Bio-treatment of Waste Streams Containing Organic Compounds and Copper (Subtask C-1-2)

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Objectives:

- Investigate feasibility of biotreatment process for organic-containing wastewater
- Develop low energy, high efficiency process for treatment, reclaim and potential recycle of organic-containing wastewater.

ESH Impact:

- Without treatment and reclaim or recycle of waste waters, large quantities of effluent are discharged.
- CMP and electroplating bath processes are known to utilize as much as 30% of a fab's UPW and contribute significantly to Copper contamination
- Effluent may be contaminated with hard-to-remove compounds.
- Environmental impact may affect industry

Alternative Methods

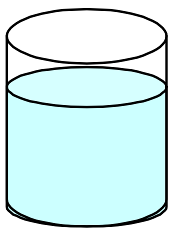
- Carbon adsorption
- UV- oxidation methods
- Catalytic Membrane

Advantages of Biotreatment

- Simplicity of Setup
- Technology is better known
- Possible Synergistic Cu - Organic Effects
- Potentially achieve lower concentration levels
- Cost and Energy efficient
- Tolerant to Changing Waste Conditions

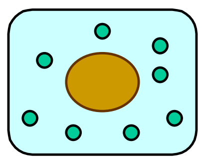
Theory and Method of Approach:

Batch Process

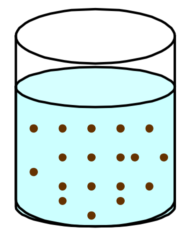


Nutrient rich media (CHs, N, P, Fe)

+

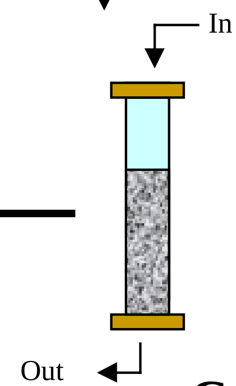


Bacteria capable of degrading organic of interest andCu



Growth can be modeled by Monod's equation:

$$\frac{dX}{dt} = \frac{\mu_{max} S}{K_S + S} X$$



Grown cells are immobilized on activated carbon column for continuous flow experiments

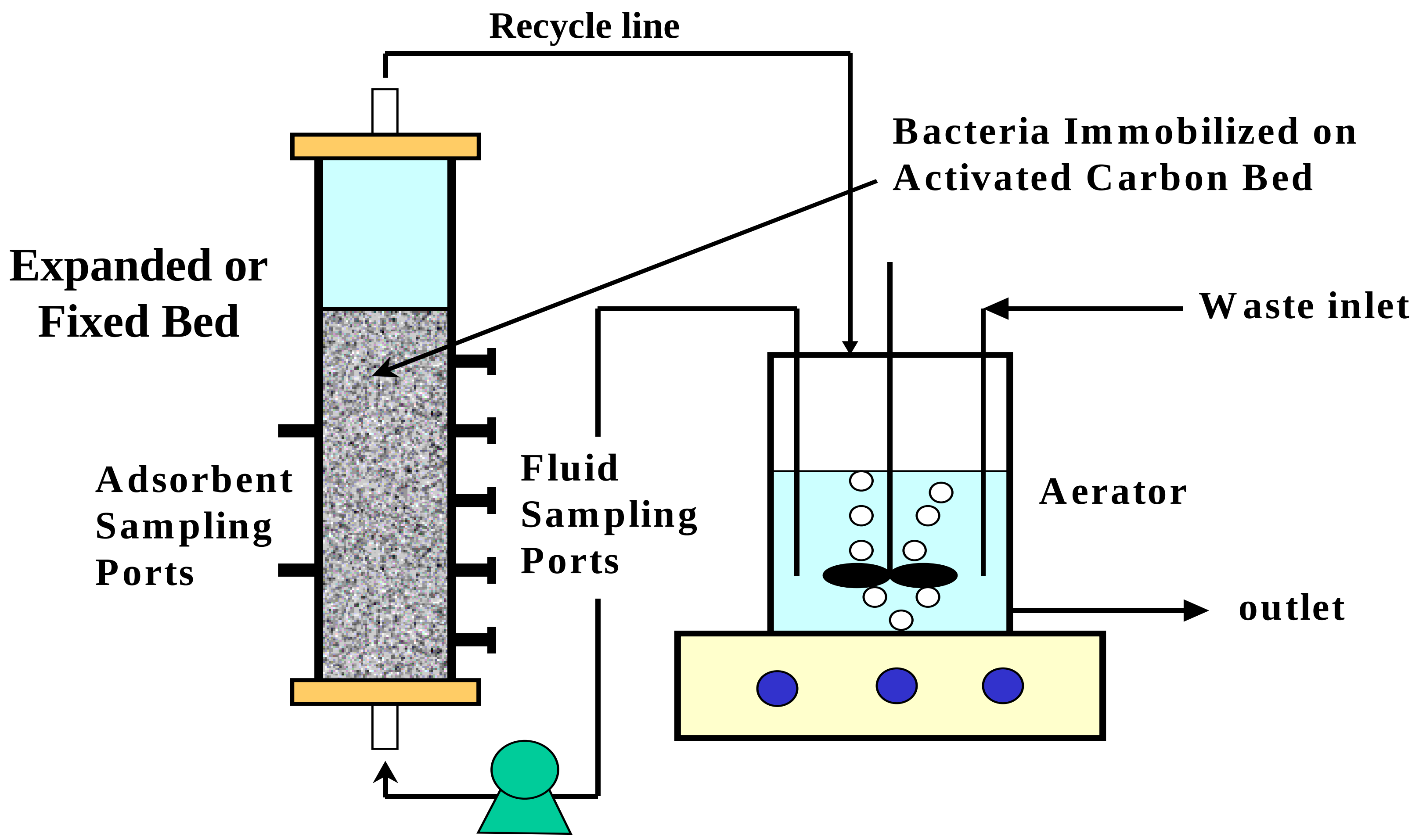
Continuous Process

Use "typical" industrial waste

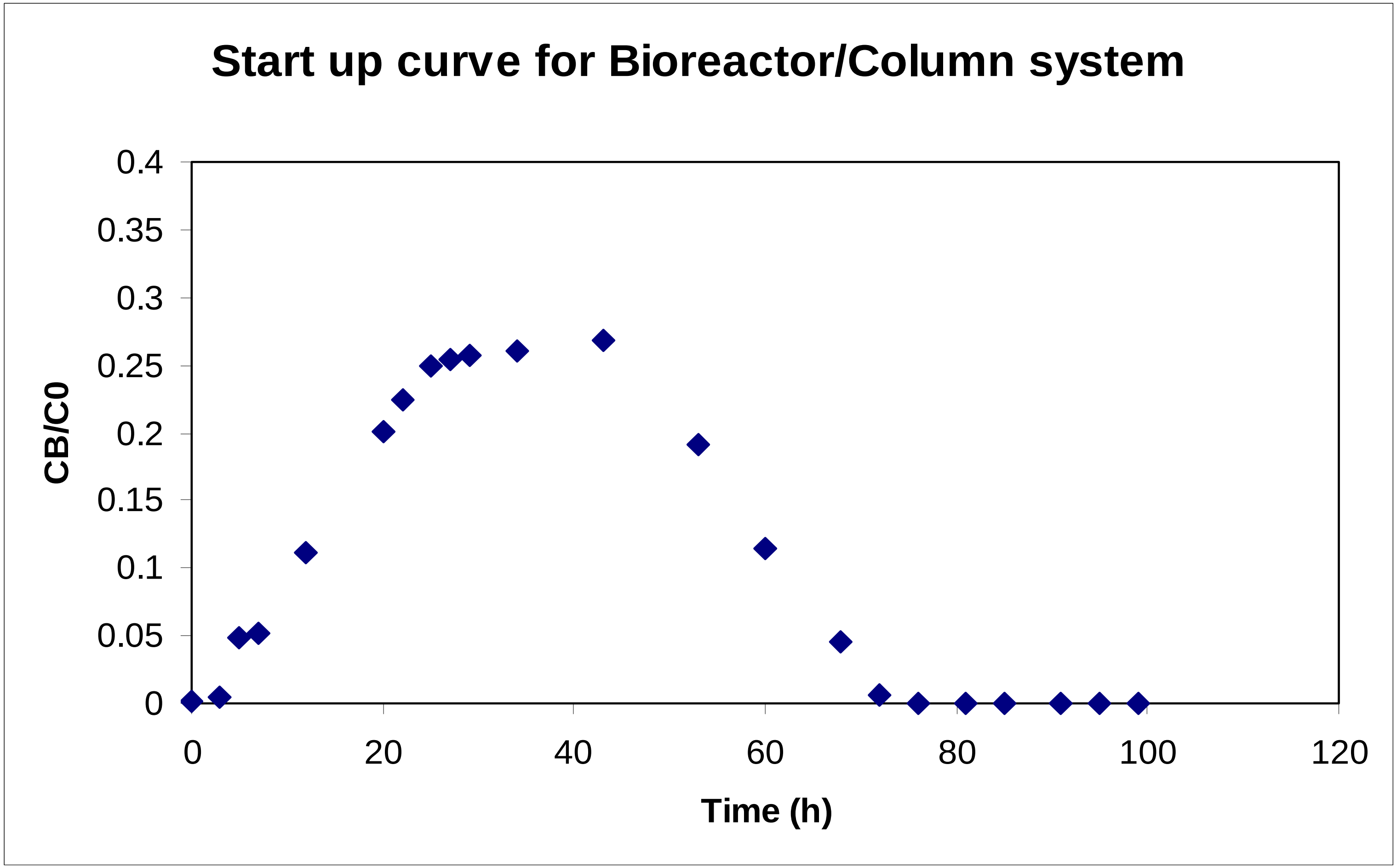
Determine:

- **Sustainability, degradation capacity**
- **Fate of organic and inorganics, and metals (Cu)**

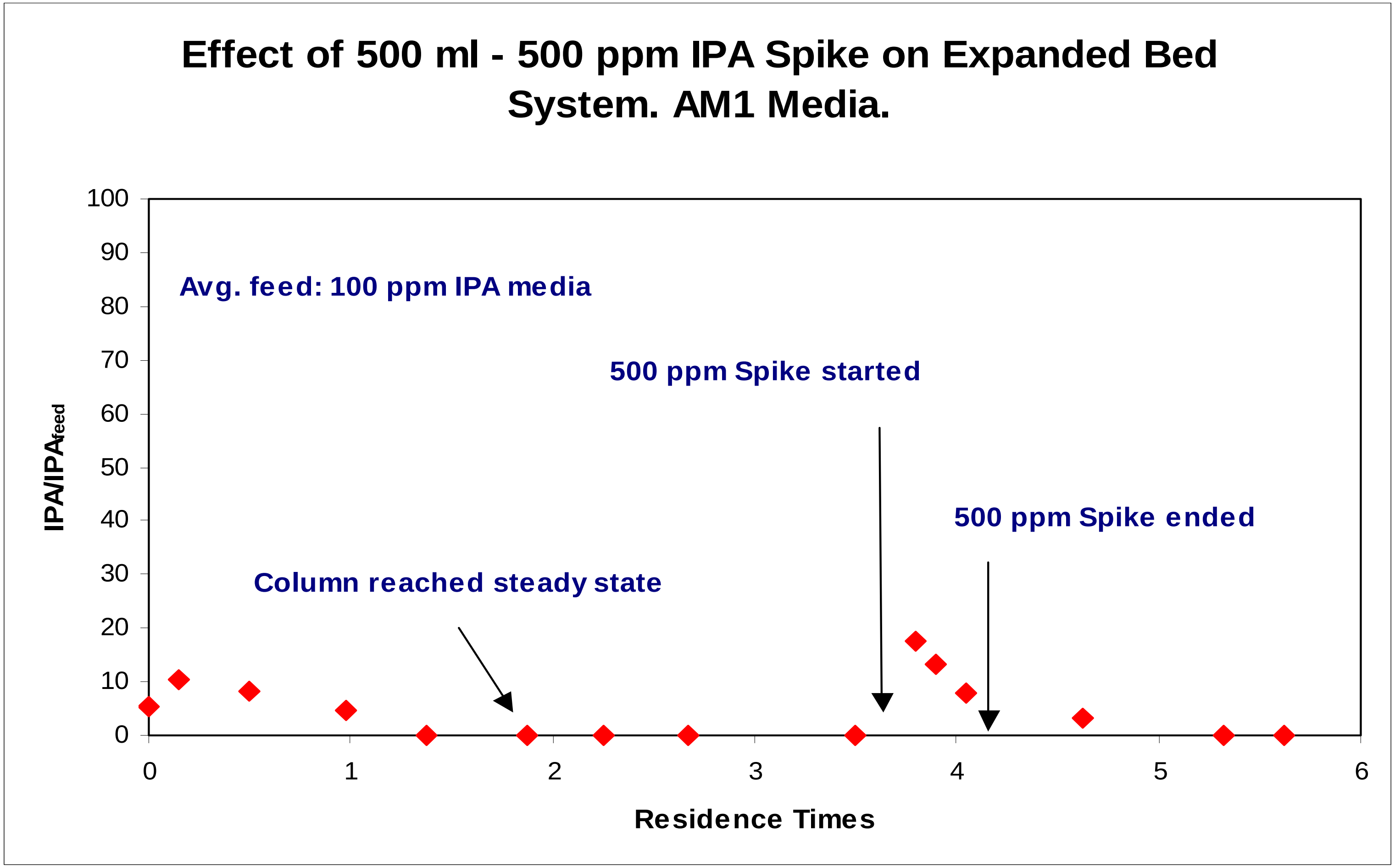
Immobilized System



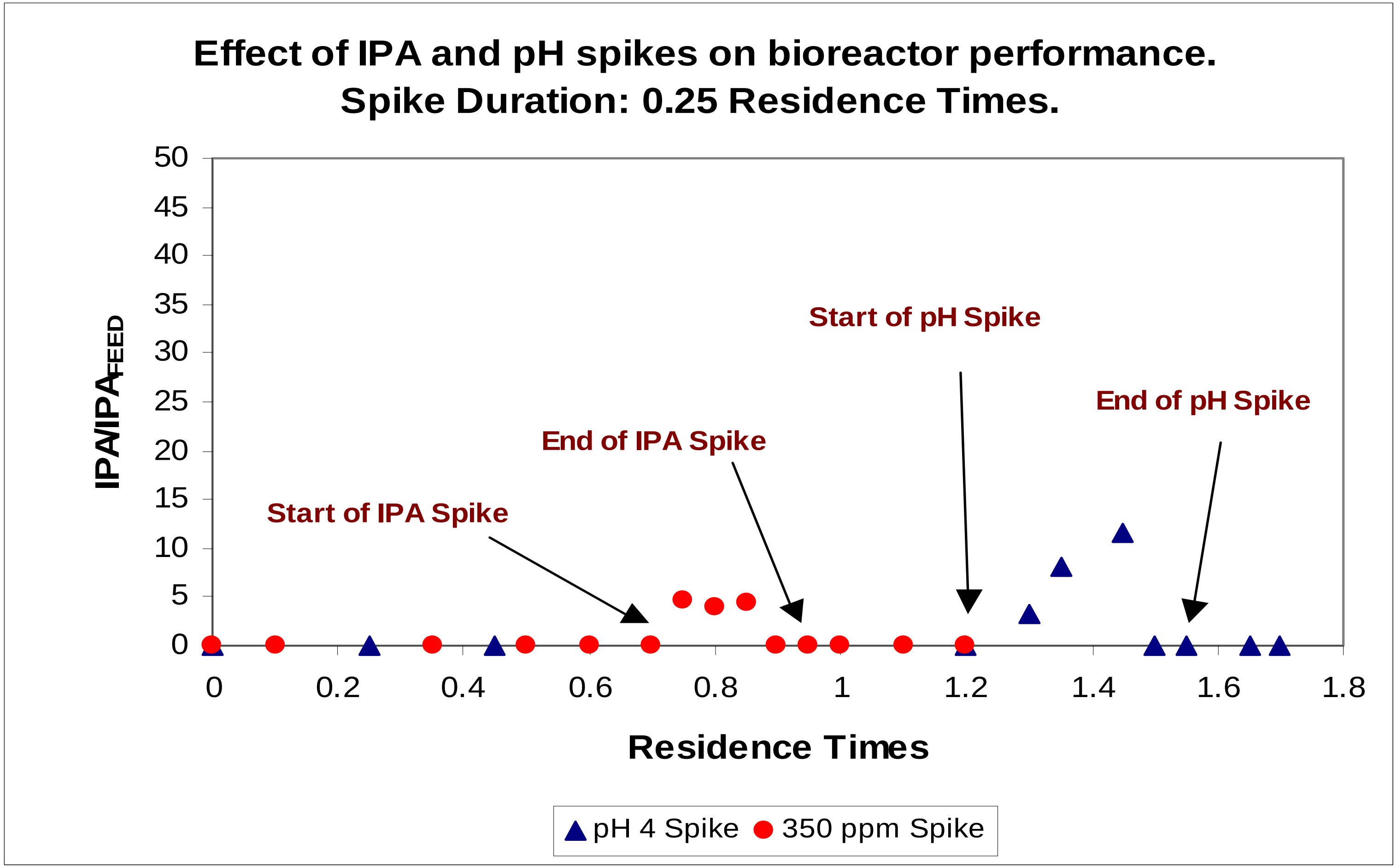
Immobilized System Start up



Effects of IPA Spikes:



Effects of IPA and pH Spikes:



Summary of Results for Column Experiments

Spike	Duration (residence times)	Effect
IPA (ppm):		
1000	0.50	40 % IPA, 8 hr Recovery
500	0.25	12 % IPA, 5hr Recovery
400	0.25	5 % IPA, Recovery during spike
350	0.25	4% IPA, Recovery during spike
300	0.25	No effect
pH:		
5	0.25	No effect
4	0.25	8 % IPA, Recovery during spike

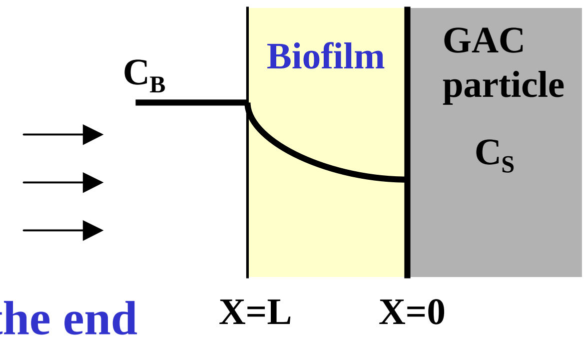
Model Formulation

Diffusion and biodegradation of Organics inside the biofilm

$$D_{eff}\frac{d^2C_{IPA}}{dx^2} = k_1^2 C_{IPA}$$

Flow of IPA into the biofilm by diffusion

Rate of Reaction (biodegradation) inside the biofilm



Concentration at the end of biofilm is same as Bulk

No transport of IPA into GAC

$$C_{IPA} = C_B \Rightarrow x = L$$

$$\frac{dC_{IPA}}{dx} = 0 \Rightarrow x = 0$$

Model Formulation (cont'd)

where:

$$k_1 = \left(\frac{\mu_{max} \rho_B}{Y K_M} \right)^{\frac{1}{2}}$$

Max bacterial growth rate (μ_{max})

Biofilm density (ρ_B)

Yield Coefficient (mg Cell produced /mg organic used) (Y)

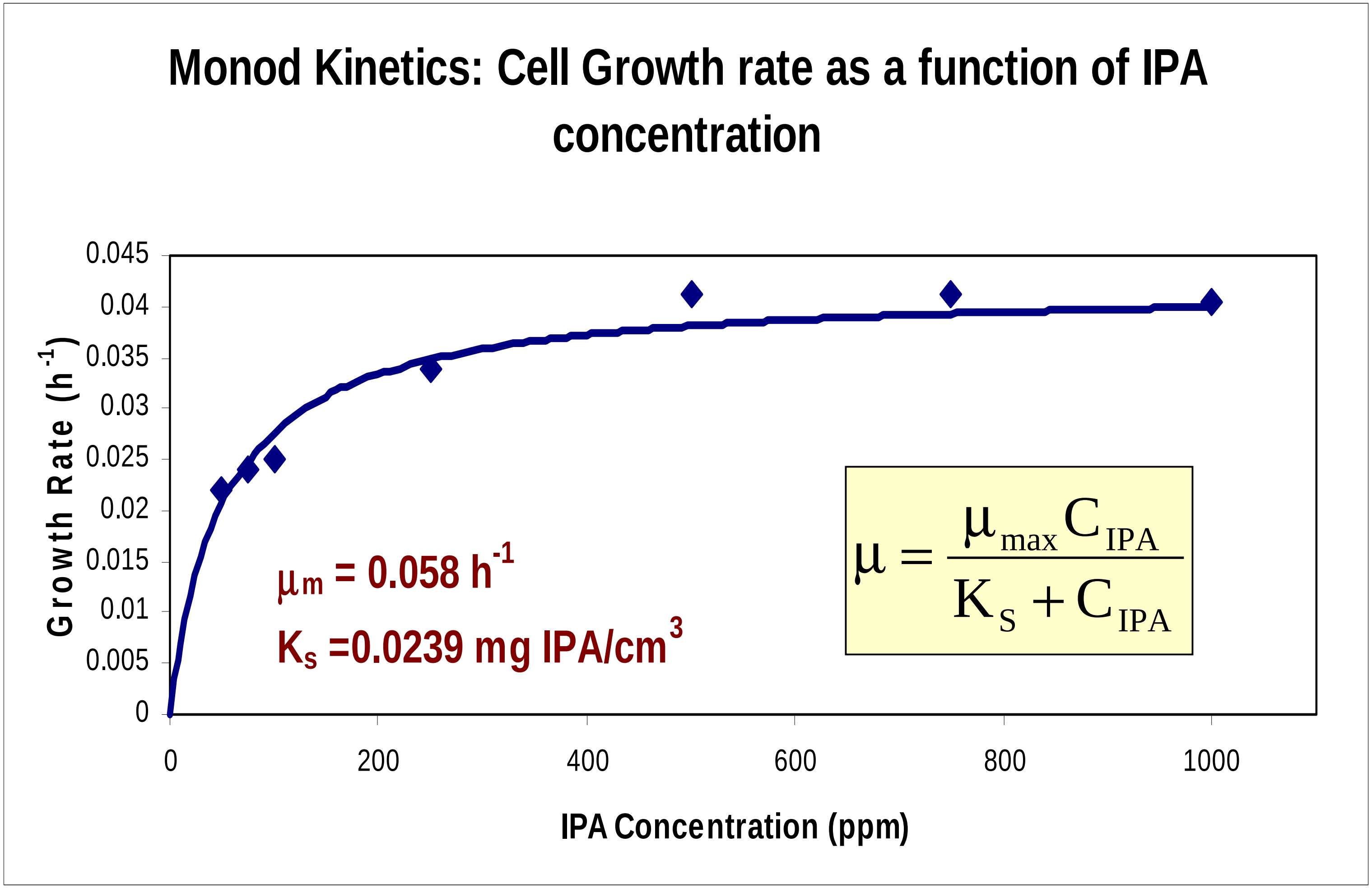
Saturation Constant For Monod Kinetics (K_M)

Solving the PDE gives us the Flow, N_T, of IPA into the biofilm:

$$N_T = k_2 C_B \mathrm{Tanh}(k_1 L)$$

$$k_2 = \alpha D_{eff} k_1$$

Determination of Model Parameters: Bacterial Growth (k)



Model Formulation – (Cont'd)

IPA balance over Reactor

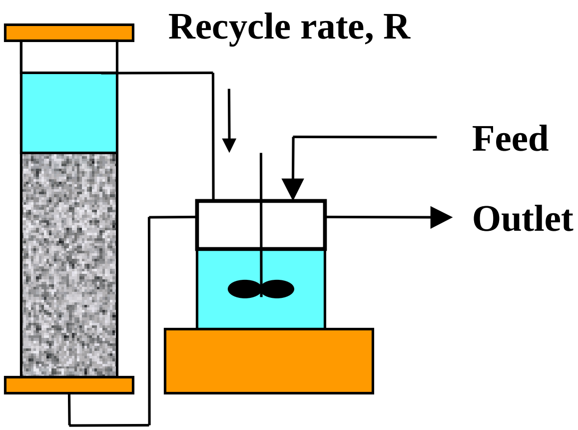
$$\frac{dC_{IPA}^{B}}{dt} = \frac{1}{\tau_1}\left(1 - C_{IPA}^{B}\right) - \tau_2 C_{IPA}^{B}\,\mathrm{Tanh}\left(k_1 L\right)$$

Rate of Change of Bulk IPA — **Dilution of IPA In the reactor** — **Flow of IPA into particles**

$$C_B = 0 \rightarrow t = 0$$

$$\tau_1 = \frac{V - \nu}{F}$$

$$\tau_2 = \frac{\nu k_2}{V - \nu}$$



Model Formulation – (Cont'd)

Biofilm Balance

$$\frac{dL}{dt} = k_3 C_B \mathrm{Tanh}\left(k_1 L\right)$$

$$L = 0.001 \rightarrow t = 0$$

Rate of change of biofilm thickness is proportional to the flow of IPA into the biofilm

Where:

$$k_3 = \frac{4\pi r_p^2 Y C_0 k_2}{\rho^*}$$

Surface area of biofilm ($4\pi r_p^2$)

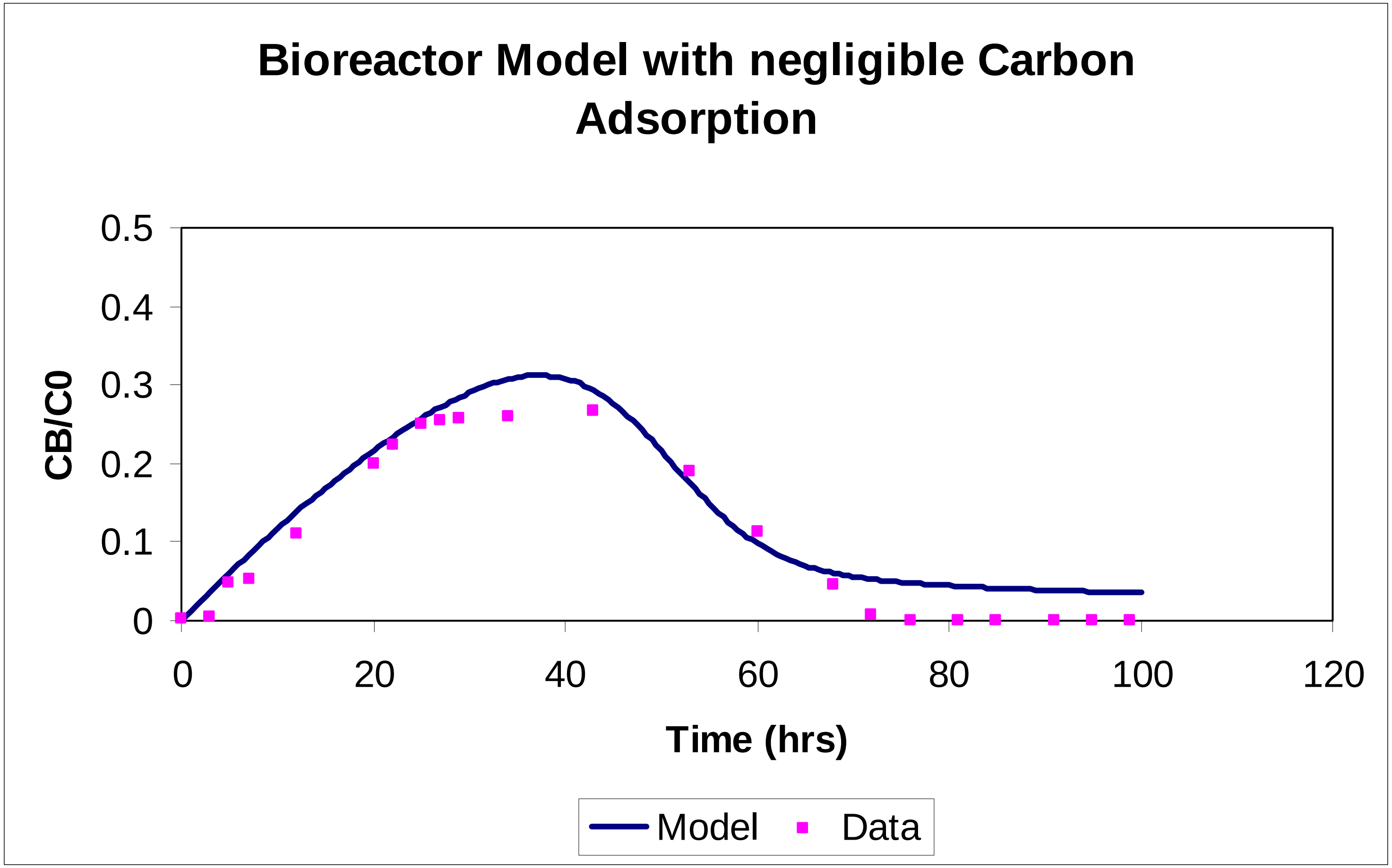
Yield Coefficient (mg Cell produced /mg organic used) (Y)

Density of cells per area (ρ^*)

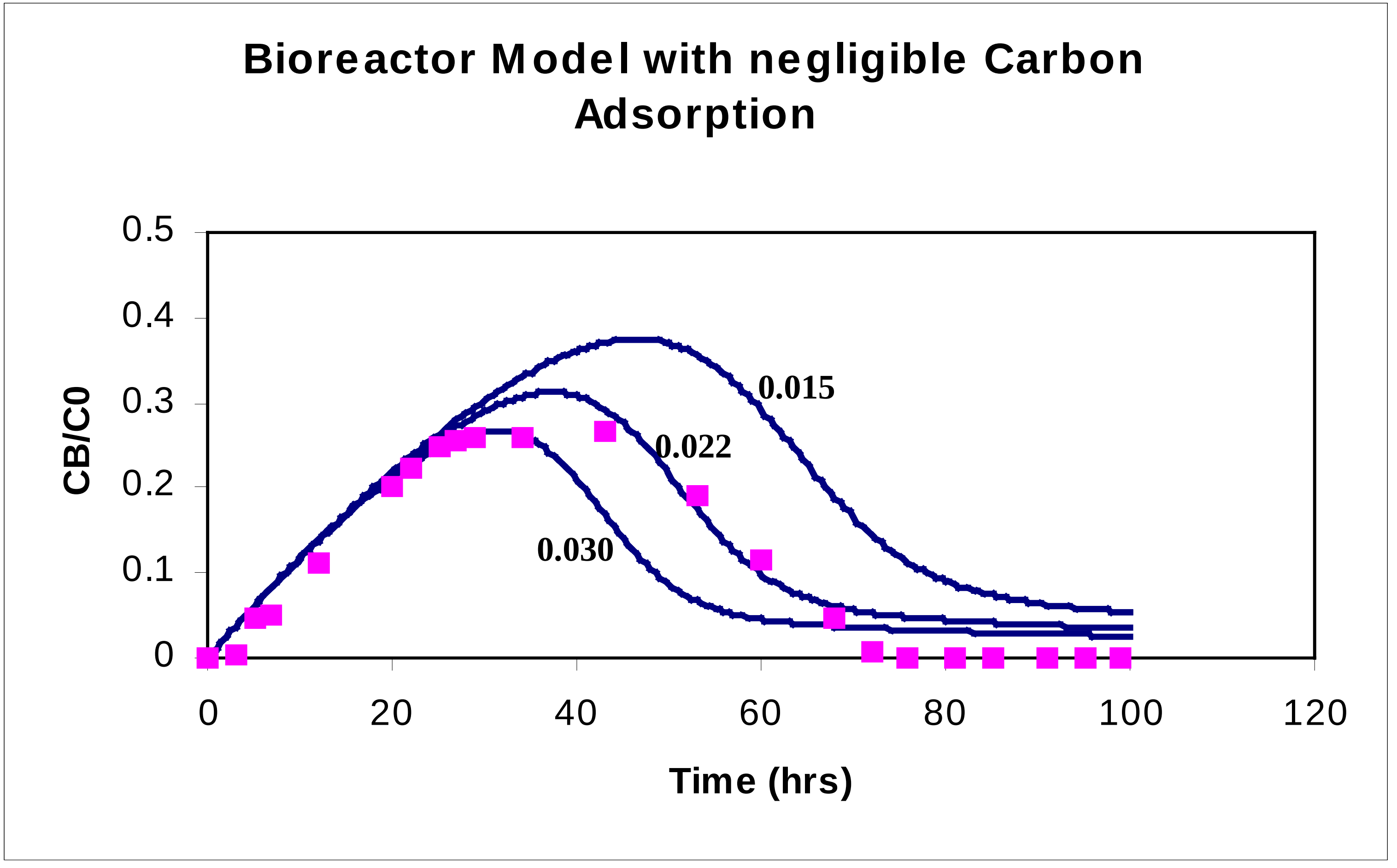
Experimental Parameters

μ_{max}	0.022	h^{-1}
K_m	0.16	mg IPA/cm^3
D_{eff}	0.001	cm^2/h
Y	0.12	mg cells/mg IPA
α	40	cm^{-1}
r_p	0.075	cm
F	100	cm^3/h
V	8000	cm^3
ν	35	cm^3
ρ	1000	mg Cells/cm^3
C_0	0.01	mg IPA/cm^3

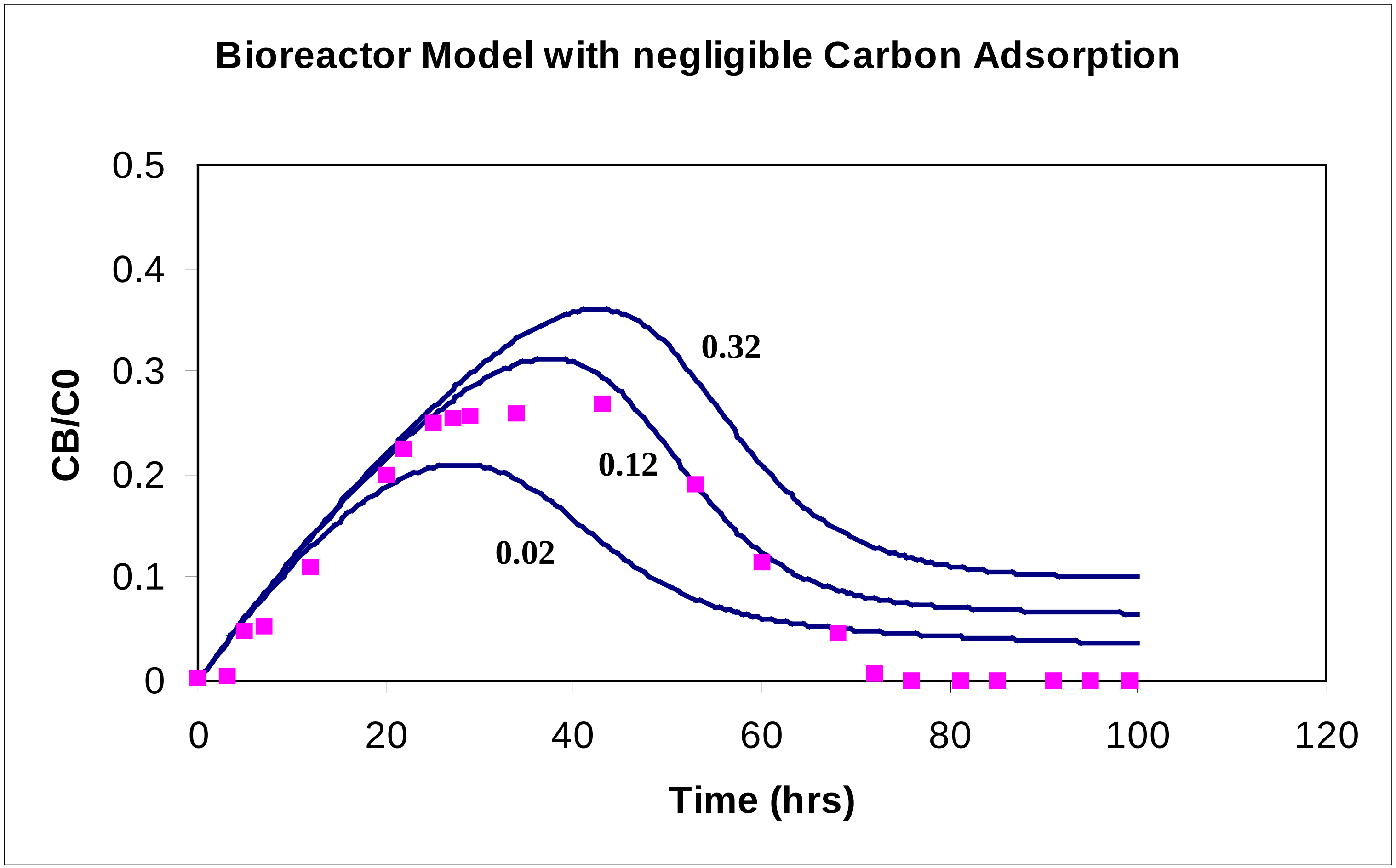
Comparison of Model to Experimental Data



Effect of μ_{max}



Effect of Yield



Publications for Cu removal

- Ogden, Muscat and Stanley “Biosorption of Copper from Chemical Mechanical Planarization Wastewaters“ **MICRO**, July/August 2001
- Stanley and Ogden “Removal of Cu from CMP waste water: Is it feasible?“ **Environmental Science & Technology** (Submitted 5/01; preprints available from Kim)

Work in Progress

- **Continue working on model**
  - **Suspended cells growth**
  - **Carbon adsorption**
  - **Test with transient IPA and pH spikes**

- **Incorporate to Biotreatment of Cu**
  - **Simultaneous Cu and Organic biotreatment**
  - **Adjust and test models**