Novel Processes for Water Purification and Wastewater Treatment

Catalytic Method for Water Purification

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Purpose and Direction

Objectives:

- Develop a novel environmentally benign water purification method

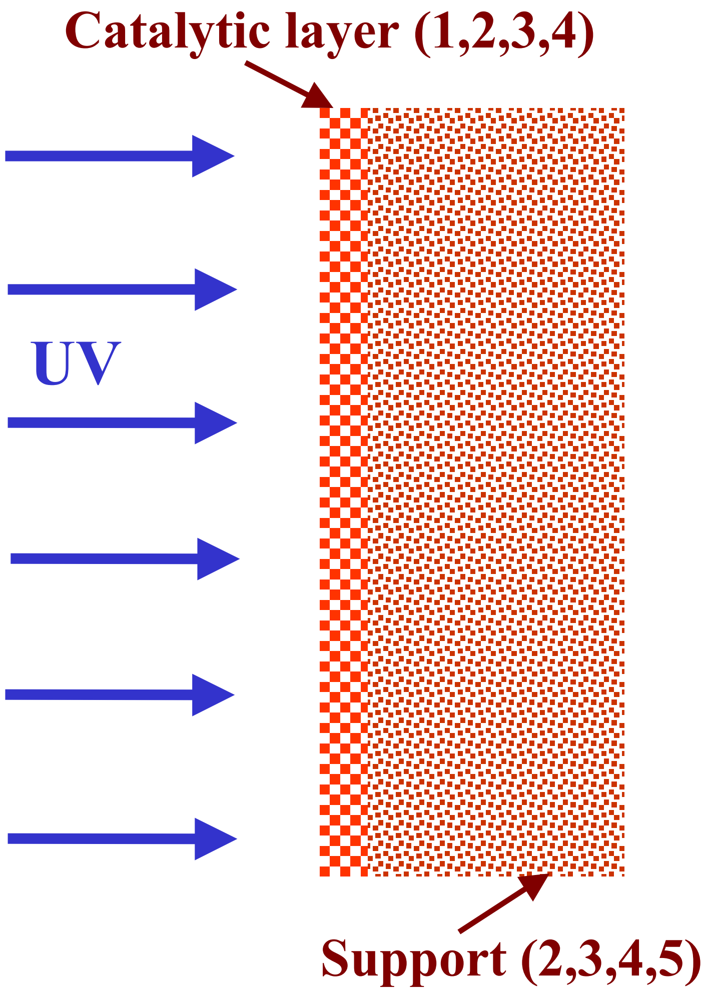
ESH Impact:

- Low energy, low chemical usage, low waste
- Facilitating larger degree of water recycling

Method of Approach:

- Fundamental study of integrating catalysis with membrane filtration and/or degasification
- Experimental validation of the technology
- Work with supplier towards development of the first generation of this catalytic treatment

Photo-Catalytic Activity



Functions:

1. Electron-hole pair formation

   $$TiO_2 \xrightarrow{hv} h^+ + e^-$$

2. Radical generation

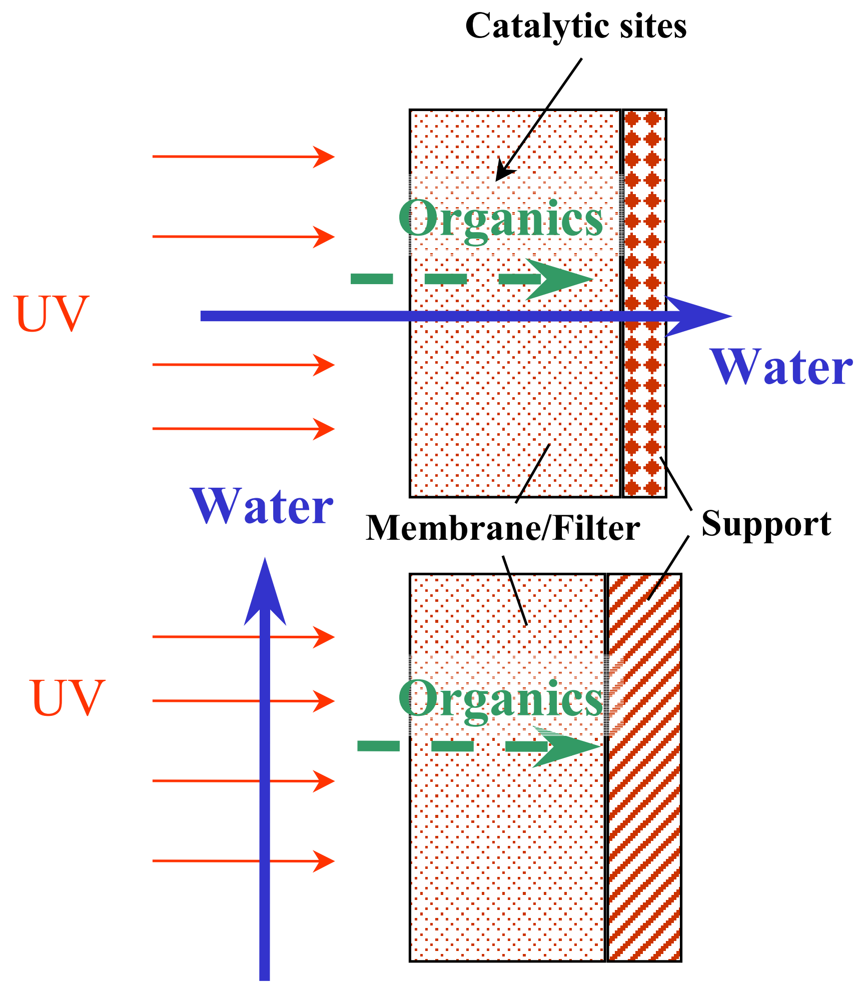
   $$H_2O + O_2 + h^+ + e^- = Ox$$

3. Impurity adsorption
4. Oxidation reaction

   $$TOC_1 + Ox \longrightarrow TOC_2 + CO_2 + H_2O$$

5. Radical quenching

Two Photo-Catalytic Configurations



Flow-through configuration:

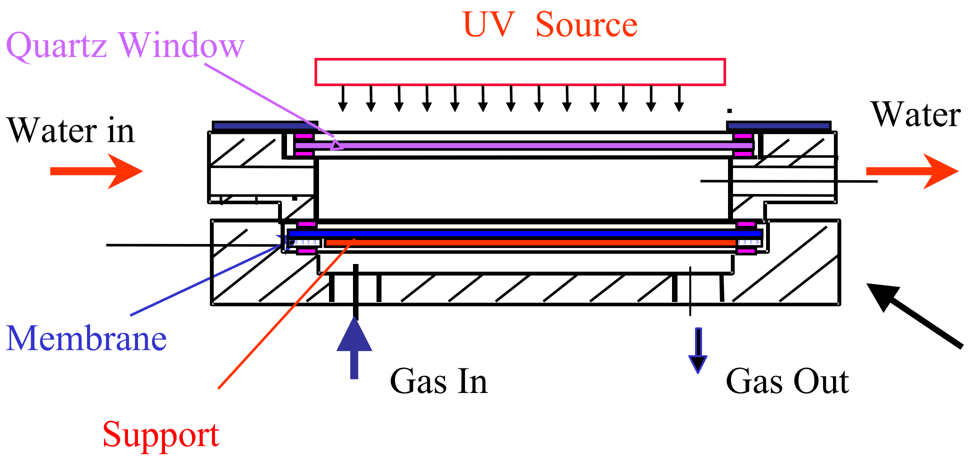
- Oxidation
- Depth filtration

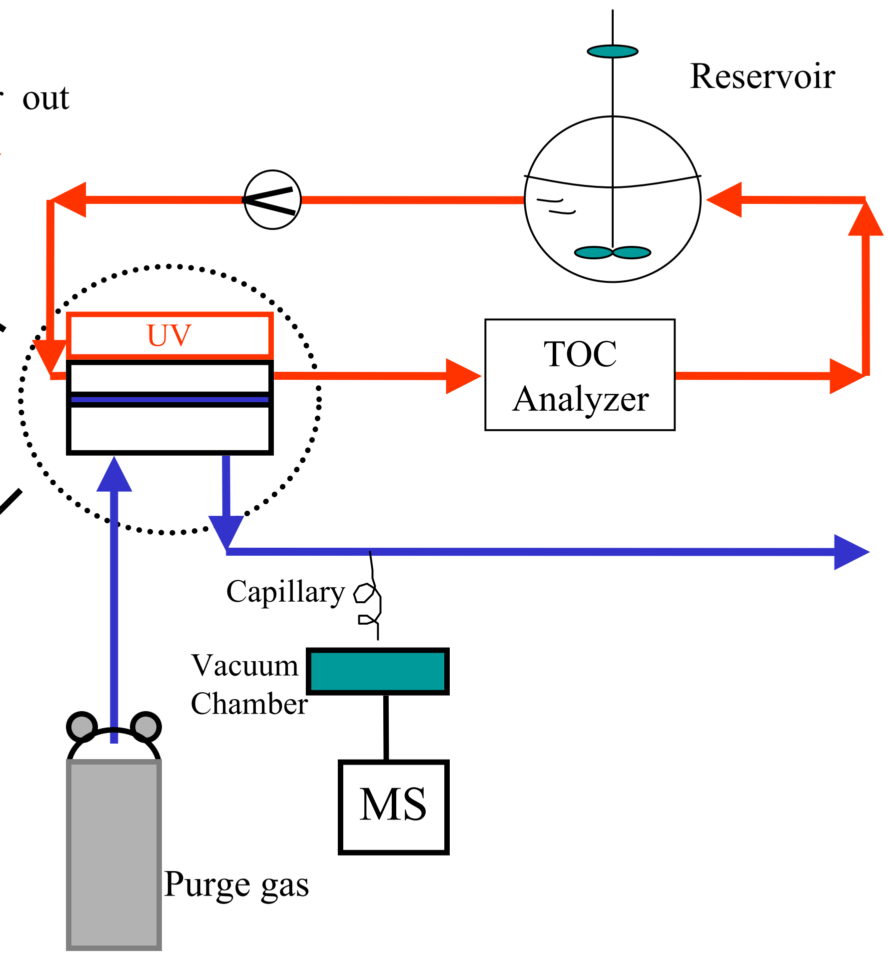
Tangential configuration:

- Oxidation
- Degasification

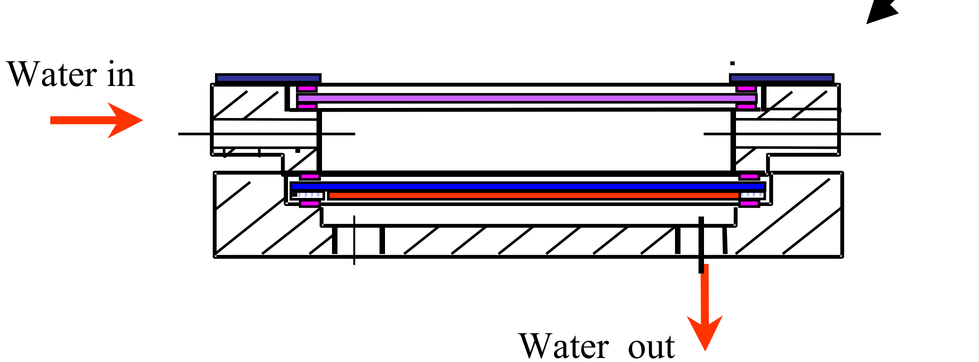
Experimental setup

Tangential flow configuration

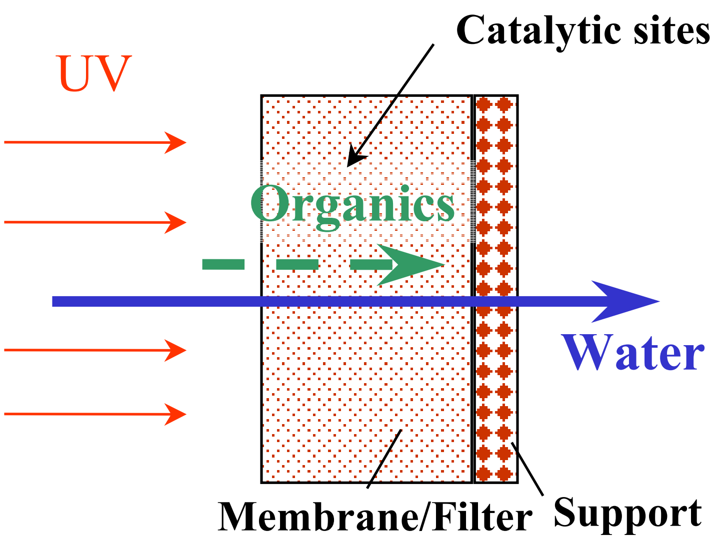


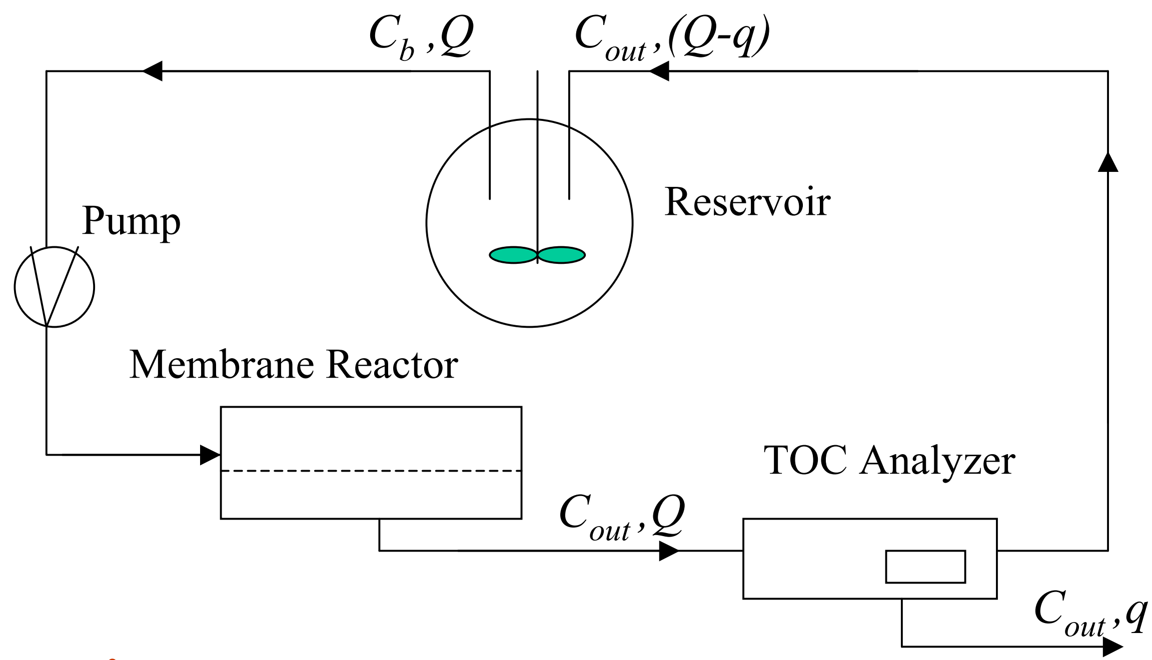


Flow-through configuration



Flow-through Filtration





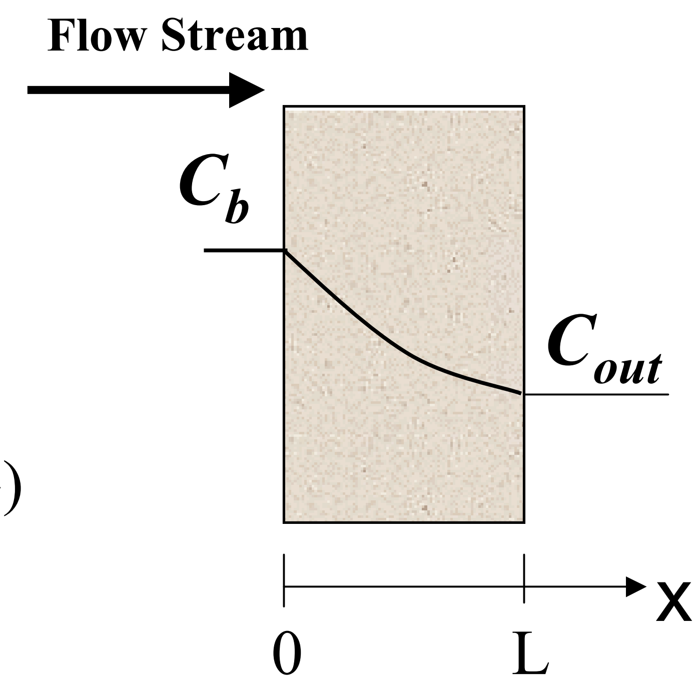
Flow-through configuration:

- Oxidation
- Depth filtration

Flow-through Filtration Process Model

- **Characterization of diffusion and reaction within the catalytic membrane.**

$$\frac{\partial C}{\partial t} = -v_x \frac{\partial C}{\partial x} + \frac{\partial}{\partial x}\left(D \frac{\partial C}{\partial x}\right) - kC$$



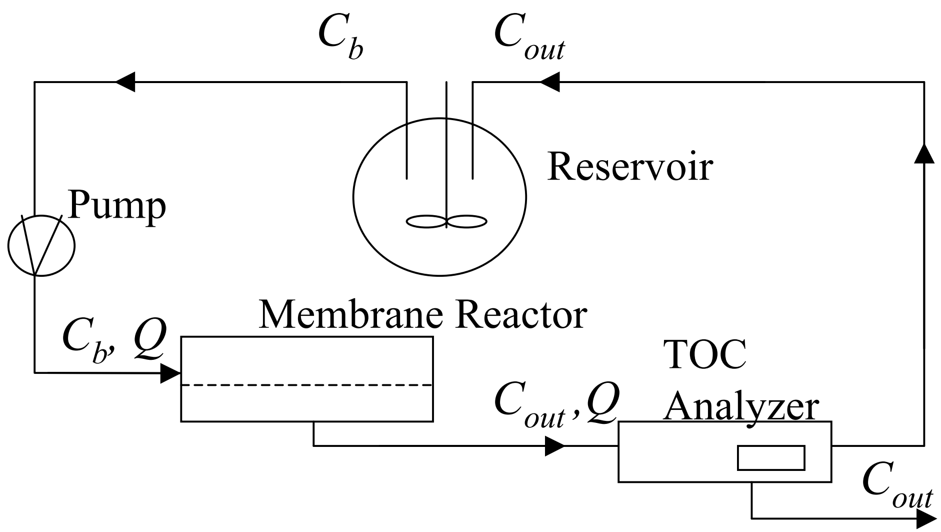
Simplifications:

1. Pseudo-steady state $\quad \frac{\partial C}{\partial t} = 0$
2. Diffusion is negligible $\quad v_x \frac{\partial C}{\partial x} \gg \frac{\partial}{\partial x}\left(D \frac{\partial C}{\partial x}\right)$
3. Reaction rate coefficient is not a constant $\quad k = k_o \exp(-\alpha x)$

$$-v_x \frac{\partial C}{\partial x} = k_0 \exp(-\alpha x) C$$

Flow-through Filtration Process Model

- **Characterization of time dependent interaction between membrane reactor and reservoir.**



Simplifying Assumptions:

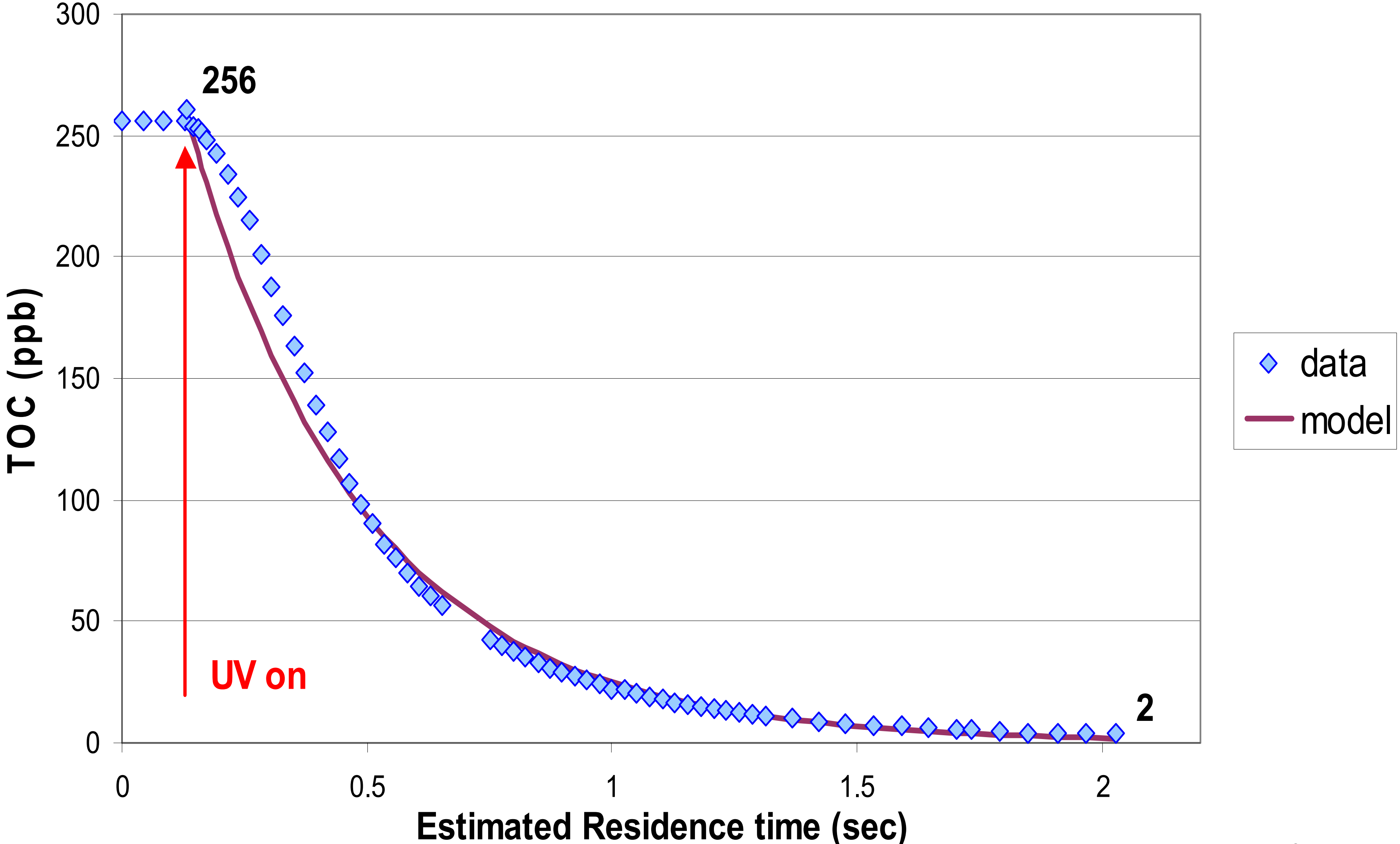
1. Membrane reactor is CSTR
2. Reservoir is CSTR
3. No mixing along the tubing
4. Waste stream out of TOC analyzer is neglected

$$C_{out}(t) = C_{initial} \exp\left[\frac{Q(A-1)}{V_{reservoir}} \times t\right] \times A \;,$$

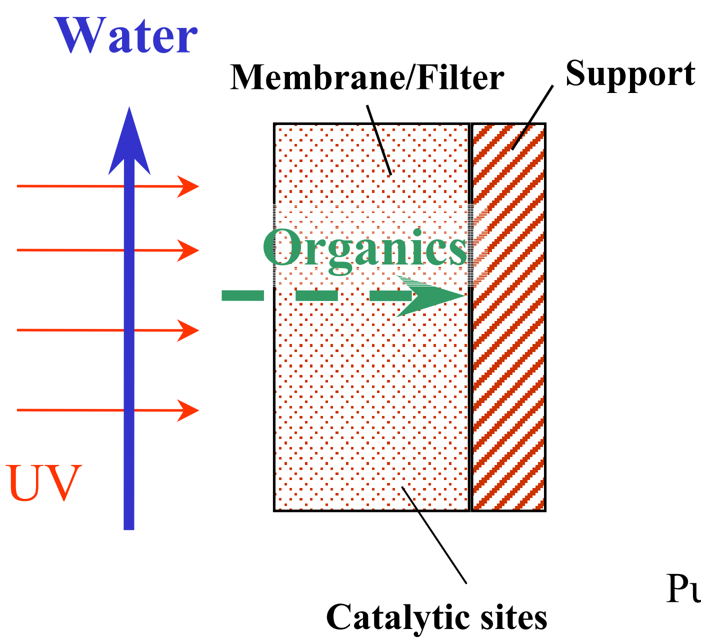
where

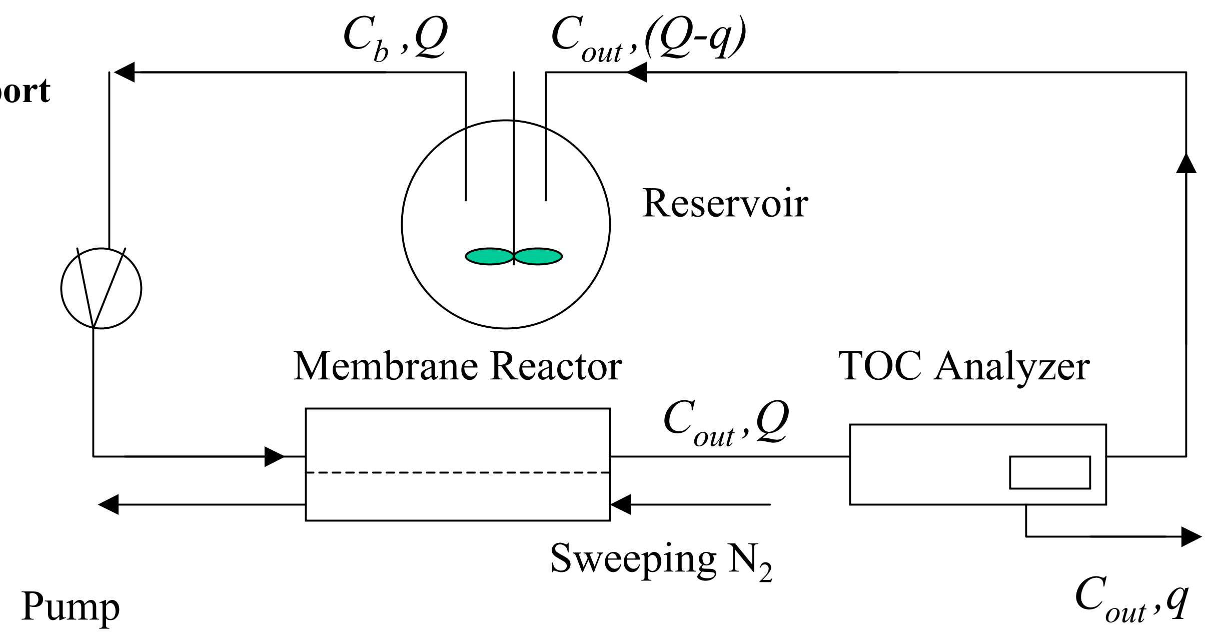
$$A = \exp\left[\frac{-k_0}{v_x \alpha}(1-\exp(-\alpha L))\right]$$

Flow-through Filtration, Model and Experimental Comparison



Tangential Flow Degasification





Tangential configuration:

- **Oxidation**
- **Degasification**

Tangential Flow Degasification Process Model

- **Characterization of transport and reaction in four zones.**

I. **Interphase Transport**

$$J = k_m(C_b - C_s)$$

II. **Equilibrium at the Interphase**

$$K_e = \frac{C_1}{C_s}$$

III. **Diffusion and Reaction**

$$\frac{\partial C}{\partial t} = \frac{\partial}{\partial x}\left(D\frac{\partial C}{\partial x}\right) - kC$$

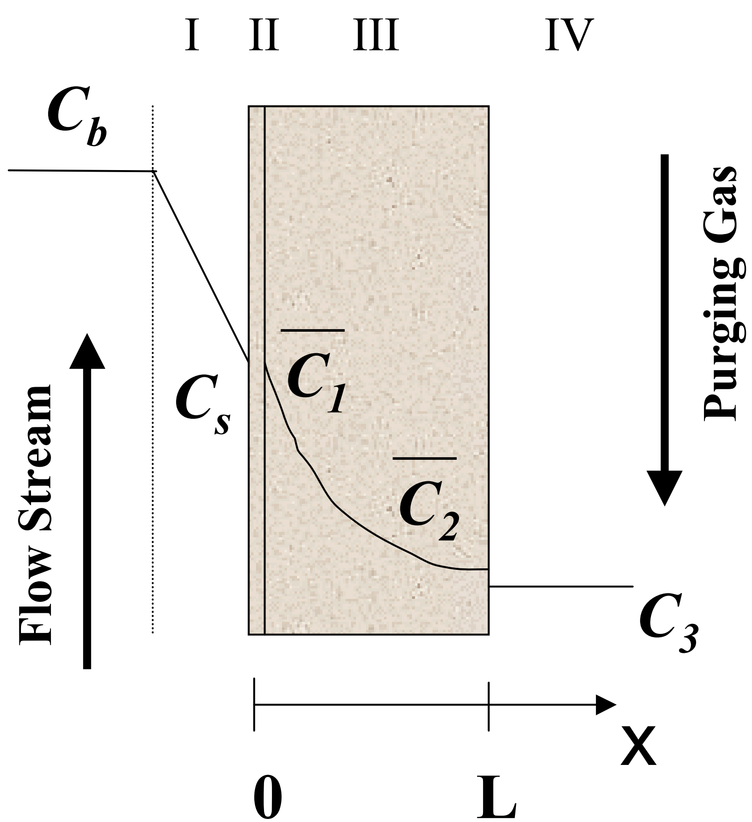
Assumptions:

1. Pseudo-steady state
2. Reaction rate coefficient is constant
3. Diffusion coefficient is constant

$$D\left(\frac{\partial^2 C}{\partial x^2}\right) = kC$$

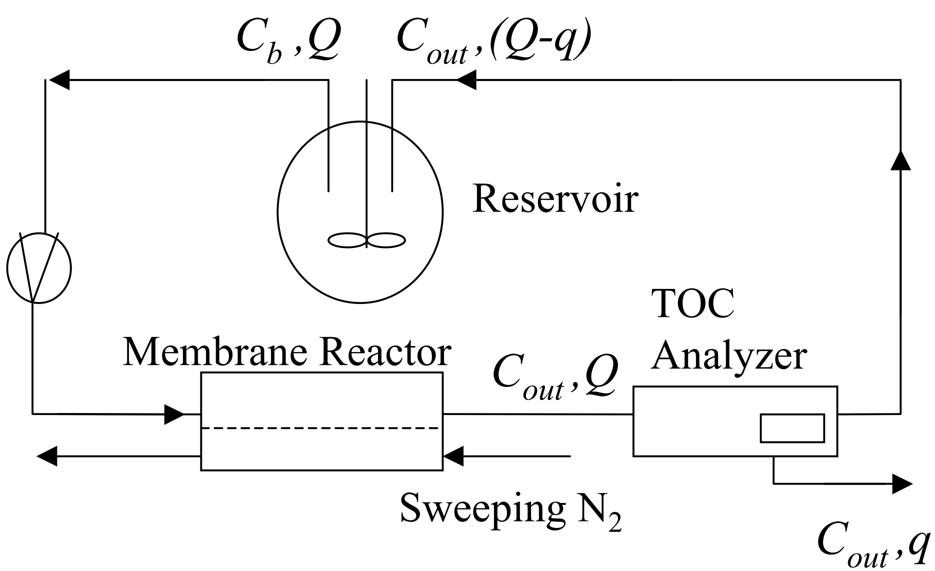
IV. **Desorption**

$$K_d = \frac{C_2}{C_3}$$



Tangential Flow Degasification Process Model

- **Characterization of time dependent interaction between membrane reactor and reservoir.**



Assumptions:

1. Membrane reactor is CSTR
2. Reservoir is CSTR
3. No mixing along the tubing

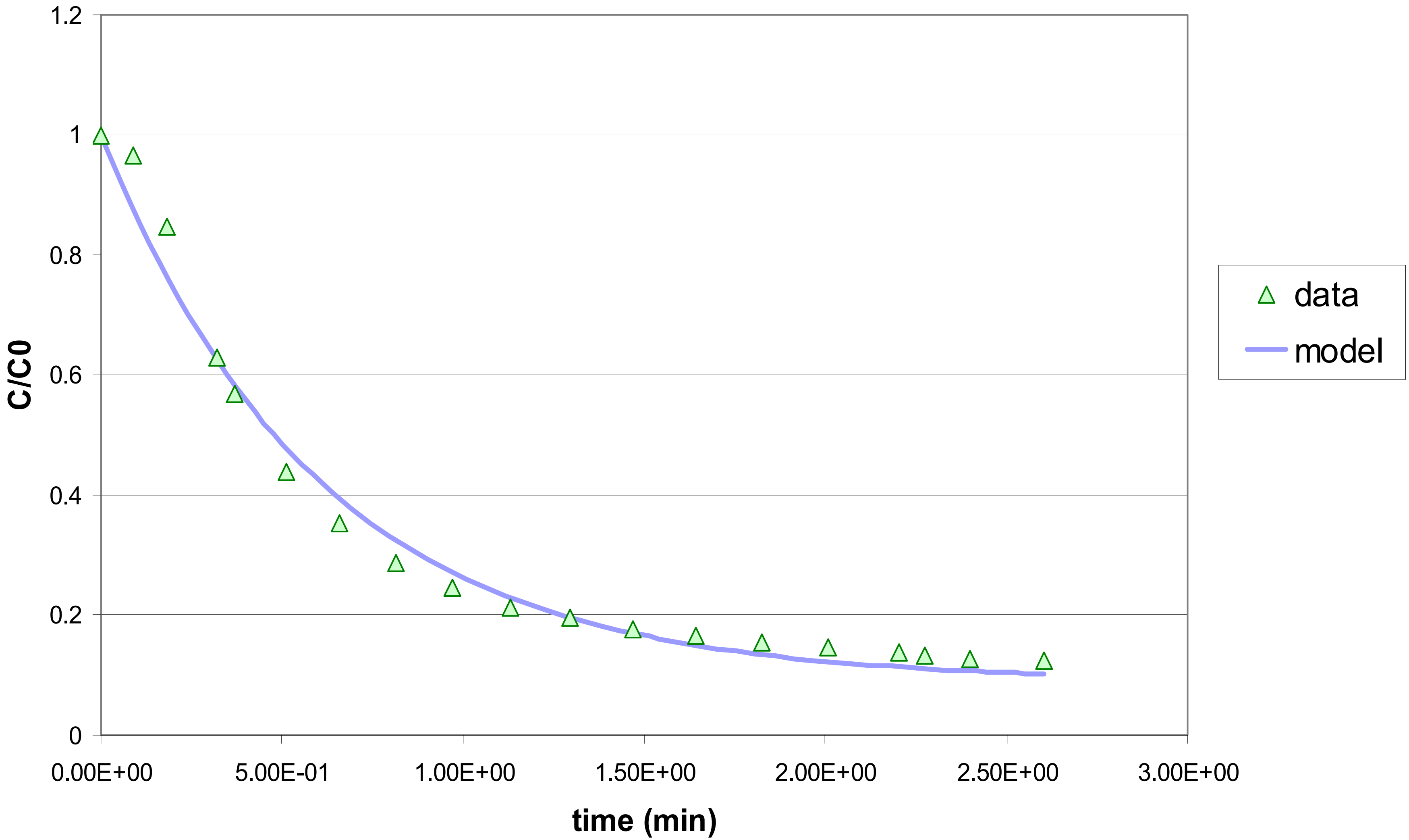
Mass Balance Equation for reservoir:

$$\frac{dC_{in}}{dt} \times (V_{reservoir} - qt) = C_{out} \times (Q - q) - C_{in} \times Q \quad ,$$

Mass Balance Equation for reactor:

$$\frac{dC_{out}}{dt} \times V_{reactor} = C_{in} \times Q - C_{out} \times Q - J \times S$$

Tangential Flow Degasification, Model and Experimental Comparison



Conclusions

- **Photo-Catalytic membranes have been proven to be effective for removal of organic contaminants**
- **A hydrophobic membrane incorporating the ERC catalytic technology has been synthesized and tested (jointly with Pall Corporation)**
- **Process models have been developed and shown to be useful for estimating process parameters for both tangential and flow-through configurations.**

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