A&WMA's 99th Annual Conference and Exhibition

Cyclic Operation of a Fixed 2-Bed Adsorption System as Load Equalization for Air Biofiltration System

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Introduction

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Introduction

Load fluctuation

Solution = Buffer unit ?

Adsorption unit can be a buffer unit for a biofilter

Current application : Single bed of carbon filter

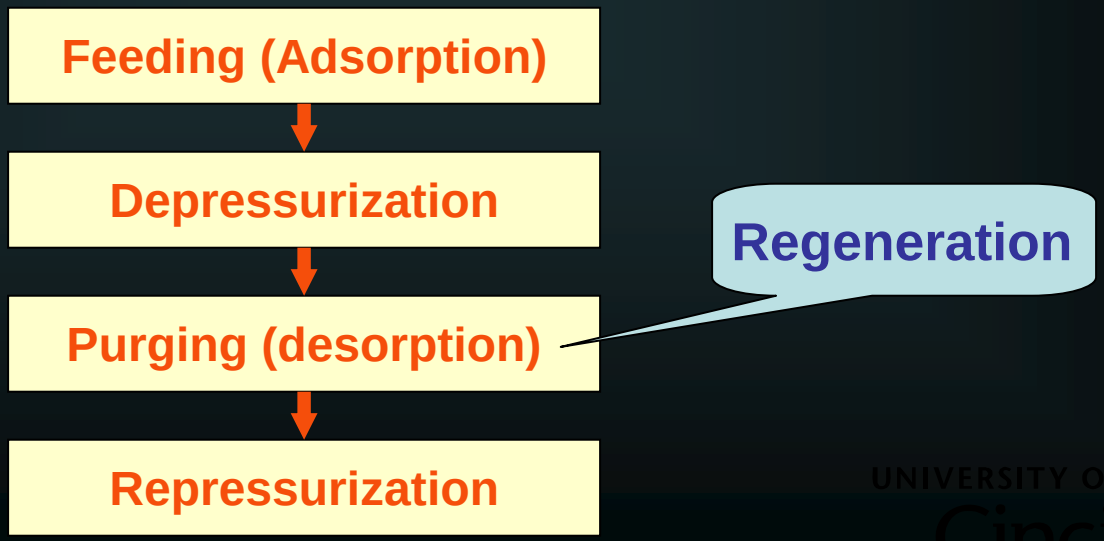
Consideration of current adsorption unit

High loading & Large fluctuation → Losing buffer capacity

Initial period of operation → No contaminant to biofilter

Concept of 2-Bed Adsorption

- Conceptually simple process to PSA
- PSA (Pressure Swing Adsorption) :
  → A technology for separation and purification for gas mixtures
  → 4 Steps for operational function



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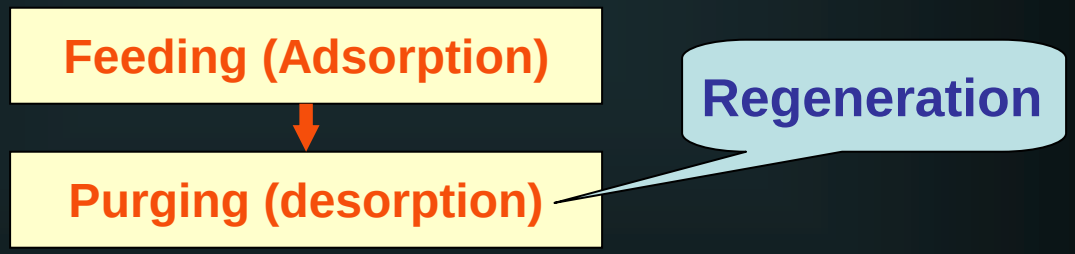
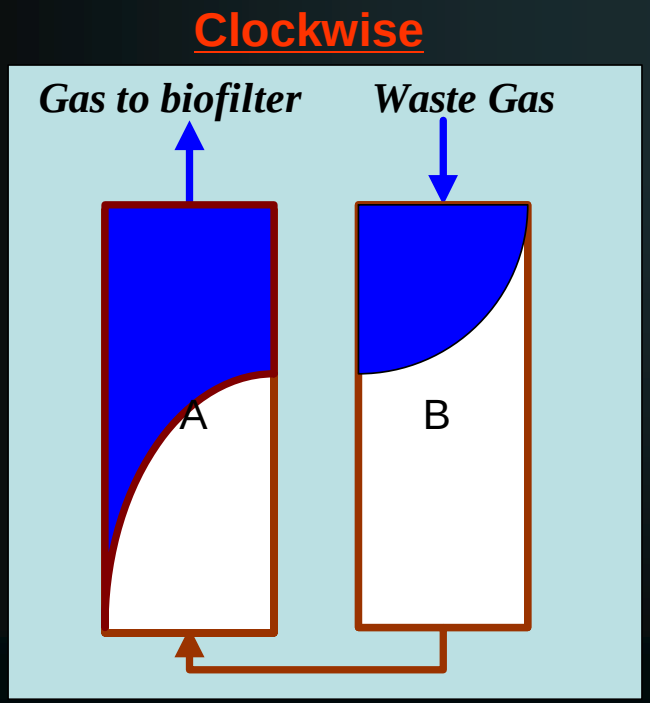
Concept of 2-Bed Adsorption

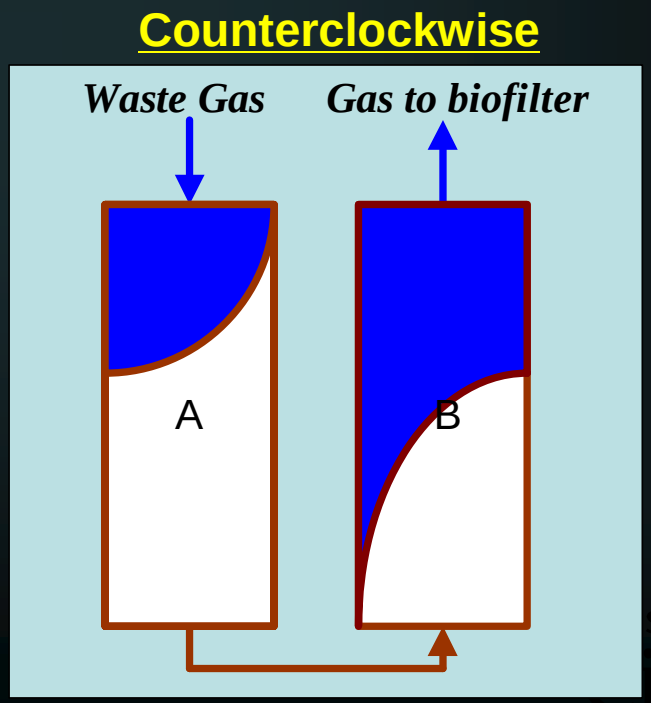
- Hypothetically, if adsorption rate is equal to its desorption rate
  → Operational function is simplified to a 2-step



Concept of 2-Bed Adsorption

- Cyclic operation : Shift of air flow direction
  - → Each bed will not be fully saturated with adsorbate





Theory of 2-Bed Adsorption

2-Bed Adsorption Unit

Will Serve as

- Polishing unit during the initial acclimation period of the biofilter
- Buffer unit in load fluctuation
- Feeding source without any feeding phase during non-use periods

Objective

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Objective

Main Objective

Evaluate Cyclic operation of 2-bed adsorption unit as load equalization For air biofiltration system

Specfic Objective

- Mathematically simulate 2-bed adsorption unit performance to compare Cyclic operation vs. Non-cyclic operation
- Experimentally evaluate the performance of the integrated scheme of 2-bed adsorption unit with air biofilter under transient loading of toluene (Integrated unit vs. control unit)

Materials and Methods

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Targeted VOC

Toluene (C_7H_8)

- Comment solvent employed in the industry
- A major component in paints and varnishes

Adsorption Unit

- 2 Beds
- Dimension : 2.5 cm (D) × 20 cm (L)
- Duration of one cycle : 8 hours
- EBRT: 5.6 sec (2.2 L/min)

- Absorbent : GAC (BPL 6 × 16)

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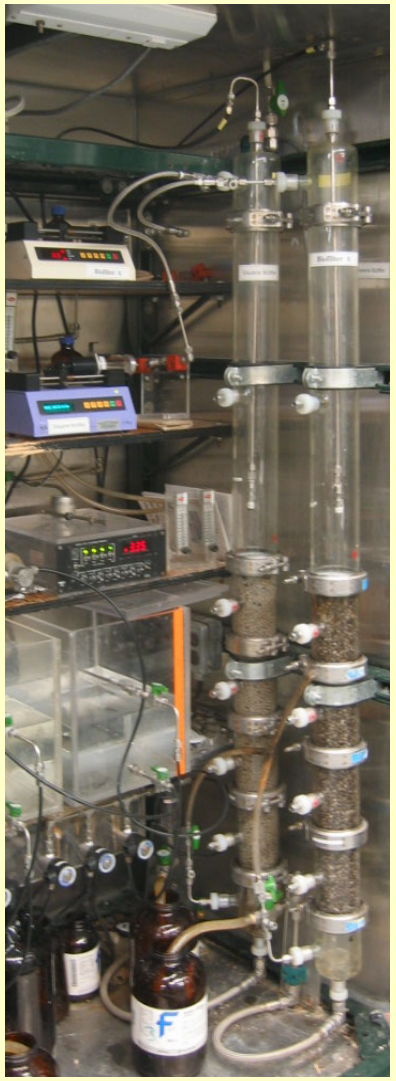
Biofilter

Trickle Bed Air Biofilter (TBAB)

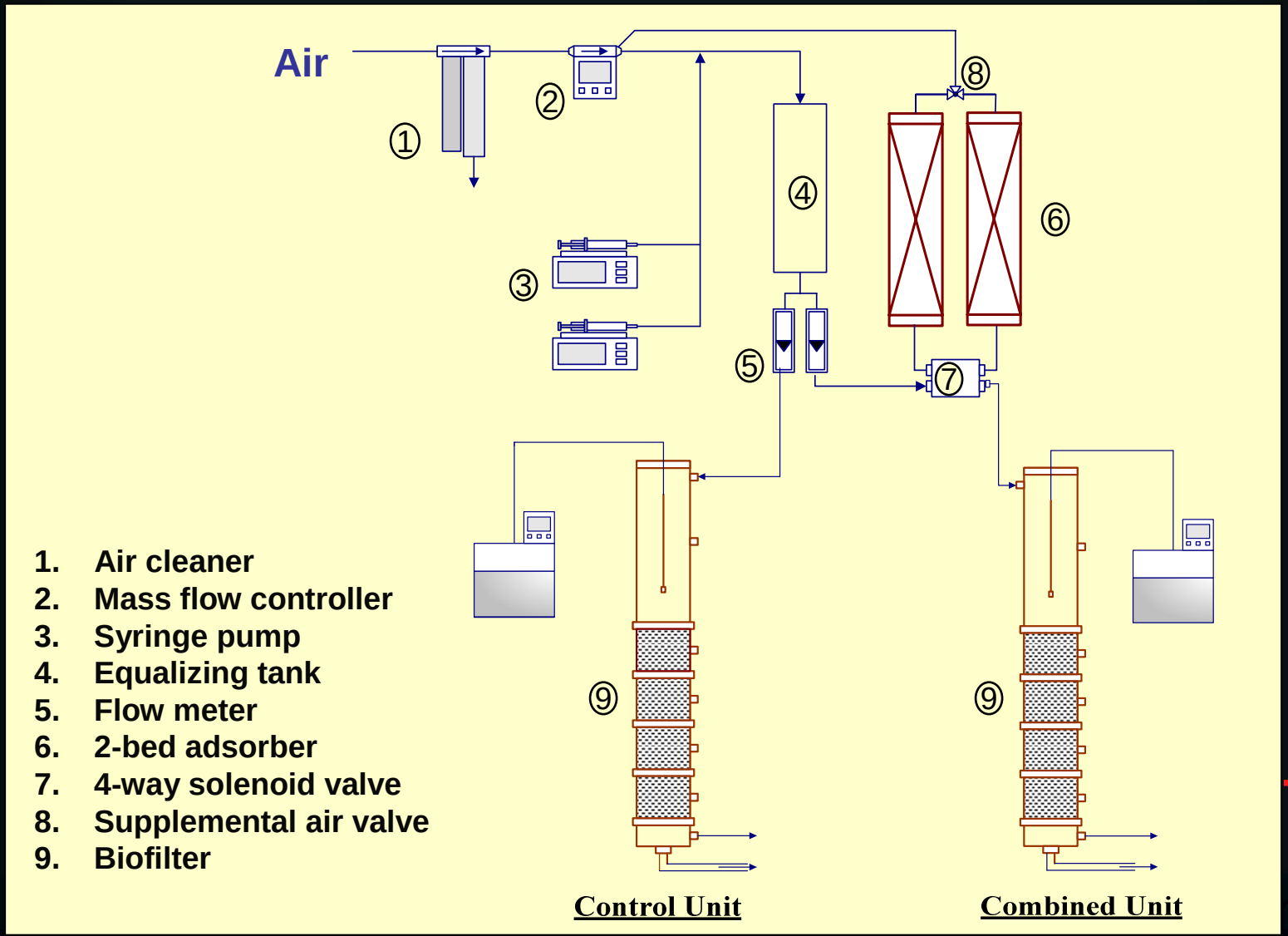
- Dimension : 76 mm (D) × 130 cm (L)
- Buffered nutrient solution supply
- Operating Temp. : 20 °C
- EBRT: 1.2 min (2.2L/min)

Media (Celite® Bio-Catalyst Carrier)

- Packing depth : 60 cm
- Seeded with aerobic microbial culture pre-acclimating to toluene
- Biomass control: Periodic Backwashing (1hour / 7days)



Schematic Diagram of Experimental Setup



1. Air cleaner
2. Mass flow controller
3. Syringe pump
4. Equalizing tank
5. Flow meter
6. 2-bed adsorber
7. 4-way solenoid valve
8. Supplemental air valve
9. Biofilter

Results: Model Simulation

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Model Simulation

- Model simulation of cyclic operation of 2-bed adsorption
- Model simulation of non-cyclic operation of 2-bed adsorption

Model Simulation

- Model simulation of cyclic operation of 2-bed adsorption

Mathematical model is formulated for a packed bed for simulation of the proposed cycle, which consists of overall and component material balances.

- Linear driving force model is incorporated into the model in order to include a mass transfer resistance with an adsorbent from a bulk gas phase.
- Freundlich isotherm equation is used for expression of isotherm capacity.

Assumption: (1) no pressure drop along a bed, (2) an isothermal operation, and (3) a plug flow through a bed with no dispersion.

- Model simulation of non-cyclic operation of 2-bed adsorption

Model Simulation

- Model simulation of cyclic operation of 2-bed adsorption

- Model simulation of non-cyclic operation of 2-bed adsorption

Plug flow homogeneous surface diffusion model (PFHSDM) which is embedded in an **Adsorption Design Software** (*AdDesignS*™) developed by Michigan Technological University is used.

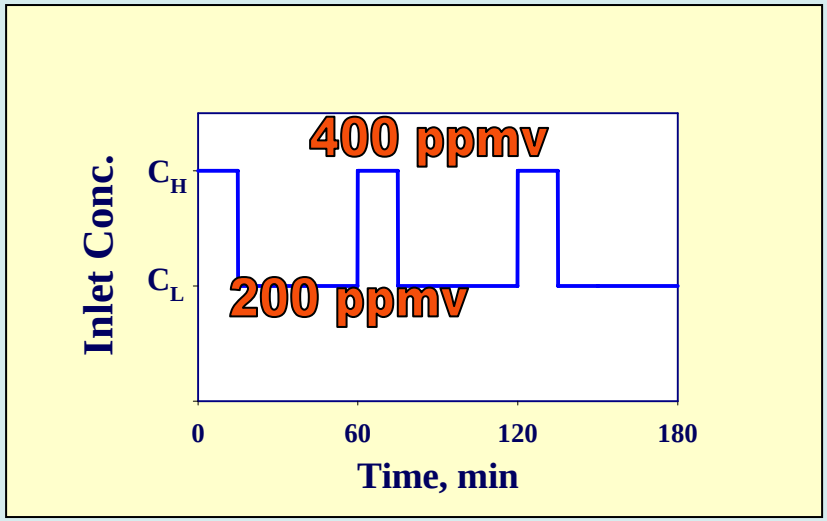
The mechanisms incorporated in this model are:

- Homogeneous surface diffusion
- Film transfer resistance at the adsorbent surface
- Advection dominates axial transport in bed.
- Local equilibrium Freundlich isotherm exists at the adsorbent surface.
- Freundlich isotherm equation is used for expression of isotherm capacity.

Model Simulation

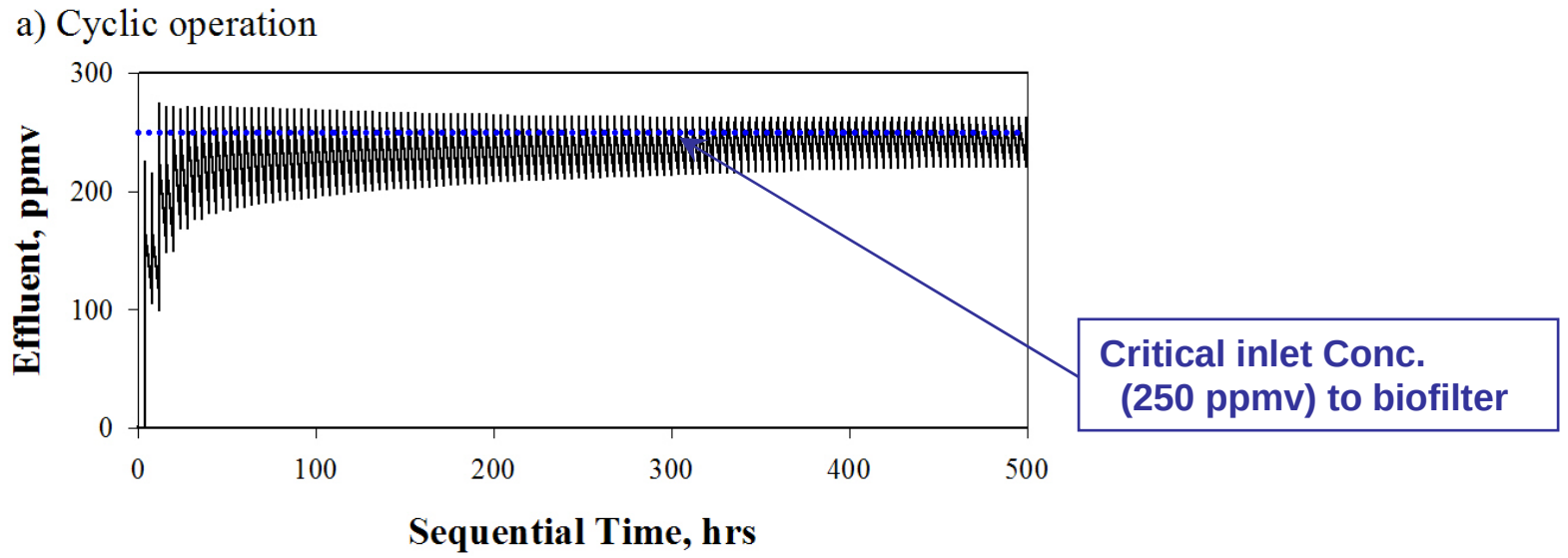
- **Effluent Responds in 2-bed Adsorption**

Transient Feeding Condition 1: Square wave change of inlet concentration
- Base = 200 ppmv
- Peak = 400 ppmv (15 mins / hour)



Model Simulation

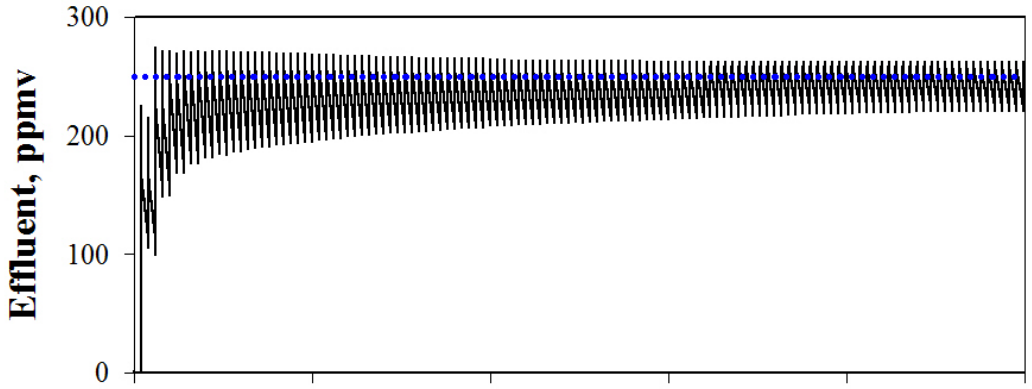
- **Effluent Responds in 2-bed Adsorption**



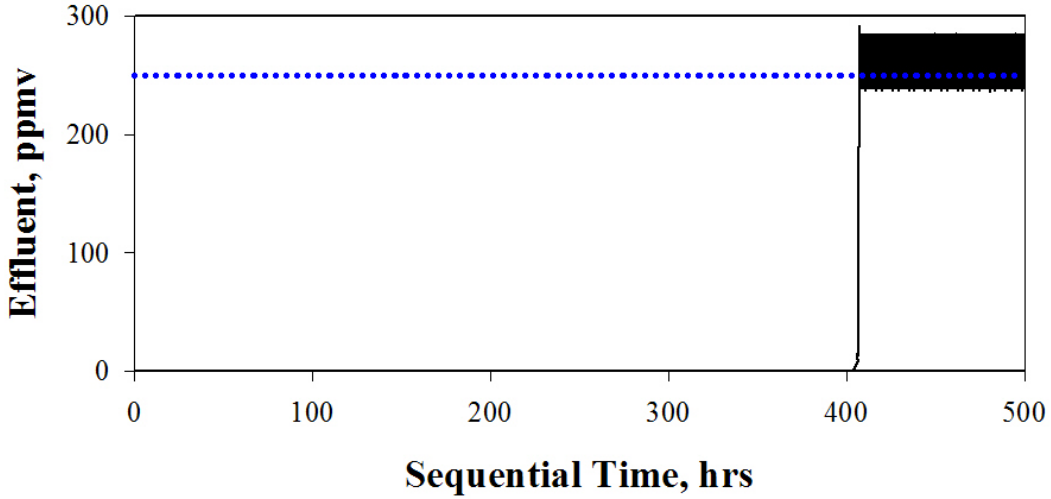
Model Simulation

- **Effluent Responds in 2-bed Adsorption**

a) Cyclic operation

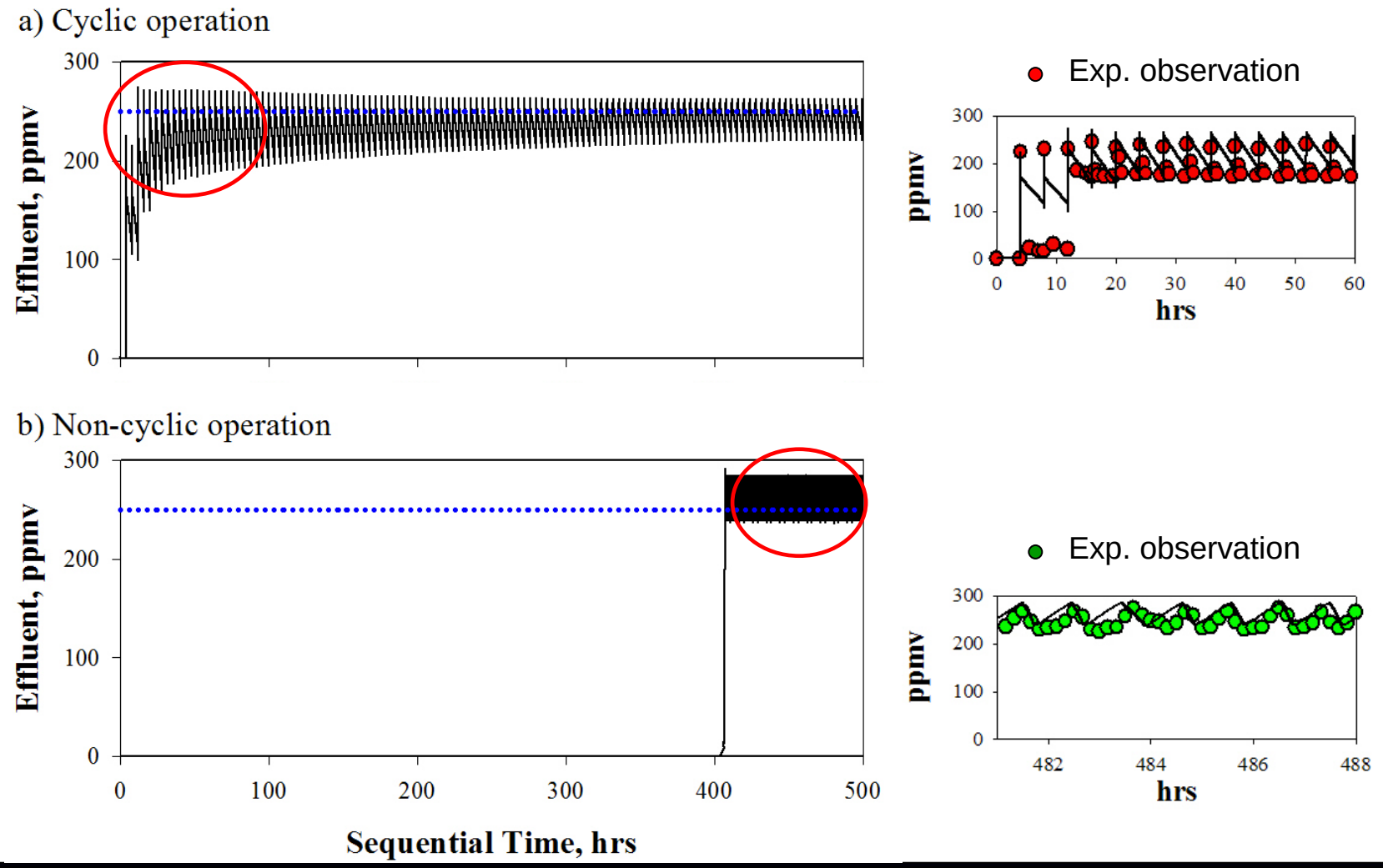


b) Non-cyclic operation



Model Simulation

- **Effluent Responds in 2-bed Adsorption**



Results: Experimental Test

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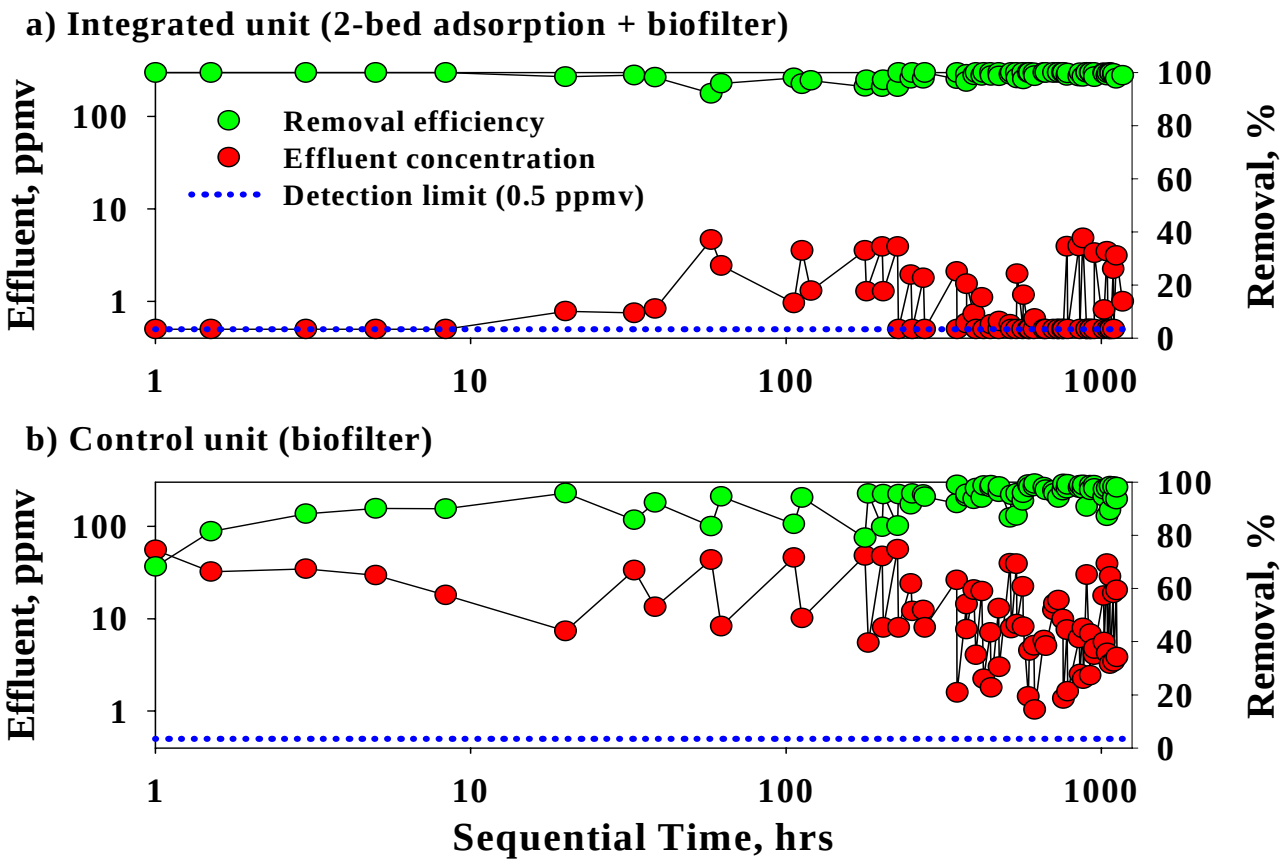
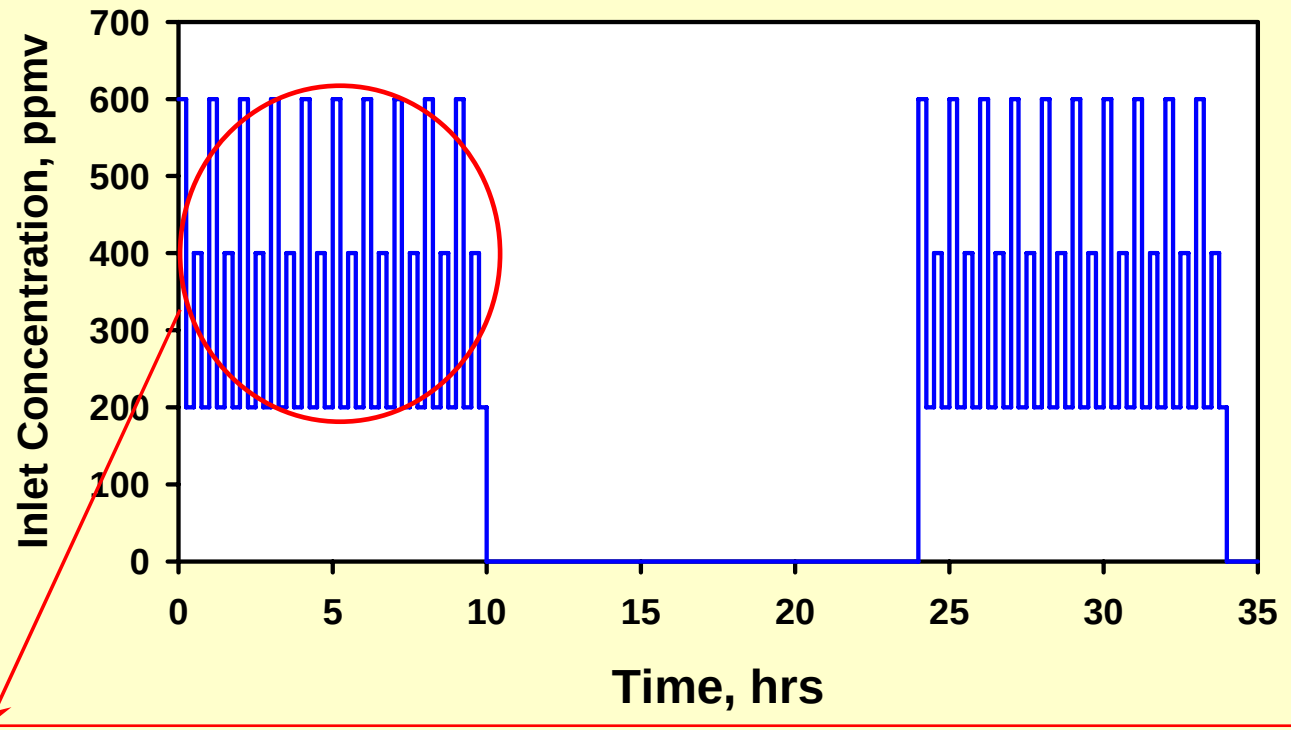
Results I: Feeding Condition 1

- Integrated unit vs. Control unit



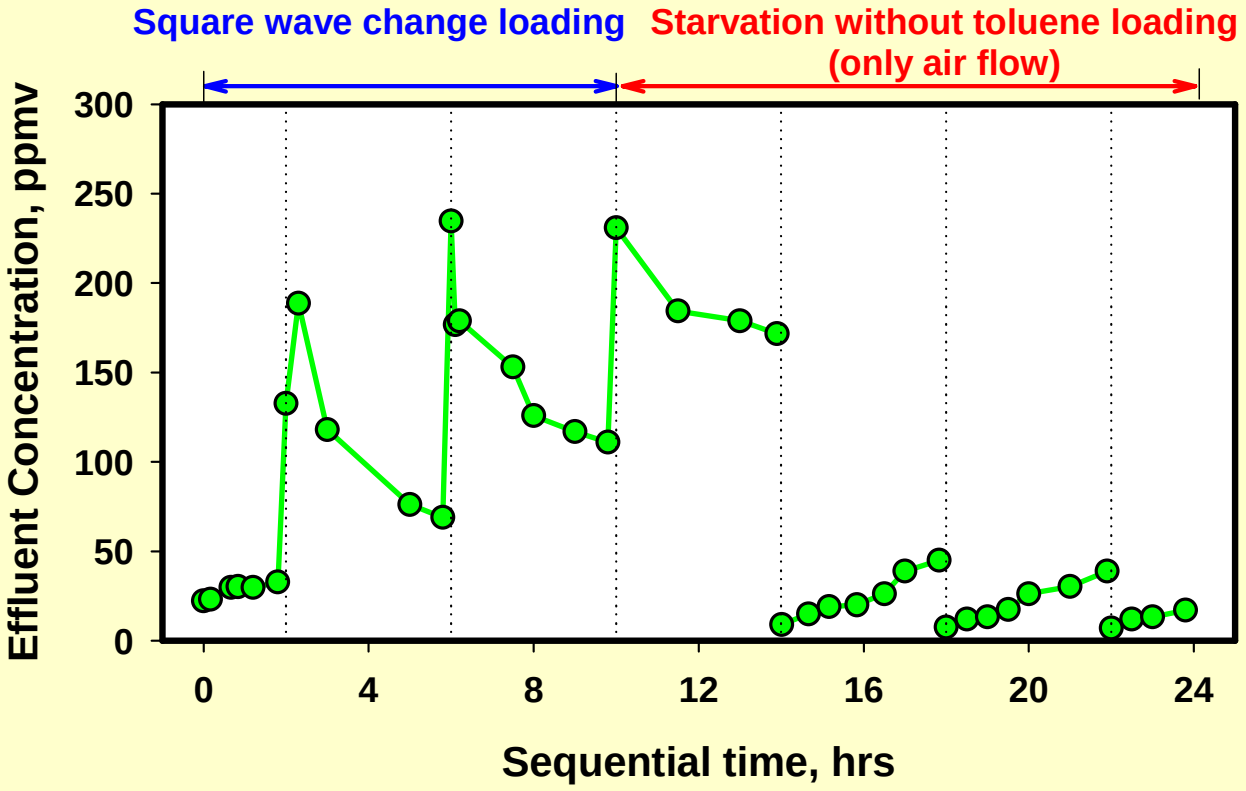
Results II: Feeding Condition 2

Transient feeding condition 2:
10 hrs square wave change + 14 hrs starvation without toluene loadings



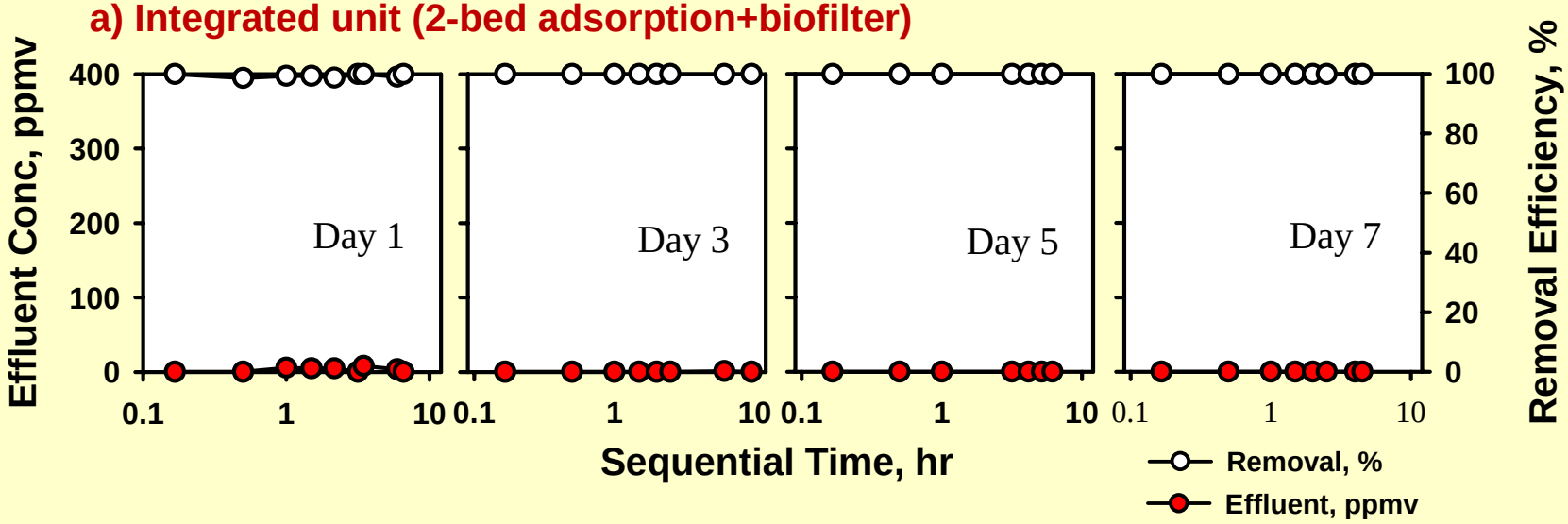
600ppmv (15min) → 200ppmv (15min) → 400ppmv(15min) → 200ppmv(15min) / 1 Hr

Desorption profiles of 2-bed adsoprion unit



Overall Removal Performance (with backwashing as biomass control)

a) Integrated unit (2-bed adsorption+biofilter)



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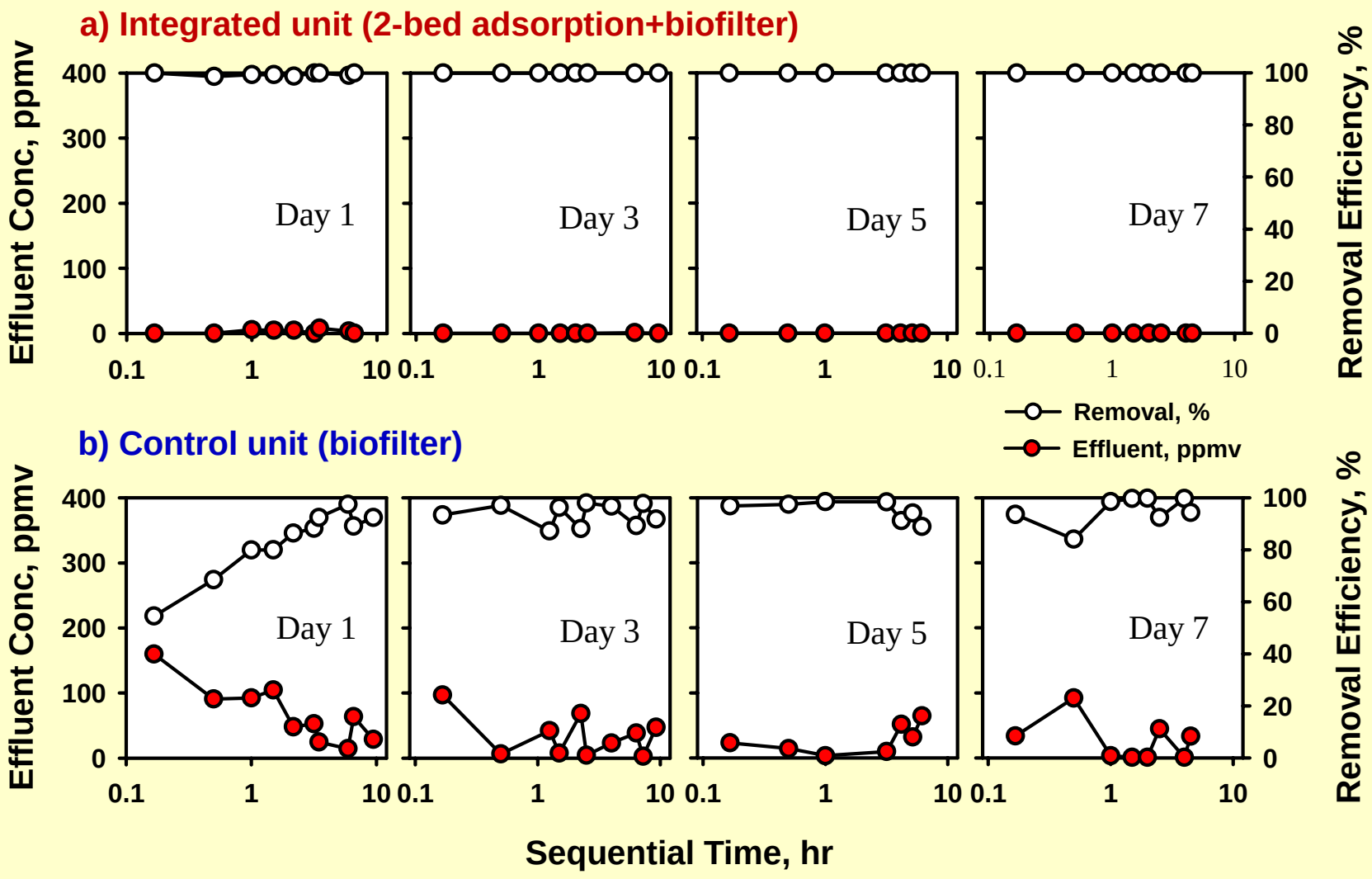
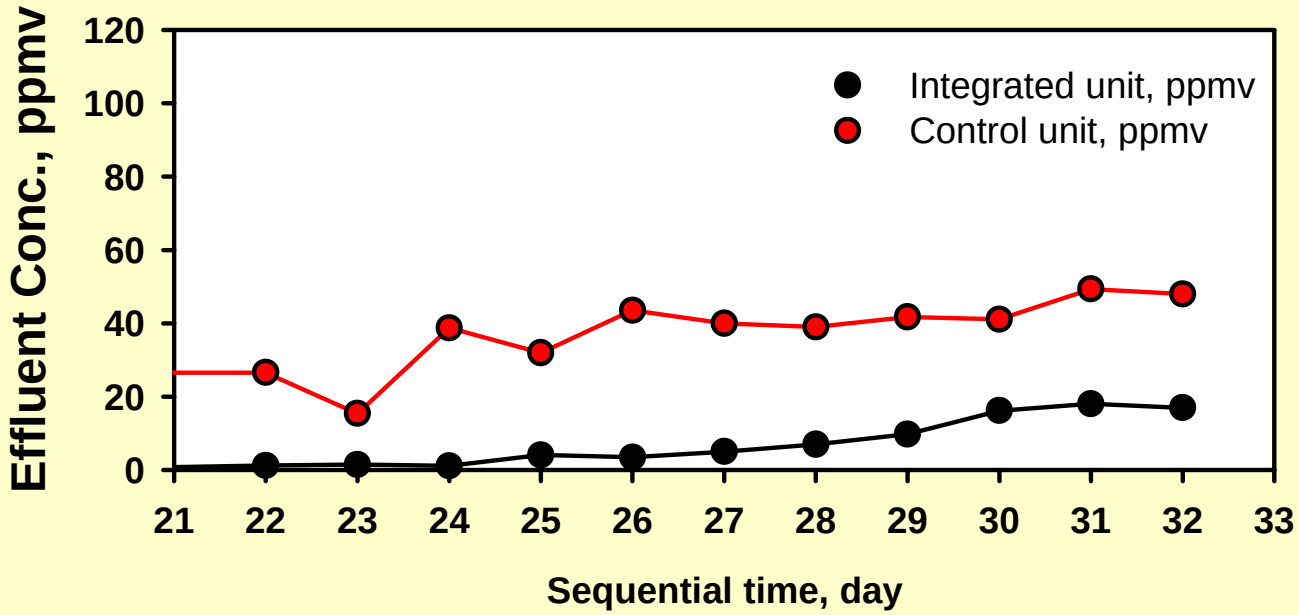


Overall Removal Performance (without backwashing as biomass control)



- **Periodic biomass control is necessary for attaining stable, long term High removal efficiencies for the biofilter, even integrated unit**

Conclusion

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Conclusion

1. 2-step cycle of adsorption and desorption involved in the fixed 2-bed adsorption unit successfully perfomed its function as Buffering unit for transient toluene loading.

2. Integrated unit of a 2-bed adsorption followed by a biofilter achieved stable toluene removal performance with +99% removal efficiency.

Acknowledgements

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