USC-TRG Conference on Biofiltration for Air Pollution Control

Effective Control of Gaseous VOC Mixture in a TBAB Coupled with Cyclic Adsorption/Desorption Beds

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Use of Integrated Systems

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

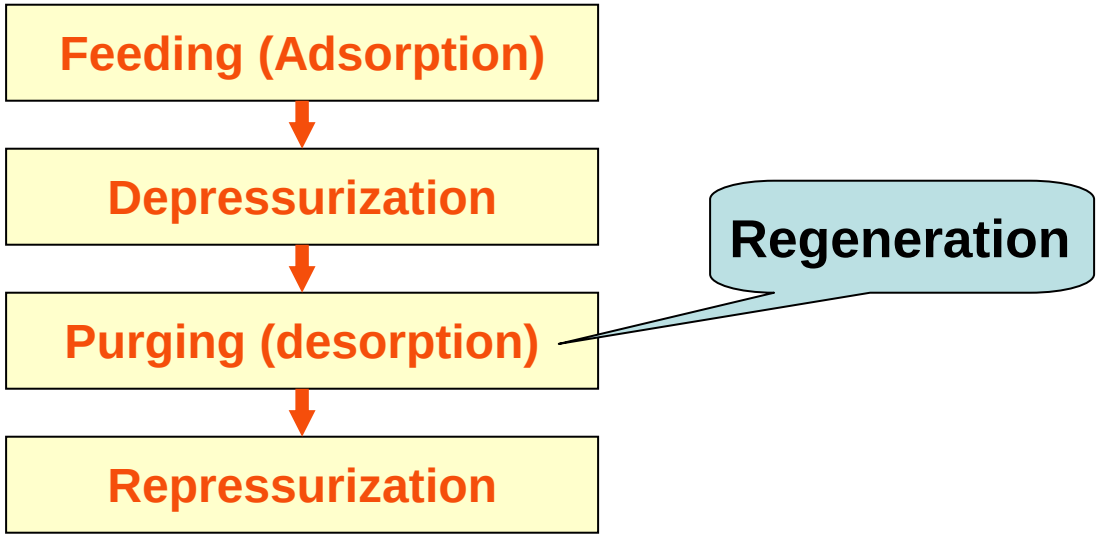
High loading & Large fluctuation → Losing buffer capacity

Initial period of operation → No contaminant in effluent

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

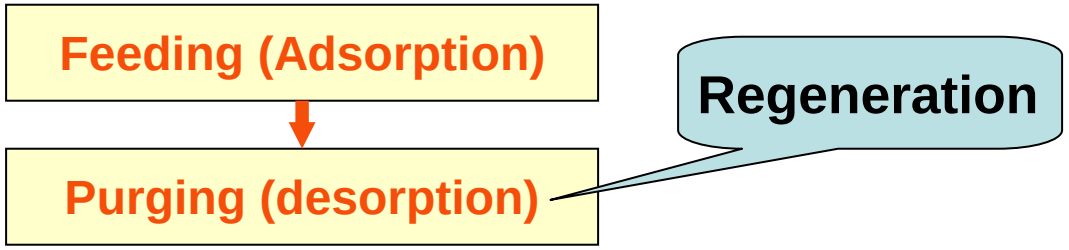


Theory of 2-Bed Adsorption

2-Bed Adsorption Unit

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

  → Operational function is simplified to a 2-step

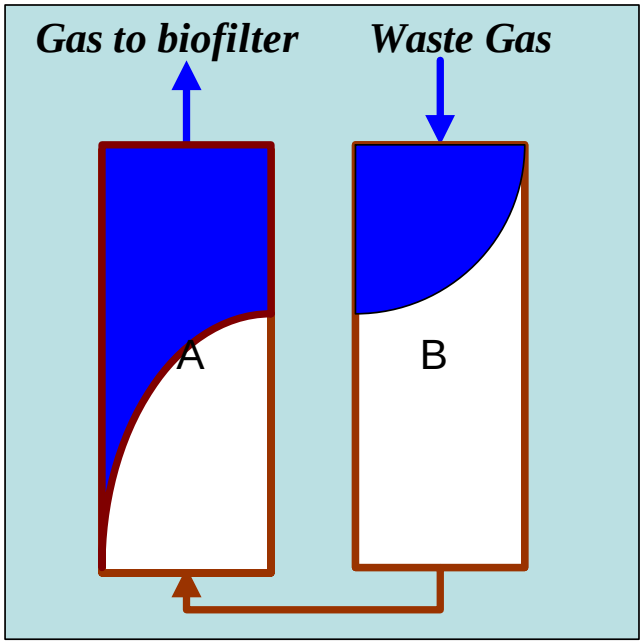


Theory of 2-Bed Adsorption

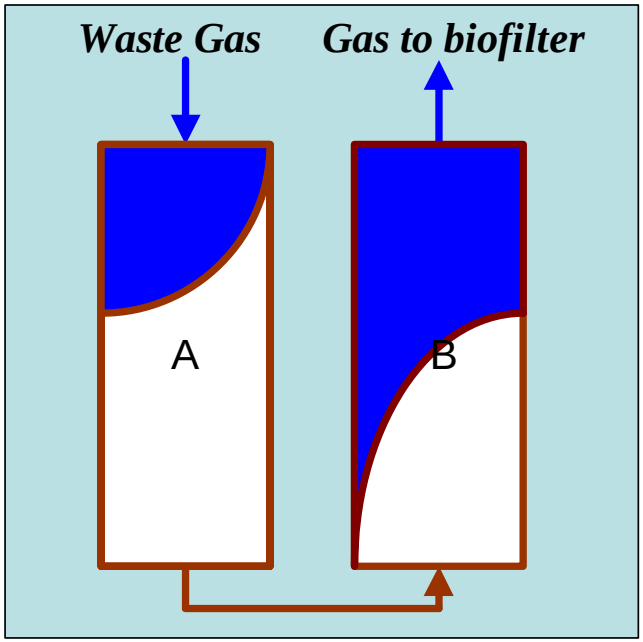
2-Bed Adsorption Unit

- 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

- Concept

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)**

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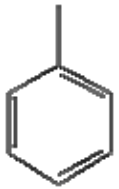
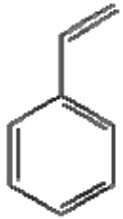
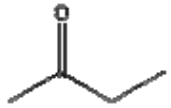
Materials and Methods

- **Feed VOCs Mixture**

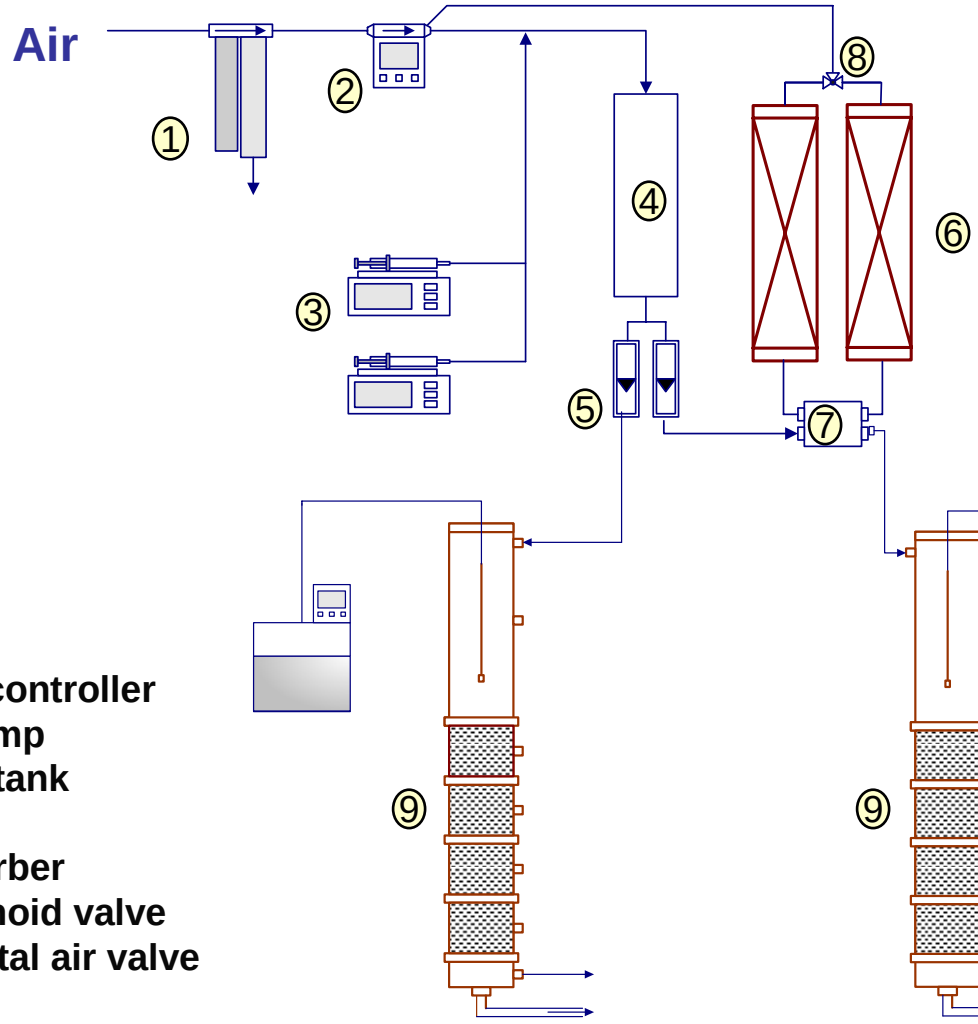
Toluene: Styrene: MEK: MIBK = 0.448: 0.260: 0.234: 0.058

(*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
$Log\ K_{ow}$	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

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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: 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**

Effective Control of Gaseous VOC Mixture in a TBAB Coupled with Cyclic Adsorption/Desorption Beds

Experimental Results

- Performance review
- Starvation effect
- Kinetics analysis

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Effective Control of Gaseous VOC Mixture in a TBAB Coupled with Cyclic Adsorption/Desorption Beds

Experimental Results

- Performance review

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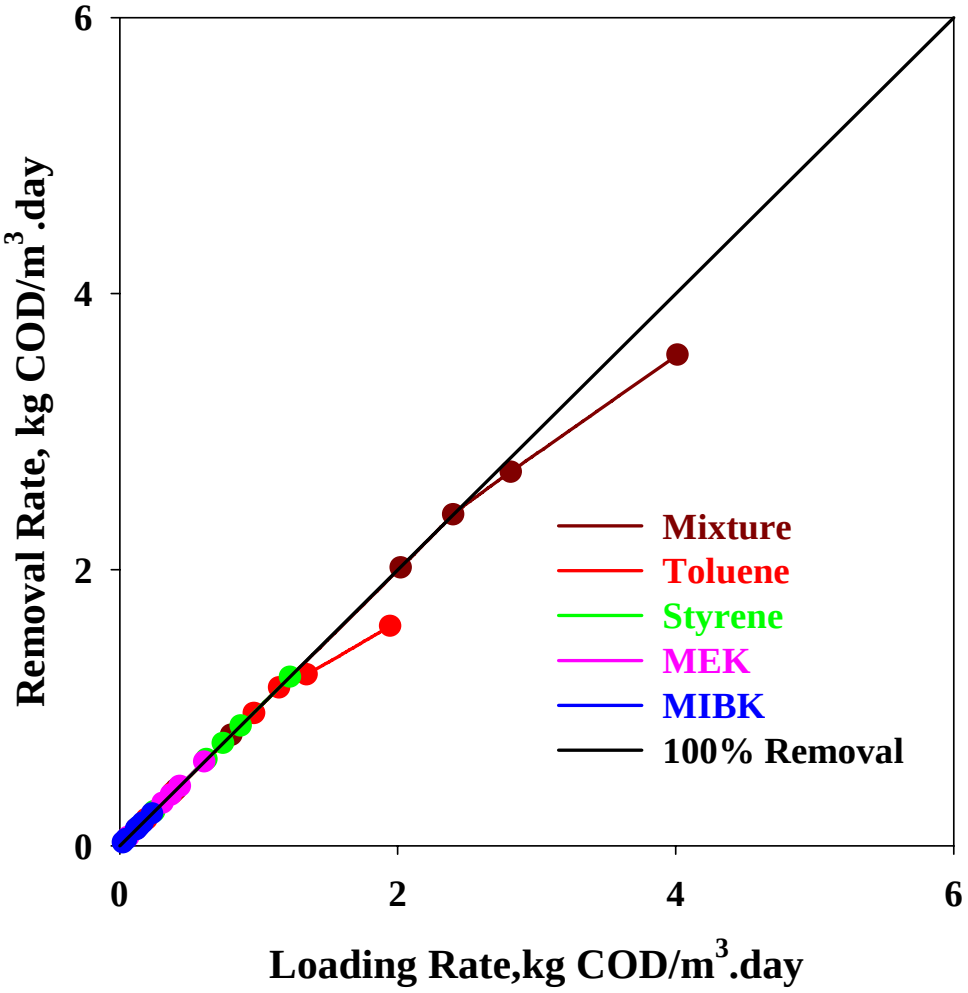
Summary of Previous Mixture Study

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

EBRT: 2.02 min

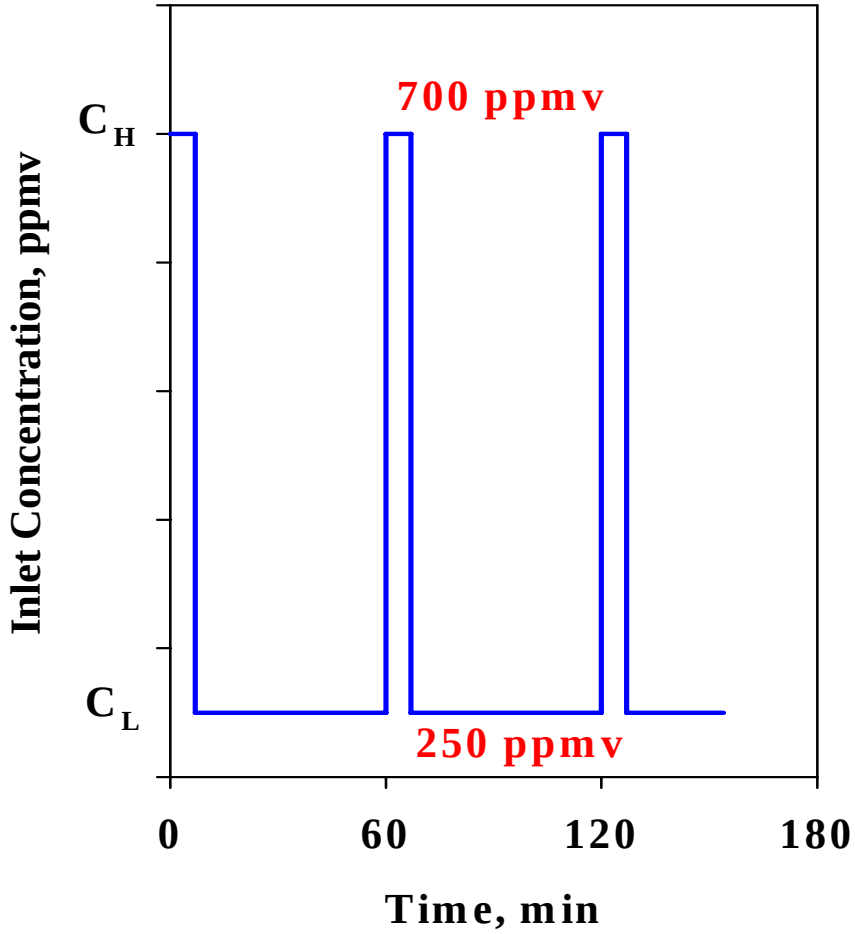
→ Inlet Conc. = 300 ppmv



Results First square wave

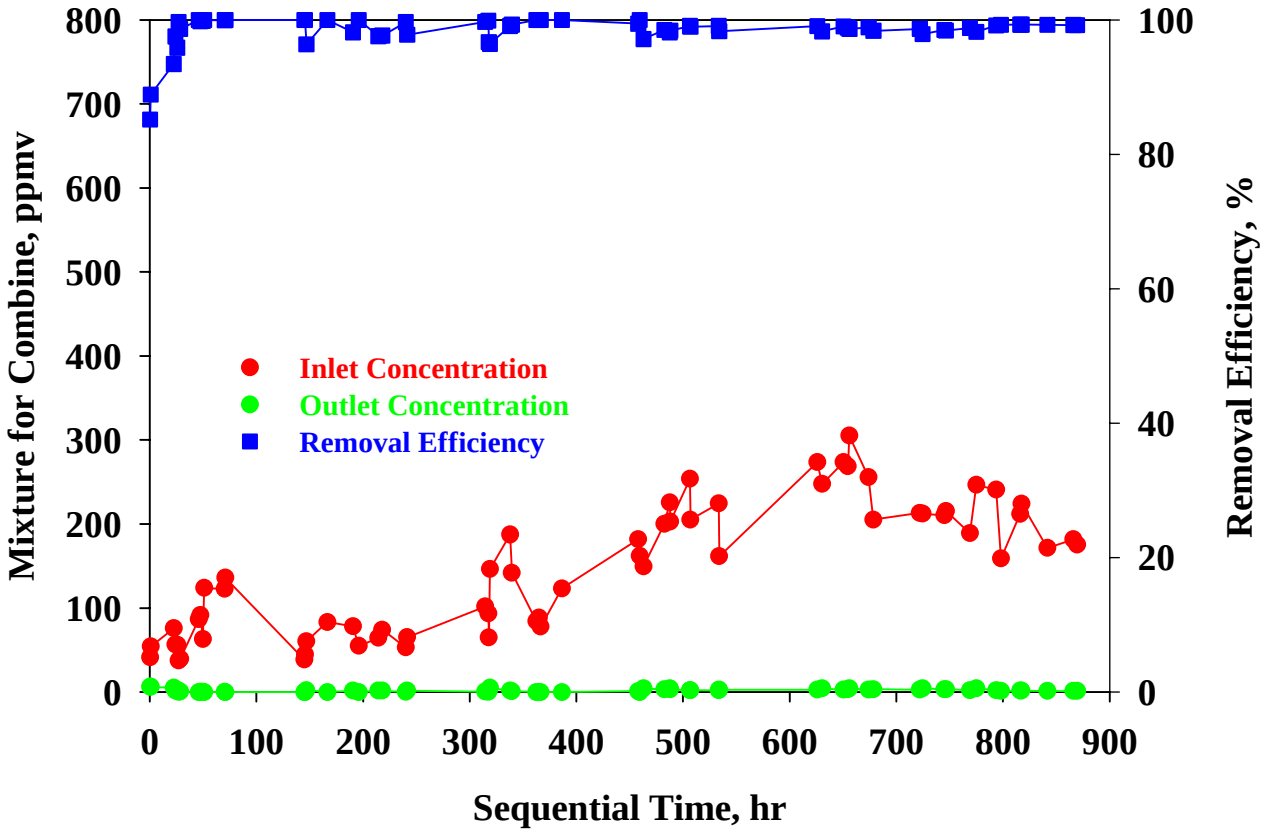
Square Wave Change

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

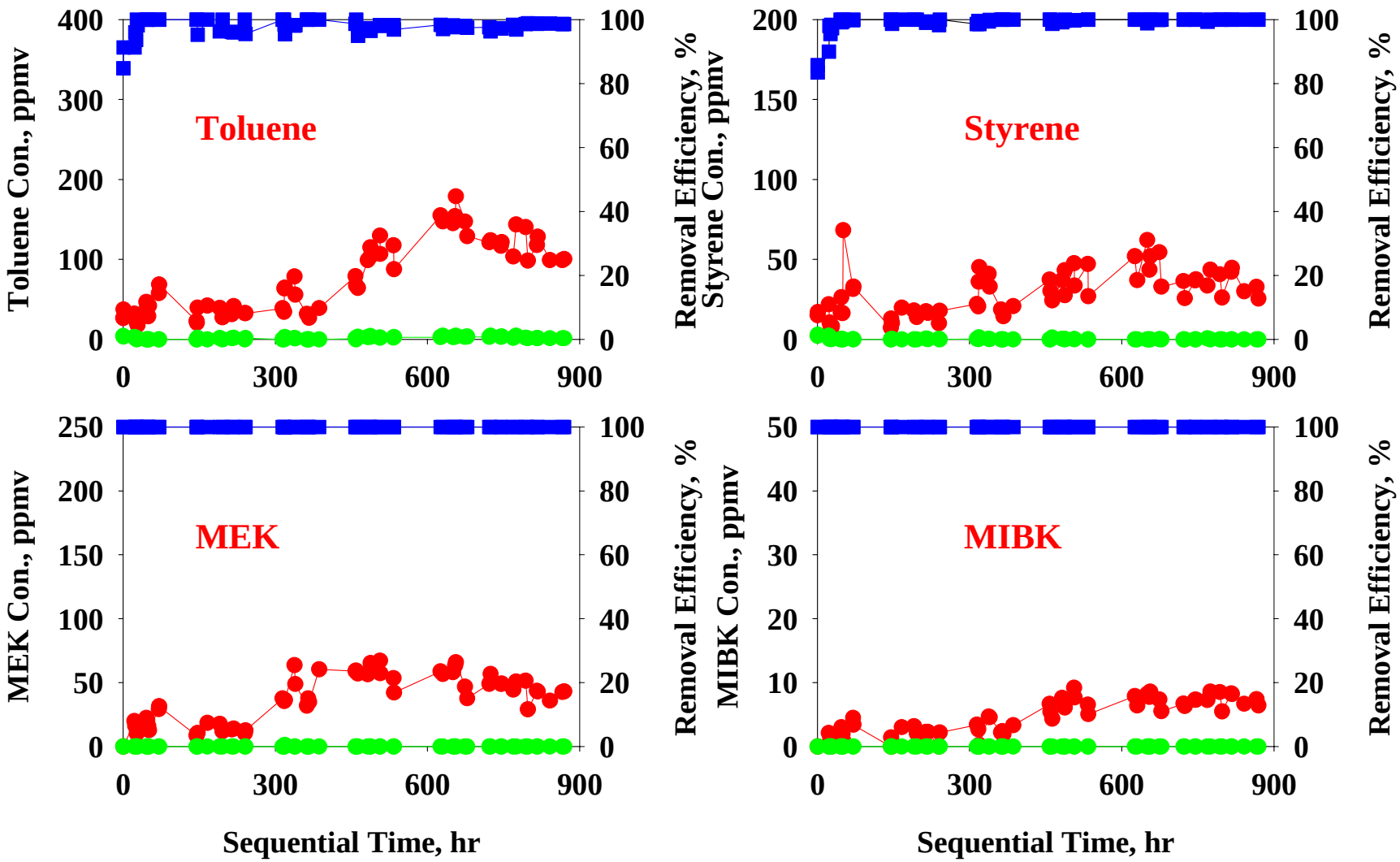


Results First square wave

Biofilter Performance in Combined System

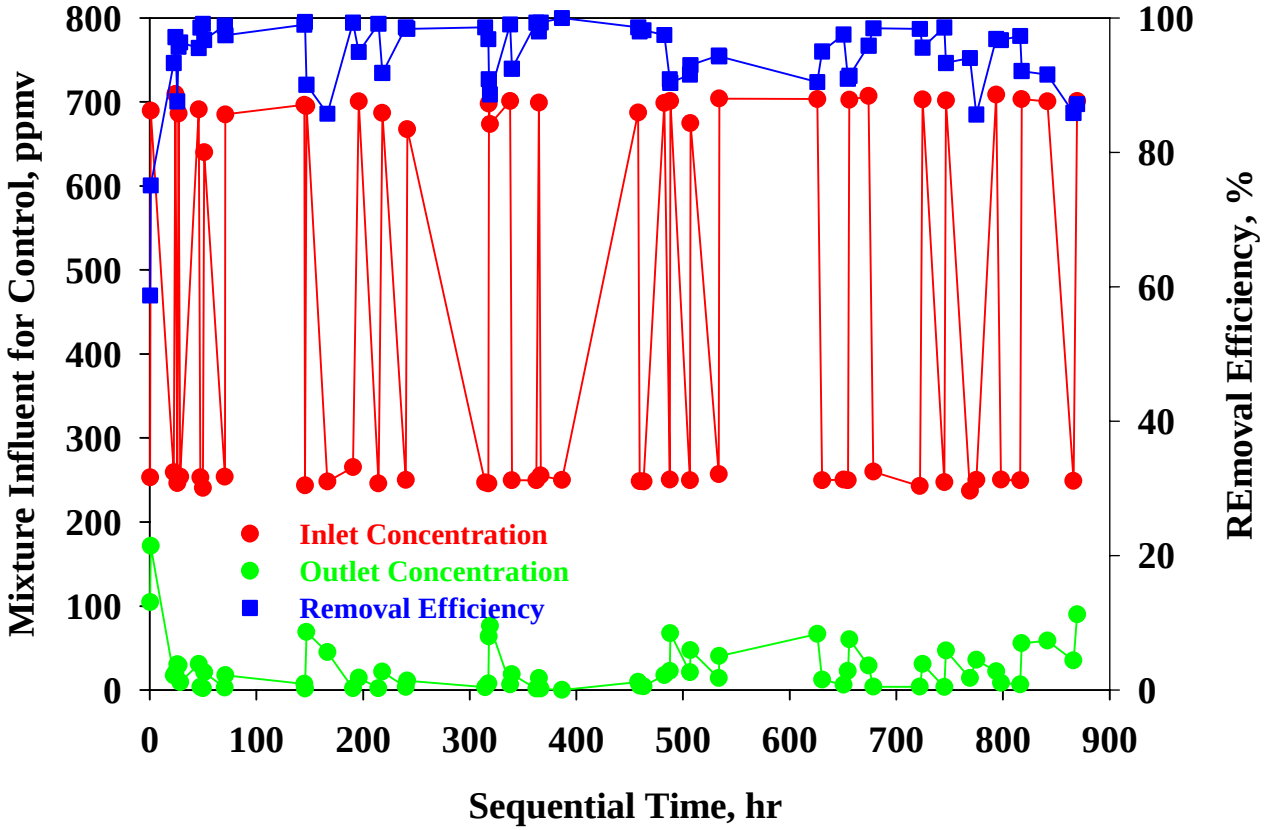


Results First square wave

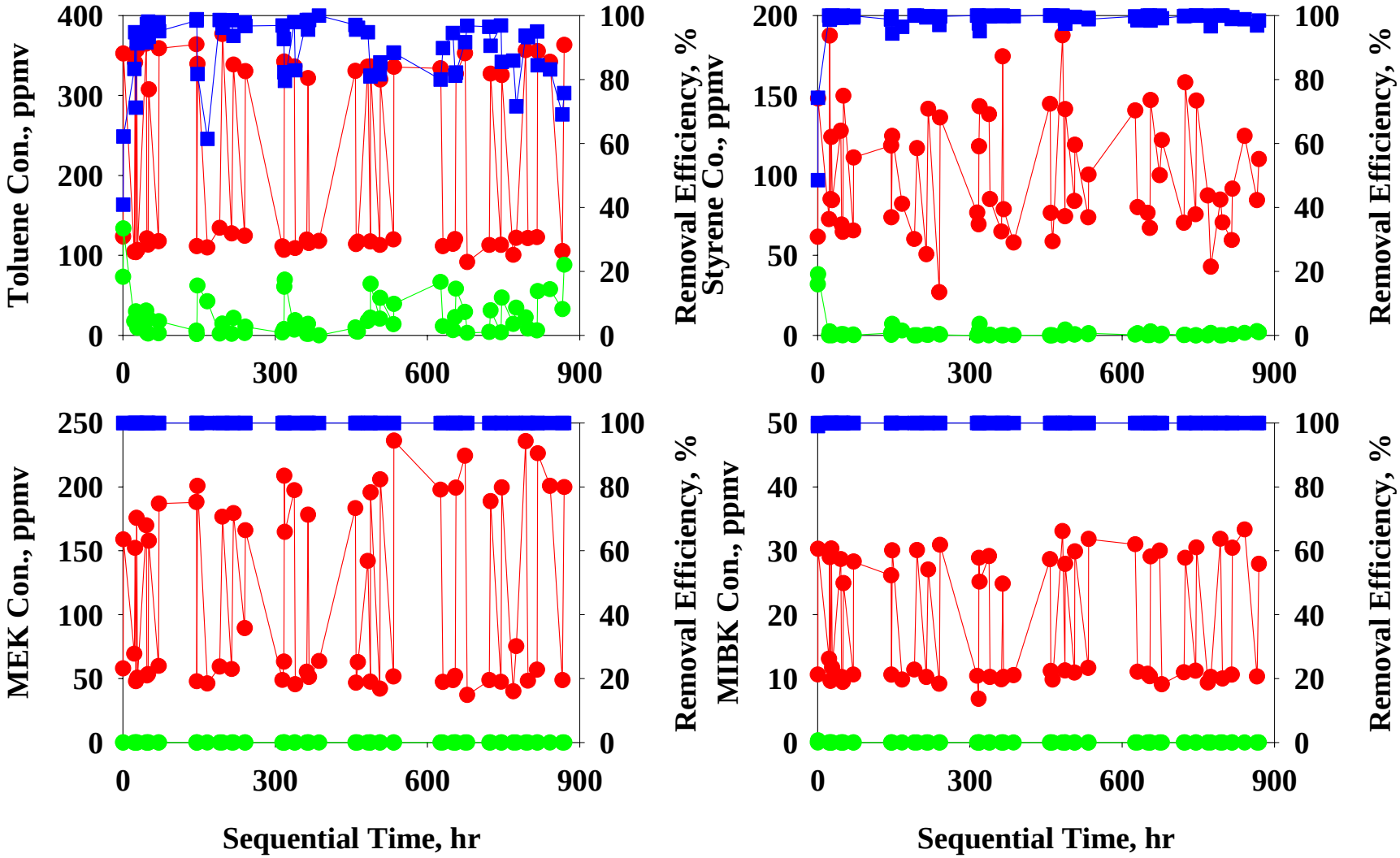


Results First square wave

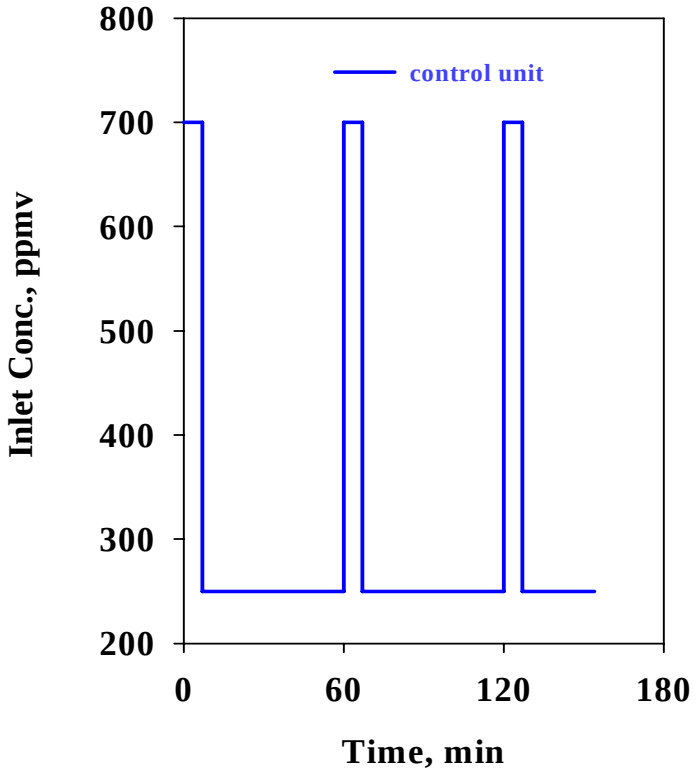
Biofilter Performance in Control System

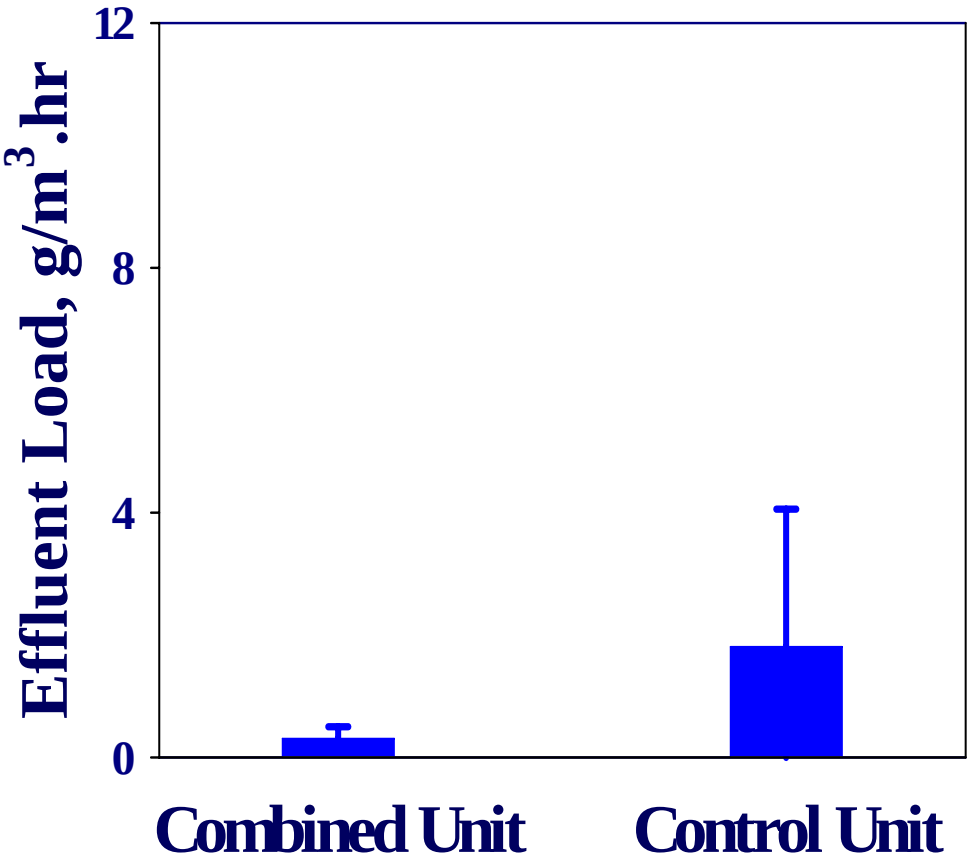


Results First square wave



Results First square wave

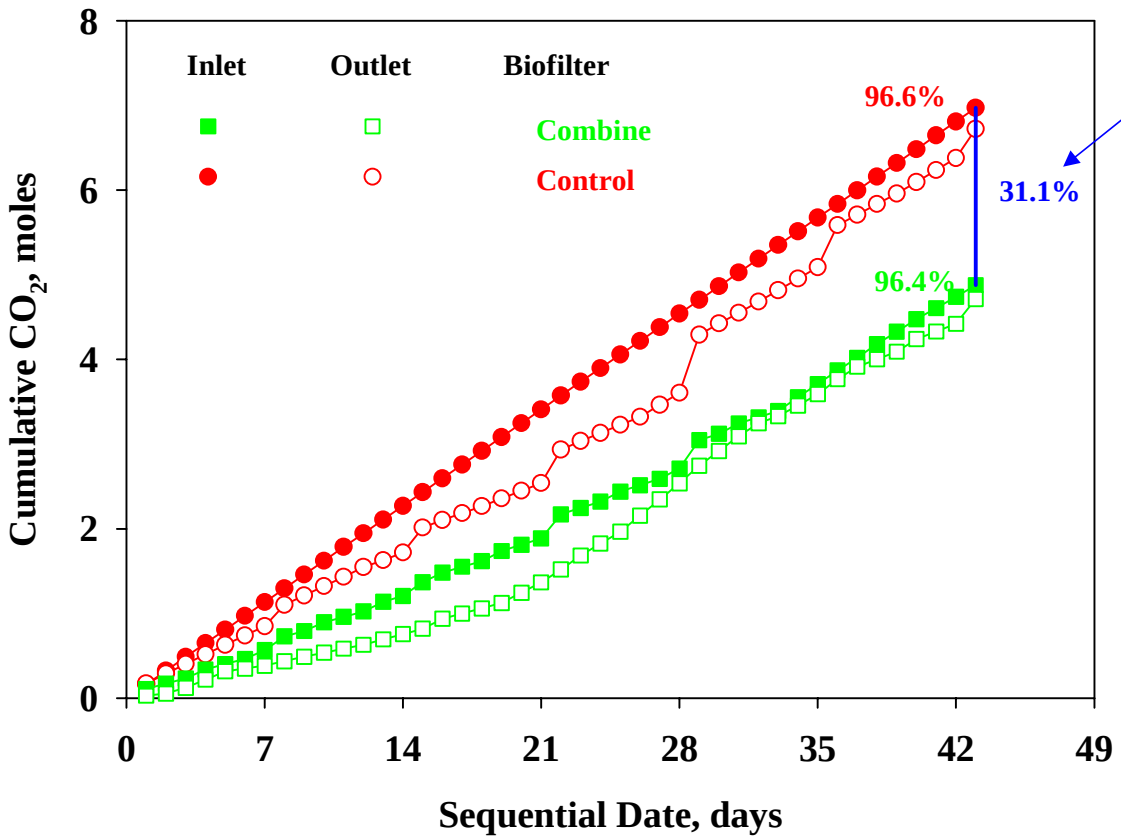




Combined	Ave	SD
ppmv	204.4	30.8

Results First square wave

Carbon Mass Balance

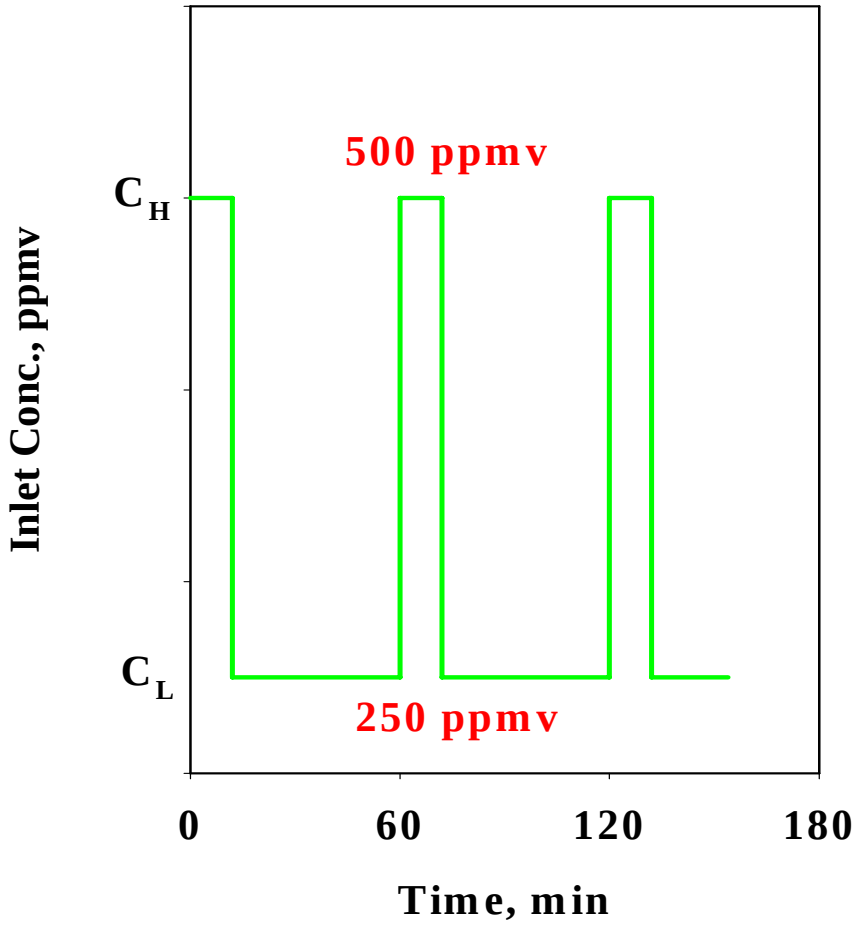


Carbon accumulation in the two beds

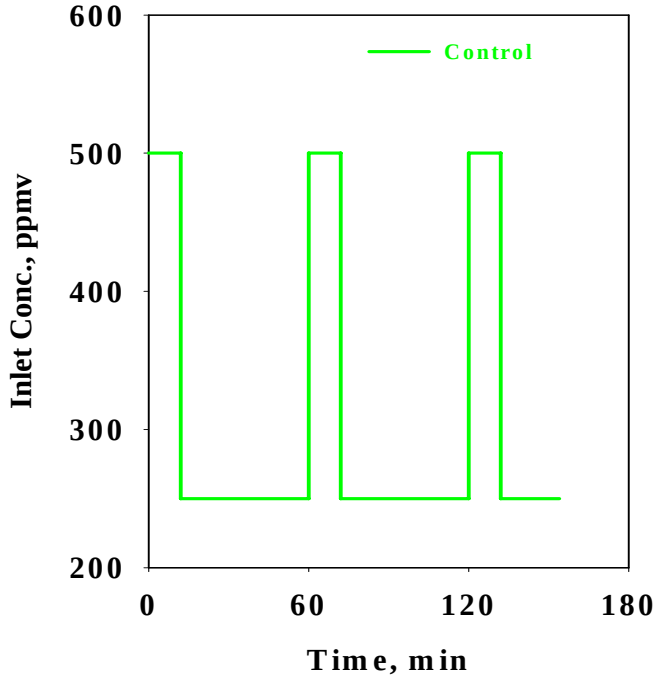
Results Second square wave

Square Wave Change

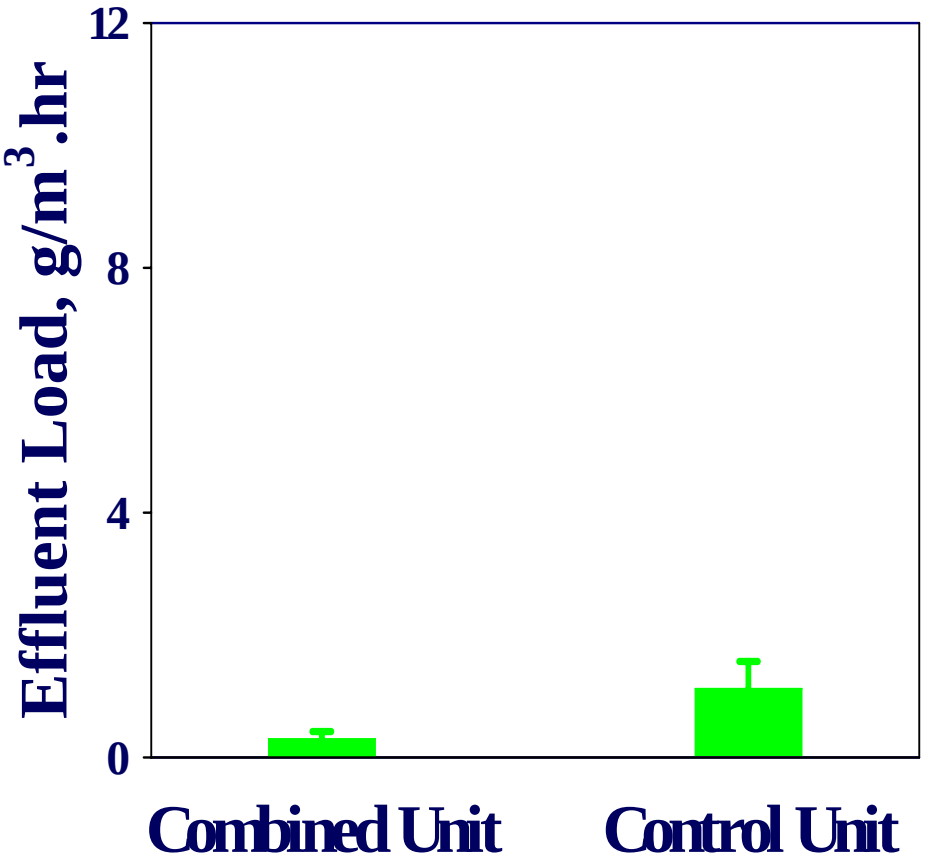
- Base = 250 ppmv
- Peak = 500 ppmv (12 mins / hour)
- Average concentration : 300 ppmv
- Average Total Loading = 34.0 g/m^3.hr
- Toluene Loading = 15.4 g/m^3.hr
- Styrene Loading = 10.1 g/m^3.hr
- MEK Loading = 6.3 g/m^3.hr
- MIBK Loading = 2.2 g/m^3.hr



Results Second square wave



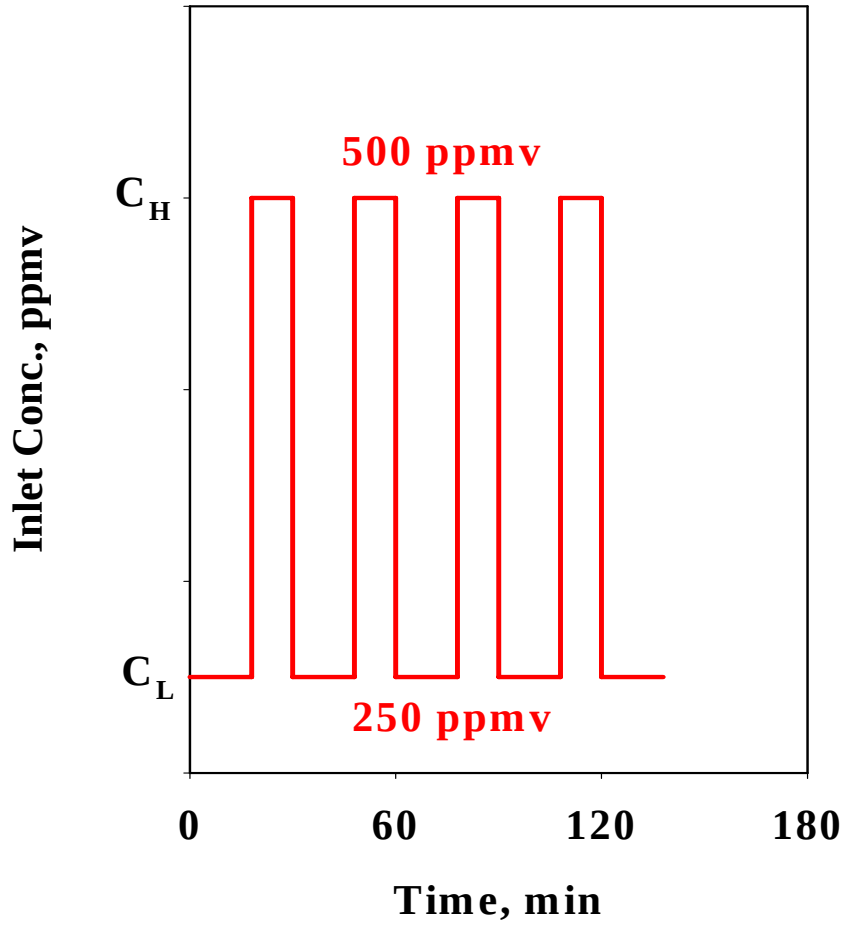
Combined	Ave	SD
ppmv	188.6	19.2



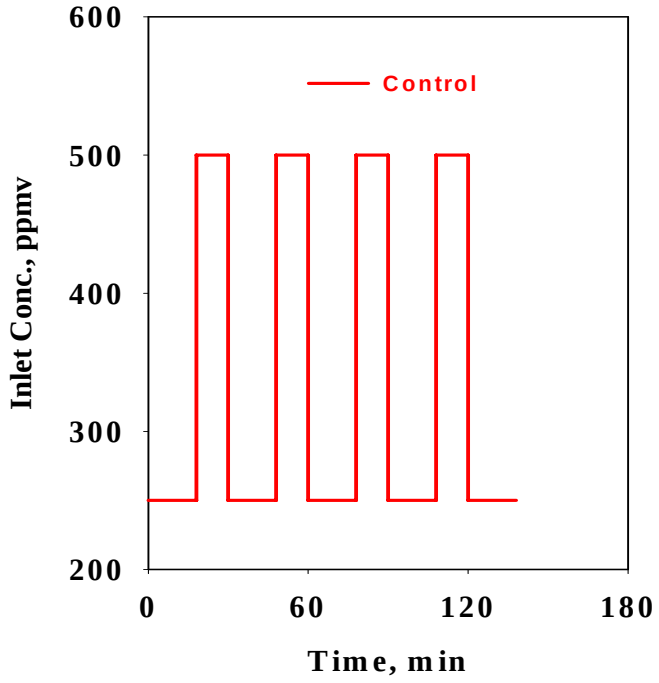
Results Third square wave

Square Wave Change

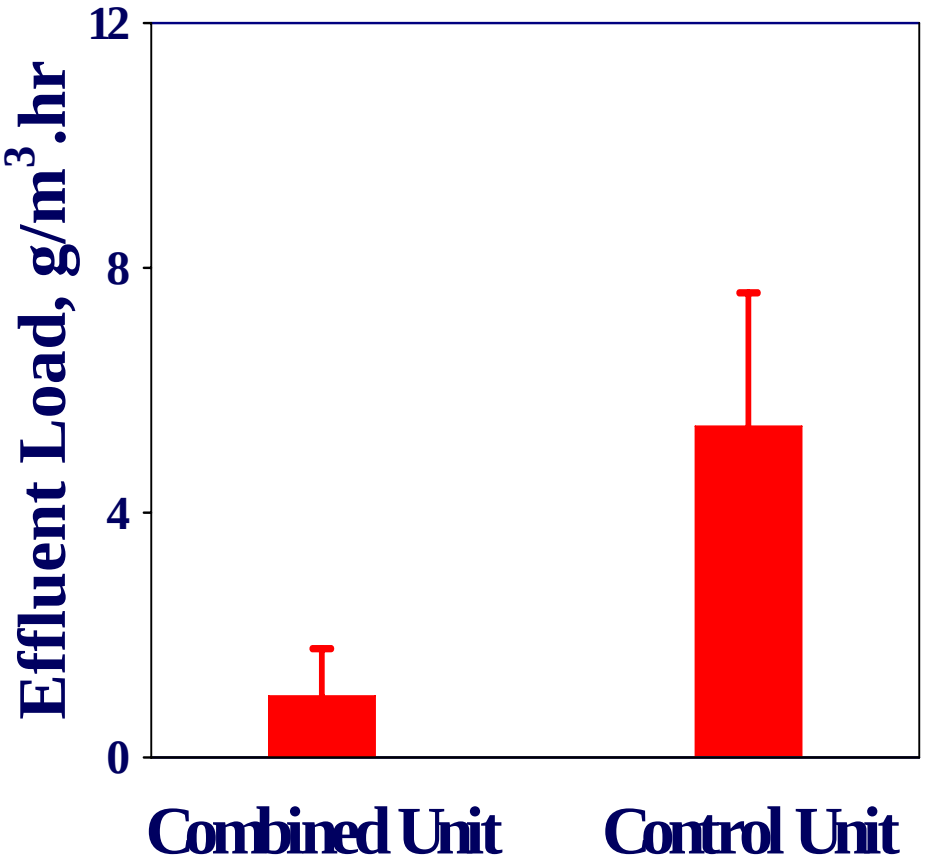
- Base = 250 ppmv
- Peak = 500 ppmv (2 × 12 mins / hr)
- Average concentration : 350 ppmv
- Average Total Loading = 39.6 g/m^3.hr
- Toluene Loading = 17.9 g/m^3.hr
- Styrene Loading = 11.8 g/m^3.hr
- MEK Loading = 7.4 g/m^3.hr
- MIBK Loading = 2.5 g/m^3.hr



Results Third square wave



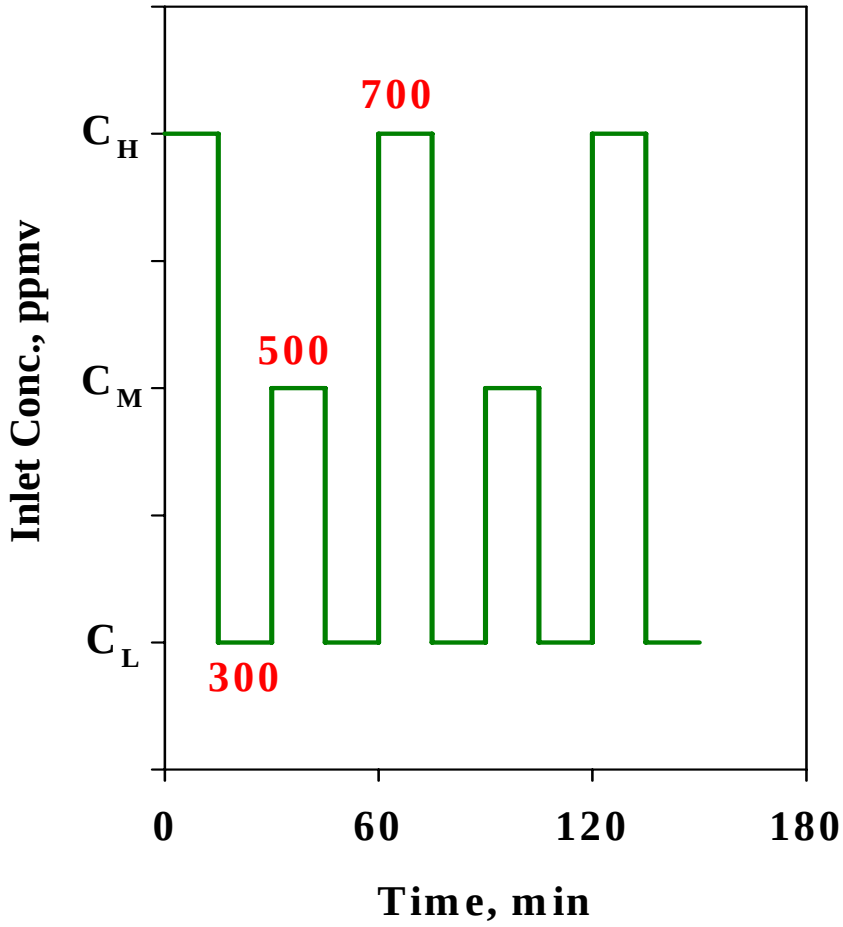
Combined	Ave	SD
ppmv	230.1	25.2



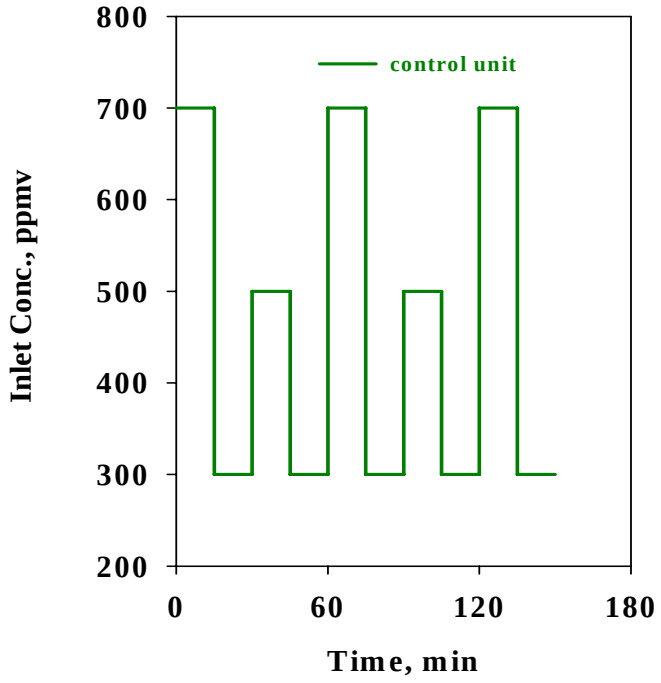
Results Fourth square wave

Square Wave Change

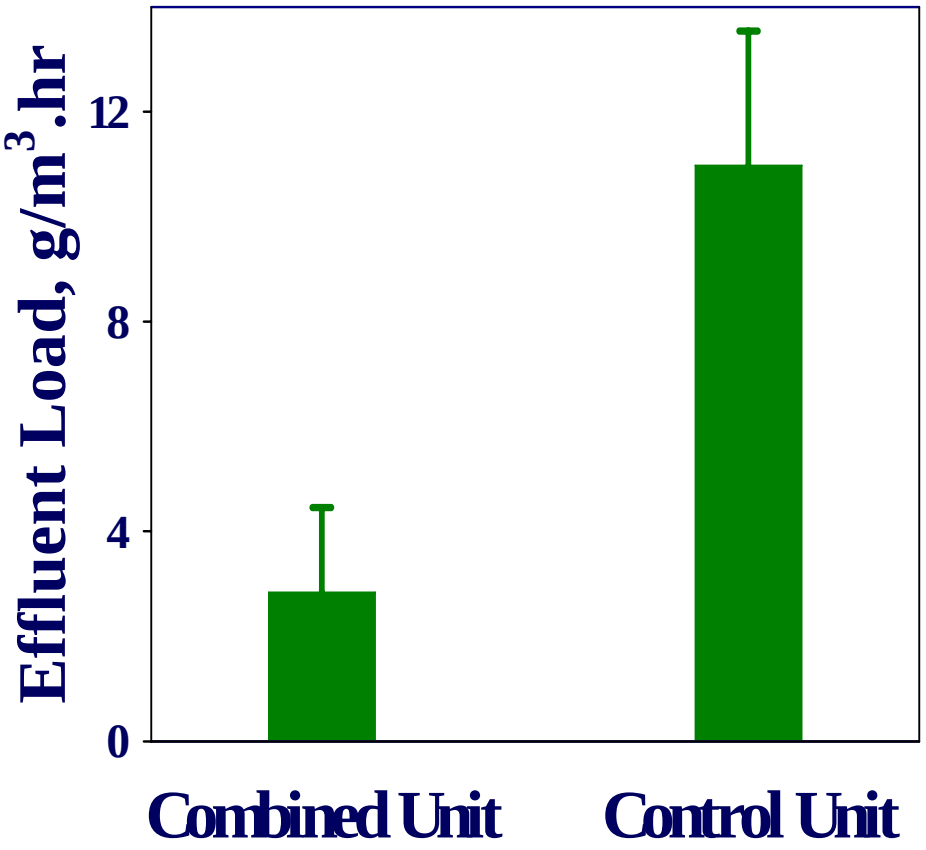
- Base = 300 ppmv
- Middle = 500 ppmv (15 mins/hour)
- Peak = 700 ppmv (15 mins / hour)
- Average concentration : 450 ppmv
- Average Loading = 50.9 g/m^3.hr
- Toluene Loading = 23.0 g/m^3.hr
- Styrene Loading = 15.1 g/m^3.hr
- MEK Loading = 9.5 g/m^3.hr
- MIBK Loading = 3.3 g/m^3.hr



Results Fourth square wave



Combined	Ave	SD
ppmv	338.1	21.2



Effective Control of Gaseous VOC Mixture in a TBAB Coupled with Cyclic Adsorption/Desorption Beds

Experimental Results

- Starvation effect (Fourth Square Wave)

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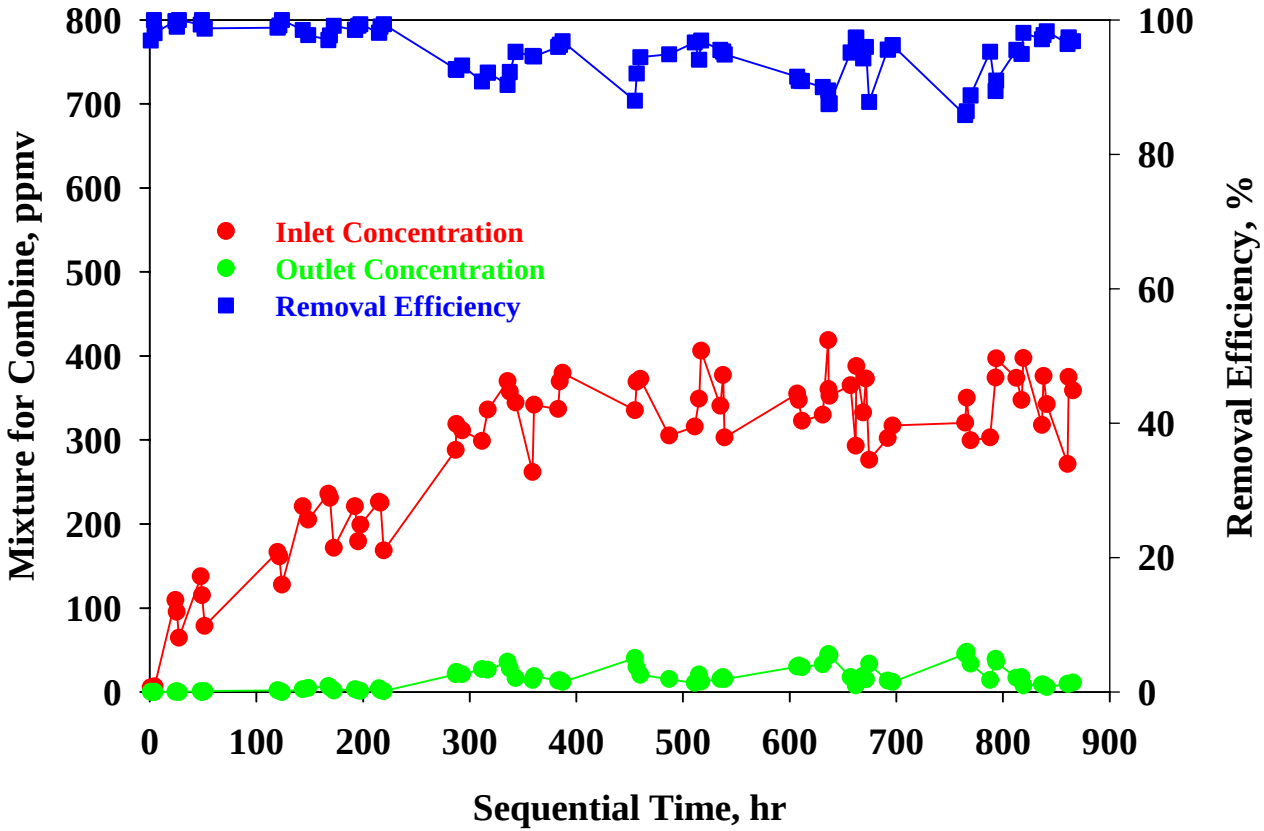
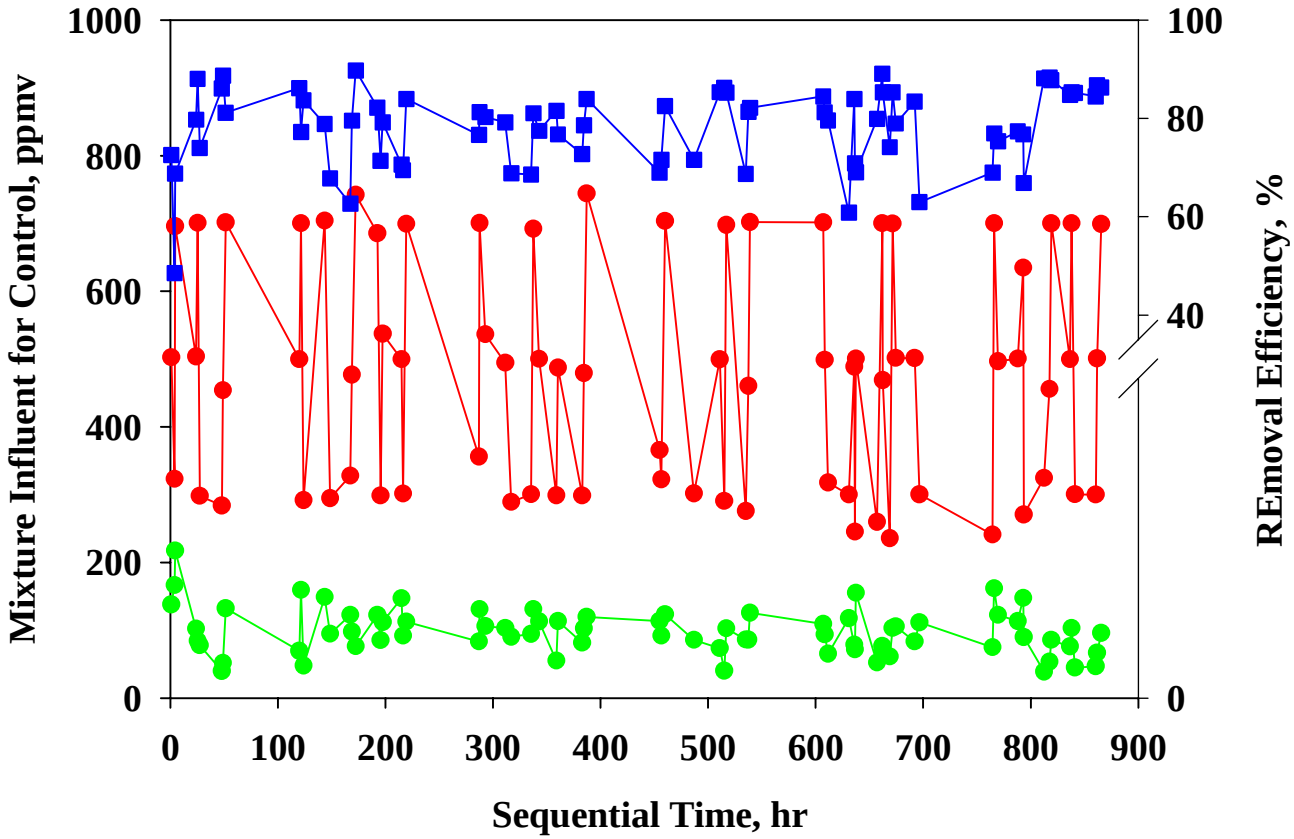
Results Fourth square wave

Biofilter Performance in Combined System-Backwashing



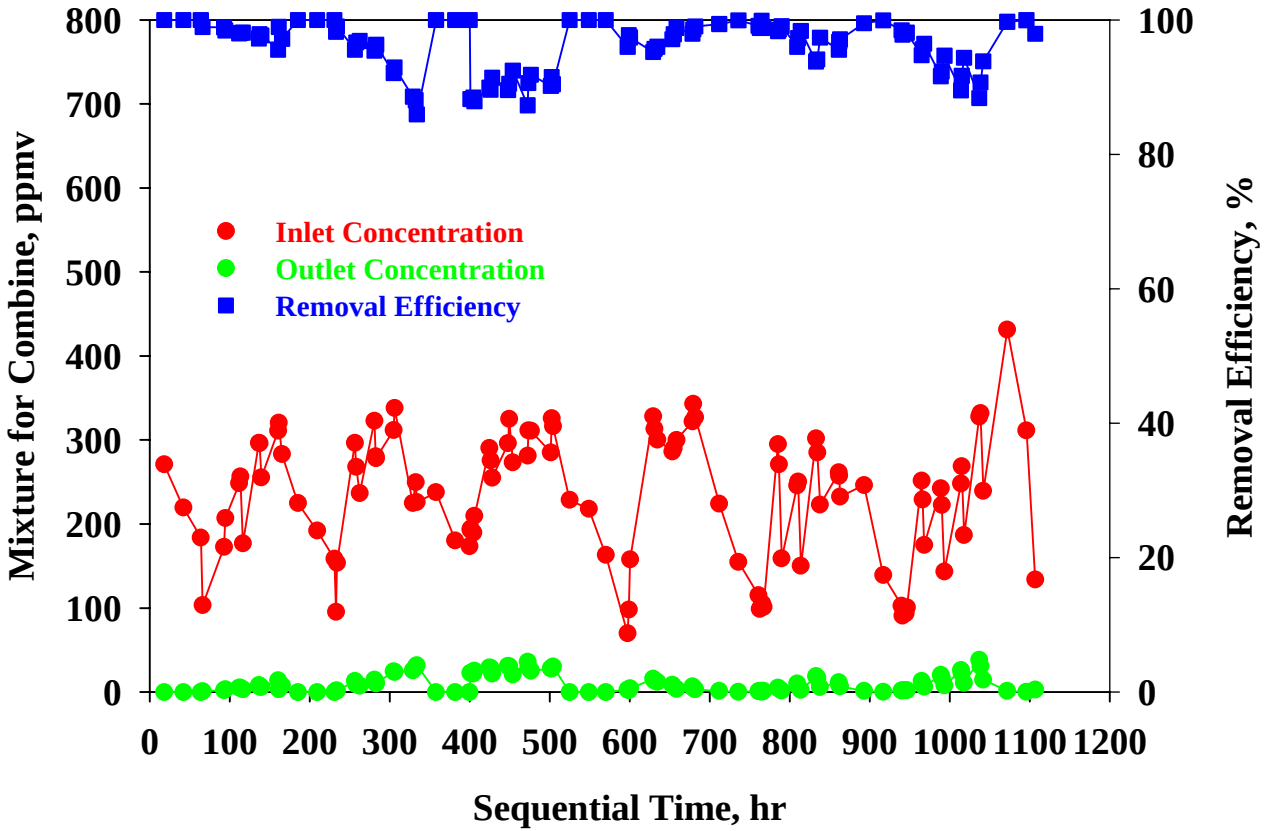
Results Fourth square wave

Biofilter Performance in Control System-Backwashing



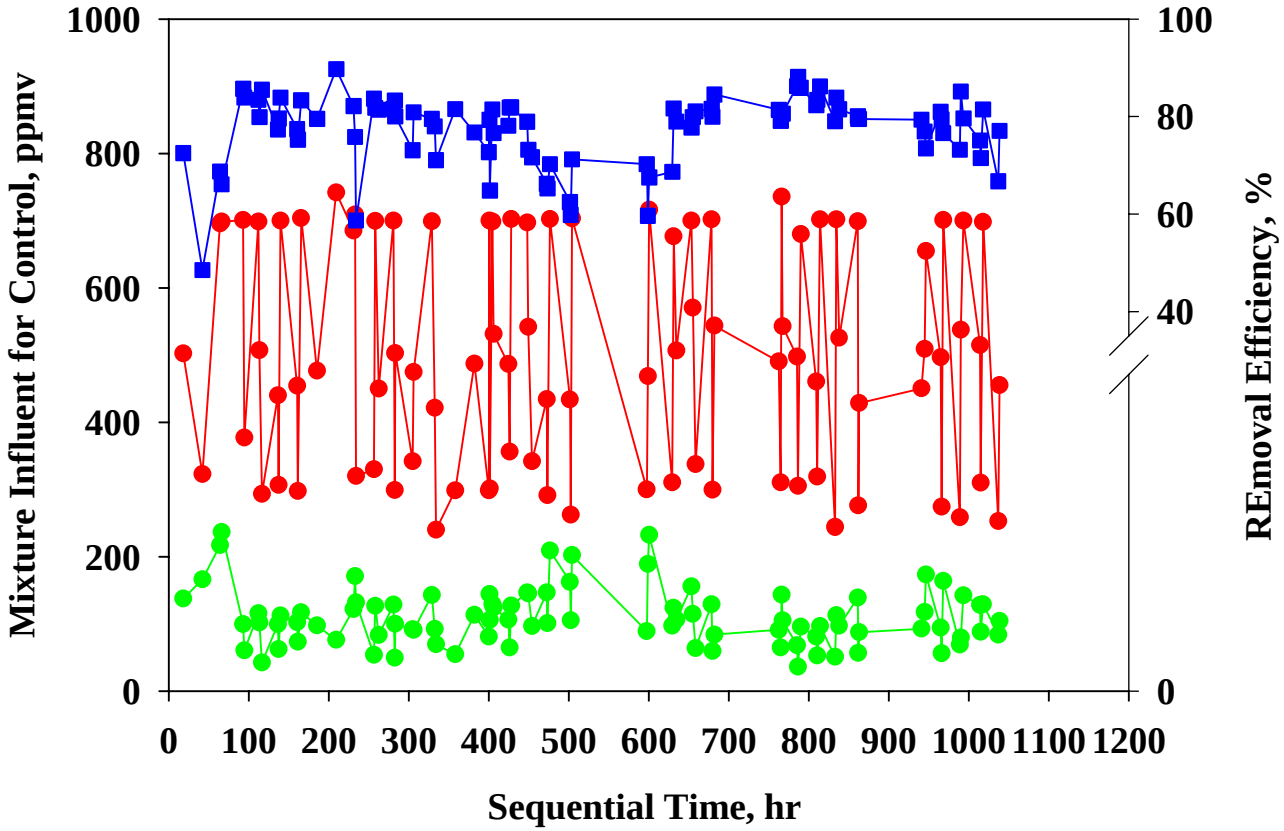
Results Fourth square wave

Biofilter Performance in Combined System-Starvation



Results Fourth square wave

Biofilter Performance in Control System-Starvation



Effective Control of Gaseous VOC Mixture in a TBAB Coupled with Cyclic Adsorption/Desorption Beds

Experimental Results

- Kinetics analysis

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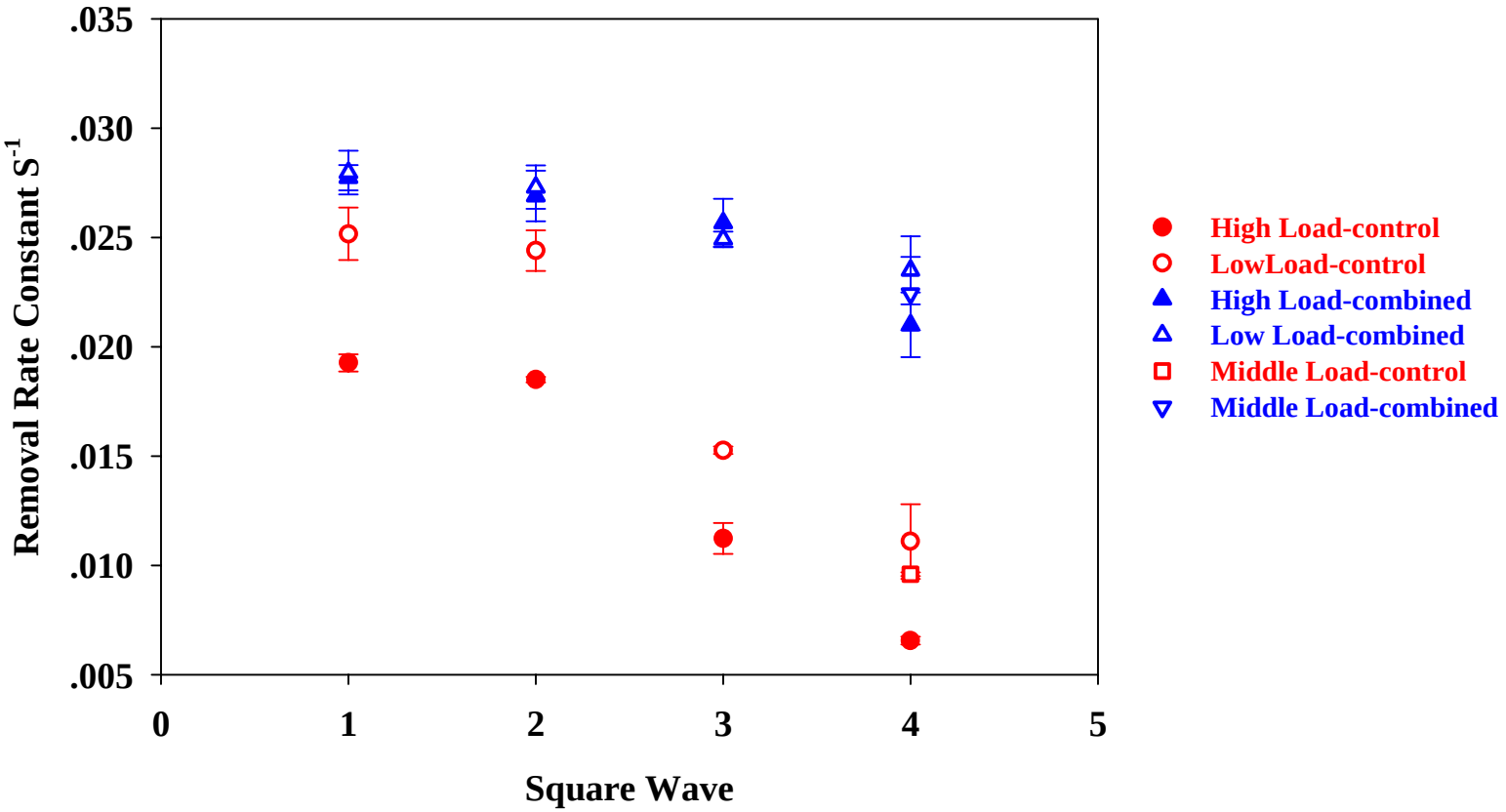
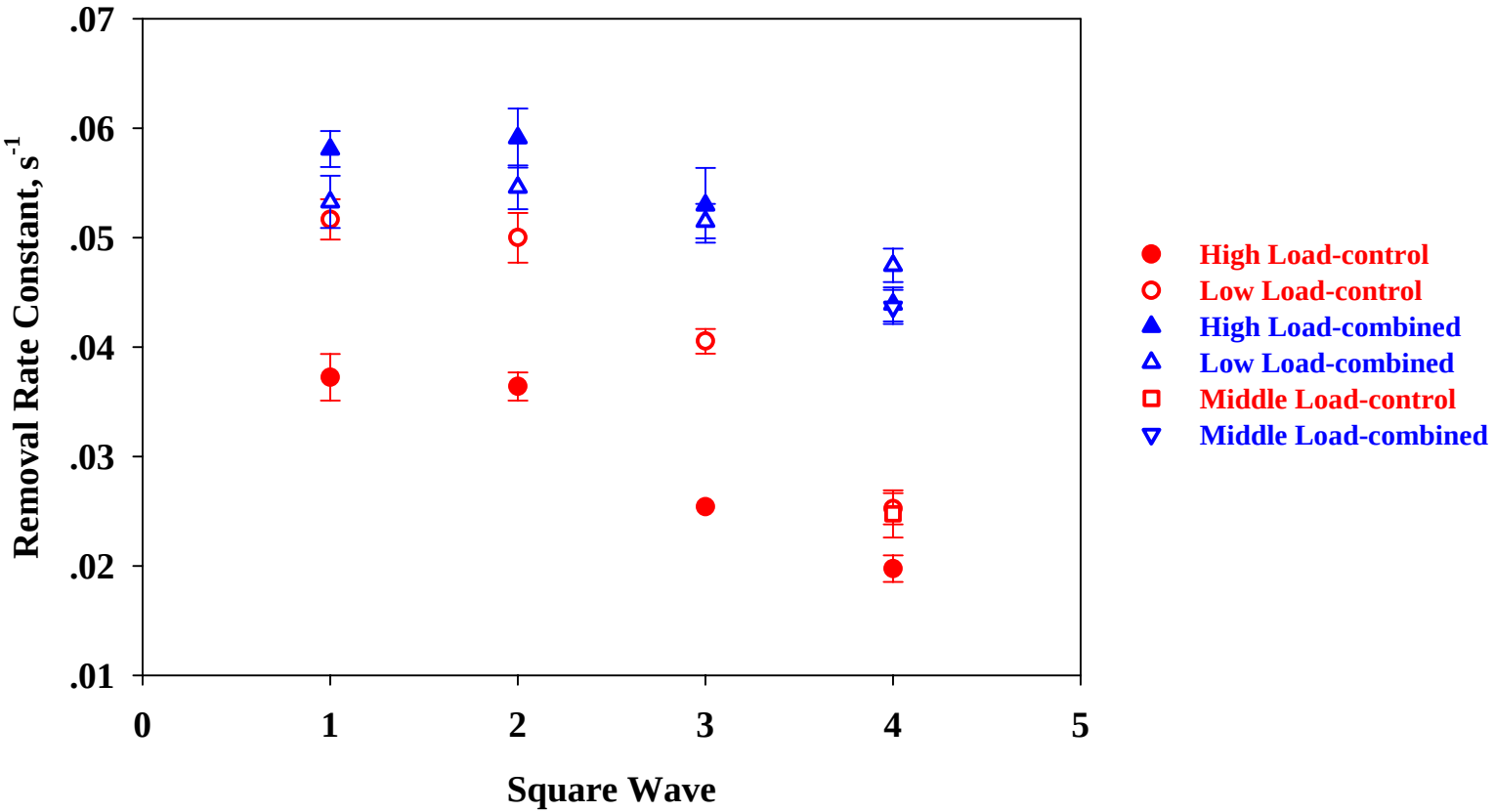
Results Kinetics analysis

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.**

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Acknowledgement

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

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Effective Control of Gaseous VOC Mixture in a TBAB Coupled with Cyclic Adsorption/Desorption Beds

Questions?

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