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Treatment of VOCs emitted from Wastewater Treatment Plant by a hybrid process scheme of a 2-bed adsorber and a biofilter

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- Theory of This Study
- Materials and Methods
- Experimental Results
- Conclusion

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Introduction

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Introduction

VOC Emission and Regulation

1. **Volatile Organic Compounds**.
2. **The passage of the 1990 Amendments to the Clean Air Act:** significantly heightened the interest in the development of innovative technologies for VOCs removal
3. **VOCs are precursors to the formation of ozone, and they have their own toxicity.**
4. **International standard on environmental management (ISS14000):** demands the treatment of VOCs emission

Introduction

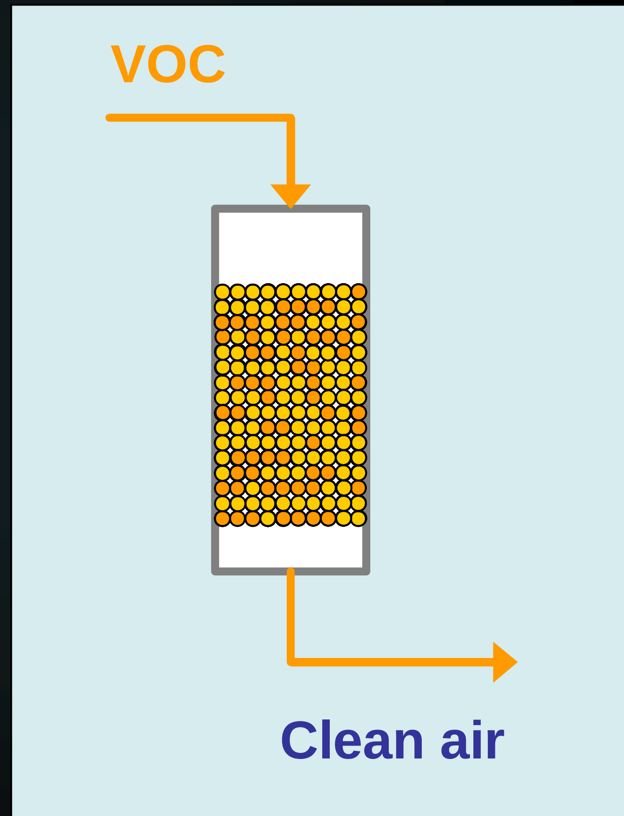
Wastewater treatment

1. **Source of VOCs to ambient atmosphere**.
   affected by the Clean Air Act Amendments.
2. **Depend on domestic, commercial, and industrial sources**
3. **VOCs are transferred into the air mainly in case of aerated bioreactor.**
   (activated sludge process)

Introduction

VOC Removal technology

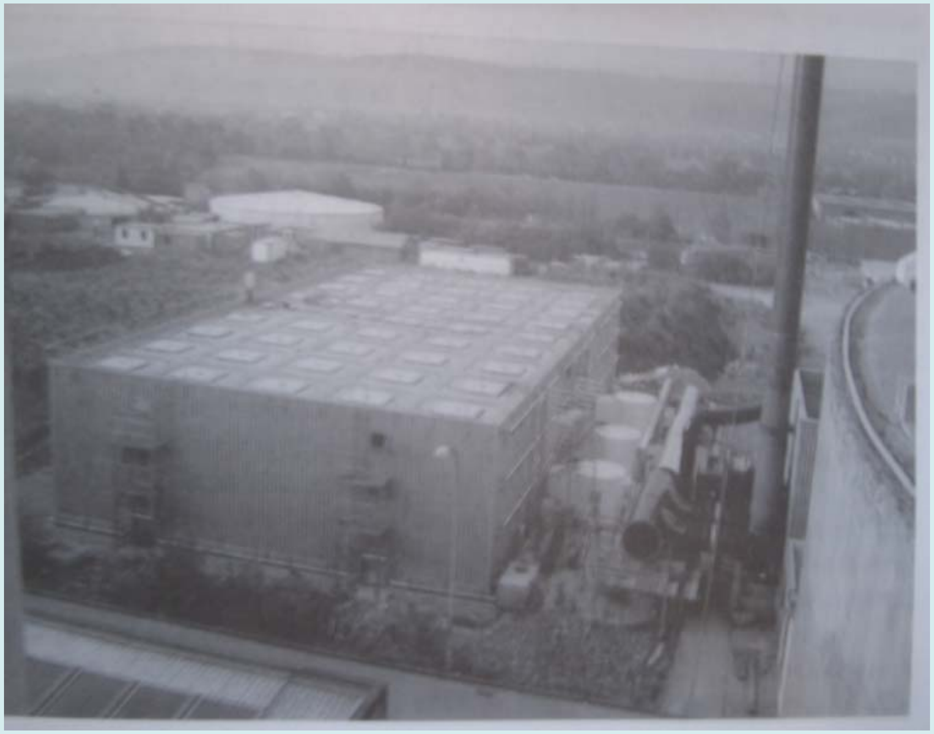
1. **Thermal oxidation, Catalytic oxidation, Condensation, Carbon adsorption, Membrane separation…**
2. **Biological treatment:**
   economical and ecological technology
3. **Biofiltration**



Introduction

Application of biofiltration

1. **Owner and location:**
   Novartis; Basle, Switzerland
2. **Air flow rate:**
   60,000 – 75,000 m^3/h
   (Exhaust air from plant)
3. **Pollutants:**
   toluene, xylene, methanol, isopropoanol, chloroform…
   Total conc. : 180 – 500 mg/m^3



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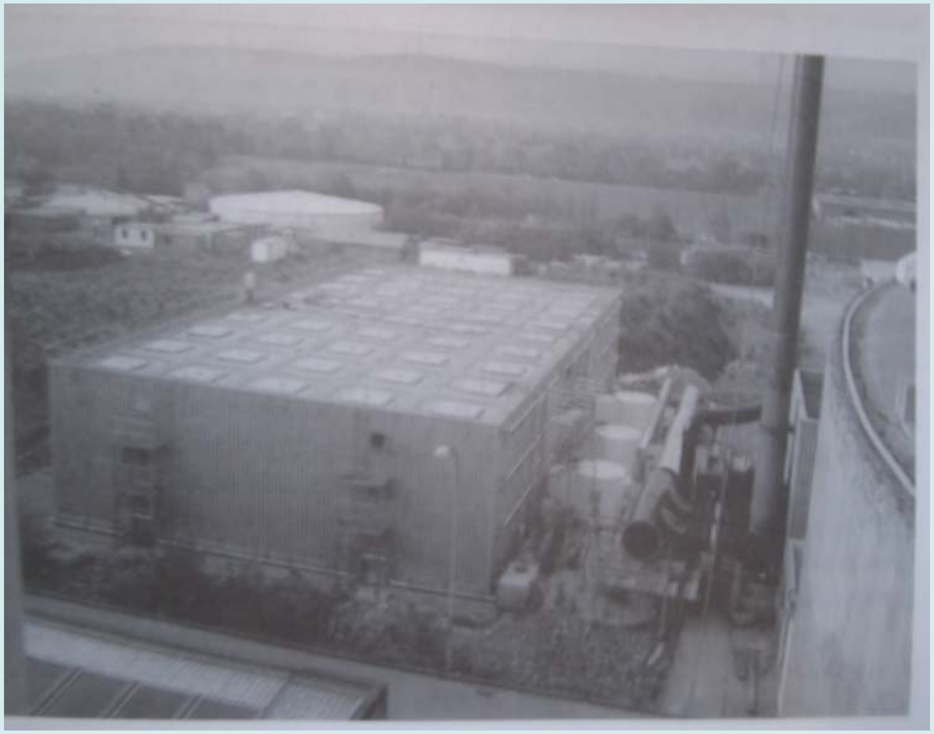
Introduction

Application of biofiltration

4. **Biofilter Design**
   Investment costs ($2,000,000)
   Treatment costs
   ($1.44 per 1000 m^3 off gas)

5. **Biofilter Performance**
   Removal: 80 %

   (depends on inlet loading)



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 in effluent

Objective

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Objective

Main Objective

A 2-bed adsorption unit is proposed to establish long-term stable buffer capacity of adsorption unit in mitigating biofilter performance

Specfic Objective

- To design and evaluate a 2-bed adsorption unit
- To evaluate the overall performance of a combined process scheme (2-bed adsorption unit + Biofilter)
- To be compared with that of a control unit without adsorption unit (Biofilter)

Theory of 2-Bed Adsorption

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Theory of 2-Bed Adsorption

2-Bed Adsorption Unit

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

Feeding (Adsorption)

↓

Depressurization

↓

Purging (desorption)

↓

Repressurization

Regeneration

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Theory of 2-Bed Adsorption

2-Bed Adsorption Unit

- Conceptually simple process to PSA
- Hypothetically, adsorption rate is equal to its desorption rate

→ Operational function is simplified to a 2-step

Feeding (Adsorption)

↓

Purging (desorption)

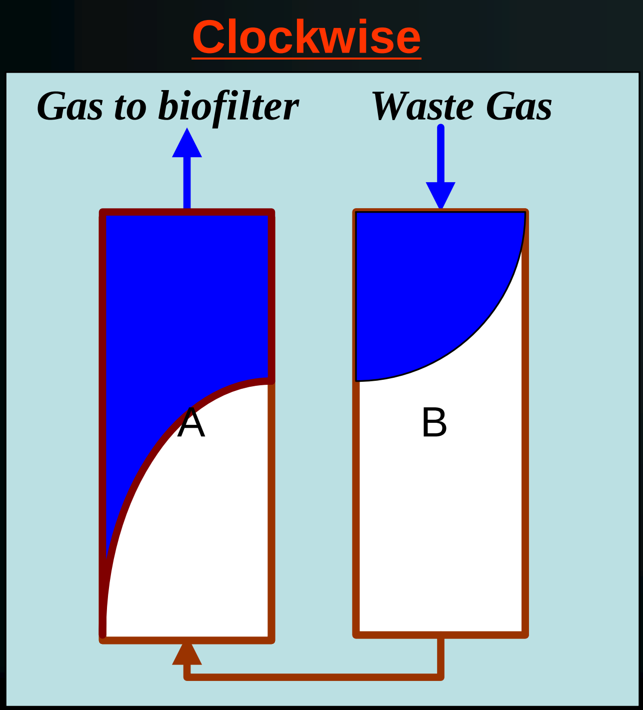
Regeneration

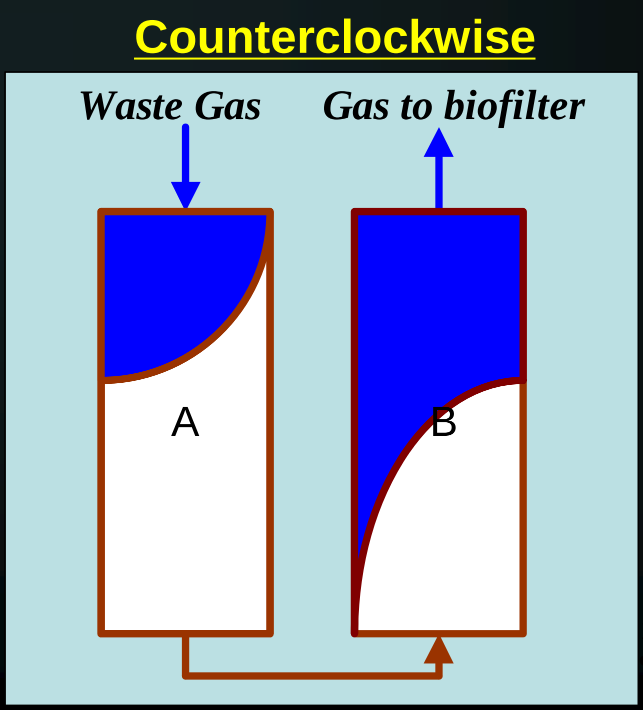
Theory of 2-Bed Adsorption

2-Bed Adsorption Unit

- 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 while non-use periods

Materials and Methods

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Feeding Condition

Targeted VOC

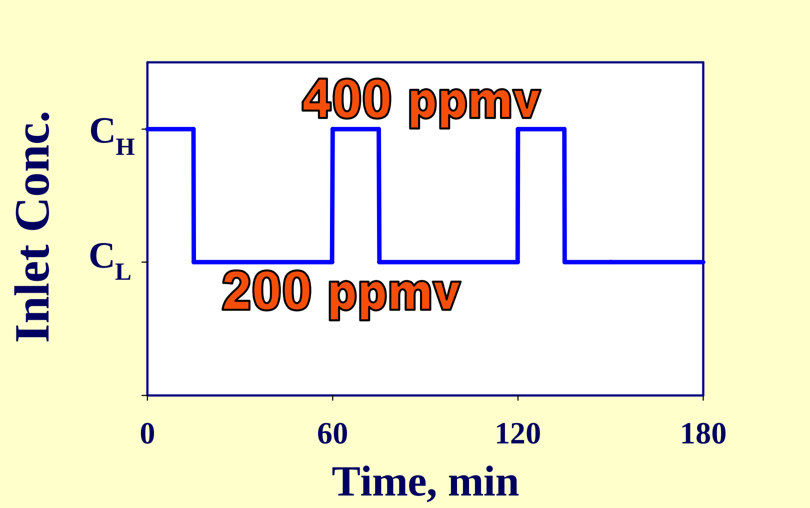
Toluene (C_7H_8)

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

Concentration & Loading

1st Condition: Square Wave Change

- Base = 200 ppmv
- Peak = 400 ppmv (15 mins / hour)
- Average concentration : 250 ppmv



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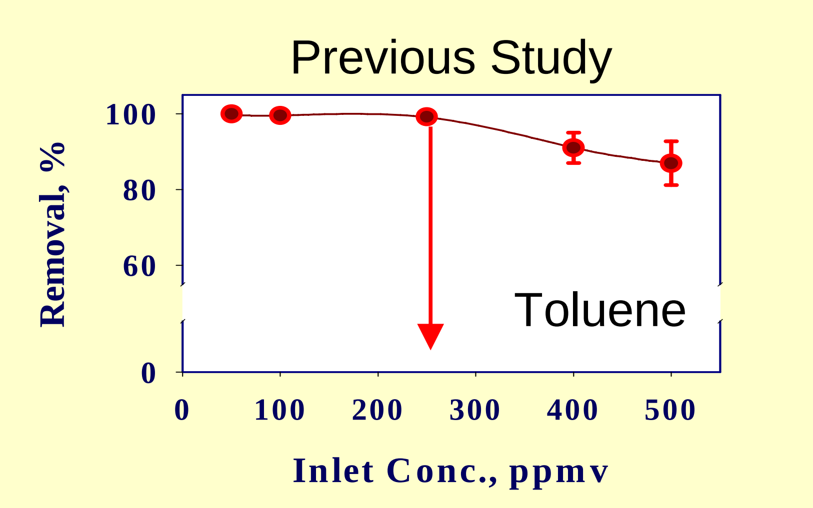

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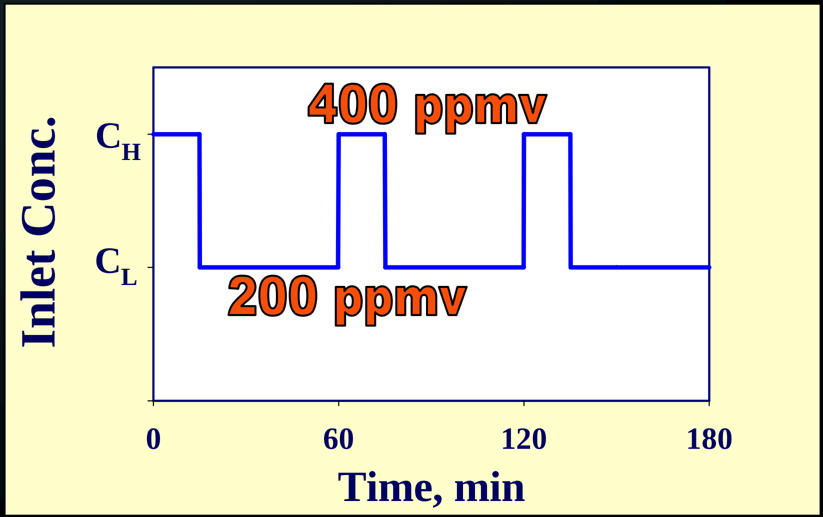
- Average concentration : 250 ppmv
- Average loading rate : 46.9 g/m^3·hr



Materials and Methods

Adsorption Unit

- 2 Beds
- Dimension : 2.5 cm (D) × 20 cm (L)
- Cyclic operation : 8 hours/ cycle
- Supplemental fresh air valve
- EBRT: 5.6 sec (2.2 L/min)

- Absorbent : GAC (BPL 6 × 16)

Materials and Methods

Biofilter

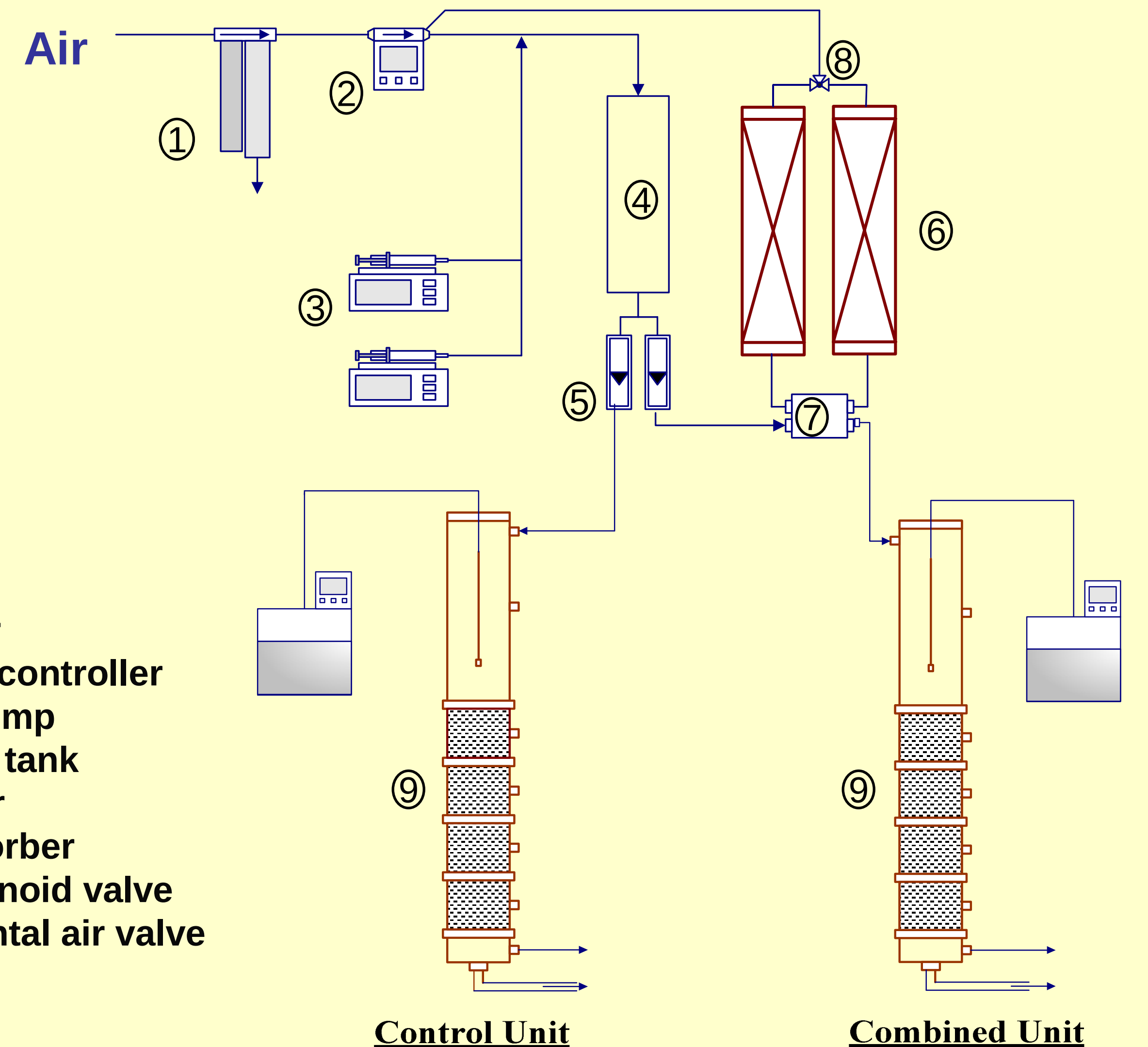
Trickle Bed Air Biofilter (TBAB)

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

Media

- Celite® 6 mm R-635 Bio-Catalyst Carrier
- Packing depth : 60 cm
- Seeded with aerobic microbial culture pre-acclimating to toluene

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

Experimental Results

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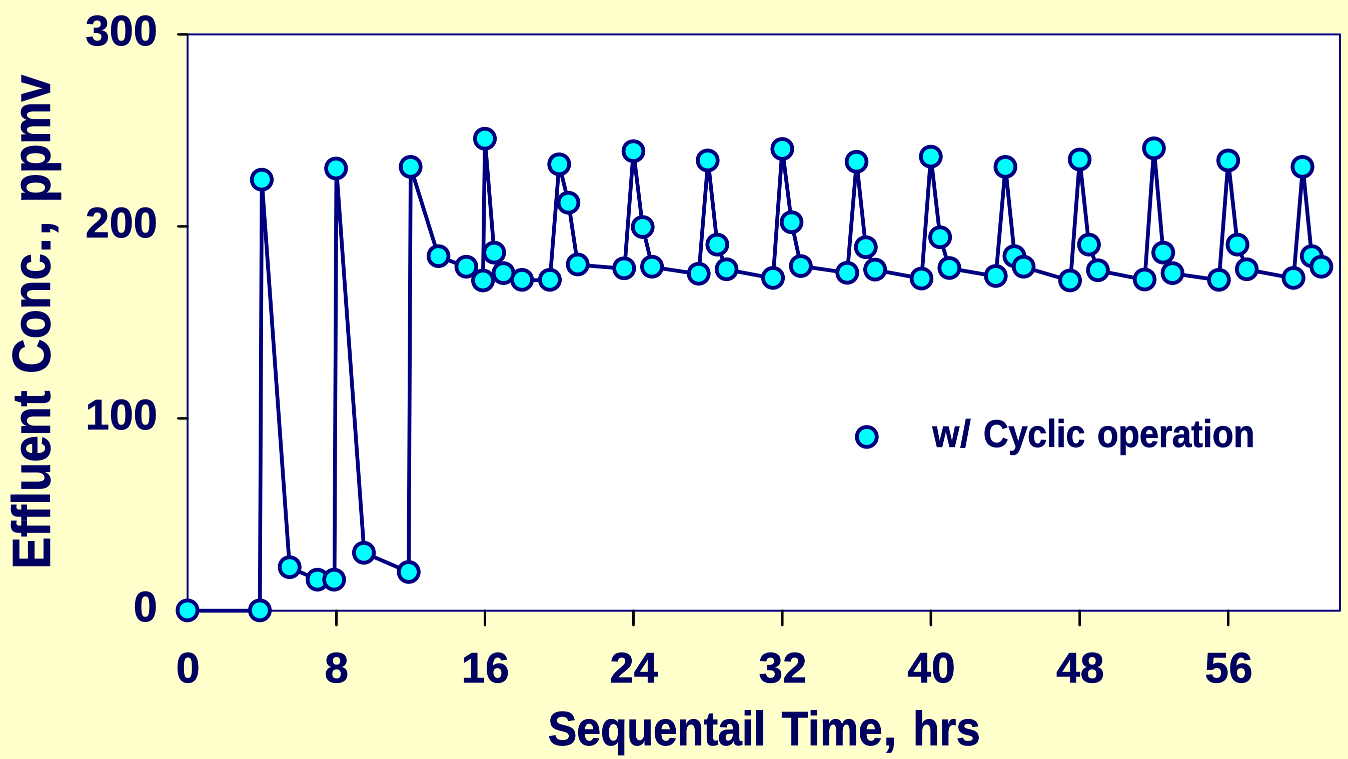
2-Bed Adsorption Performance

Square wave change of inlet concentration



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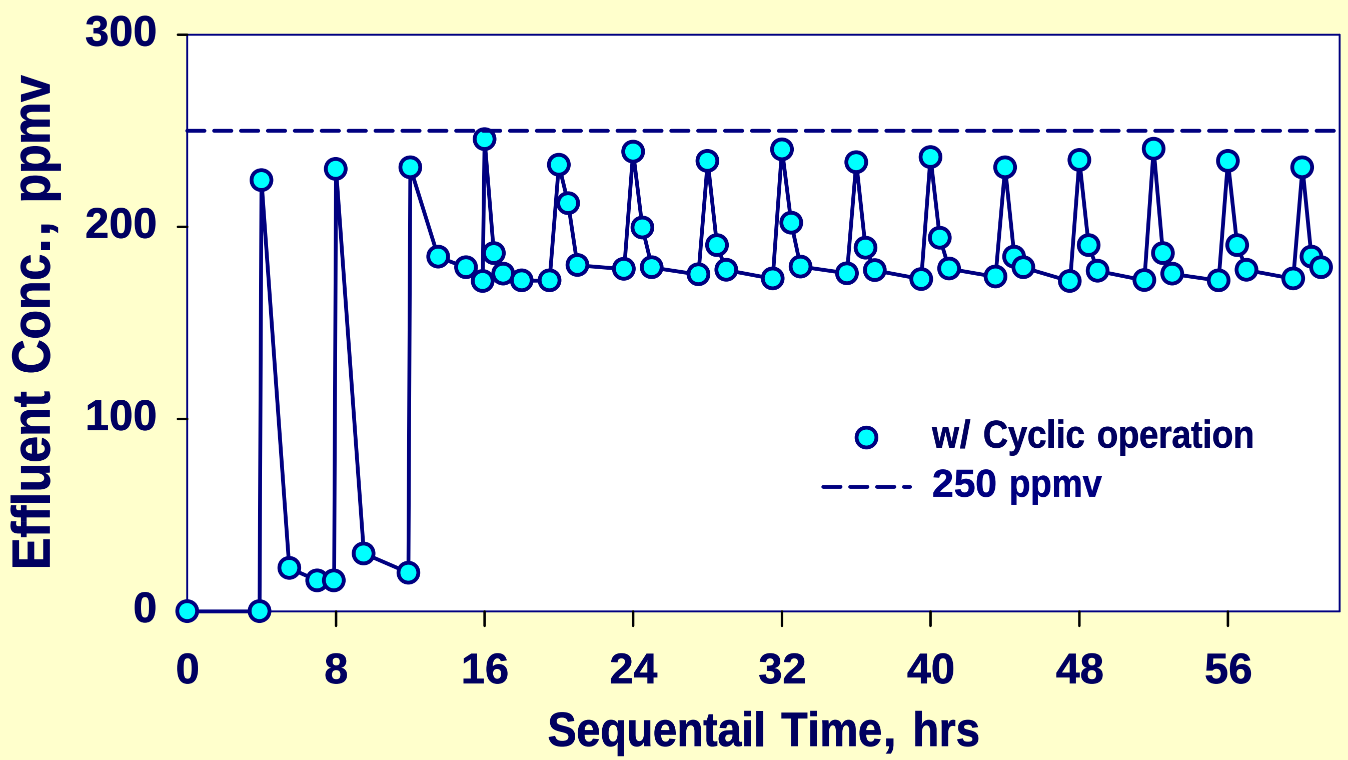

2-Bed Adsorption Performance

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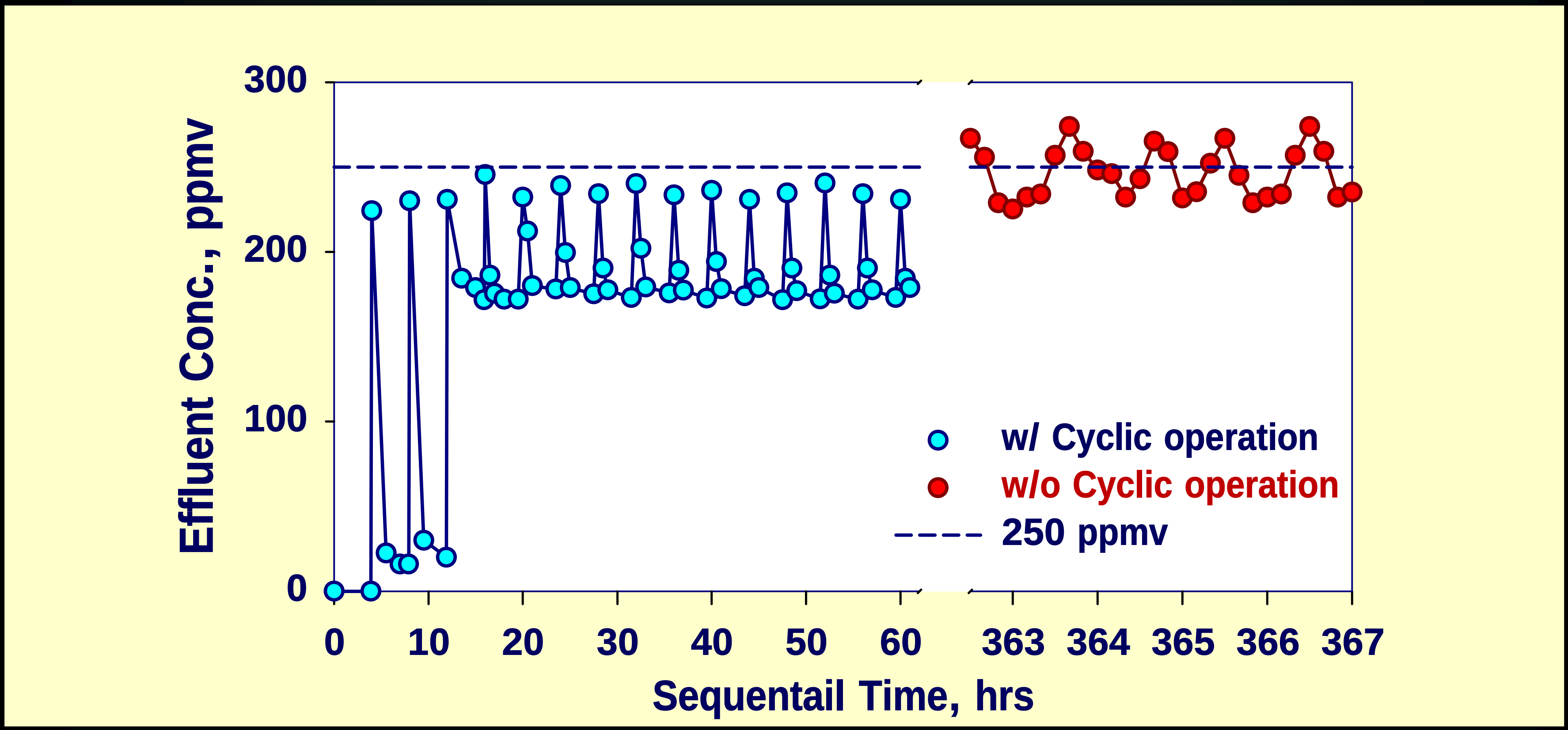
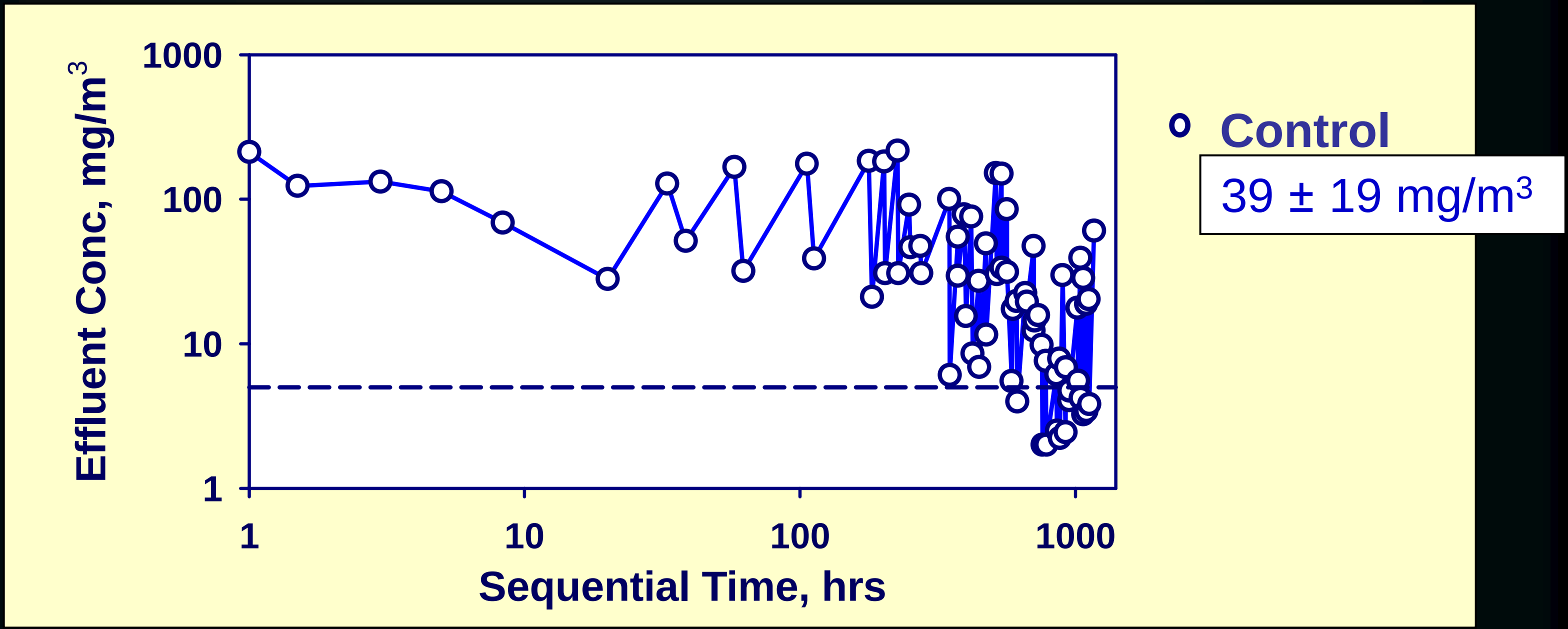


Toluene Removal Performance

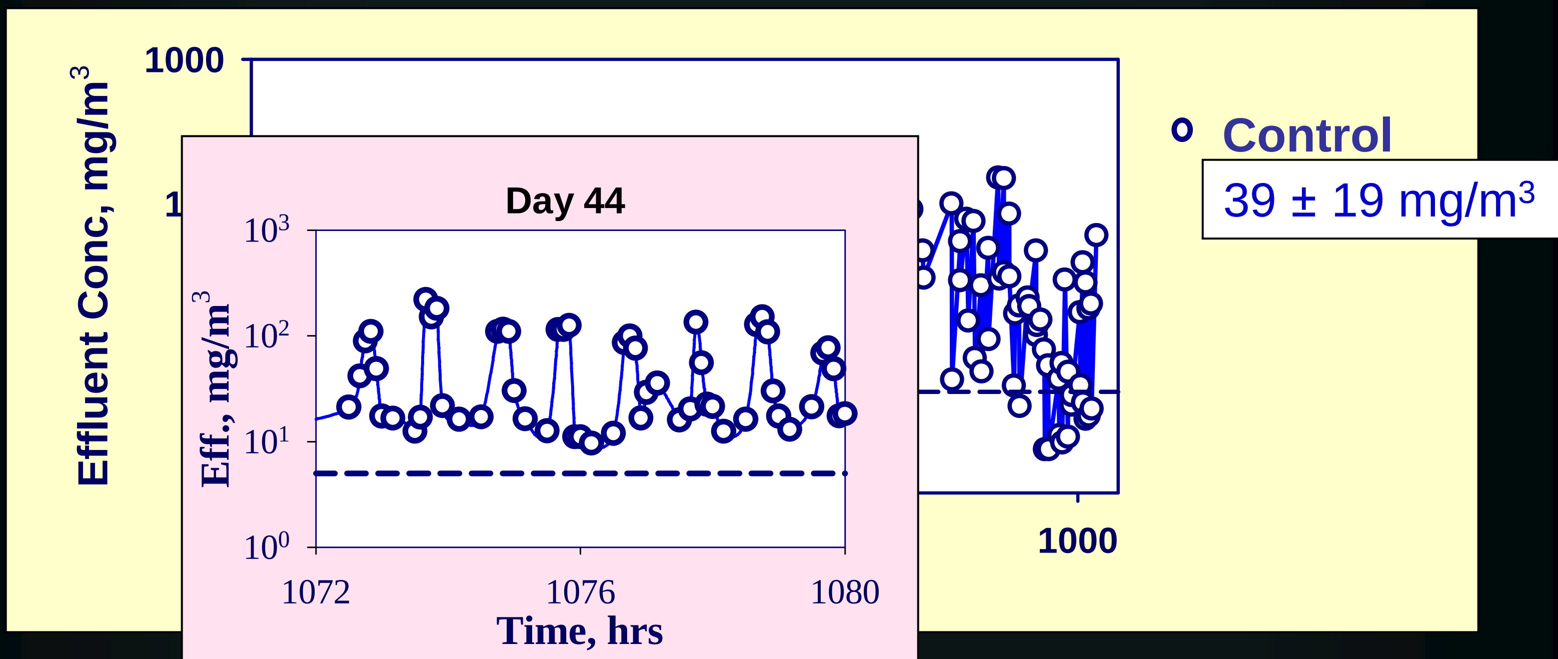
Effluent Concentration



Exposure guideline : 5 mg/m^3 (AIHA)

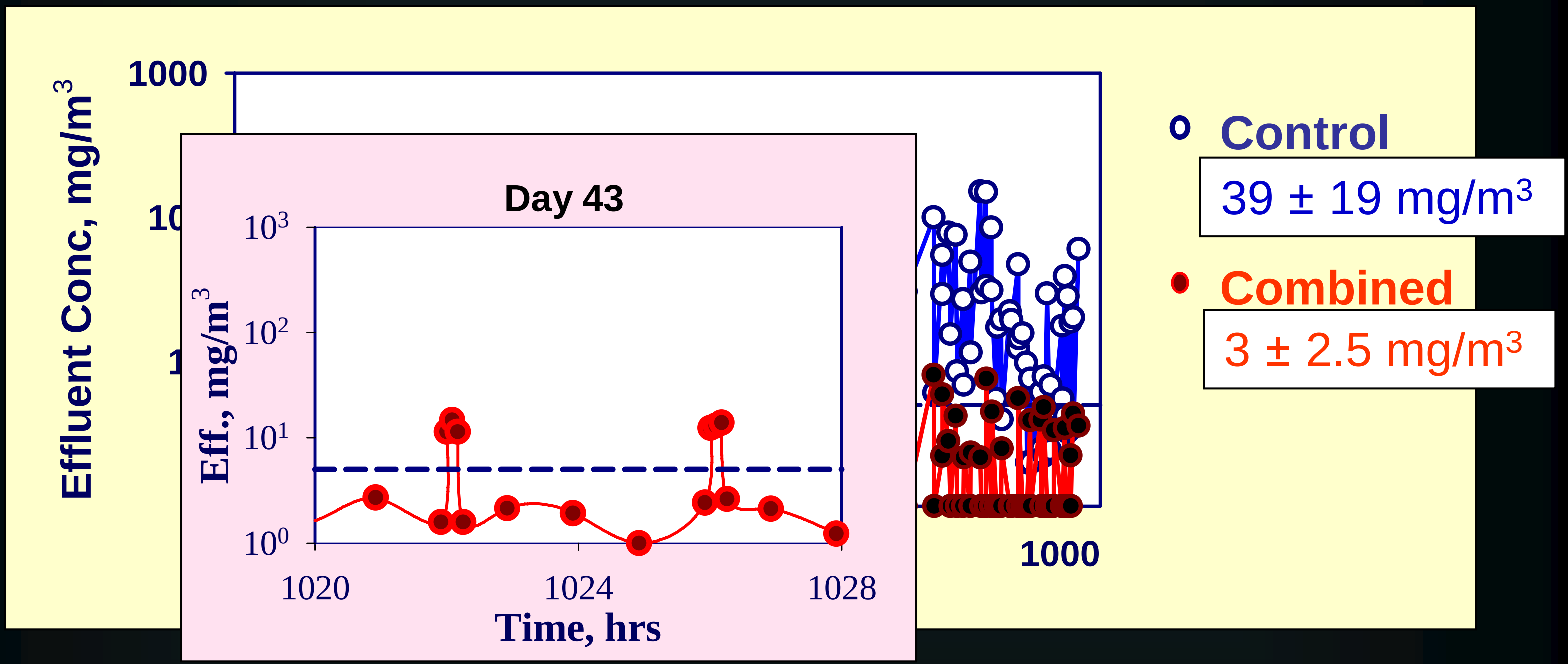
Toluene Removal Performance

Effluent Concentration



Toluene Removal Performance

Effluent Concentration



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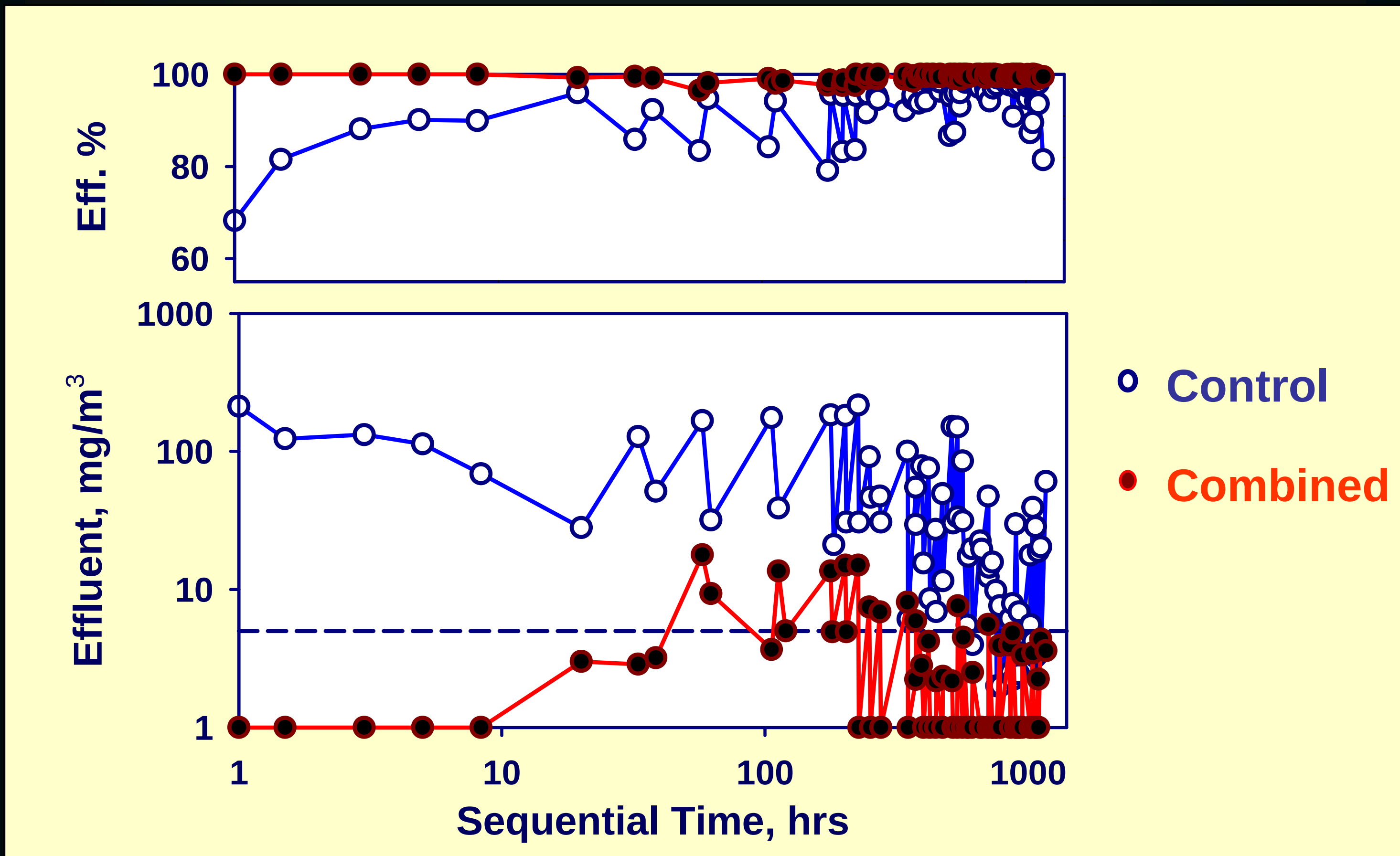
Toluene Removal Performance

Removal Efficiency

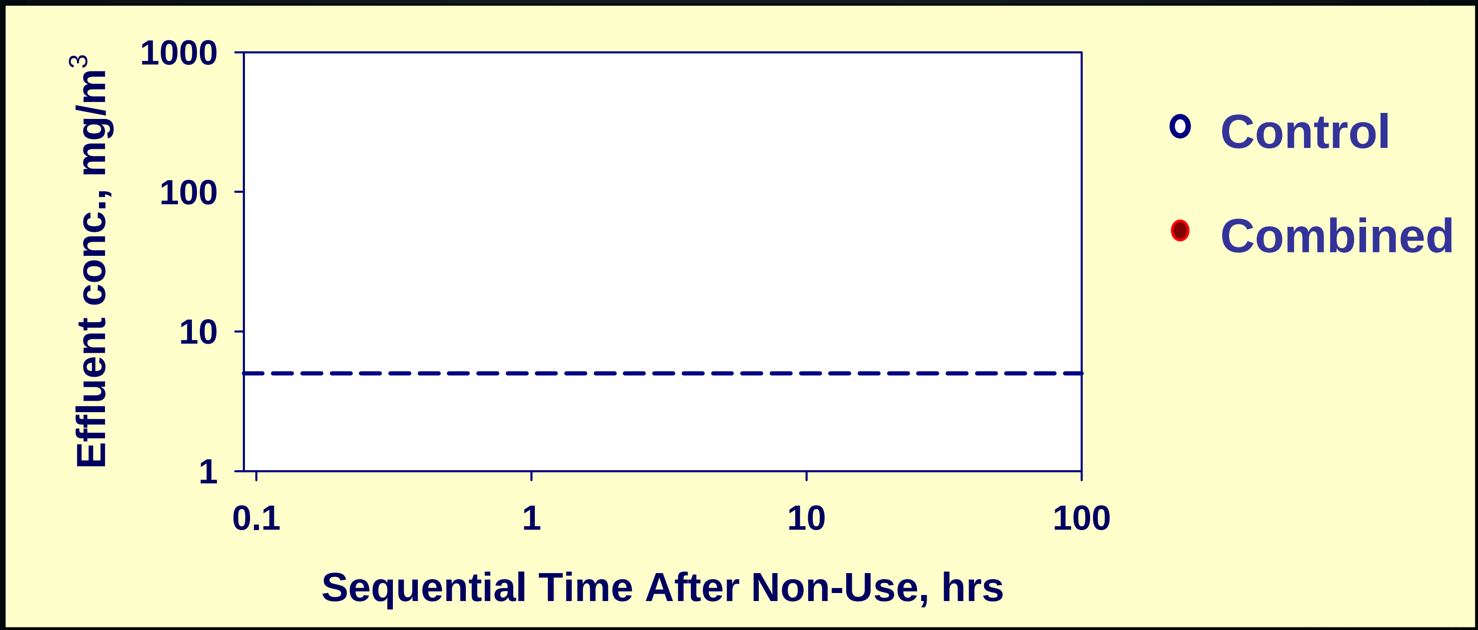


Effect of Non-Use Periods

Effect of Non-Use Periods

Reacclimation

Effluent response after 2 days of starvation



Effect of Non-Use Periods

Reacclimation

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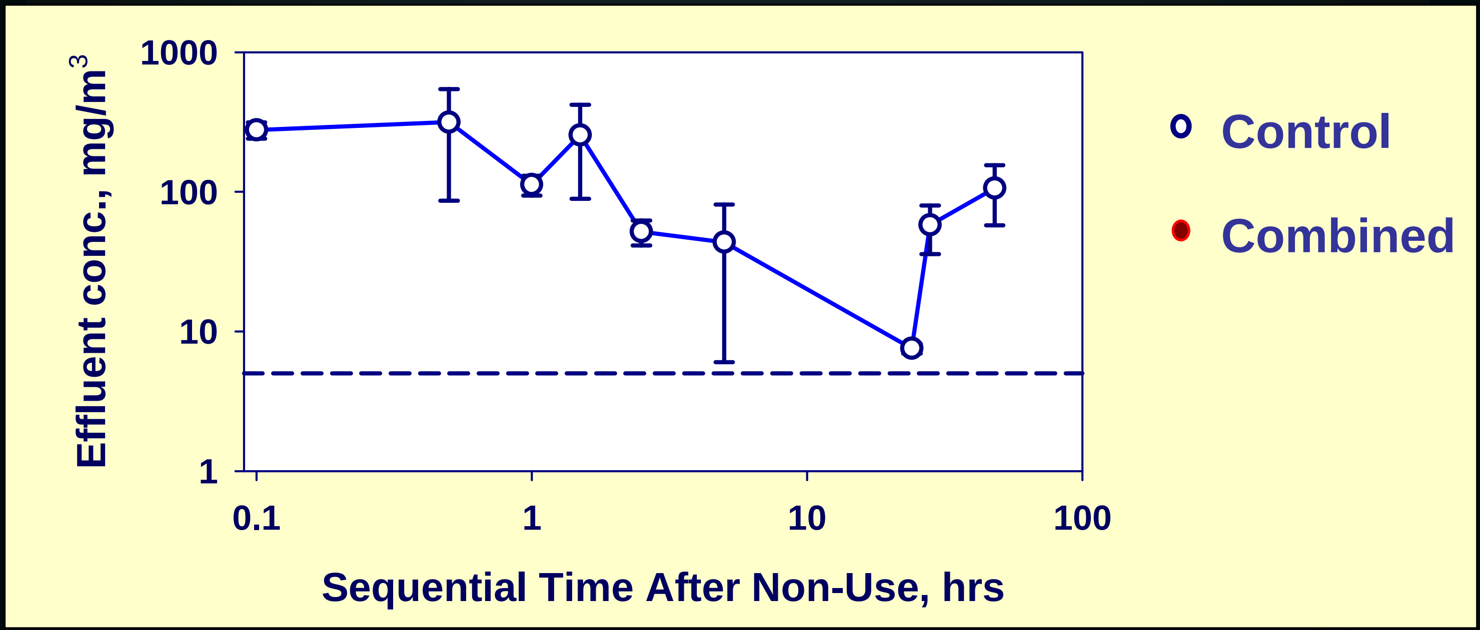

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Reacclimation

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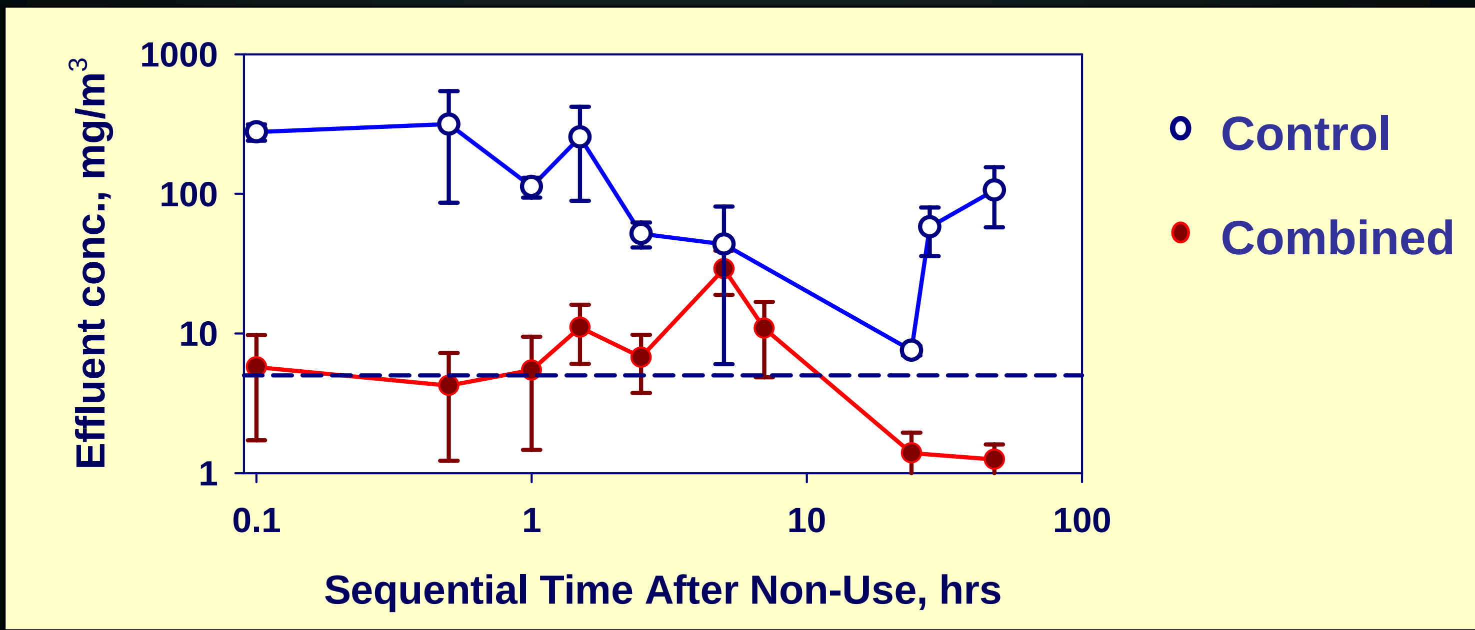


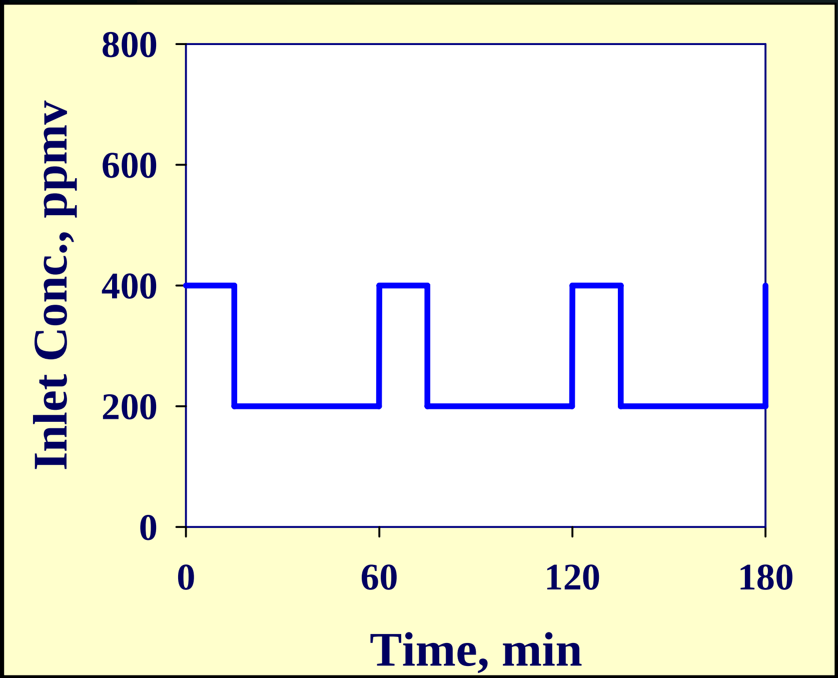
Further Application

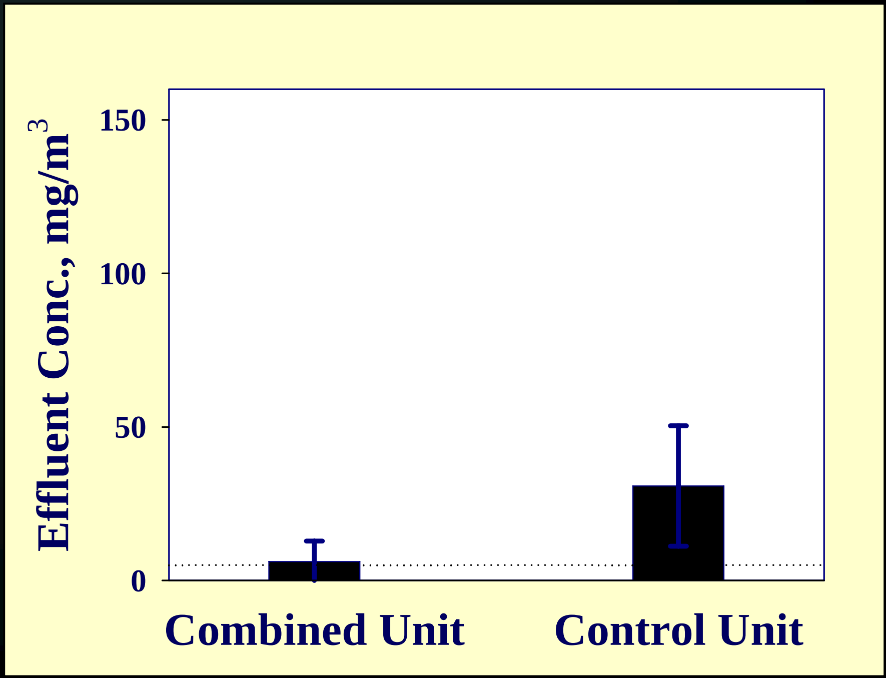
Feeding Conditions

Further Application

Feeding Conditions

- 1st : 46.9 g/m³·hr

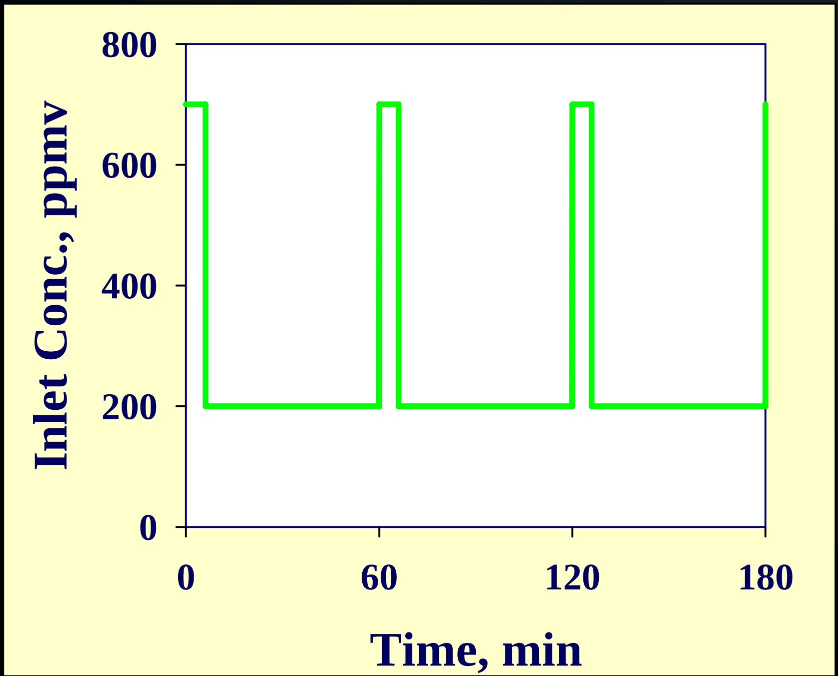


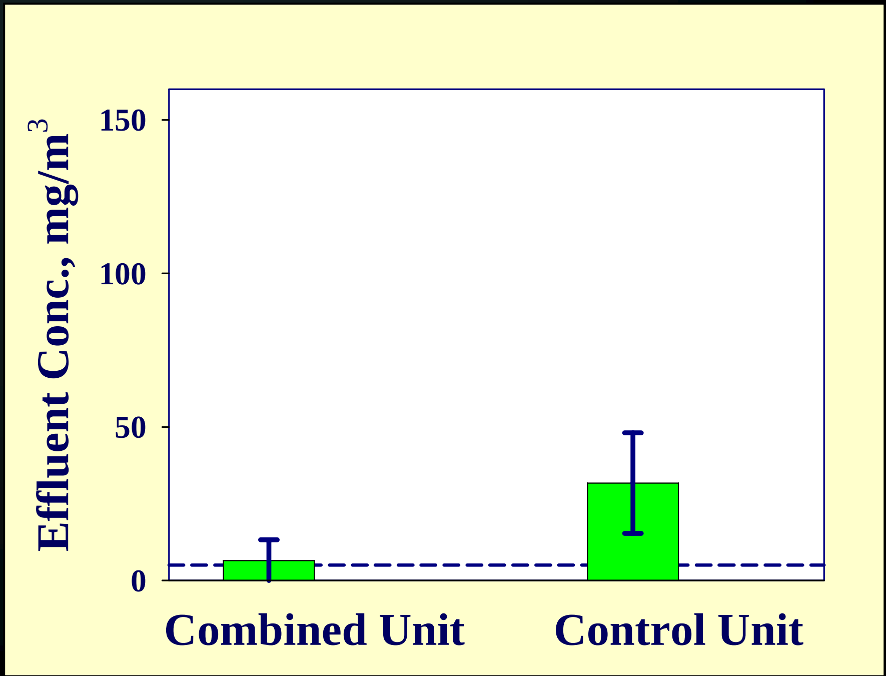


Further Application

Feeding Condition

- 2^{nd} : High concentration of peak, 46.9 g/m^3·hr

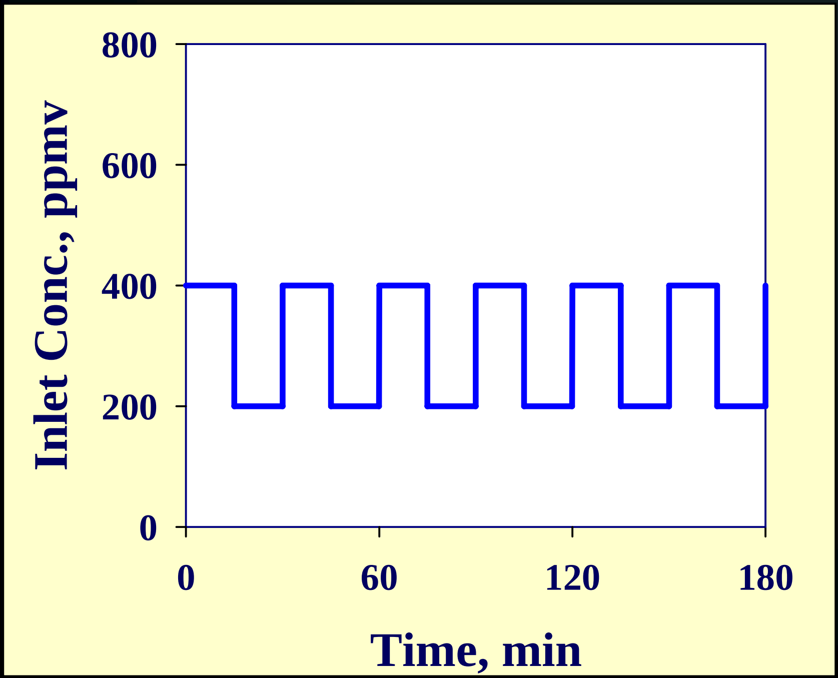


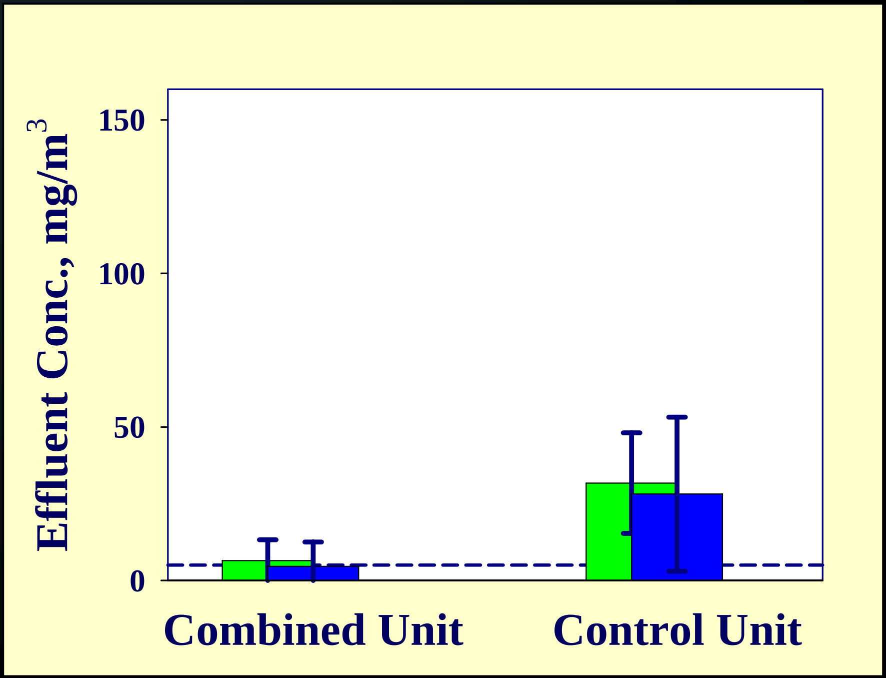


Further Application

Feeding Condition

- 2nd : High concentration of peak, 46.9 g/m³·hr
- 3rd : Frequent peak, 56.3 g/m³·hr

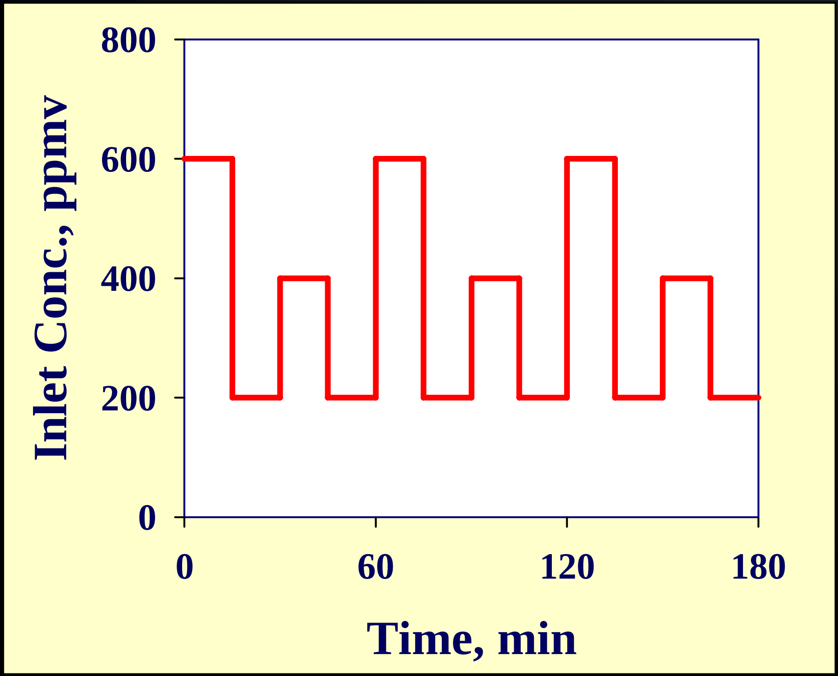


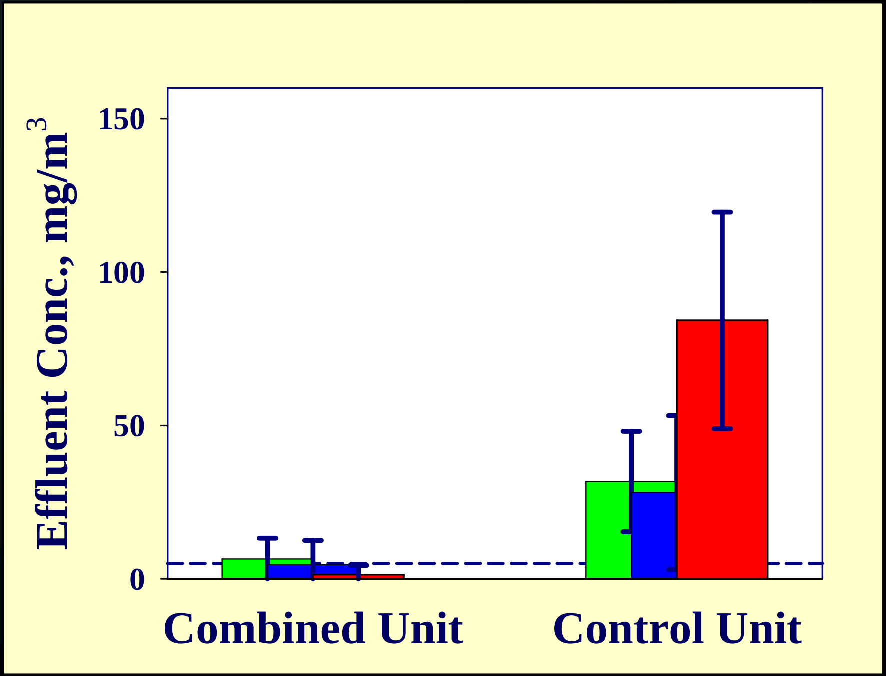


Further Application

Feeding Condition

- 2nd : High concentration of peak, 46.9 $g/m^3 \cdot hr$
- 3rd : Frequent peak, 56.3 $g/m^3 \cdot hr$
- 4th : High con. and frequent peak, 65.9 $g/m^3 \cdot hr$





Conclusion

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Conclusion

1. During unsteady-state loading conditions,
The 2-step of adsorption and desorption cycle in the 2-bed adsorption mitigated the adverse effects of load fluctuation on biofilter performance

2. The 2-Step cycle, i.e., adsorption and desorption, functioned as

- A polishing unit to abate the initial acclimation for the biofilter
- A buffering unit to dampen the biofilter performance
- A feeding source to the biofilter during non-use periods

Conclusion

3. By mitigate the adverse effects of load fluctuation,
   It also has the potential to reduce the total size of the system
   as compared with the single biofilter.

Acknowledgements

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