

**A&WMA's 99th Annual Conference and Exhibition**

**Treatment of VOC Mixture in a Trickle-Bed Air Biofilter  
Integrated with Cyclic Adsorption/Desorption Beds**

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- **Introduction**
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- **Materials and Methods**
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# Introduction

## **2-Bed Adsorption/Desorption Unit**

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

## Main Objective

Propose and apply a new technology by integrating a trickle-bed air biofilter with cyclic adsorption/desorption beds to maintain long-term high level VOC removal

## Specific Objectives

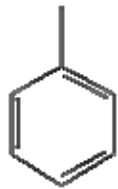
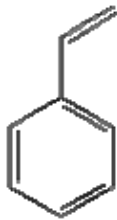
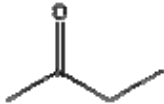

- To evaluate the overall performance of a combined process scheme (2-bed adsorption unit + Biofilter)
- To compare with that of a control unit without adsorption unit (Biofilter only)

# Materials and Methods

## ➤ Feed VOCs Mixture

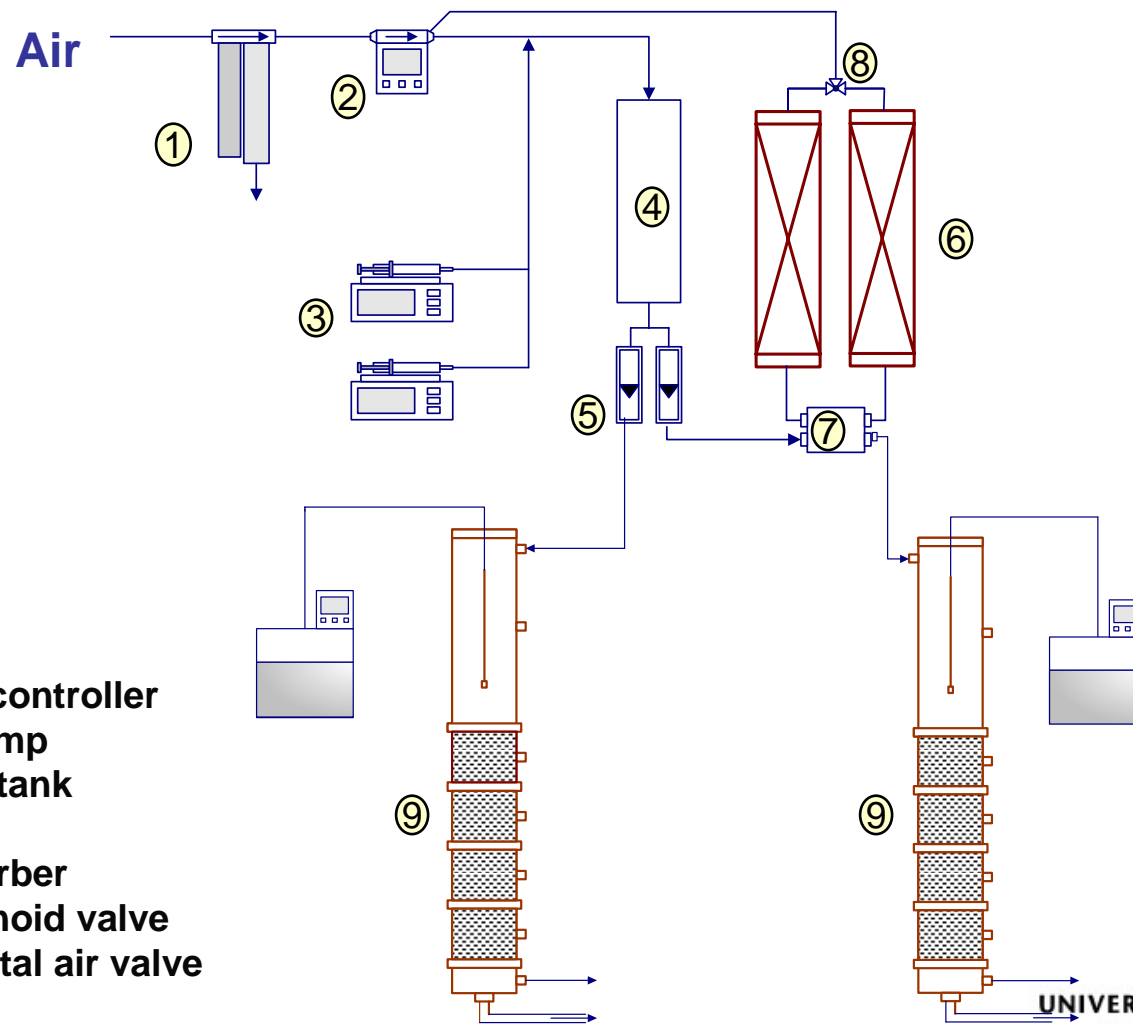
**Toluene: Styrene: MEK: MIBK = 0.448: 0.260: 0.234: 0.058**

*(EPA 2003 toxic release report for chemical industries )*

|                      | Aromatic compounds   |  | Oxygenated compounds   |  |
|----------------------|--|--|--|--|
|                      | Toluene  | Styrene  | Methyl ethyl ketone (MEK)  | Methyl isobutyl ketone (MIBK)  |
|                      |  |  |  |  |
| $K'_H$               | 0.280  | 0.109  | 0.00194  | 0.00062  |
| $\text{Log } K_{ow}$ | 2.58   | 3.16   | 0.28   | 1.09   |

$K'_H$  = dimensionless Henry's law constant,  $K_{ow}$  = Octanol-water partition coefficient

# Materials and Methods



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

# Materials and Methods

## ***Adsorption Unit***

- 2 Beds
- Dimension : 2.5 cm (D) × 20 cm (L)
- Duration of one cycle : 8 hours
- EBRT: 9.1 sec (1.35 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 °C
- EBRT: 2.0 min (1.35L/min)

### Media

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





# Materials and Methods

## ➤ Operating conditions

### Square Wave Change

- Base = 250 ppmv
- Peak = 500 ppmv (12 mins / hour)
- Average concentration : 300 ppmv

### Square Wave Change

- Base = 250 ppmv
- Peak = 700 ppmv (7 mins / hour)
- Average concentration : 300 ppmv

### Square Wave Change

- Base = 250 ppmv
- Peak = 500 ppmv (2 × 12 mins / hr)
- Average concentration : 350 ppmv

### Square Wave Change

- Base = 300 ppmv
- Middle = 500 ppmv (15 mins/hour)
- Peak = 700 ppmv (15 mins / hour)
- Average concentration : 450 ppmv

# Materials and Methods

## ■ Biomass control

- Backwashing : 1 hour of duration / week
- Starvation: two days / week

# Treatment of VOC Mixture in a Trickle-Bed Air Biofilter Integrated with Cyclic Adsorption/Desorption Beds

## Experimental Results

- Performance review
- Starvation effect
- Kinetics analysis

# Treatment of VOC Mixture in a Trickle-Bed Air Biofilter Integrated with Cyclic Adsorption/Desorption Beds

## Experimental Results

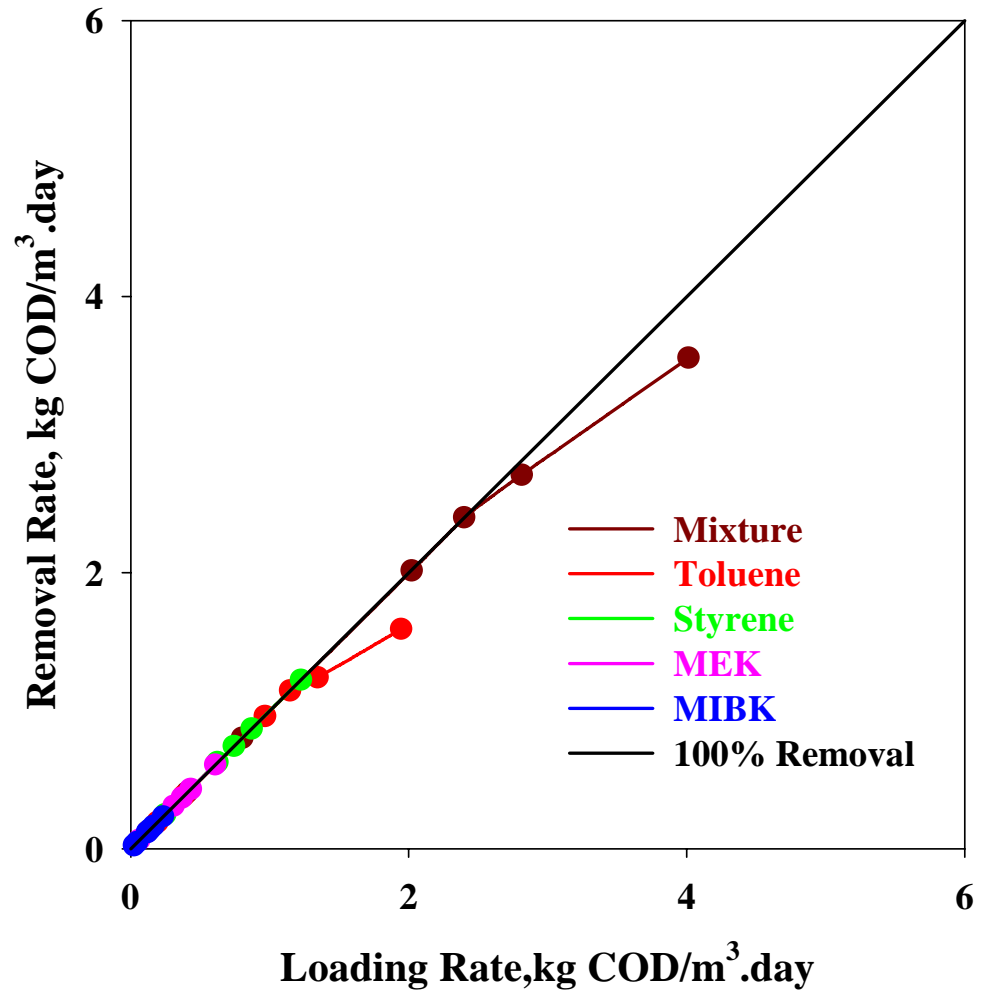
- Performance review

# Summary of Previous Mixture Study

- **Critical loading**  
2.4 kg COD/m<sup>3</sup>·day  
(34.0 g/m<sup>3</sup>·hr)
- **Maximum removal capacity**  
3.6 kg COD/m<sup>3</sup>·day  
(50.7 g/m<sup>3</sup>·hr)

EBRT: 2.02 min

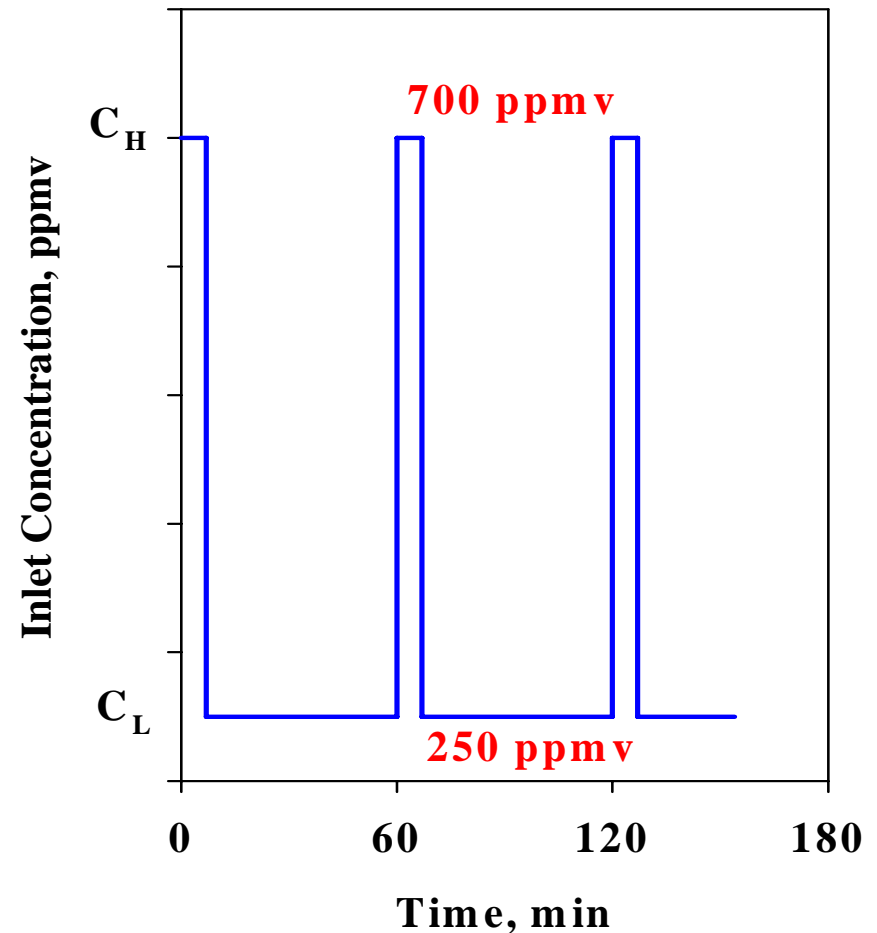
→ Inlet Conc. = 300 ppmv



# Results First square wave

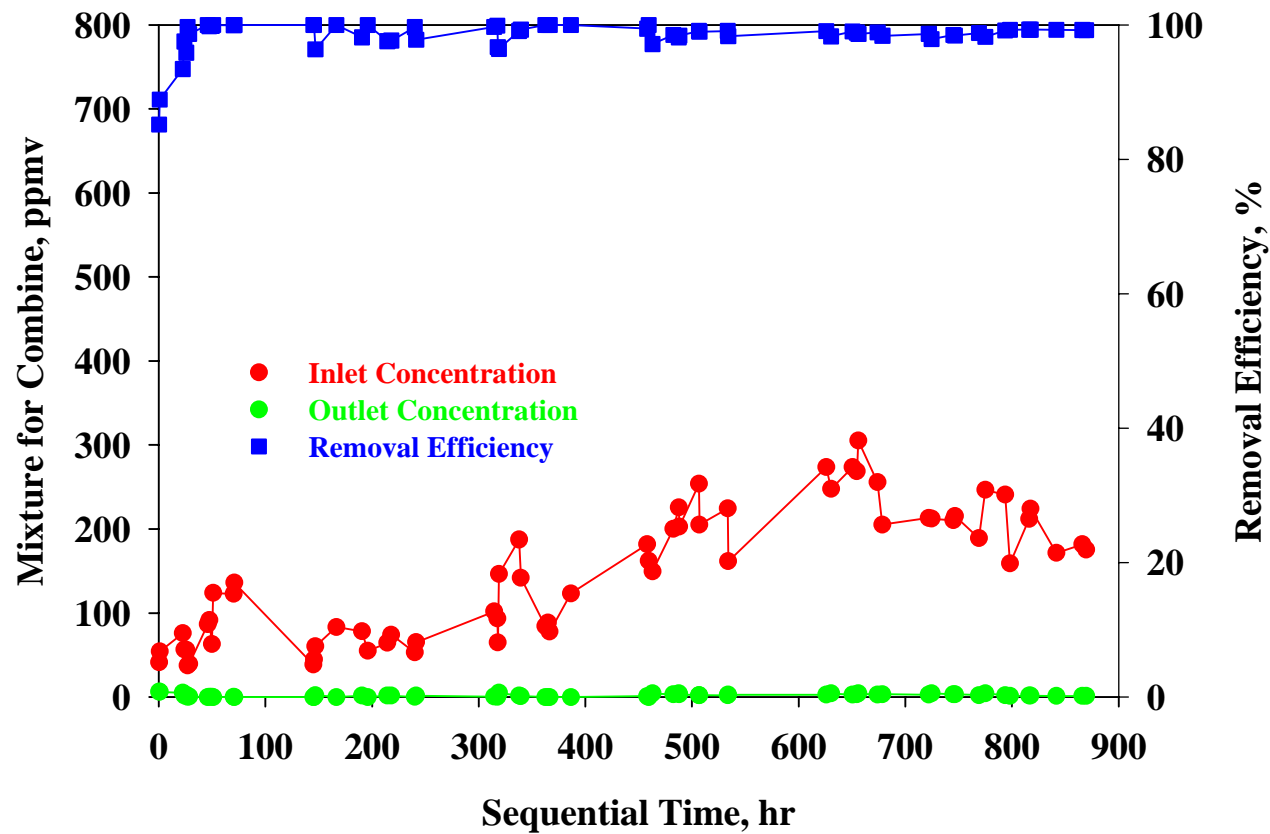
## Square Wave Change

- Base = 250 ppmv
- Peak = 700 ppmv (7 mins / hour)
- Average concentration : 300 ppmv
- Average Total Loading = 34.0 g/m<sup>3</sup>.hr
- Toluene Loading = 15.4 g/m<sup>3</sup>.hr
- Styrene Loading = 10.1 g/m<sup>3</sup>.hr
- MEK Loading = 6.3 g/m<sup>3</sup>.hr
- MIBK Loading = 2.2 g/m<sup>3</sup>.hr

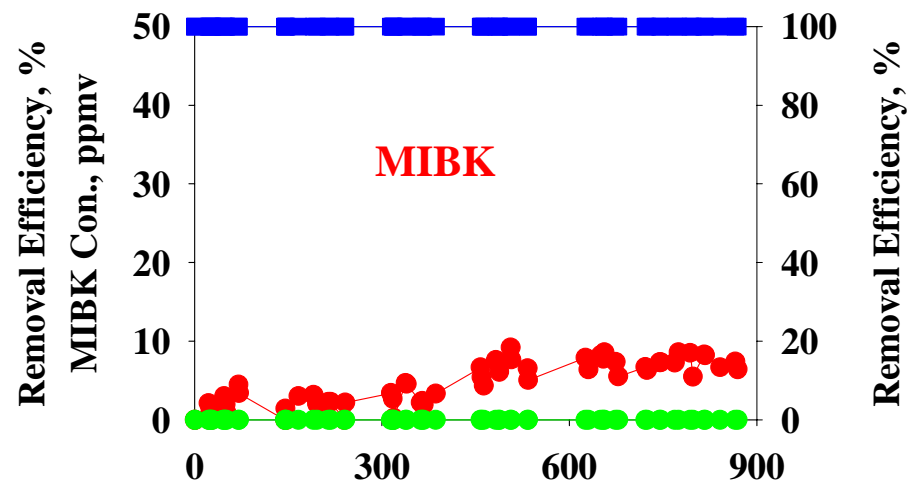
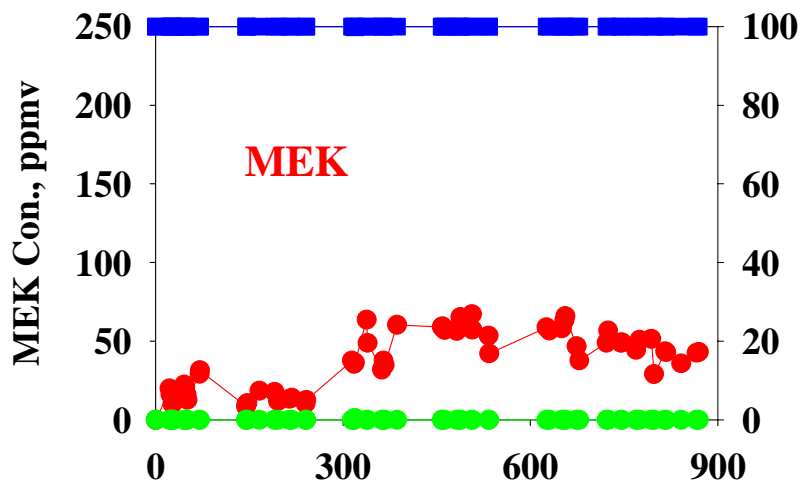
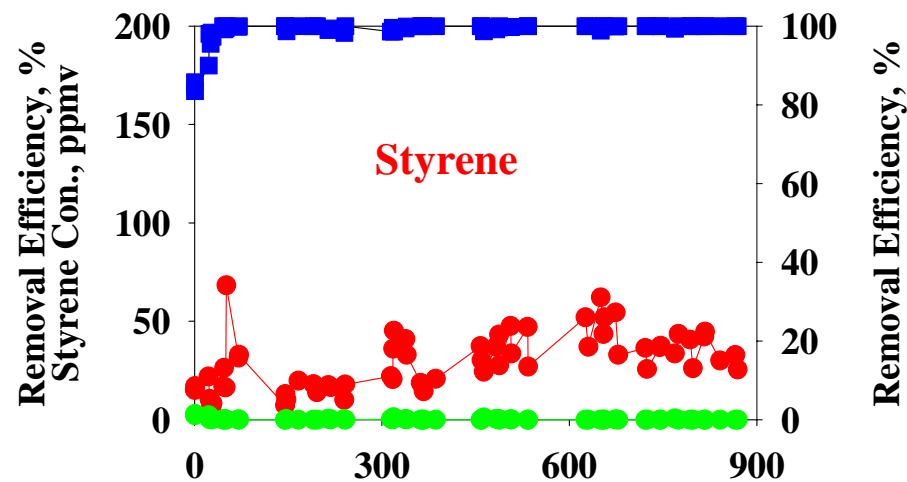
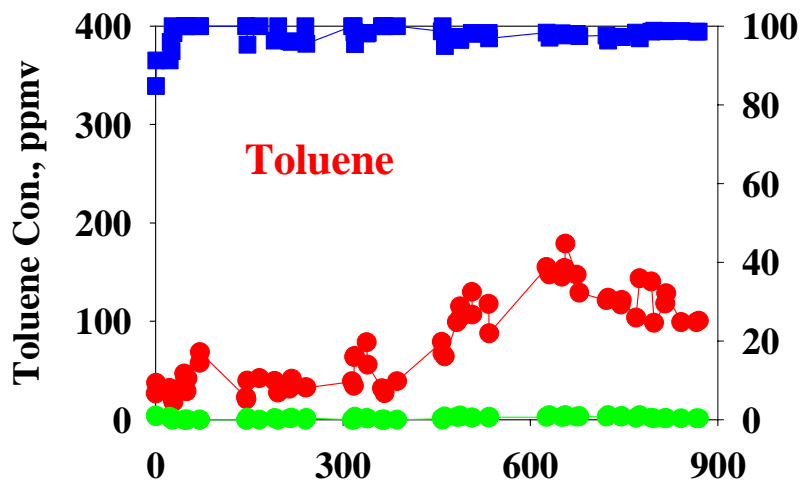


# Results First square wave

## Biofilter Performance in Combined System



# Results First square wave



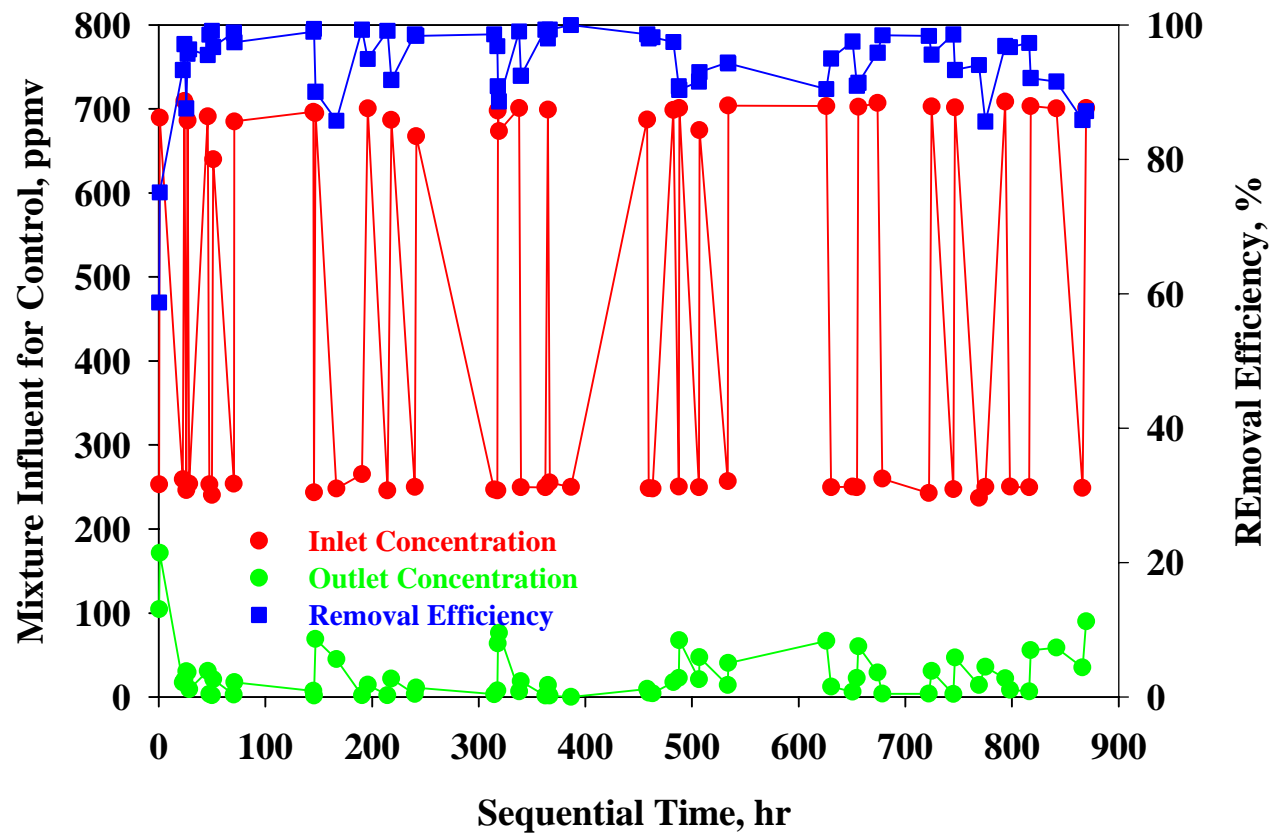
Sequential Time, hr

Sequential Time, hr

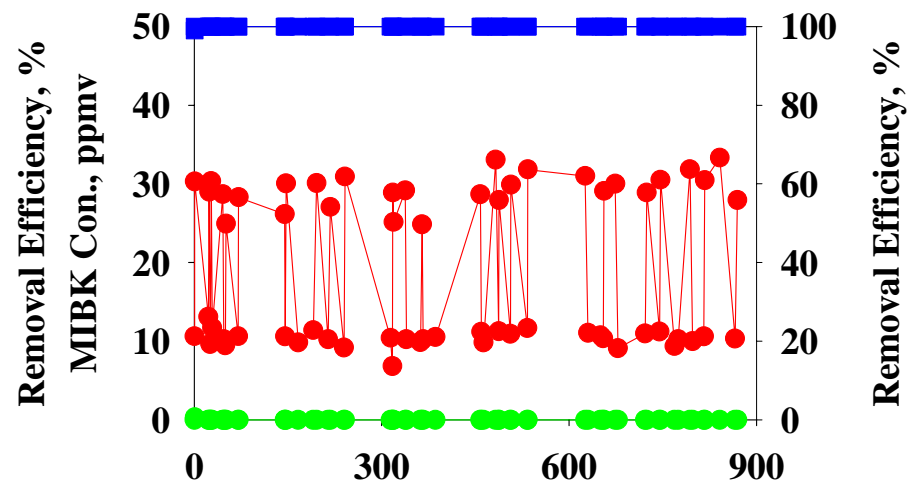
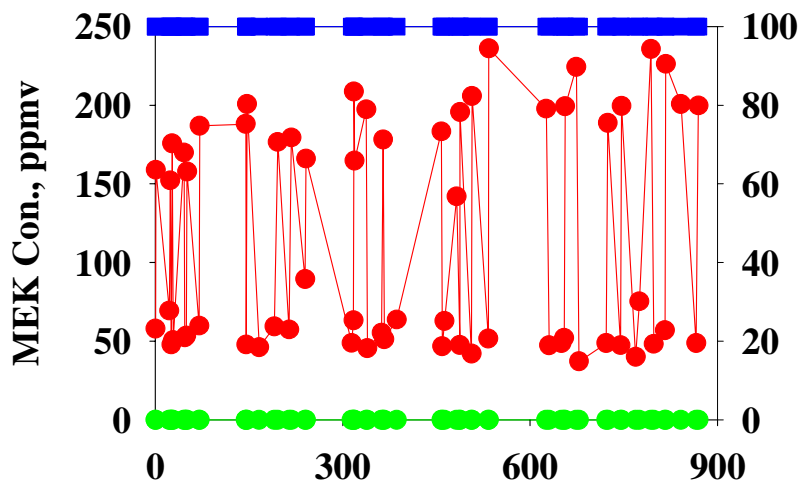
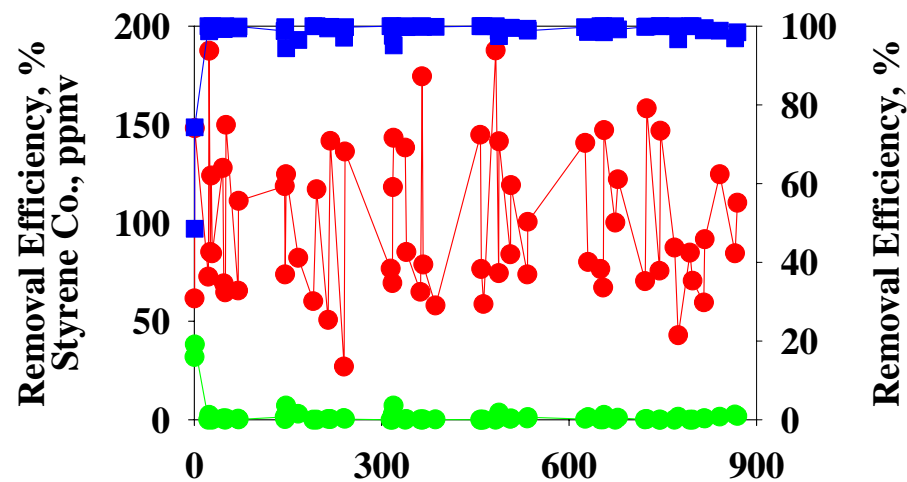
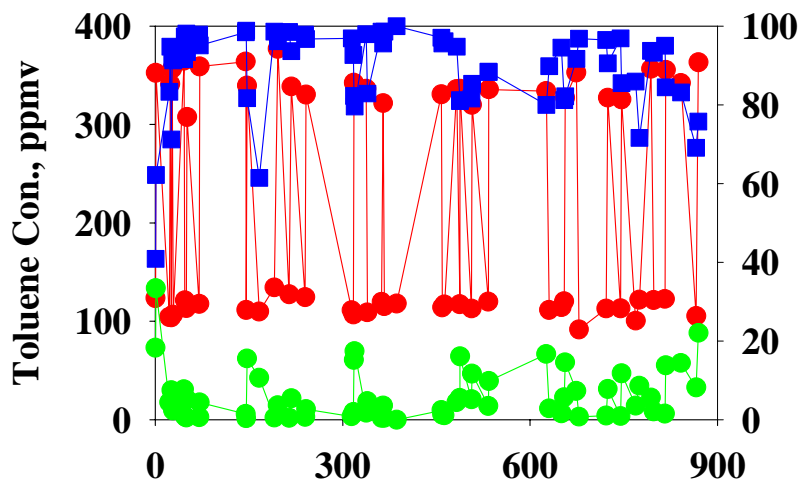


# Results First square wave

## Biofilter Performance in Control System



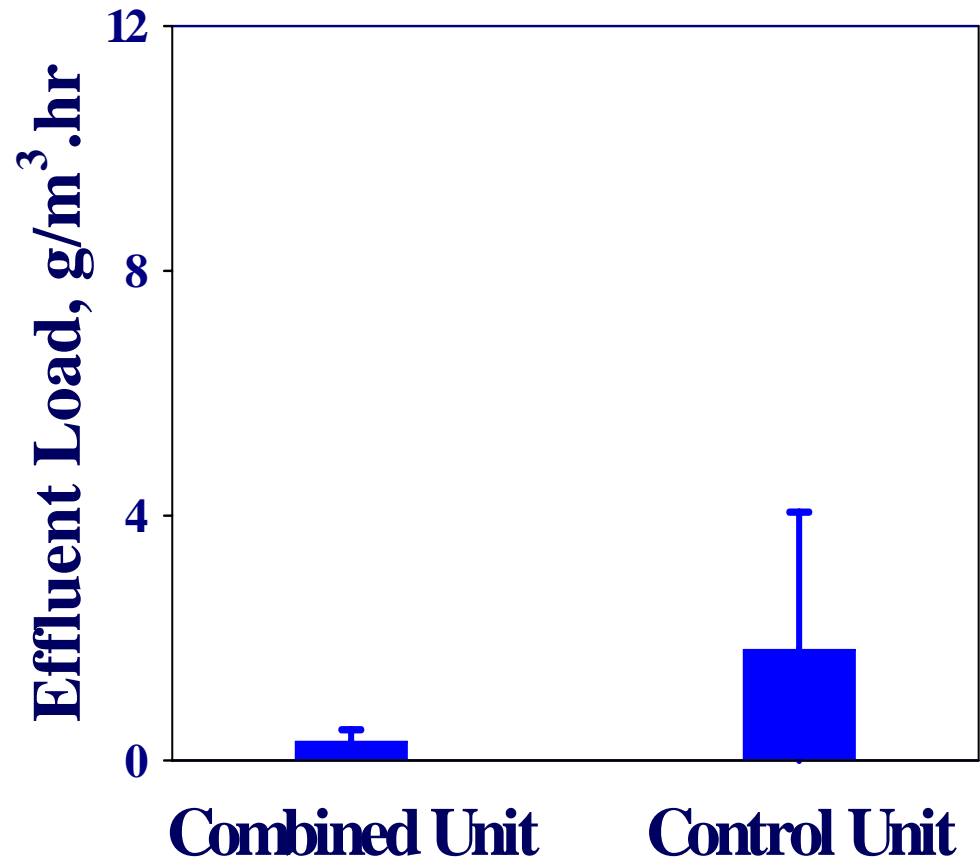
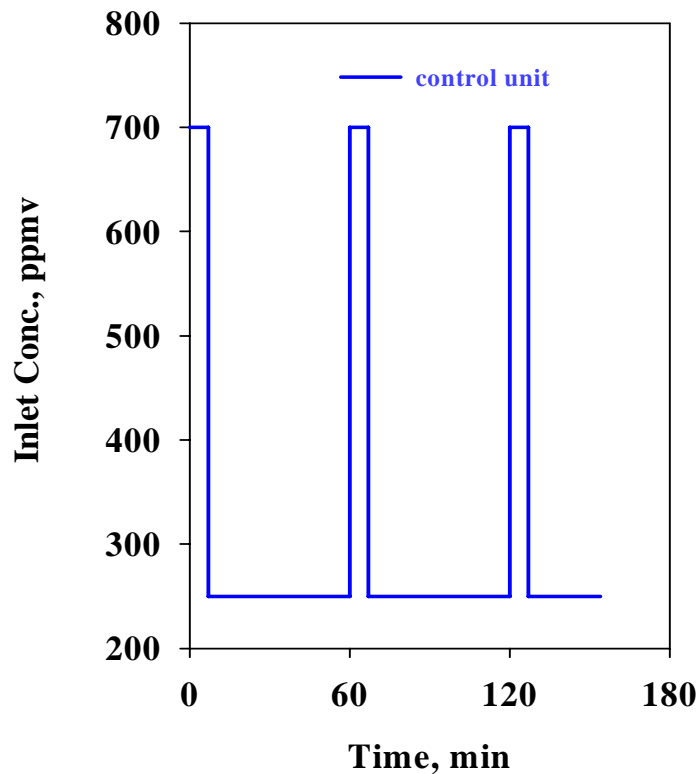
# Results First square wave



Sequential Time, hr

Sequential Time, hr

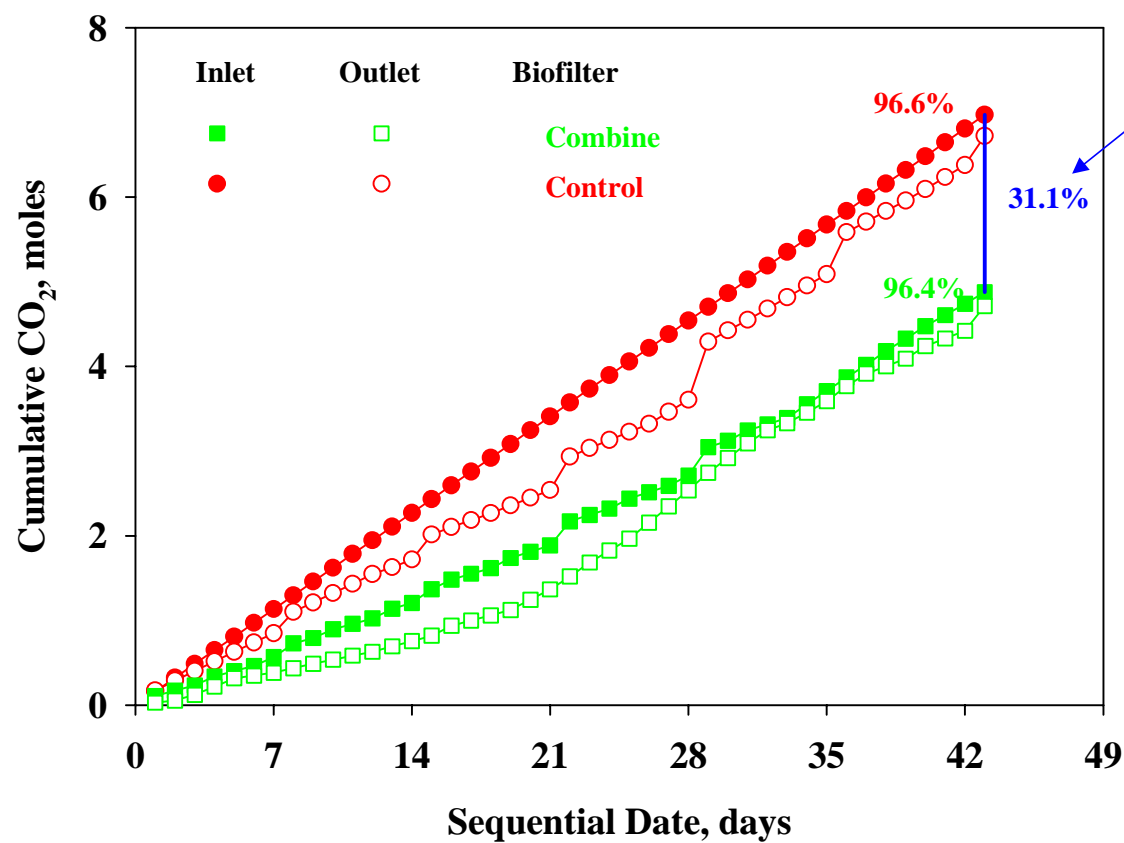
# Results First square wave



| Combined | Ave   | SD   |
|----------|-------|------|
| ppmv     | 204.4 | 30.8 |

# Results First square wave

## Carbon Mass Balance

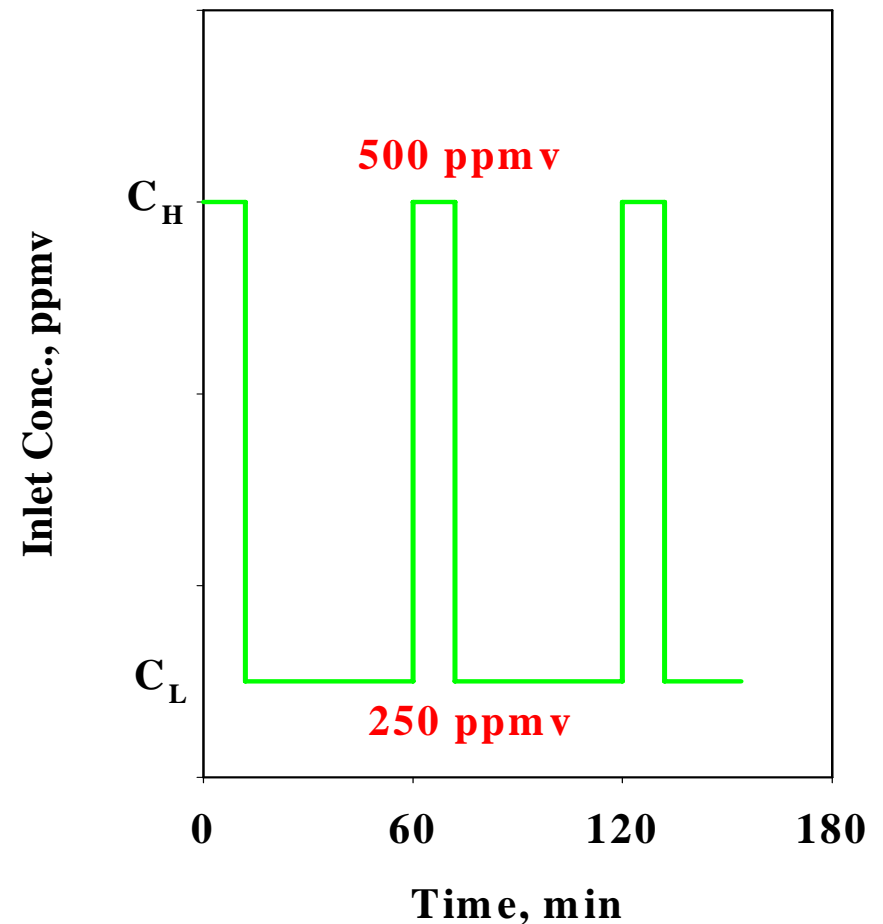


Carbon accumulation  
in the two beds

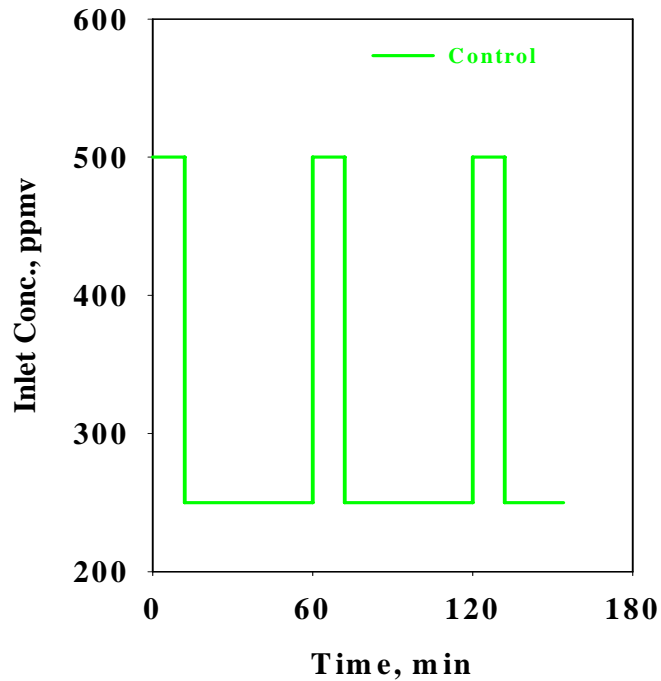
# Results **Second square wave**

## Square Wave Change

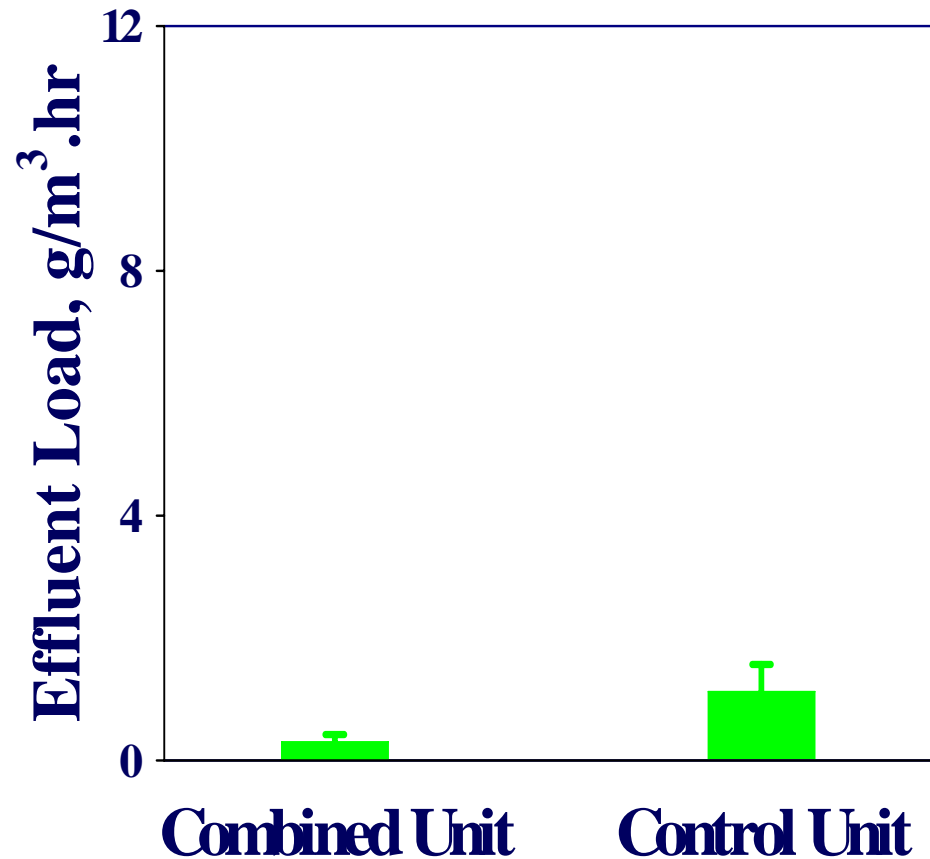
- Base = 250 ppmv
- Peak = 500 ppmv (12 mins / hour)
- Average concentration : 300 ppmv
- Average Total Loading = 34.0 g/m<sup>3</sup>.hr
- Toluene Loading = 15.4 g/m<sup>3</sup>.hr
- Styrene Loading = 10.1 g/m<sup>3</sup>.hr
- MEK Loading = 6.3 g/m<sup>3</sup>.hr
- MIBK Loading = 2.2 g/m<sup>3</sup>.hr



# Results Second square wave



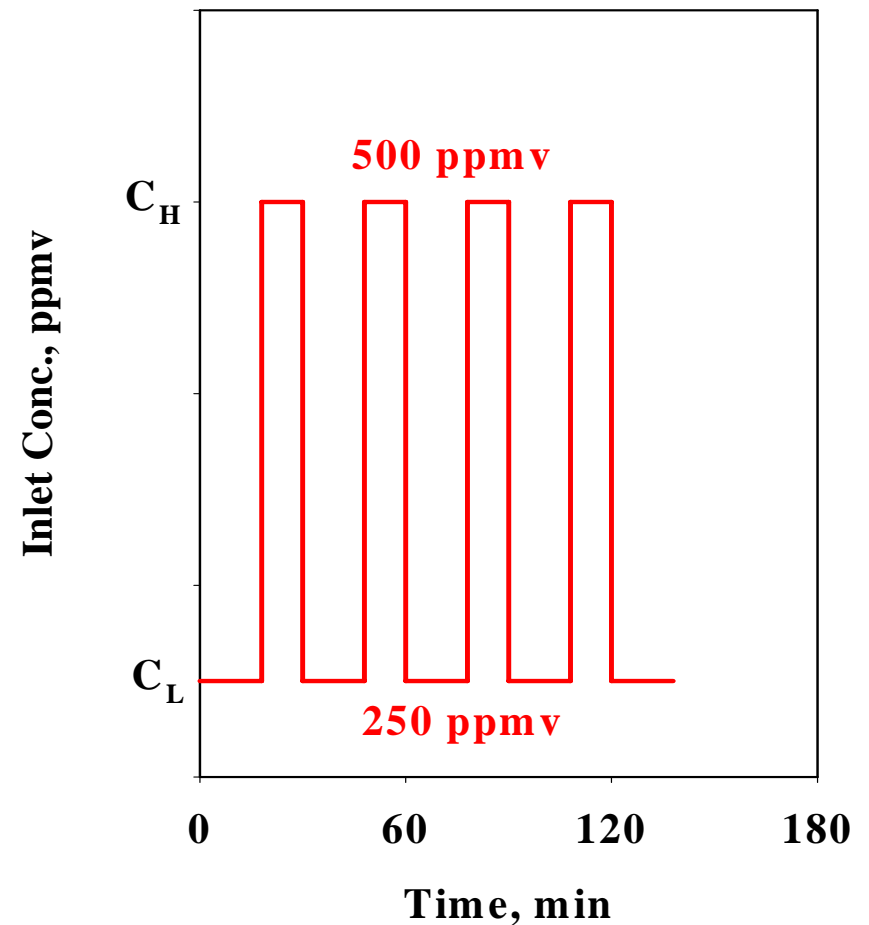
| Combined | Ave   | SD   |
|----------|-------|------|
| ppmv     | 188.6 | 19.2 |



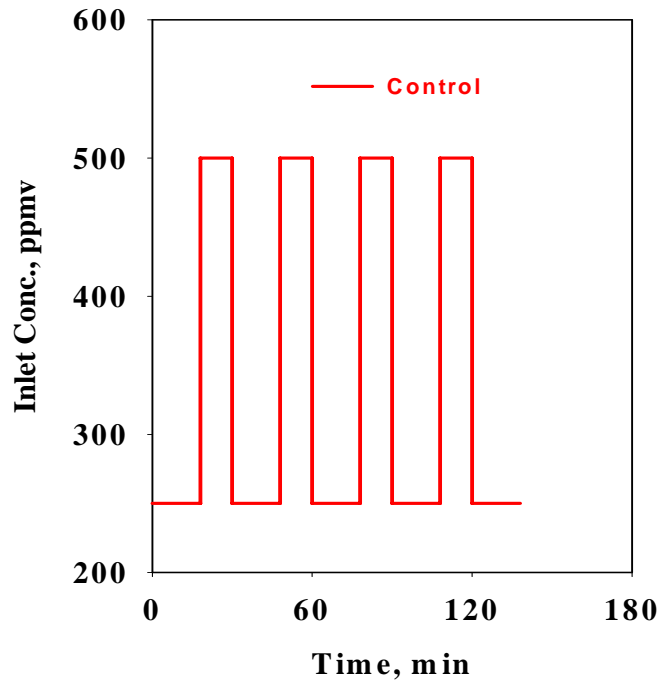
# Results Third square wave

## Square Wave Change

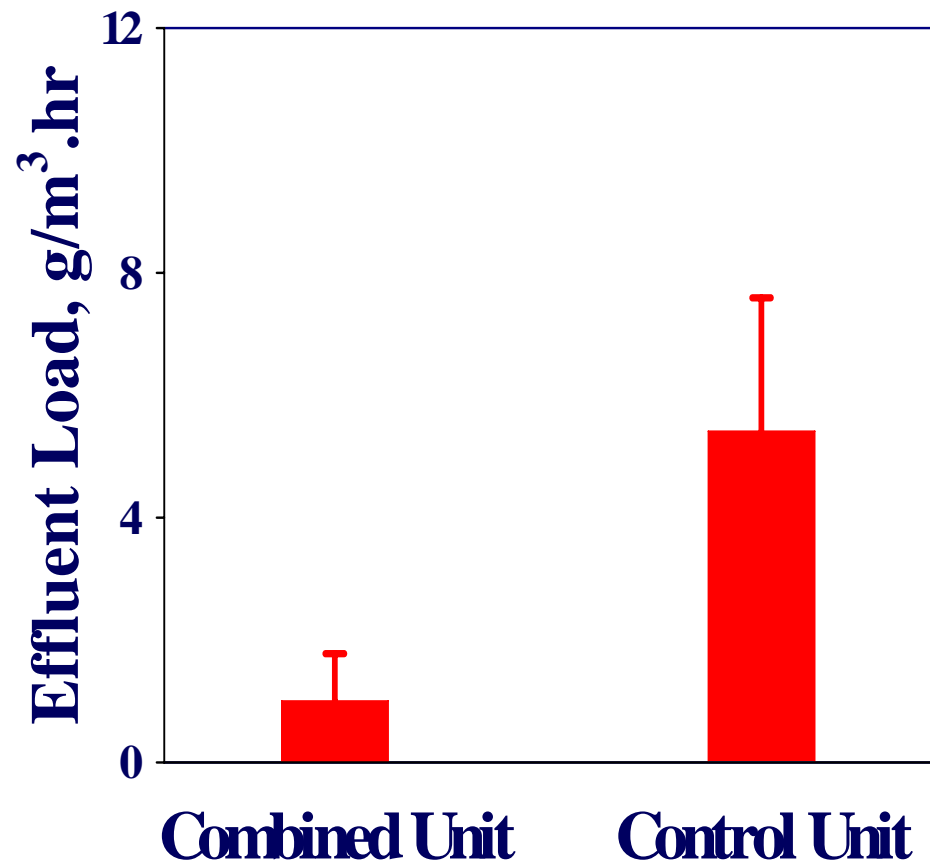
- Base = 250 ppmv
- Peak = 500 ppmv ( $2 \times 12$  mins / hr)
- Average concentration : 350 ppmv
- Average Total Loading =  $39.6 \text{ g/m}^3\cdot\text{hr}$
- Toluene Loading =  $17.9 \text{ g/m}^3\cdot\text{hr}$
- Styrene Loading =  $11.8 \text{ g/m}^3\cdot\text{hr}$
- MEK Loading =  $7.4 \text{ g/m}^3\cdot\text{hr}$
- MIBK Loading =  $2.5 \text{ g/m}^3\cdot\text{hr}$



# Results Third square wave



| Combined | Ave   | SD   |
|----------|-------|------|
| ppmv     | 230.1 | 25.2 |

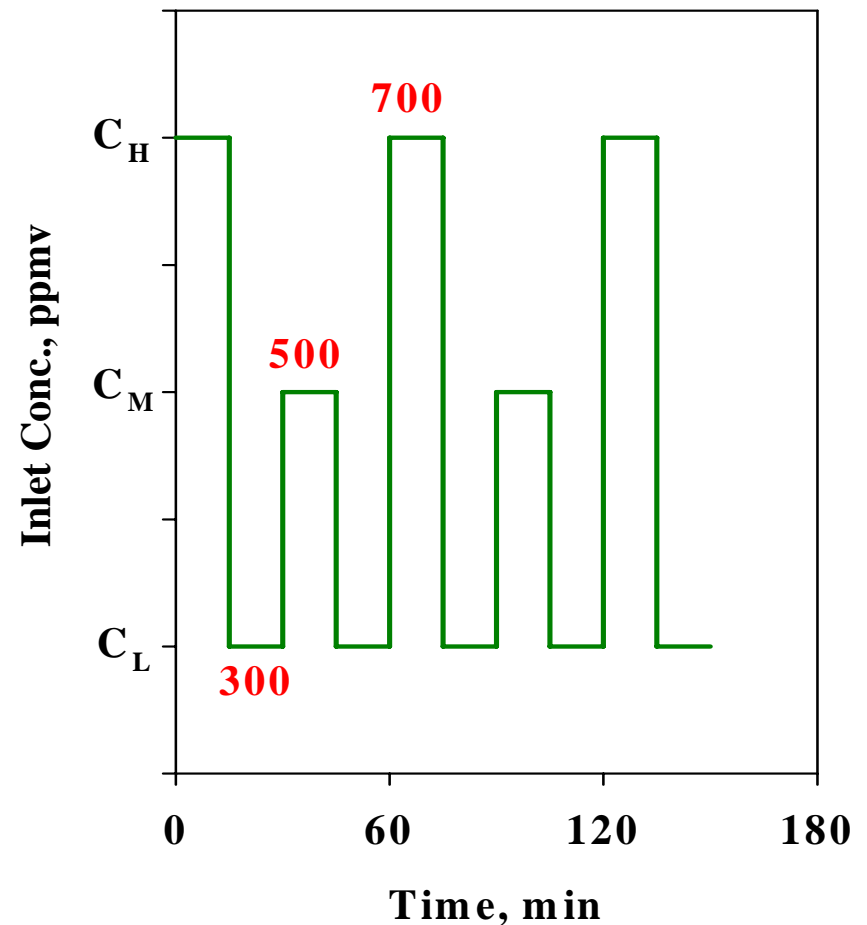




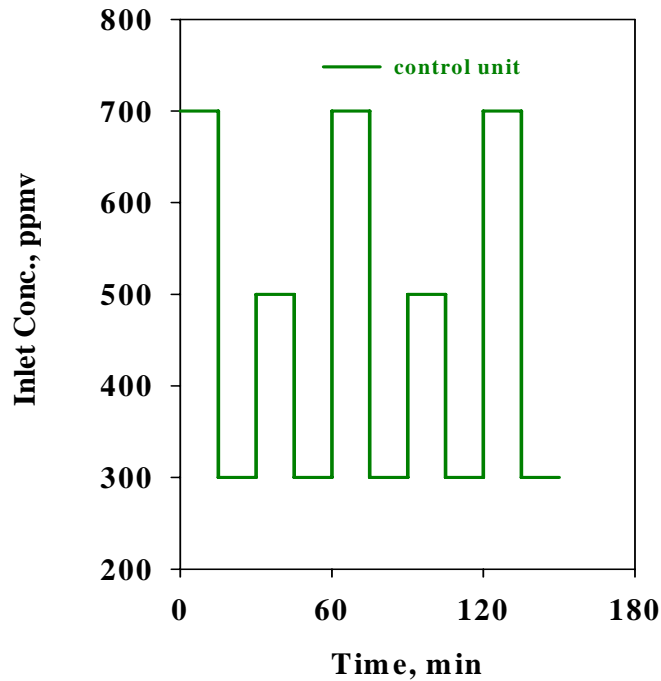
# Results Fourth square wave

## Square Wave Change

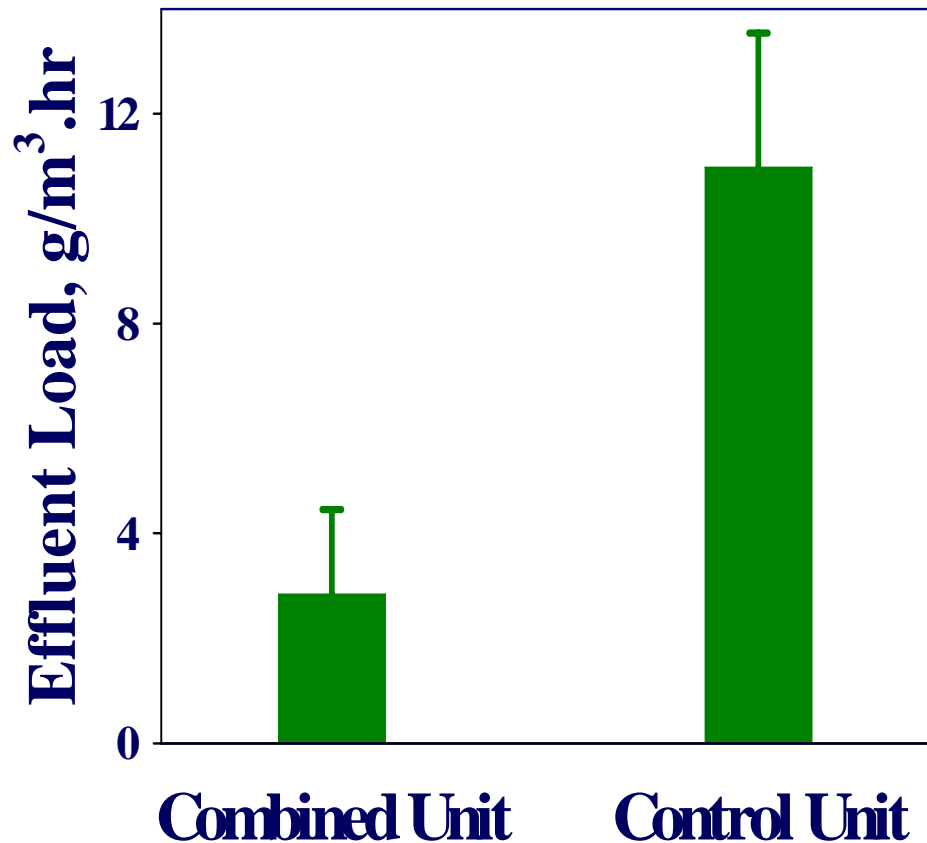
- Base = 300 ppmv
- Middle = 500 ppmv (15 mins/hour)
- Peak = 700 ppmv (15 mins / hour)
- Average concentration : 450 ppmv
- Average Loading = 50.9 g/m<sup>3</sup>.hr
- Toluene Loading = 23.0 g/m<sup>3</sup>.hr
- Styrene Loading = 15.1 g/m<sup>3</sup>.hr
- MEK Loading = 9.5 g/m<sup>3</sup>.hr
- MIBK Loading = 3.3 g/m<sup>3</sup>.hr



# Results Fourth square wave



| Combined | Ave   | SD   |
|----------|-------|------|
| ppmv     | 338.1 | 21.2 |



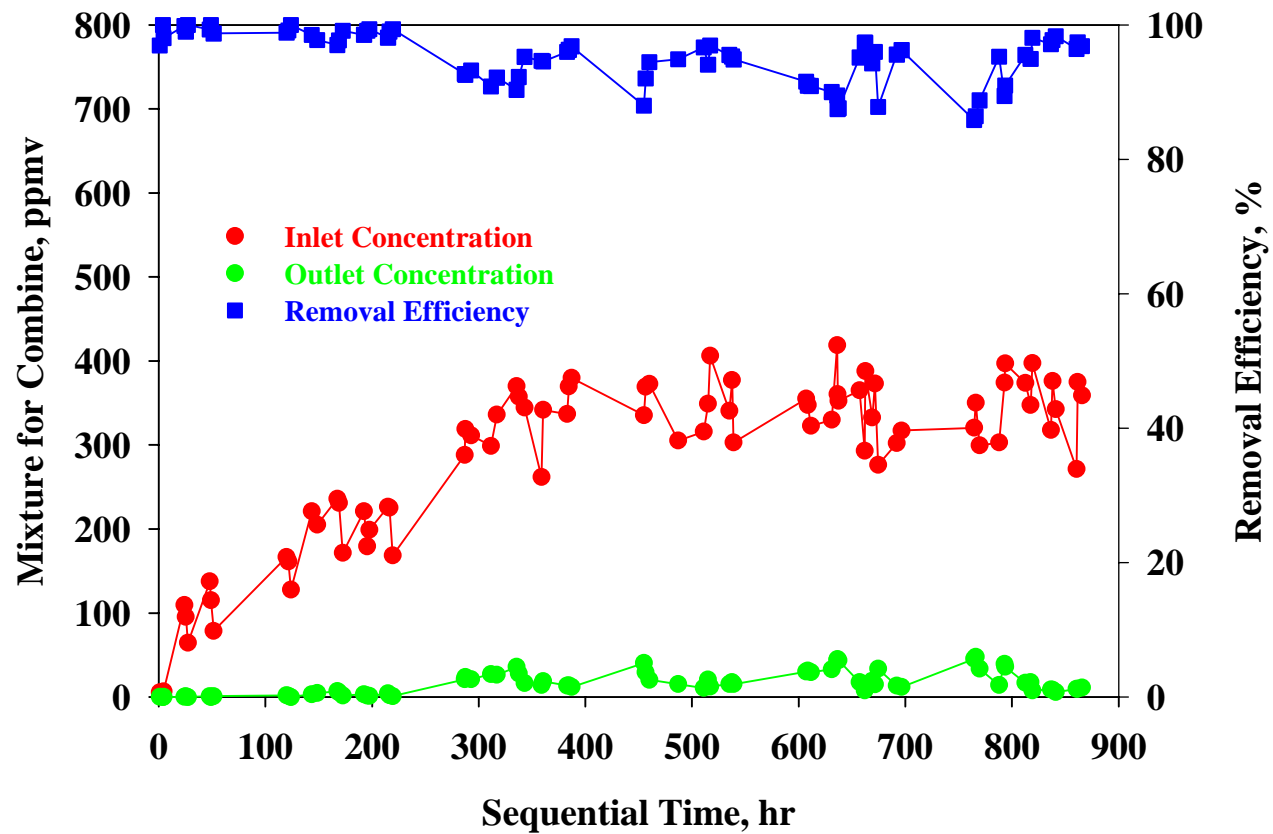
# Treatment of VOC Mixture in a Trickle-Bed Air Biofilter Integrated with Cyclic Adsorption/Desorption Beds

## Experimental Results

- Starvation effect (Fourth Square Wave)

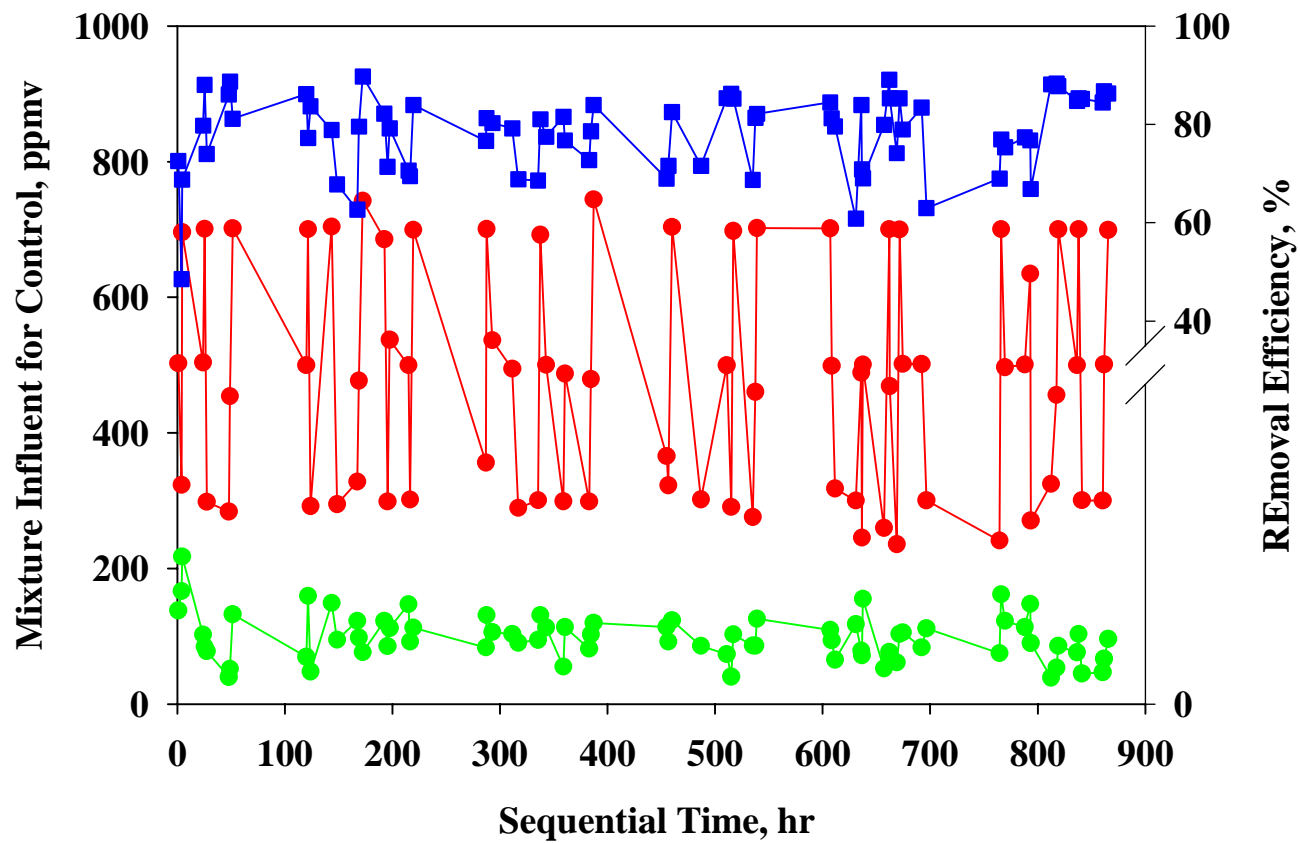
# Results Fourth square wave

## Biofilter Performance in Combined System-Backwashing



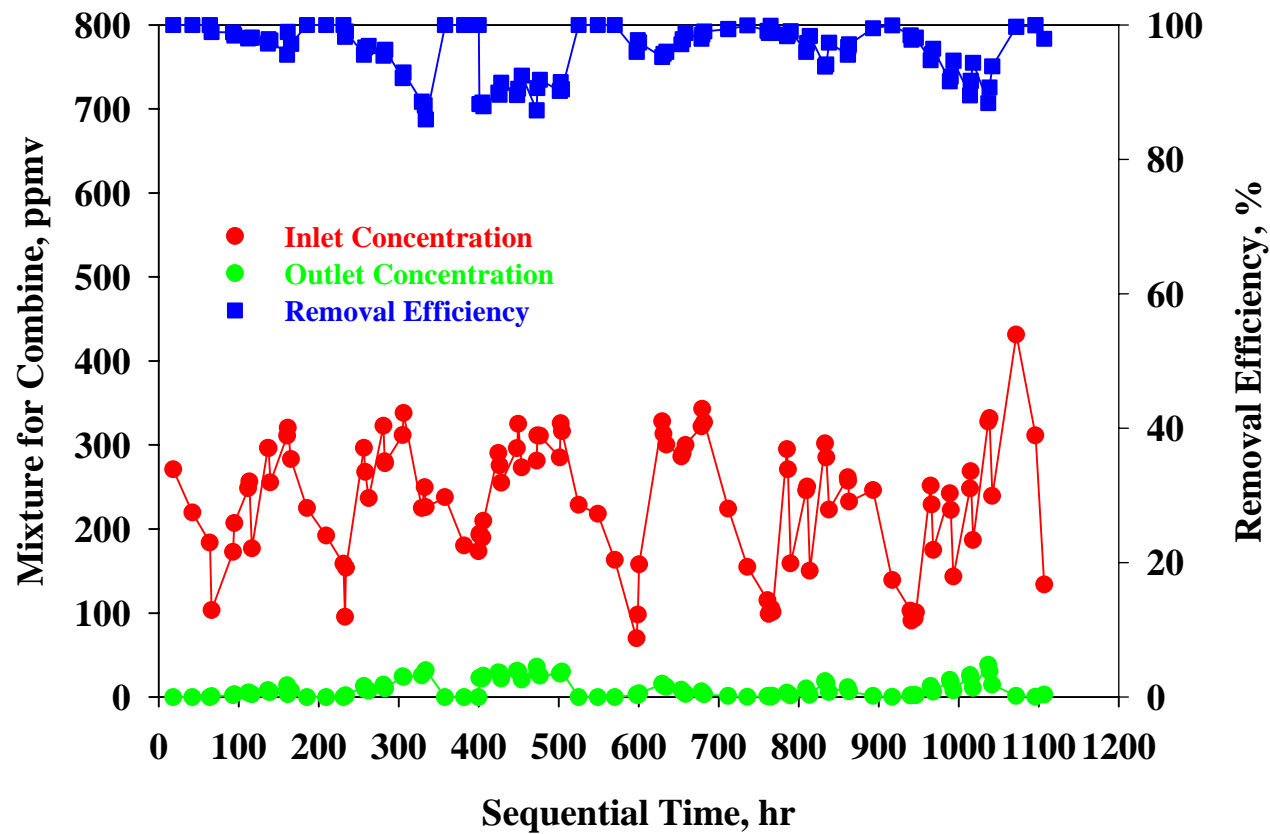
# Results Fourth square wave

## Biofilter Performance in Control System-Backwashing



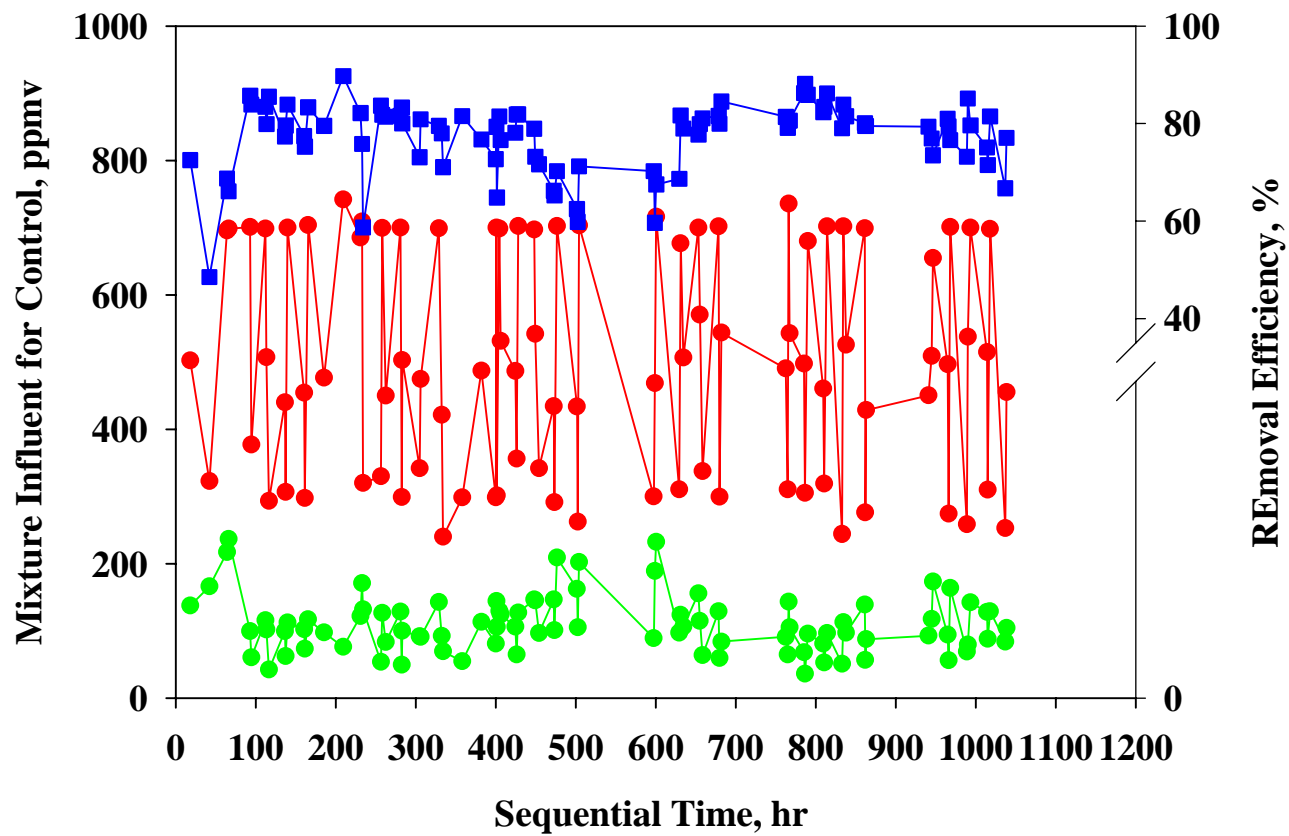
# Results Fourth square wave

## Biofilter Performance in Combined System-Starvation



# Results Fourth square wave

## Biofilter Performance in Control System-Starvation



# Treatment of VOC Mixture in a Trickle-Bed Air Biofilter Integrated with Cyclic Adsorption/Desorption Beds

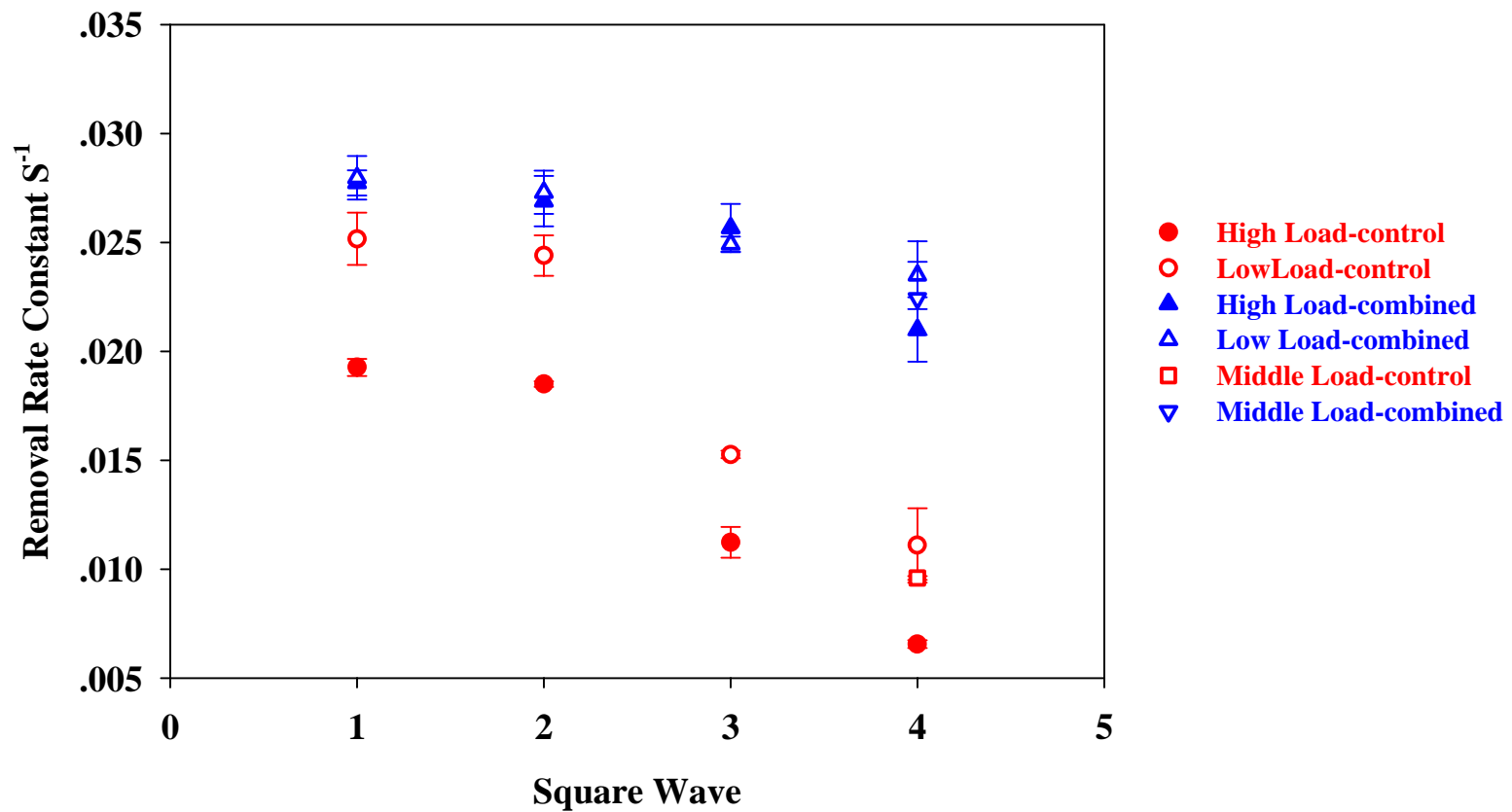
## Experimental Results

➤ Kinetics analysis



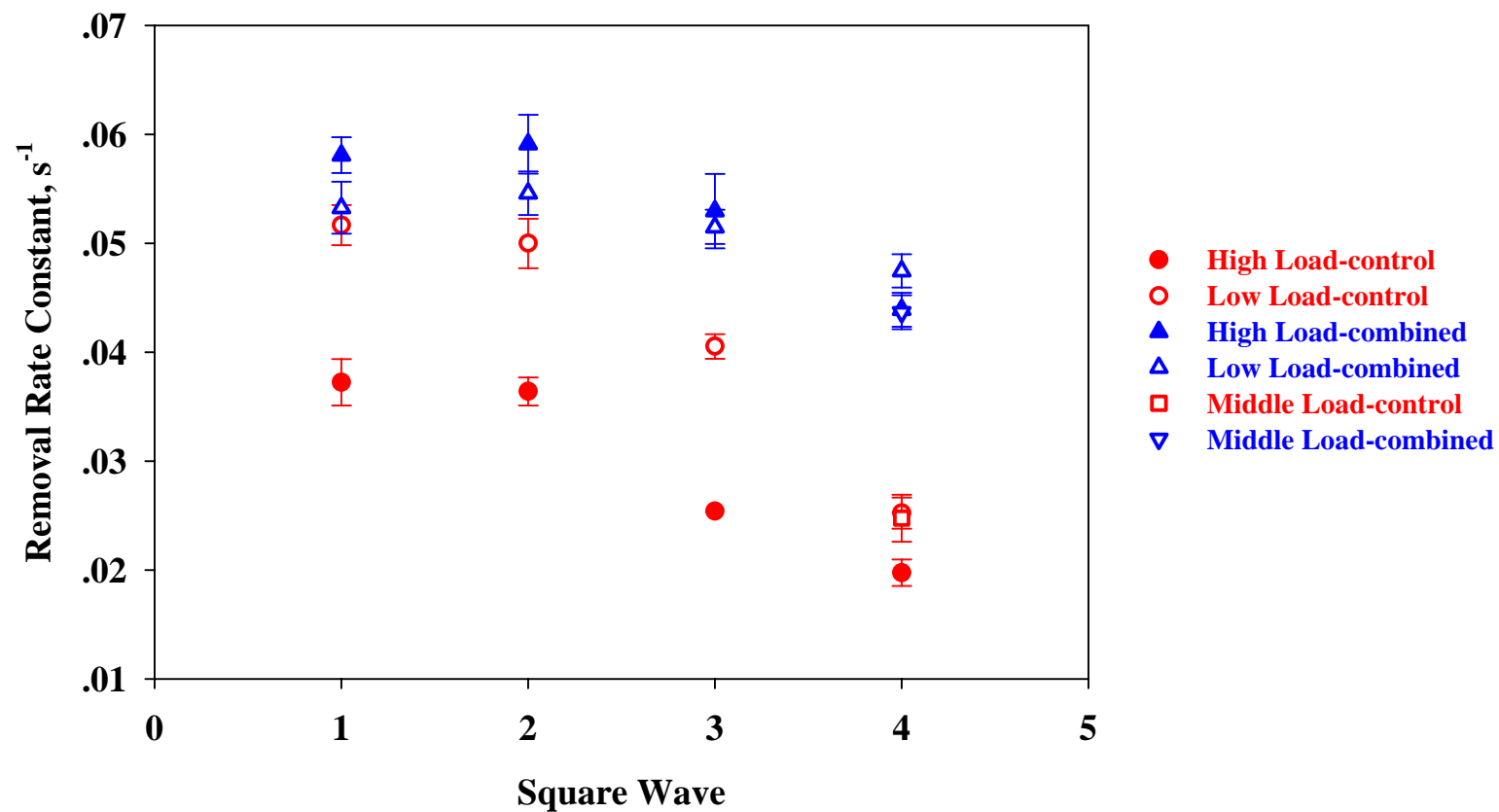
# Results Kinetics analysis

## Toluene removal kinetics in mixture



# Results Kinetics analysis

## Styrene removal kinetics in mixture



# Conclusions

- The cyclic 2-bed adsorption/desorption unit successfully dampened loading fluctuation of VOCs mixture to the followed biofilter.
- The integrated trickling biofilter with cyclic 2-bed adsorption/desorption unit could maintain long-term high level removal efficiency.
- The integrated system showed significant improvement as compared to a stand alone biofilter for more frequent or/and higher magnitude fluctuation in feeding conditions.
- The cyclic 2-bed unit successfully functioned as feeding source to the followed biofilter during starvation period.

# Acknowledgement

- Dr. Daekeun Kim
- Environmental Chemistry Lab Colleagues
- Financial support for the research by National Science Foundation under award # BES 0229135

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# Treatment of VOC Mixture in a Trickle-Bed Air Biofilter Integrated with Cyclic Adsorption/Desorption Beds

Questions?

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