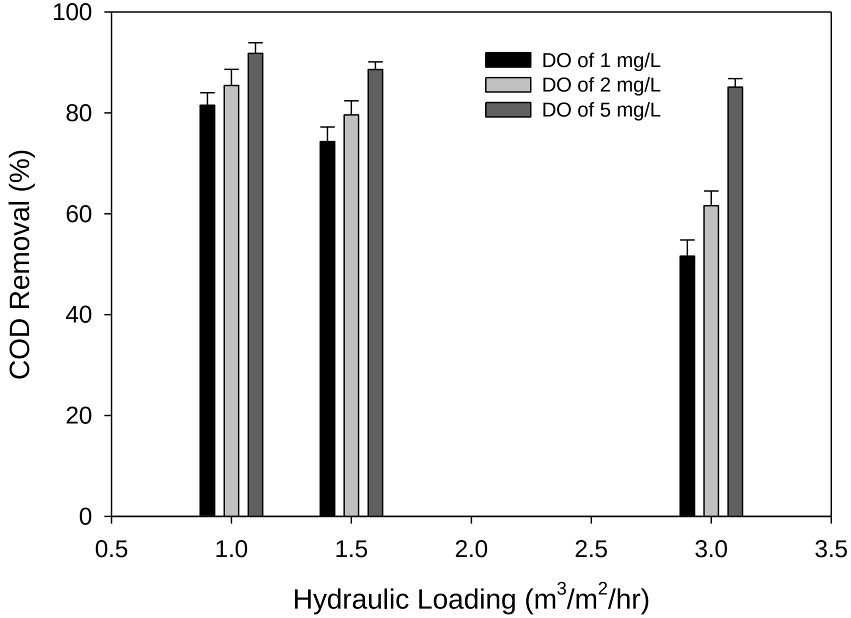
Organic Removal as a Function of Oxidation





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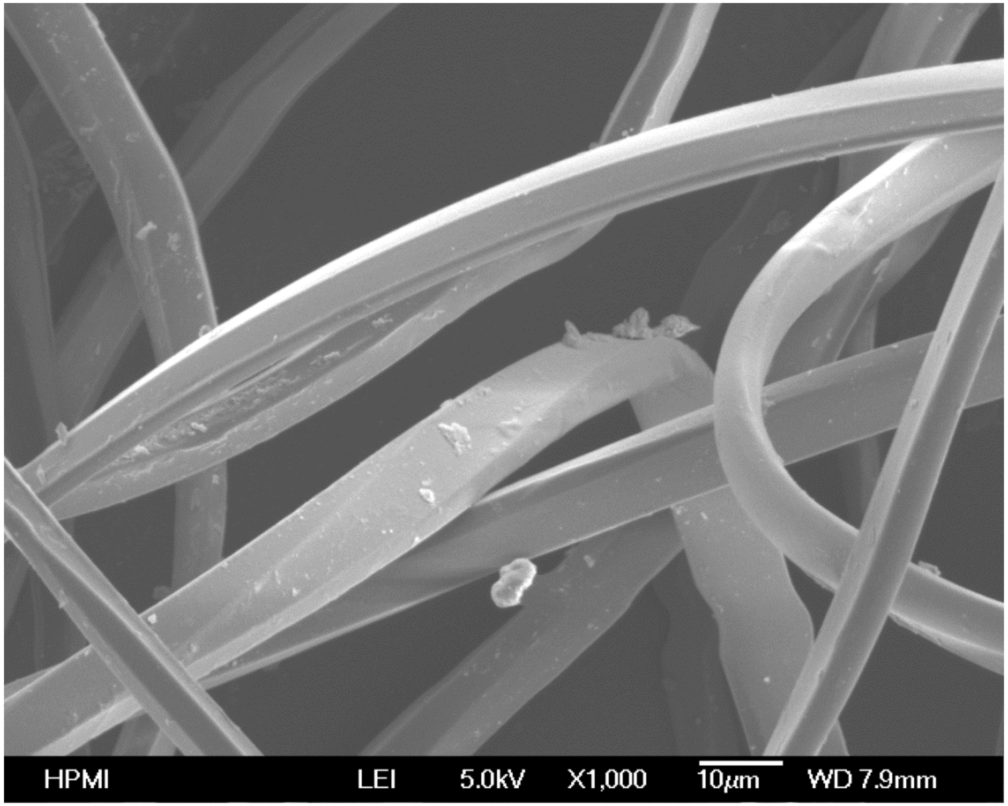

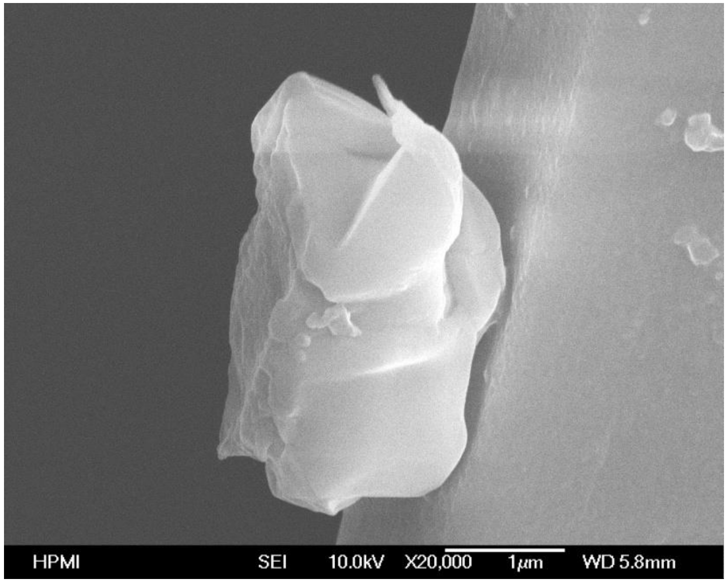

Iron Accumulation on the Fiber

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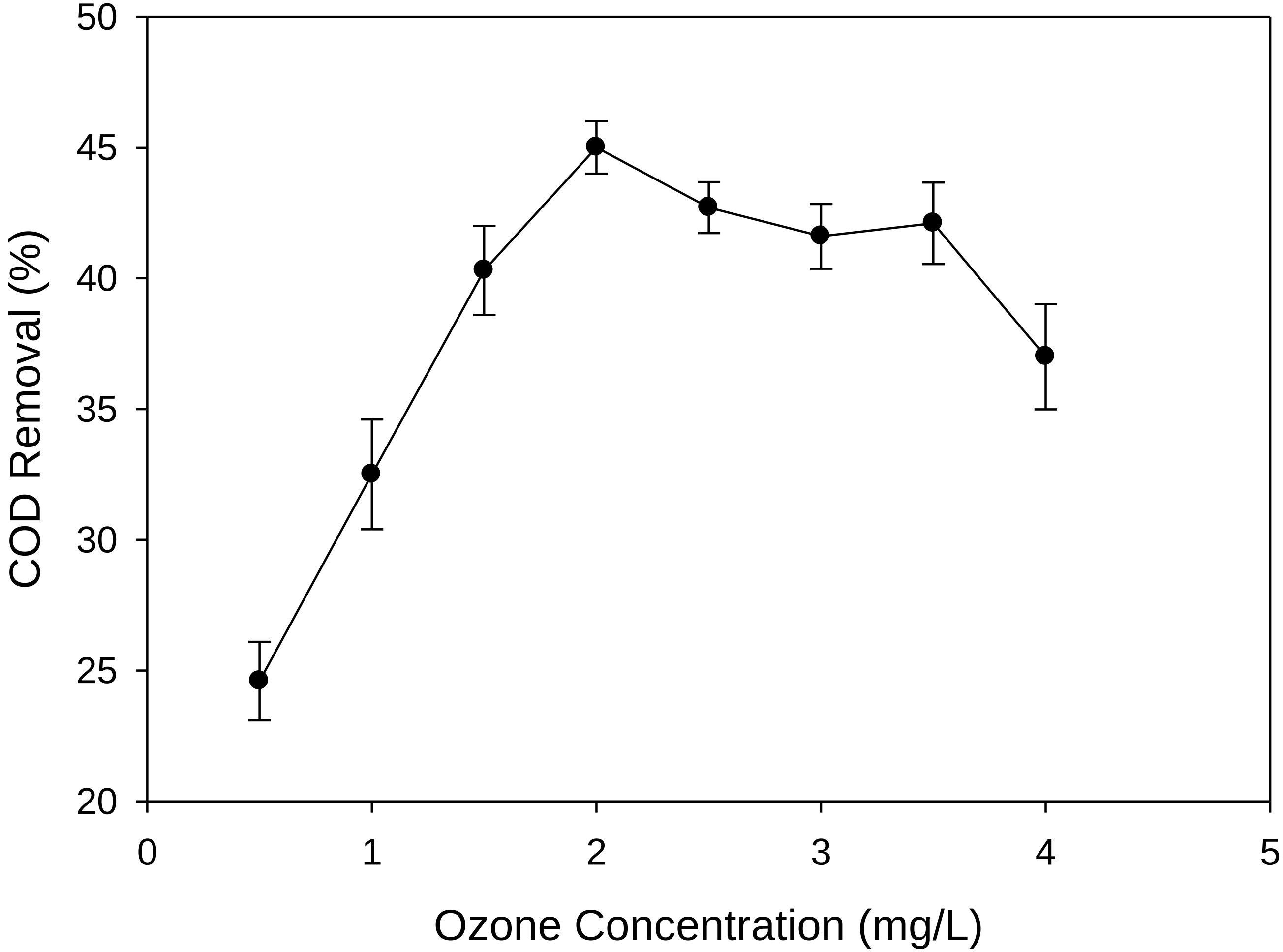
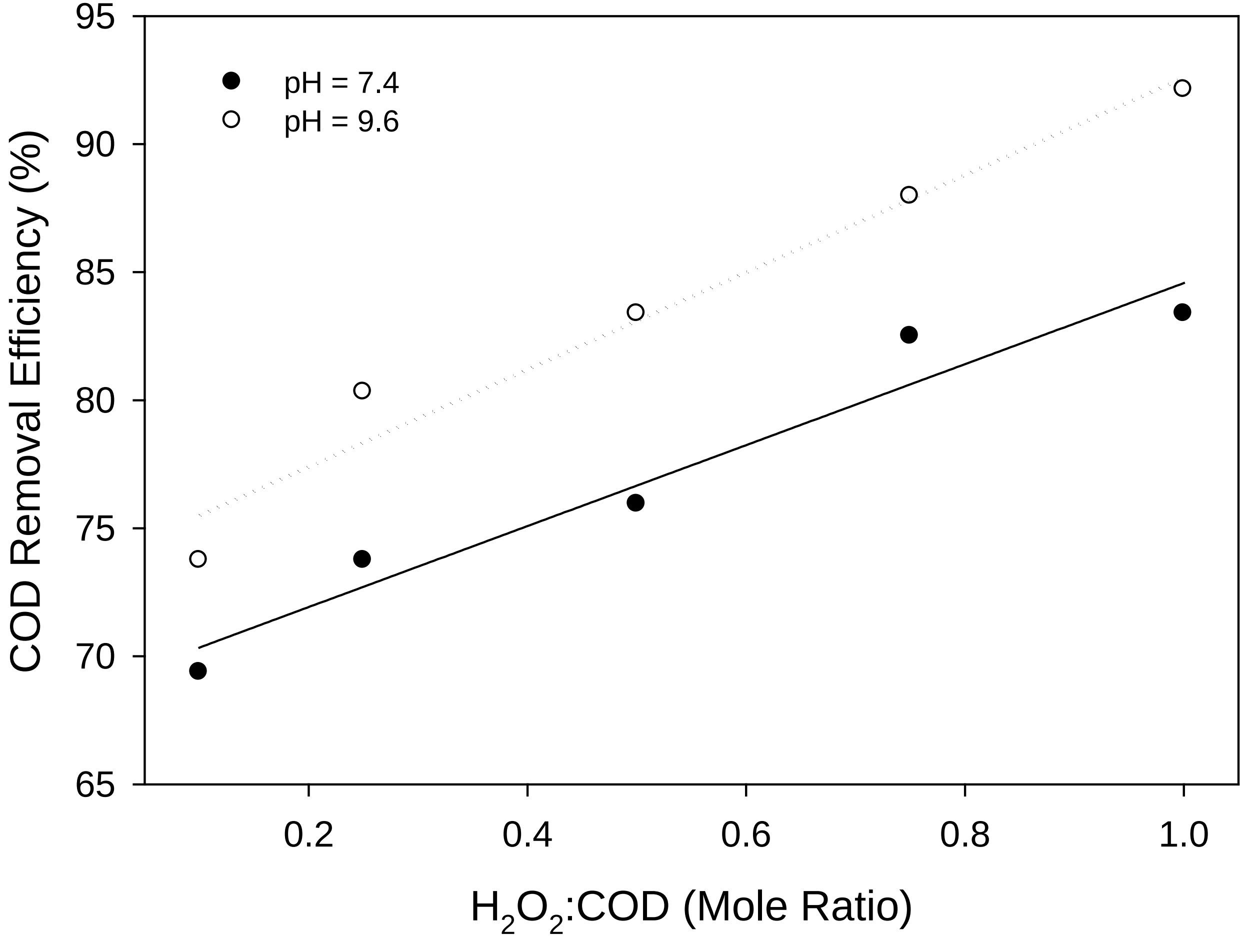
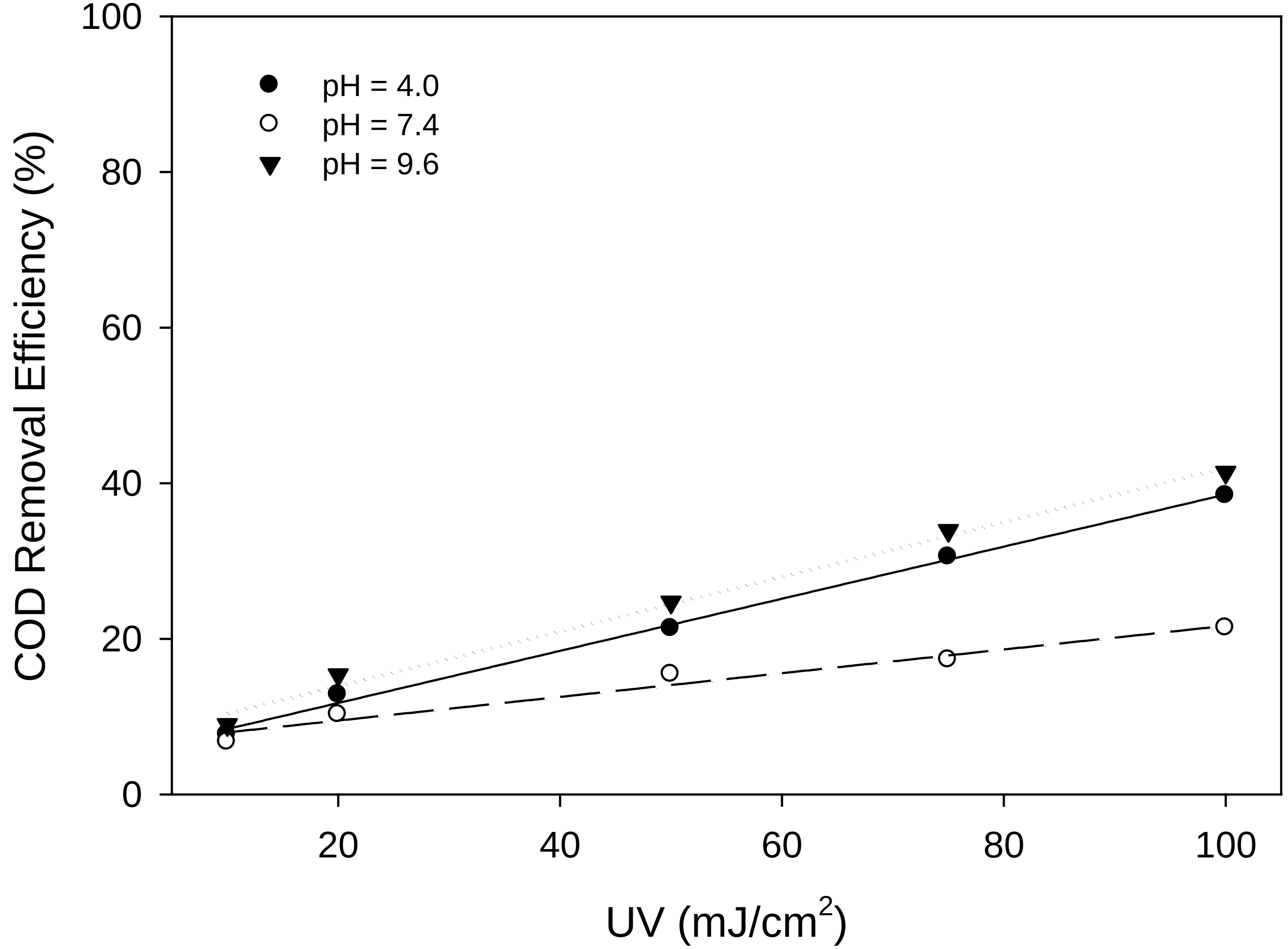
Organic Removal as a Function of O_3



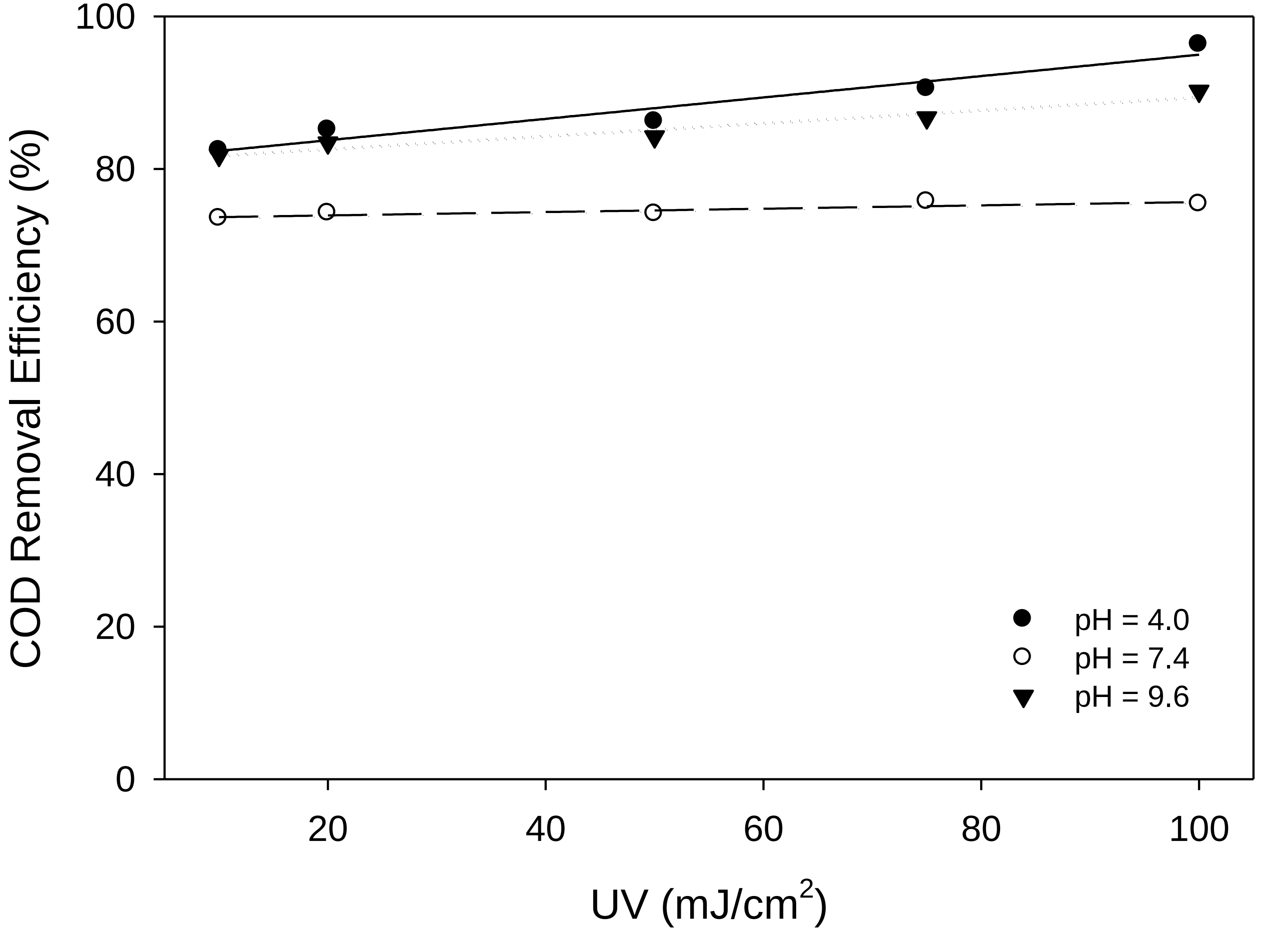
COD Removal with Variable H_2O_2 Dosages at pH 7.4 and 9.6



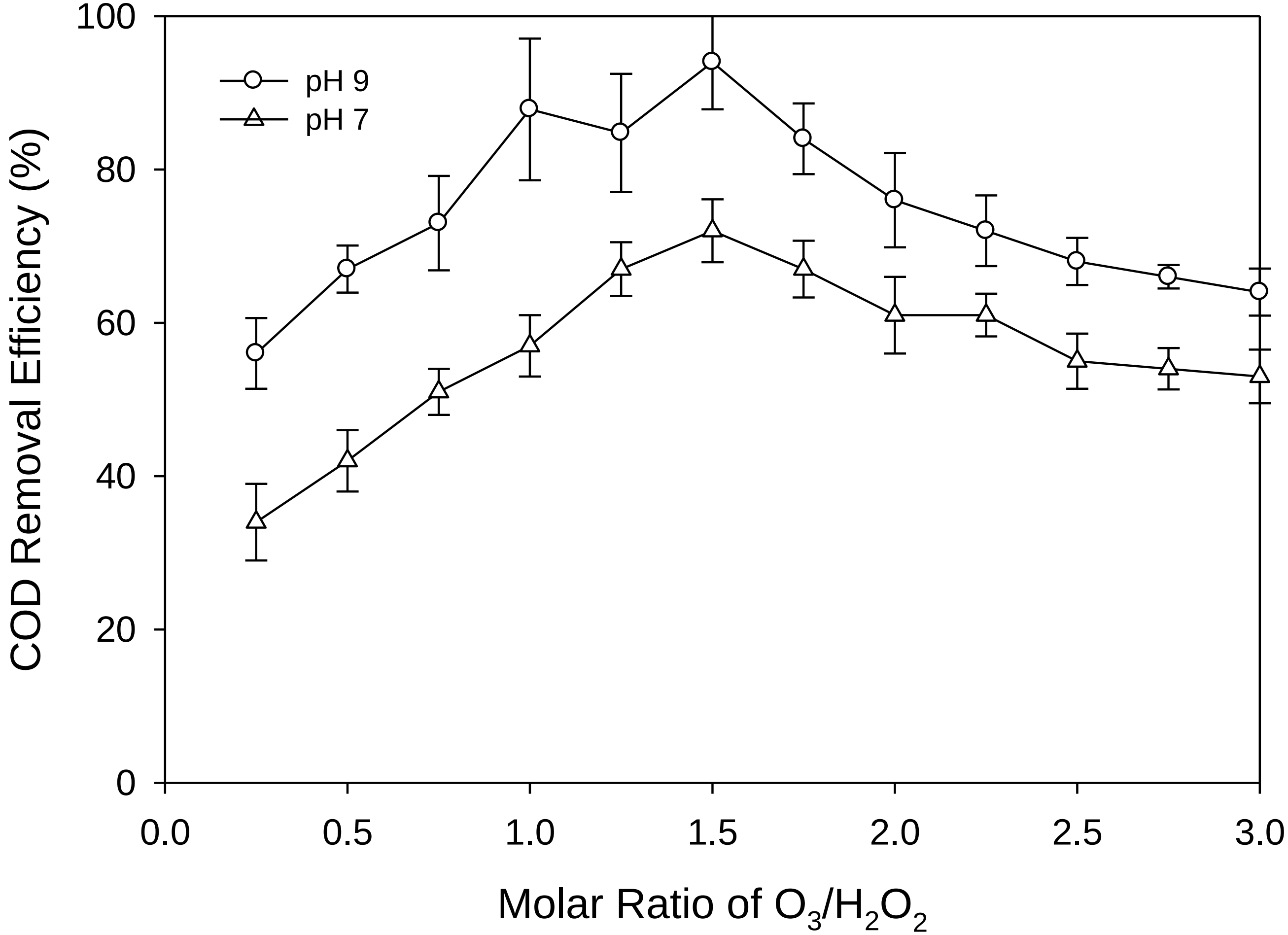
COD Removal with Variable UV Radiation at pH 4.0, 7.4 and 9.6



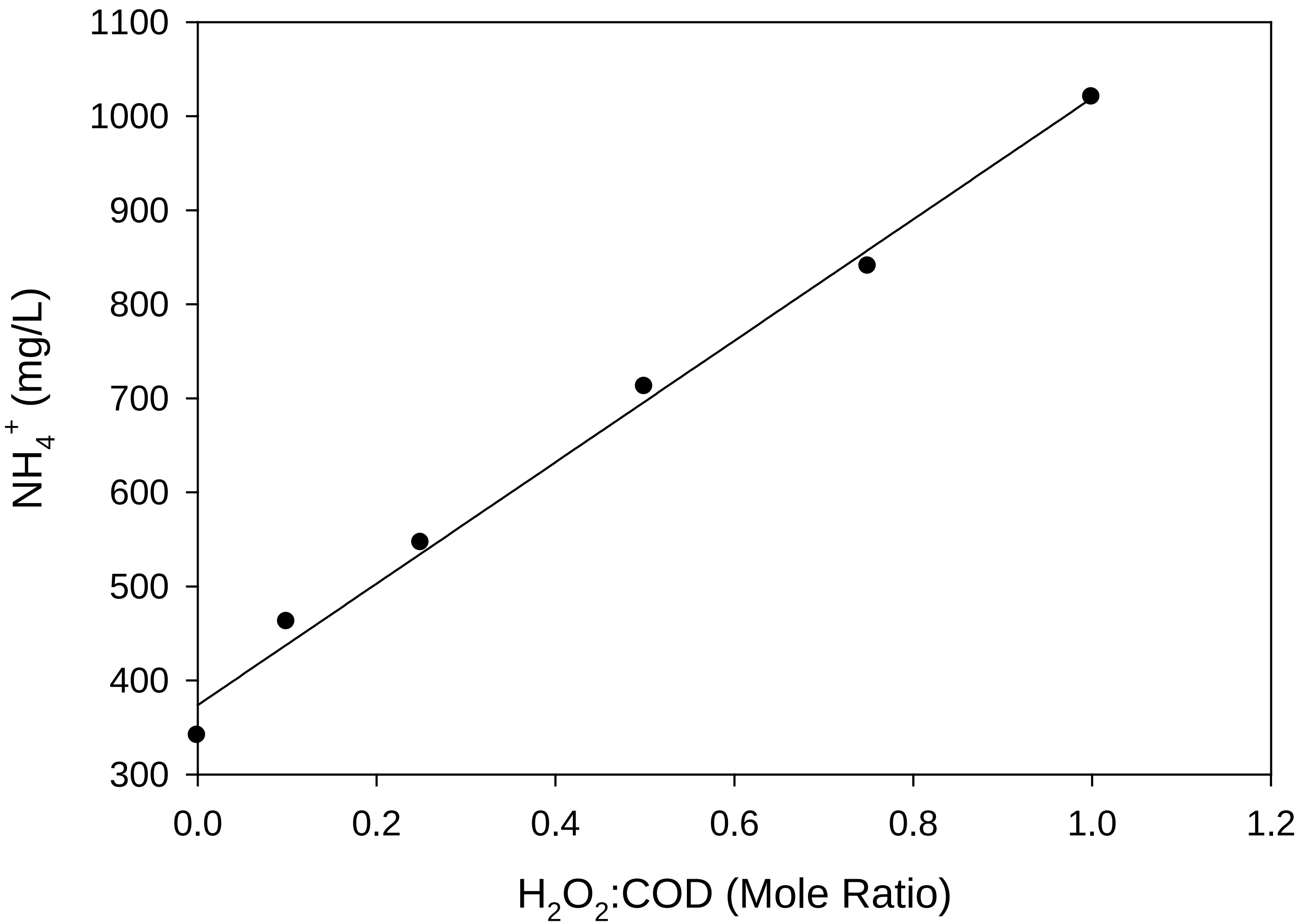
COD Removal with Variable UV Radiation at H_2O_2 Dosage of H_2O_2: COD = 0.25:1 and pH 4.0, 7.4 and 9.6



Organic Removal as a Function of O_3/H_2O_2



NH_4^+ Release as a Function of H_2O_2 Dosage



Xenobiotics

The word points out a large range of *artificial* components such as

Chemicals

Sources:

Chemical Industries (mainly)

Drugs - Medication

Sources:

Pharma Industries
Hospitals, Medical Centres and Human and Animal wastes

Pesticides

& Fungicides

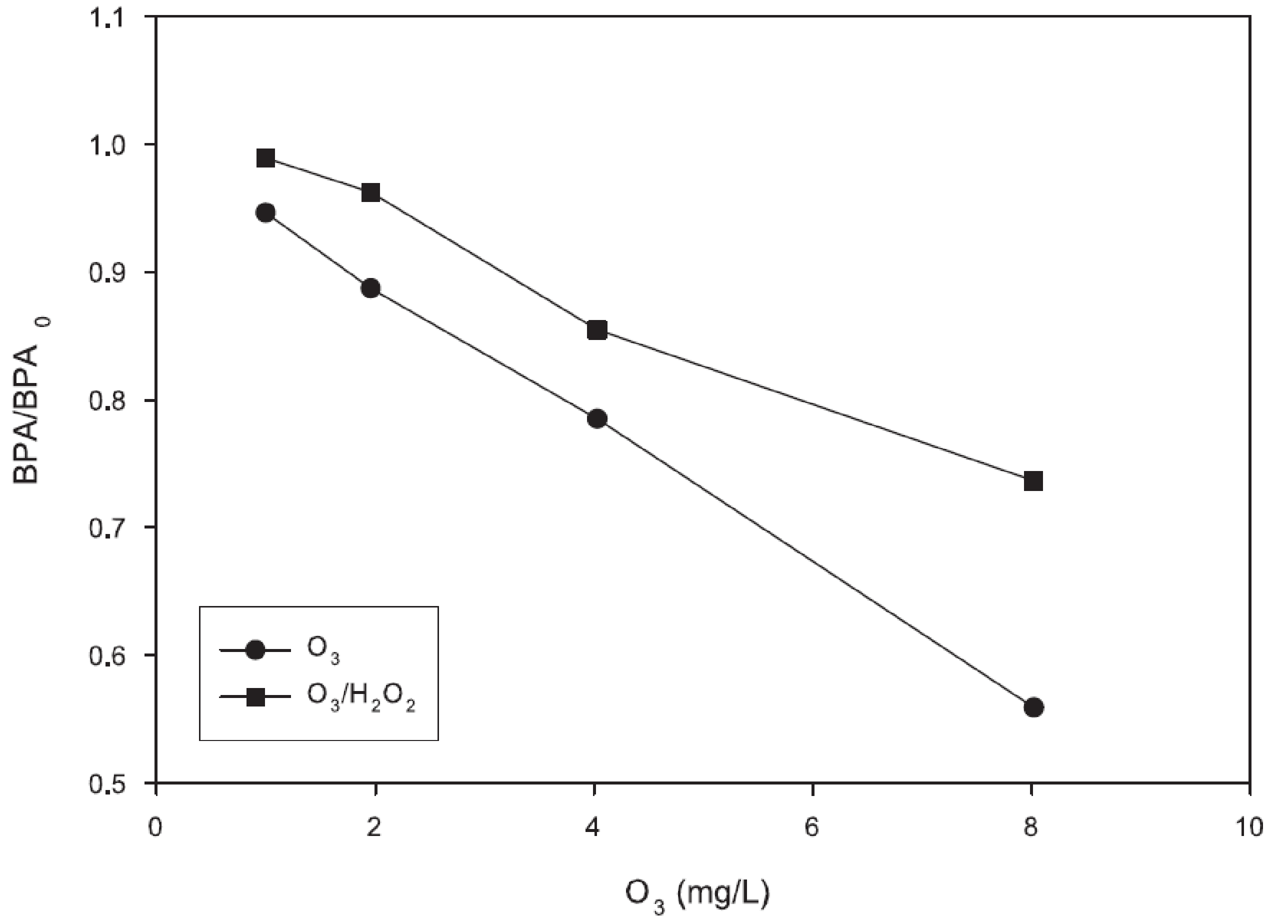
Sources:

Agriculture

Aromatic Hydrocarbons	Range (µg/L)	Halogenated Hydrocarbons	Range (µg/L)
Benzene	0.2-1630	Chlorobenzene	0.1-110
Toluene	1-12300	1,2-Dichlorobenzene	0.1-32
Xylenes	0.8-3500	1,3-Dichlorobenzene	5.4-19
Ethylbenzene	0.22329	1,1,1-Trichloroethane	0.01-3810
Trimethylbenzene	0.3-250	Trans-1,2-Dichloeoethylene	1.6-6582
n-propylbenzene	0.3-16	Trichloroethylene	0.05-750
t-Butylbenzene	2.1-21	Tetrachloroethylene	0.01-250
o-Ethyltoluene	0.5-45	**Phenols**	
m-Ethyltoluene	0.3-21	Phenol	0.6-1200
p-Ethyltoluene	0.2-10	Cresols	1-2100
Naphthalene	0.1-260	Bisphenol A	200-240

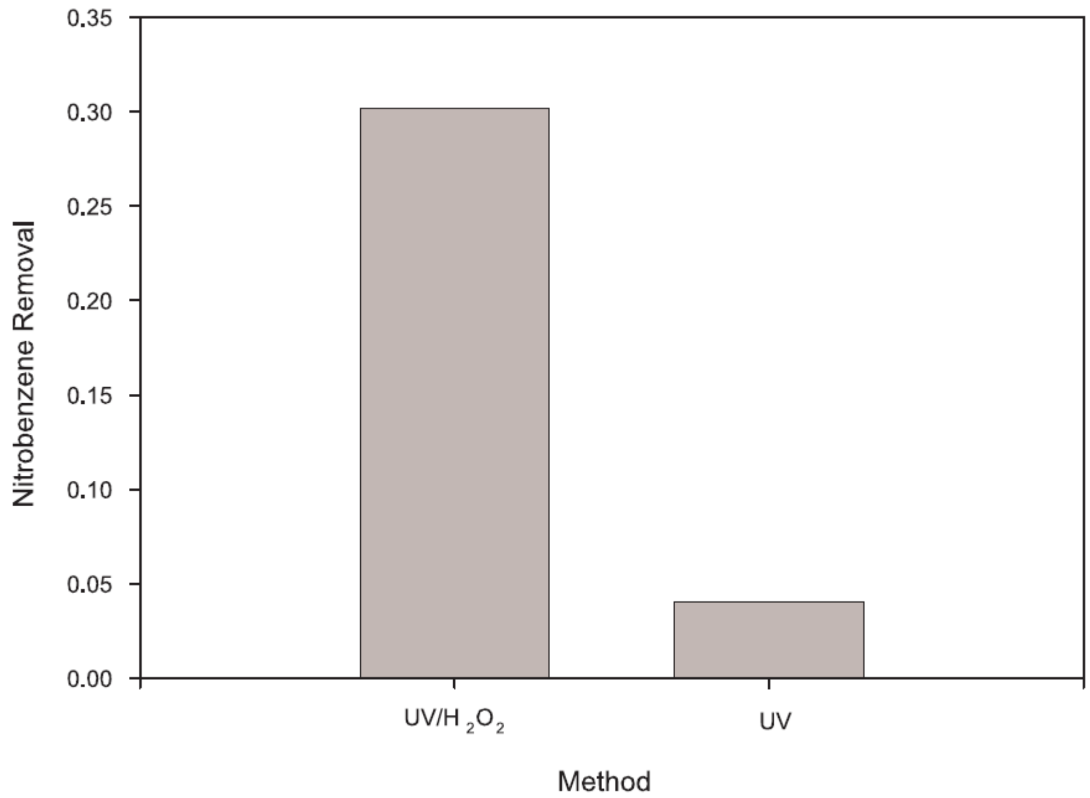
Xenobiotic Organic Compounds in landfill Leachate

Bisphenol A is an organic synthetic compound with the chemical formula $(CH_3)_2C(C_6H_4OH)_2$ belonging to the group of diphenylmethane derivatives and bisphenols, with two hydroxyphenyl groups.



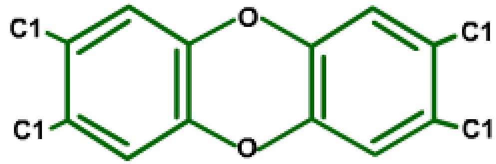
BPA Removal as a Function of O_3 and O_3/H_2O_2

Nitrobenzene is an organic compound with the chemical formula $C_6H_5NO_2$. It is a water-insoluble pale yellow oil with an almond-like odor.



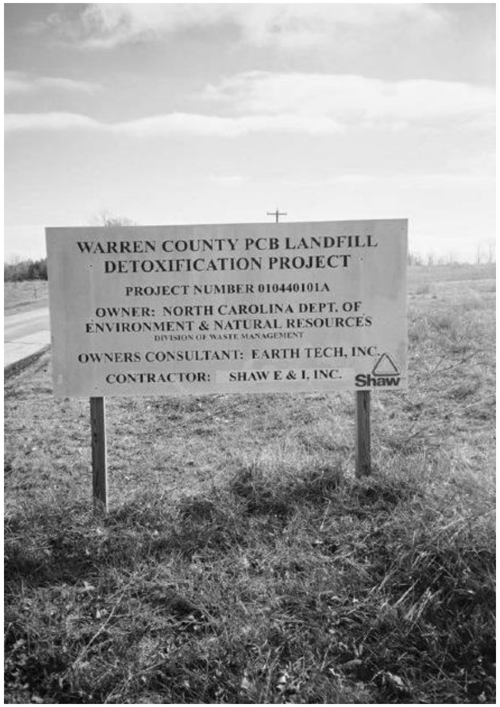
Nitrobenzene Removal as a Function of UV and UV/H_2O_2

Dioxin



2,3,7,8-TCDD -
the most toxic dioxin

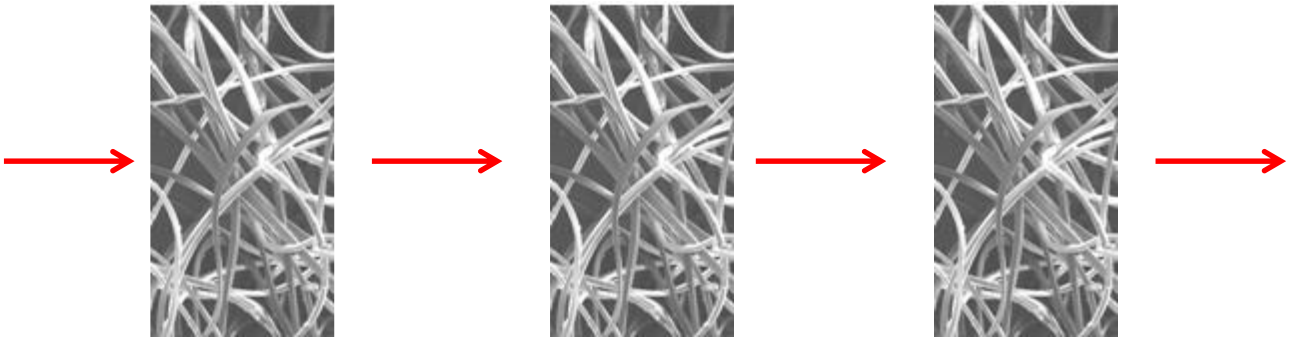
Polychlorinated dibenzodioxins (PCDDs), or simply dioxins, are a group of polyhalogenated organic compounds

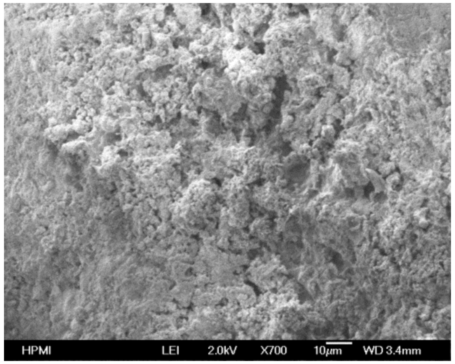


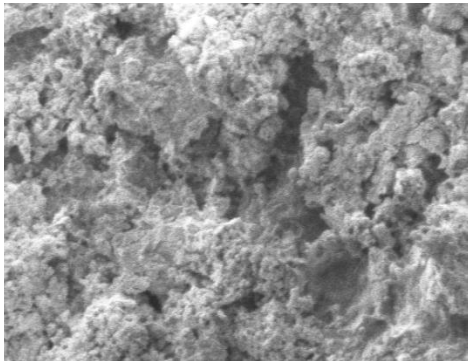
Cornwall Avenue Landfill

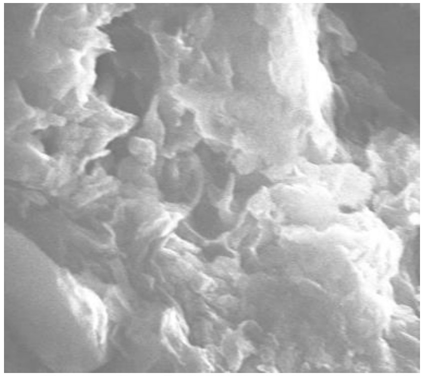
The mountain consists of two large piles of dioxin-contaminated sediment dredged from Squalicum Harbor. It is covered with a white plastic sheet held in place with sandbags. The city and port, as co-owners of the landfill, obtained approval from the Washington State Department of Ecology (DOE) to dump this material at the landfill. The public was never advised that the sediment contained dioxin.

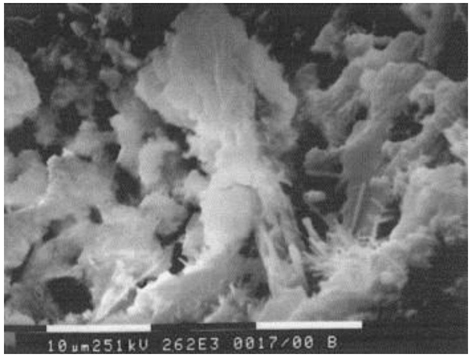
Solid Components in Landfill Leachate











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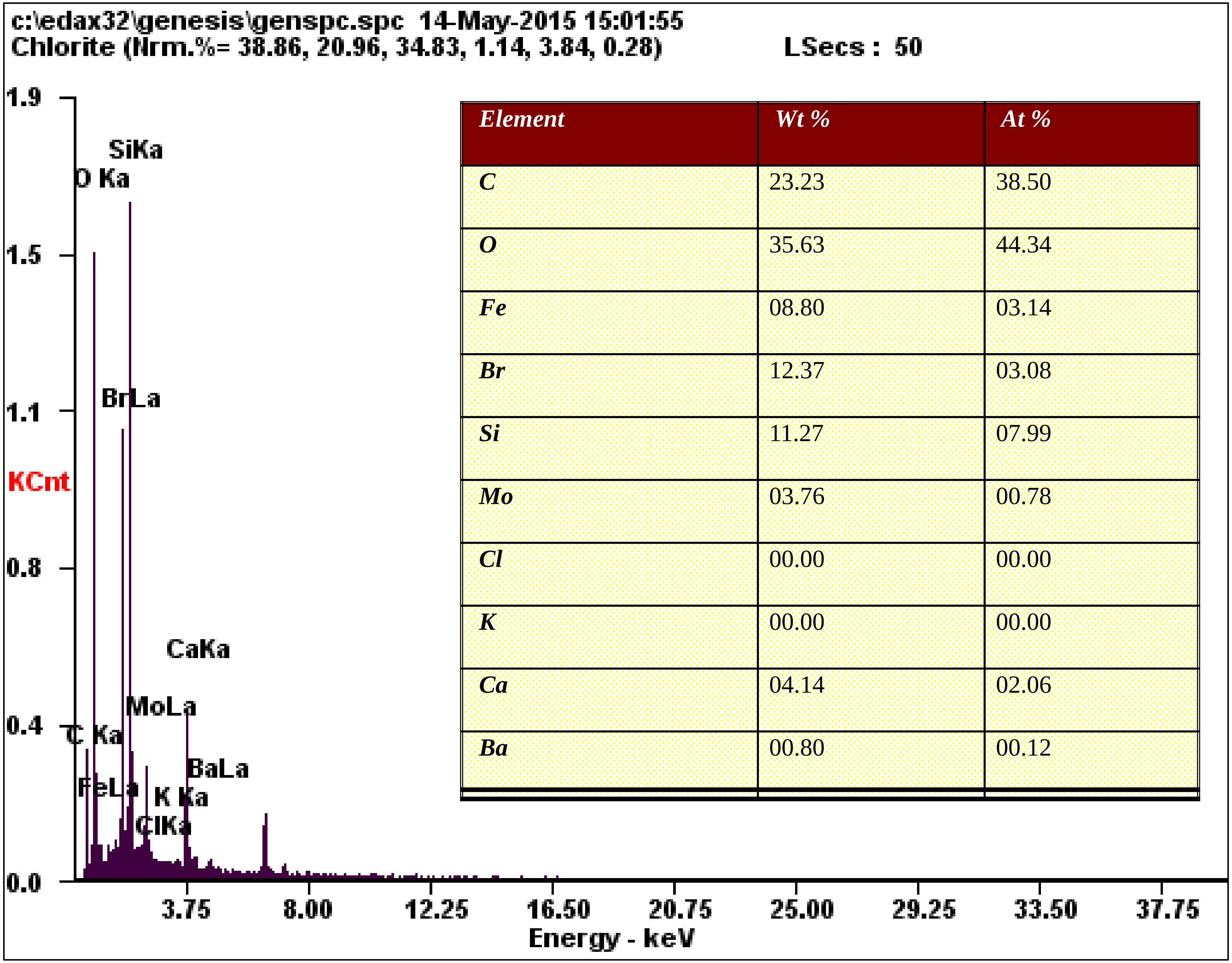

Element	Wt %	At %
C	23.23	38.50
O	35.63	44.34
Fe	08.80	03.14
Br	12.37	03.08
Si	11.27	07.99
Mo	03.76	00.78
Cl	00.00	00.00
K	00.00	00.00
Ca	04.14	02.06
Ba	00.80	00.12

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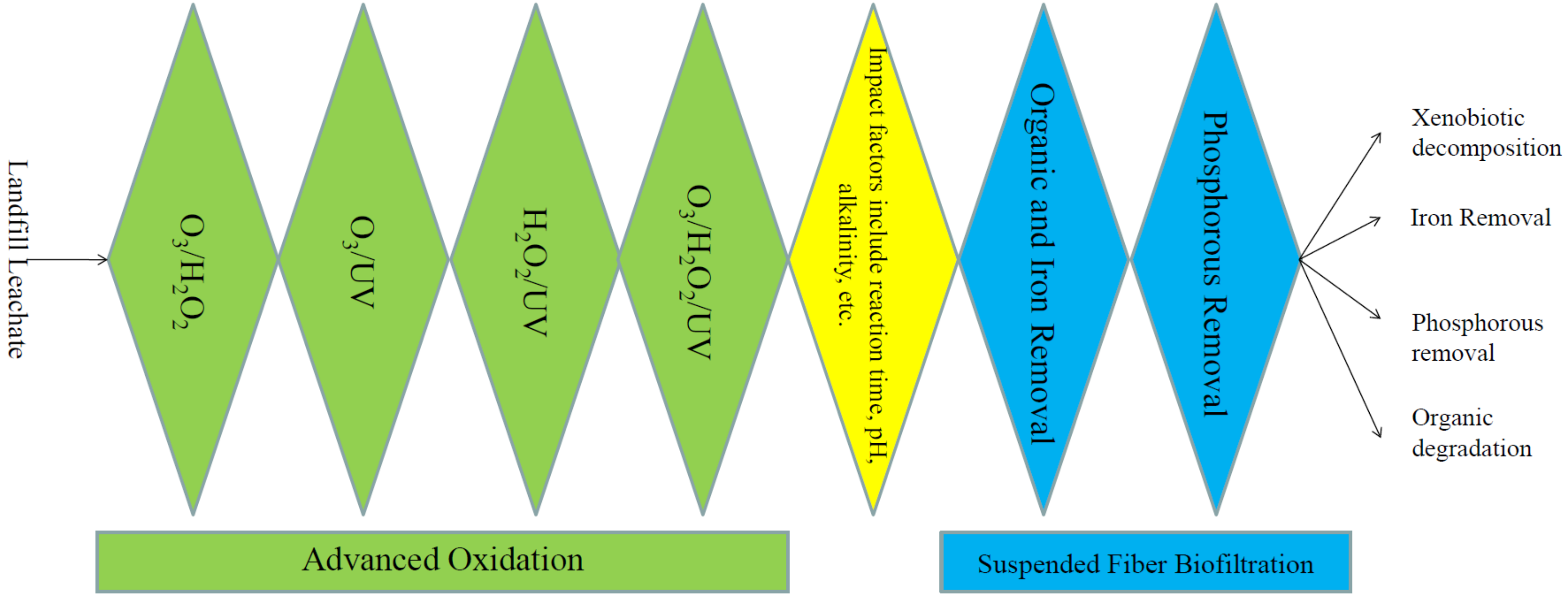
Expected Results



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Model Simulations

Ozone Transfer

$$\frac{d[O_3]}{dt} = k_L\alpha(\frac{P}{H} - [O_3]) - \sum k_j[S_j][O_3]$$

$$\frac{d[O_3]}{dt} = k_L\alpha(\frac{P}{H} - [O_3]) - 2k_2(10^{pH-pK})[H_2O_2][O_3] - (k_9(10^{pH-pK}) + k_{10})[H_2O_2][OH] - 2k_{14}[O_3][OH]$$
$$- S_{PER}(k_{12}[HCO_3^-] + k_{13}[CO_3^{2-}])[OH] - 3k_3[OH^-][O_3]$$

$$S_{PER} = \frac{k_{15}[CO_3^{2-}][H_2O_2]}{k_{15}[CO_3^-][H_2O_2] + \sum k_j[CO_3^{2-}][I_j]}$$

- $k_L\alpha$: overall mass-transfer coefficient
- P: ozone partial pressure
- H: Henry's law constant for ozone
- $[S_j]$: concentration of all species that react with ozone with second-order rate constants k_j

Model Simulations

Iron Removal

$$d[Fe^{2+}]/dt = X_{Fe^{2+}} \cdot (-\mu_{max} \cdot [Fe^{2+}]/([Fe^{2+}] + K_{Fe^{2+}})/Y_{Fe^{2+}})$$

$[Fe^{2+}]$: Ferrous iron concentration

X_{Fe2+} : Iron oxidizing bacteria concentration

μ_{max} : Iron oxidizing bacterial maximal specific growth rate

K_{Fe2+} : Michaelis-Menten constant for ferrous iron oxidation

Y_{Fe2+}: Yield coefficient for iron oxidizing bacteria

t: Time

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Model Simulations

Organic Decomposition

$$\frac{dS}{dt} = -\frac{1}{Y}\frac{\mu_m SX}{K_s + S} \qquad \frac{dX}{dt} = \frac{\mu_m SX}{K_s + S} - \frac{bX}{K_s + S}$$

$$\frac{dS}{dt} = -\frac{1}{Y}\frac{\mu_m S[X_0 + Y(S_0 - S)]}{K_s + S}$$

S: Organic Concentration X: Bacterial cell concentration

μ_m: Bacterial maximum specific growth rate t: Time

K_s: Half saturation constant Y: Yield coefficient

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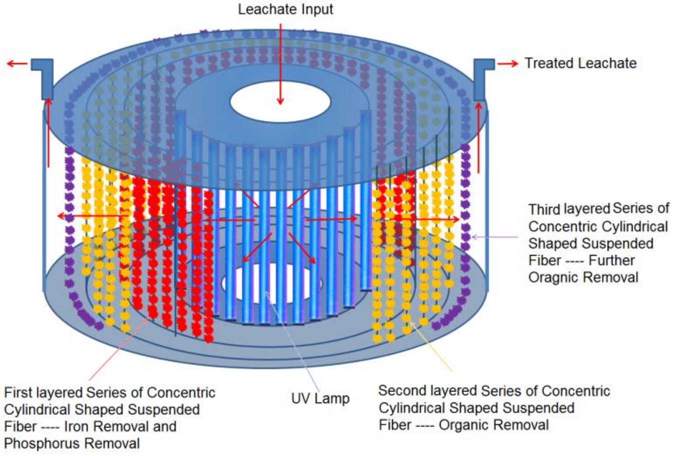
System Comparison

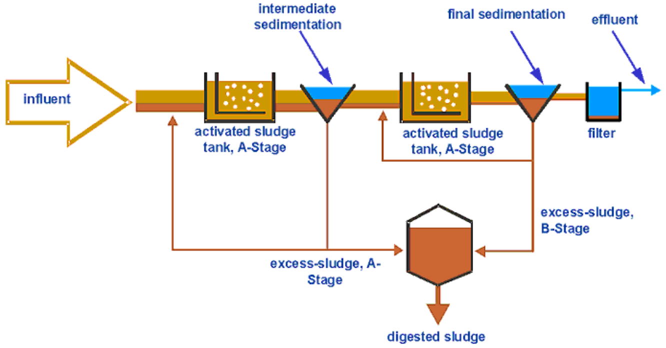
➢ Operation parameters to be optimized based on individual and overall treatment results

- ❖ Treatment costs
- ❖ Effluent quality

➢ Cost benefits analysis and comparison with conventional treatment processes



versus



Timeline of Milestones

Activity (Monthly)	1- 3	3 - 6	7 - 9	9 - 12
Reactor Design, Setup and Parameter Characterization				
Consortia Cultivation				
Reactor Operation				
System Optimization and Cost Analysis				
Model Simulations				
Reporting	Quarterly	Quarterly	Quarterly	Final

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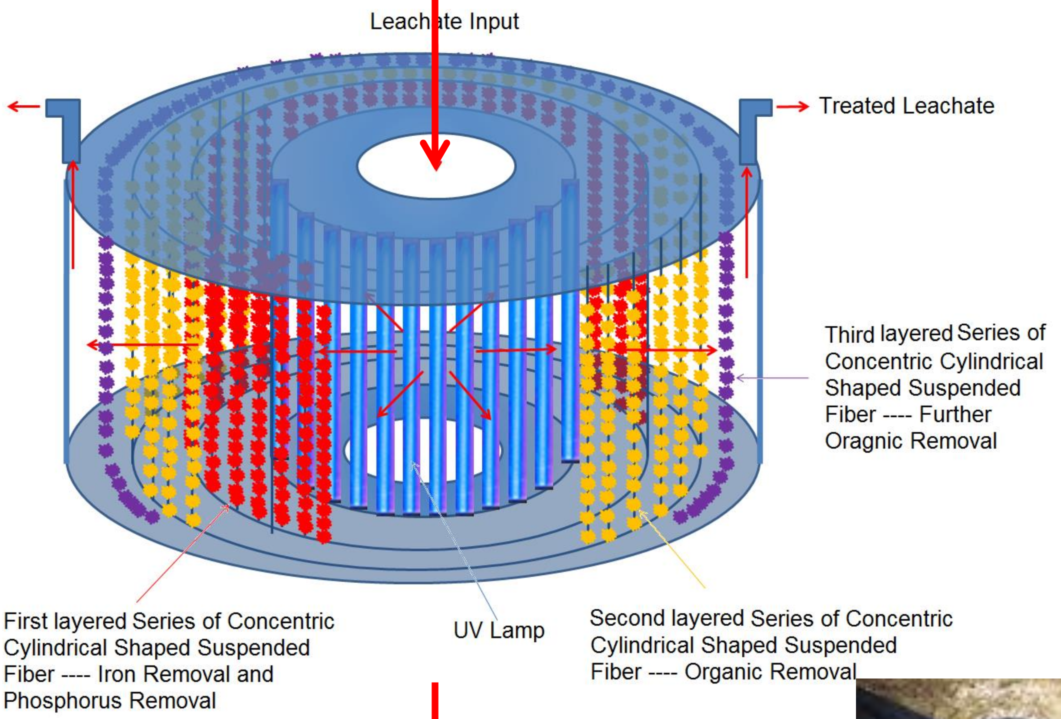
Questions?


Leachate Input
Treated Leachate
Third layered Series of Concentric Cylindrical Shaped Suspended Fiber ---- Further Oragnic Removal
First layered Series of Concentric Cylindrical Shaped Suspended Fiber ---- Iron Removal and Phosphorus Removal
UV Lamp
Second layered Series of Concentric Cylindrical Shaped Suspended Fiber ---- Organic Removal