A&WMA's 99th Annual Conference and Exhibition

Performance of a Trickle-Bed Air Biofilter for Removal of Paint Booth VOCs Mixture

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Introduction

Conceptually identical process to the biofilter

- Microbial attachment: Synthetic inorganic or polymeric media
- Intermittent delivery of Nutrient & Buffer to the media

⇒ ✓ **Consistent Nutrient & pH control**

✓ **Optimizing the waste utilizing kinetics**

Trickle-Bed Air Biofilter (TBAB)

- **Consistent**
- **Long-term**
- **High**

Removal Performance

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Introduction

for more successful application in industry

Challenges

Source Characteristics

- Transient loading
- VOCs composition
- Emission mode: non-use periods

Biofilter Maintenance

- Biomass accumulation
- Microbial activity

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Objective

Main Objective

To evaluate performance of TBAB for VOC mixtures

Specific Objectives

- **Effect of step-change in influent concentration**
- **Effect of non-use periods**
- **Re-acclimation**
- **Carbon mass balance**

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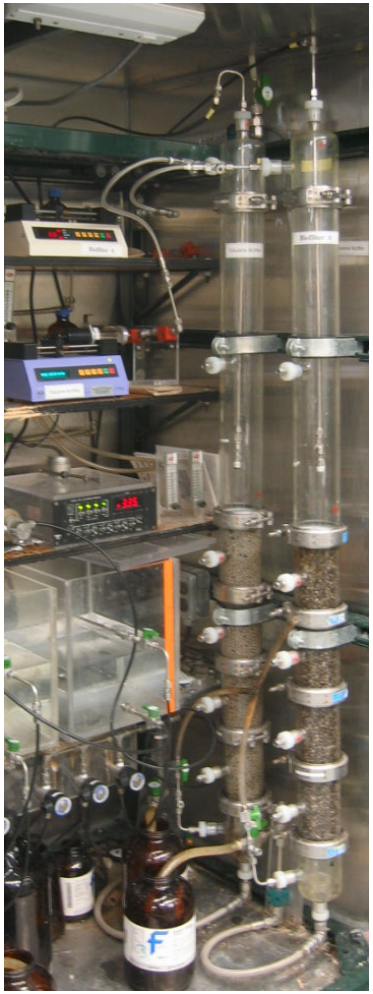
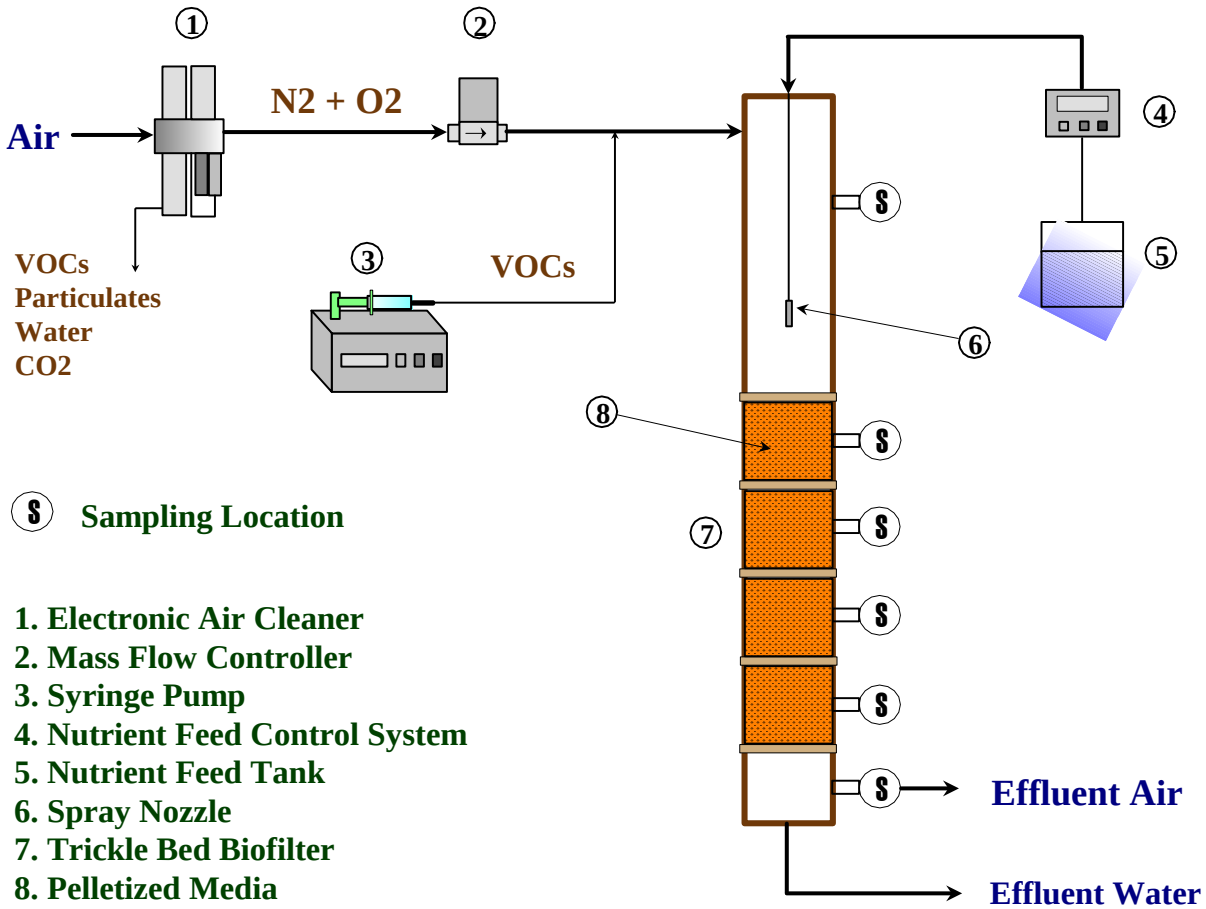
Materials and Methods

- **Reactor** : Independent lab-scale TBAB
- **Media**: pelletized biological support media



Materials and Methods



1. Electronic Air Cleaner
2. Mass Flow Controller
3. Syringe Pump
4. Nutrient Feed Control System
5. Nutrient Feed Tank
6. Spray Nozzle
7. Trickle Bed Biofilter
8. Pelletized Media

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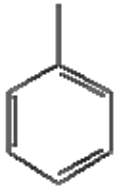
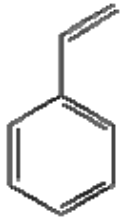
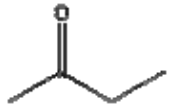
Materials and Methods

- **Feed VOCs**

	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

- **Feed VOC Mixtures**
  - **Feeding condition to Biofilter A: Equal Molar Ratio**
    - **Toluene: Styrene: MEK: MIBK = 1: 1: 1: 1**
  - **Feeding condition to Biofilter B: Emission Ratio Based on *EPA 2003 toxic release report* for chemical industries**
    - **Toluene: Styrene: MEK: MIBK = 0.448: 0.260: 0.234: 0.058**

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Materials and Methods

➢ Operating Conditions

- **Inlet concentration of feed VOCs**
  - 50 ppmv ~ 1000 ppmv for Biofilter A
  - 50 ppmv ~ 500 ppmv for Biofilter B
- **Flow rate**
  - Air flow = 1.35 L/min **(Constant EBRT = 2.02 min)**
- **Biomass control**
  - Backwashing : 1 hour of duration / week
  - Starvation: two days / week

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Materials and Methods

➢ Biofilter Operating Conditions

Biofilter A					
Experimental Stage	**I**	**II**	**III**	**IV**	**V**
Concentration, ppmv	**50**	**100**	**250**	**500**	**1000**
Toluene loading rate kg COD/m^3.day	**0.11**	**0.22**	**0.54**	**1.07**	**2.14**
Styrene loading rate kg COD/m^3.day	**0.12**	**0.24**	**0.60**	**1.19**	**2.39**
MEK loading rate kg COD/m^3.day	**0.07**	**0.13**	**0.33**	**0.66**	**1.32**
MIBK loading rate kg COD/m^3.day	**0.10**	**0.20**	**0.51**	**1.02**	**2.03**
Total Loading rate kg COD/m^3·day	**0.40**	**0.79**	**1.98**	**3.94**	**7.88**

Materials and Methods

➢ Biofilter Operating Conditions

Biofilter B						
Experimental Stage	I	II	III	IV	V*	VI
Concentration, ppmv	50	100	250	500	350	300
Toluene loading rate kg COD/m^3.day	0.19	0.38	0.96	1.92	1.34	1.15
Styrene loading rate kg COD/m^3.day	0.12	0.25	0.62	1.24	0.87	0.74
MEK loading rate kg COD/m^3.day	0.06	0.12	0.31	0.62	0.43	0.37
MIBK loading rate kg COD/m^3.day	0.02	0.05	0.12	0.24	0.17	0.14
Total Loading rate kg COD/m^3·day	0.39	0.80	2.01	4.02	2.81	2.40

* Only Backwashing conducted for stage V

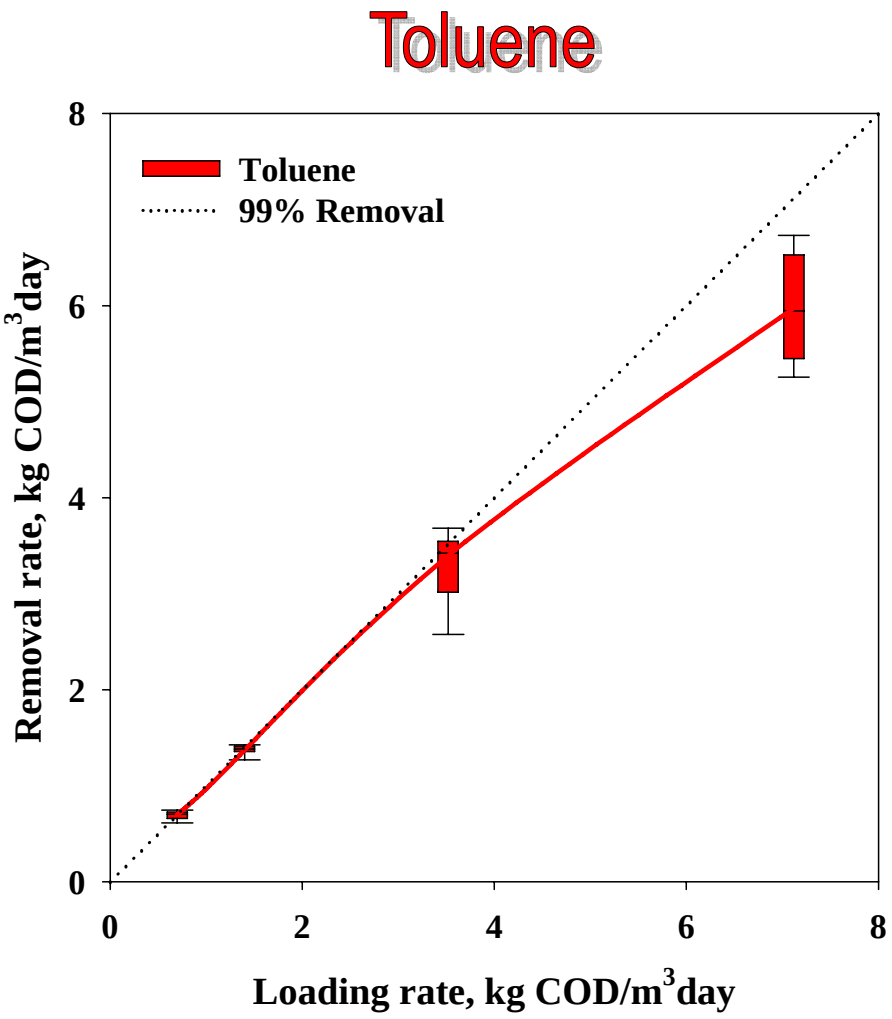
Summary of Previous Study

Toluene removal

- **Critical loading**
  3.5 kg COD/m^3·day
  (46.6 g/m^3·hr)
- **Maximum removal capacity**
  6.0 kg COD/m^3·day
  (79.9 g/m^3·hr)

EBRT: 1.23 min

→ Inlet Conc. = 250 ppmv



Ref: Kim, D., Cai, Z., Sorial, G.A., 2005. Behavior of trickle bed air biofilter for toluene removal: effect of non-use periods. *Environ. Prog.* 24, 155-161.

Previous Study

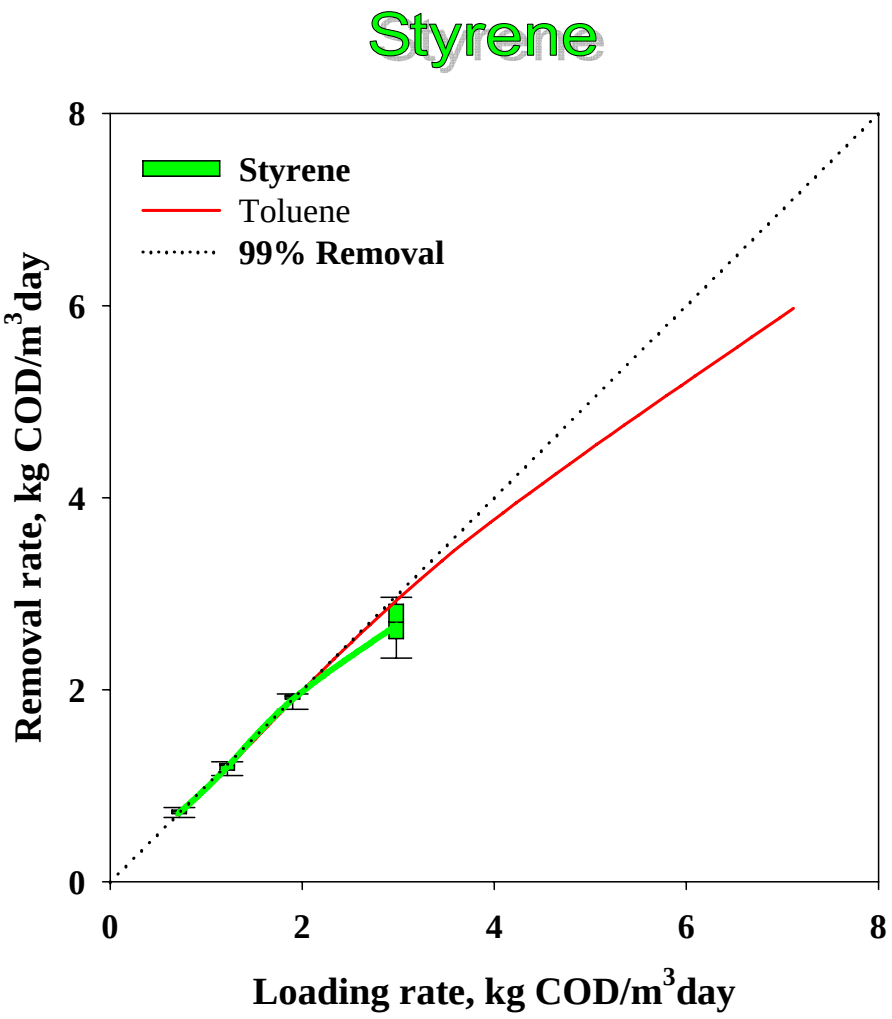
Styrene removal

- **Critical loading**
  1.9 kg COD/m^3·day
  (25.8 g/m^3·hr)

- **Maximum removal capacity**
  2.7 kg COD/m^3·day
  (36.6 g/m^3·hr)

EBRT: 2.02 min

→ Inlet Conc. = 200 ppmv



Ref: Kim, D., Cai, Z., Sorial, G.A., 2005. Evaluation of trickle-bed air biofilter performance under periodic stressed operating conditions as a function of styrene loading. *J. Air Waste Manage. Assoc.* 55, 200-209.

Previous Study

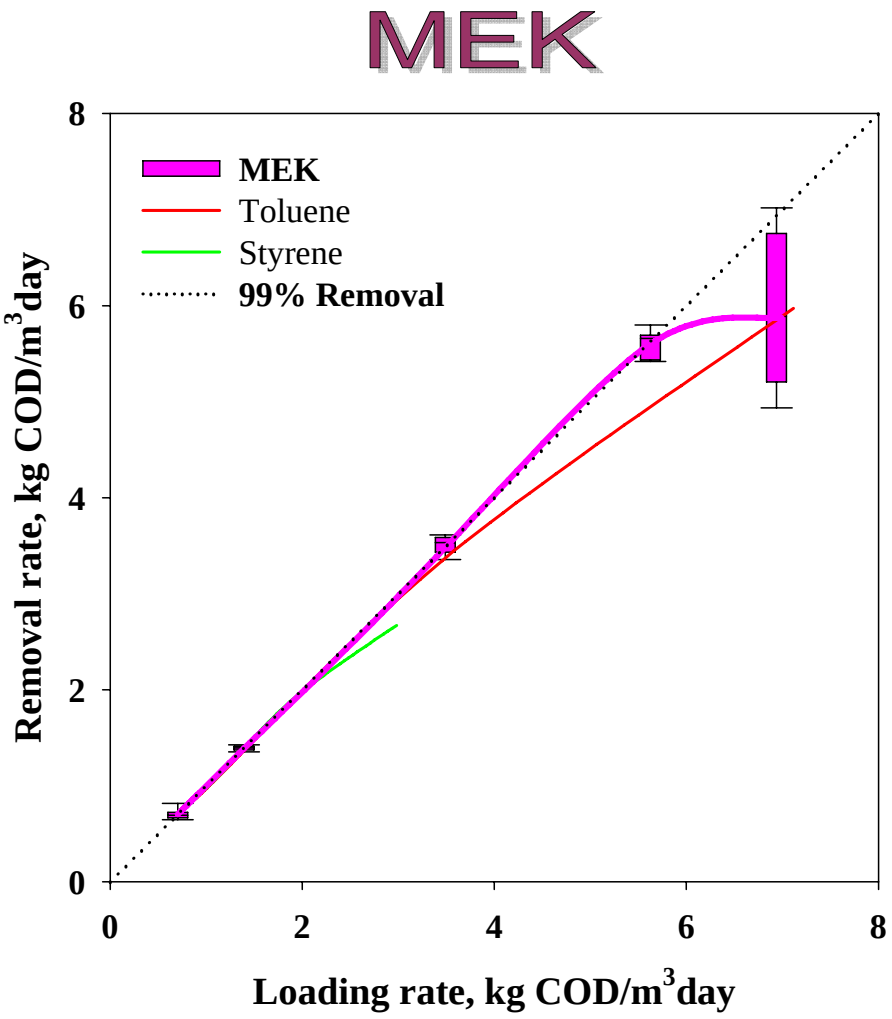
MEK removal

- **Critical loading**
  5.6 kg COD/m^3·day
  (95.6 g/m^3·hr)

- **Maximum removal capacity**
  5.9 kg COD/m^3·day
  (100.7 g/m^3·hr)

EBRT: 0.76 min

→ Inlet Conc. = 400 ppmv



Ref: Cai, Z., Kim, D., Sorial, G.A., 2004. Evaluation of trickle-bed air biofilter performance for MEK removal. J. Hazard. Mater. 114, 153-158.

Previous Study

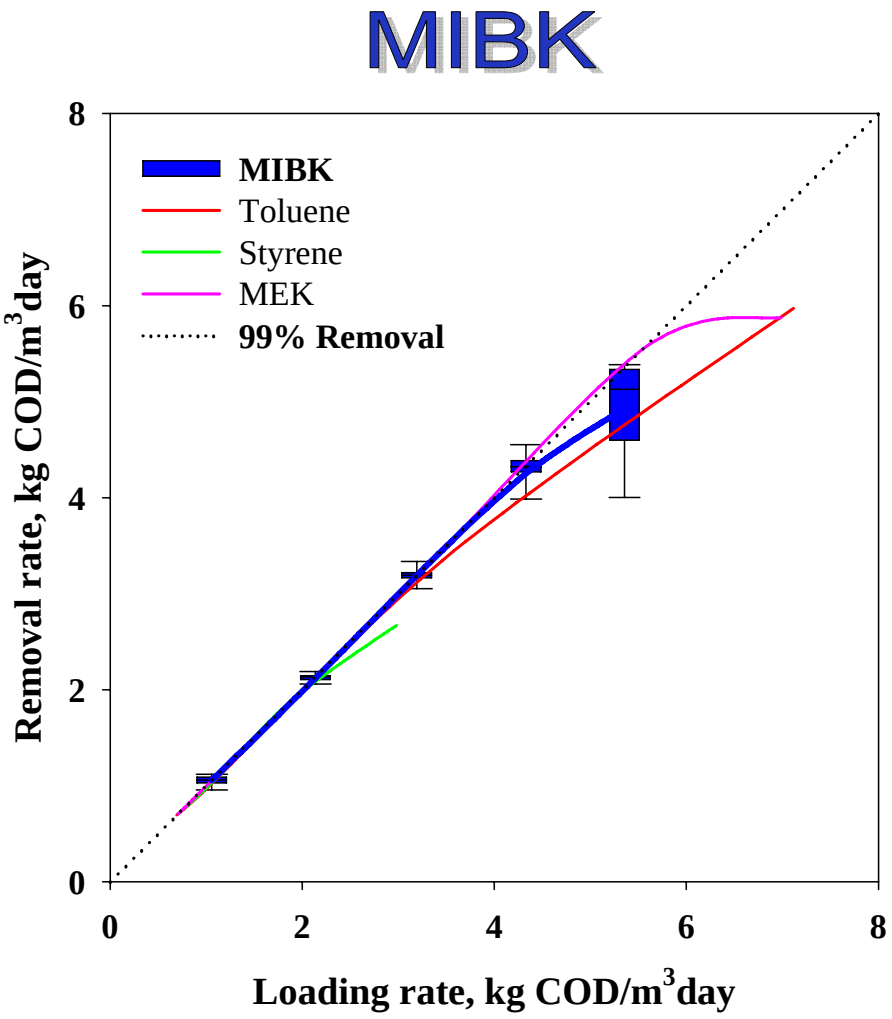
MIBK removal

- **Critical loading**
  4.3 kg COD/m^3·day
  (65.9 g/m^3·hr)

- **Maximum removal capacity**
  4.9 kg COD/m^3·day
  (75.1 g/m^3·hr)

EBRT: 0.76 min

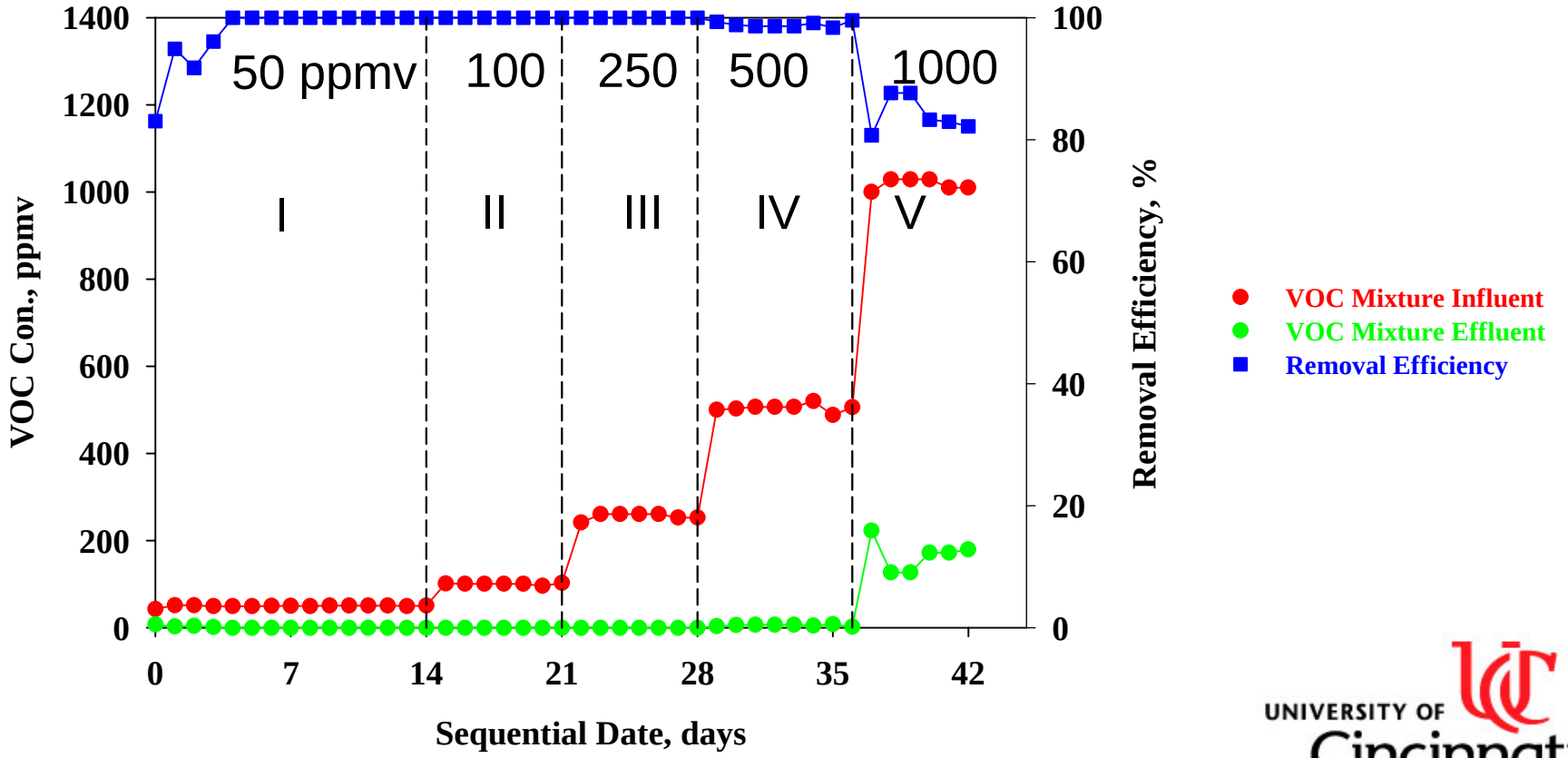
→ Inlet Conc. = 150 ppmv



Ref: Cai, Z., Kim, D., Sorial, G.A., 2005. Removal of methyl isobutyl ketone from contaminated air by trickle-bed ai biofilter. *J. Environ Eng.* 131, 1322-1329.

Results : Biofilter A Backwashing

- **TBAB performance with respect to VOC removal**



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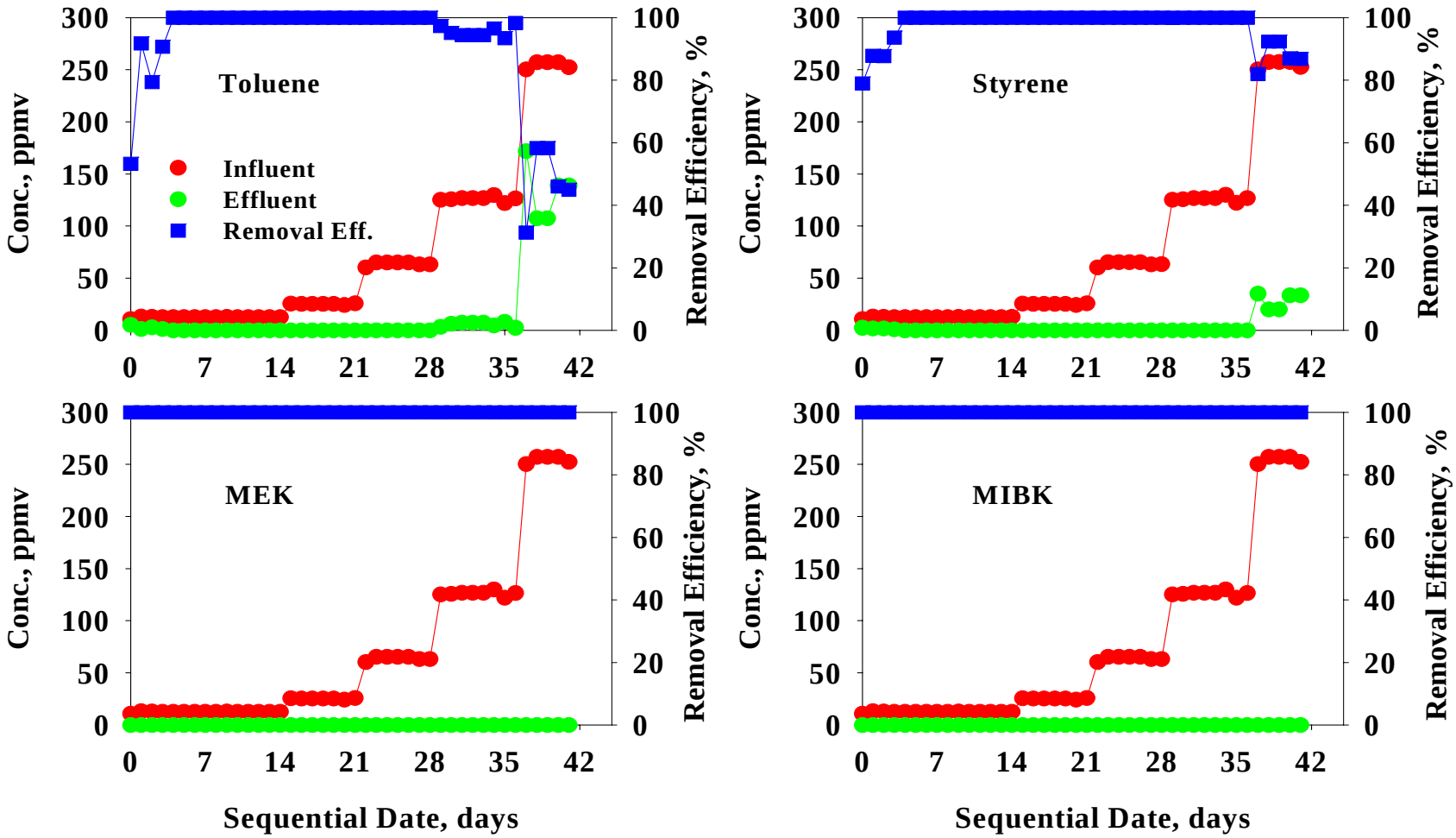
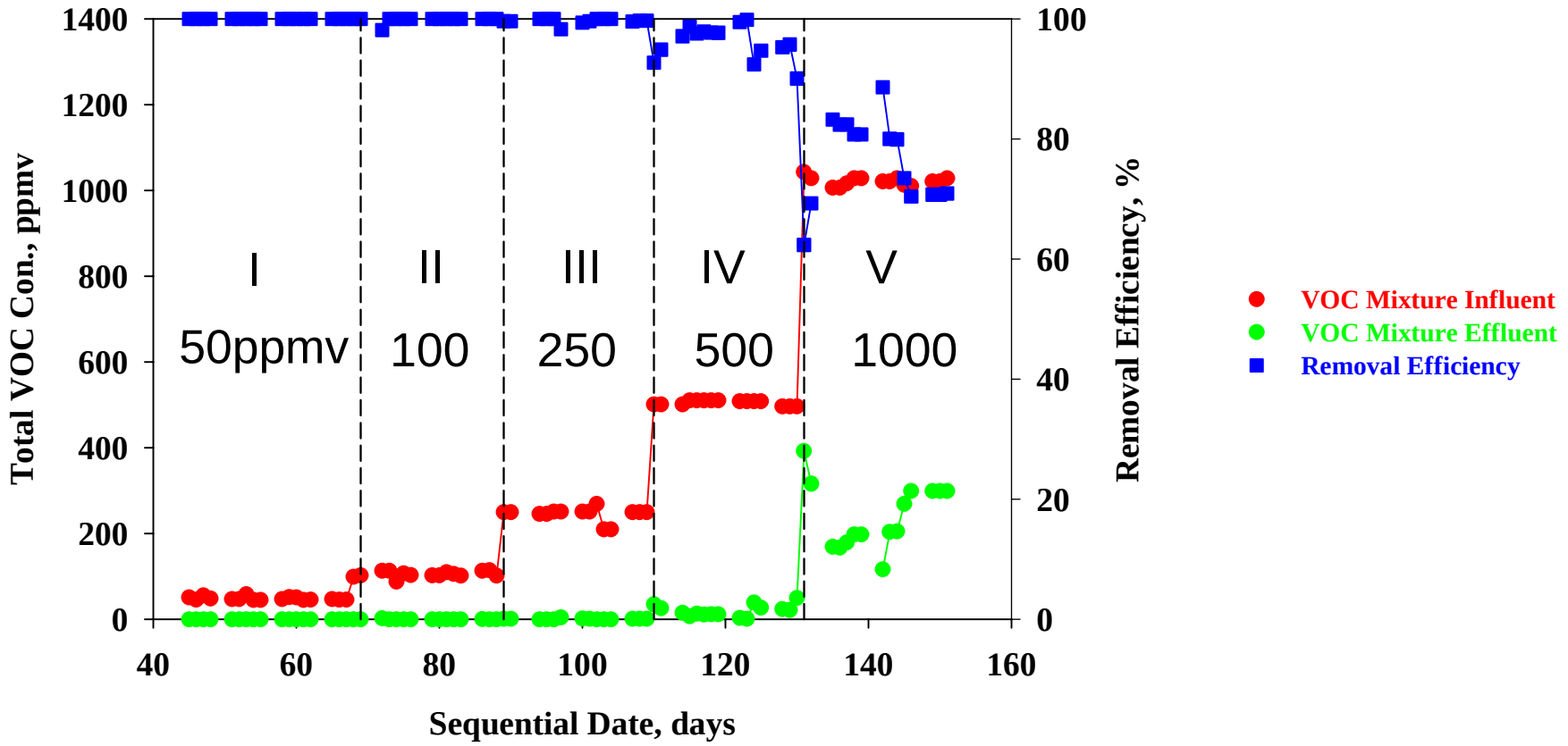
Results : Biofilter A Backwashing

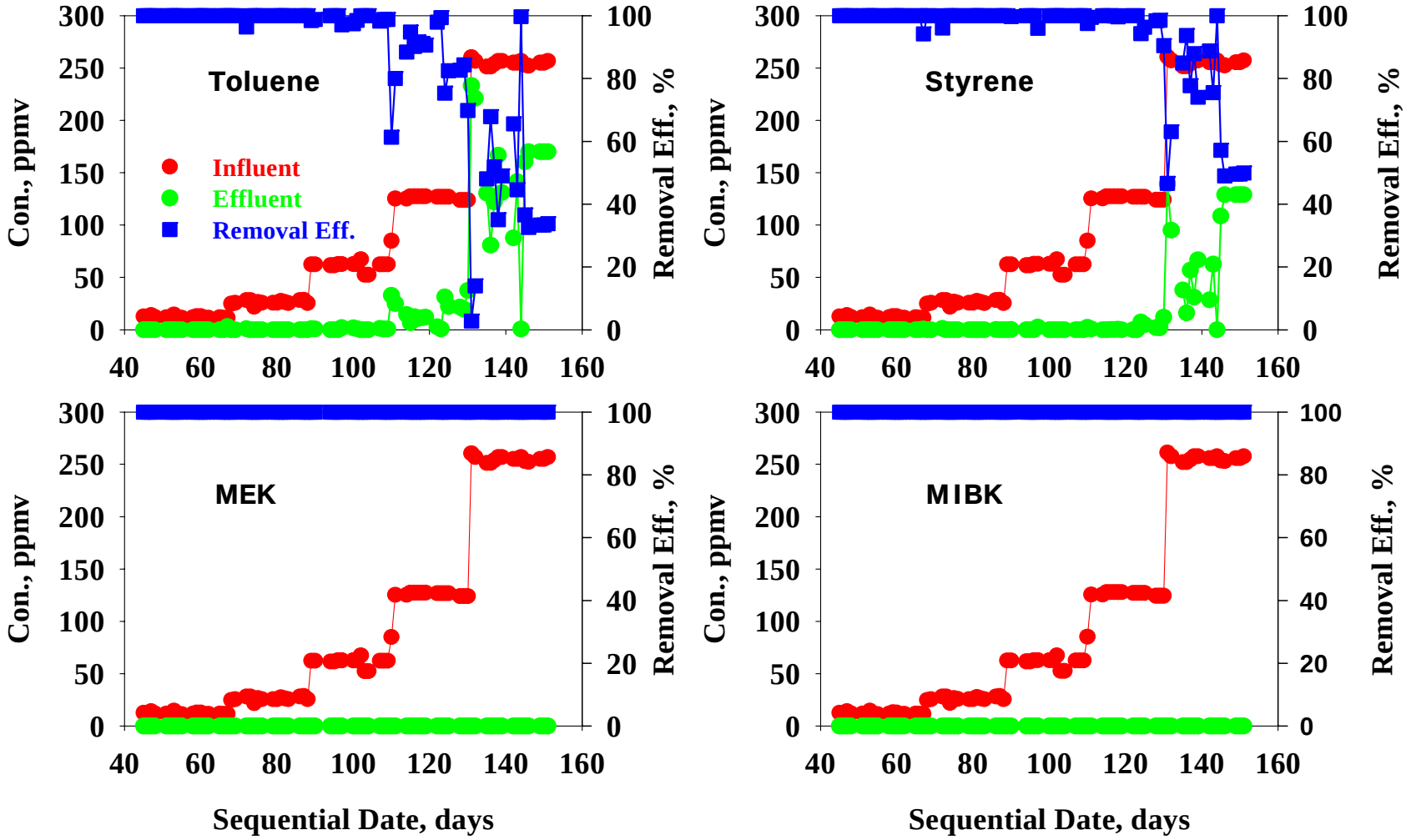


Results : Biofilter A Starvation

- **TBAB performance with respect to VOC removal**

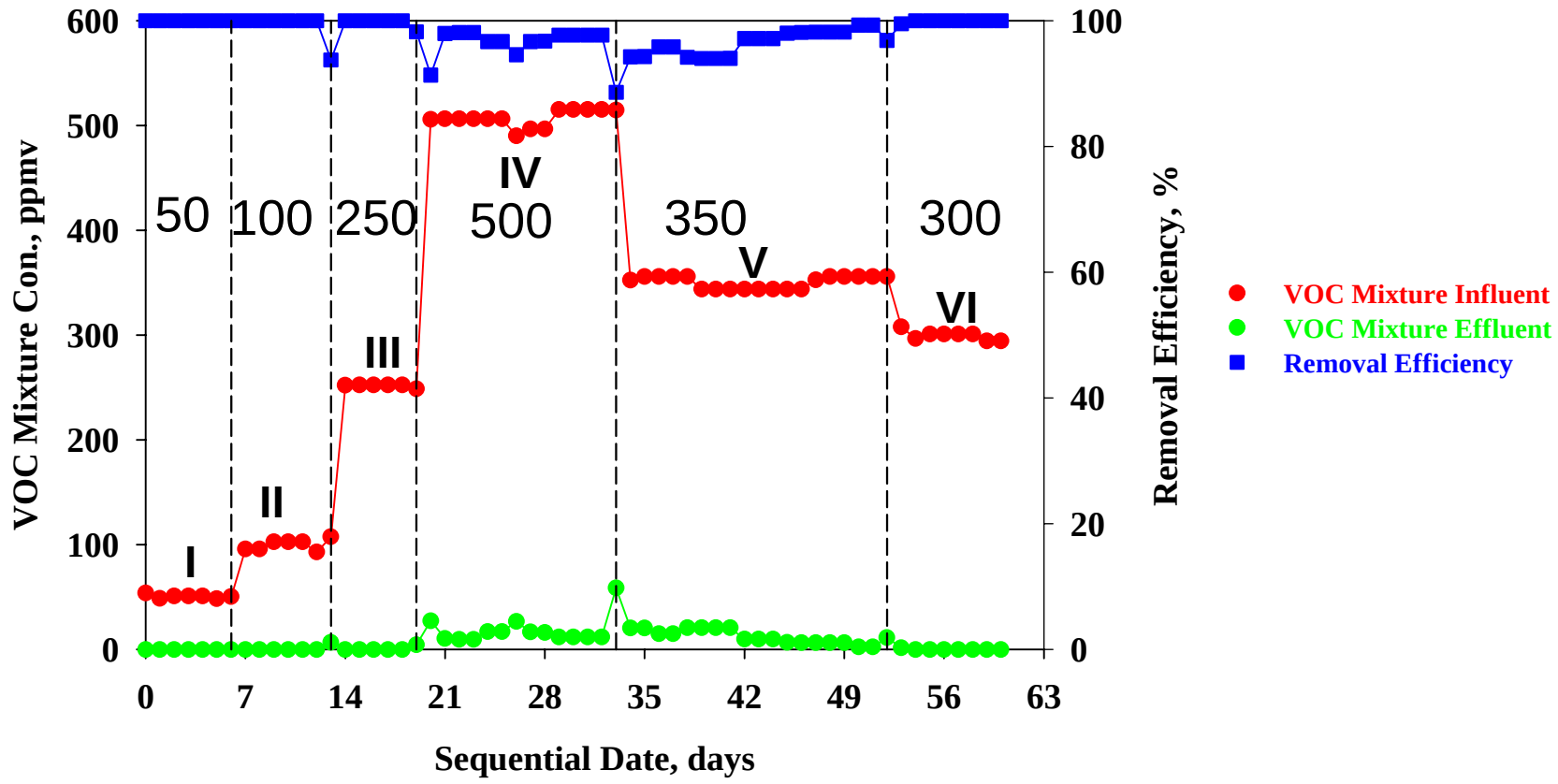


Results : Biofilter A Starvation

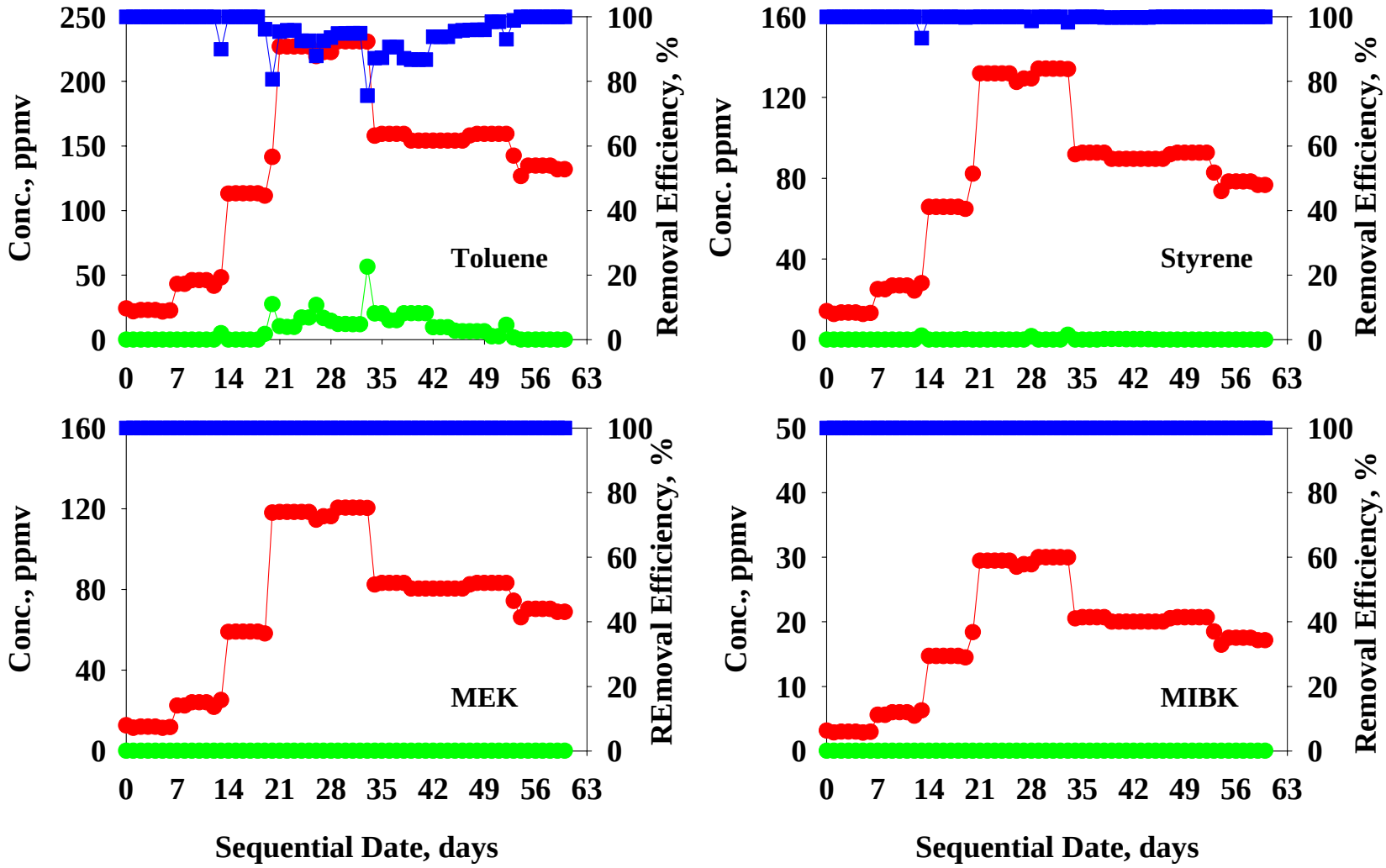


Results : Biofilter B Backwashing

- **TBAB performance with respect to VOC removal**

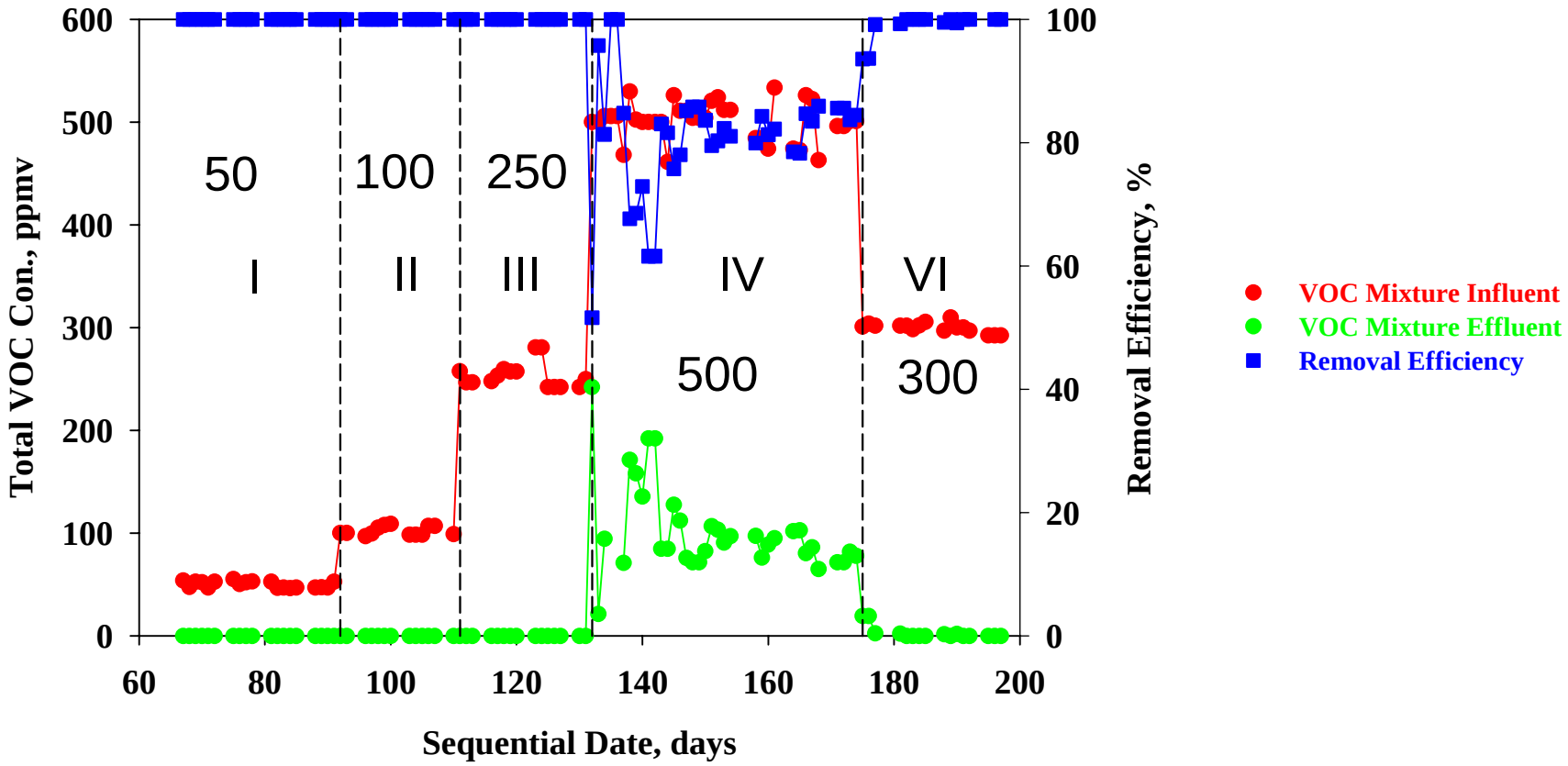


Results : Biofilter B Backwashing

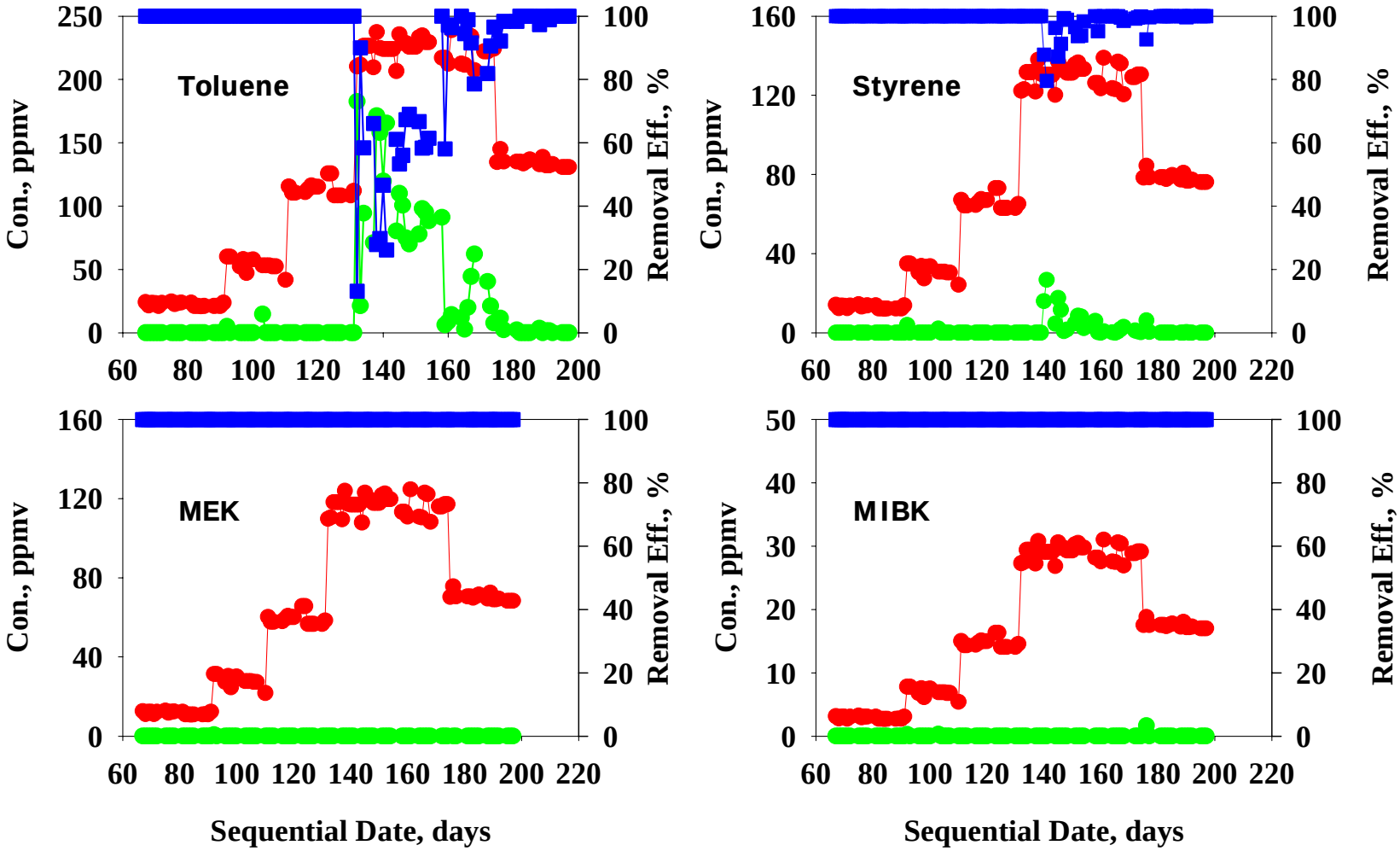


Results : Biofilter B Starvation

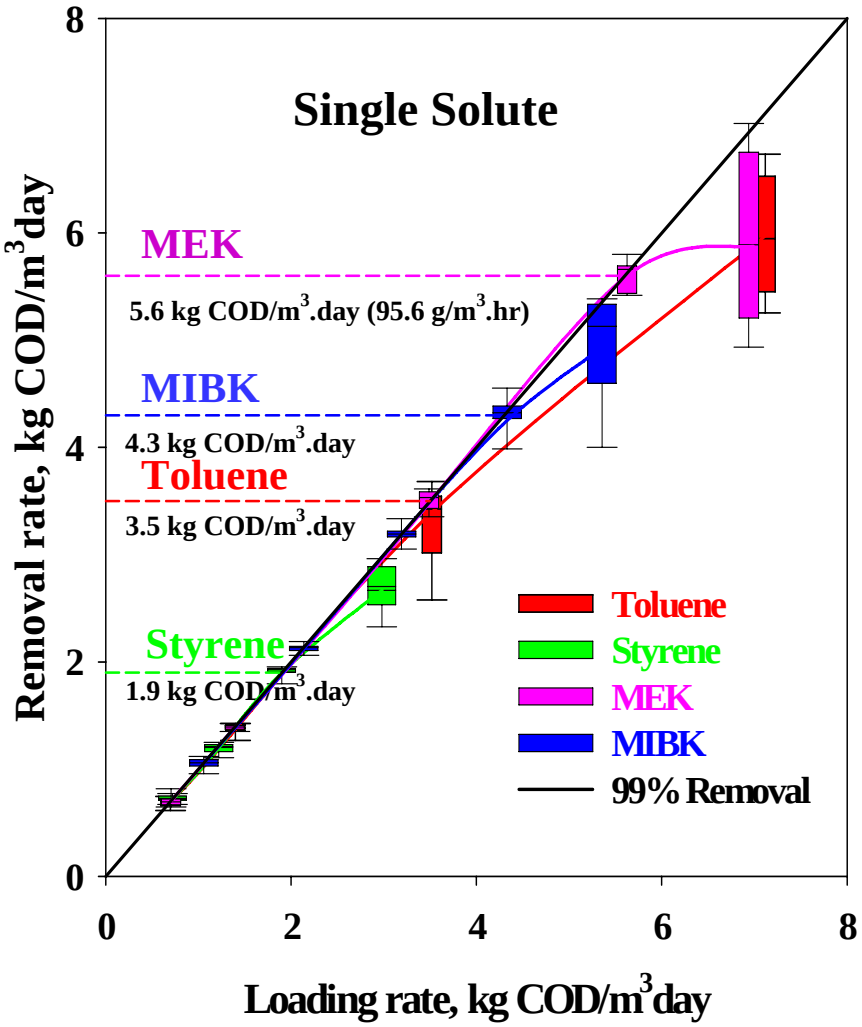
- **TBAB performance with respect to VOC removal**

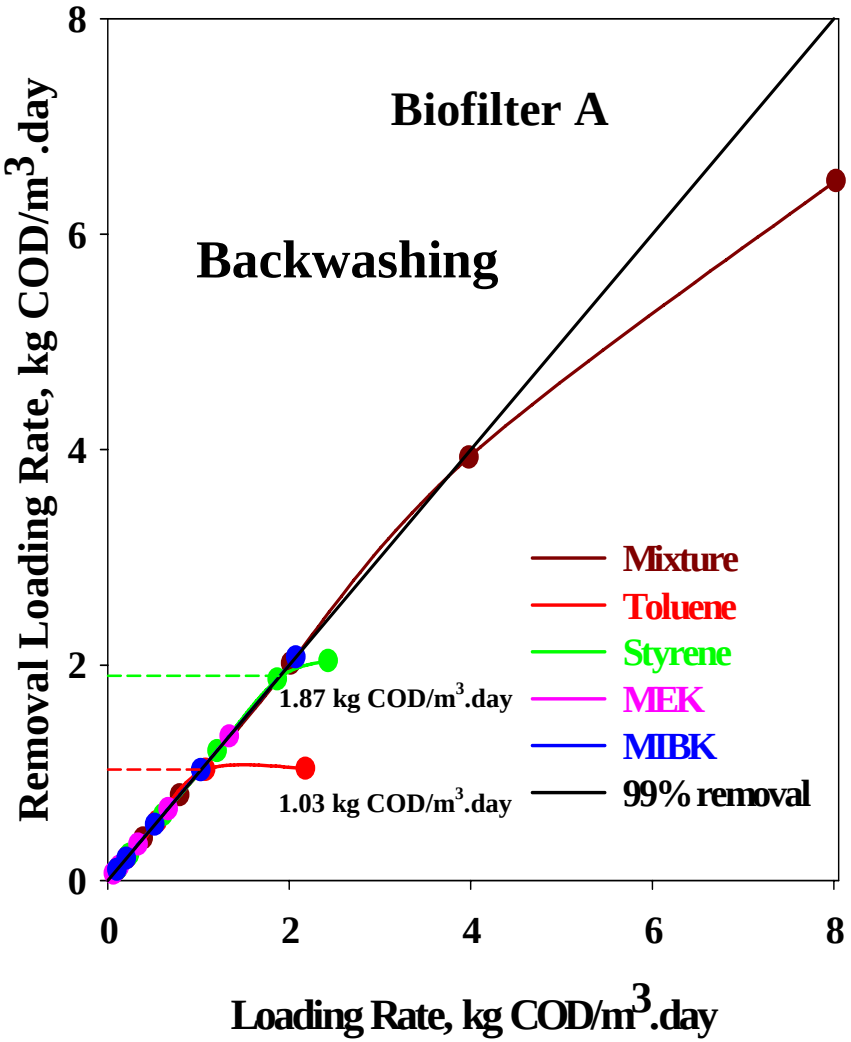


Results : Biofilter B Starvation

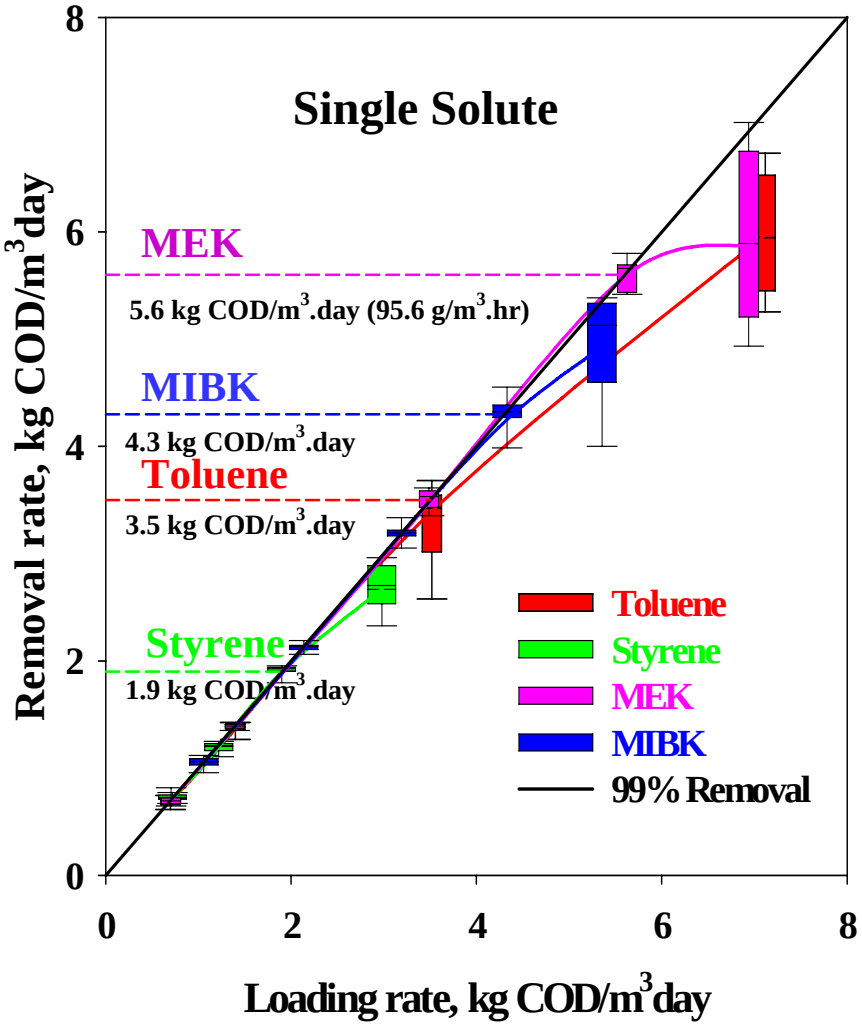


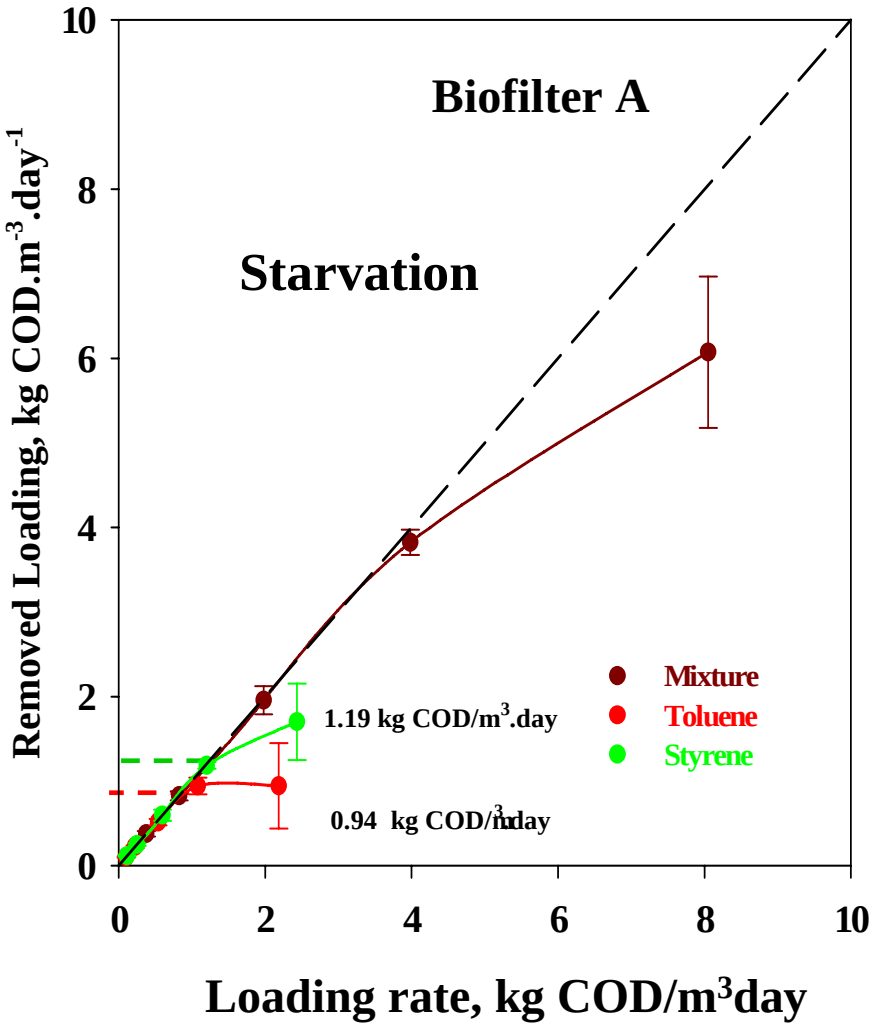
Results : Elimination Capacity for Biofilter A



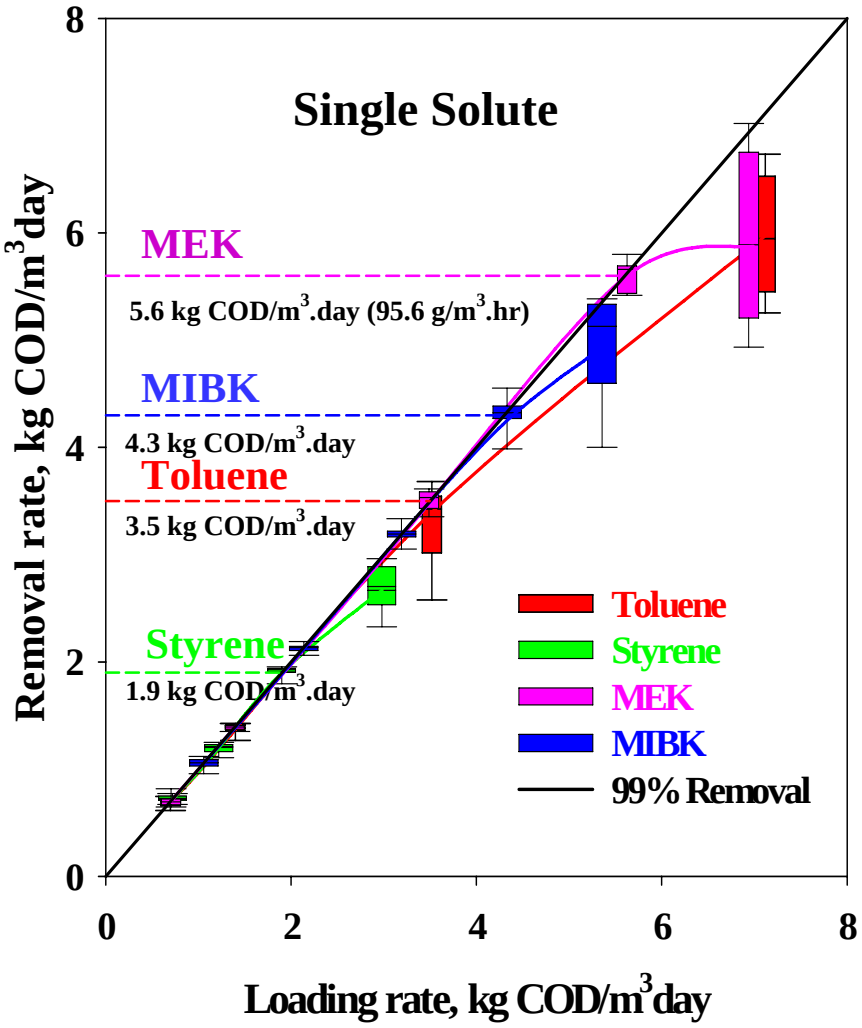


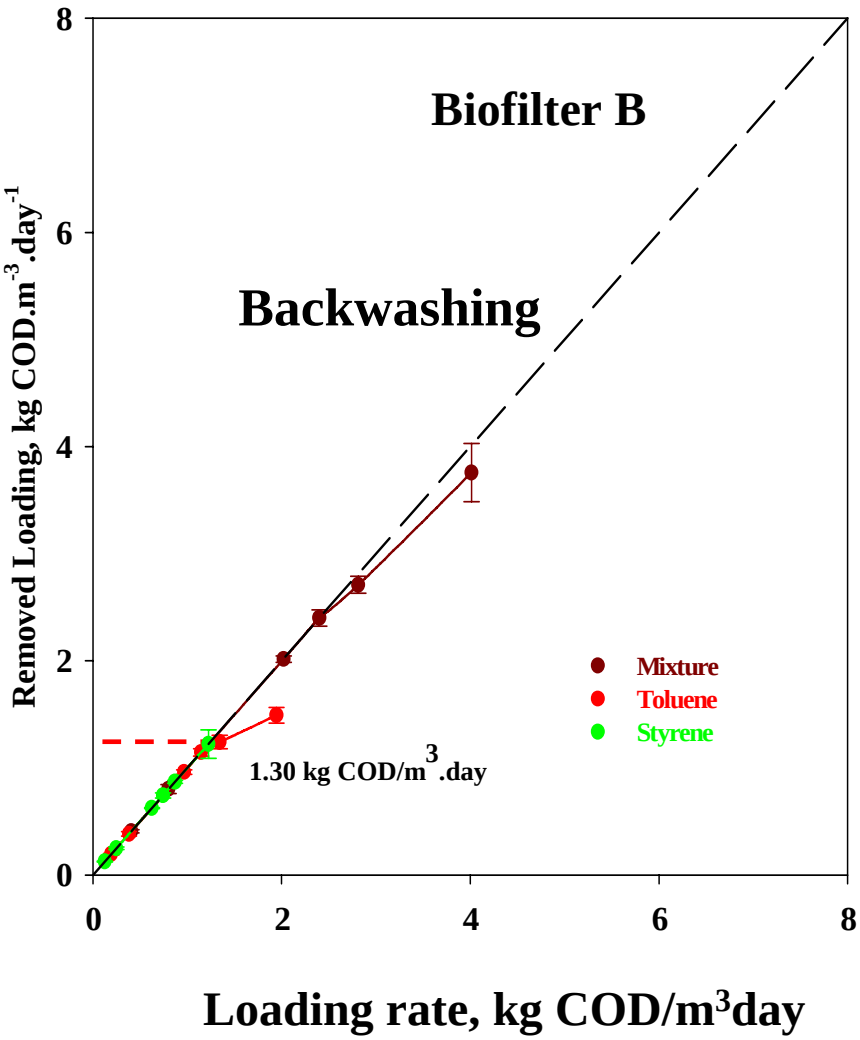
Results : Elimination Capacity for Biofilter A



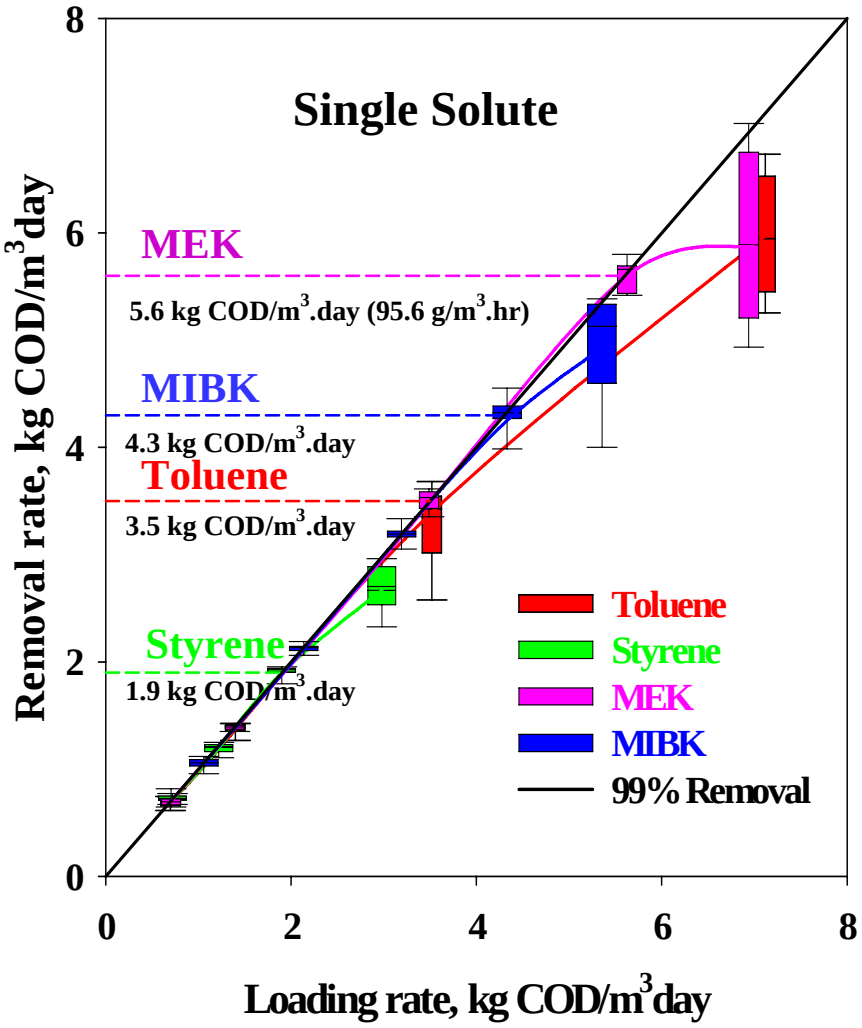


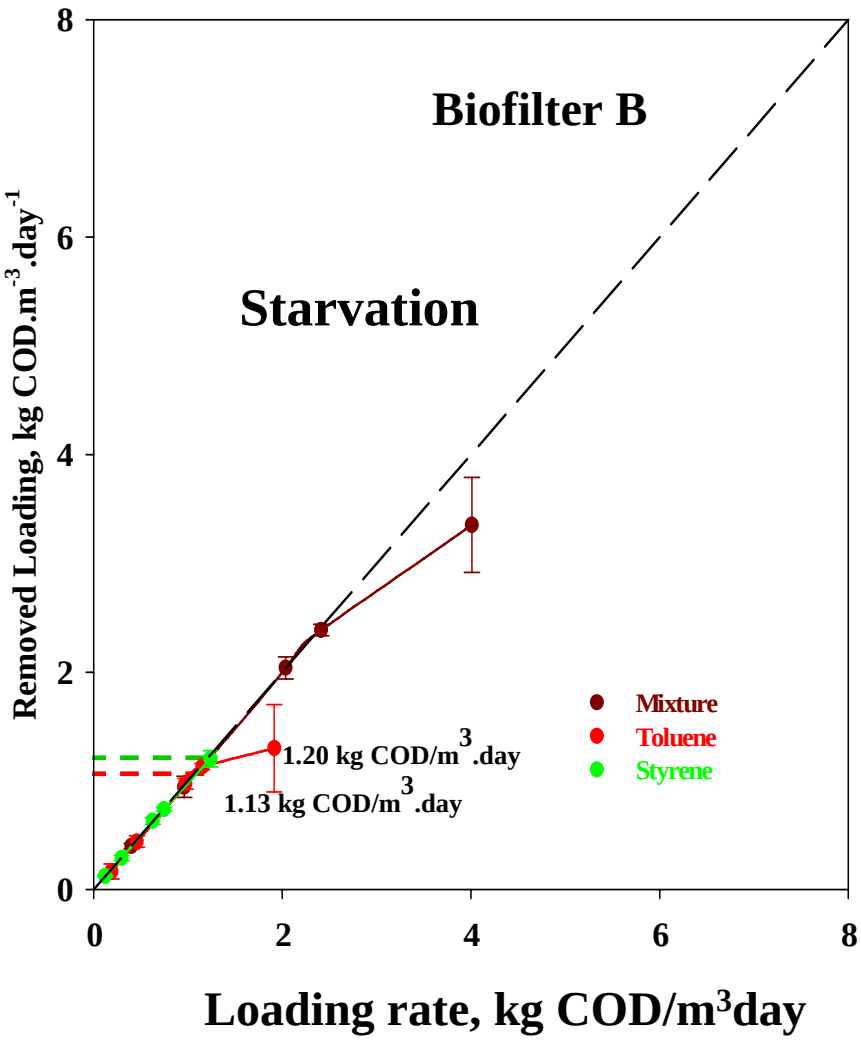
Results : Elimination Capacity for Biofilter B





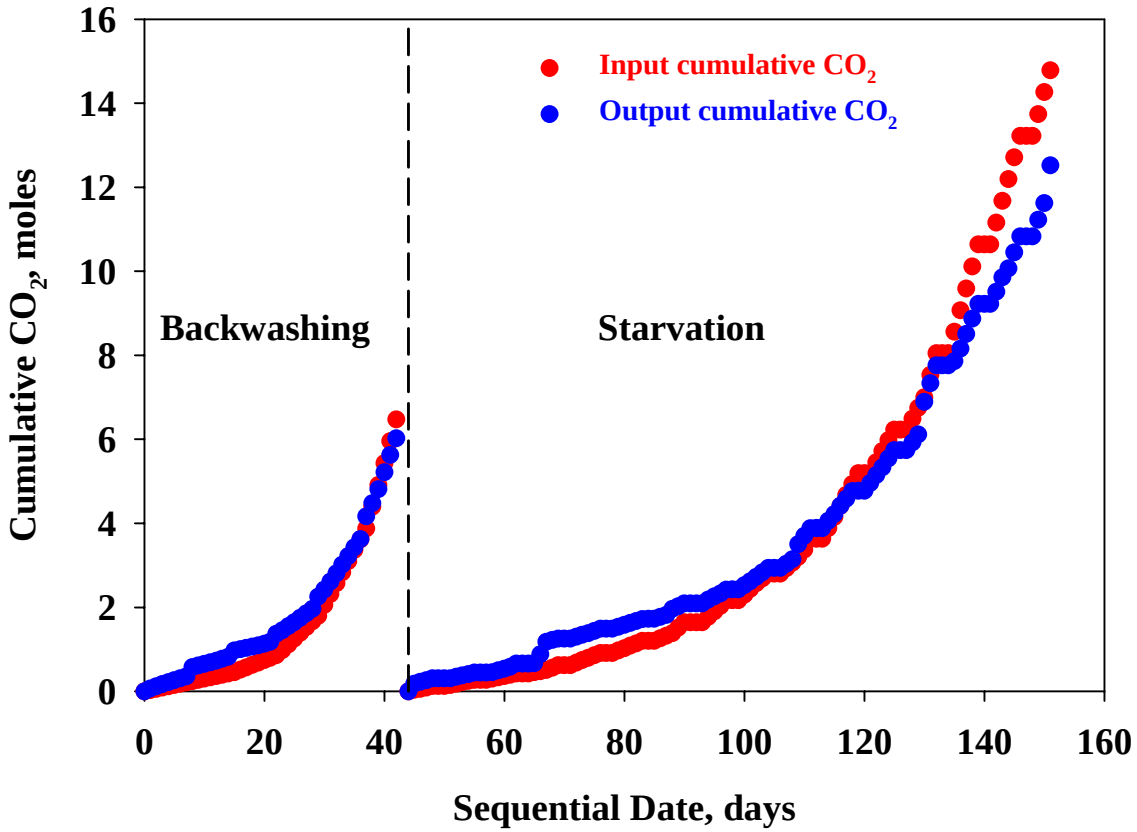
Results : Elimination Capacity for Biofilter B





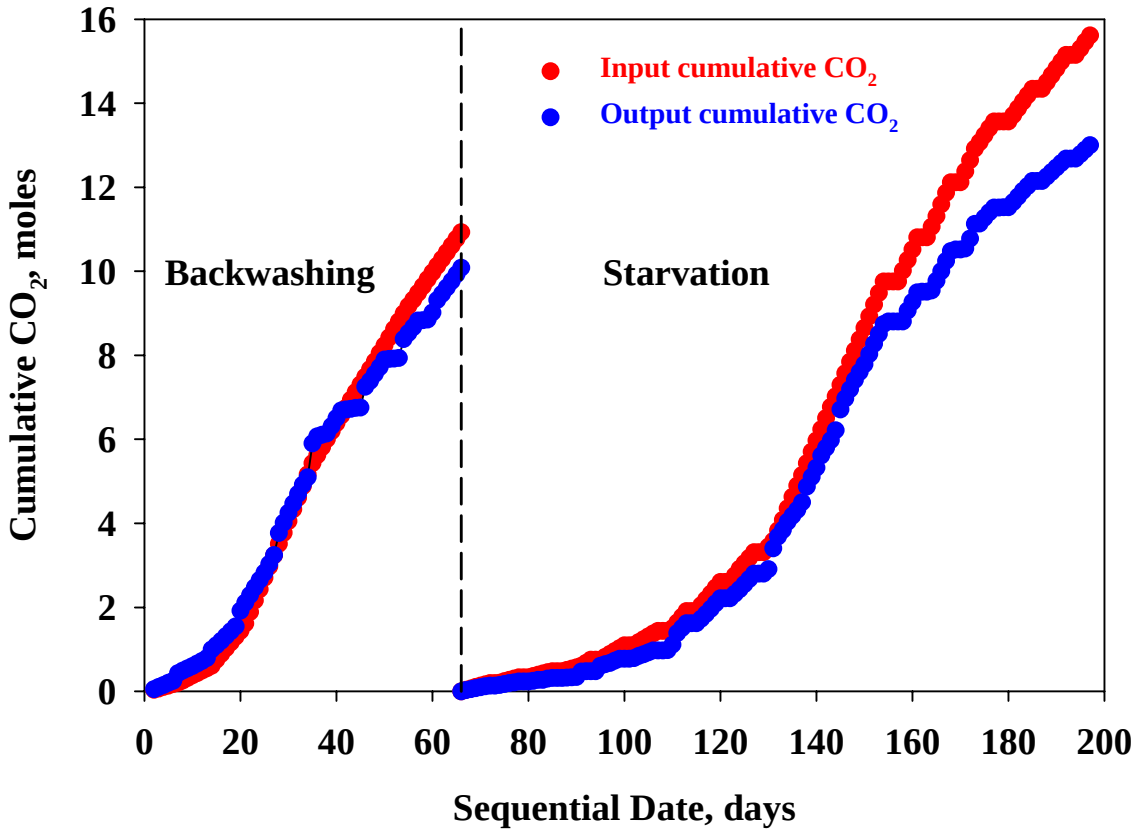
Results : Carbon Mass Balance

- **Mixture 1**



Results : Carbon Mass Balance

- **Mixture 2**



Conclusions

- **Over 99% removal efficiency could be maintained at inlet concentrations up to 500 ppmv for mixture 1 and 300 ppmv for mixture 2 under backwashing operating conditions.**

- **Starvation operation helped in maintaining high level performance and could be used as another means of biomass control provided the inlet concentration did not exceed 250 ppmv (2.01 kg COD/m3-d) and 300 ppmv for mixture 1 and mixture 2, respectively.**

- **Re-acclimation was delayed for both mixtures with increase of inlet concentrations. The biofilter performance for mixture 2 required longer time to recover than that mixture 1 due to higher toluene content in mixture 2.**

- **Toluene content in the mixture played a major role in the biofilter overall performance. The removal efficiency of toluene decreased with increase of content of MEK and MIBK in the mixtures.**

- **Carbon mass balance was more than 95% for backwashing conditions, but it was only around 83% for starvation conditions.**

Acknowledgement

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

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Questions?

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