

A Novel Integrated Scheme for Stabilizing Biological Oxidation Process Performance in Treating Waste Gas Streams

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Introduction

Introduction

VOC: Volatile organic compounds

- Typical air contaminants found in waste gas stream
 - Environmental concern due to their toxicity
 - Serious health problems: cancer
 - Precursor of Ozone (O₃)
- Sources of VOCs
 - Chemical manufacturing
 - Dry cleaners,
 - Paint booths,
 - and other sources using solvent.

Introduction

VOC Control Technology

- Carbon adsorption,
- Liquid scrubbing,
- Condensation,
- Catalytic incineration,
- and Biological oxidation treatment.



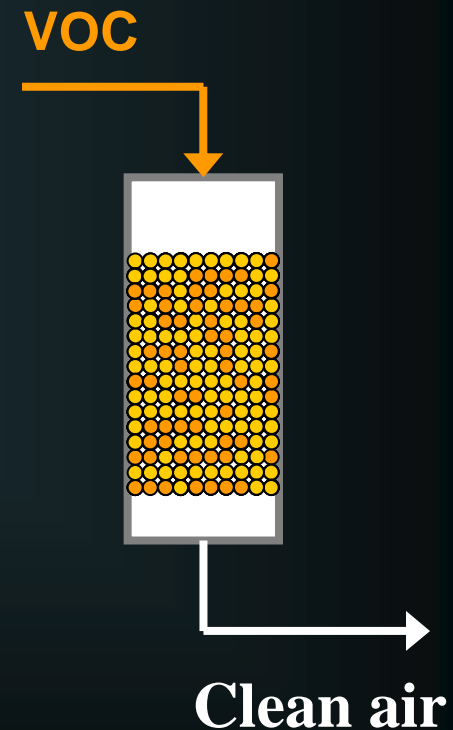
Biological oxidation !!!

Introduction

Biological Oxidation Process

→ Biofiltration

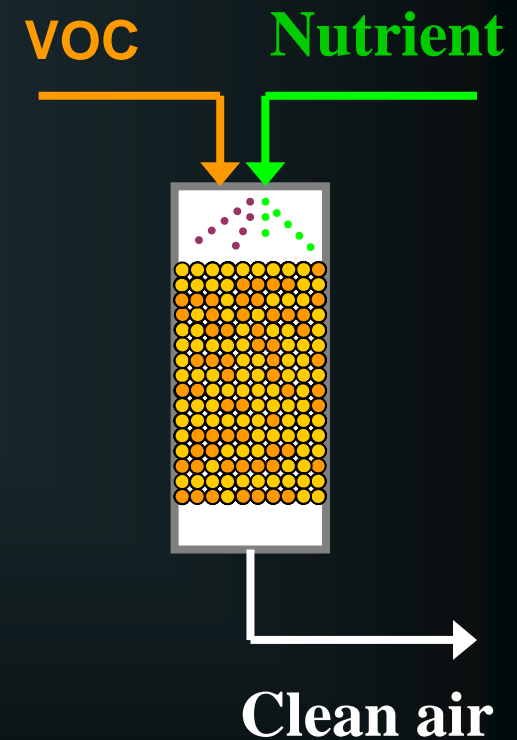
- Typical biological oxidation process
- VOCs are removed through a biologically active media
- Natural organic media (soil, compost)
 - easily exhaust nutrient & buffer capacity
 - long term operation is not practical



Introduction

Trickle Bed Air Biofilter (TBAB)

- Nutrient & buffer control
- Synthetic & inorganic media
 - Optimizing the contaminant utilizing kinetics for microorganisms
 - Long term, high removal performance



Introduction

For more successful application in real industry

 **Load fluctuations**

- Biofilter performance is best at steady loads of contaminants in waste stream
- Practically, waste streams in industry have
 - Variable airflow-rate
 - Variable VOC concentration
 - Non-use periods (e.g. weekend; holidays)

Introduction

Load fluctuation

Solution = Buffer unit

Adsorption unit can be a buffer unit for a biofilter

Current application : **Single bed of carbon filter**

Problems of current adsorption unit

- **High loading & Large fluctuation** → **Losing buffer capacity**
- **Initial period of operation** → **No contaminant to biofilter**

Objective

Objective

Main Objective

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

Specific Objective

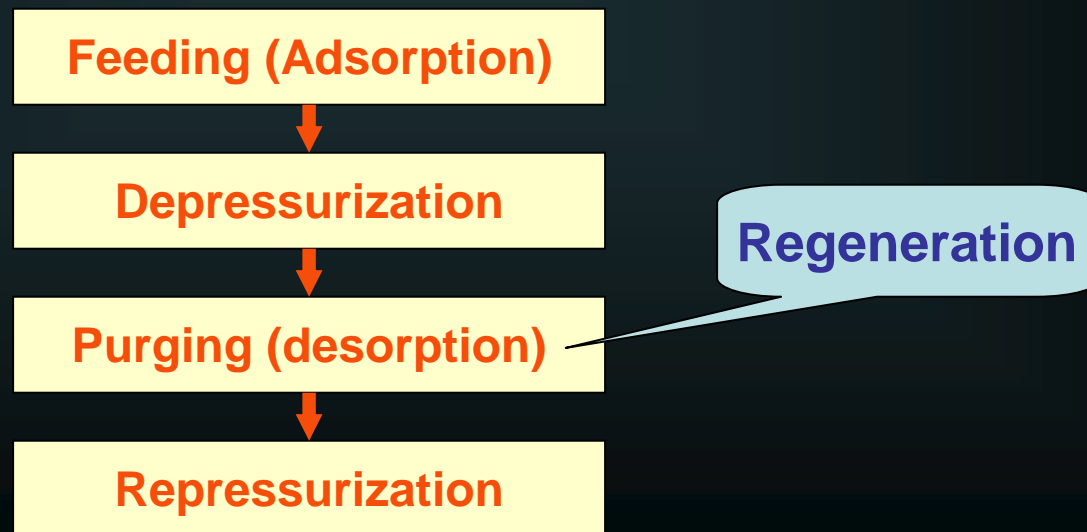
- To evaluate the overall performance of a integrated process scheme (2-bed adsorption unit + Biofilter)
- To be compared with that of a control unit without adsorption unit (Biofilter)

Theory of 2-Bed Adsorption

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



Theory of 2-Bed Adsorption

2-Bed Adsorption Unit

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

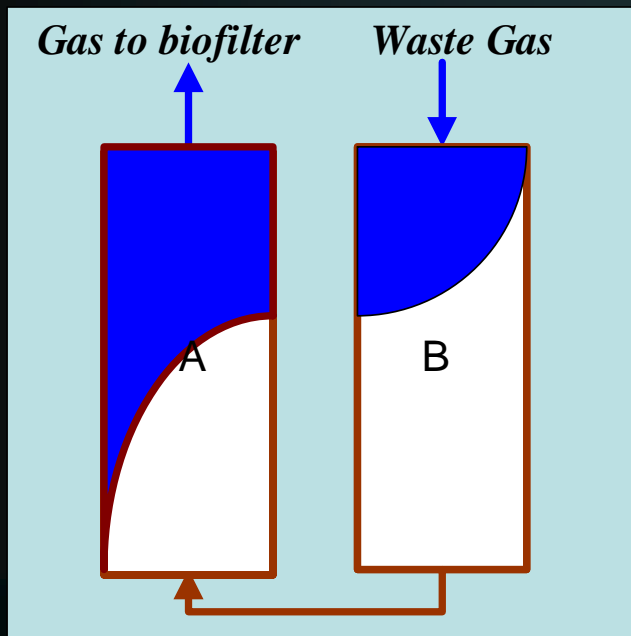


Theory of 2-Bed Adsorption

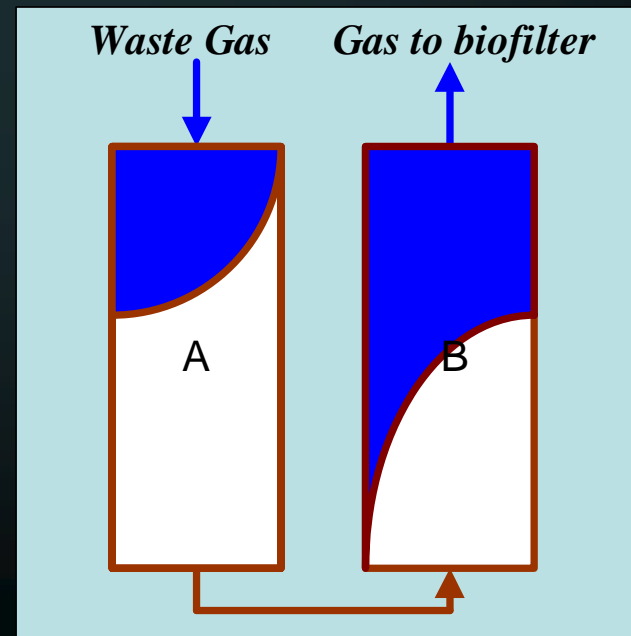
2-Bed Adsorption Unit

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

Clockwise



Counterclockwise



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

Materials and Methods

Feeding Condition

Targeted VOC

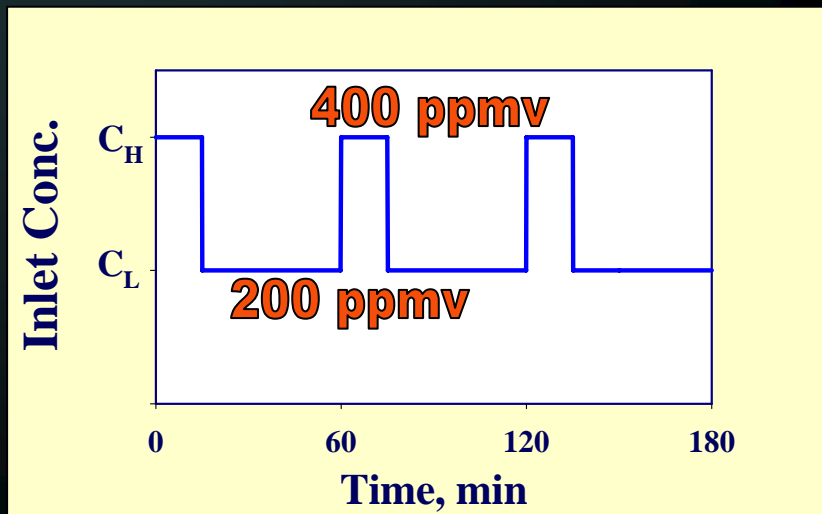
Toluene (C_7H_8)

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

Concentration & Loading

Square Wave Change

- Base = 200 ppmv
- Peak = 400 ppmv (15 mins / hour)
- Average concentration : 250 ppmv
- Average loading rate : 46.9 g/m³·hr



Feeding Condition

Targeted VOC

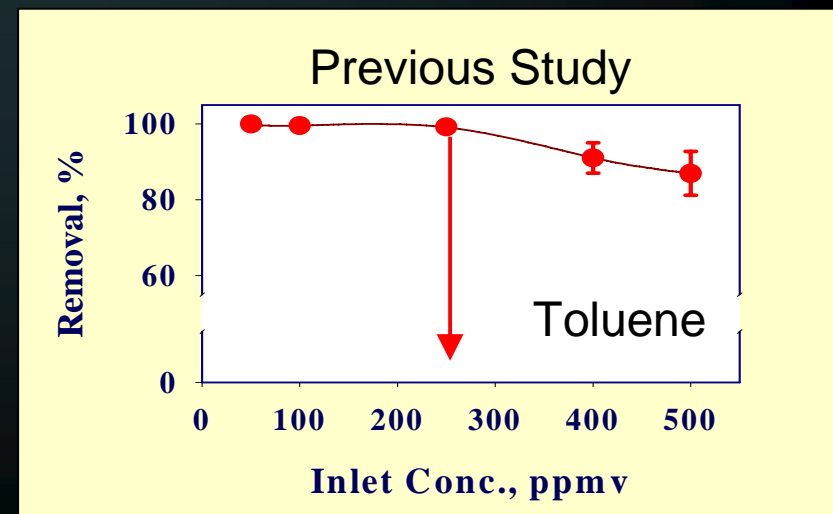
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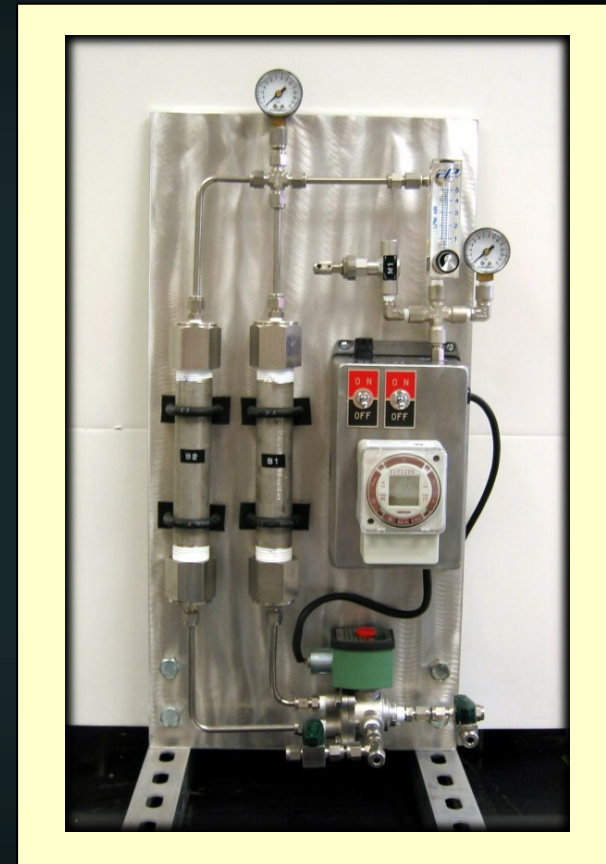


Materials and Methods

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 mesh)



Materials and Methods

Biofilter

Trickle Bed Air Biofilter (TBAB)

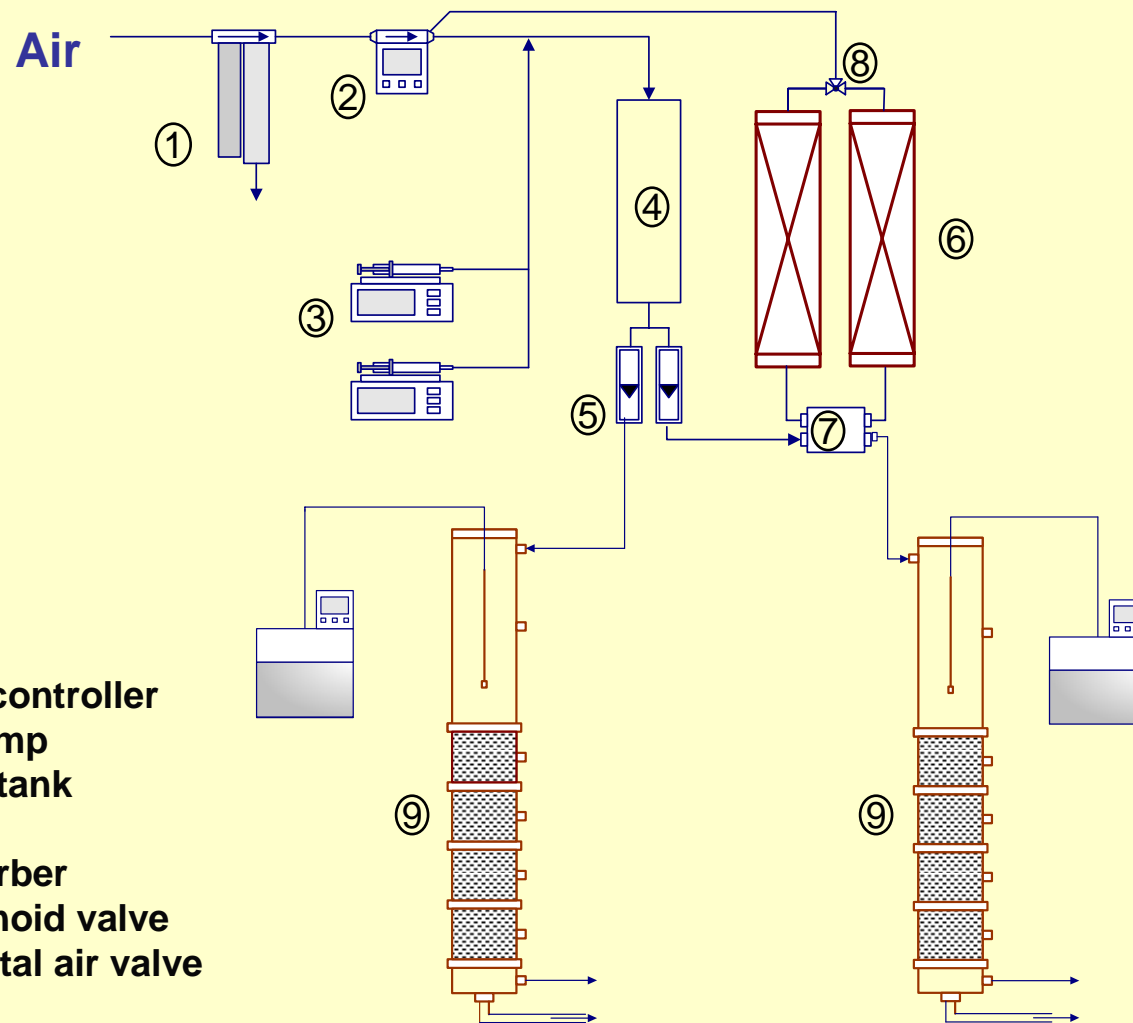
- Dimension : 76 mm (D) × 130 cm (L)
- Buffered nutrient solution supply
- Operating Temp. : 20 °C
- EBRT: 1.2 min (2.2L/min)

Media

- Celite® 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



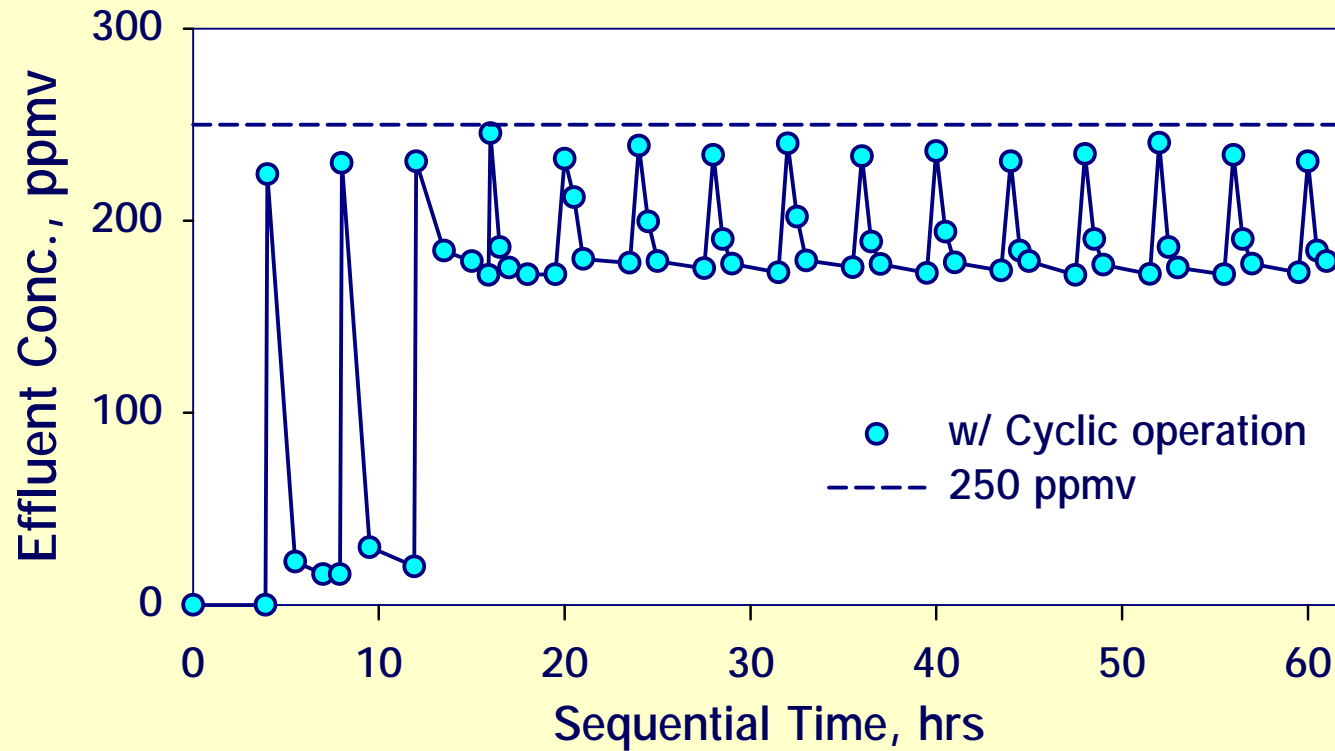
1. Air cleaner
2. Mass flow controller
3. Syringe pump
4. Equalizing tank
5. Flow meter
6. 2-bed adsorber
7. 4-way solenoid valve
8. Supplemental air valve
9. Biofilter

Control Unit

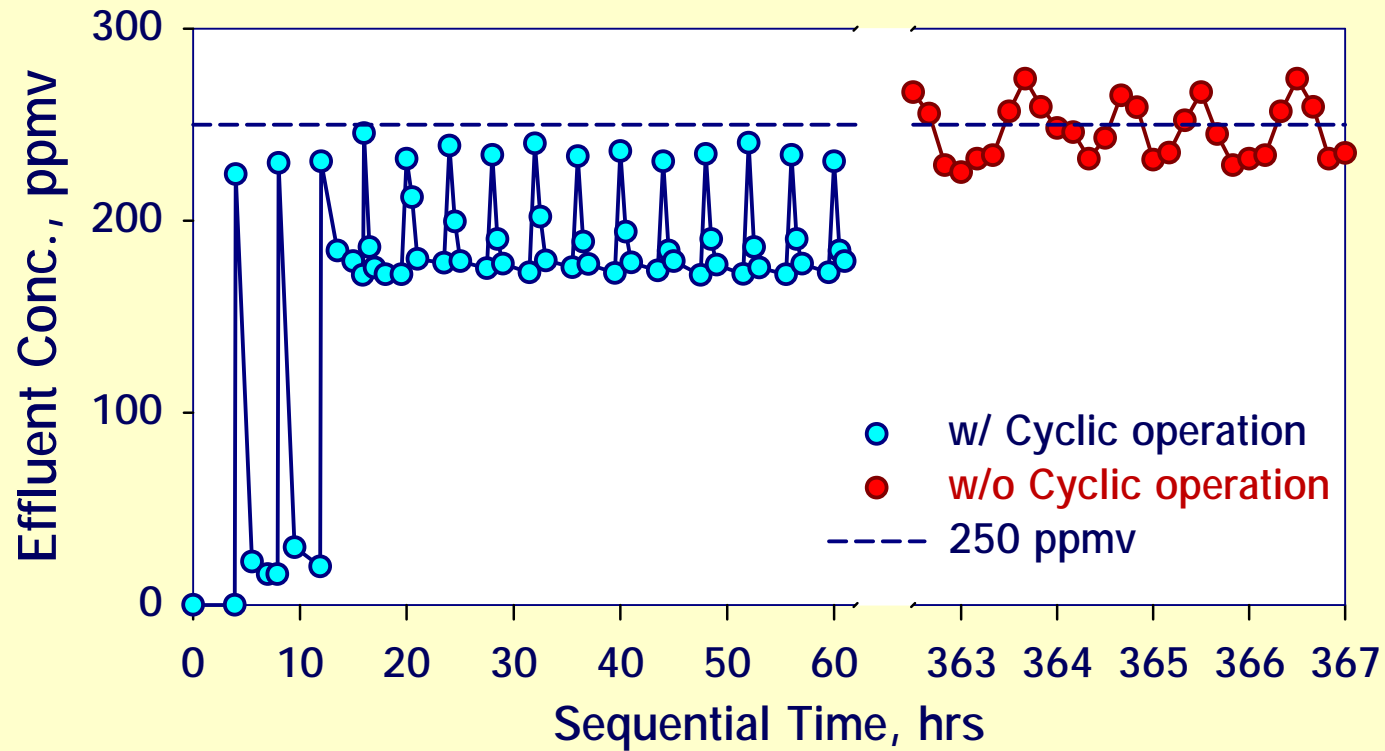
Combined Unit

Experimental Results

2-Bed Adsorption Performance

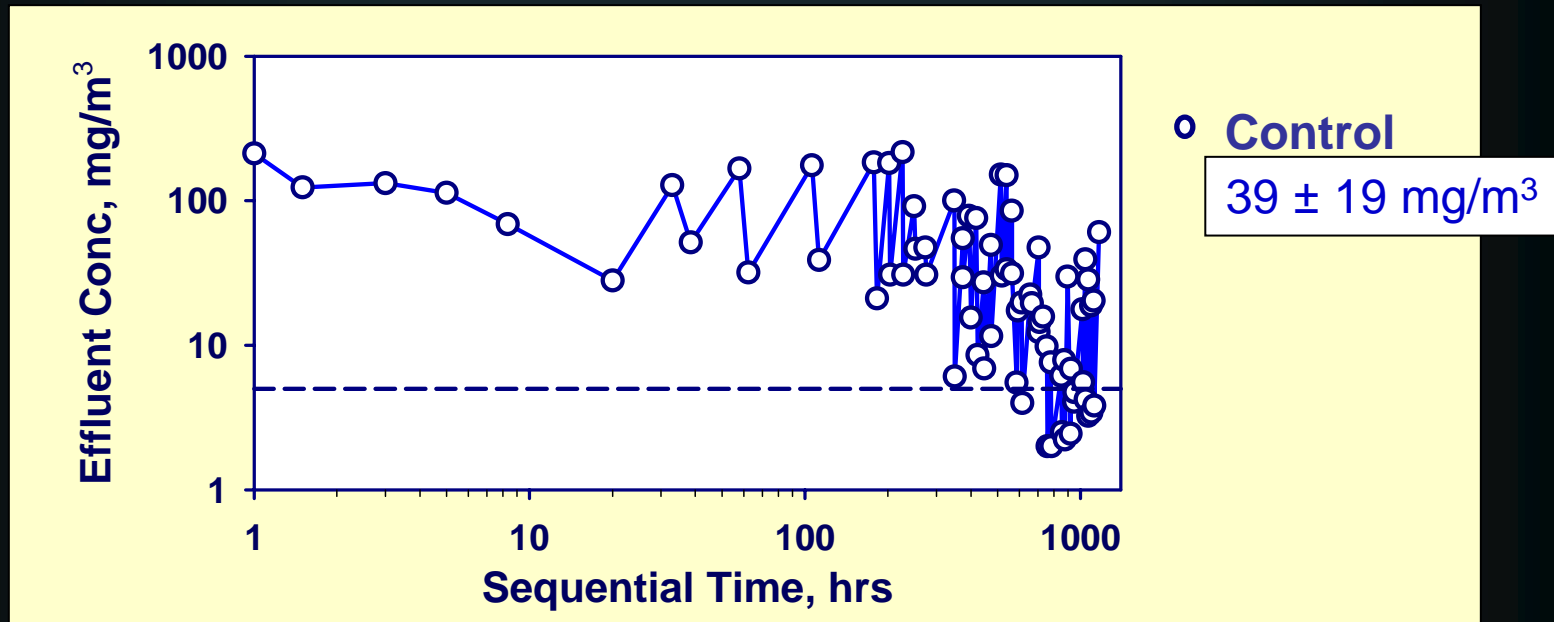


2-Bed Adsorption Performance



Toluene Removal Performance

Effluent Concentration

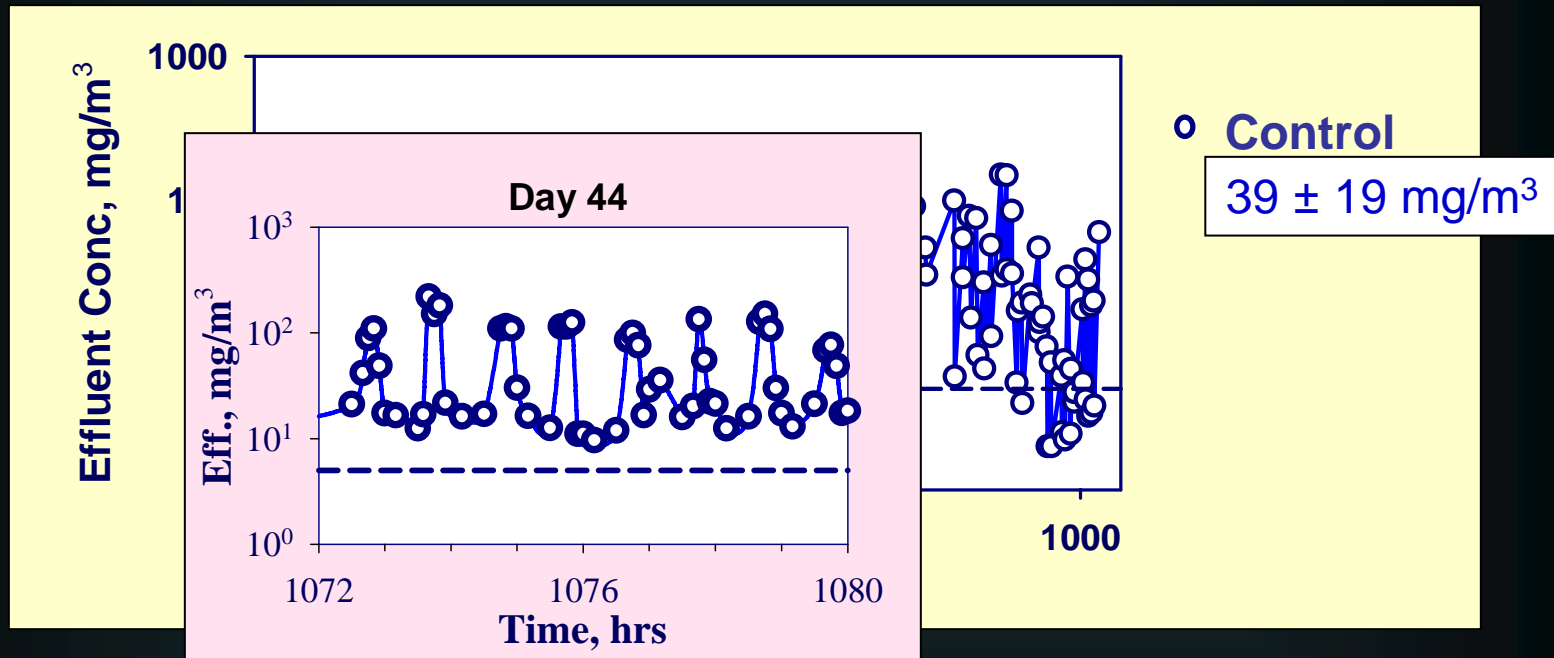


Exposure guideline (10 hrs average) : **5 mg/m³**

(issued by American Industrial Hygiene Association)

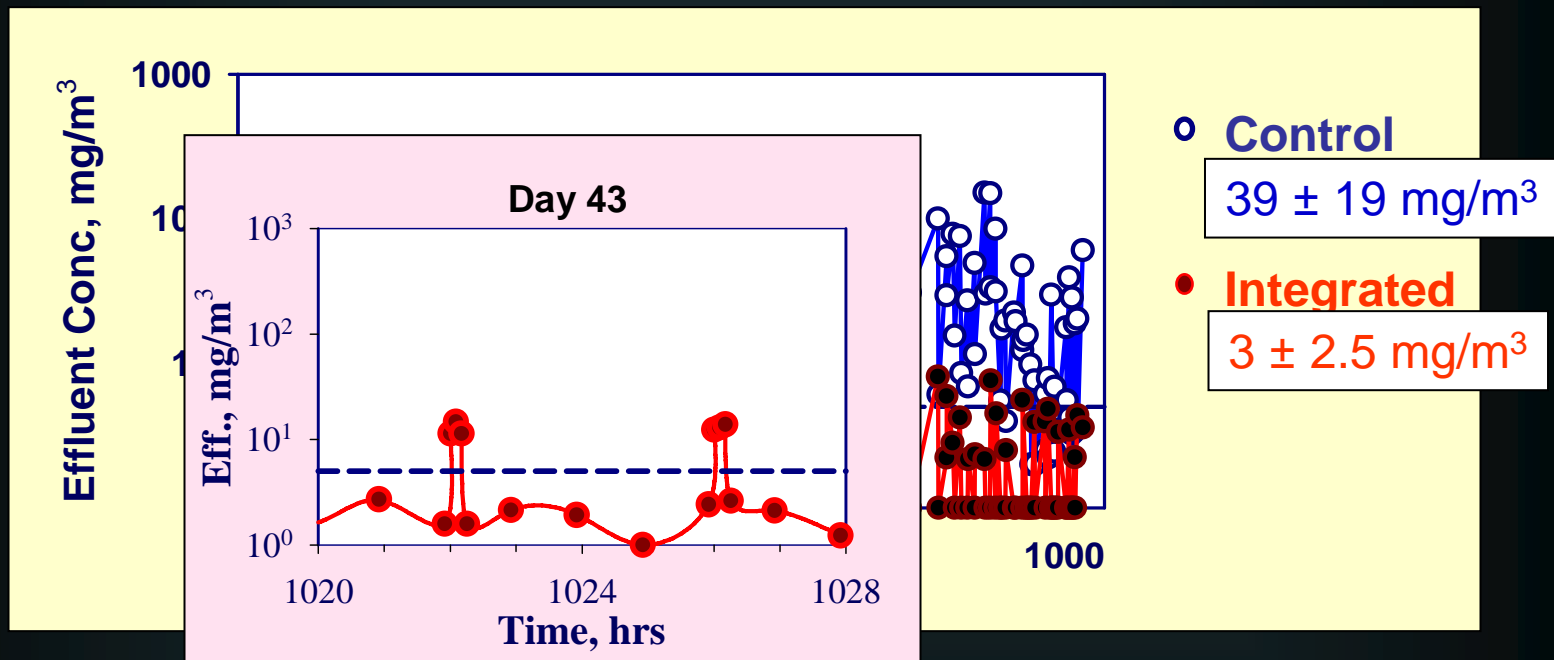
Toluene Removal Performance

Effluent Concentration



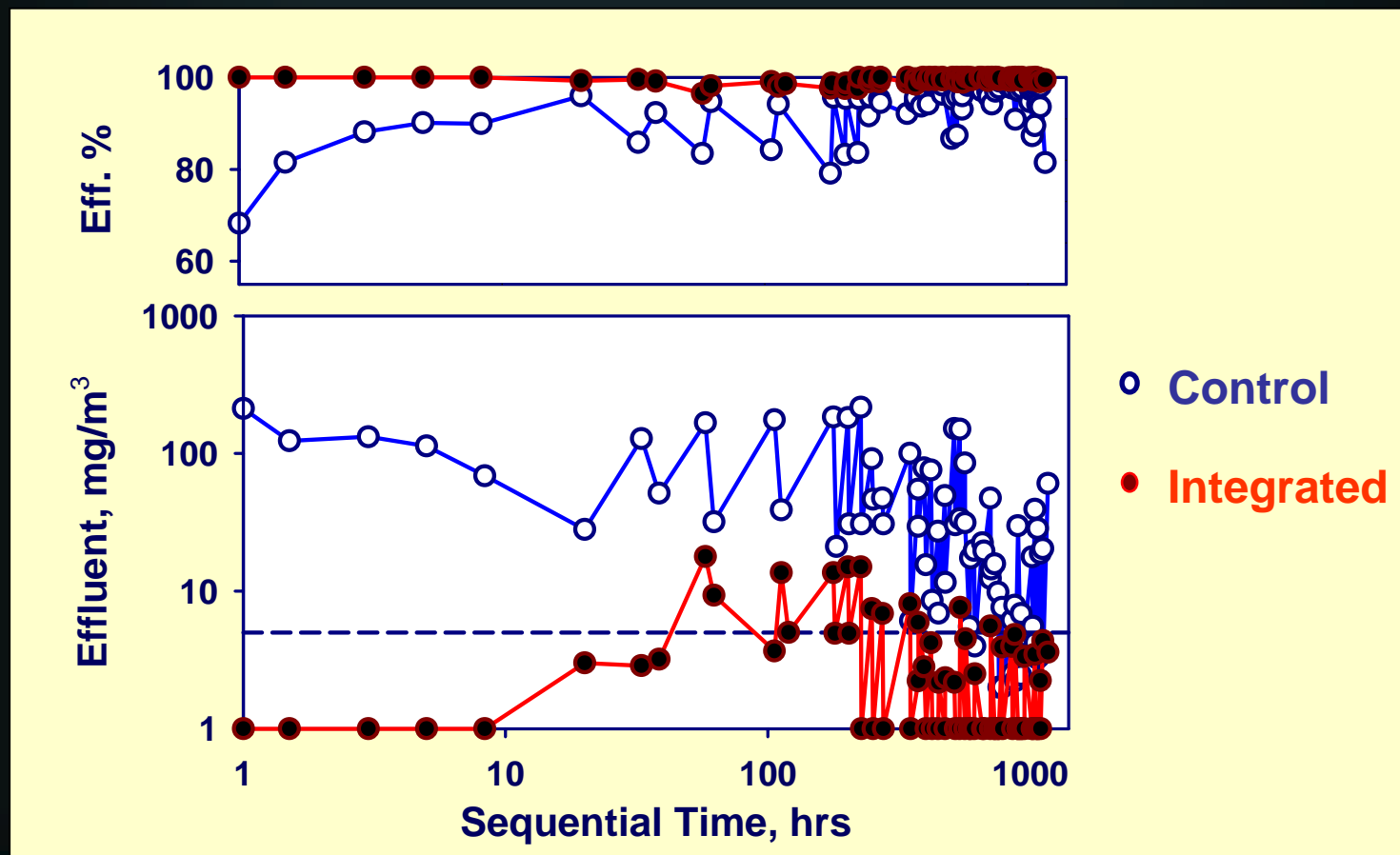
Toluene Removal Performance

Effluent Concentration



Toluene Removal Performance

Removal Efficiency

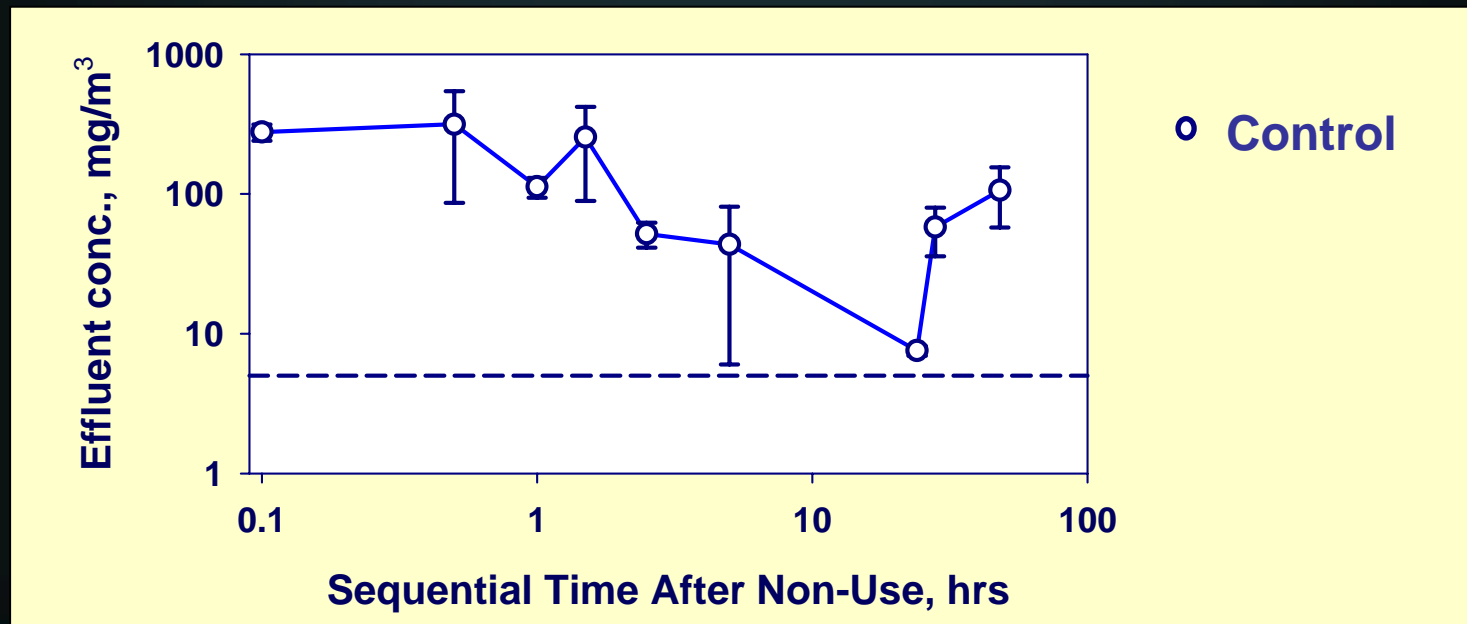


Effect of Non-Use Periods

Effect of Non-Use Periods

Reacclimation

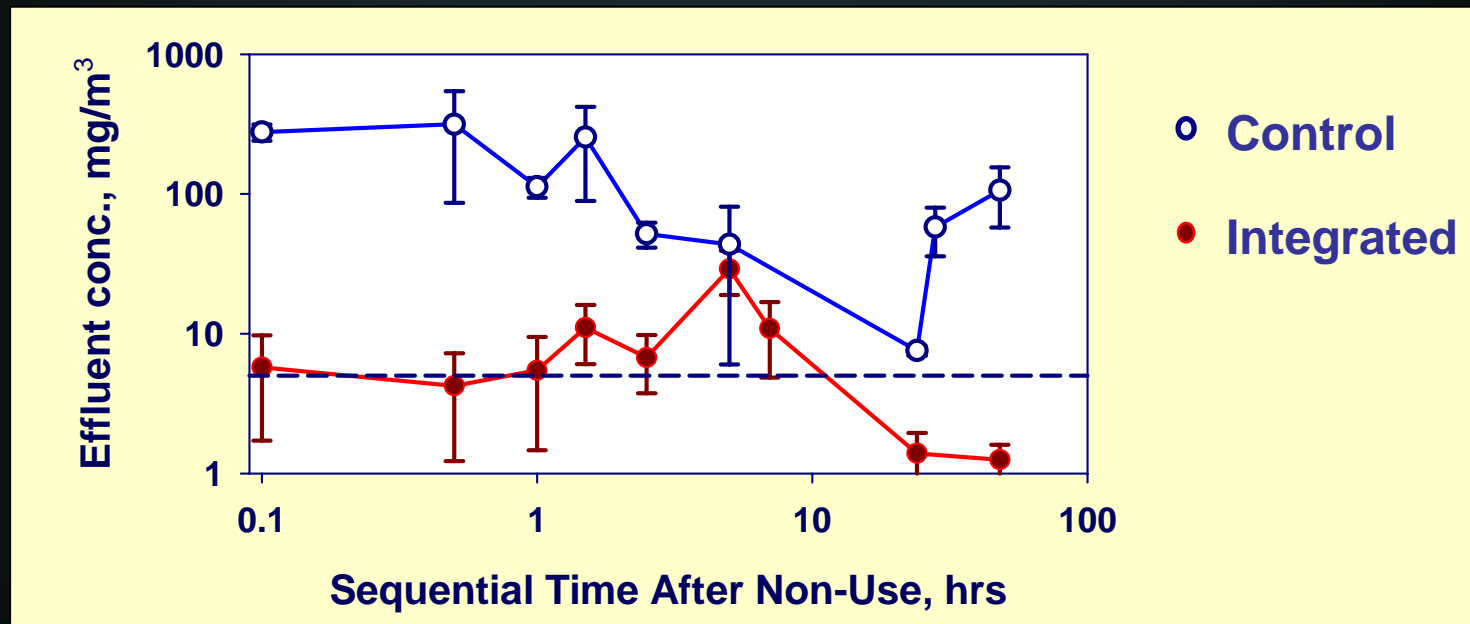
Effluent response after 2 days of starvation



Effect of Non-Use Periods

Reacclimation

Effluent response after 2 days of starvation

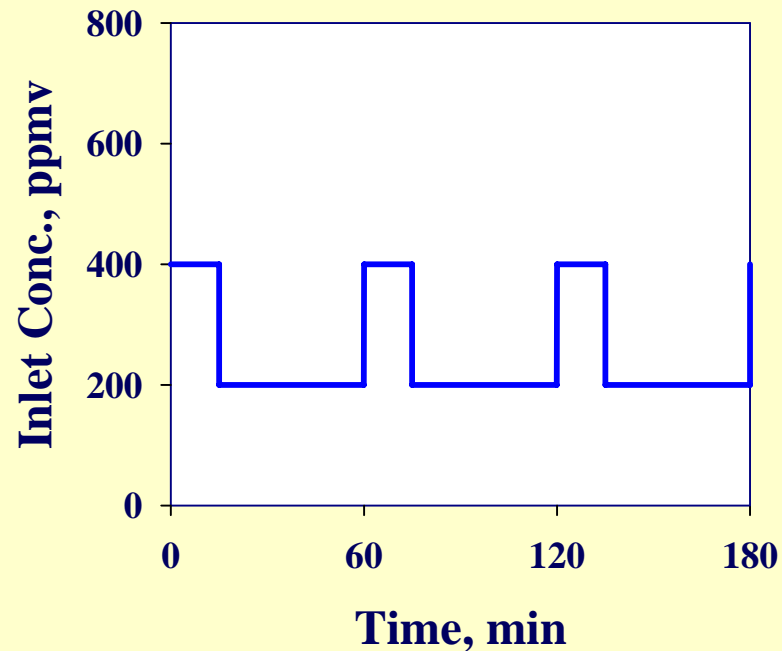


Further Application

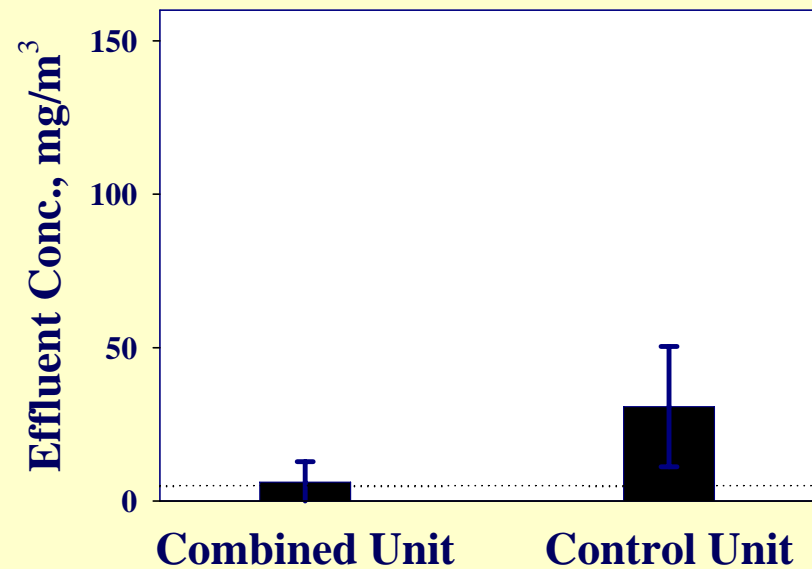
Further Application

Feeding Conditions

- 1st : 46.9 g/m³-hr
 - Peak: 400 ppmv for 15 mins
 - Base: 200 ppmv for 45 mins



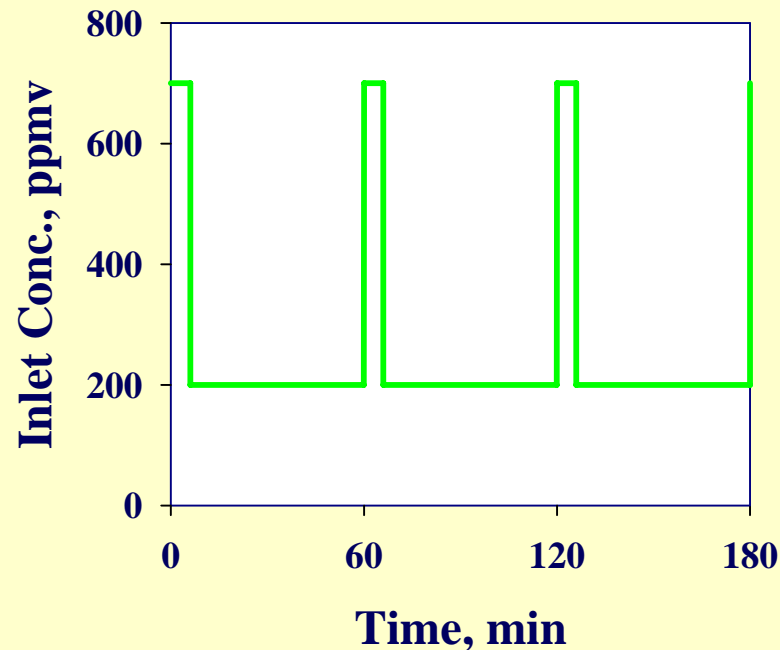
Results (8-hrs average)



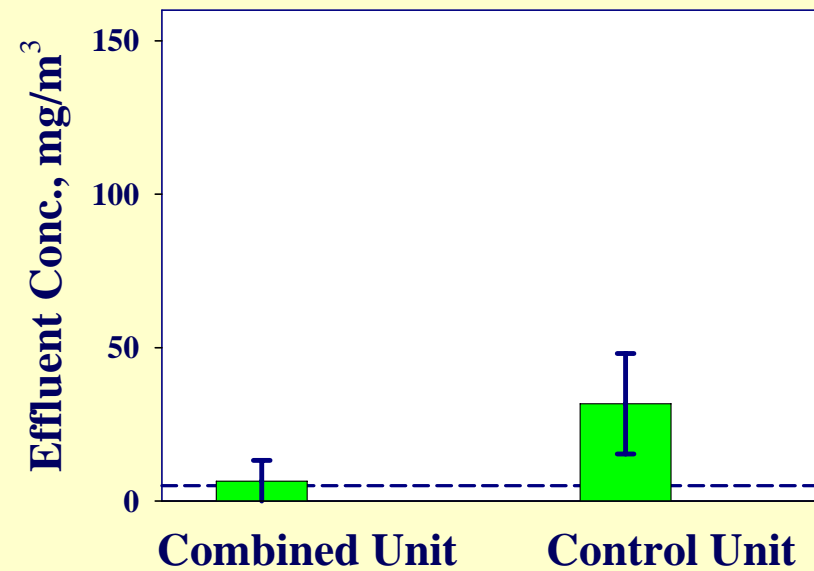
Further Application

Feeding Condition

- 2nd : High concentration of peak, 46.9 g/m³·hr
Peak: 700 ppmv for 6 mins
Base: 200 ppmv for 54 mins



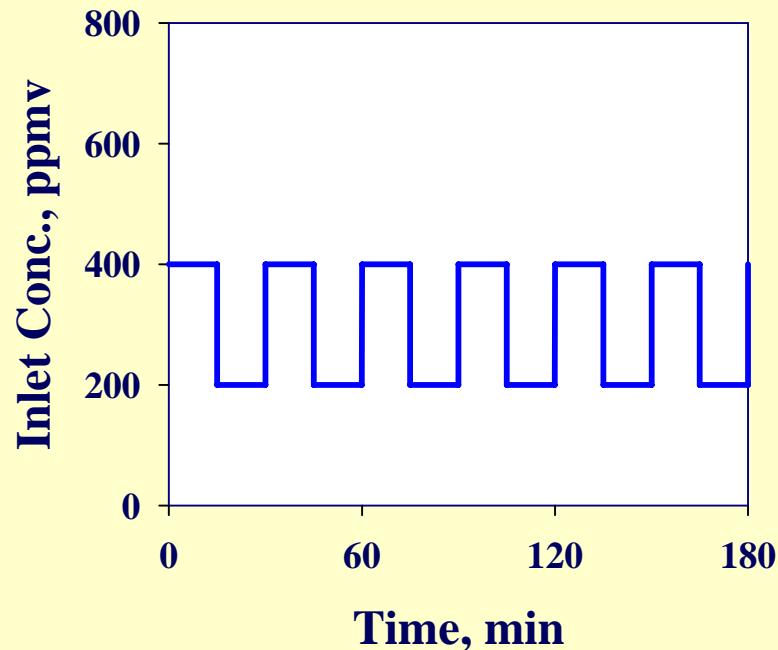
Results (8-hrs average)



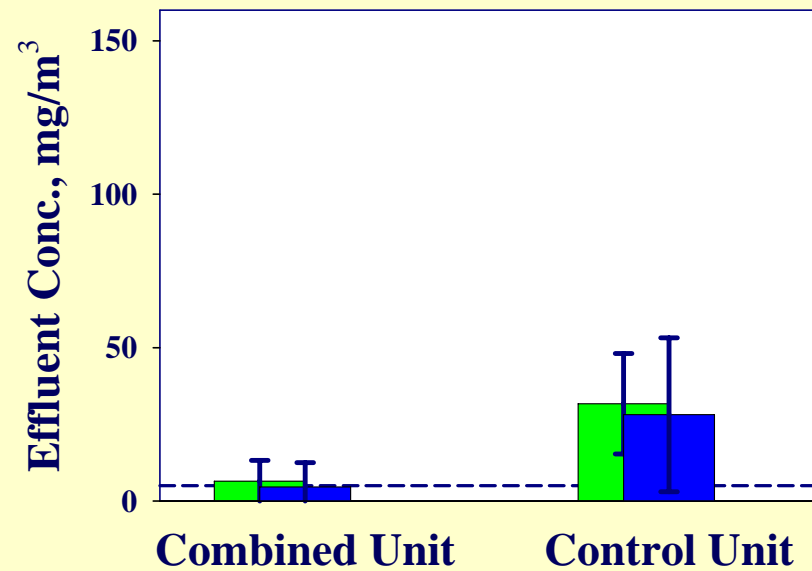
Further Application

Feeding Condition

- 3rd : **Frequent peak**, 56.3 g/m³·hr
Peak: 400 ppmv for 30 mins
Base: 200 ppmv for 30 mins



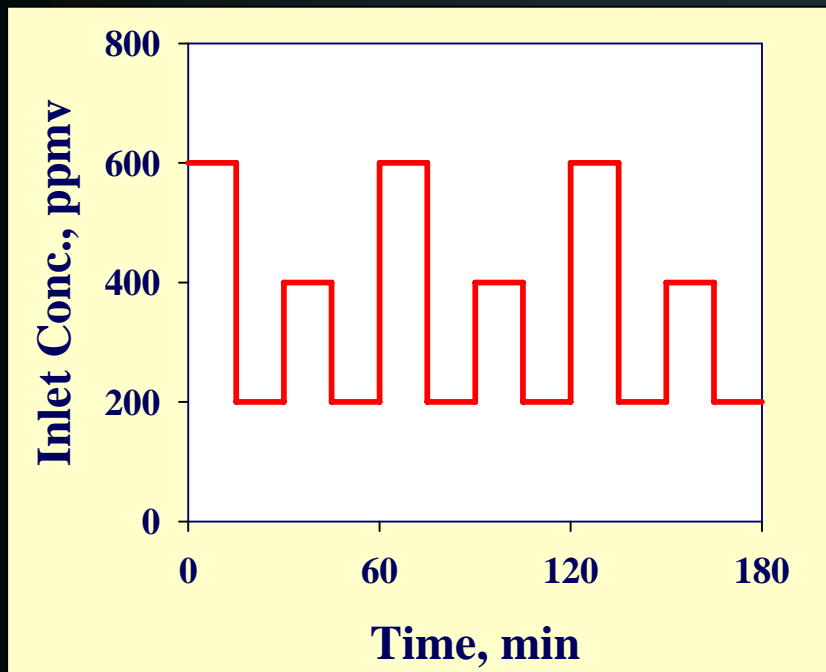
Results (8-hrs average)



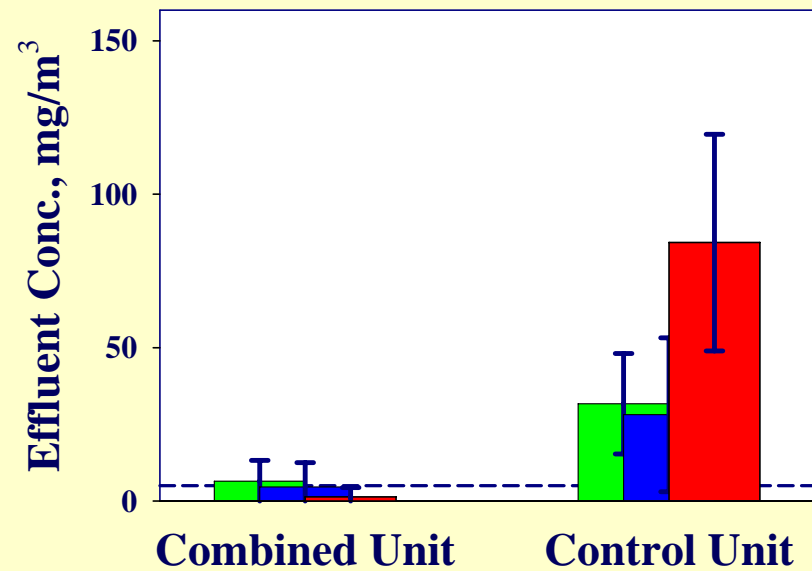
Further Application

Feeding Condition

- 4th : **High & Frequent peak**, 65.9 g/m³·hr
Peak: 600 ppmv for 15 mins & 400 ppmv for 15 mins
Base: 200 ppmv



Results (8-hrs average)



Conclusion

Conclusion

During unsteady-state loading conditions,

The **2-step of adsorption and desorption cycle** in a 2-bed adsorption mitigated the adverse effect of load fluctuation on biofilter performance

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

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