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Effect of VOCs Interchanging on Performance and Microbial Diversity in Trickle-Bed Air Biofilter

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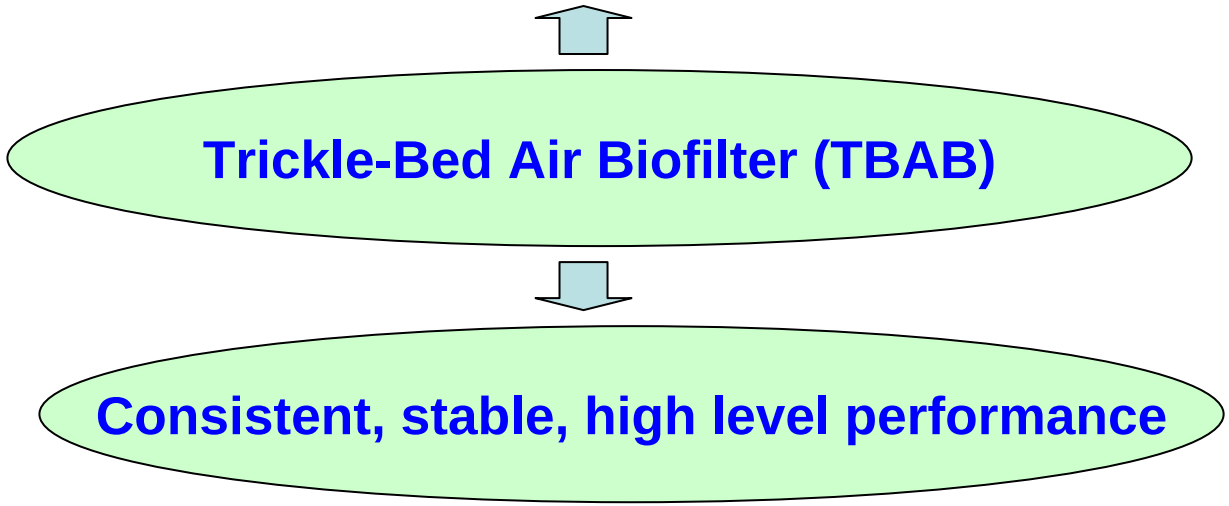
Introduction

Trickling biofilter concept:

- **Microbial attachment: Synthetic inorganic or polymeric media**
- **Intermittent delivery of Nutrient & Buffer to the media**
  - ✓ **Consistent Nutrient & pH control**
  - ✓ **Optimizing the waste utilizing kinetics**



Introduction

challenges in application

Characteristic source

- **Variation in Concentration**
- **Variation in Composition**
- **Non-use periods**

Operation maintenance

- **Biomass accumulation**

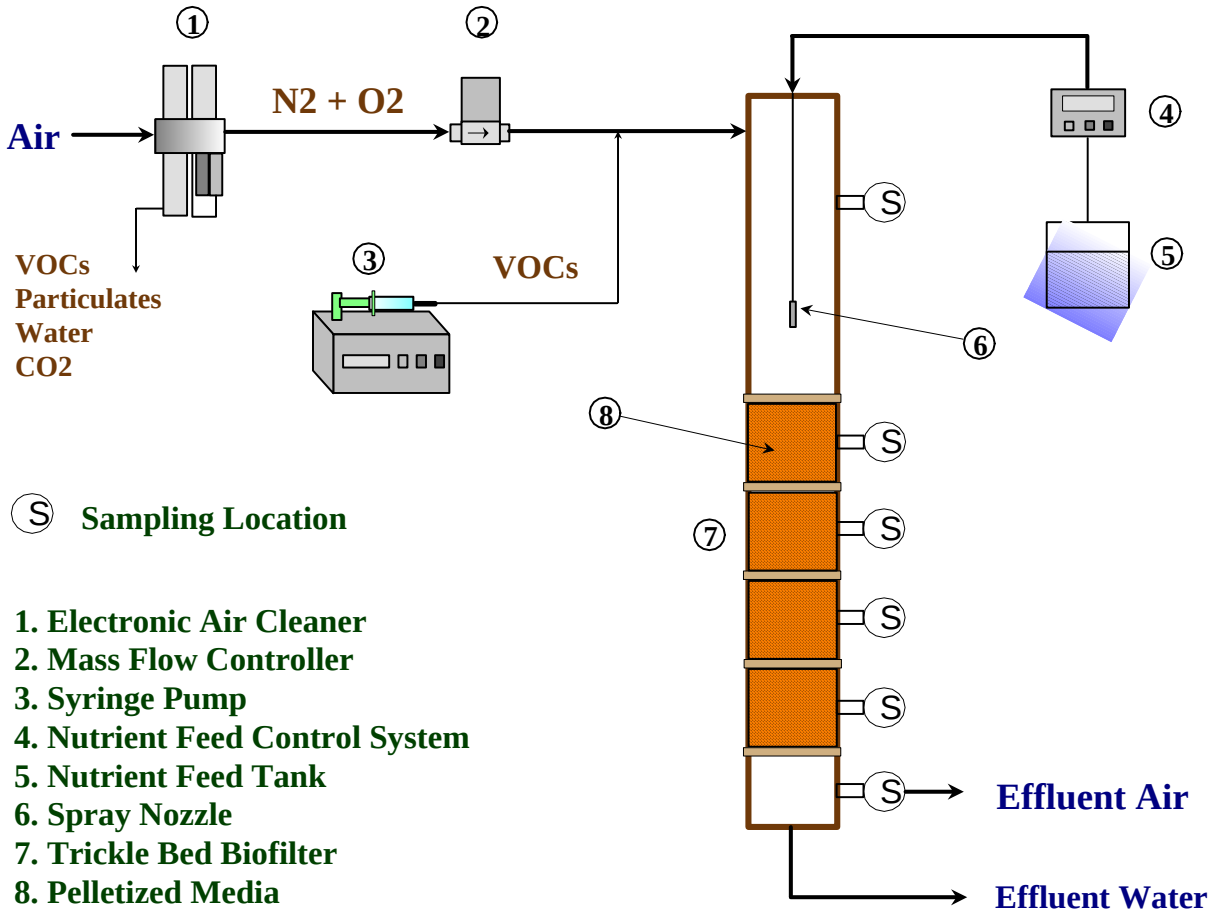
Objective

- **Characterization of TBAB performance under adverse operating conditions**
  - **Effect of step-change in influent concentration**
  - **Effect of non-use periods**
  - **Effect of interchanging the feed VOCs**
  - **Effect of VOCs composition**

Materials and Methods

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

Materials and Methods



Materials and Methods

- Feed VOCs

	Aromatic		Oxygenated	
	Toluene	Styrene	Methyl ethyl ketone (MEK)	Methyl isobutyl ketone (MIBK)
K'_H	0.280	0.109	0.00194	0.00062
S	534.8	310	239×10^3	20.4×10^3

K'_H = dimensionless Henry's law constant S = water solubility, mg/L

Materials and Methods

➢ Operating Condition

- **Sequence of Feed VOCs**
  - **Study 1:** Styrene → MEK → Toluene → MIBK → Styrene
  - **Study 2:** MIBK → Toluene → MEK → Styrene → MIBK
  - **Study 3:** MEK → Toluene → MIBK → Styrene → MEK
- **Inlet concentration of feed VOCs**
  50 ppmv ~ the critical inlet concentration
- **Flow rate**
  - **Study 1:** Air flow = 1.35 L/min (Constant EBRT = 2.02 min)
  - **Study 2:** Air flow = variable (Different EBRT for each VOC)
  - **Study 3:** Air flow = variable (Different EBRT for each VOC)
- **Biomass control : Periodic in-situ backwashing**
  Frequency: 1 hour of duration / a week

Previous study

- **Removal capacity of single VOCs in TBAB**

	Toluene		Styrene	
	Previous	Study 1	Previous	Study 1
EBRT, min	1.23	2.02	2.02	2.02
Critical Con., ppmv	250	400	200	200
	MEK		MIBK	
	Previous	Study 1	Previous	Study 1
EBRT, min	0.76	2.02	0.76	2.02
Critical Con., ppmv	400	1080	150	400

Results

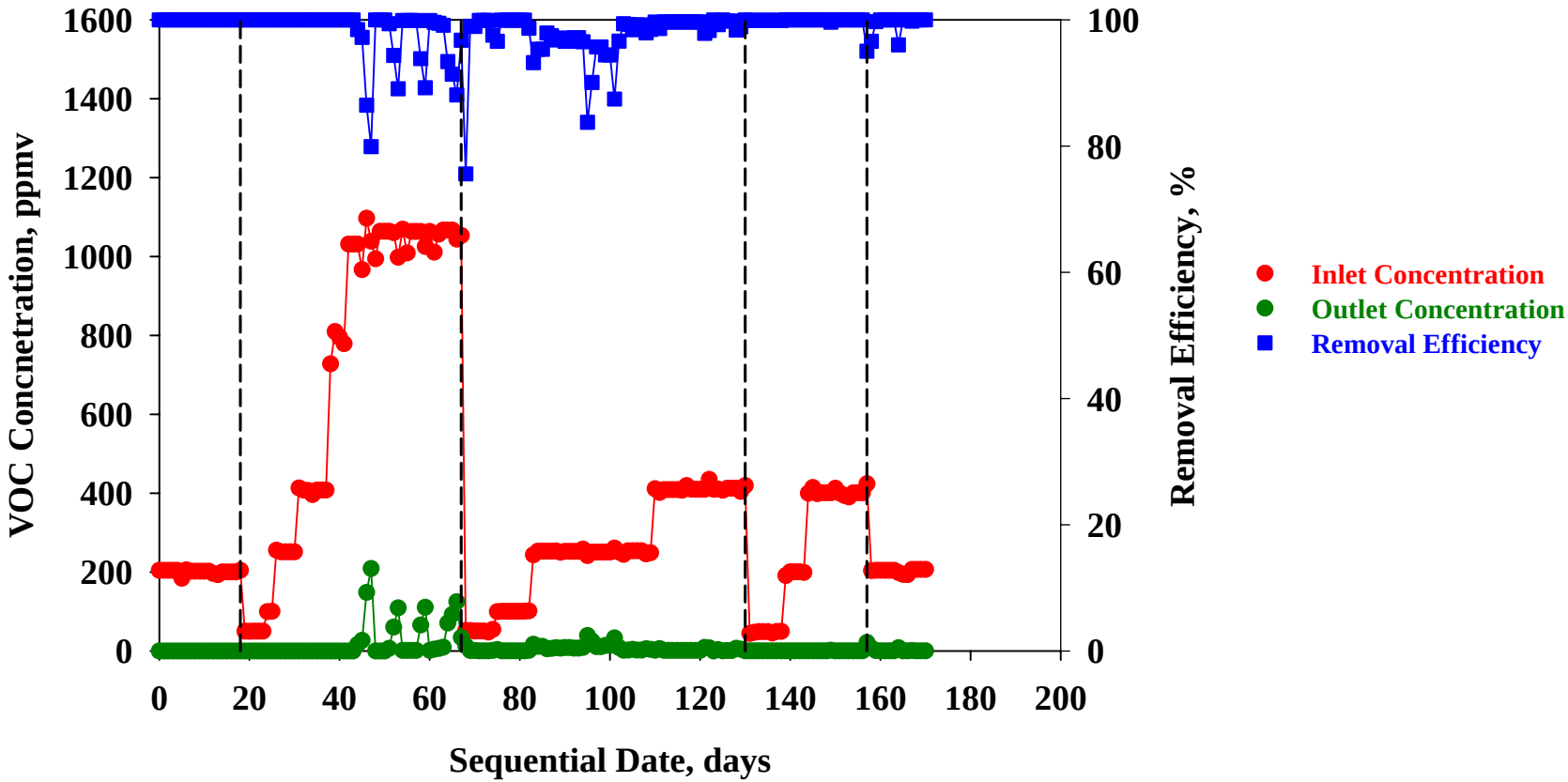
- **Current Study (interchange of the feed VOCs)**
  - ✓ **TBAB performance with respect to VOC removal**
  - ✓ **Effluent response corresponding to interchanging of feeding VOCs**
    - → **Removal efficiency**
    - → **CO_2 production**
  - ✓ **Microbial Community corresponding to interchanging of feeding VOCs**

Results : Study 1 (Constant EBRT)

- **TBAB performance with respect to VOC removal**
  : *EBRT = 2.02 min*

Results : Study 1 (Constant EBRT)

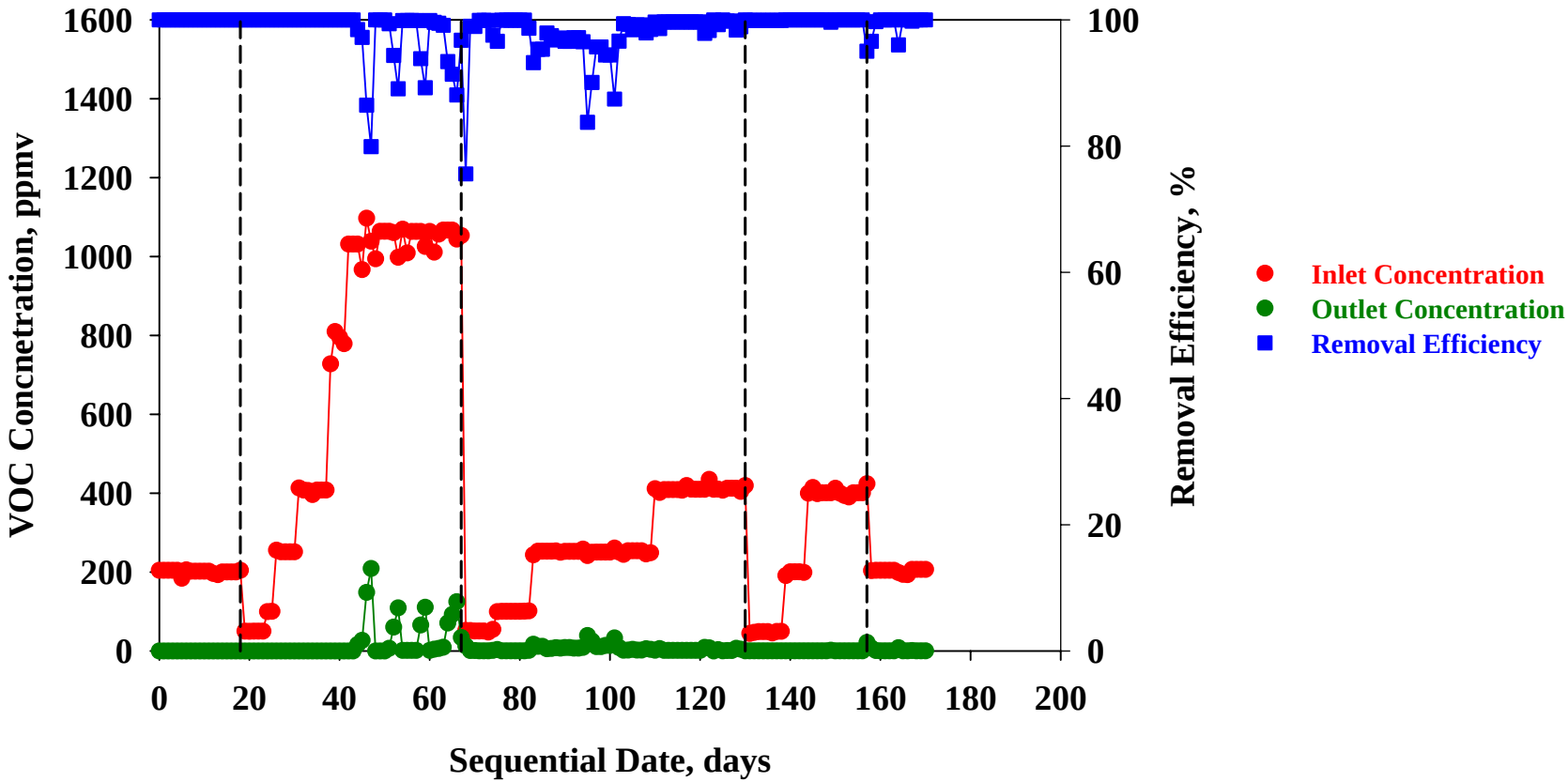
- **TBAB performance with respect to VOC removal**



Results : Study 1 (Constant EBRT)

Styrene

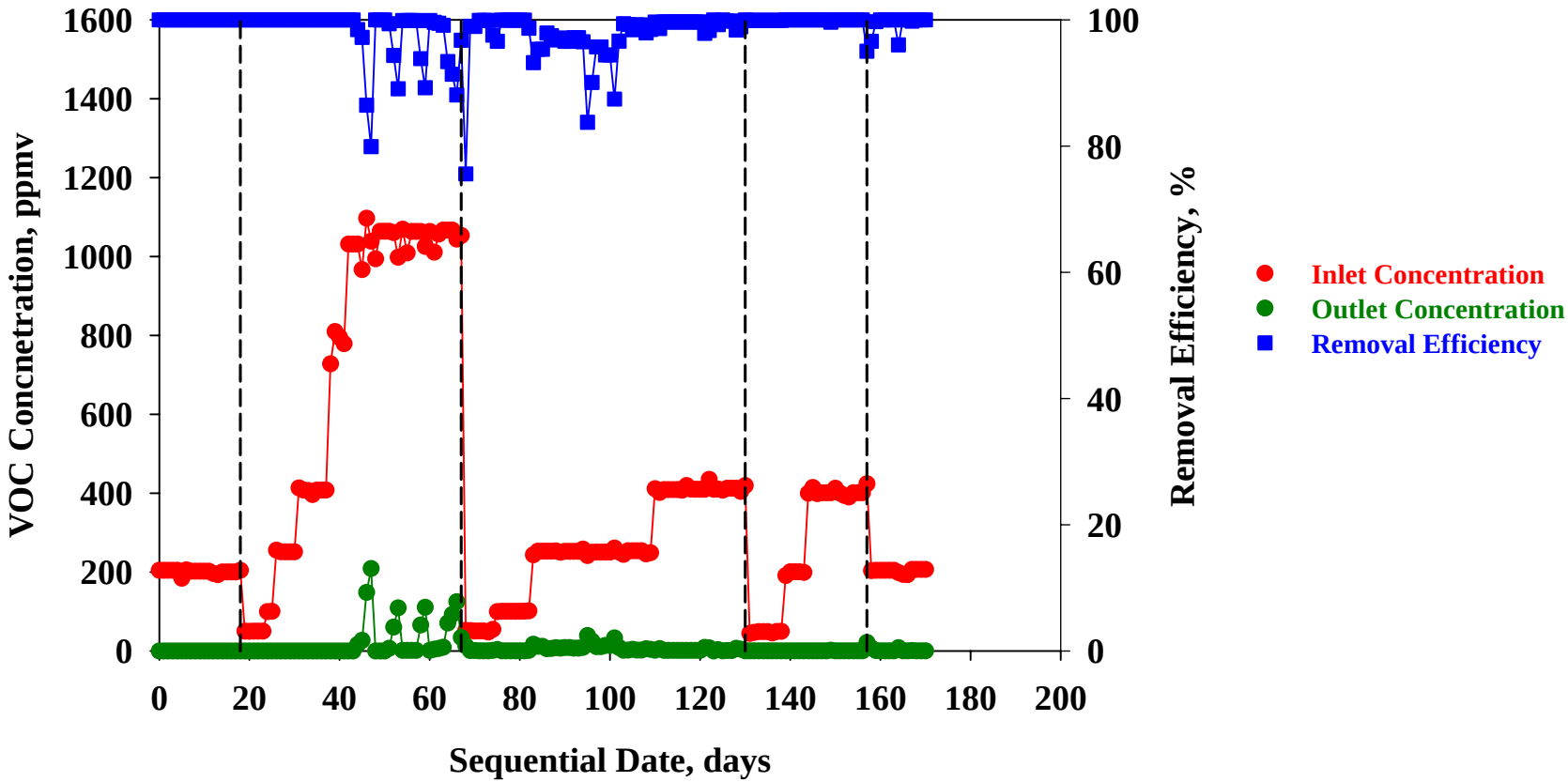
- Inlet: 200 ppmv



Results : Study 1 (Constant EBRT)

MEK

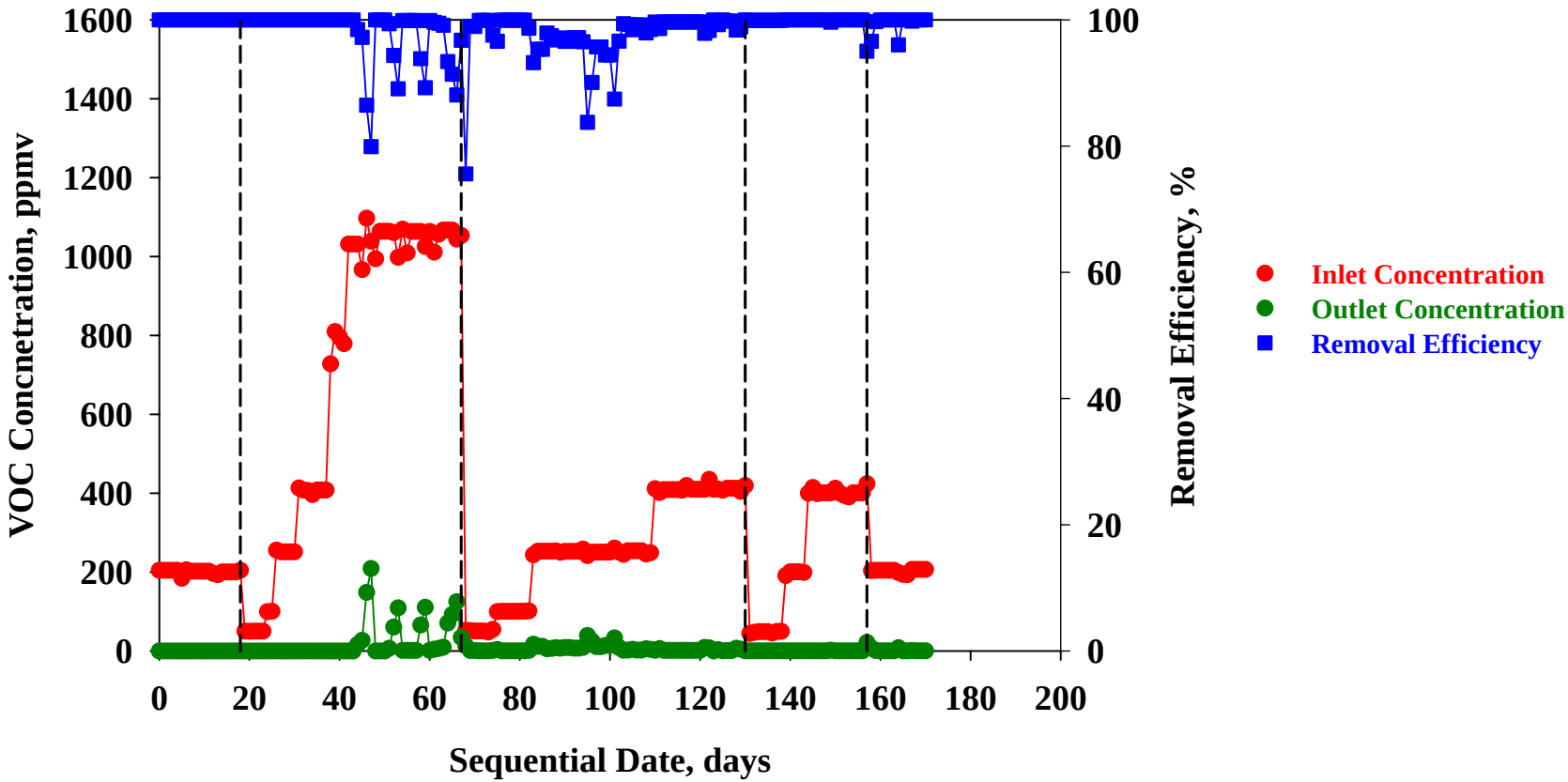
- Inlet: 50 - 1080 ppmv



Results : Study 1 (Constant EBRT)

Toluene

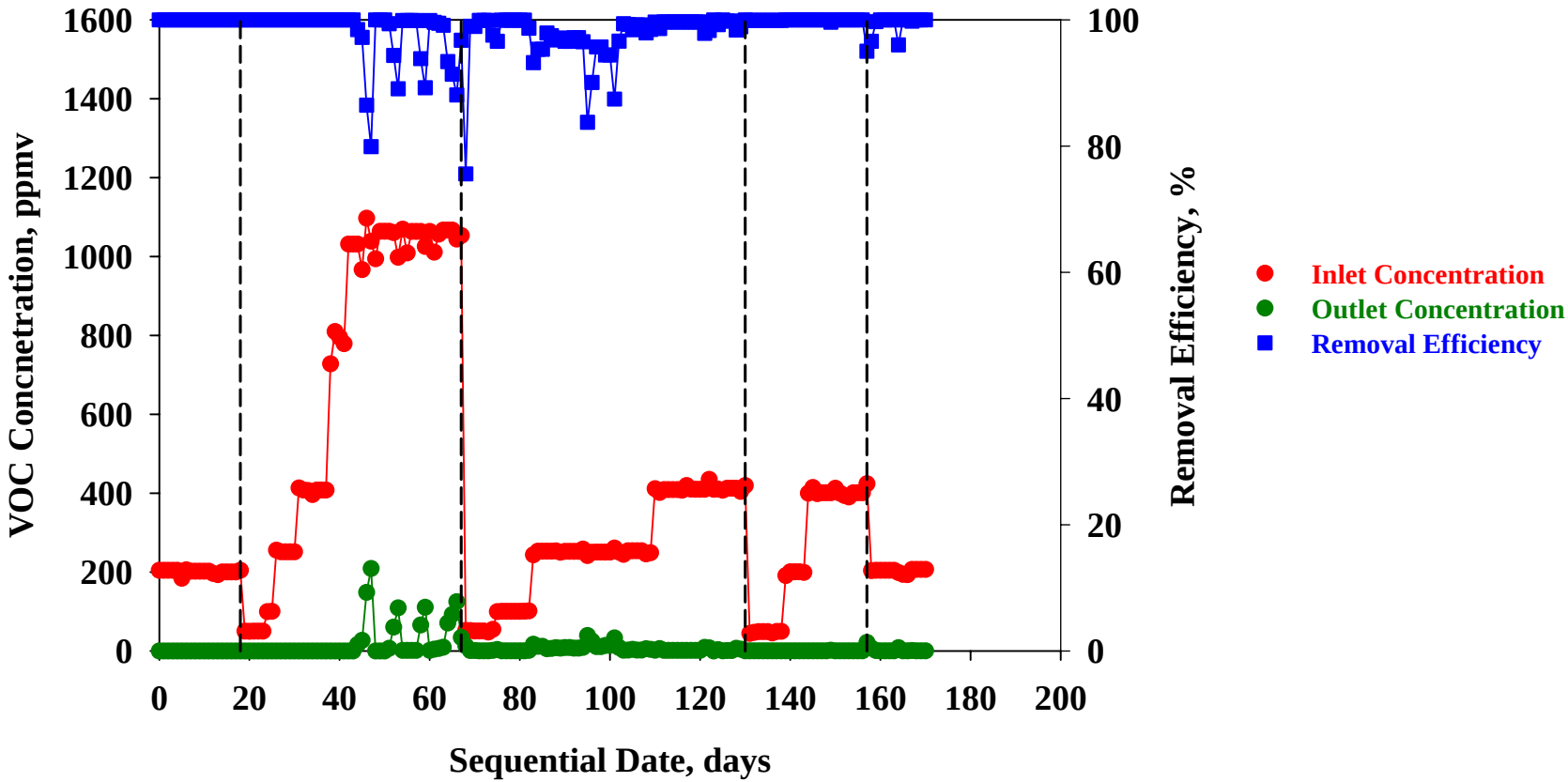
- Inlet: 50 - 400 ppmv



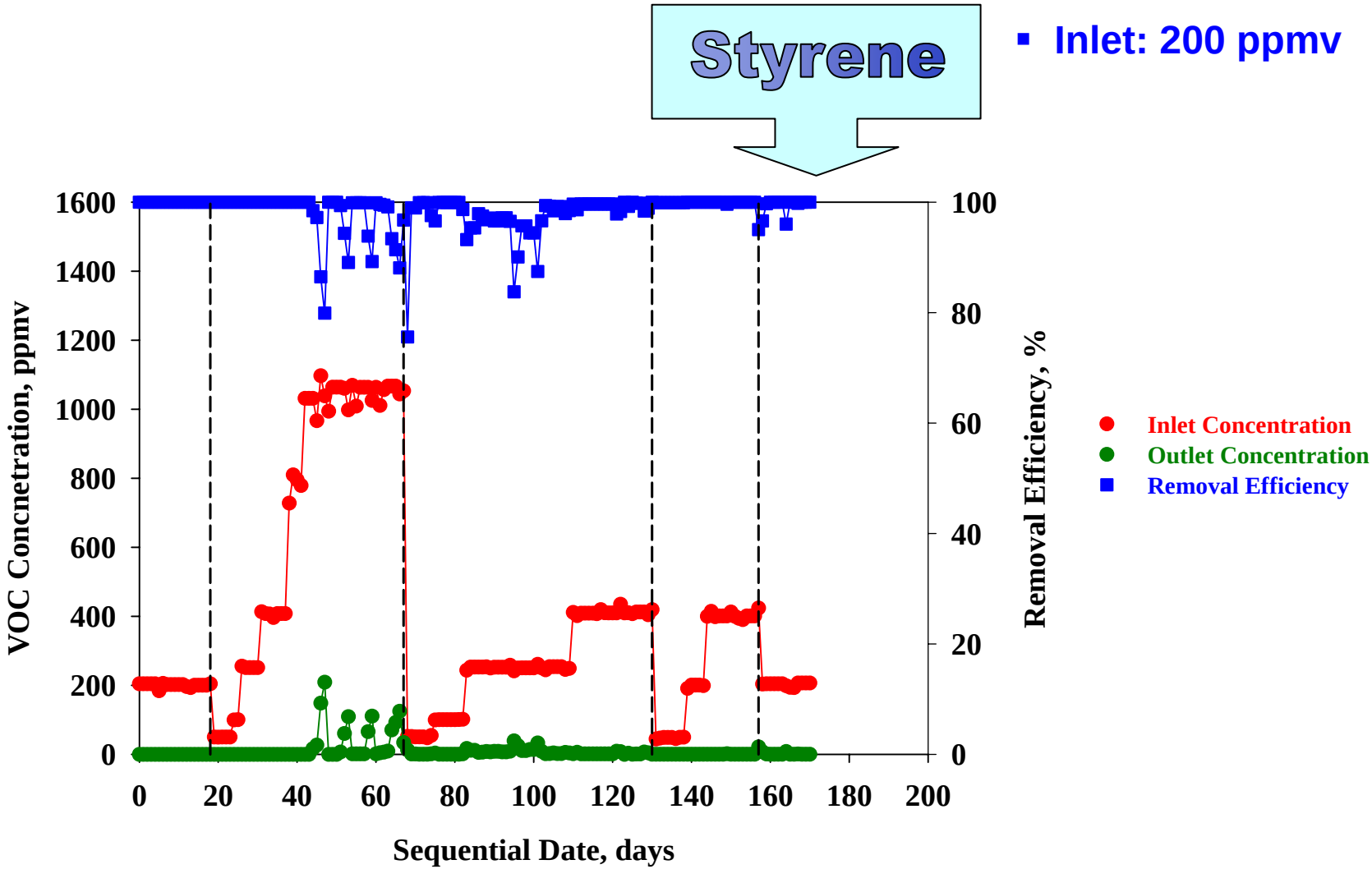
Results : Study 1 (Constant EBRT)

MIBK

- Inlet: 50 - 400 ppmv



Results : Study 1 (Constant EBRT)



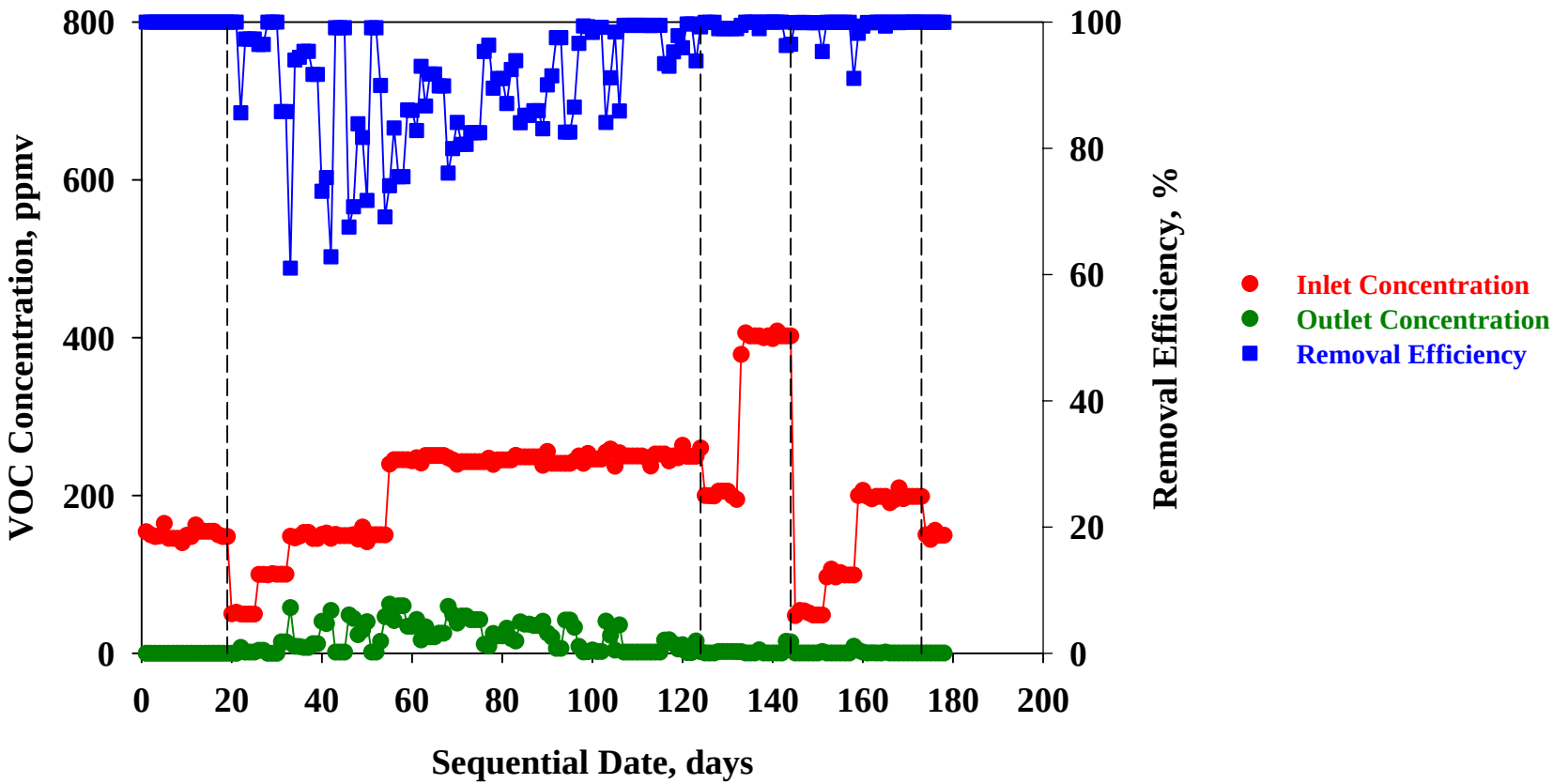
- Inlet: 200 ppmv

Results : Study 2 (Differenet EBRT)

- **TBAB performance with respect to VOC removal**
  : Variable *EBRT*

Results : Study 2 (Different EBRT)

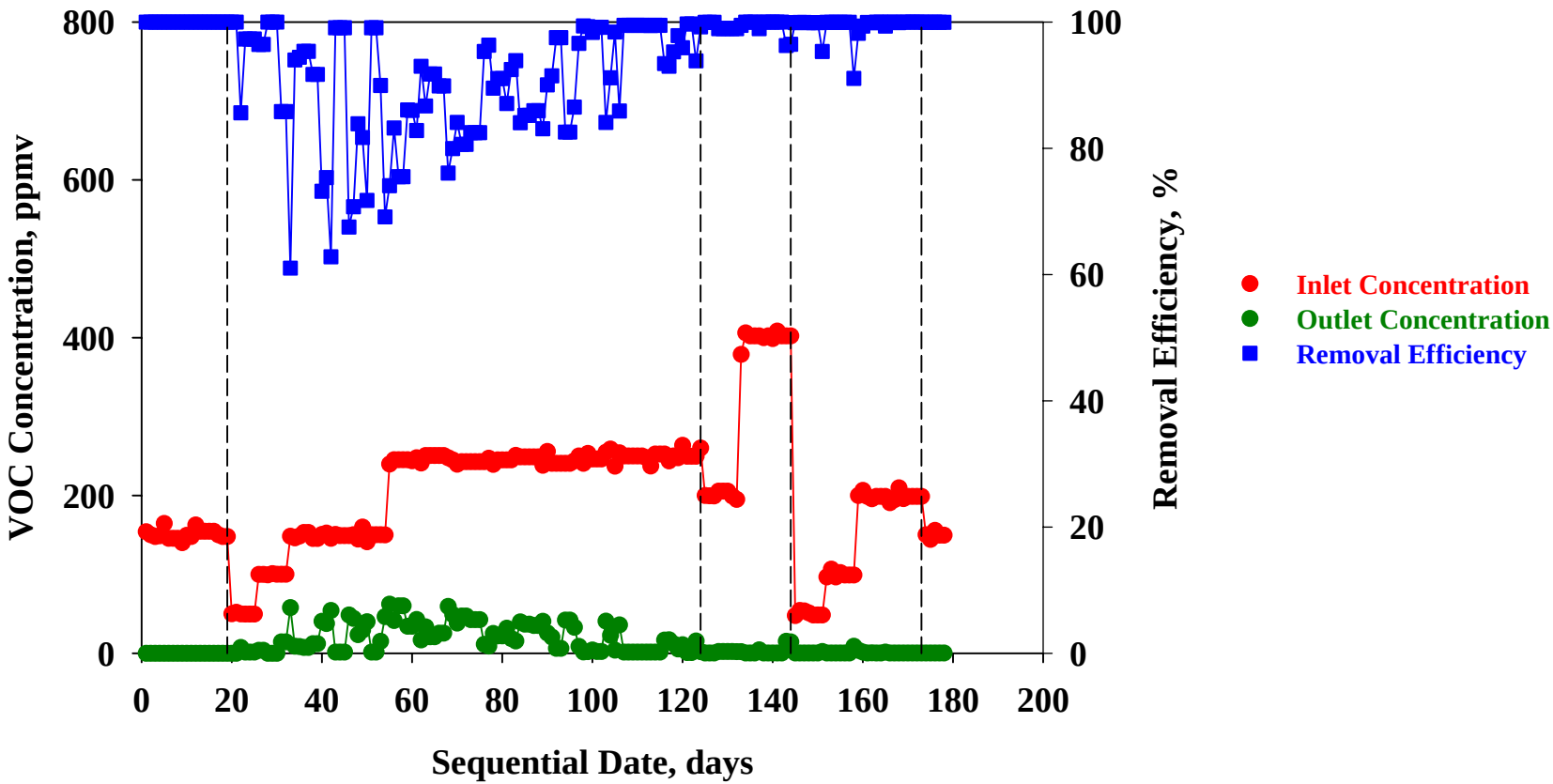
- **TBAB performance with respect to VOC removal**



Results : Study 2 (Different EBRT)

MIBK

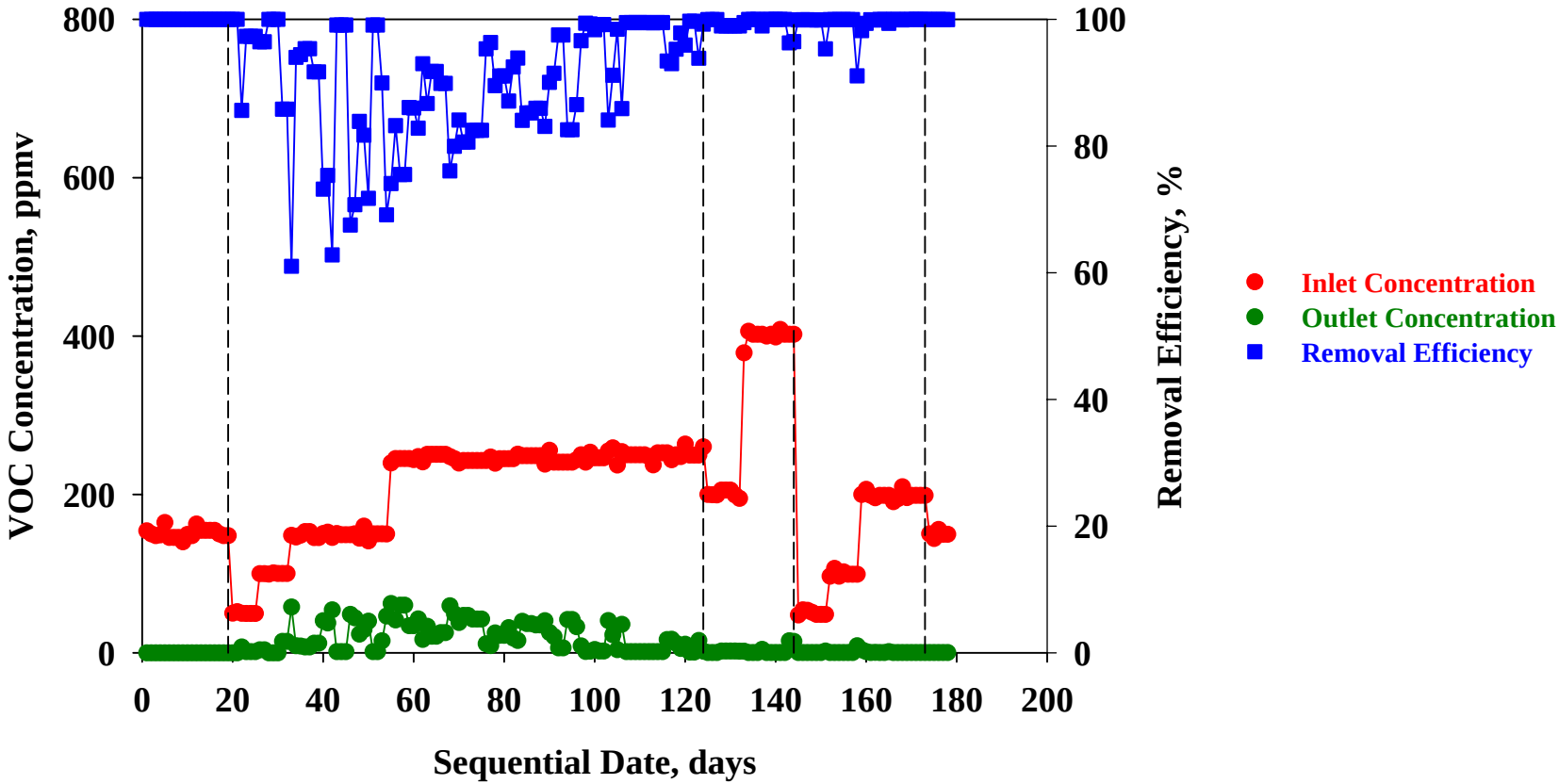
- Inlet: 150 ppmv
- 0.76 min EBRT



Results : Study 2 (Different EBRT)

Toluene

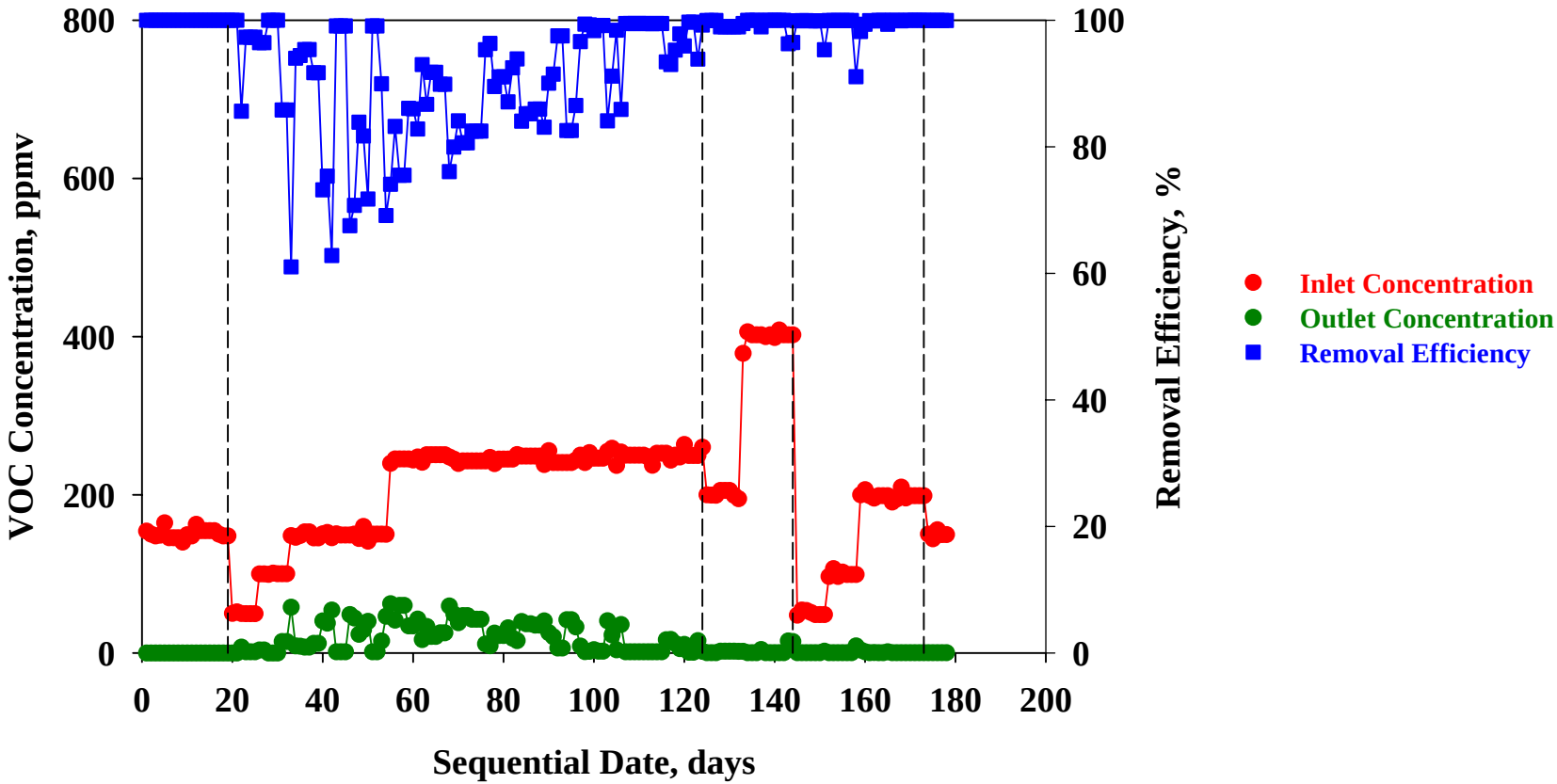
- Inlet: 50 - 250 ppmv
- 1.23 EBRT



Results : Study 2 (Different EBRT)

MEK

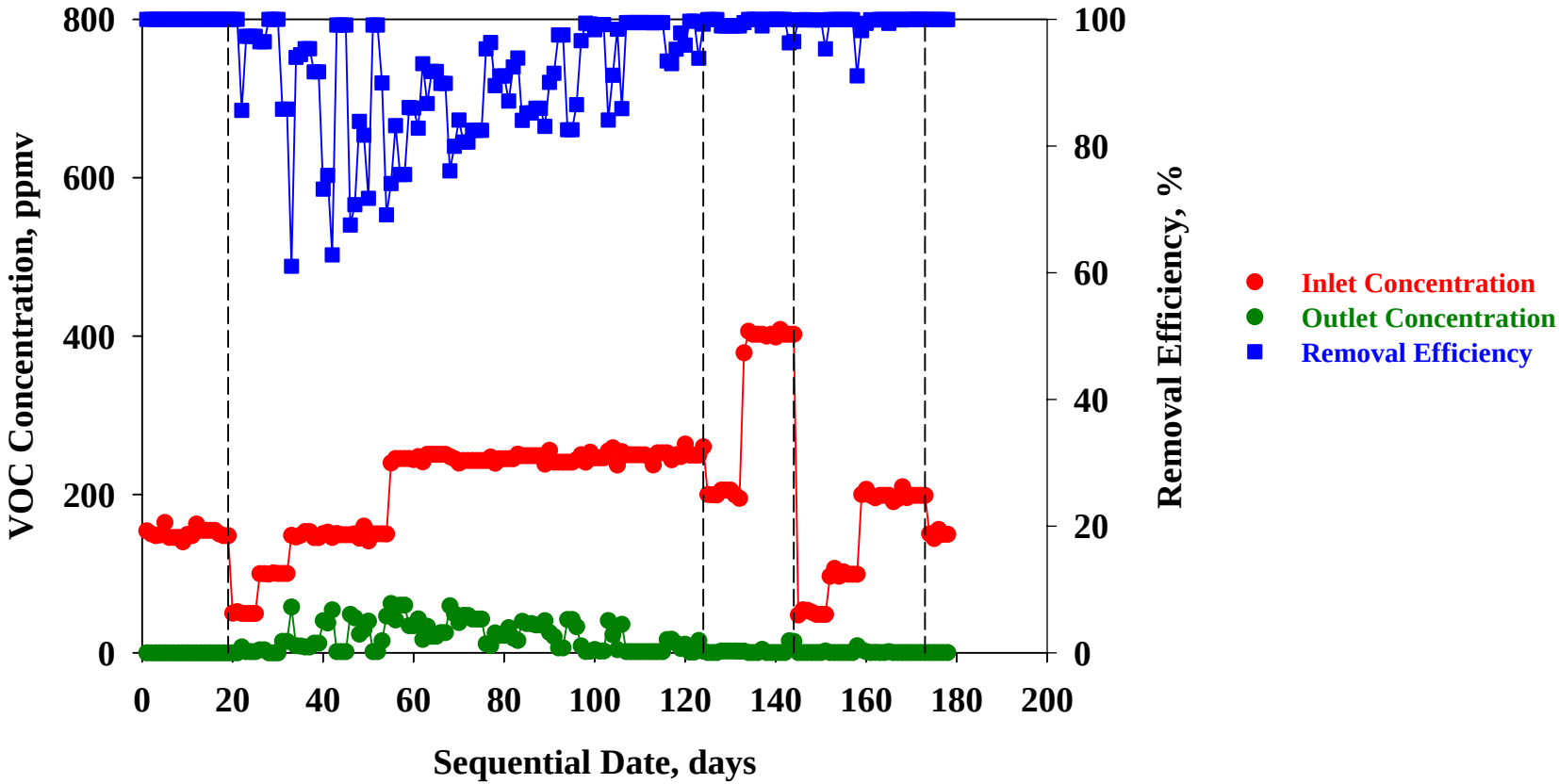
- Inlet: 200 - 400 ppmv
- 0.76 min EBRT



Results : Study 2 (Different EBRT)

Styrene

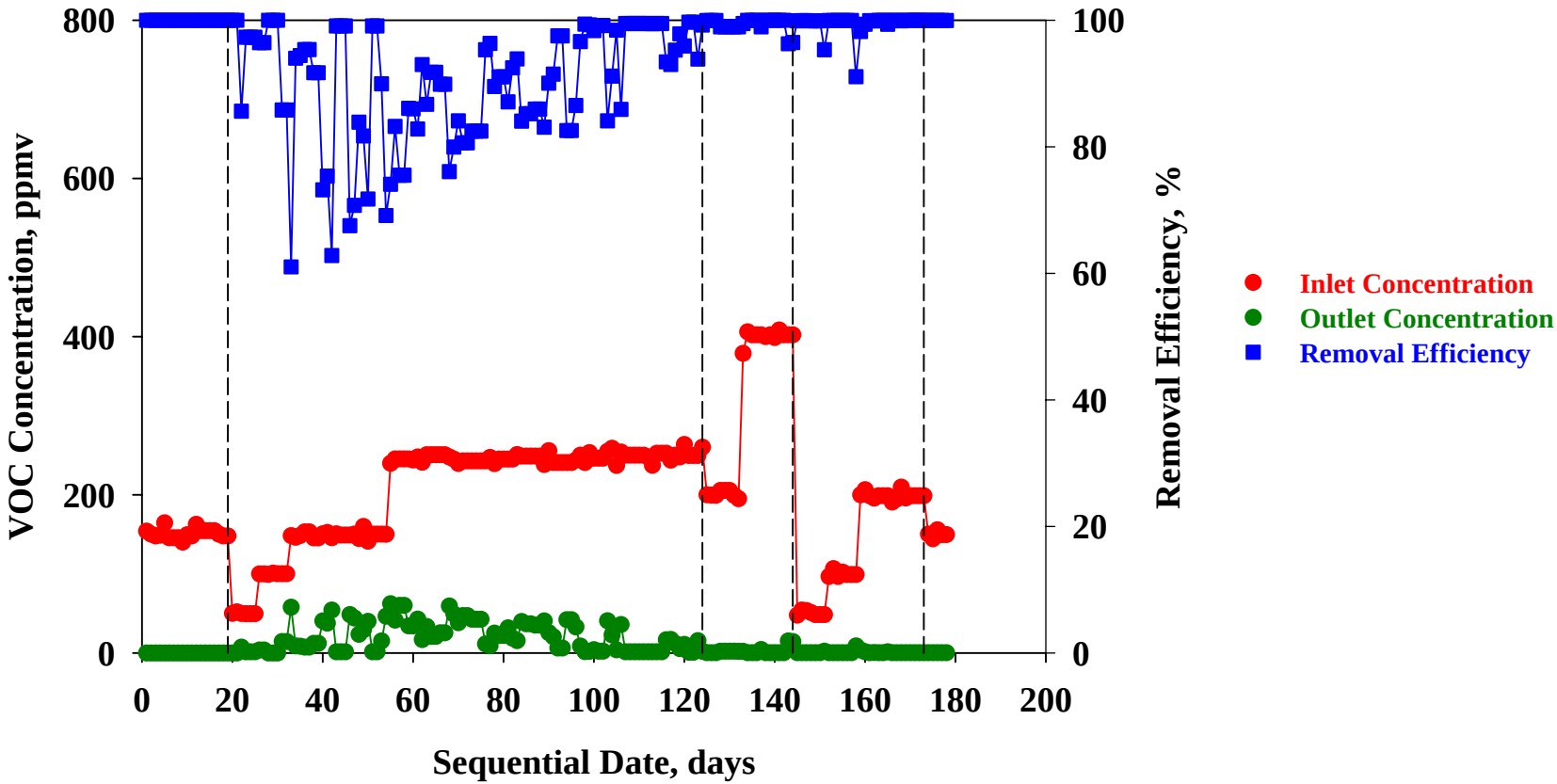
- Inlet: 50-200 ppmv
- 2.02 min EBRT



Results : Study 2 (Different EBRT)

MIBK

- Inlet: 150 ppmv
- 0.76 min EBRT

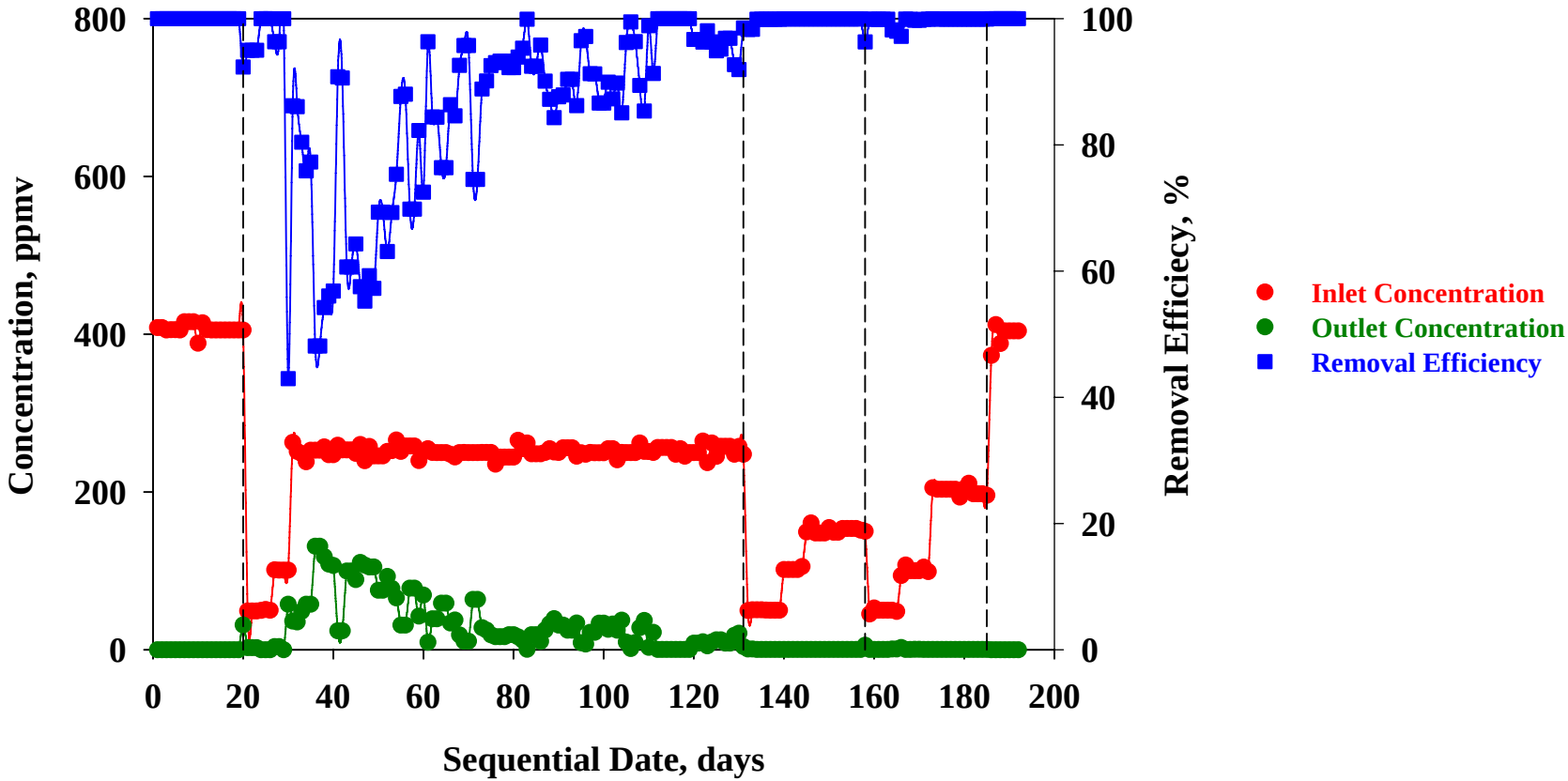


Results : Study 3 (Different EBRT)

- **TBAB performance with respect to VOC removal**
  : Variable *EBRT*

Results : Study 3 (Different EBRT)

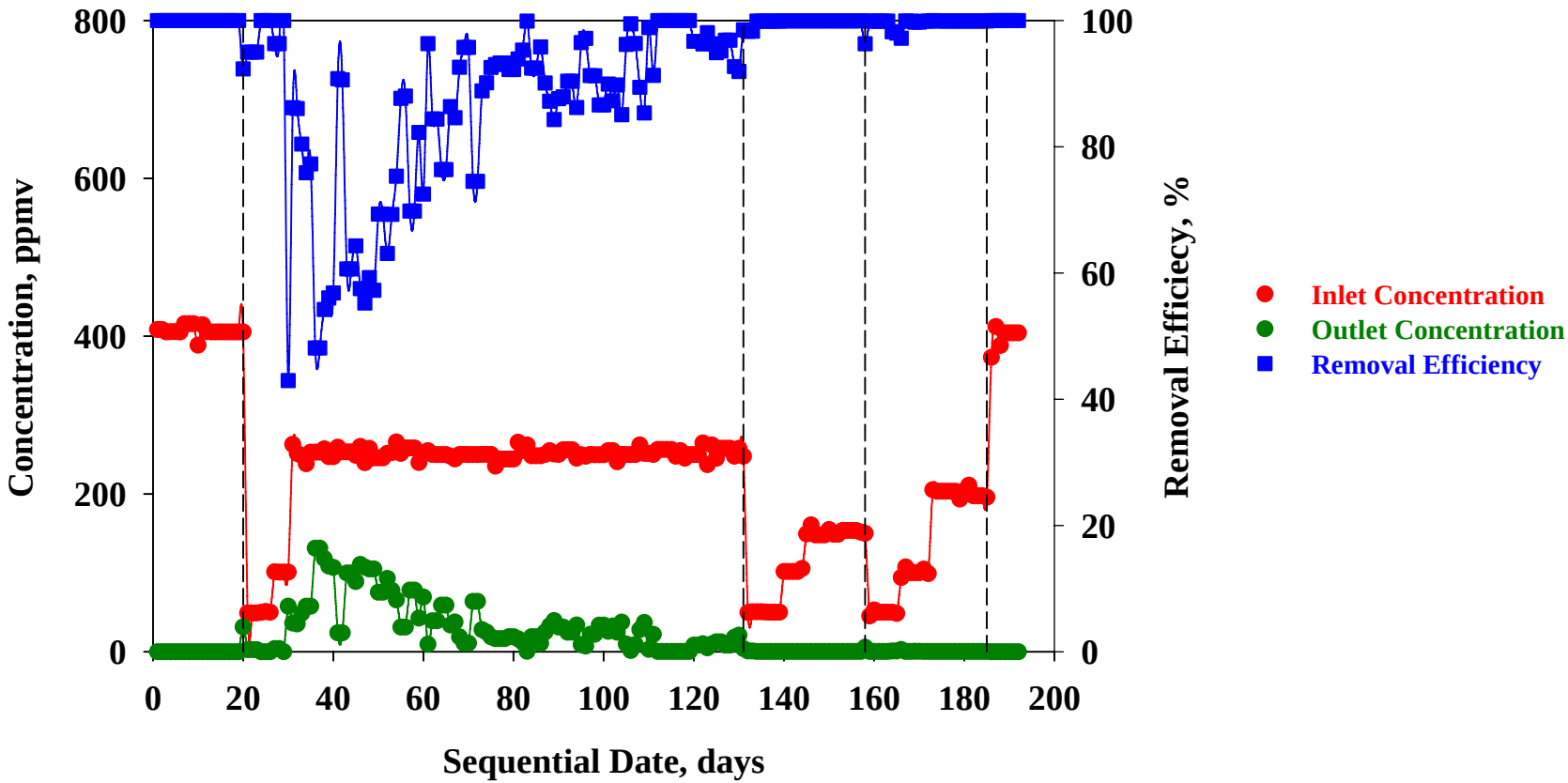
➢ **TBAB performance with respect to VOC removal**



Results : Study 3 (Different EBRT)

MEK

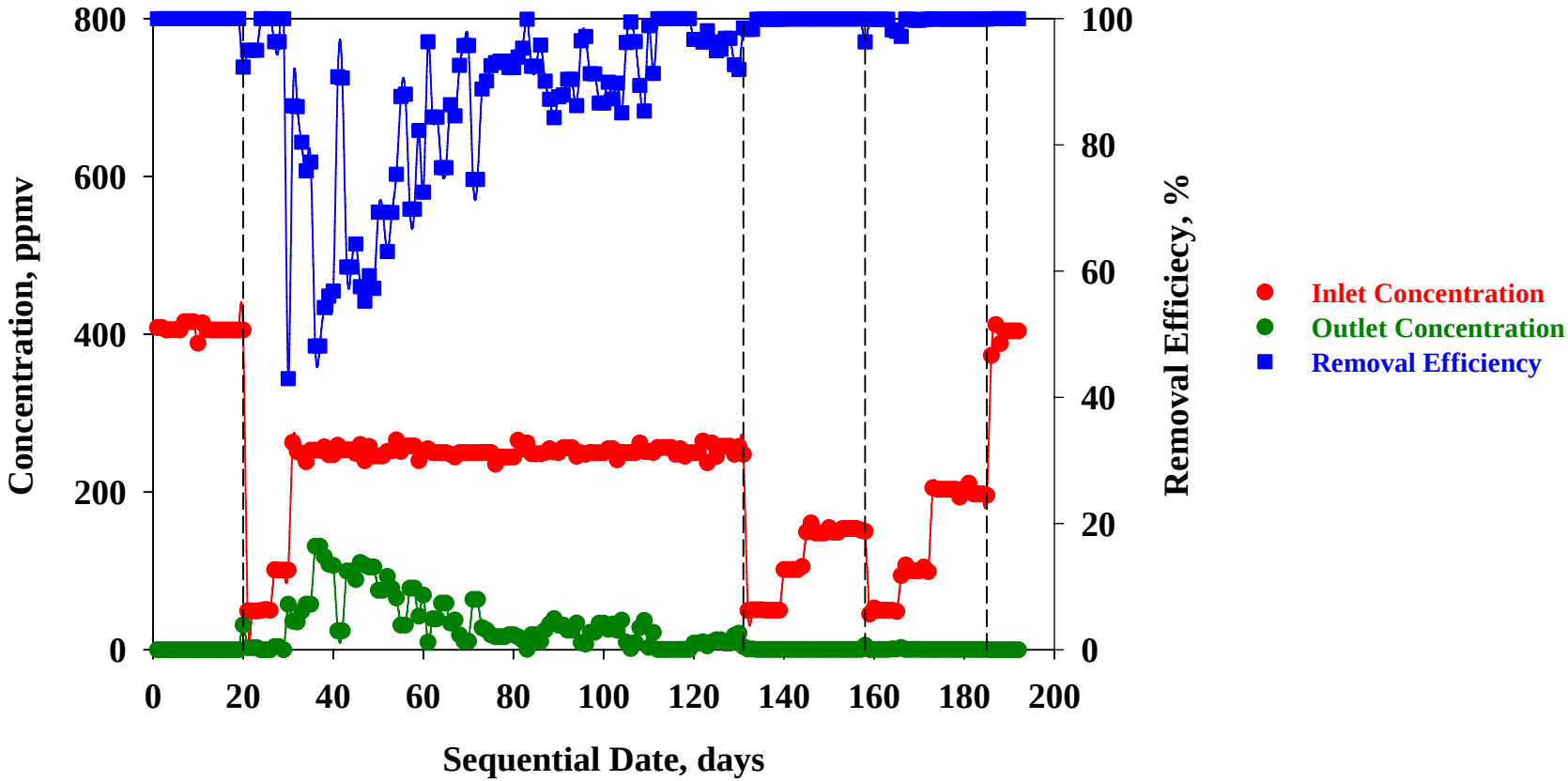
- Inlet: 400 ppmv
- 0.76 min EBRT



Results : Study 3 (Different EBRT)

Toluene

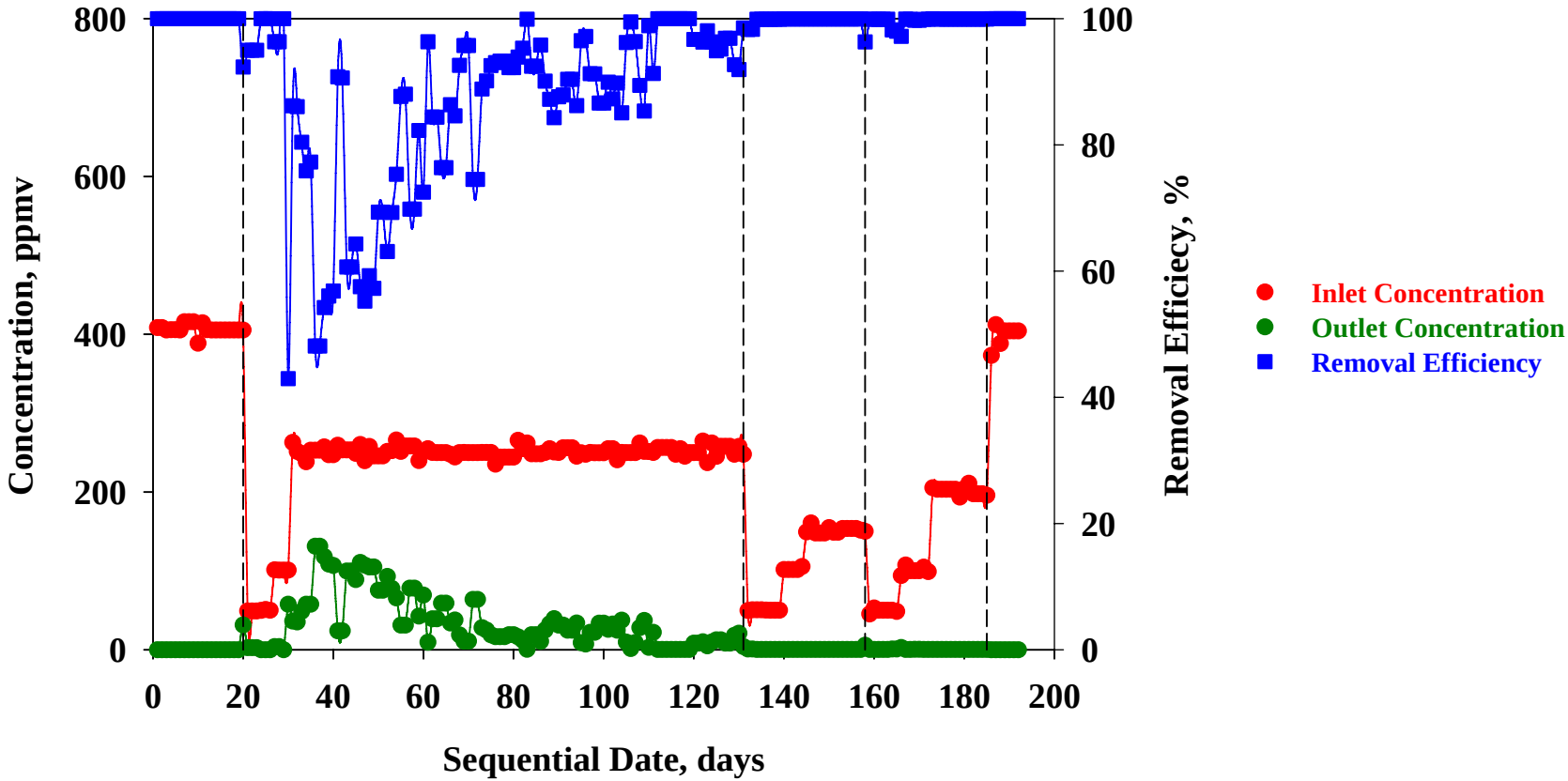
- Inlet: 50 - 250 ppmv
- 1.23 EBRT



Results : Study 3 (Different EBRT)

MIBK

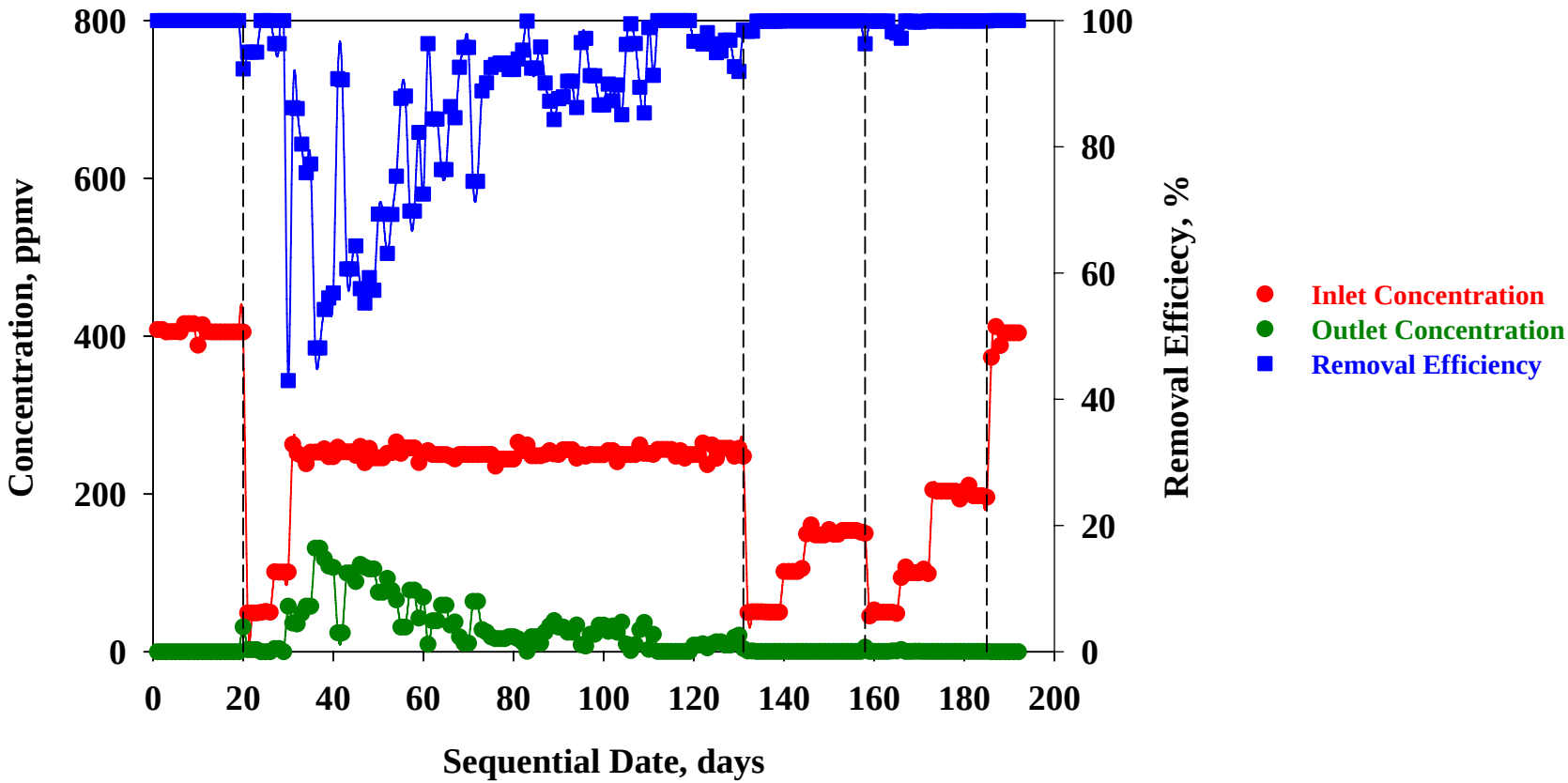
- Inlet: 50 -150 ppmv
- 0.76 min EBRT



Results : Study 3 (Different EBRT)

Styrene

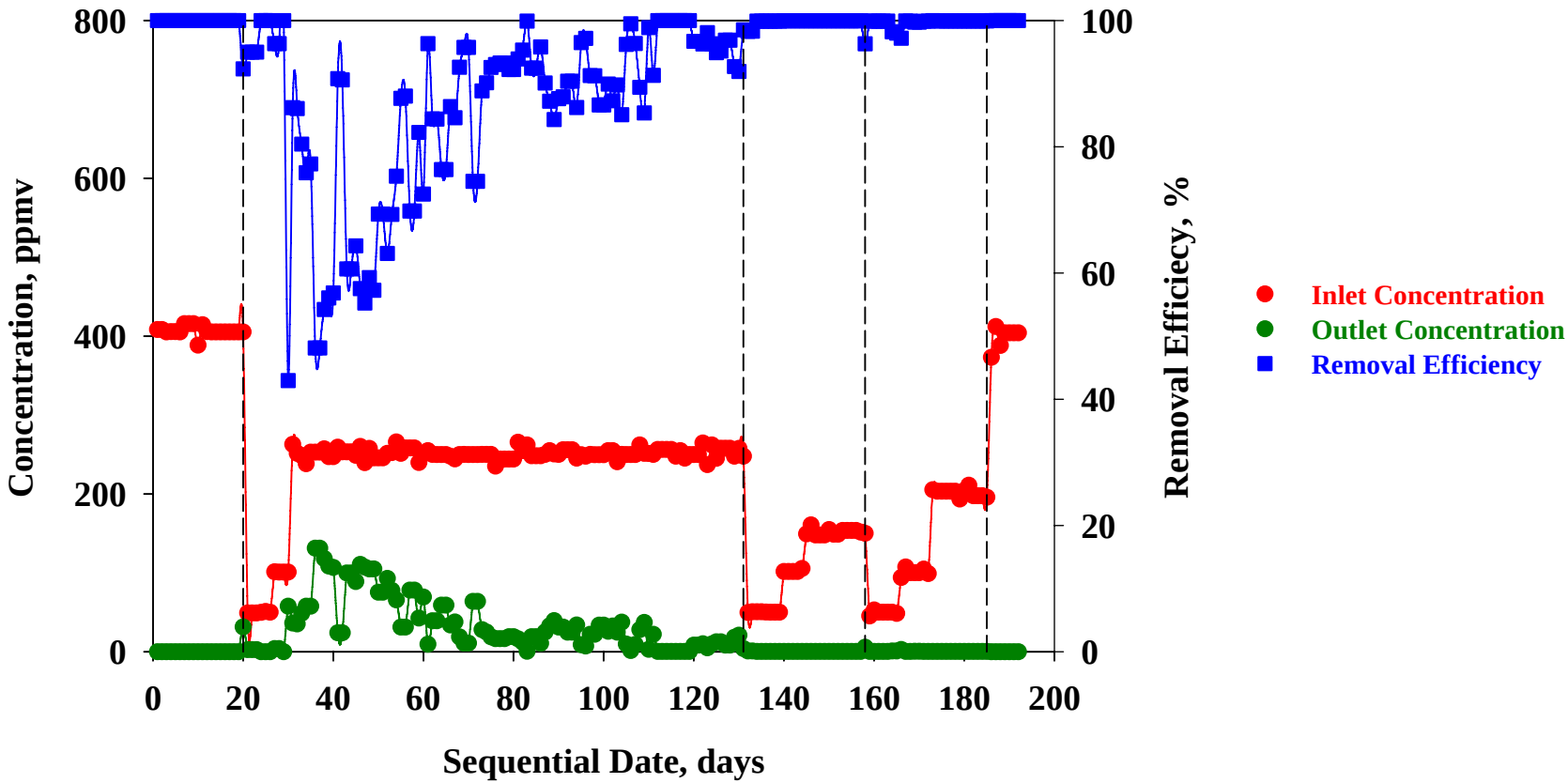
- Inlet: 50-200 ppmv
- 2.02 min EBRT



Results : Study 3 (Different EBRT)

MEK

- Inlet: 400 ppmv
- 0.76 min EBRT



Results

- **Biofilter Response after interchanging VOCs**

Results : Study 1 (Constant EBRT)

- Biofilter Response after interchanging VOCs

Time, min	Styrene to MEK	MEK to Toluene	Toluene to MIBK	MIBK to Styrene
30	99.9	55.4	99.4	61.2
60	99.9	58.2	99.9	77.3
300	99.9	65.6	99.9	91.8
600	99.9	73.5	99.9	96.8
1200	99.9	75.6	99.9	95.0
2880	99.9	99.0	99.9	96.6

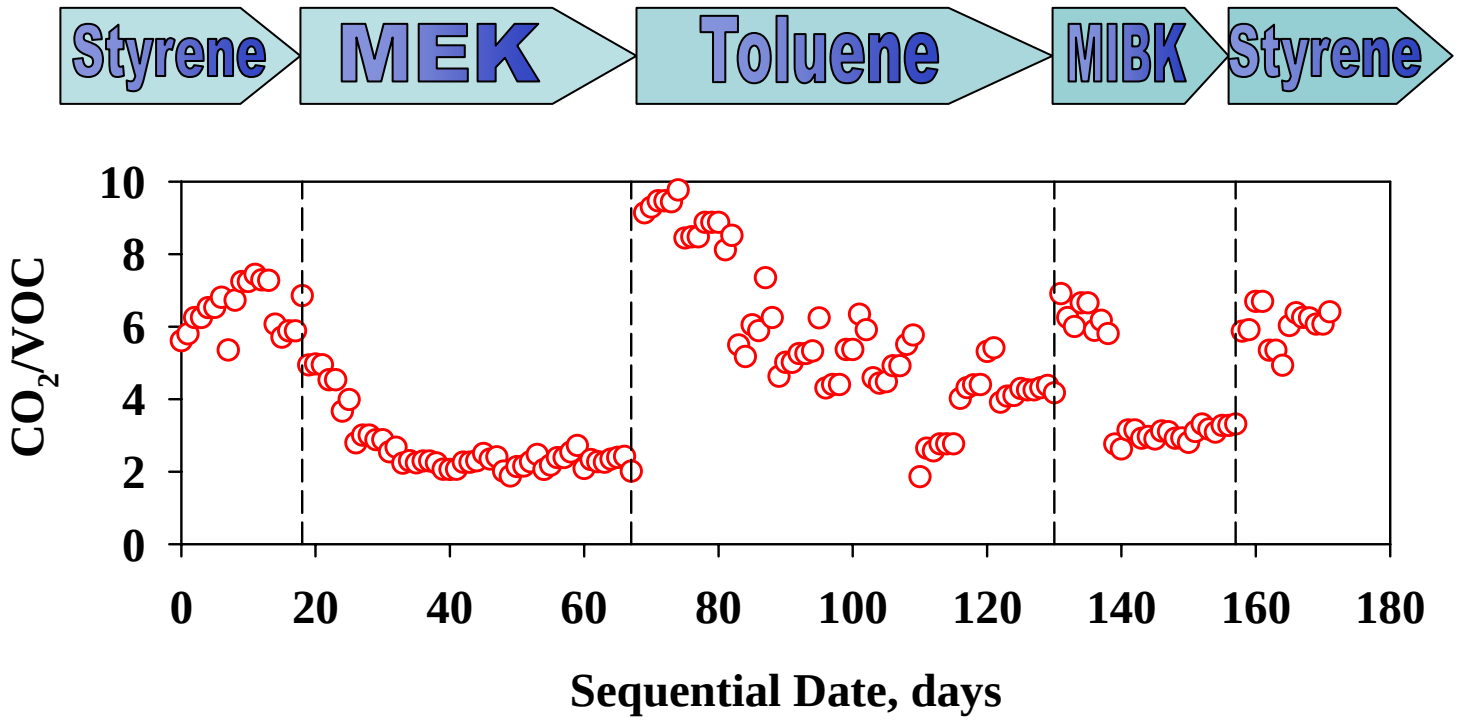
Results : Study 2 (Different EBRT)

- Biofilter Response after interchanging VOCs

Time, min	MIBK to Toluene	Toluene to MEK	MEK to Styrene	Styrene to MIBK
30	10.2	98.7	14.6	99.8
60	38.8	99.9	26.0	99.9
300	82.1	99.9	67.8	99.9
600	91.3	99.9	94.0	99.9
1200	85.6	99.9	99.9	99.9
2880	97.3	99.9	99.9	99.9

Results : Study 1 (Constant EBRT)

- CO_2 Production



Results : Study 1 (Constant EBRT)

- **CO_2 / VOC Removal**

Stage	Average Value	Theoretical Complete Oxidation Value
Styrene	6.49 ± 0.63	8
Styrene → MEK	2.66 ± 0.82	4
MEK → Toluene	6.68 ± 1.24	7
Toluene → MIBK	3.04 ± 0.20	6
MIBK → Styrene	6.01 ± 0.51	8

Results : Microbial Analysis

- **DGGE of PCR-amplified 16S rDNA**

Results : Microbial Analysis

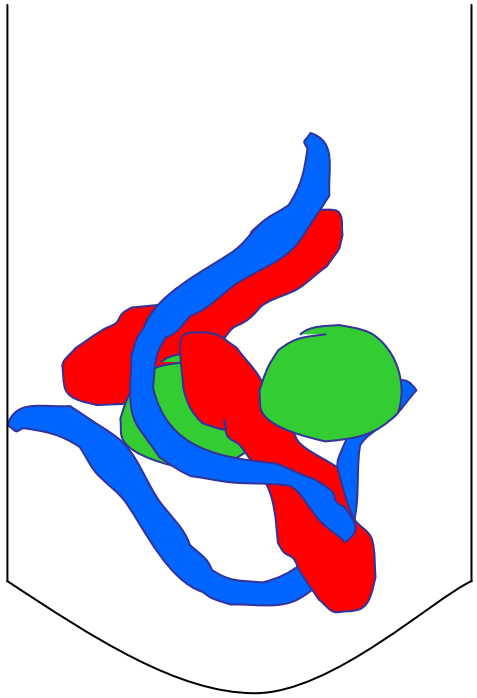
- **PCR**

- ✓ **Polymerase chain reaction**
- ✓ **To “grow up” extra copies of a target nucleic acid sequence**

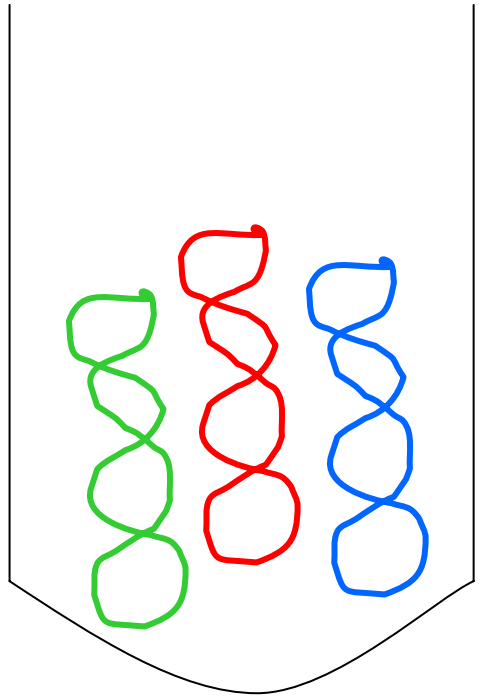
Results : Microbial Analysis

- **Extract Genomic DNA**

Mixture of Microorganisms

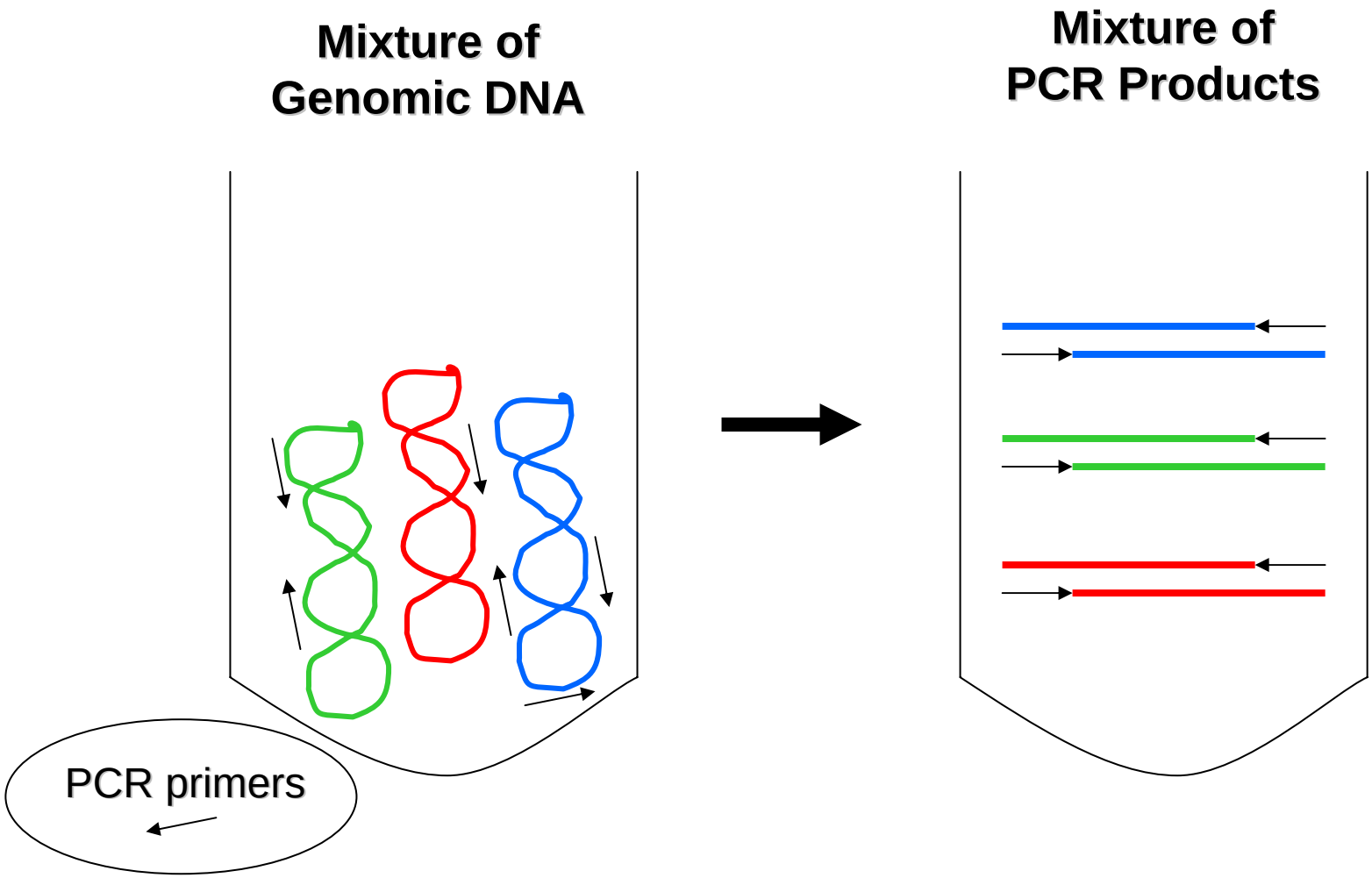


Mixture of Genomic DNA



Results : Microbial Analysis

- **PCR 16S rDNA Genes**

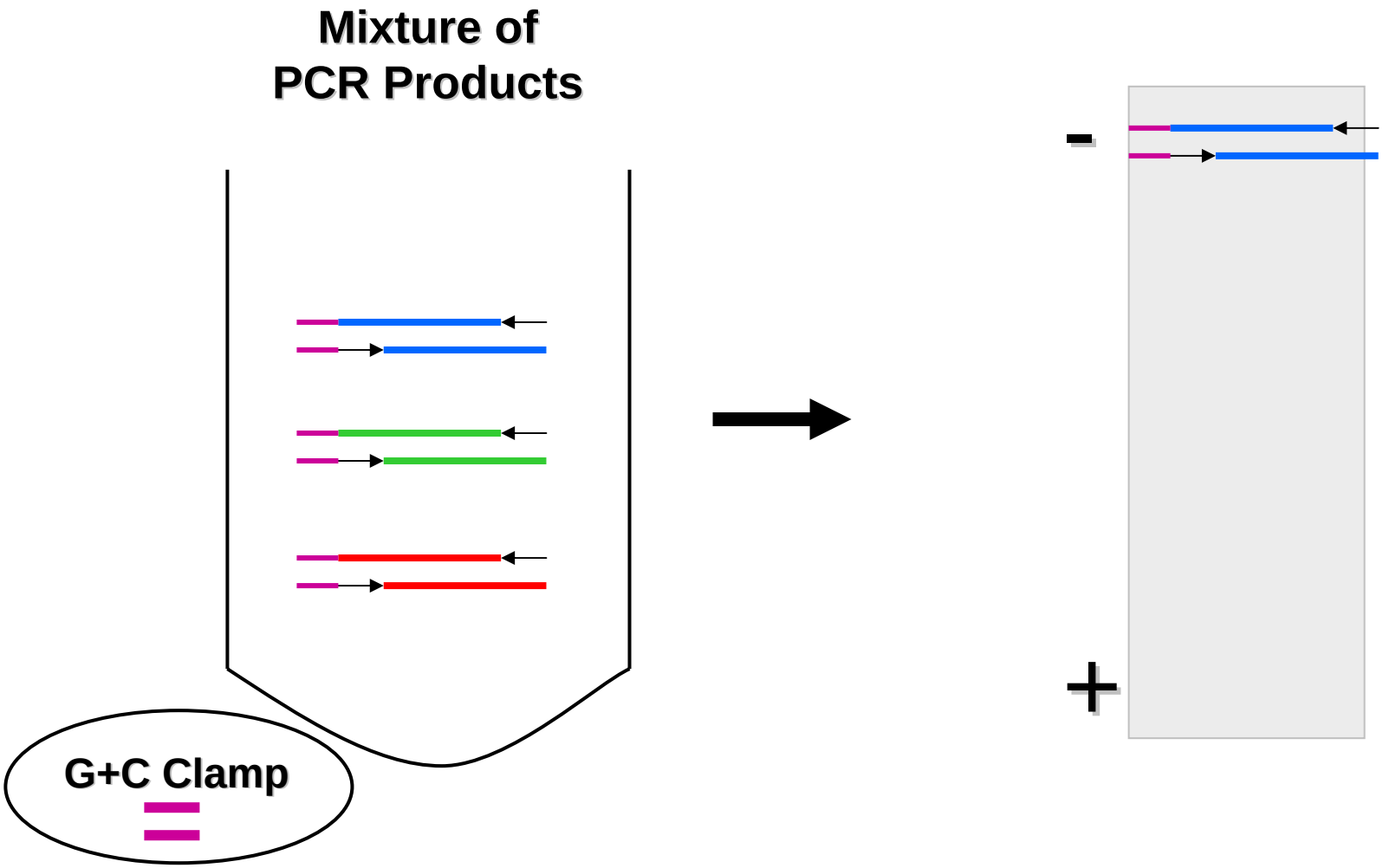


Results : Microbial Analysis

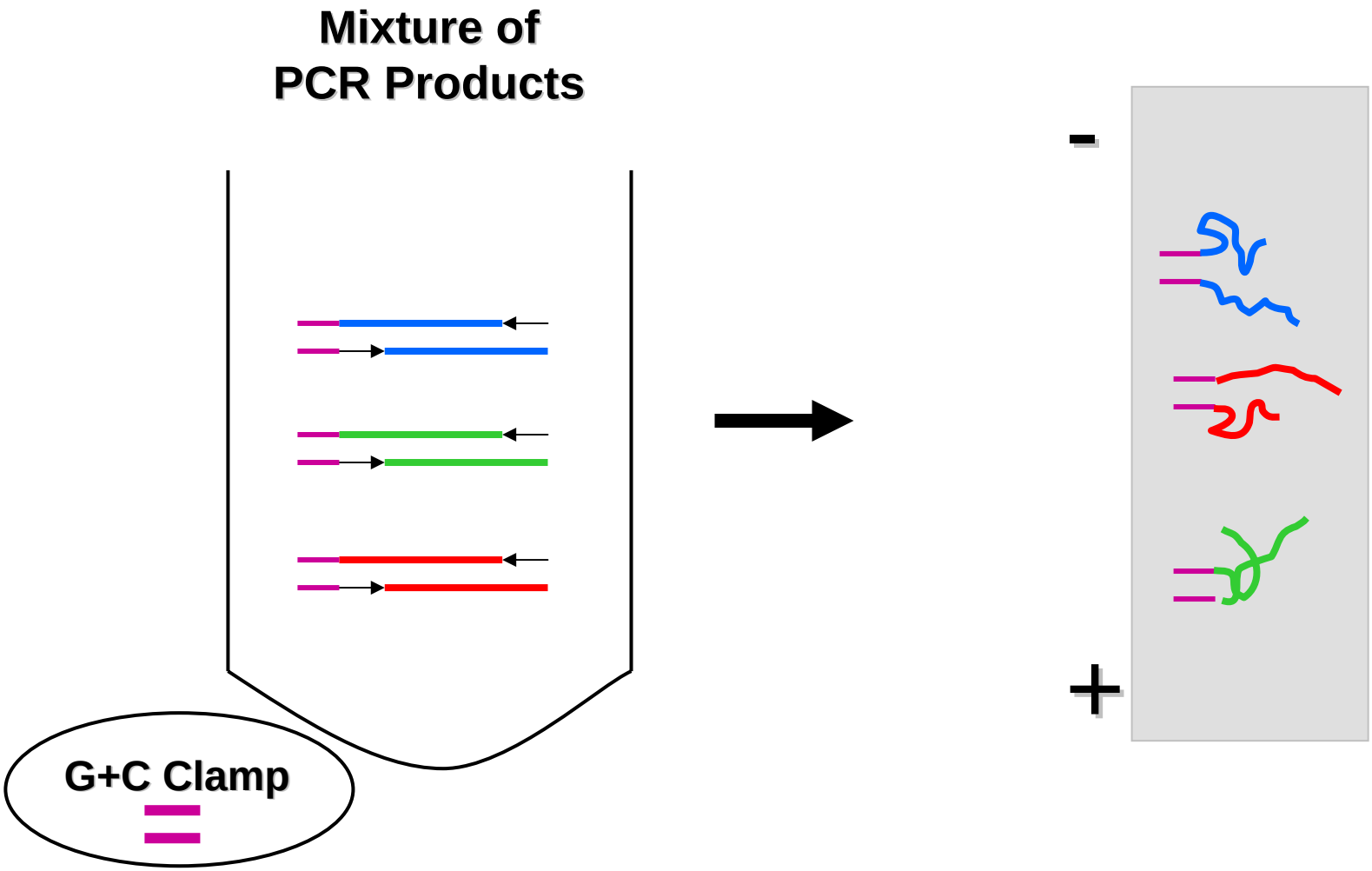
- **DGGE**

- ✓ **Denaturing gradient gel electrophoresis**
- ✓ **To separate PCR fragments based upon G+C content of DNA**
- ✓ **Higher G+C content are more stable and "run" further into a denaturing gel**

DGGE Process 1

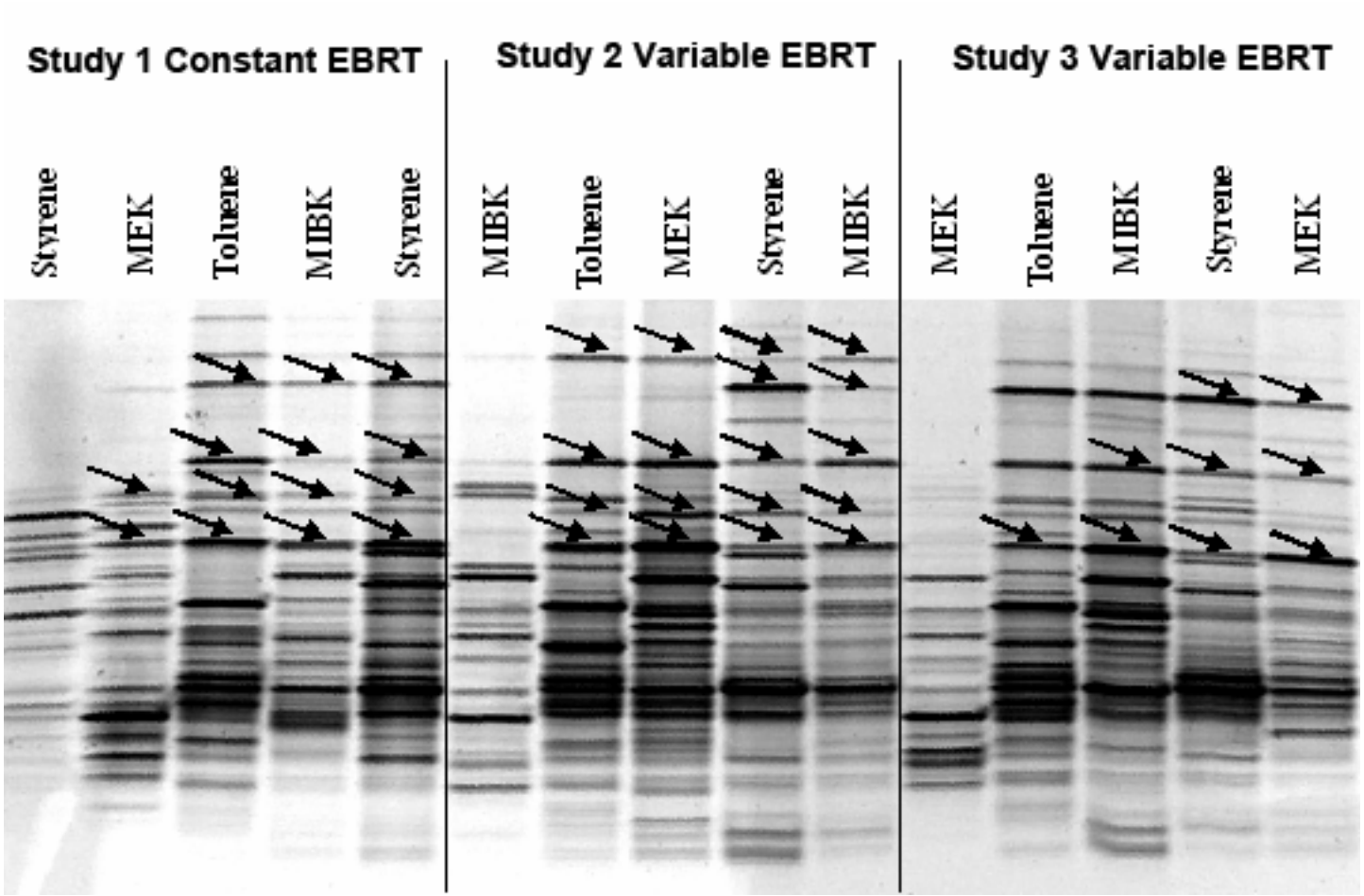


DGGE Process 2



Results : Microbial Analysis

- **DGGE of PCR-amplified 16S rDNA**



Conclusions

- High removal performances were observed in the interchanging VOC-fed TBAB.
- Prolonged EBRT had no apparent effect on the biofilter performance for MEK and MIBK, while the prolonged EBRT improved the biofilter performance of styrene and toluene significantly.
- The initial compound did not have apparent effect on performance of VOC interchanging in the biofilter.

Conclusions

- **TBAB easily acclimated to MEK & MIBK, while TBAB acclimations to Toluene & Styrene were delayed for about 2 days.**

- **The destructed toluene and styrene were eliminated exclusively by aerobic biodegradation, however, the destructed MEK and MIBK were eliminated by aerobic biodegradation and possible denitrification.**

- **The results from DGGE analysis revealed that the microbial community structure was different after each interchange of VOCs.**

Future Work

- **Further microbial study: Identifying the species of microorganisms in biofilters.**
  - ✓ **DGGE of all other interchanging samples**
  - ✓ **Sequencing if the PCR bands from DGGE**

- **Investigating biofilter performance under VOC mixtures.**
  - ✓ **Two ratios of mixture for these four VOCs**
    - **Even ratio**
    - **Emission ratio from *EPA 2003 toxic release report***

Acknowledgement

- The authors are pleased to acknowledge the financial support for the research by National Science Foundation under award # BES 0229135