

ATOs-11

Biological Oxidation of Gaseous VOC Mixtures in Trickle-Bed Air Biofilter

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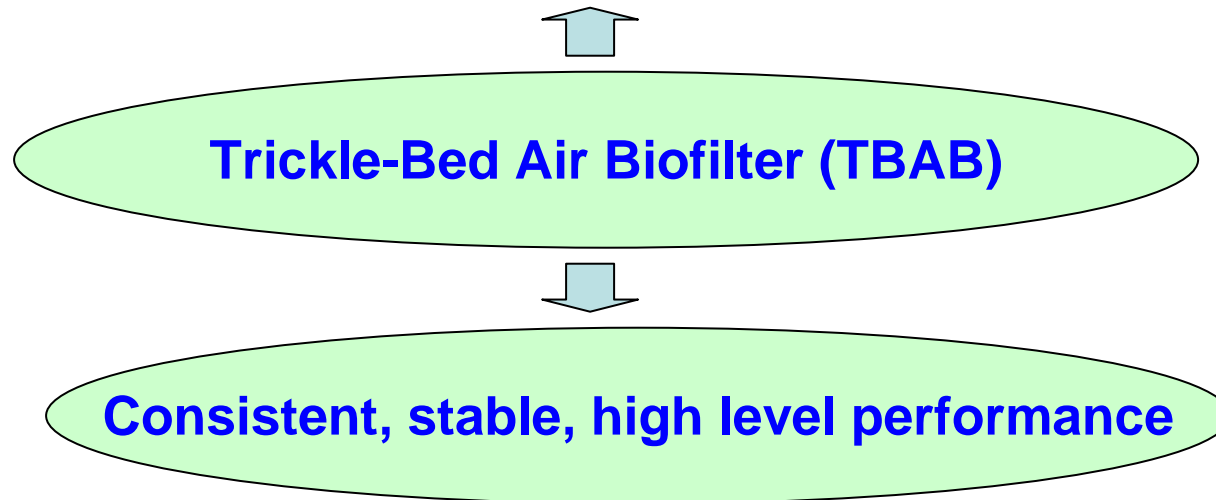
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Introduction

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

```
graph TD; A[challenges in application] --> B[Characteristic source]; A --> C[Operation maintenance]; B --> D["> Variation in Concentration<br/>> Variation in Composition<br/>> Non-use periods"]; C --> E["> Biomass accumulation"];
```

Characteristic source

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

Operation maintenance

- **Biomass accumulation**

Objective

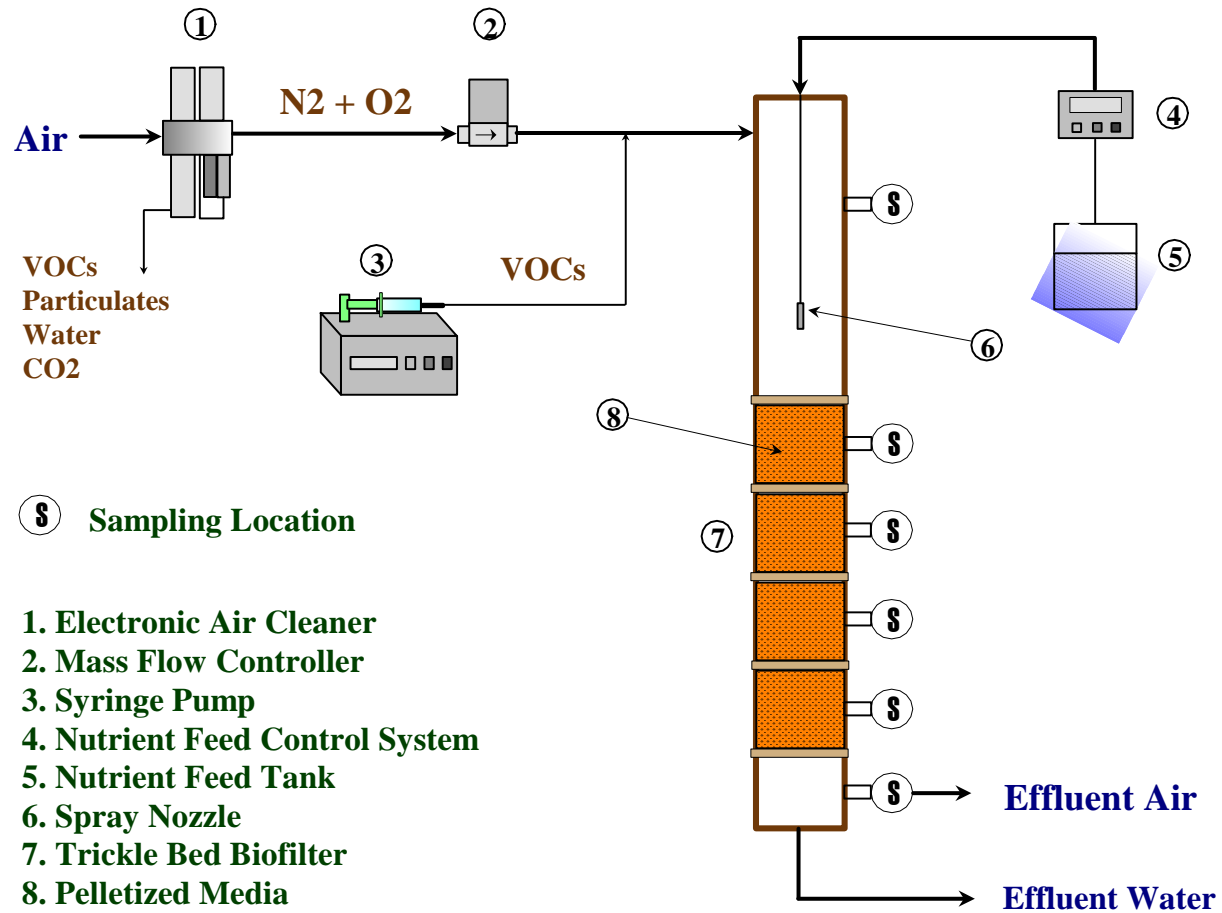
- **Characterization of TBAB performance under adverse operating conditions**
 - **Effect of step-change in single solute concentration**
 - **Effect of non-use periods**
 - **VOC Interchanging**
 - **VOCs Mixtures**
 - **TBAB Integrated with Adsorption Unit**

Materials and Methods

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



Materials and Methods



Materials and Methods

➤ Feed VOC Mixtures

	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

➤ Feed VOC Mixtures

➤ Mixture 1: Equal Molar Ratio

- Toluene: Styrene: MEK: MIBK = 1: 1: 1: 1

➤ Mixture 2: Emission Ratio Based on *EPA 2003 toxic release report* for chemical industries

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

Materials and Methods

➤ Operating Condition

- **Inlet concentration of feed VOCs**
 - 50 ppmv ~ 1000 ppmv for mixture 1
 - 50 ppmv ~ 500 ppmv for mixture 2
- **Flow rate**
 - Air flow = 1.35 L/min (**Constant EBRT = 2.02 min**)
- **Biomass control : Periodic in-situ backwashing**
 - Frequency: 1 hour of duration / a week

Materials and Methods

➤ Operating Condition for Mixture 1

Operation stage	I	II	III	IV	V
EBRT, min	2.02	2.02	2.02	2.02	2.02
Inlet Conc., ppmv	50	100	250	500	1000
Total Loading Kg COD/m ³ -d	0.39	0.79	1.97	3.94	7.88
Buffered nutrient flow L/d	2.4	2.4	2.4	2.4	2.4

Materials and Methods

➤ Operating Condition for Mixture 2

Operation stage	I	II	III	IV	V	VI
EBRT, min	2.02	2.02	2.02	2.02	2.02	2.02
Inlet Conc., ppmv	50	100	250	500	350	300
Total Loading Kg COD/m ³ -d	0.40	0.80	2.01	4.02	2.81	2.41
Buffered nutrient flow L/d	2.4	2.4	2.4	2.4	2.4	2.4

Previous study

➤ Removal capacity of single VOCs in TBAB

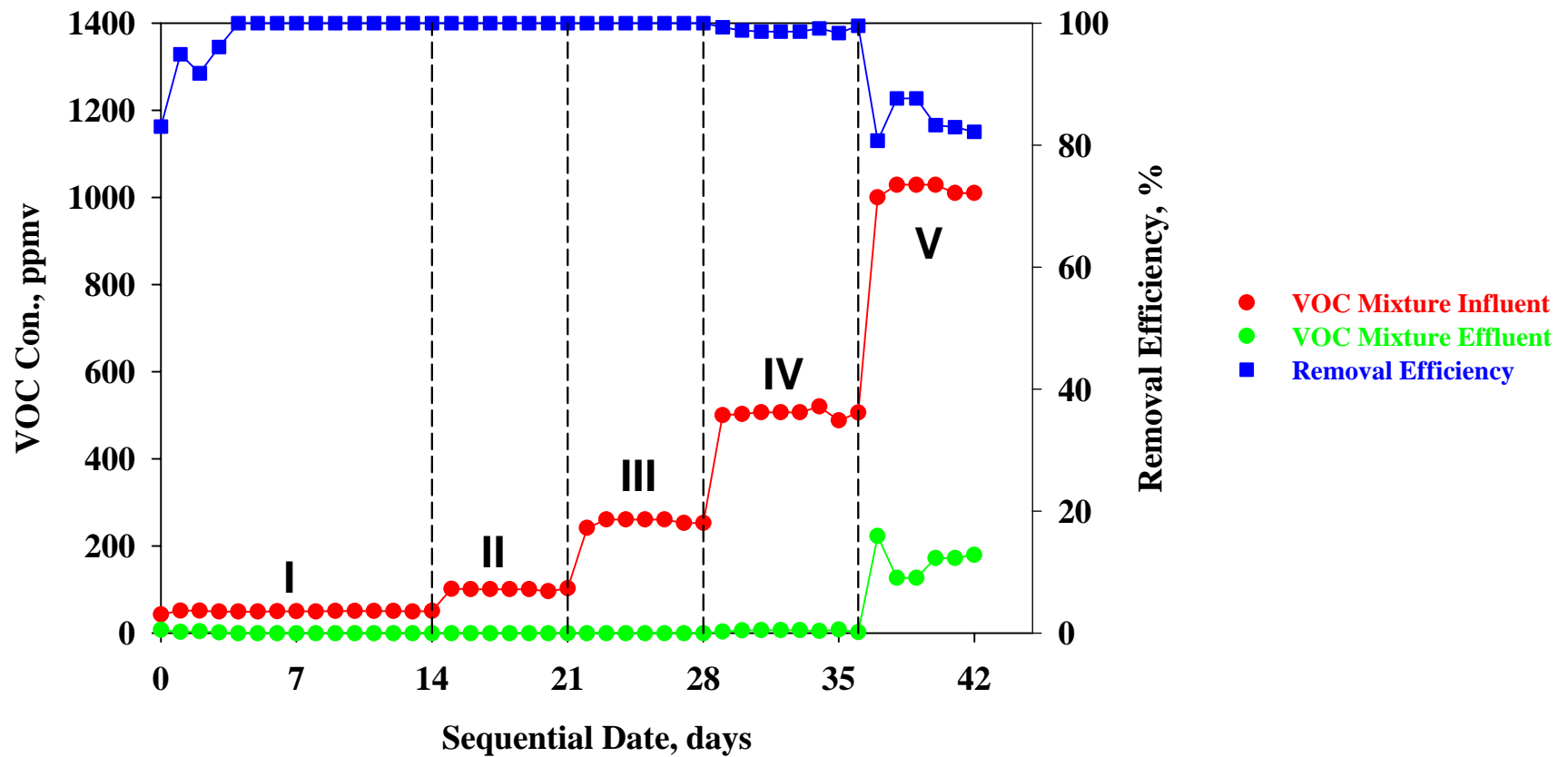
	Toluene		Styrene	
	Previous	Current	Previous	Current
EBRT, min	1.23	2.02	2.02	2.02
Critical Con., ppmv	250	400	200	200
	MEK		MIBK	
	Previous	Current	Previous	Current
EBRT, min	0.76	2.02	0.76	2.02
Critical Con., ppmv	400	1080	150	400

Results

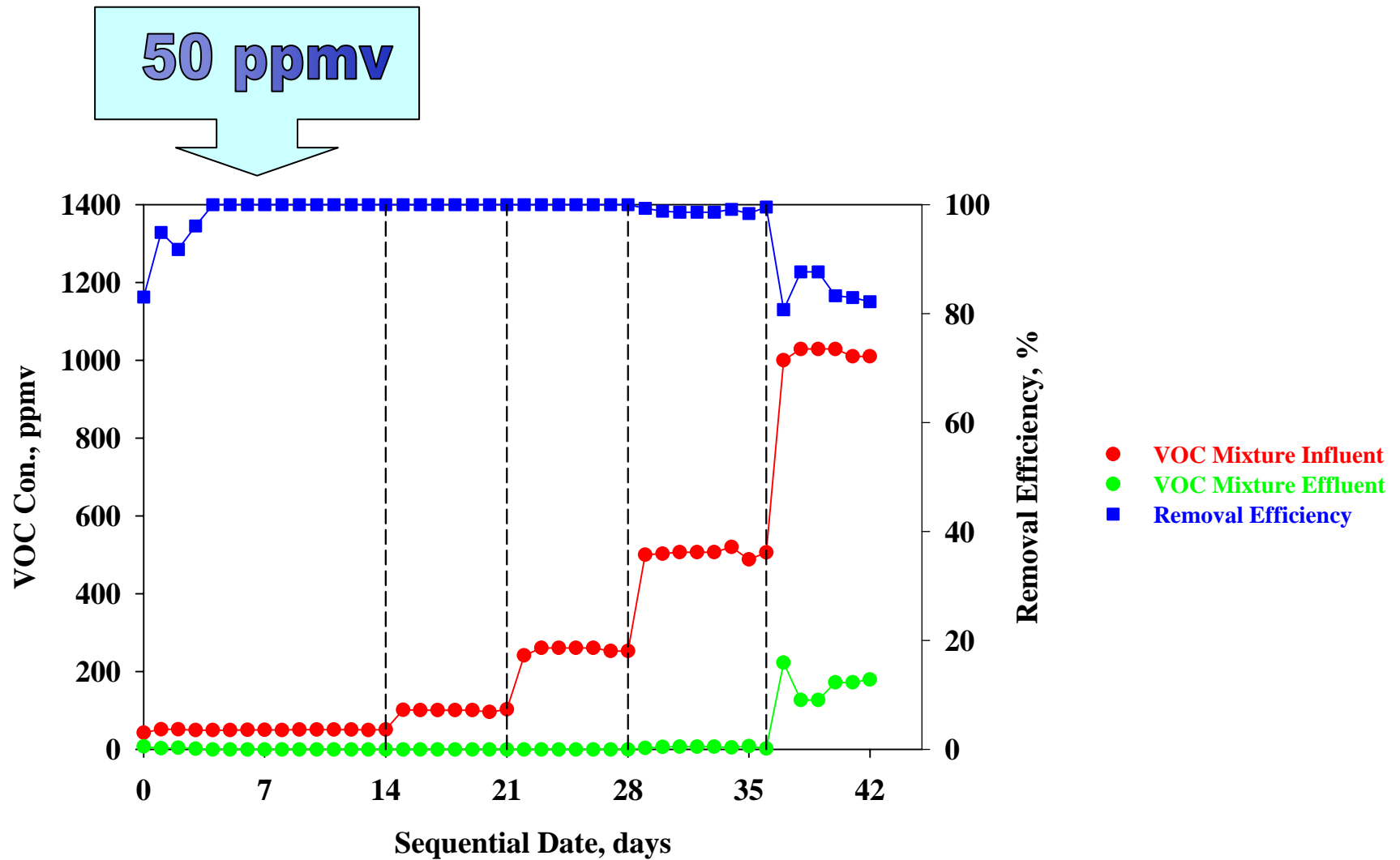
- **Current Study (VOCs Mixtures)**
 - ✓ **TBAB performance with respect to VOC removal**
 - ✓ **Effluent response corresponding to step change of feeding VOCs**
 - ✓ **Removal profile along biofilter depth**

Results : Mixture 1

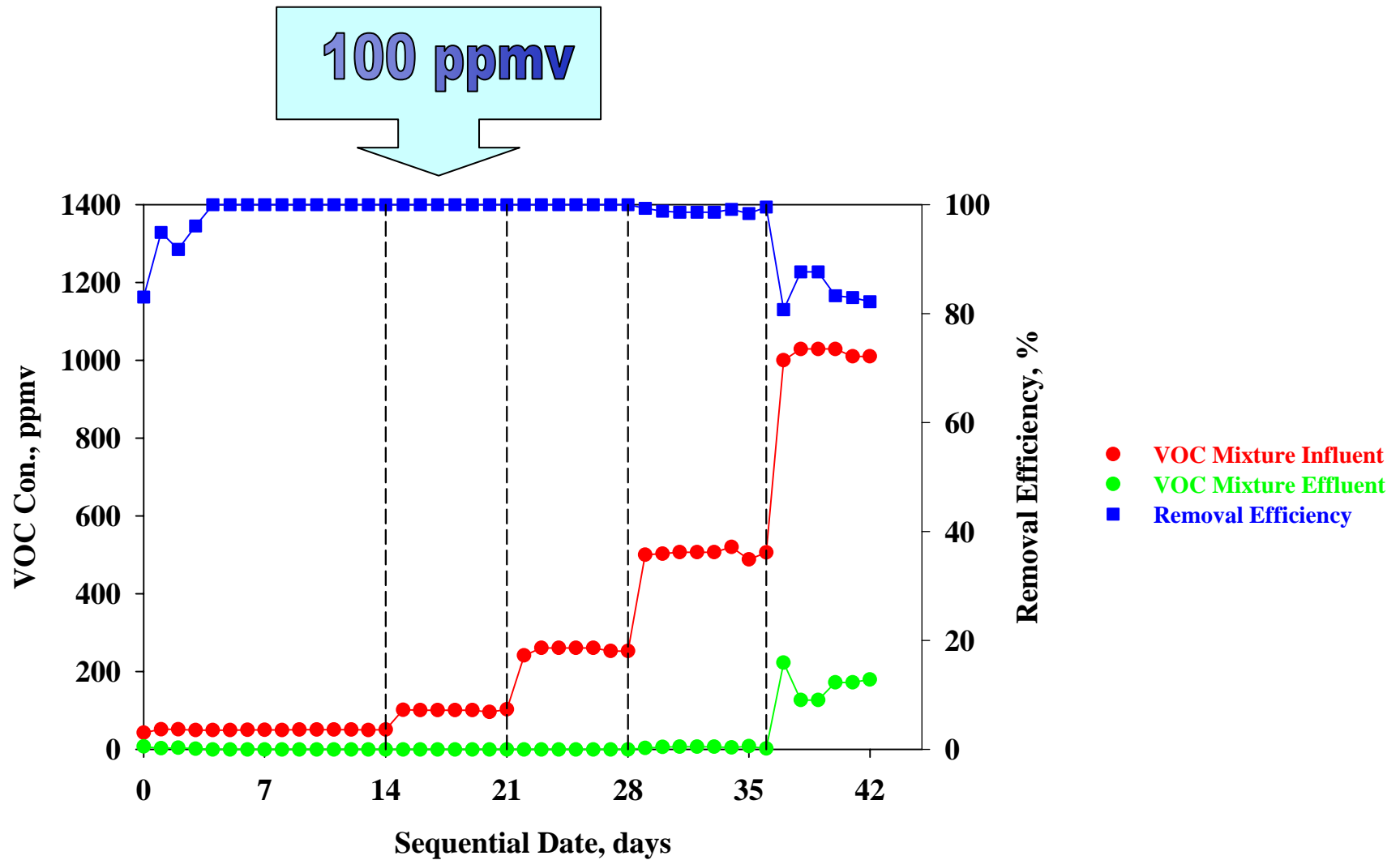
➤ TBAB performance with respect to VOC removal



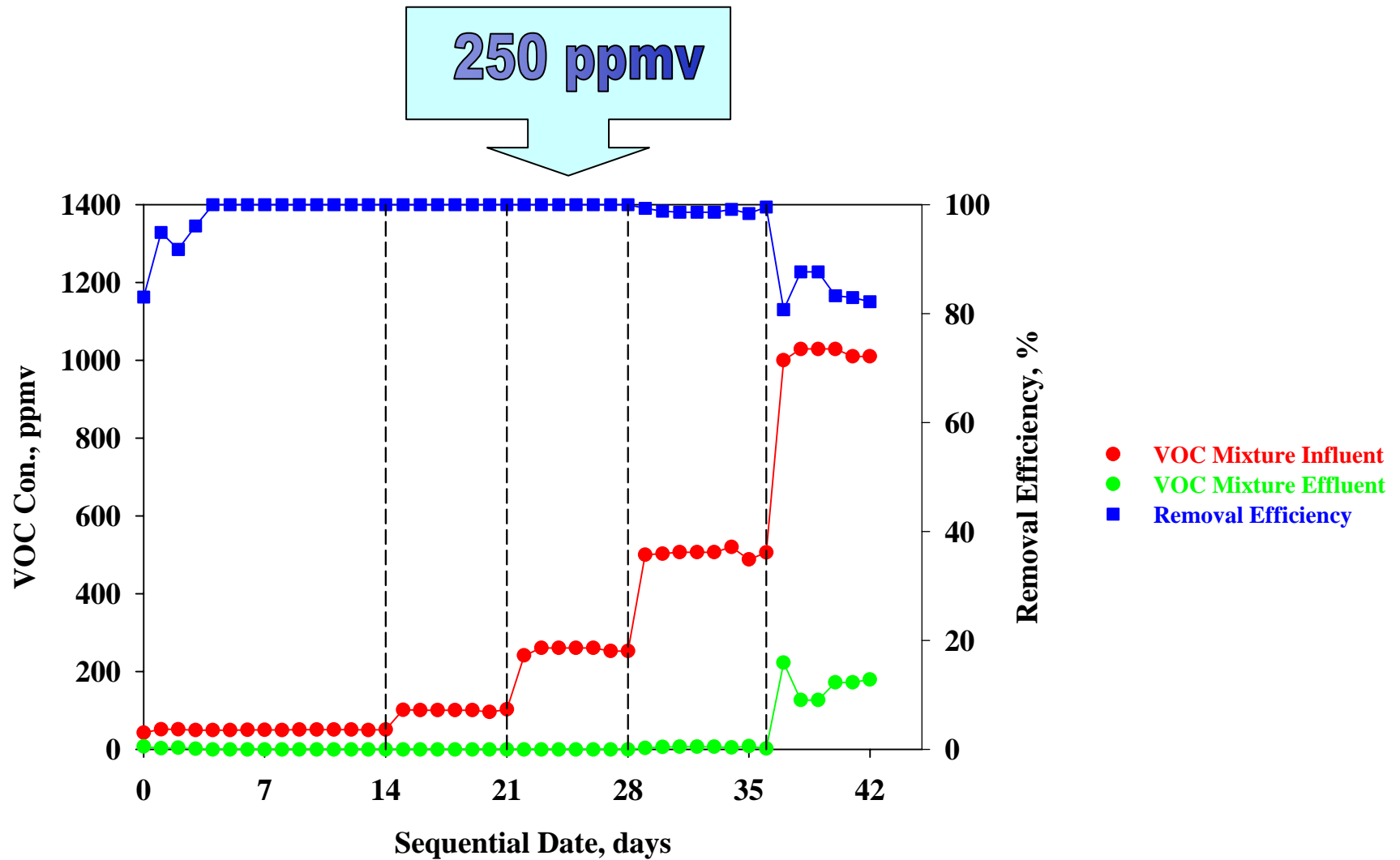
Results : Mixture 1



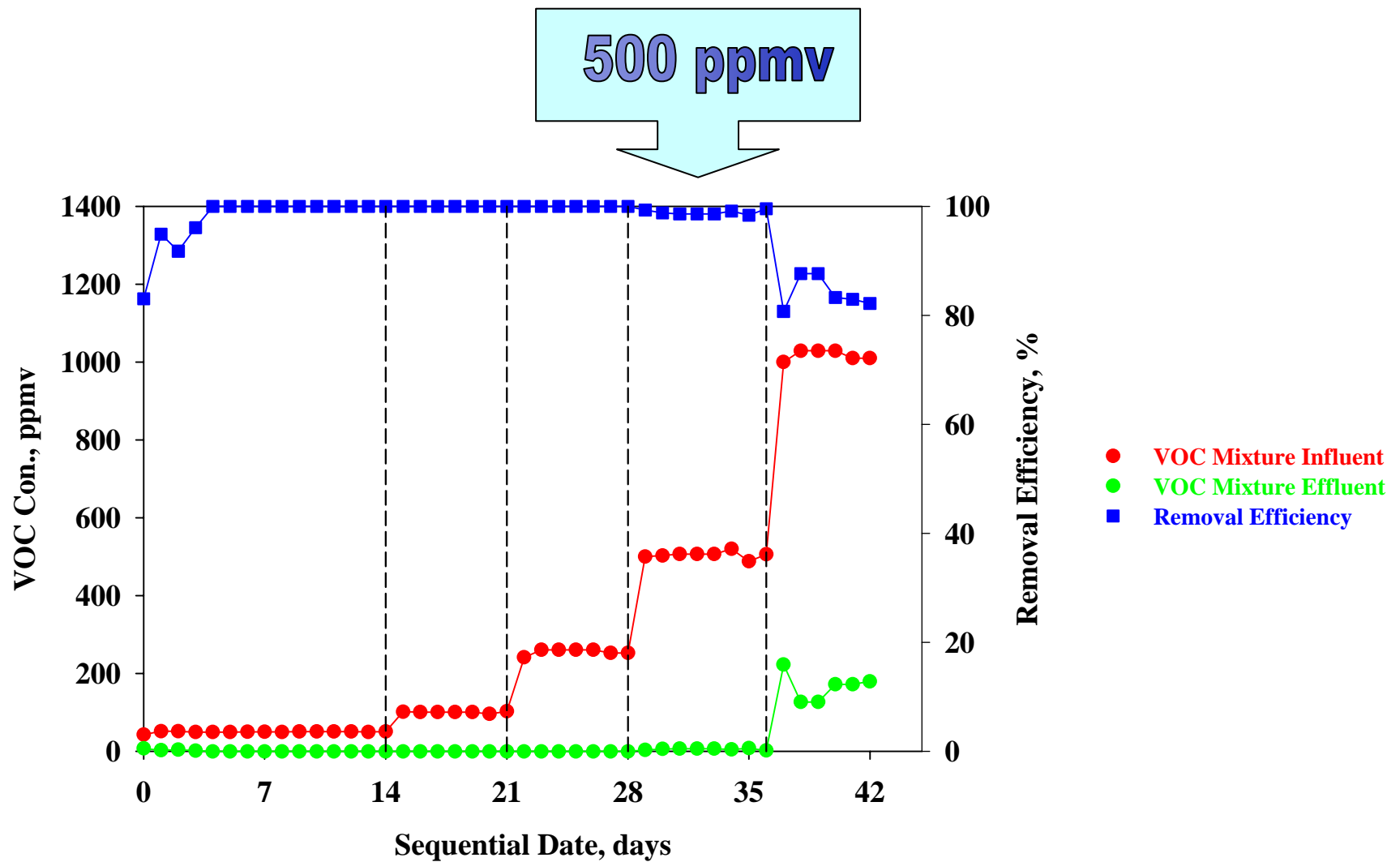
Results : Mixture 1



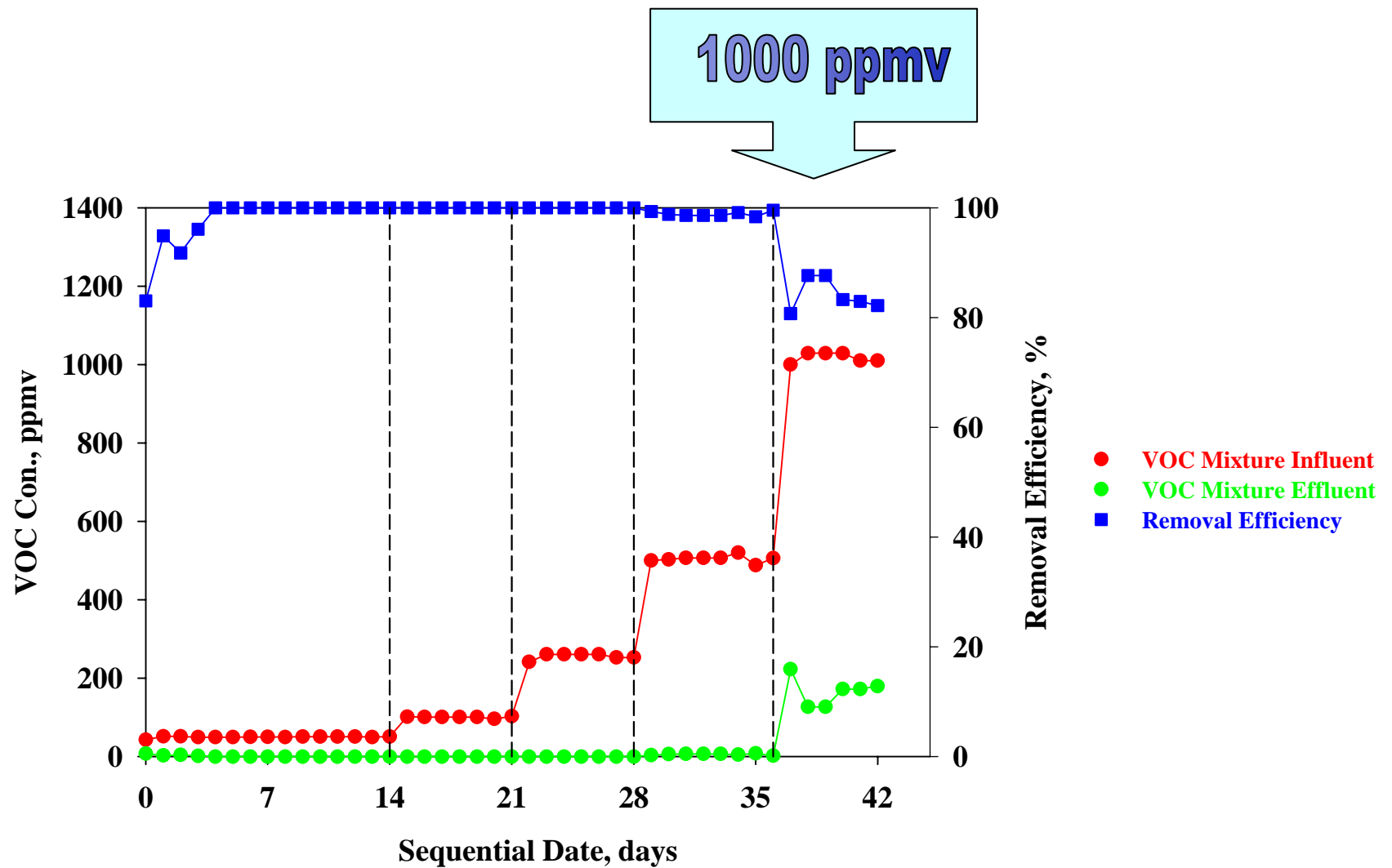
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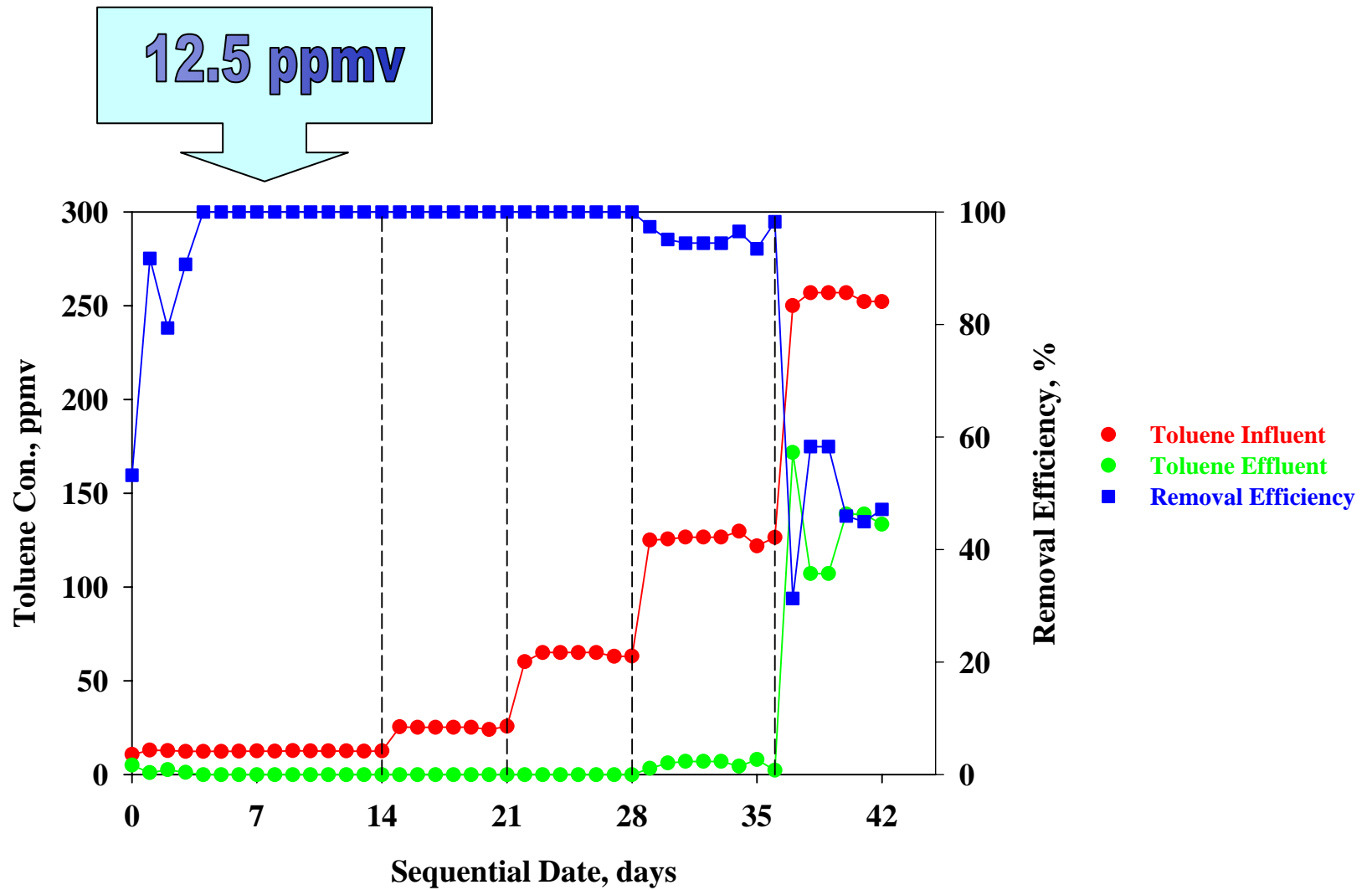
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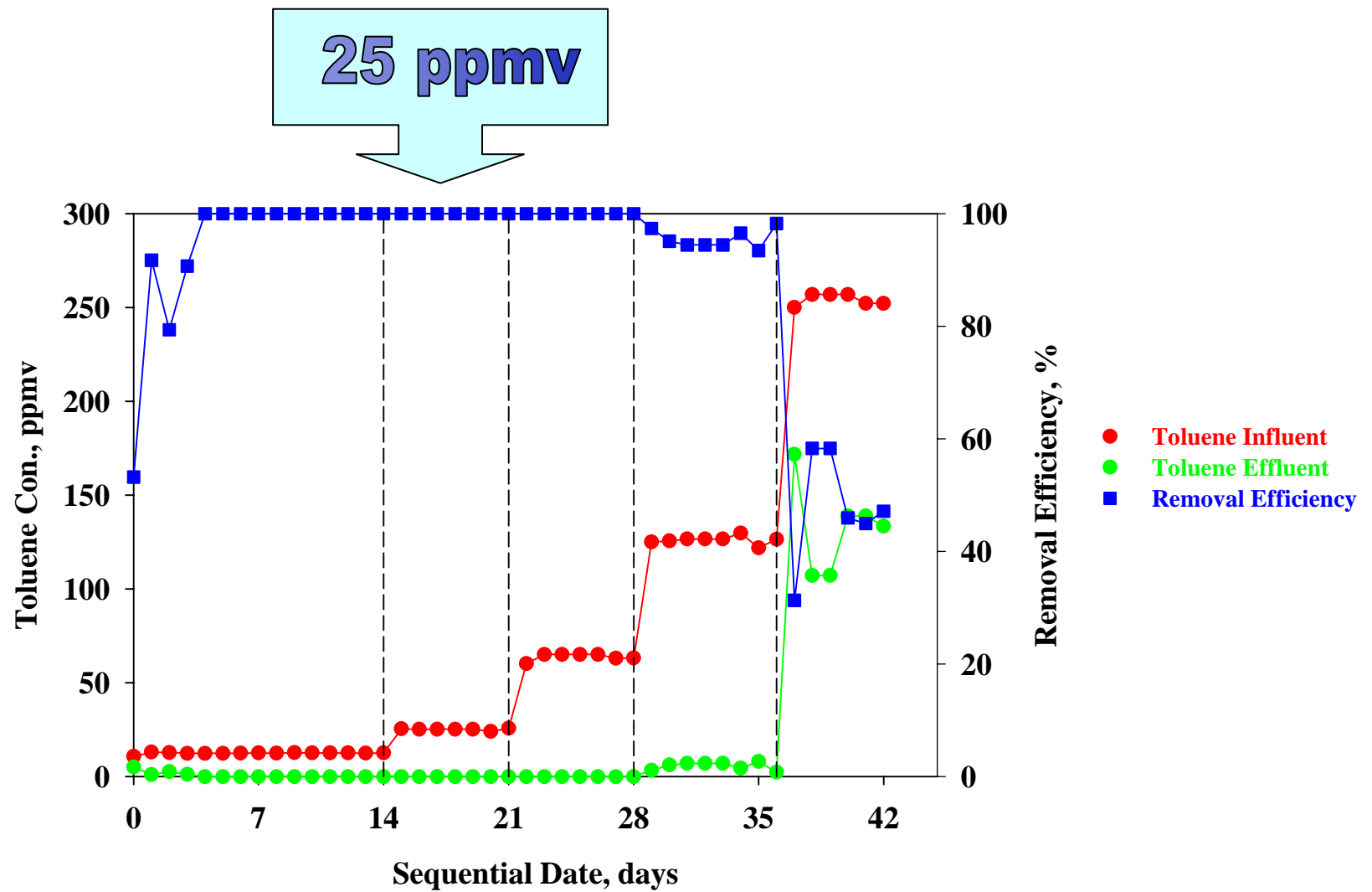
Results : Mixture 1



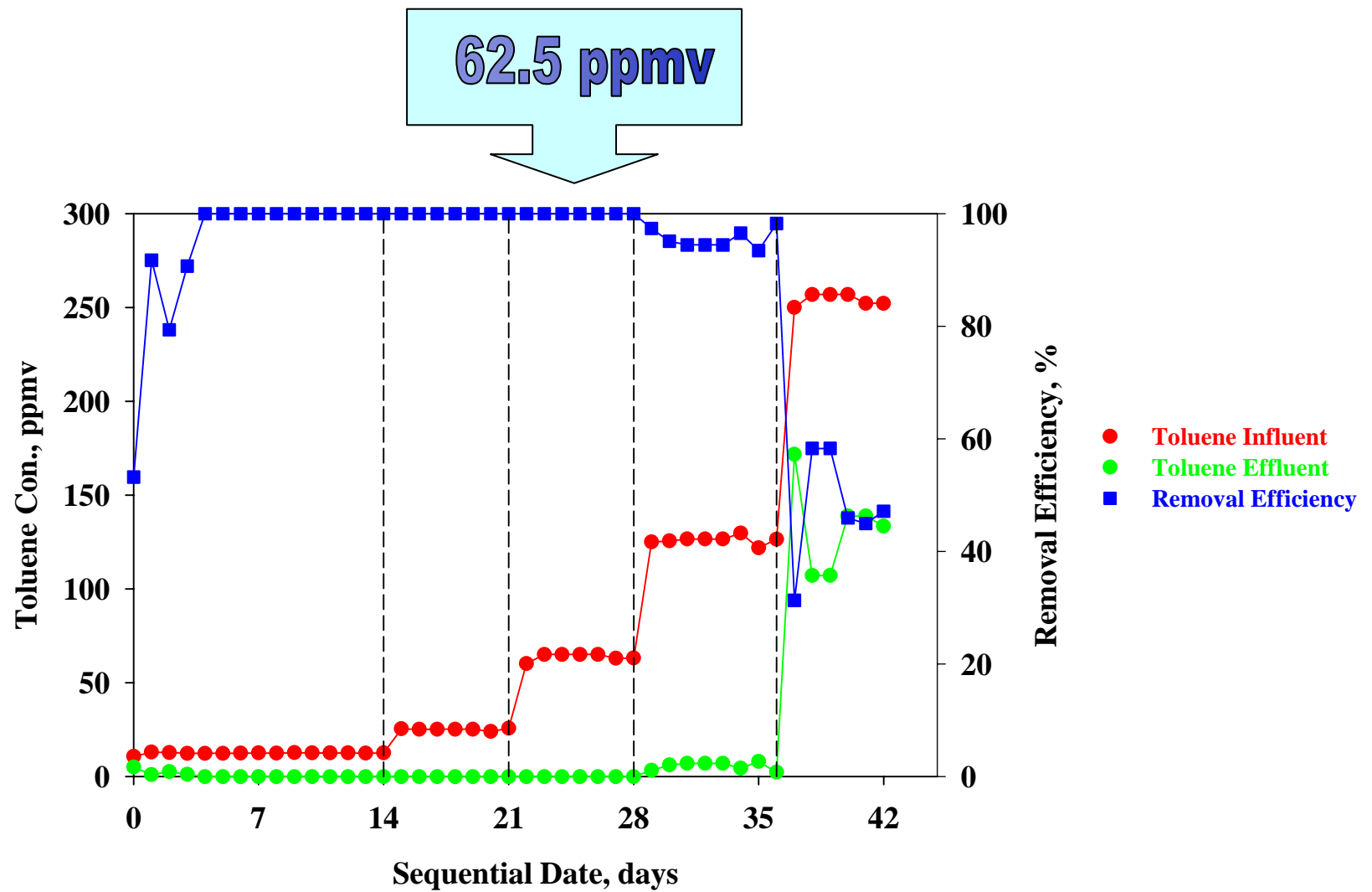
Results : Toluene in Mixture 1



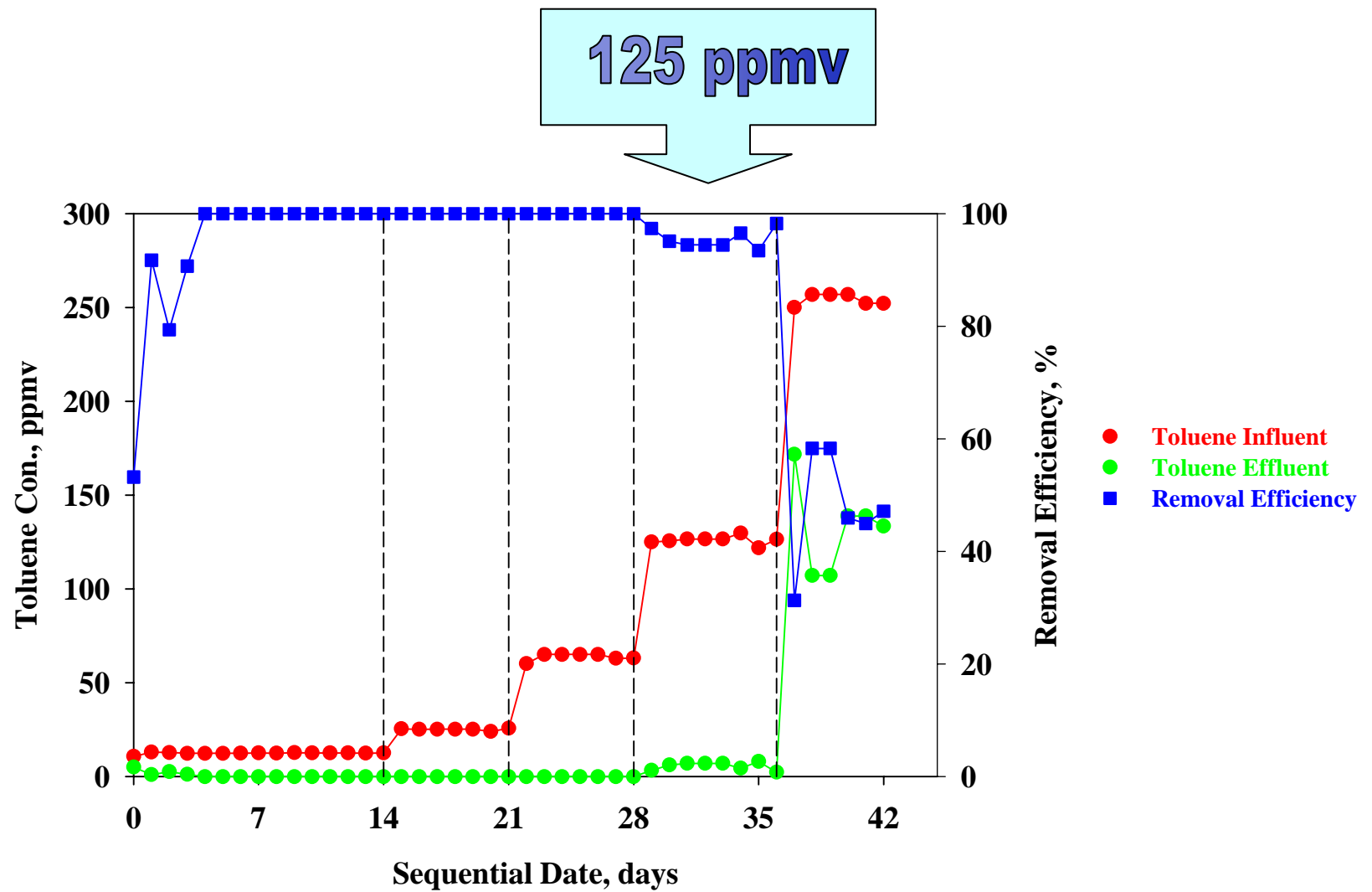
Results : Toluene in Mixture 1



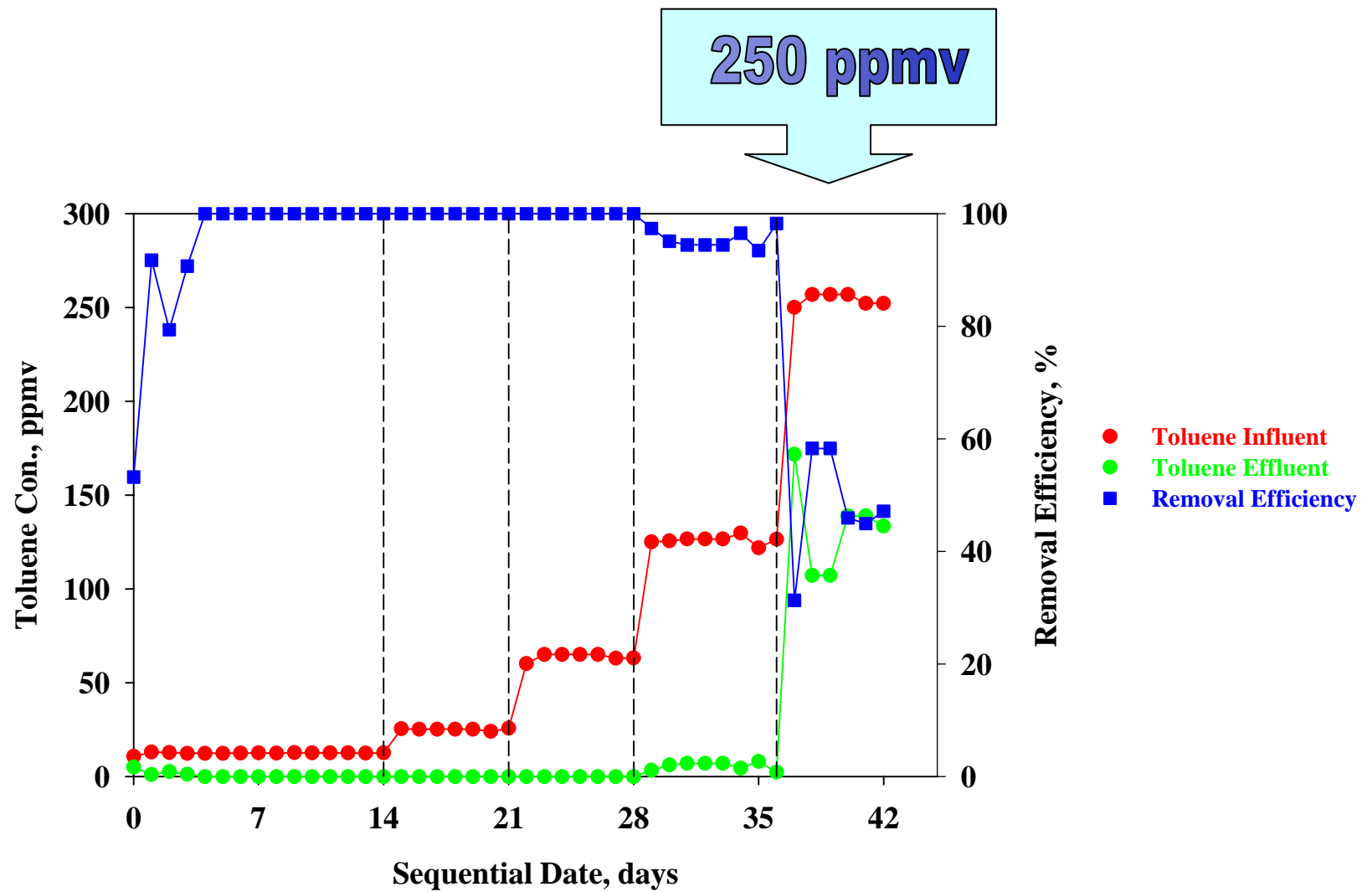
Results : Toluene in Mixture 1



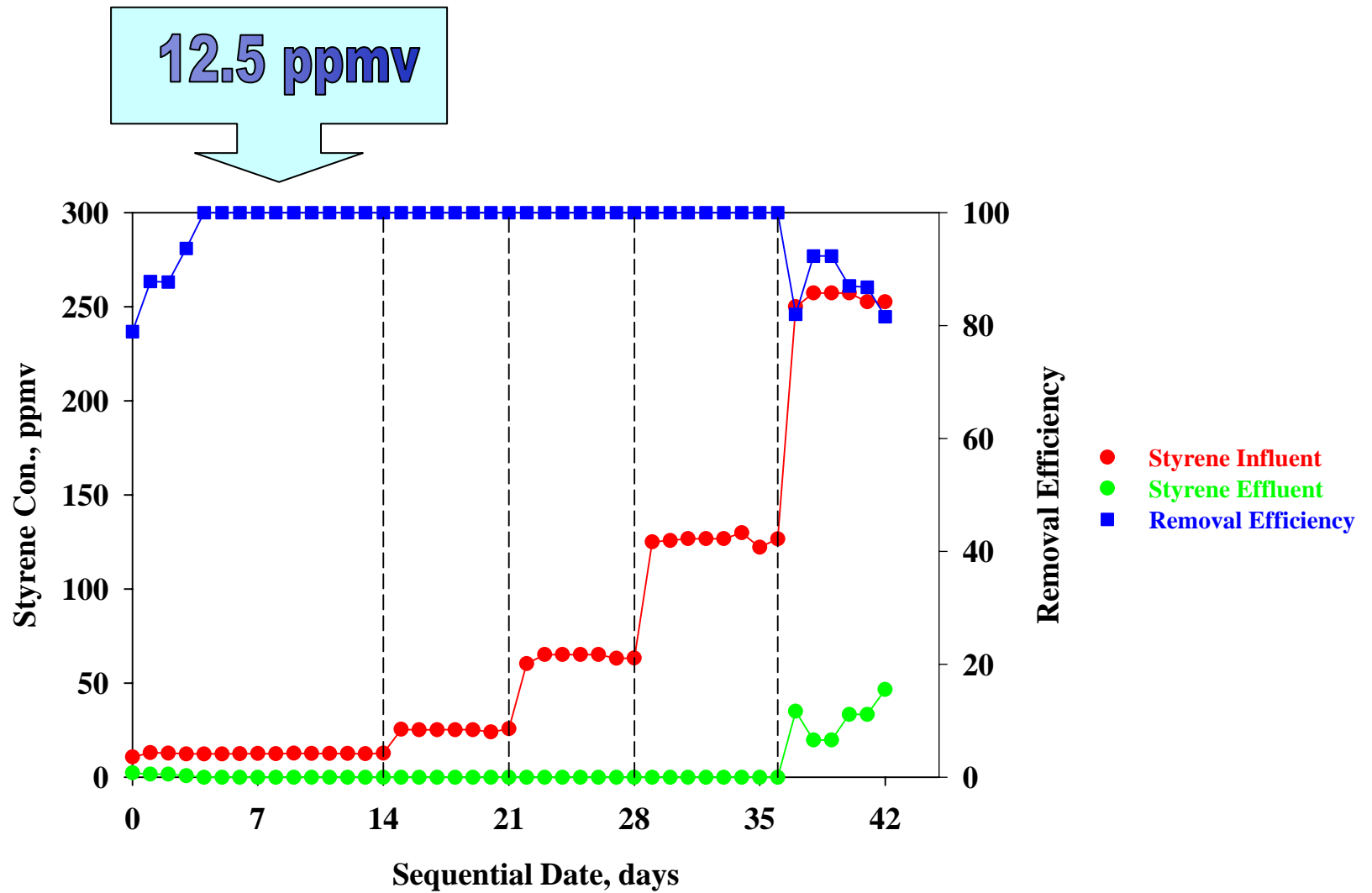
Results : Toluene in Mixture 1



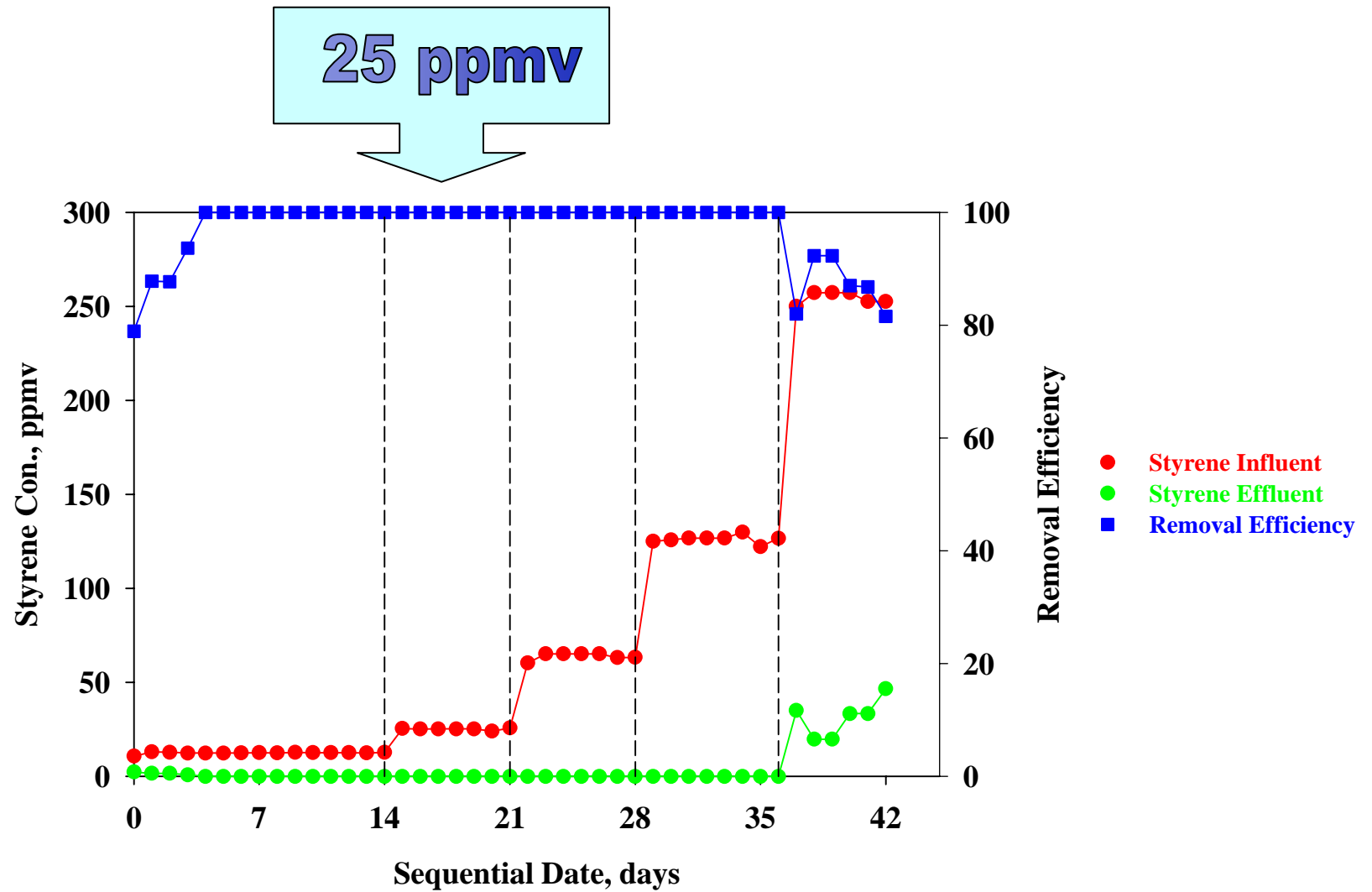
Results : Toluene in Mixture 1



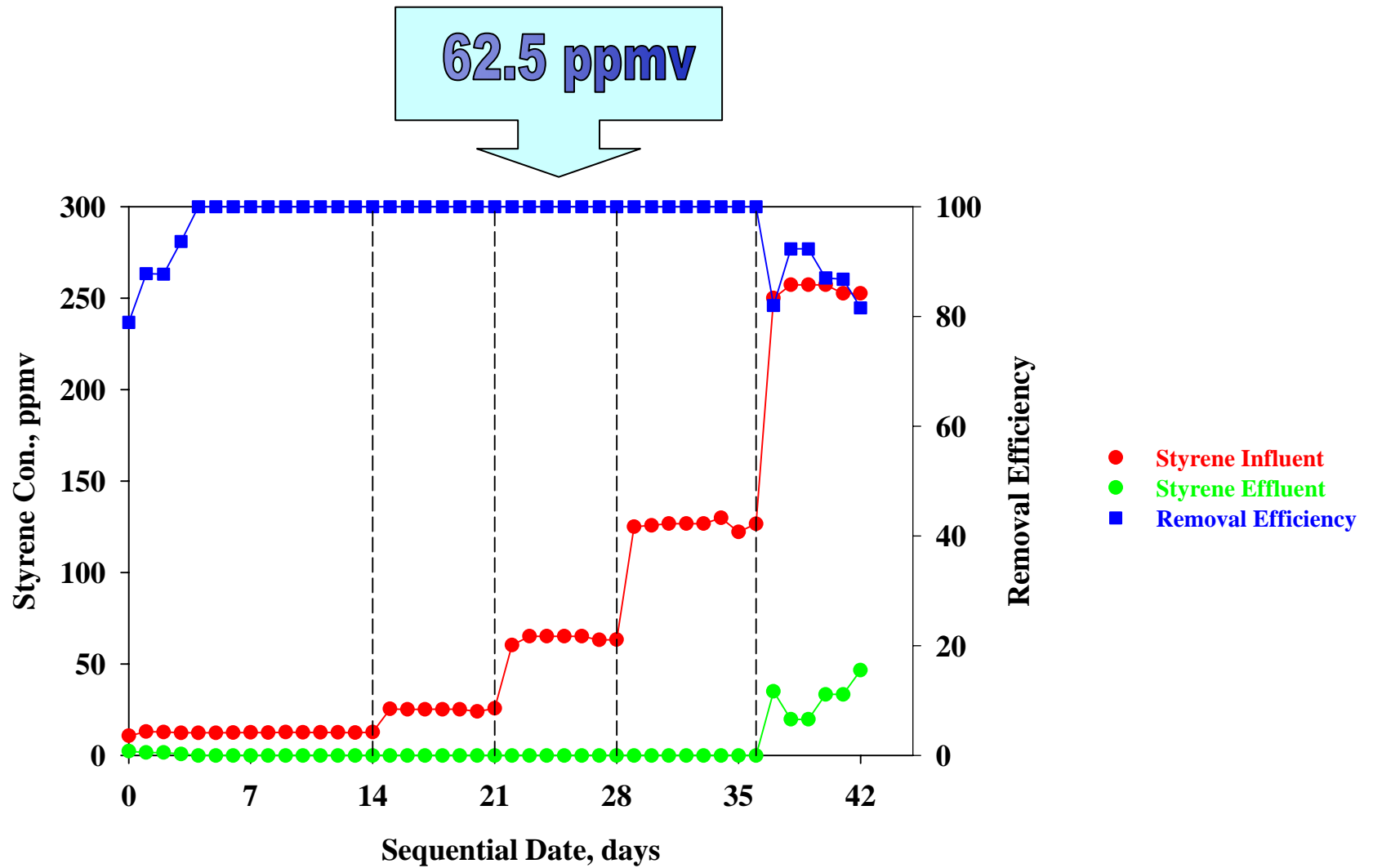
Results : Styrene in Mixture 1



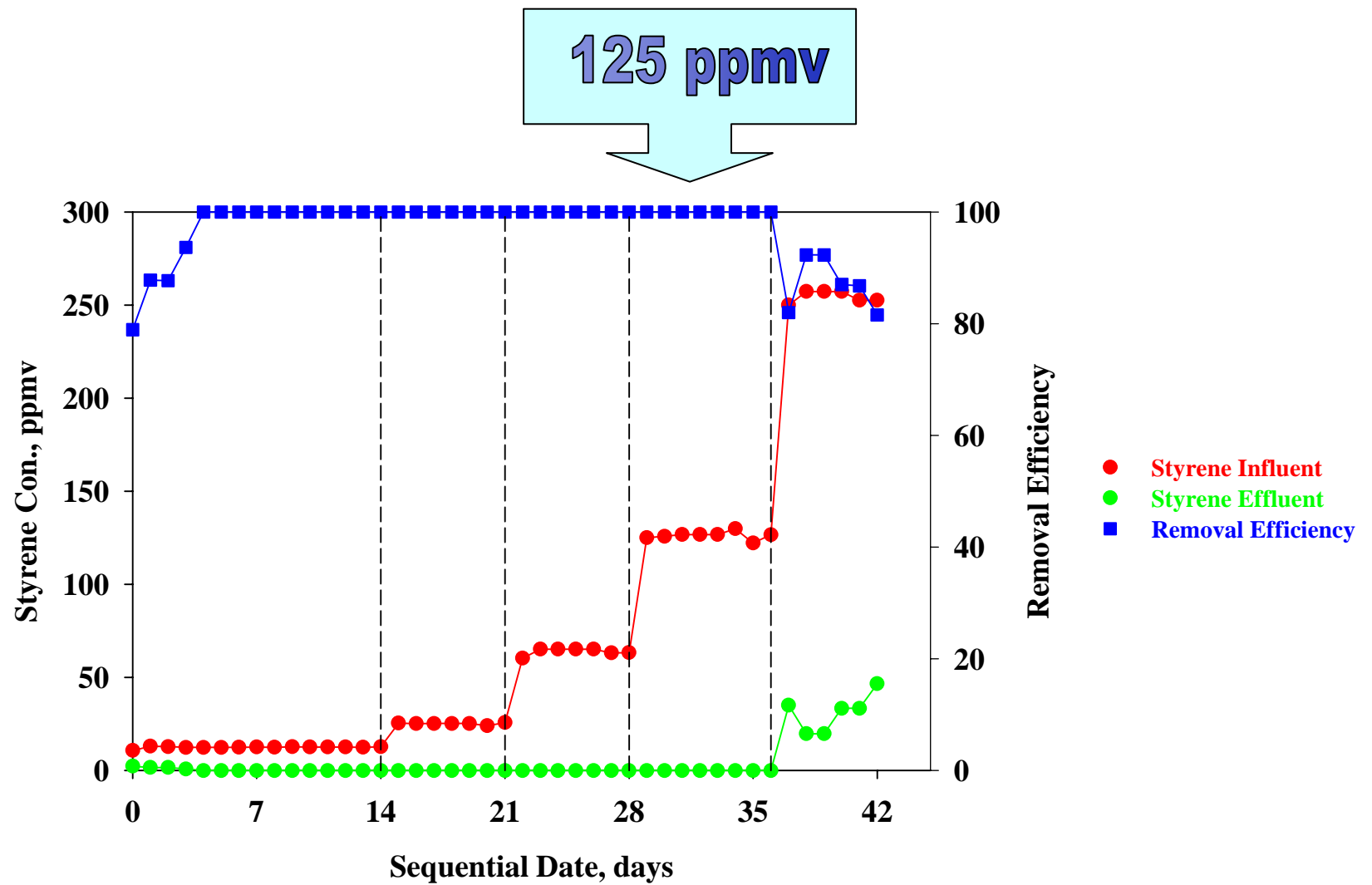
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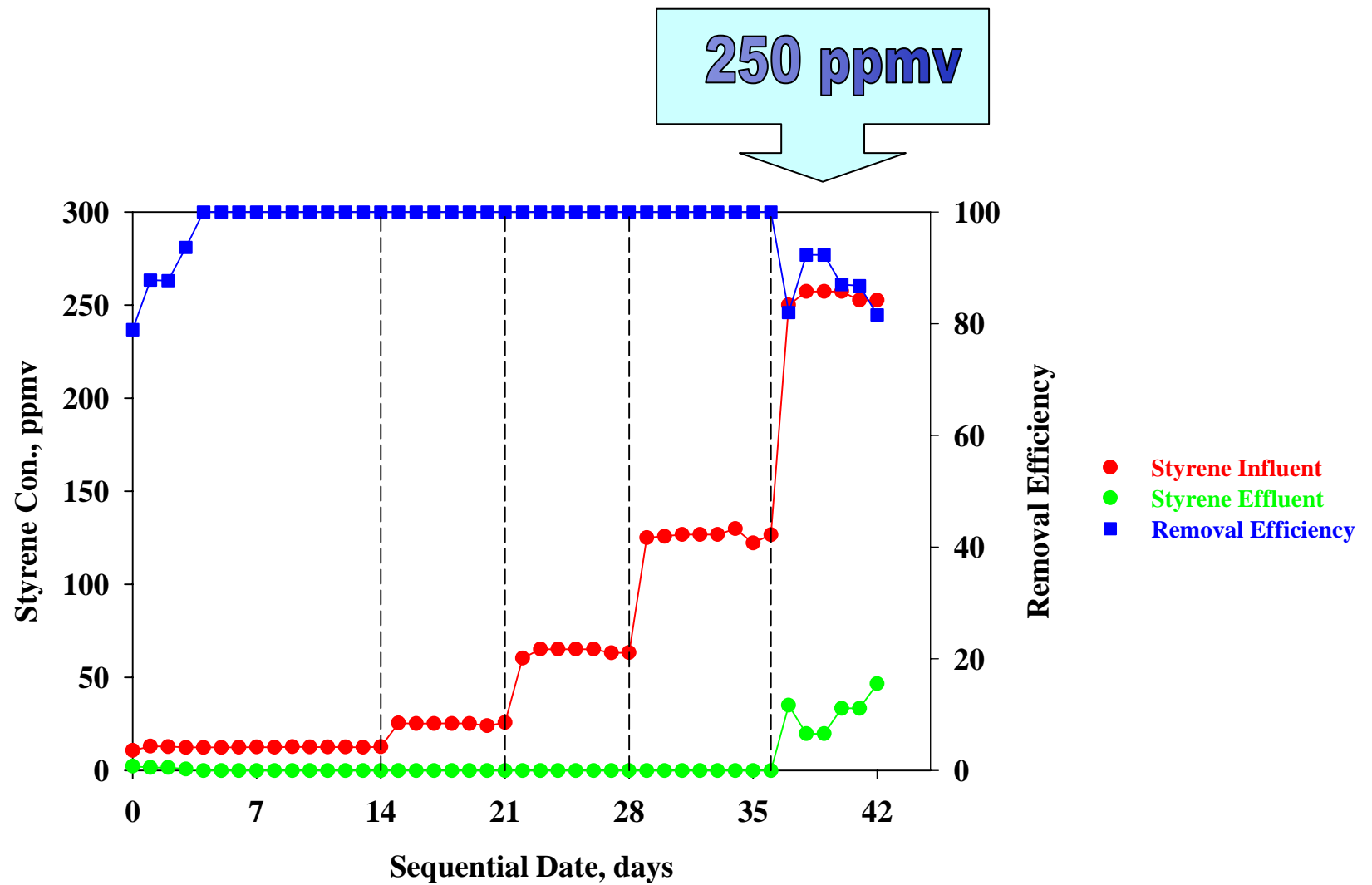
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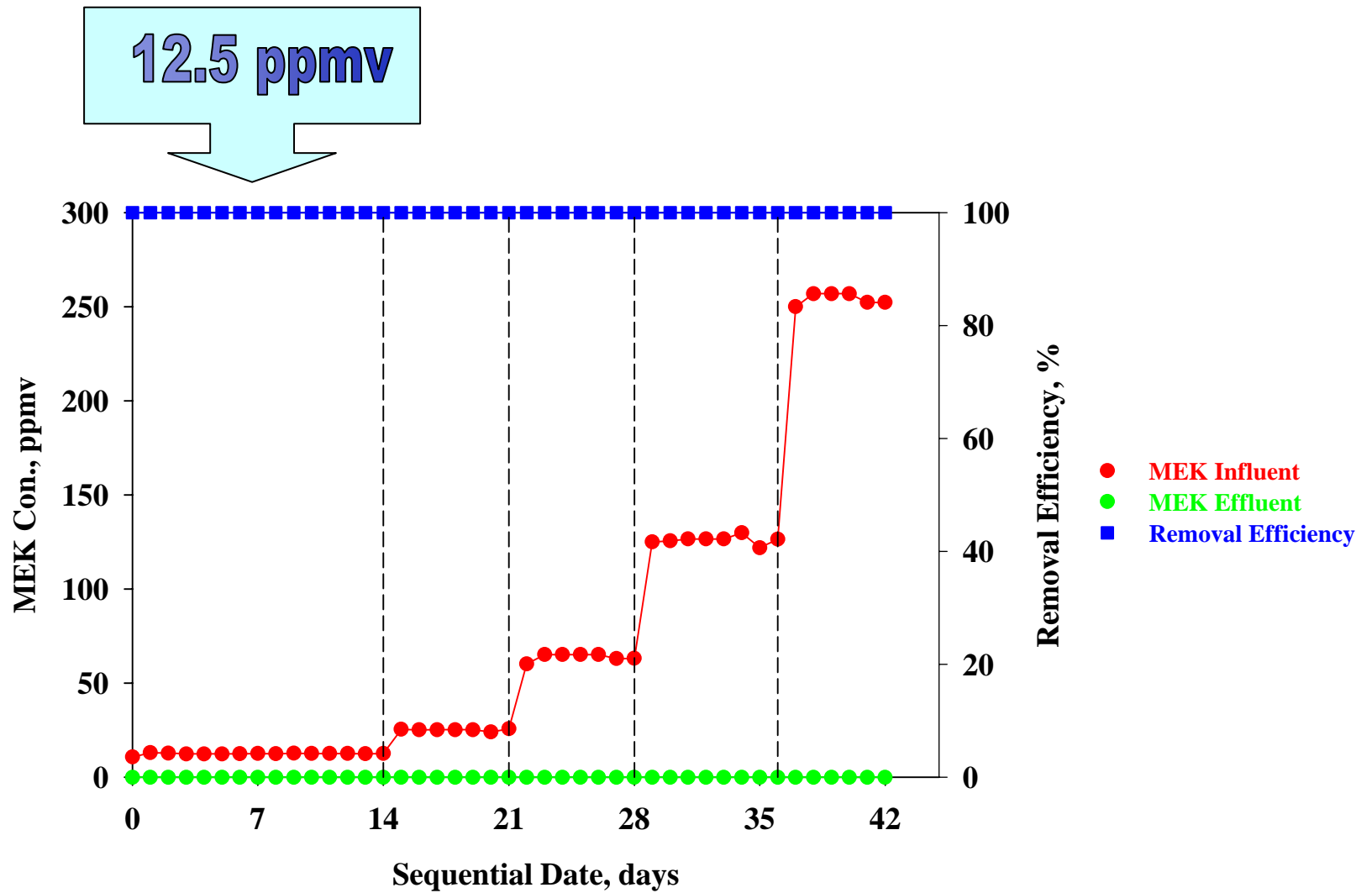
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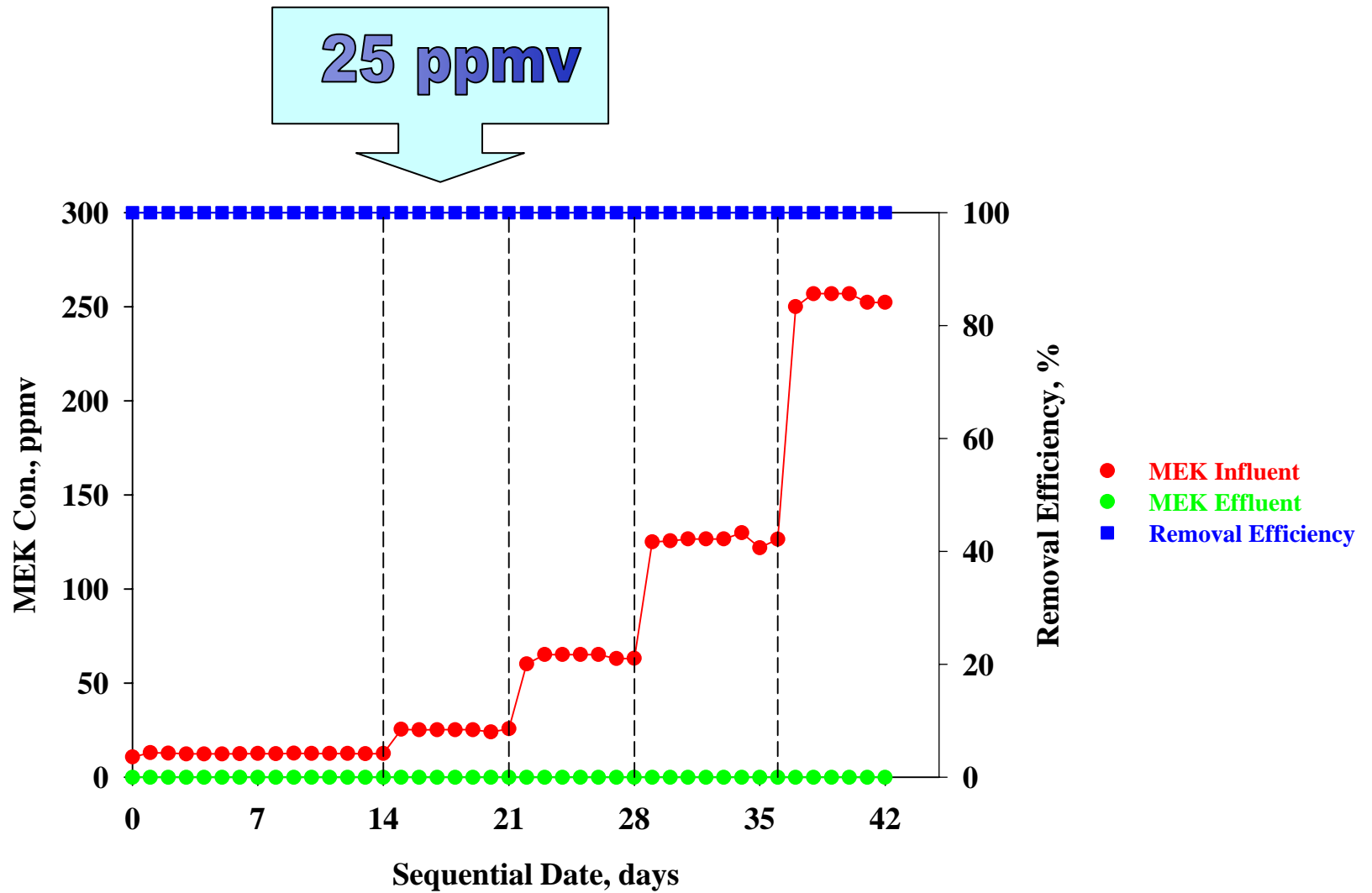
Results : Styrene in Mixture 1



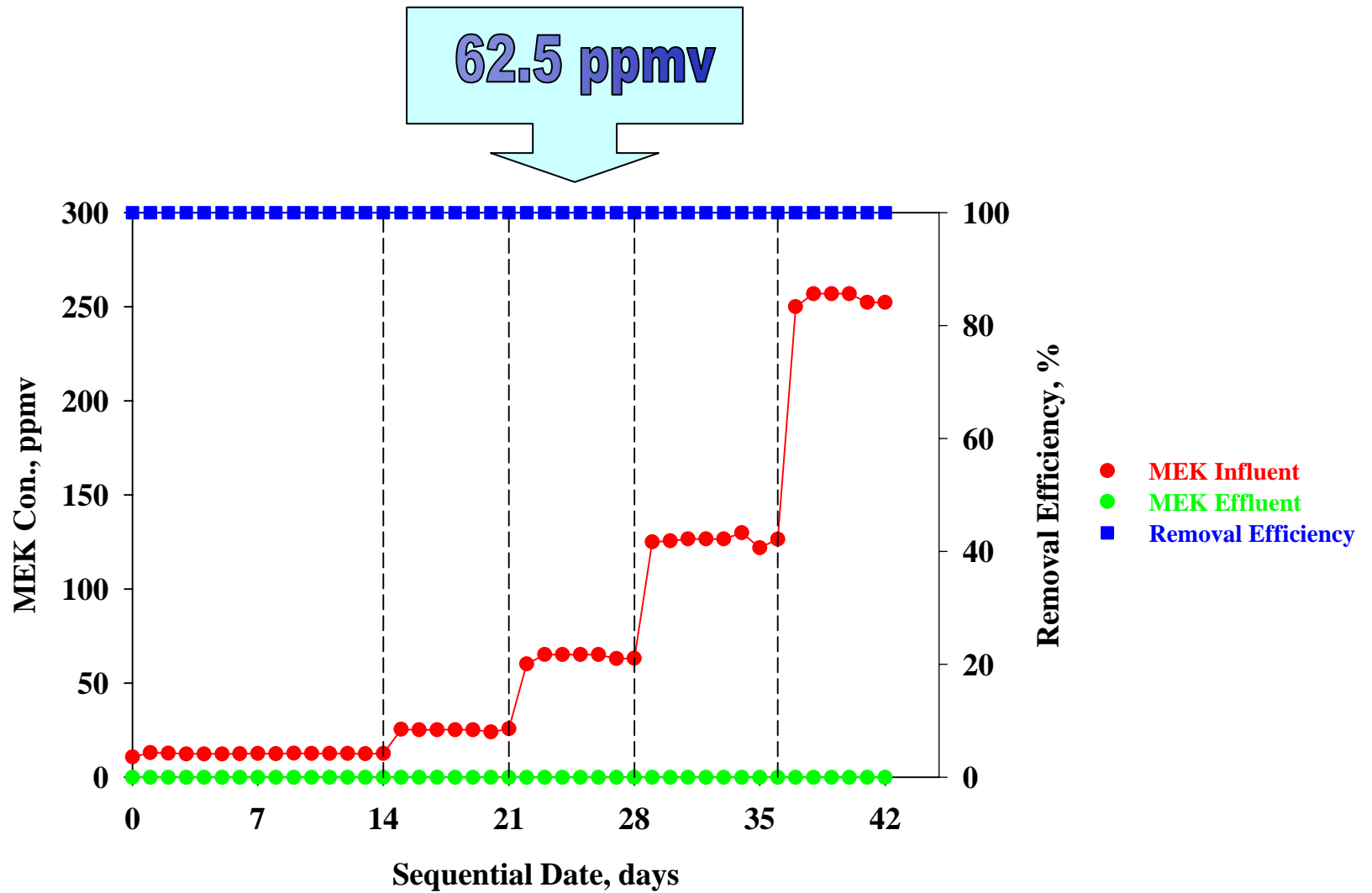
Results : MEK in Mixture 1



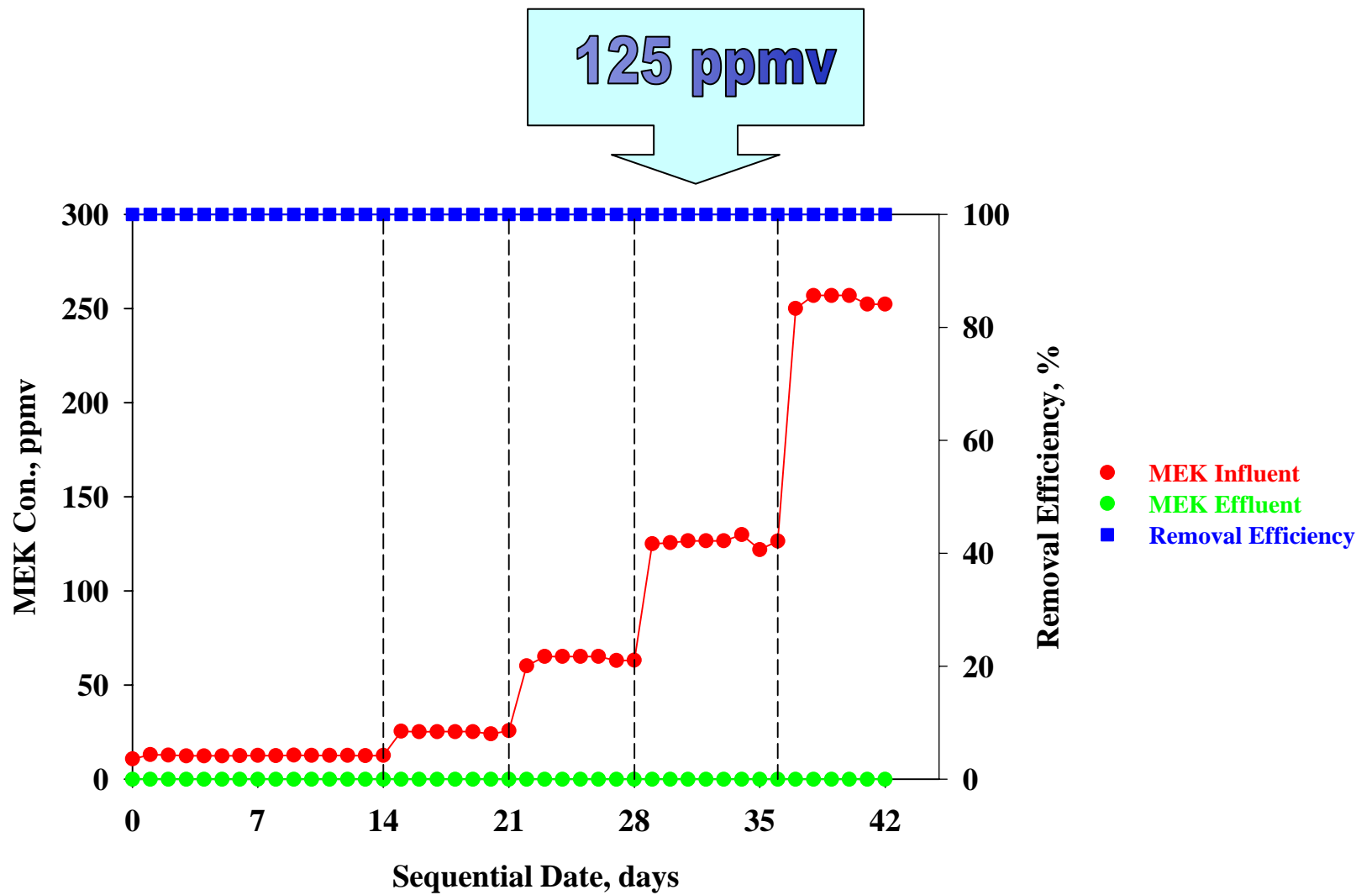
Results : MEK in Mixture 1



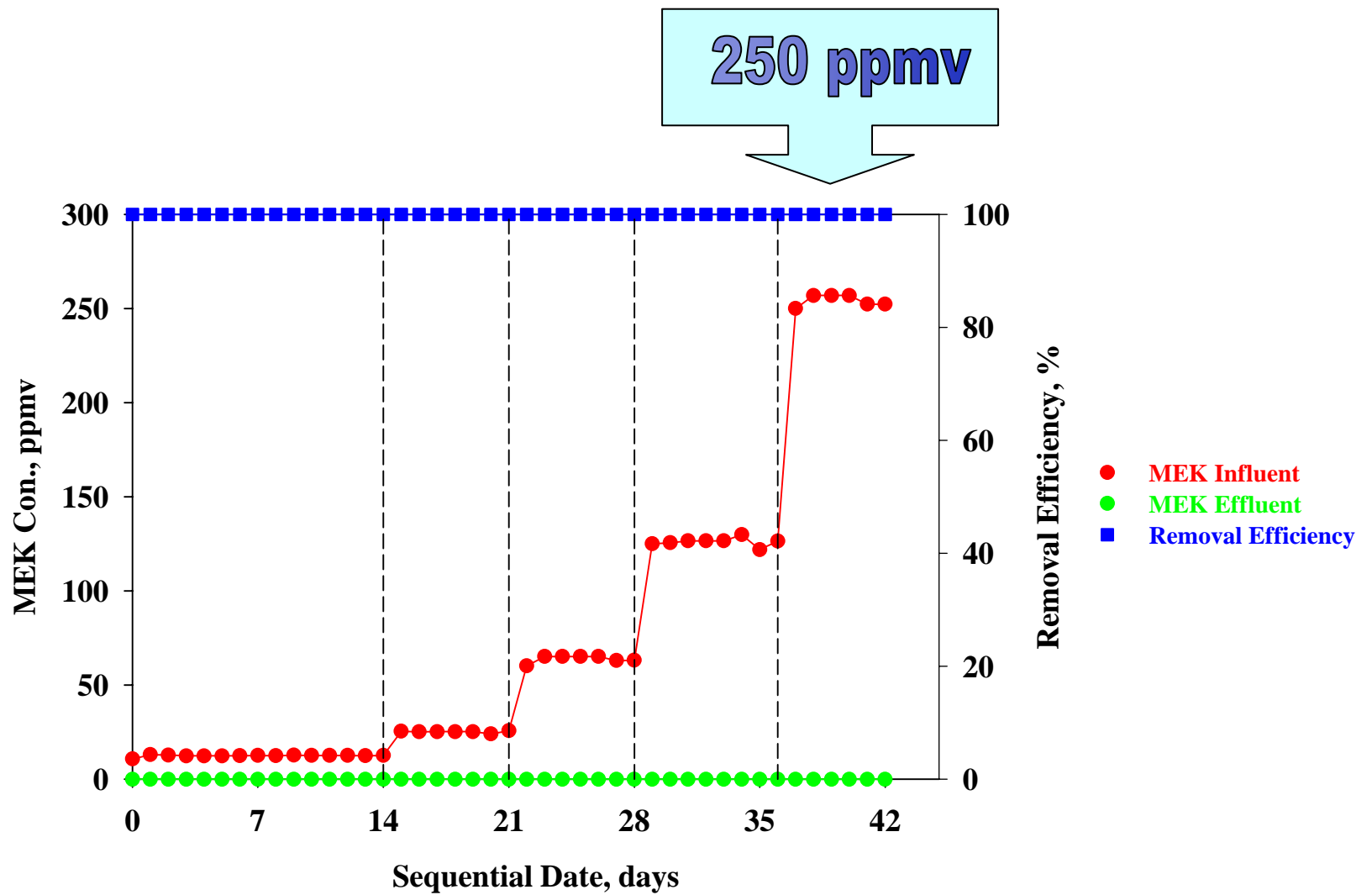
Results : MEK in Mixture 1



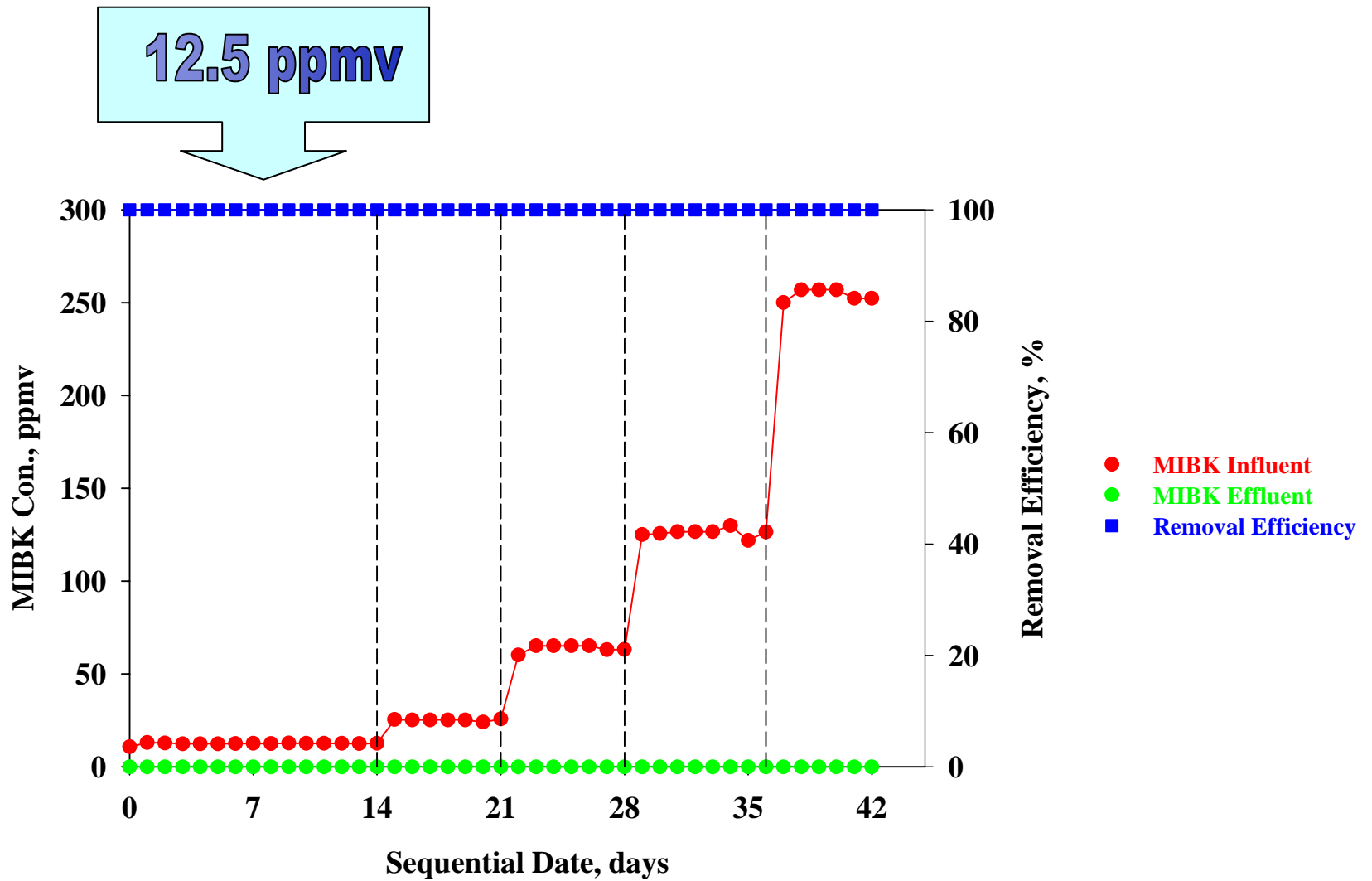
Results : MEK in Mixture 1



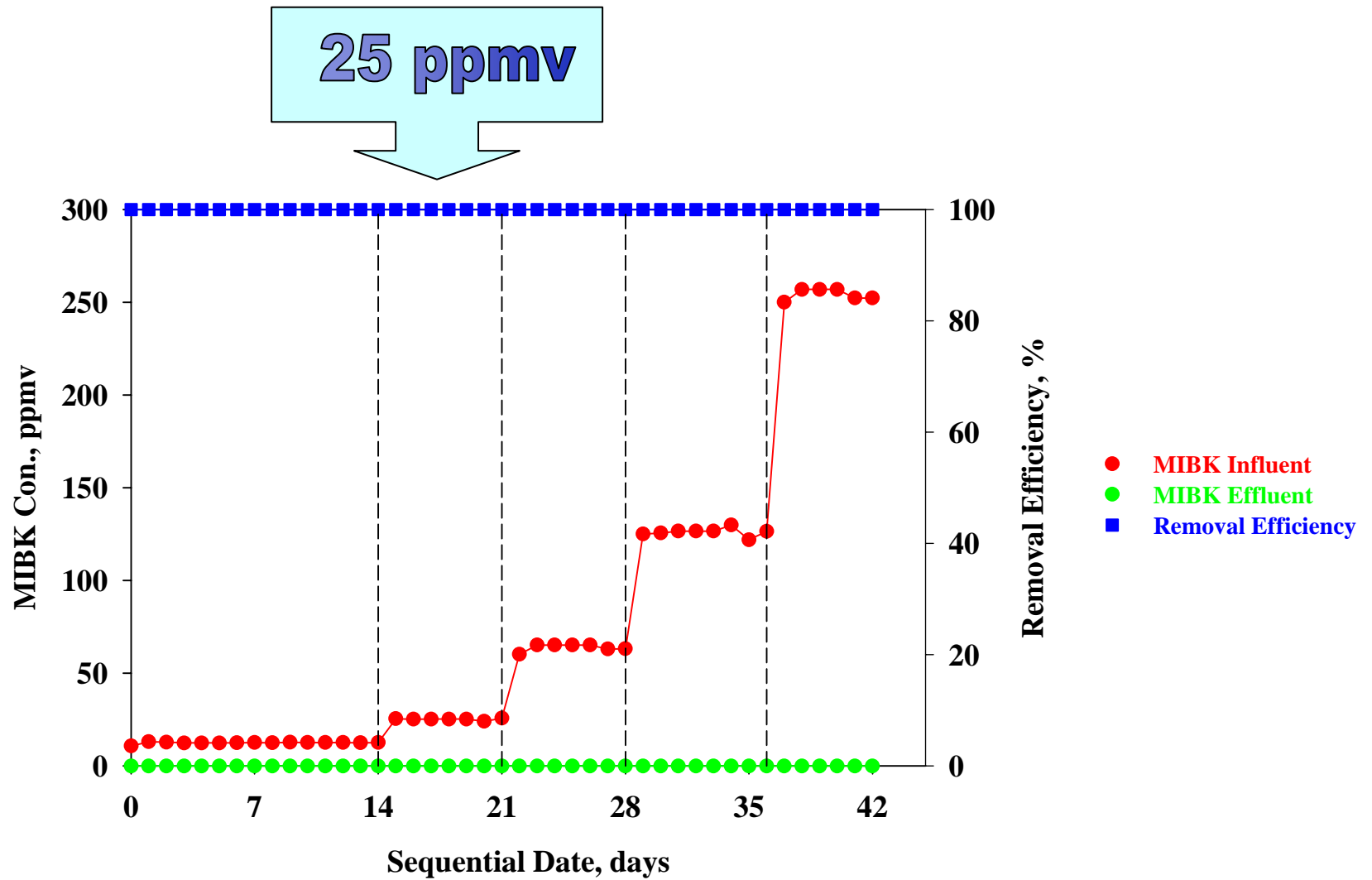
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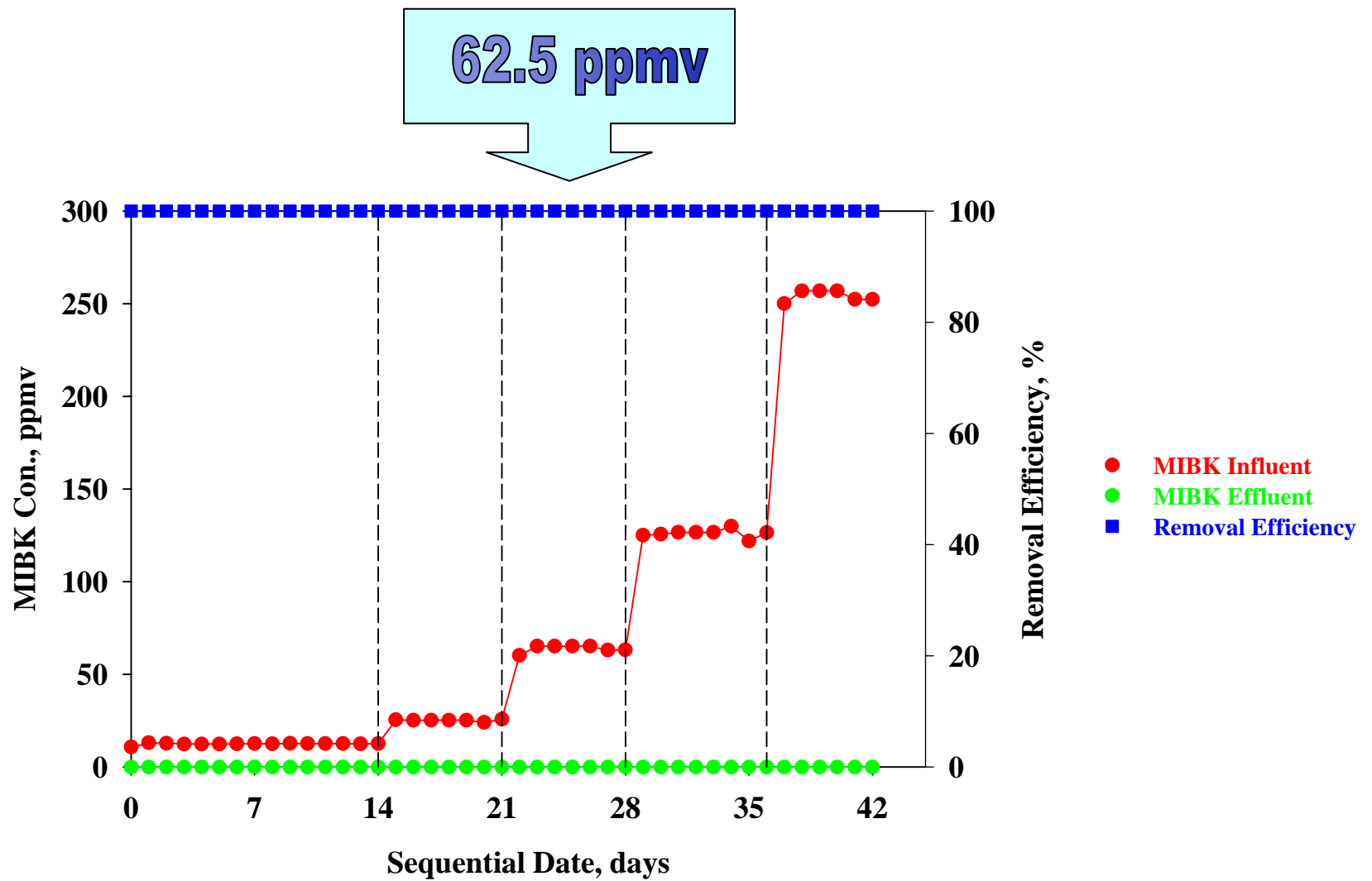
Results : MIBK in Mixture 1



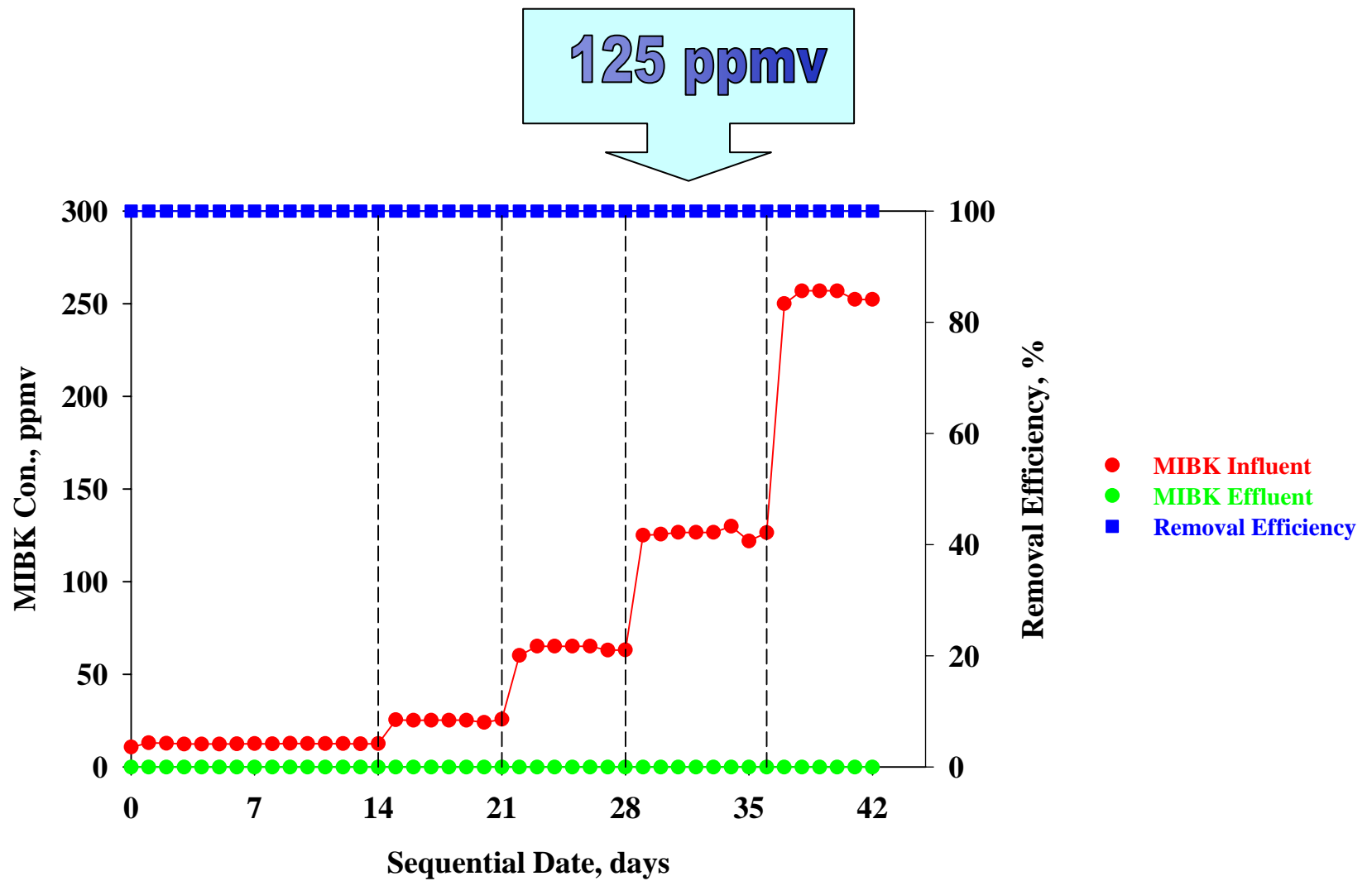
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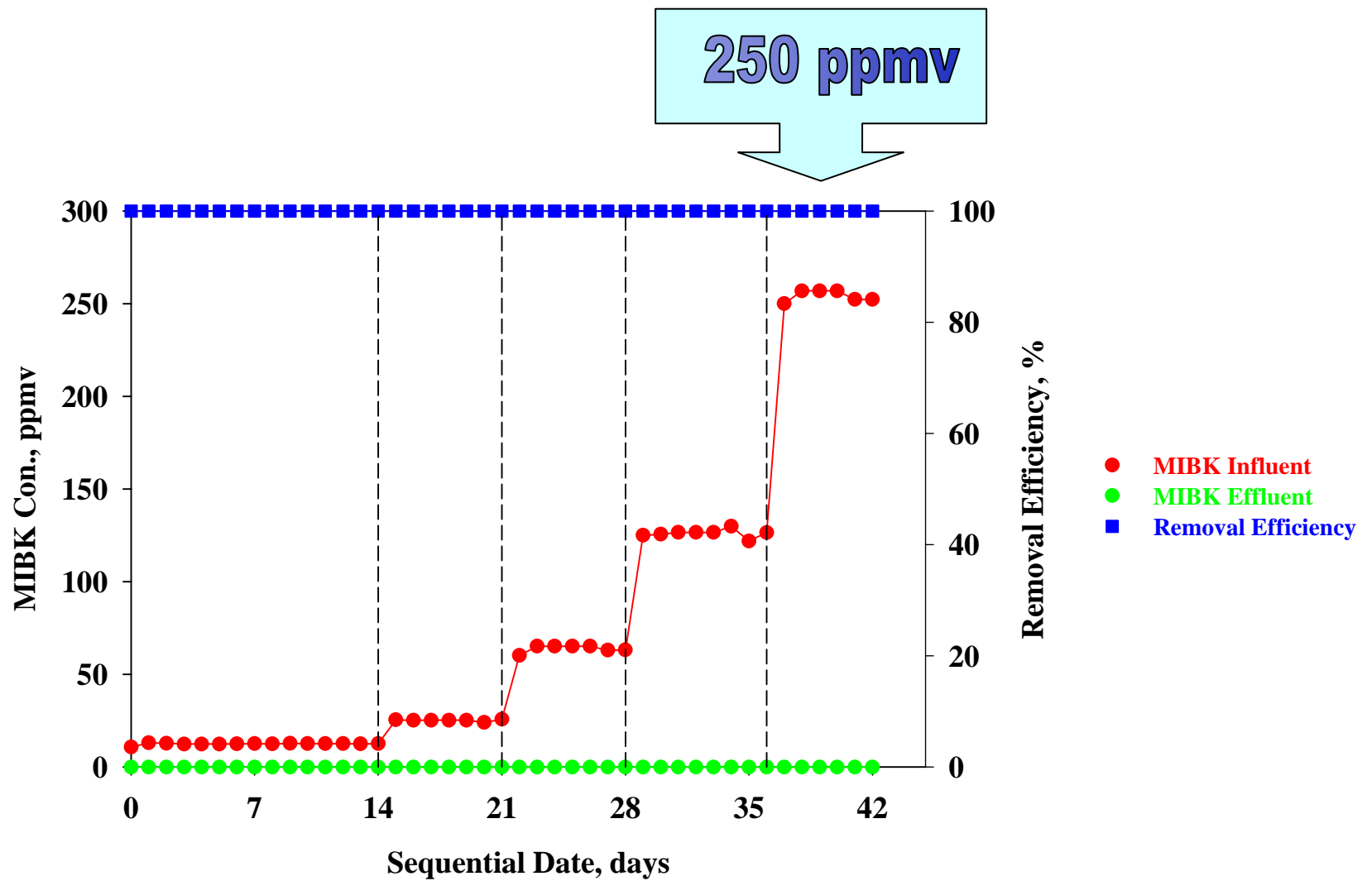
Results : MIBK in Mixture 1



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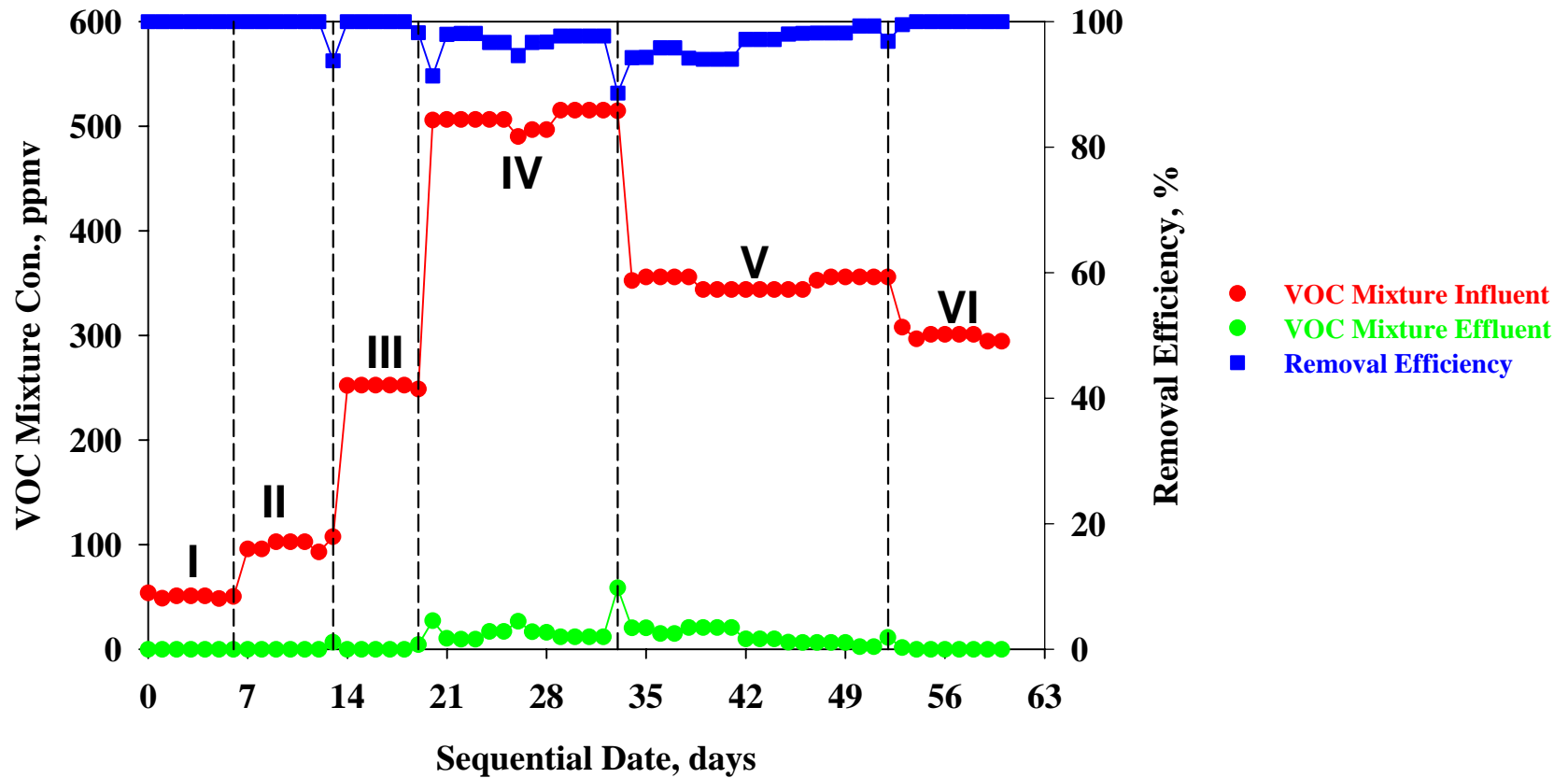


Results : MIBK in Mixture 1



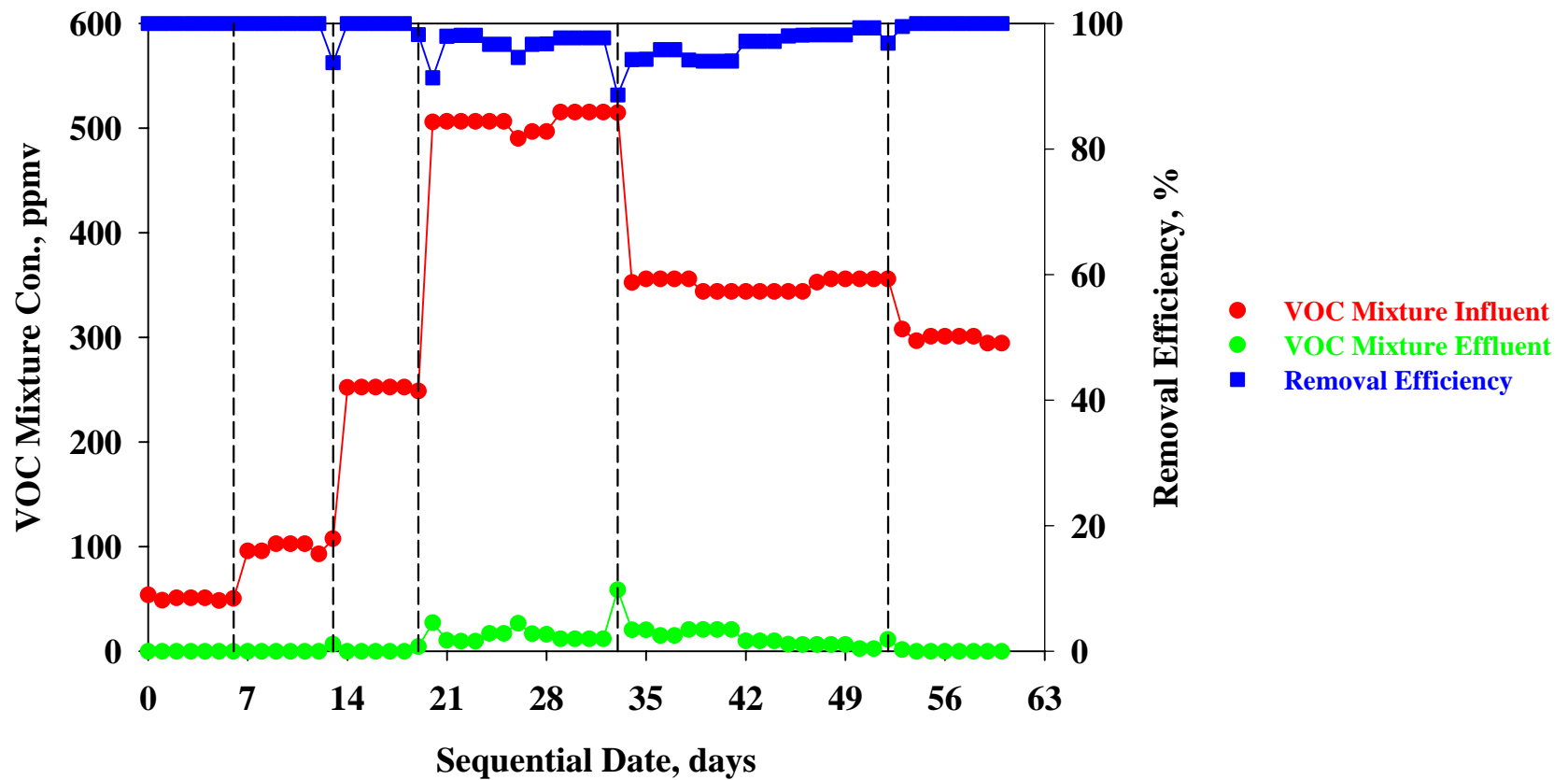
Results : Mixture 2

➤ TBAB performance with respect to VOC removal

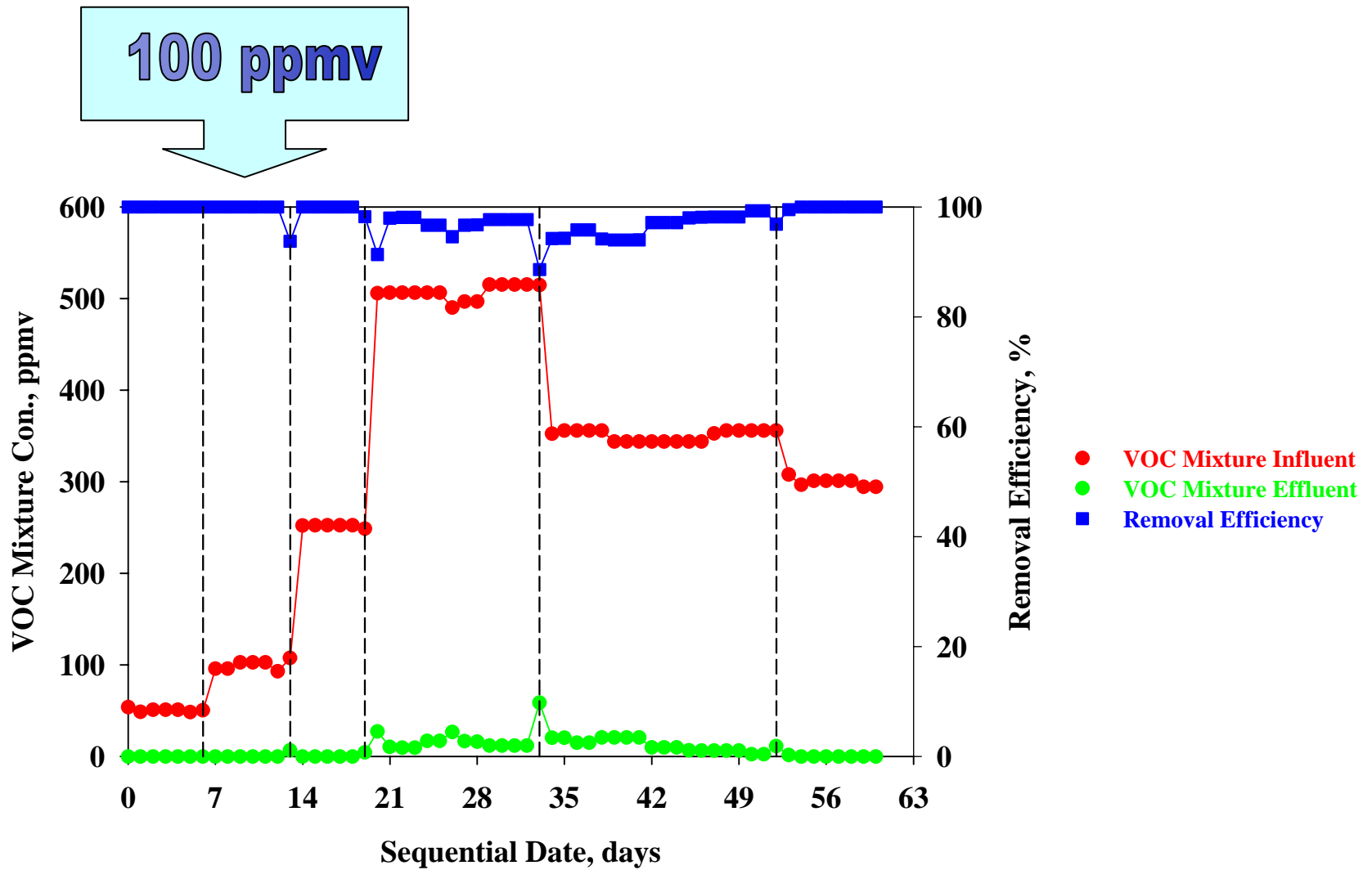


Results : Mixture 2

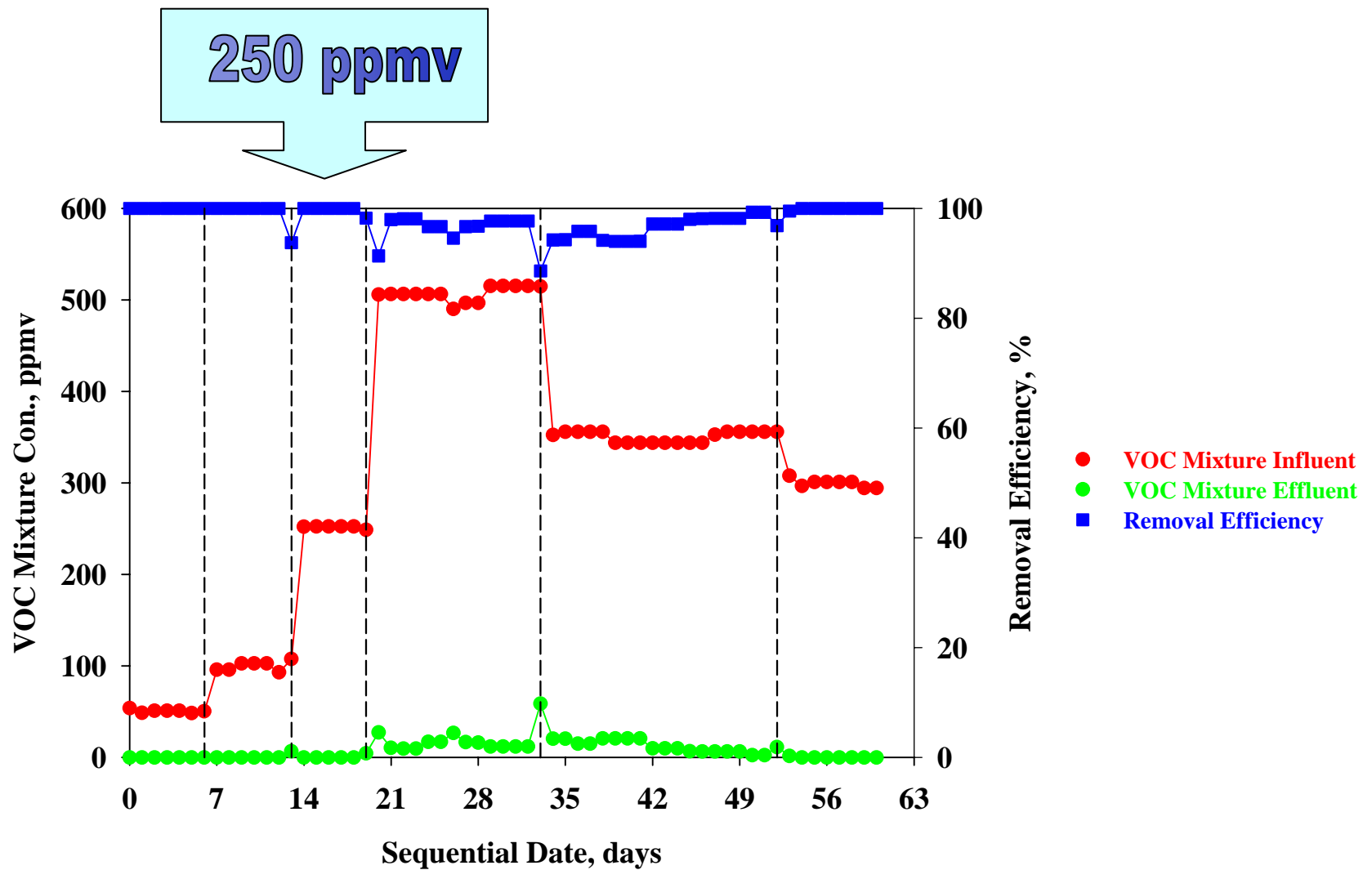
50 ppmv



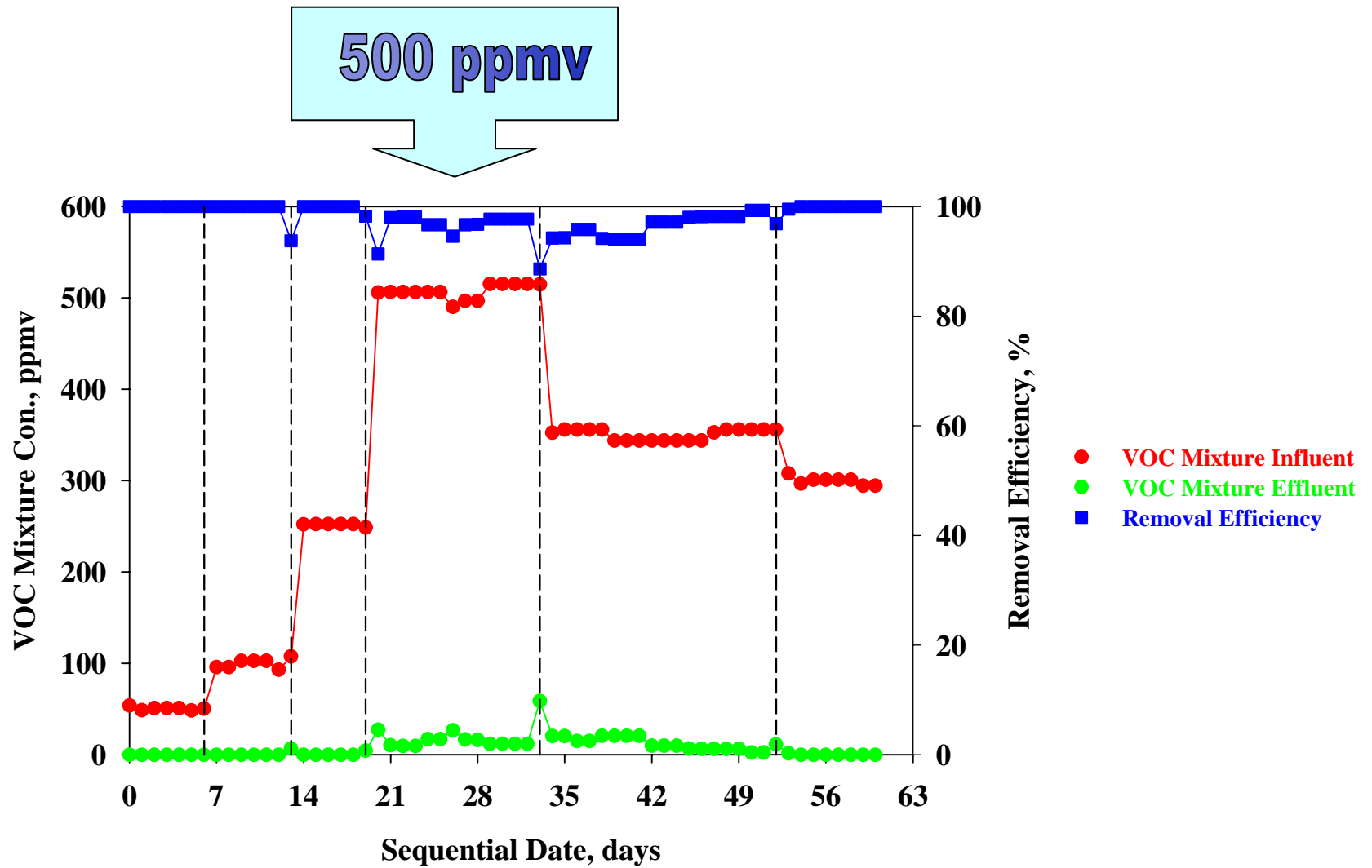
Results : Mixture 2



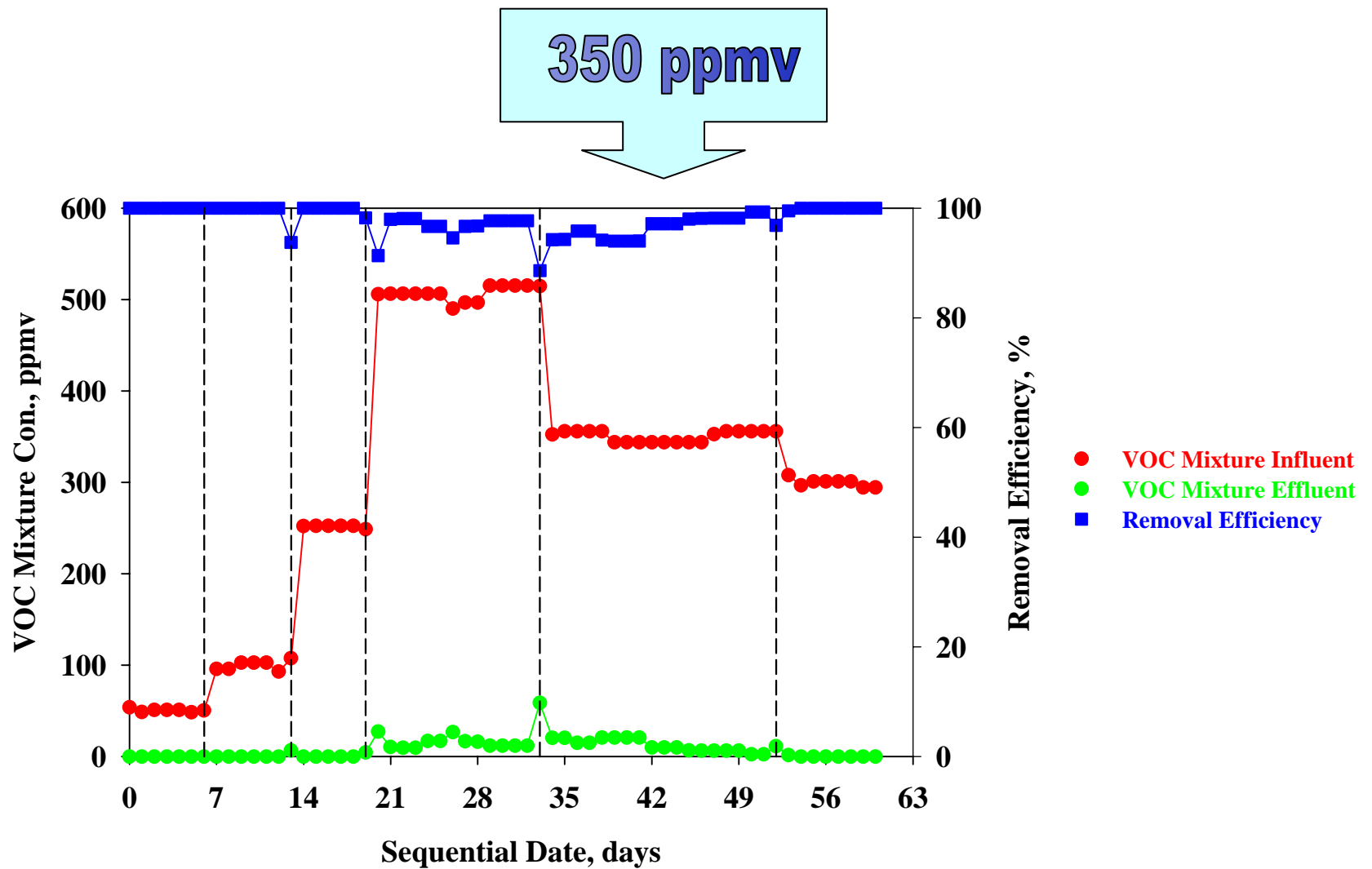
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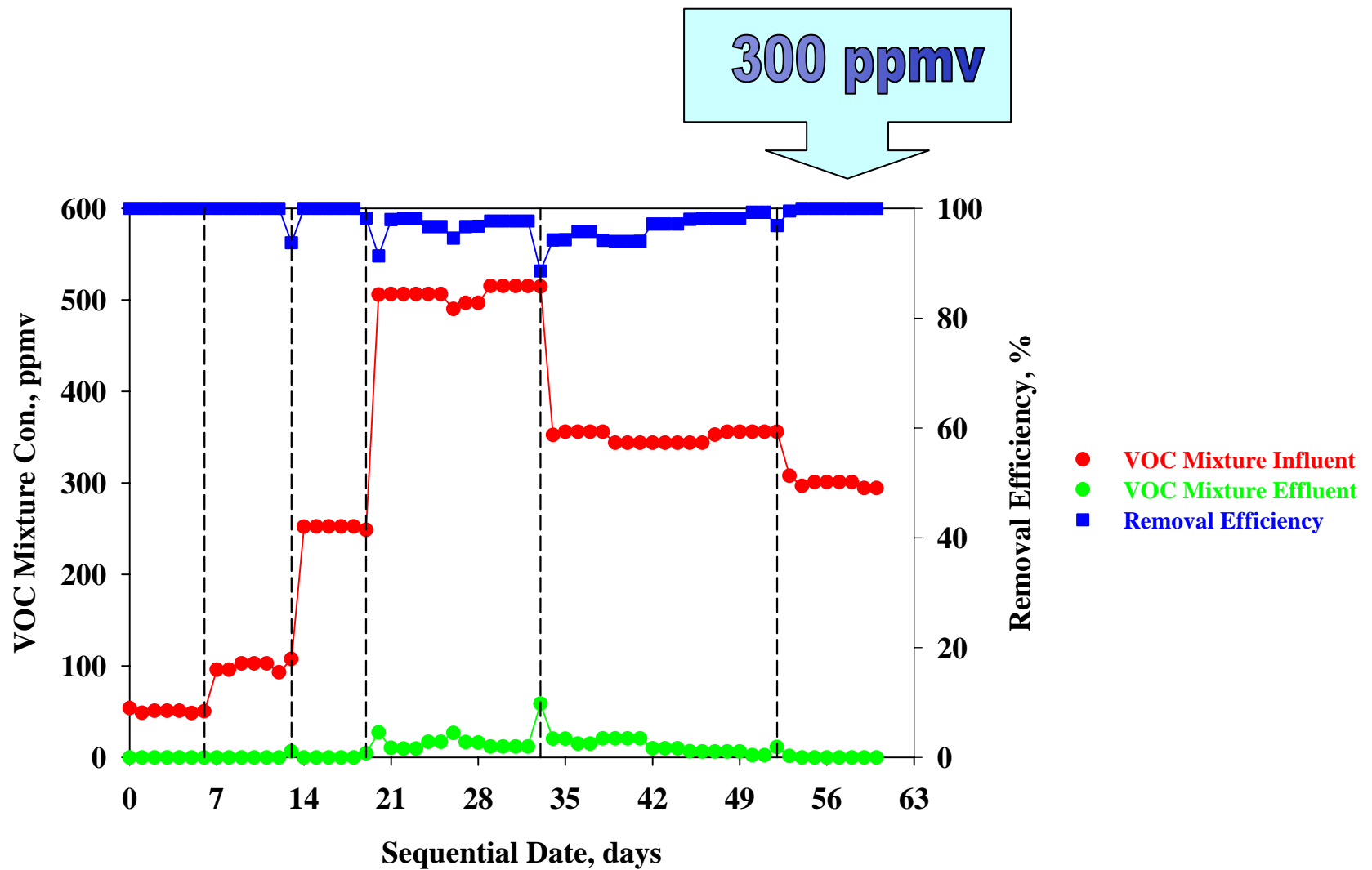
Results : Mixture 2



Results : Mixture 2

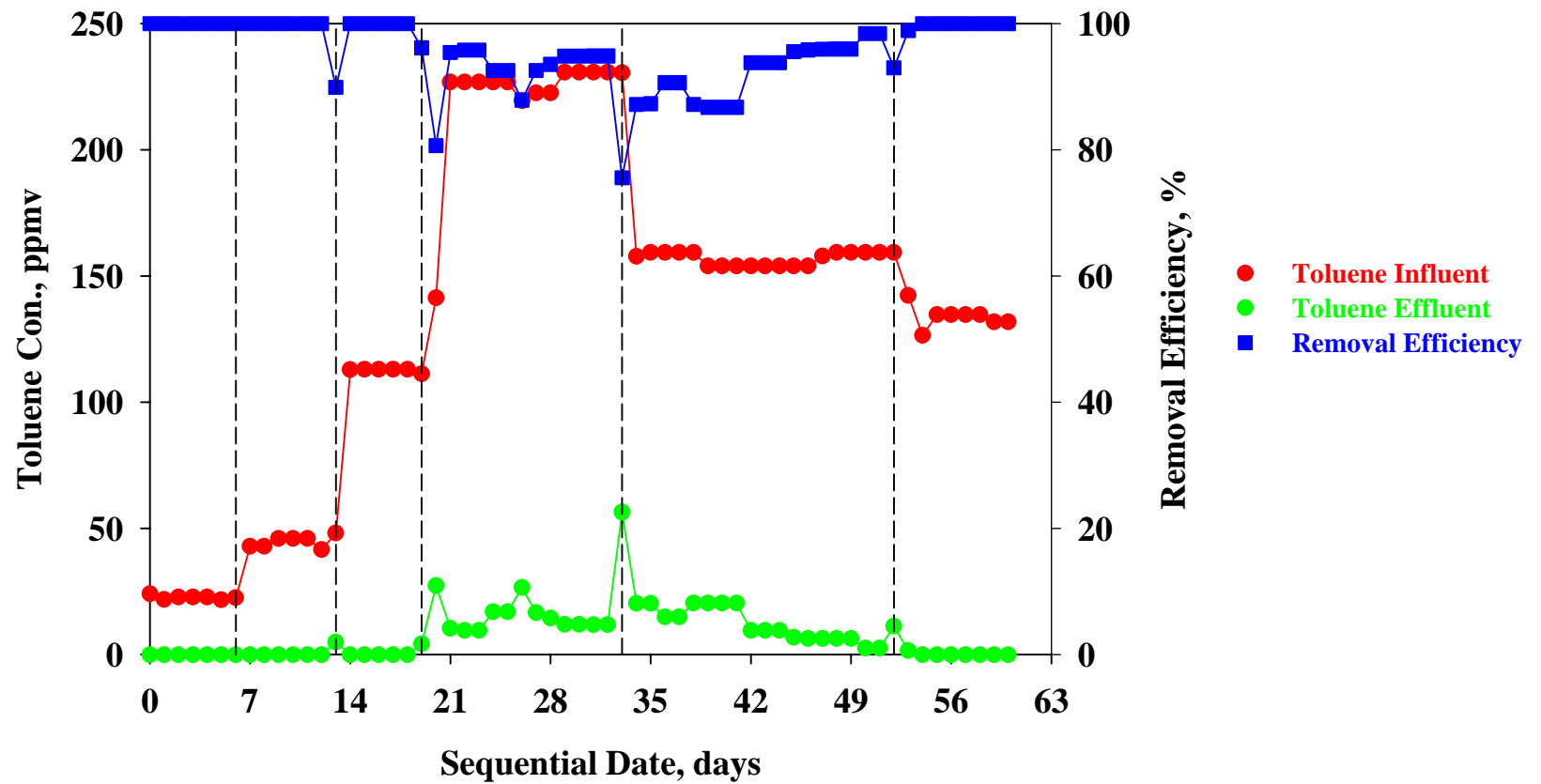


Results : Mixture 2

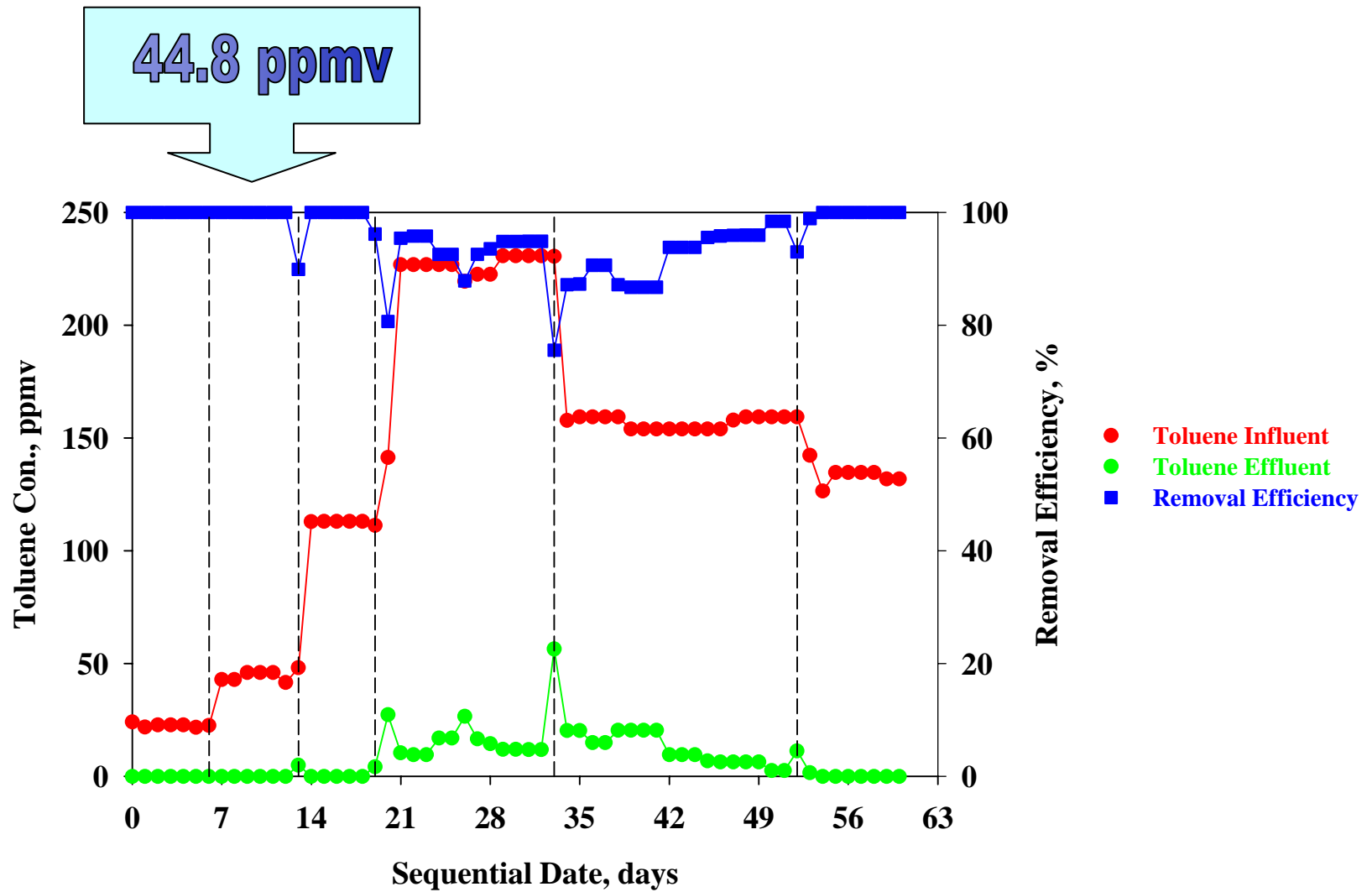


Results : Toluene in Mixture 2

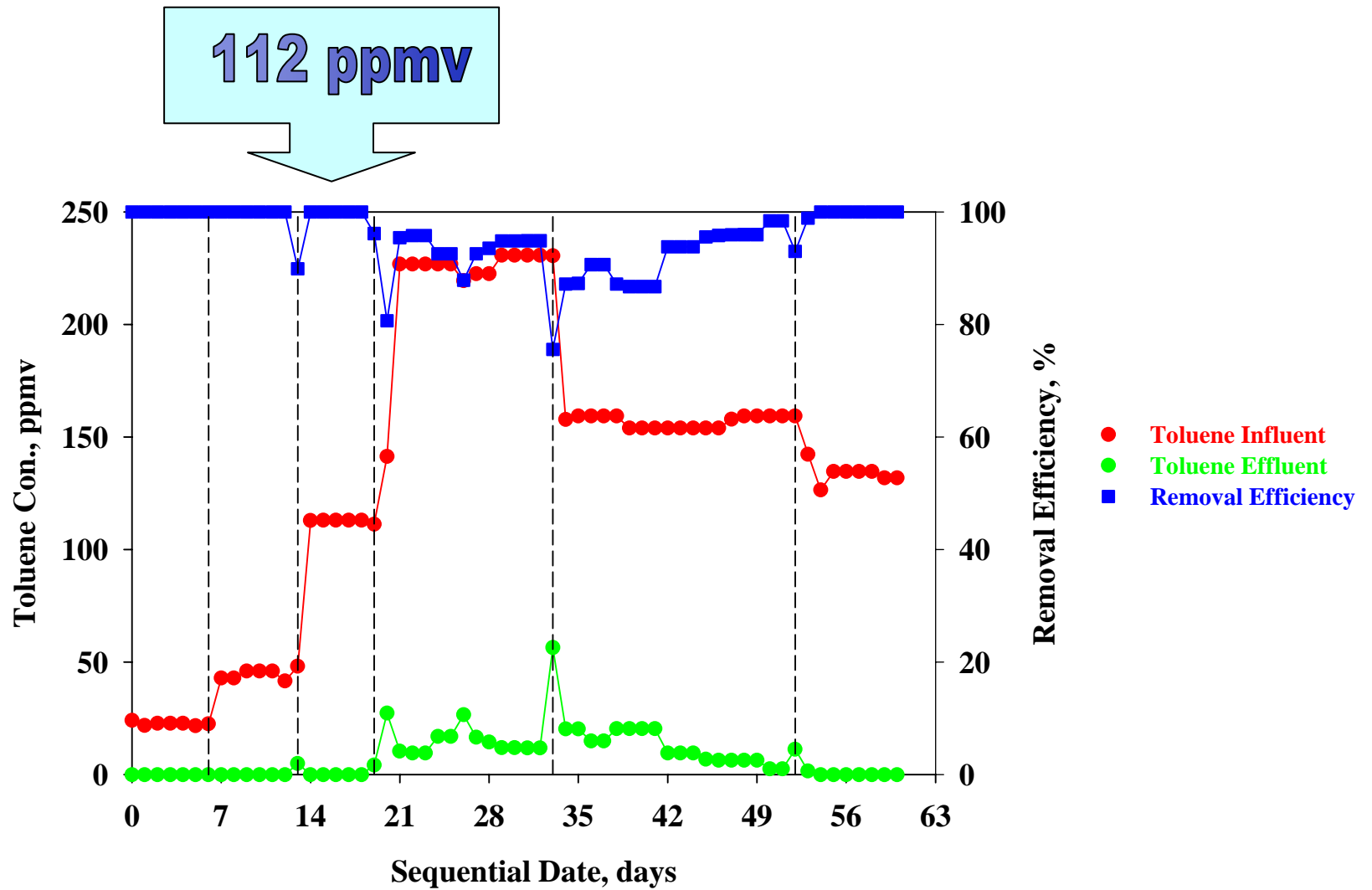
22.4 ppmv



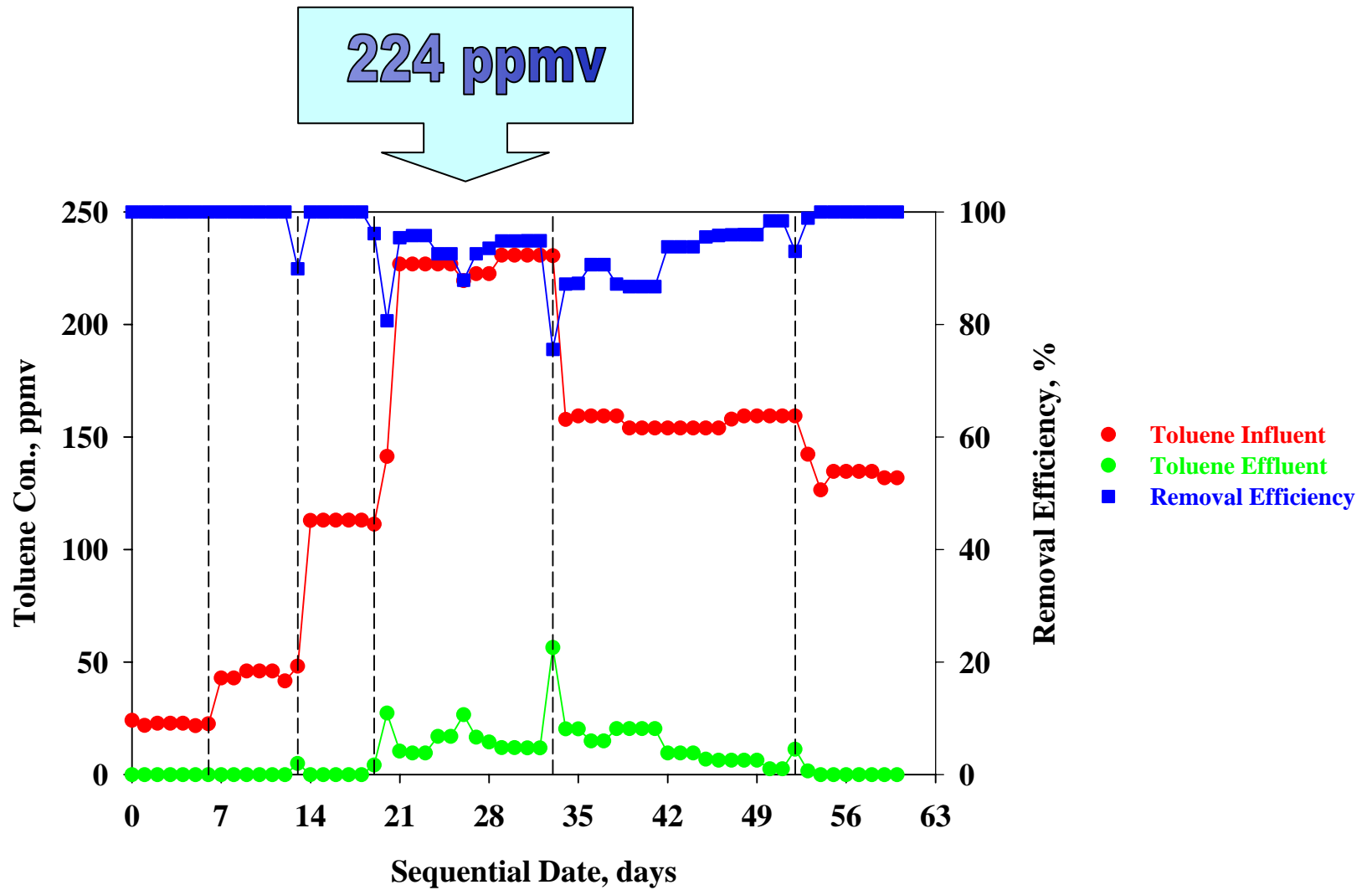
Results : Toluene in Mixture 2



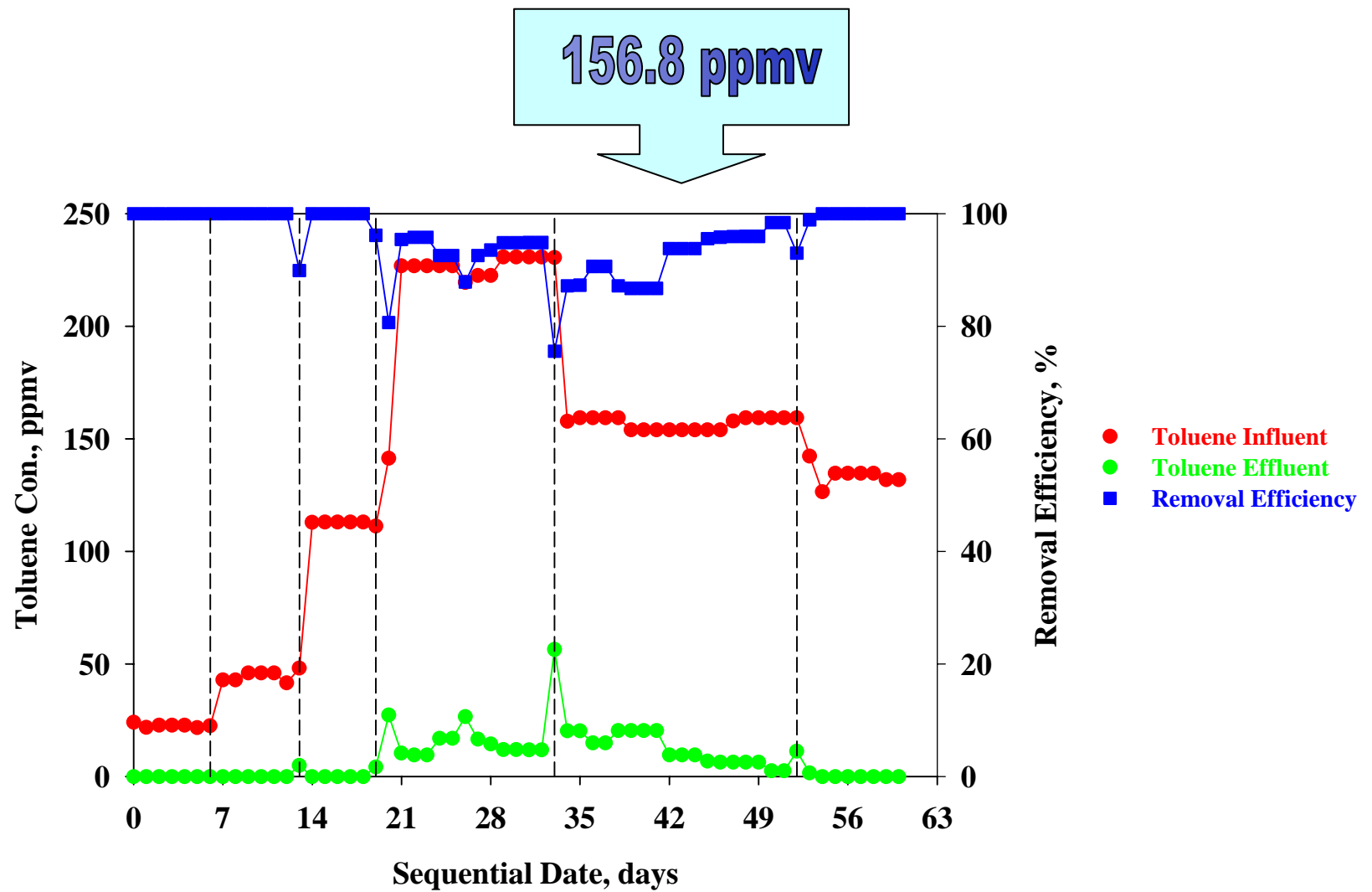
Results : Toluene in Mixture 2



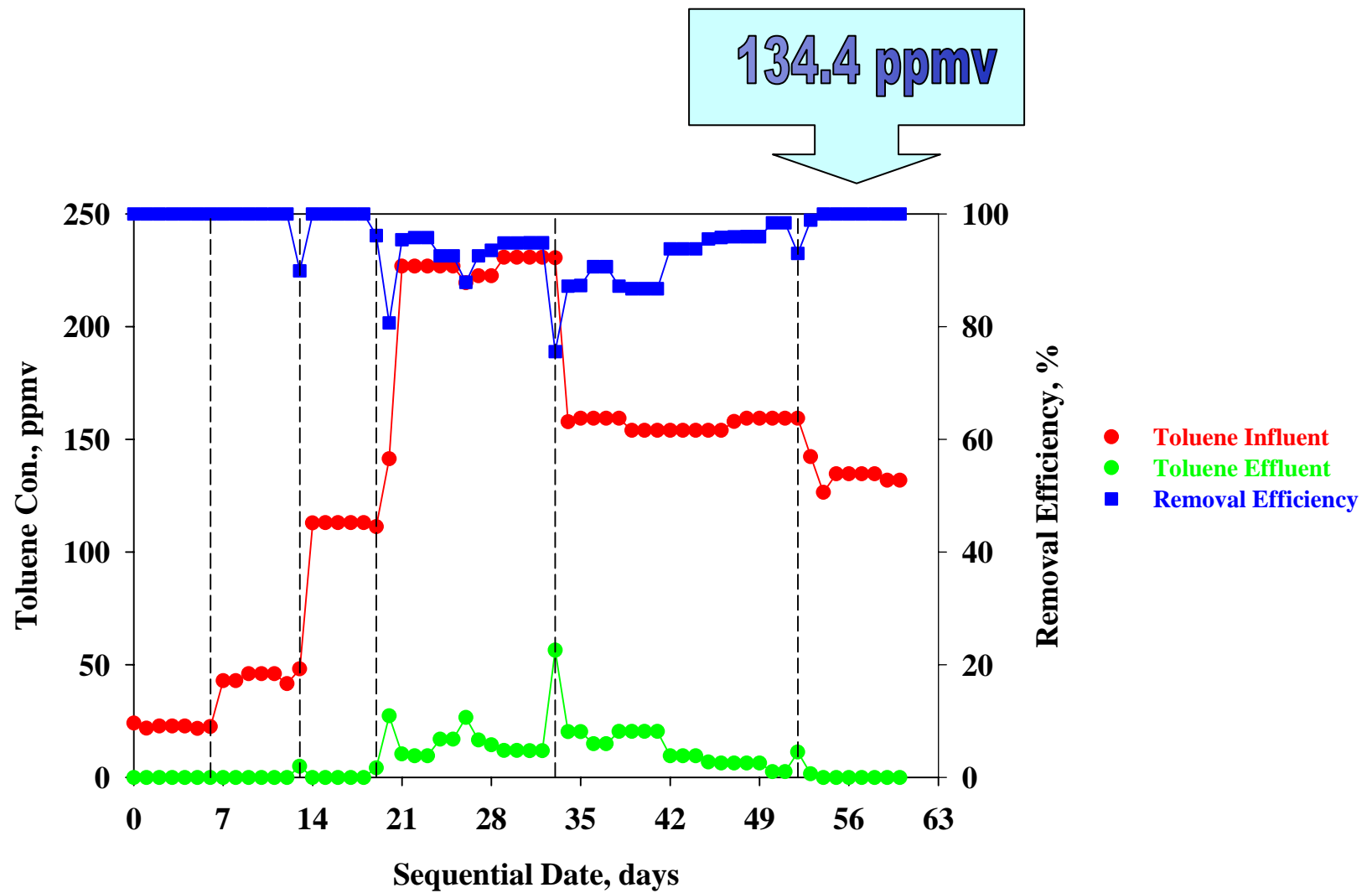
Results : Toluene in Mixture 2



Results : Toluene in Mixture 2

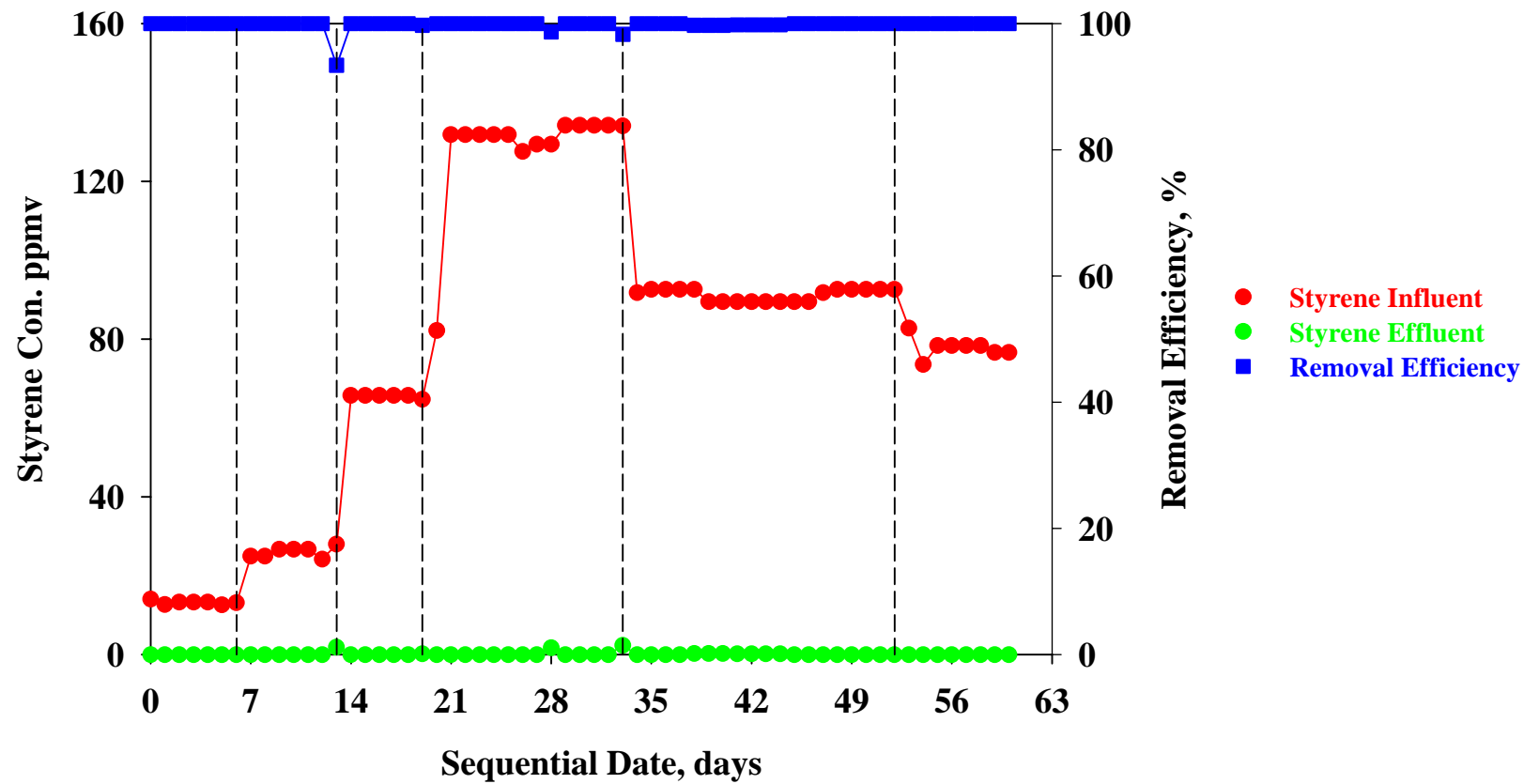


Results : Toluene in Mixture 2

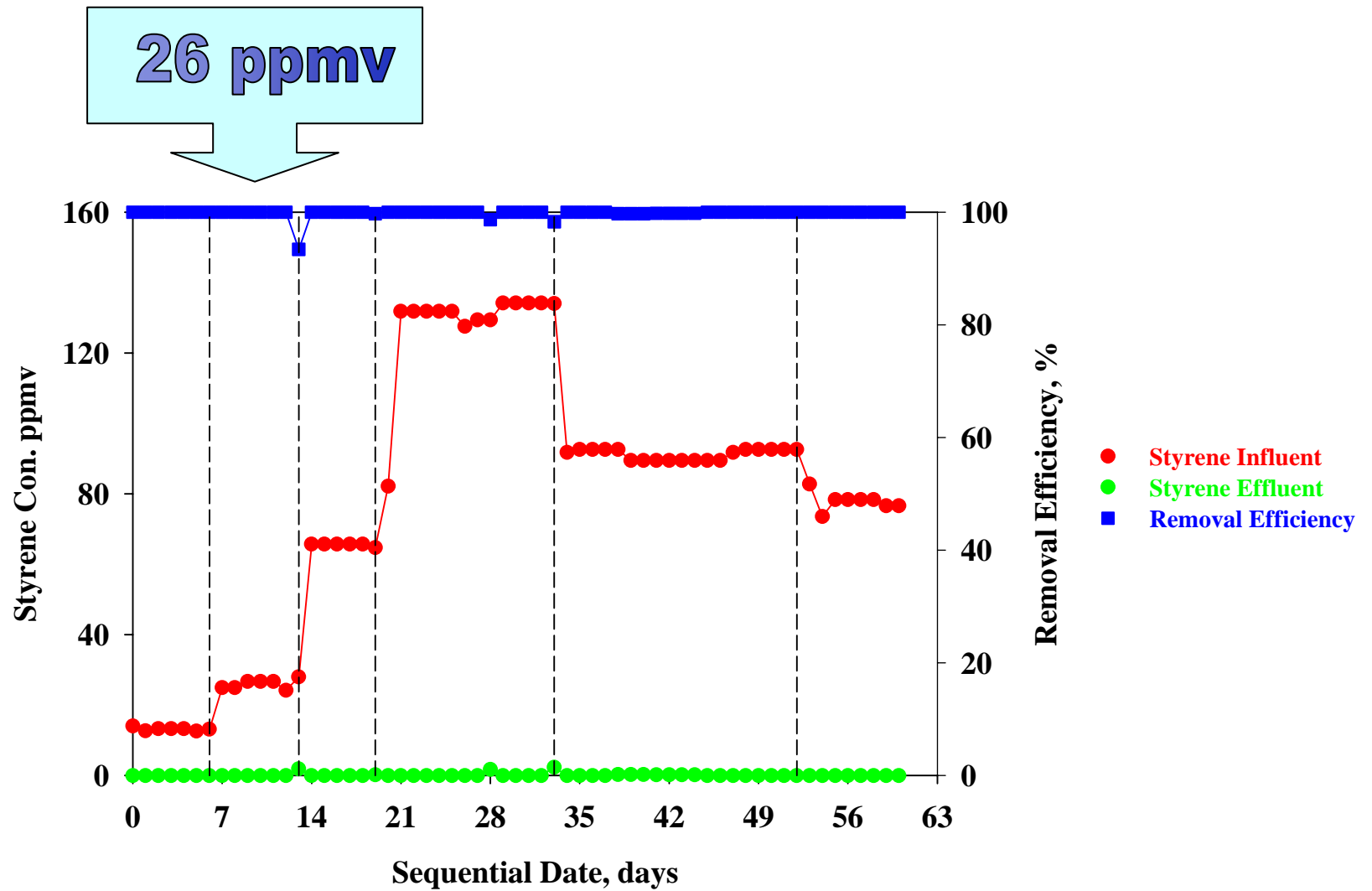


Results : Styrene in Mixture 2

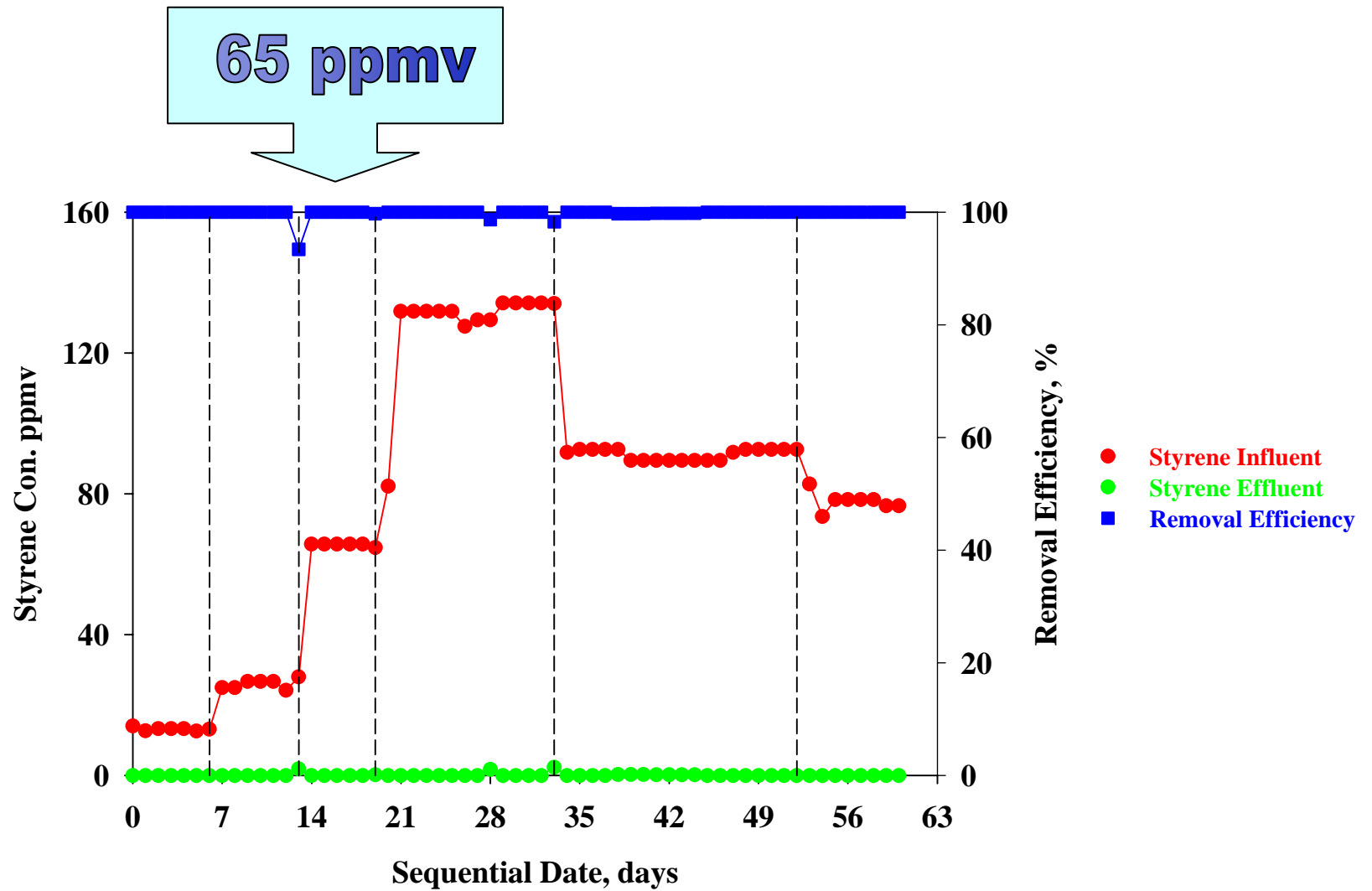
13 ppmv



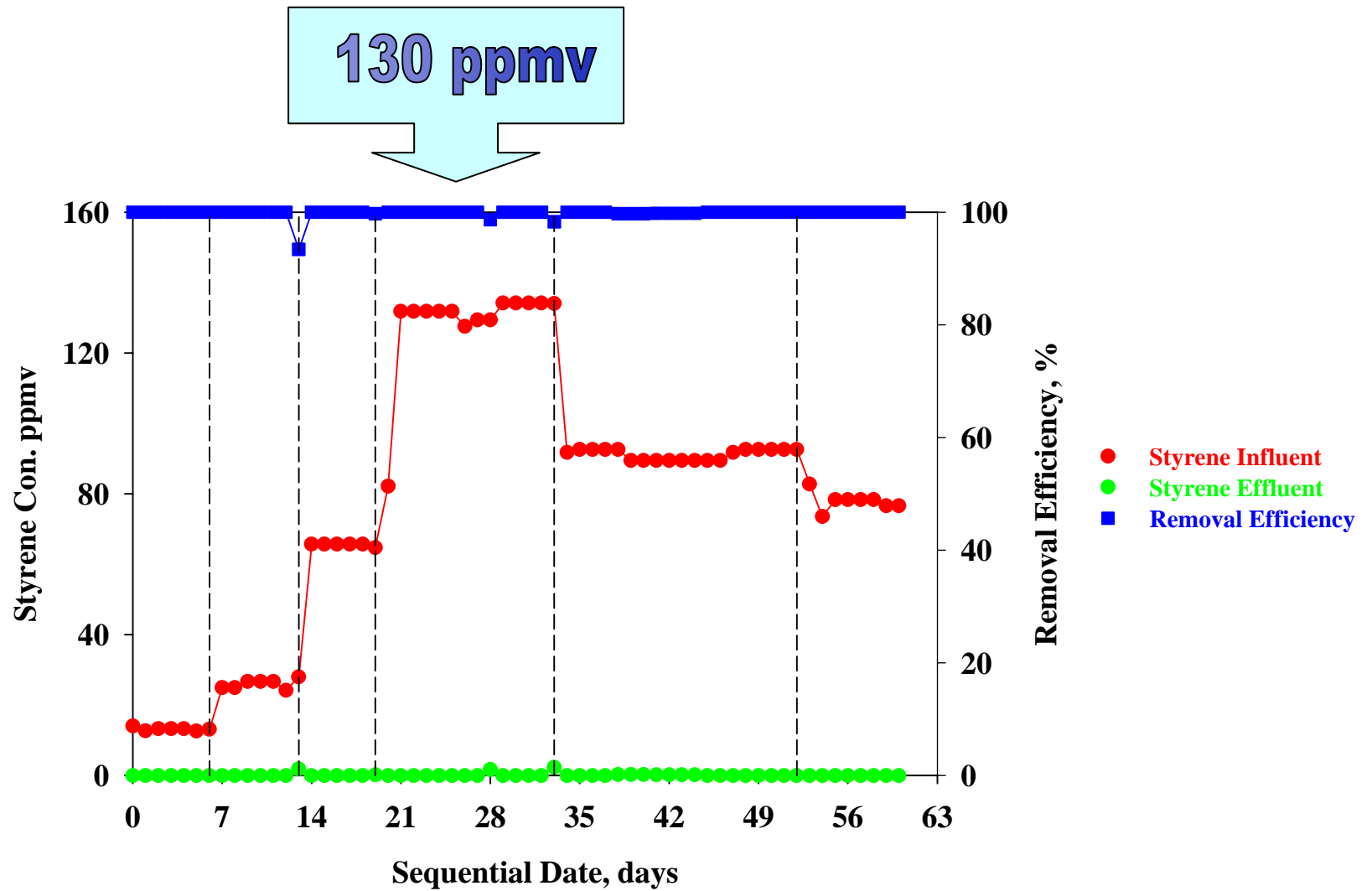
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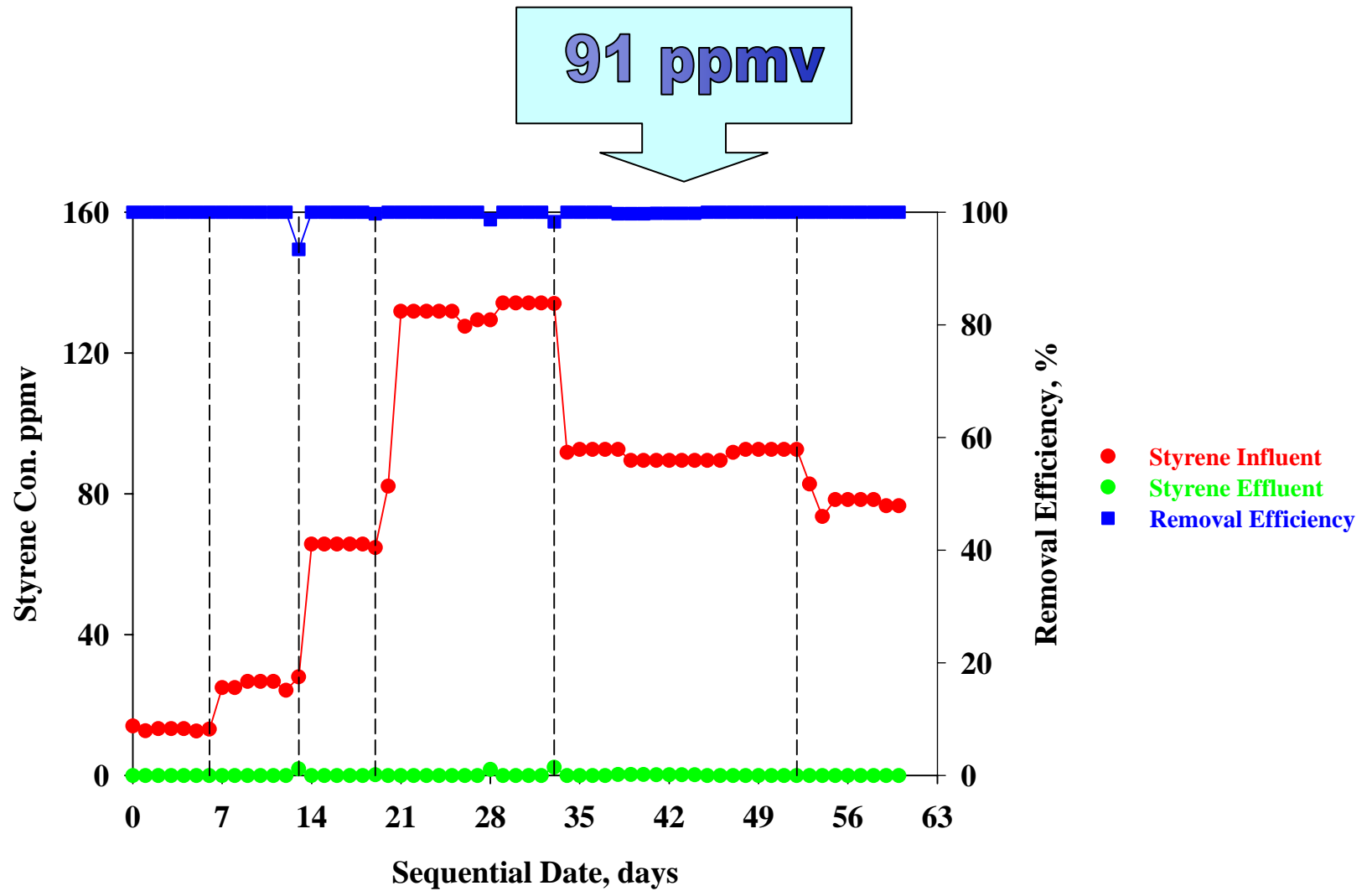
Results : Styrene in Mixture 2



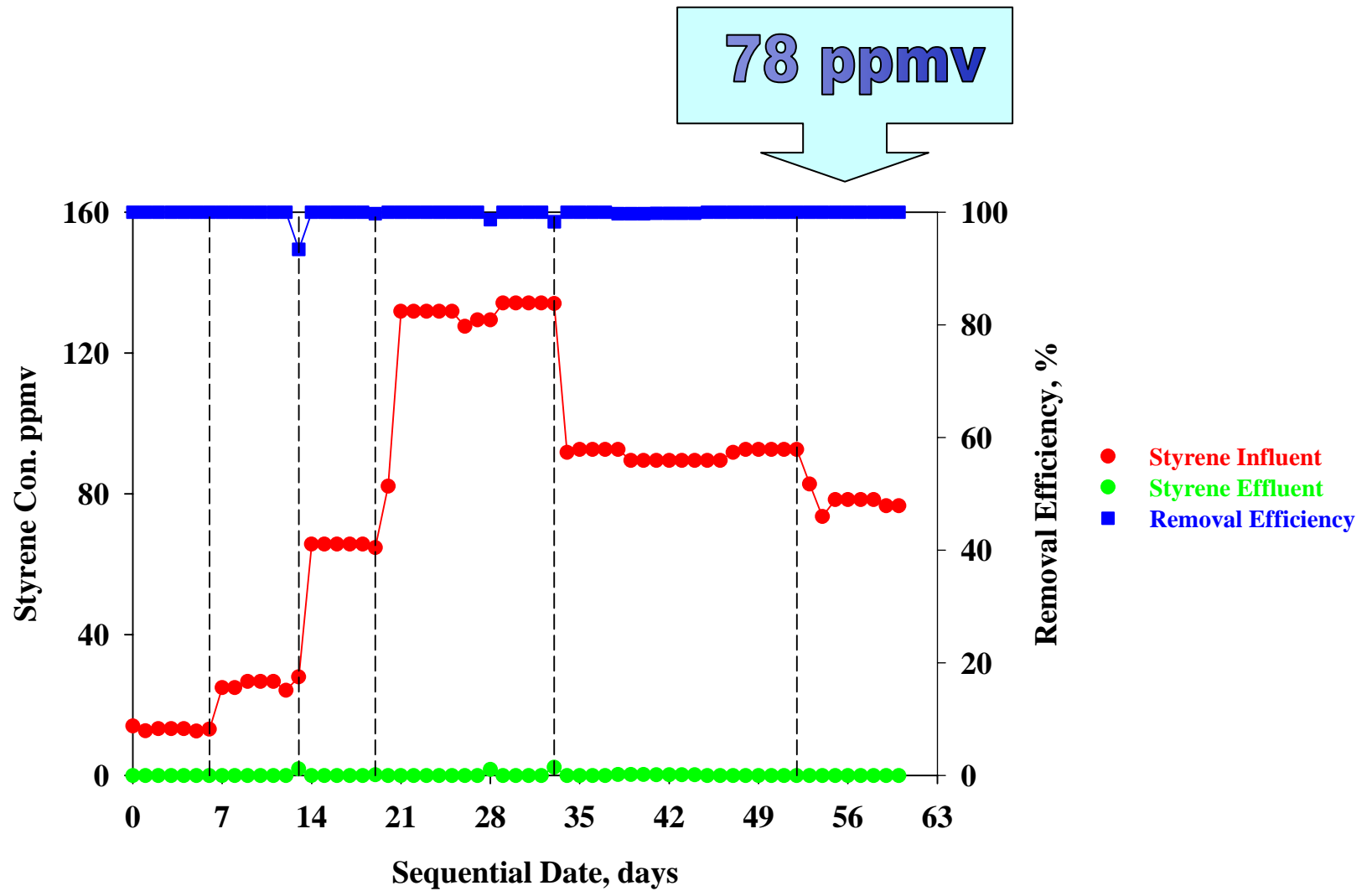
Results : Styrene in Mixture 2



Results : Styrene in Mixture 2

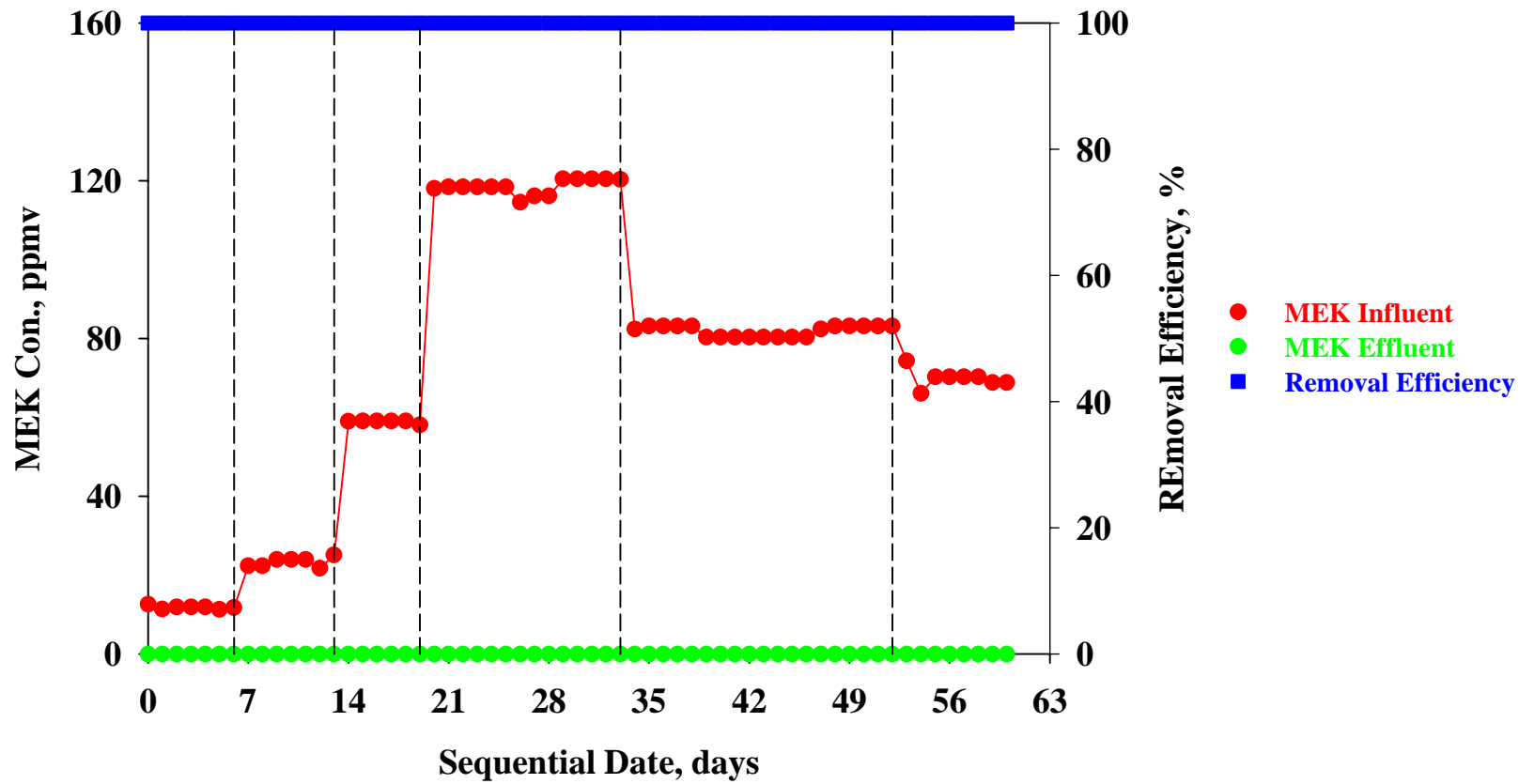


Results : Styrene in Mixture 2

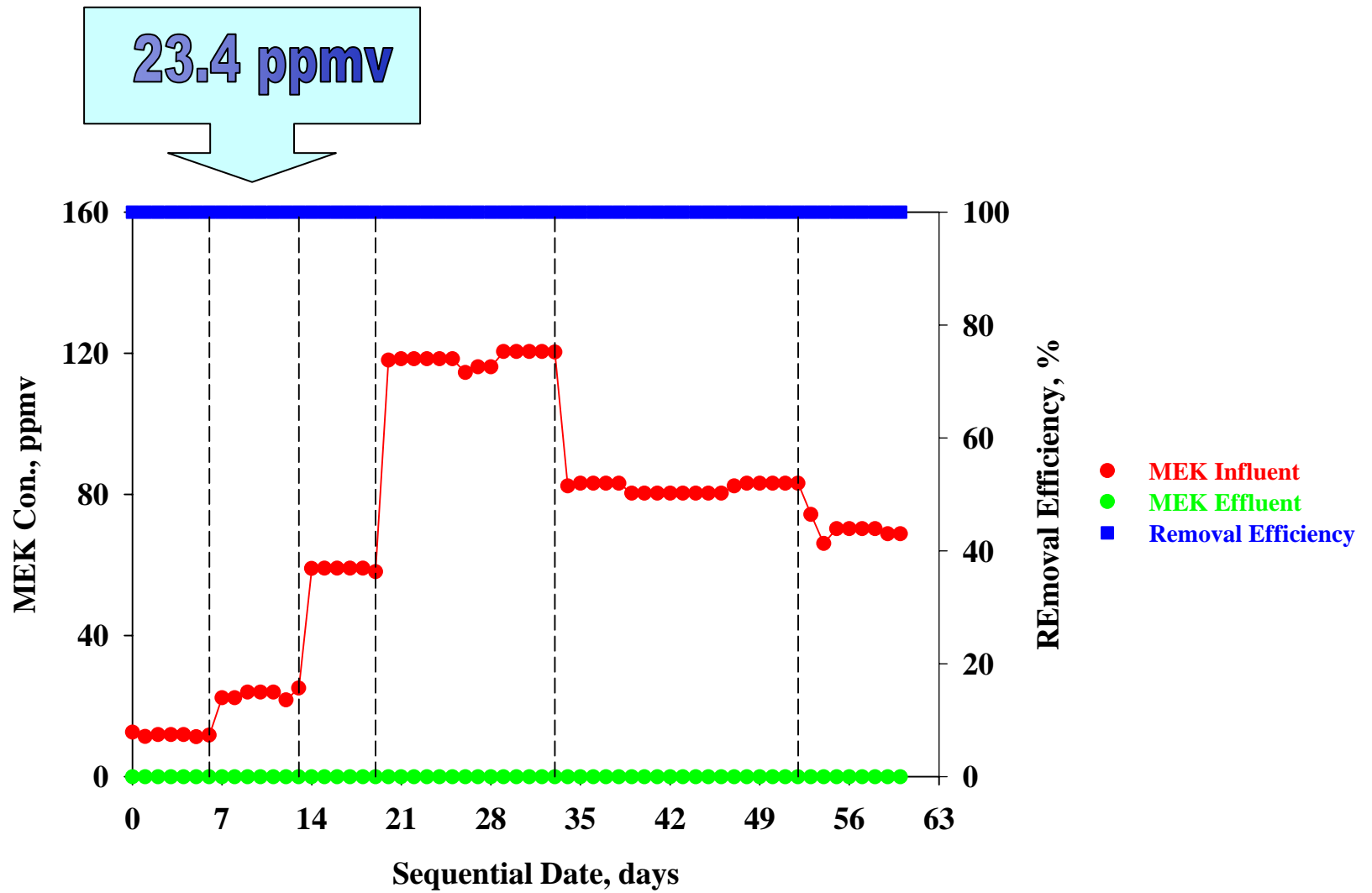


Results : MEK in Mixture 2

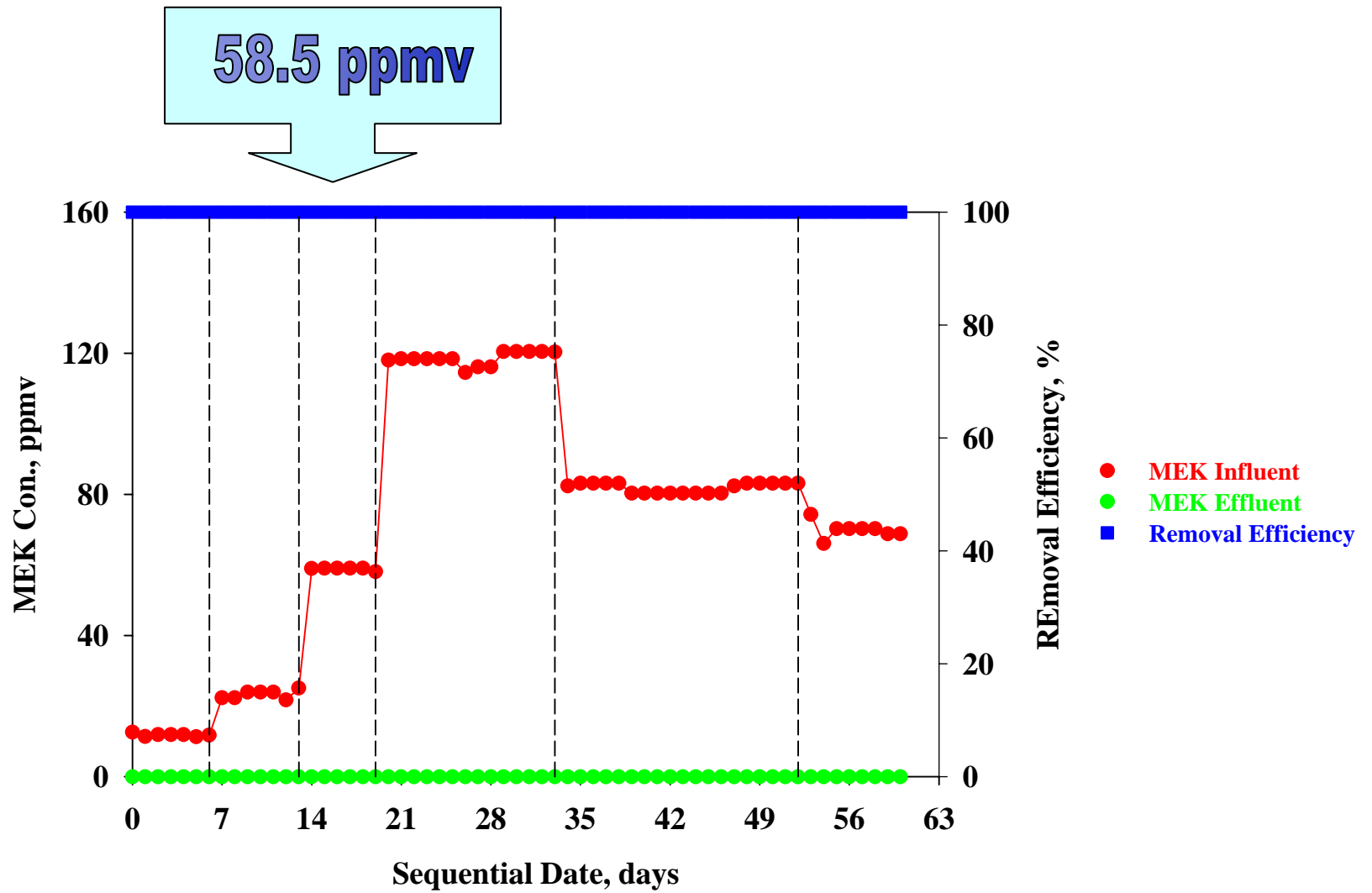
11.7 ppmv



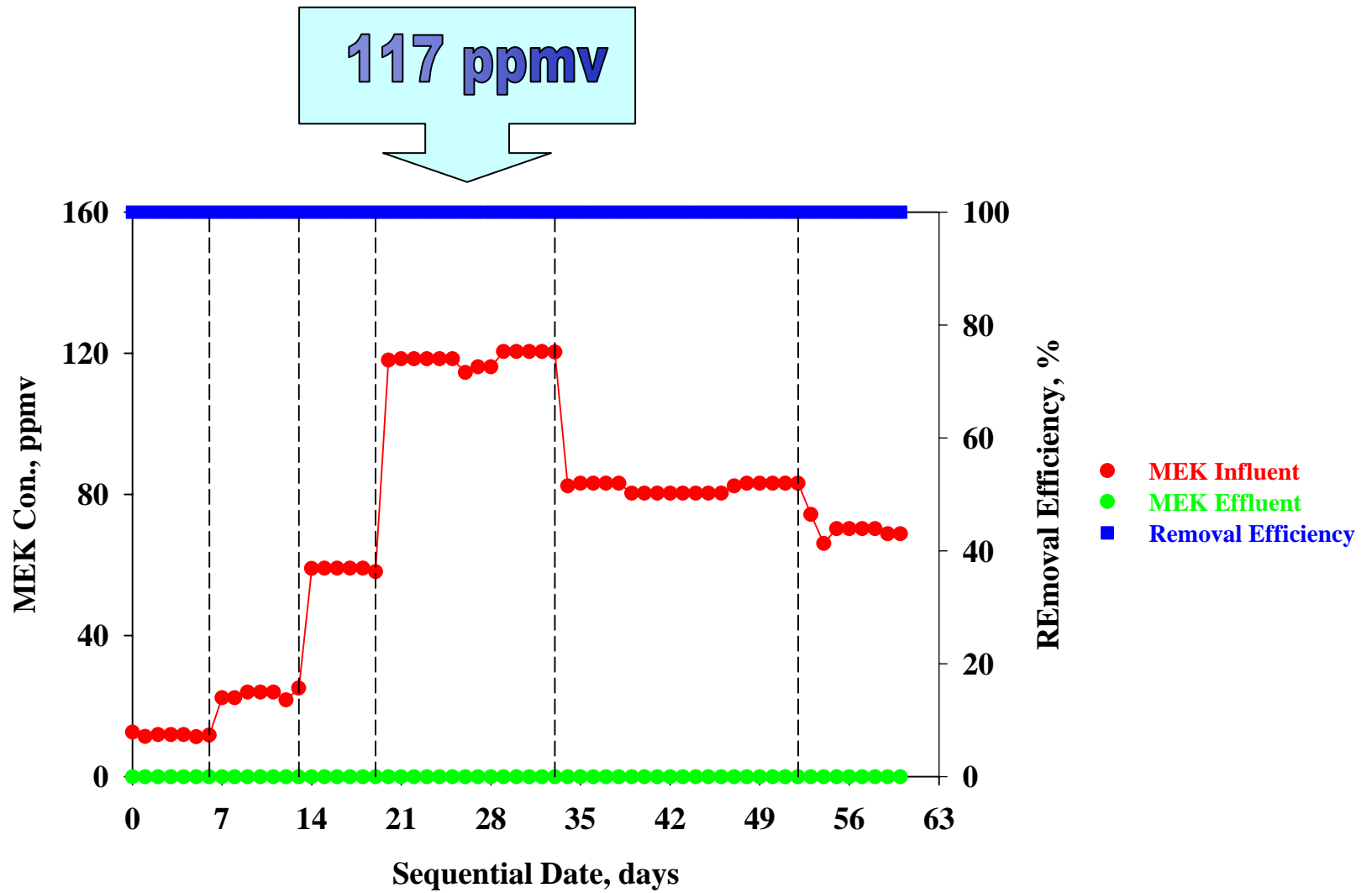
Results : MEK in Mixture 2



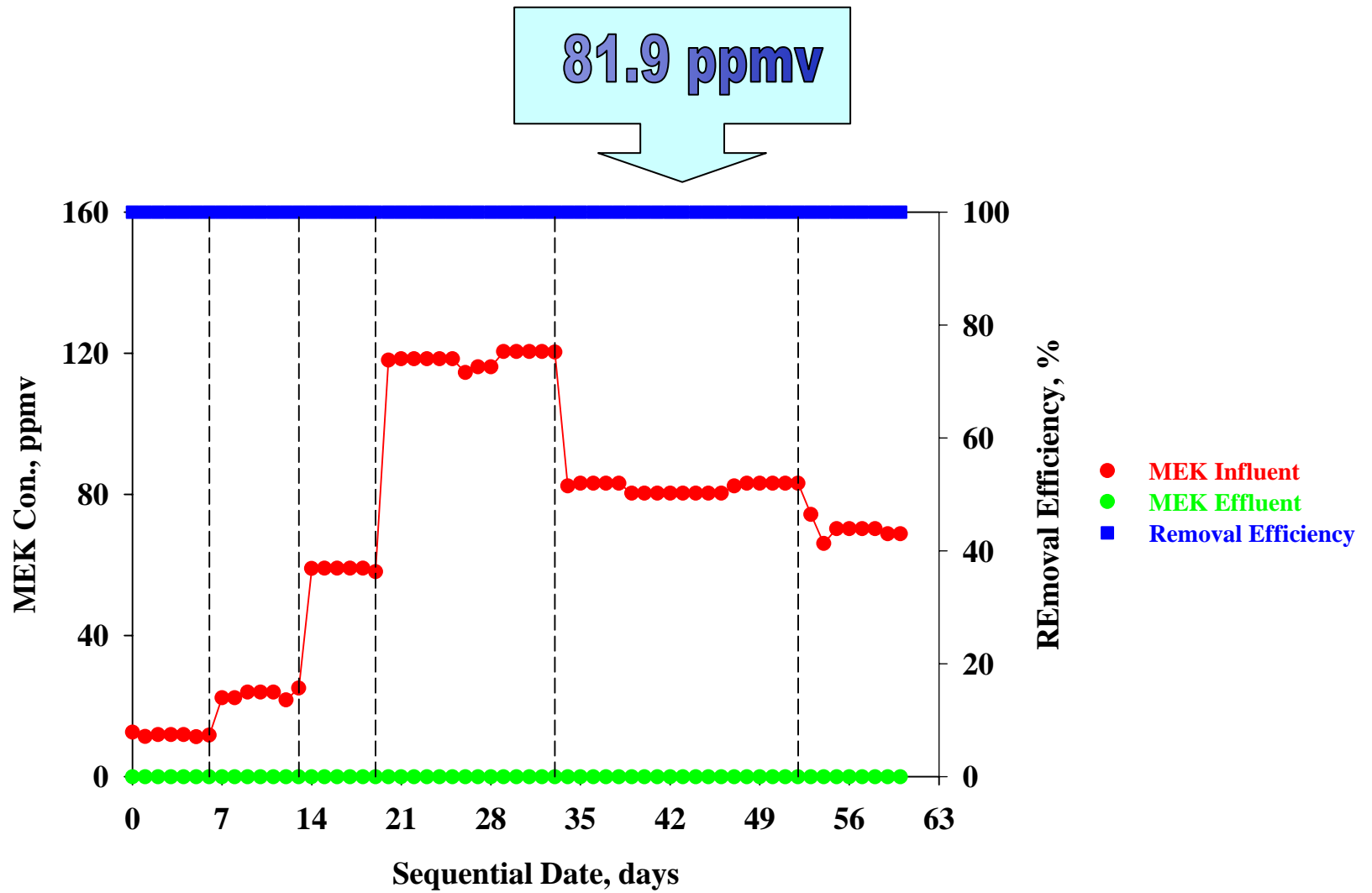
Results : MEK in Mixture 2



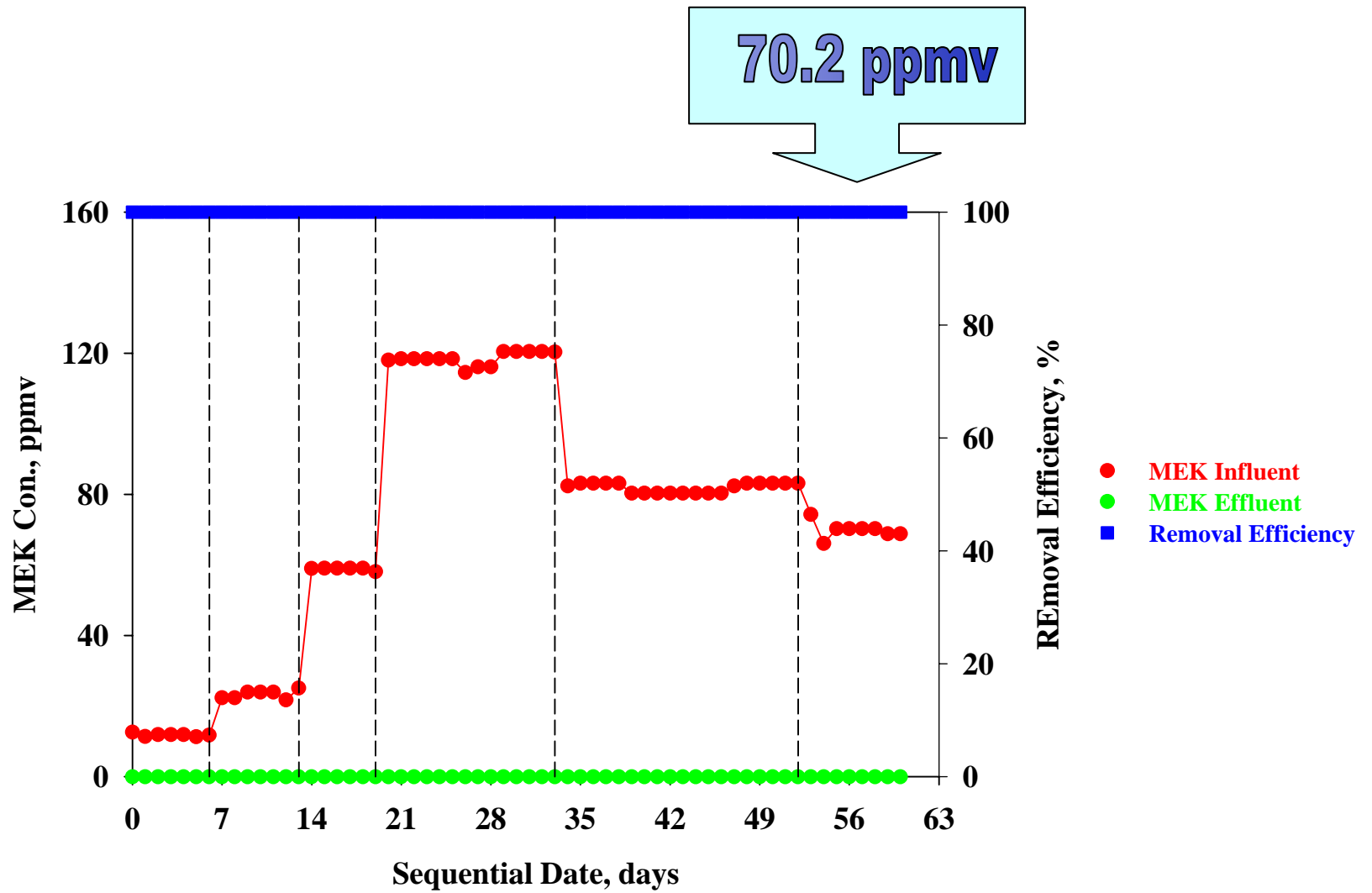
Results : MEK in Mixture 2



Results : MEK in Mixture 2

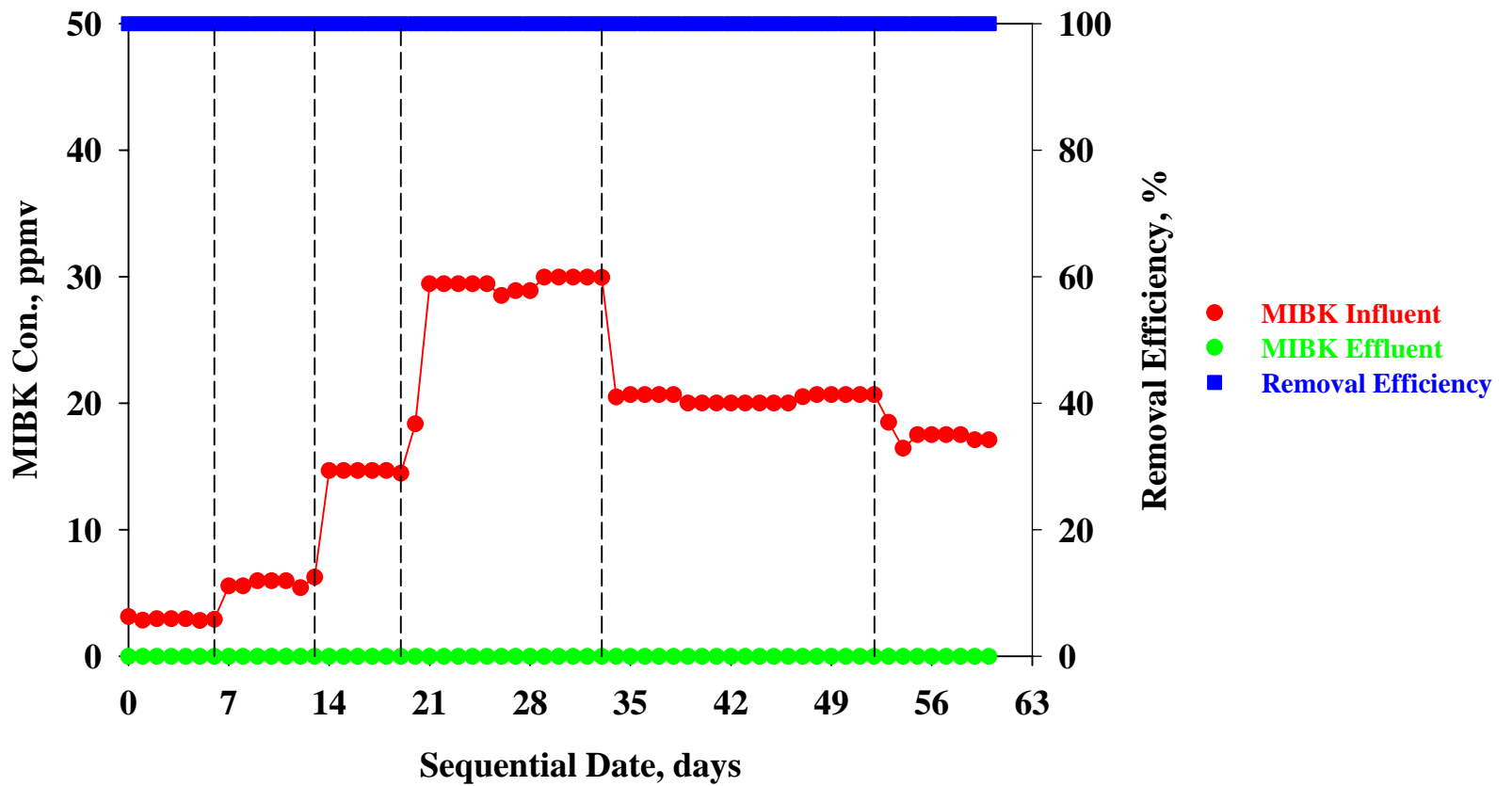


Results : MEK in Mixture 2

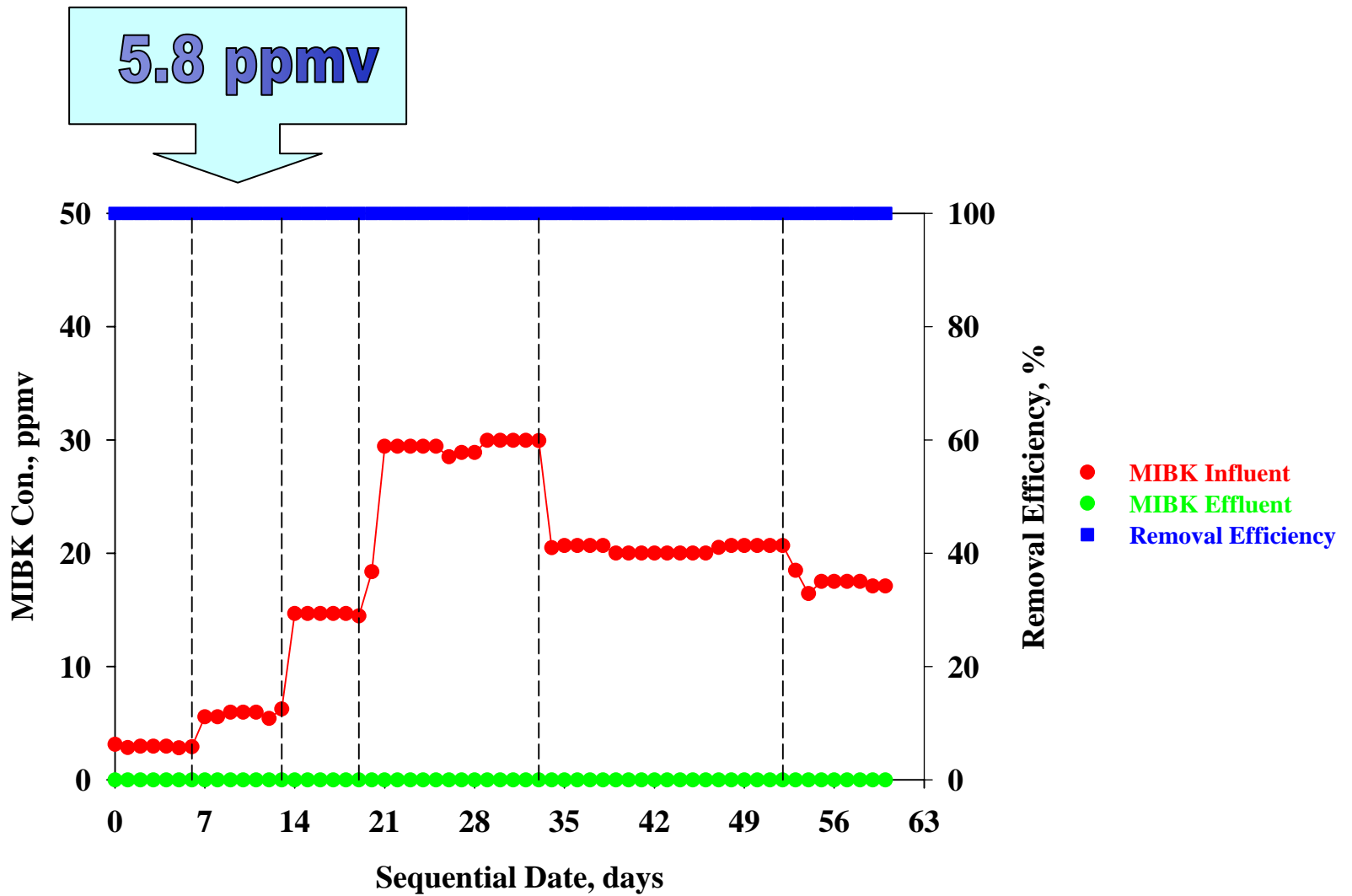


Results : MIBK in Mixture 2

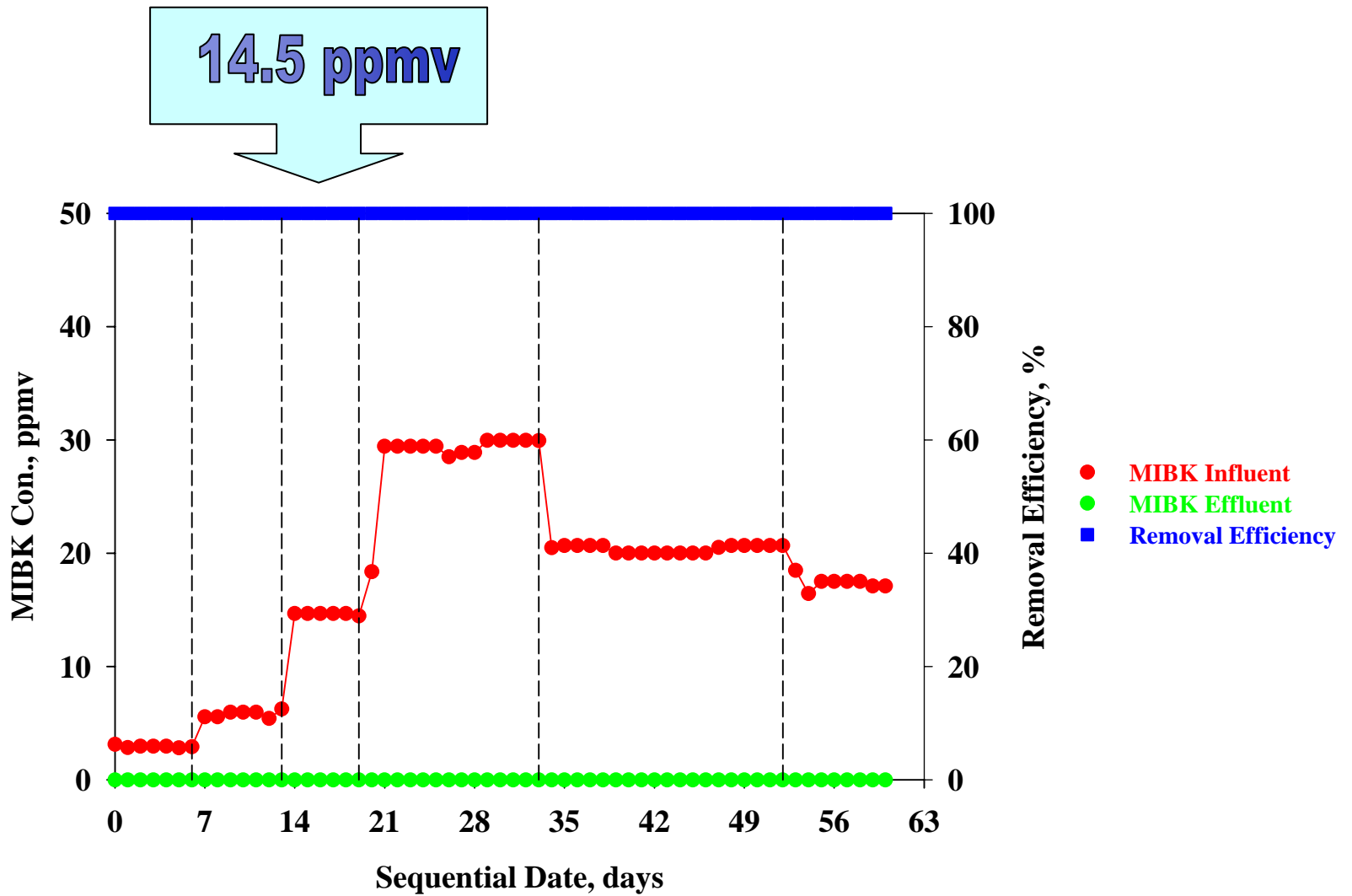
2.9 ppmv



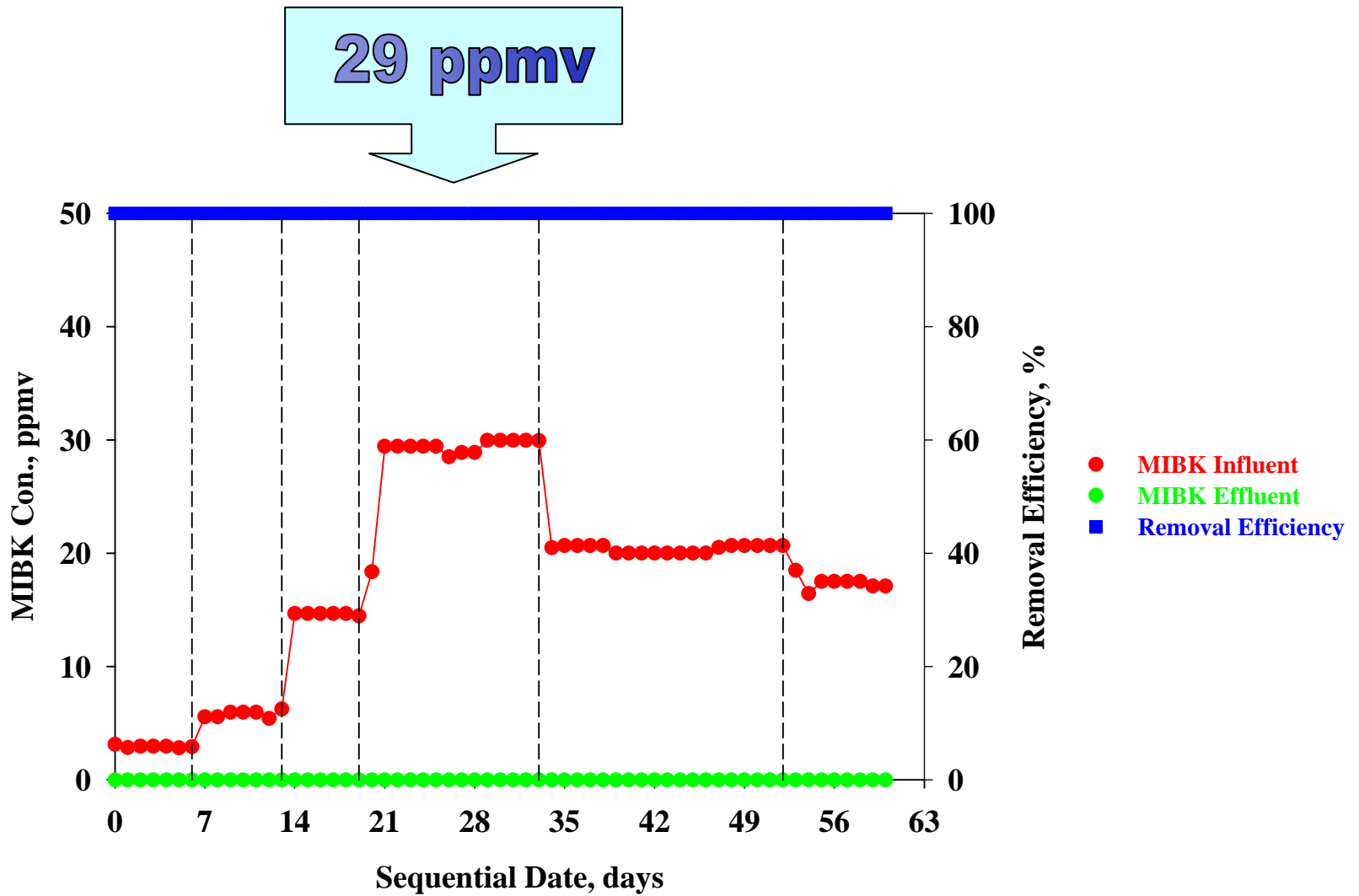
Results : MIBK in Mixture 2



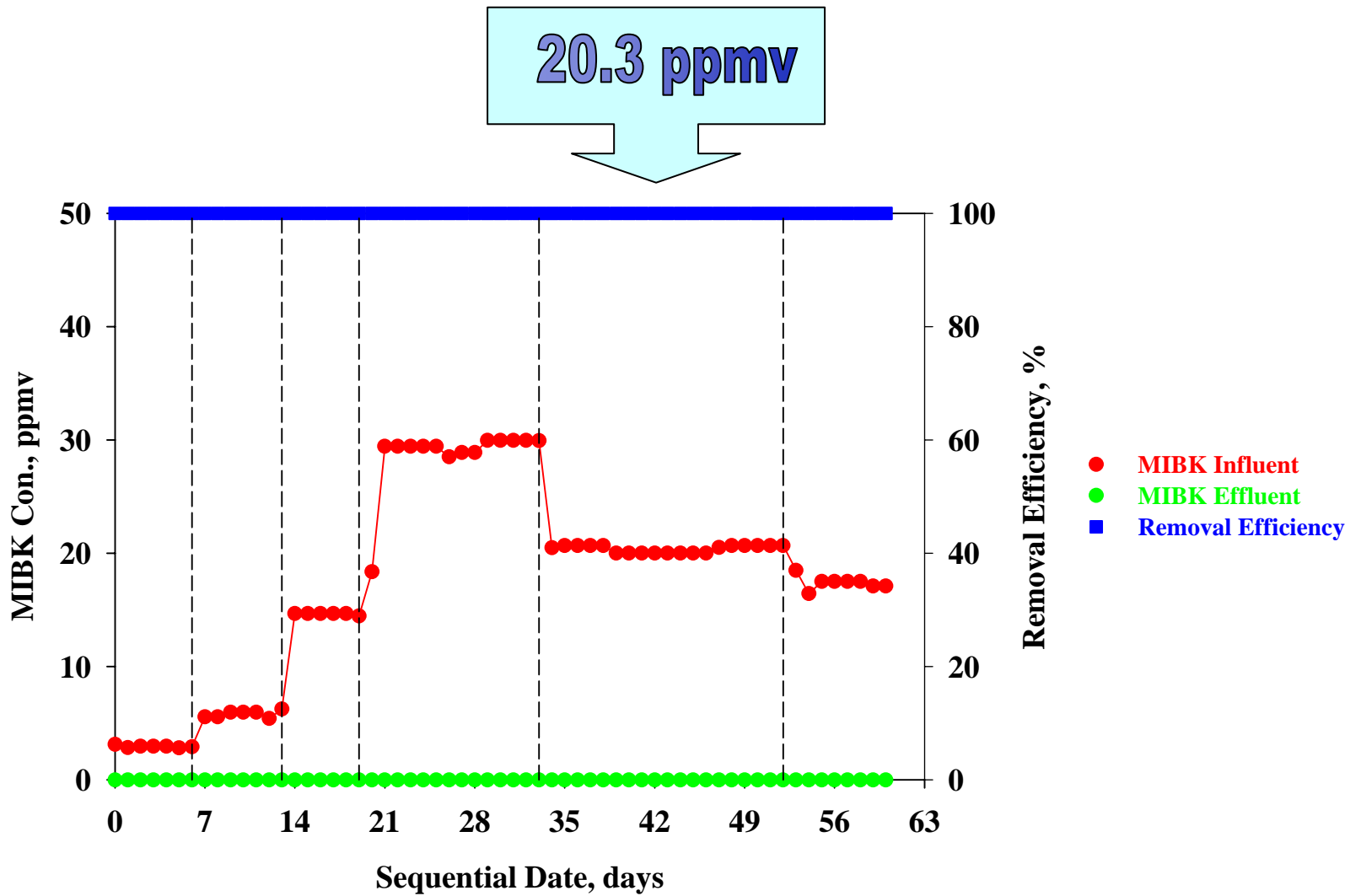
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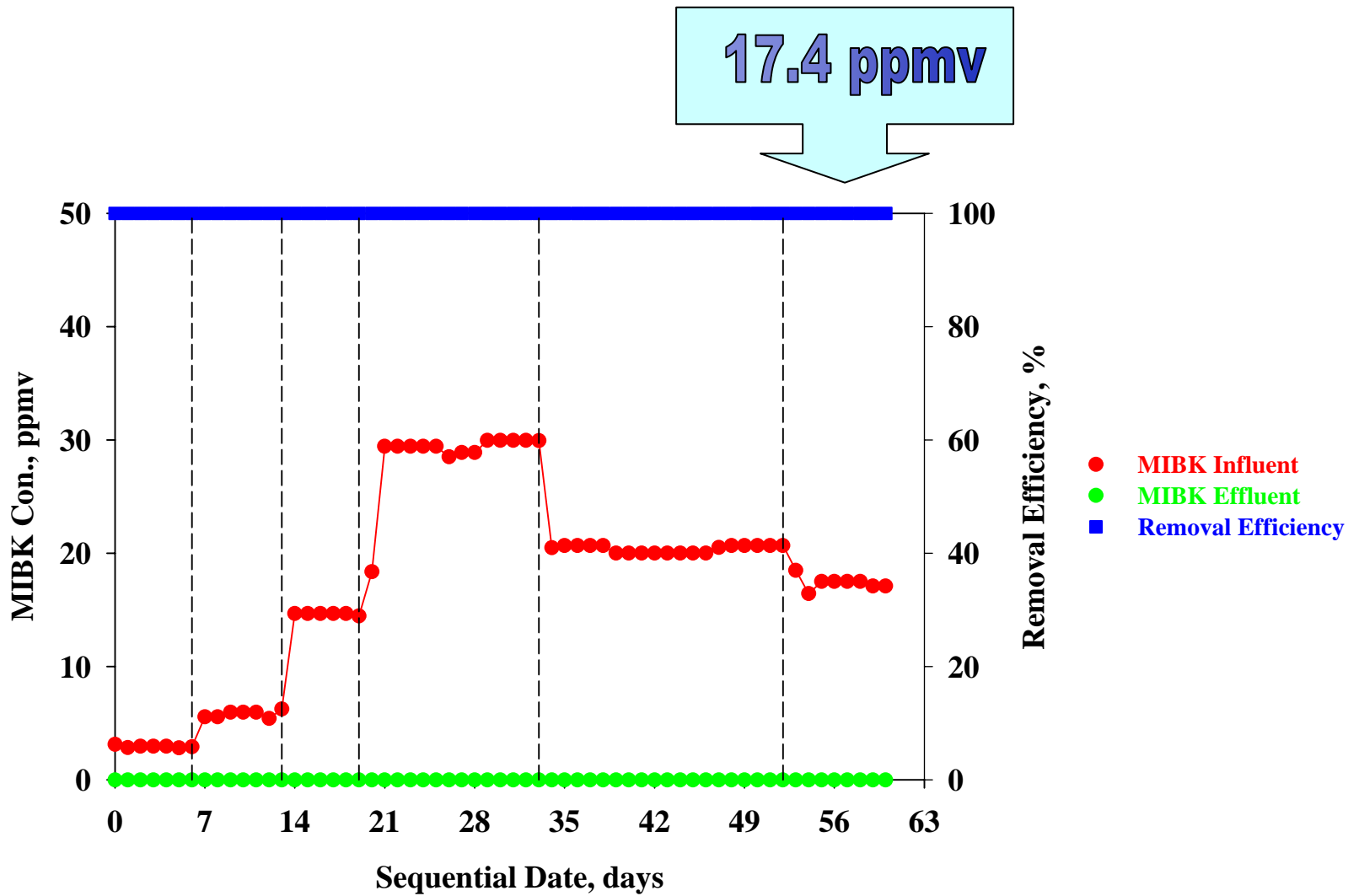
Results : MIBK in Mixture 2



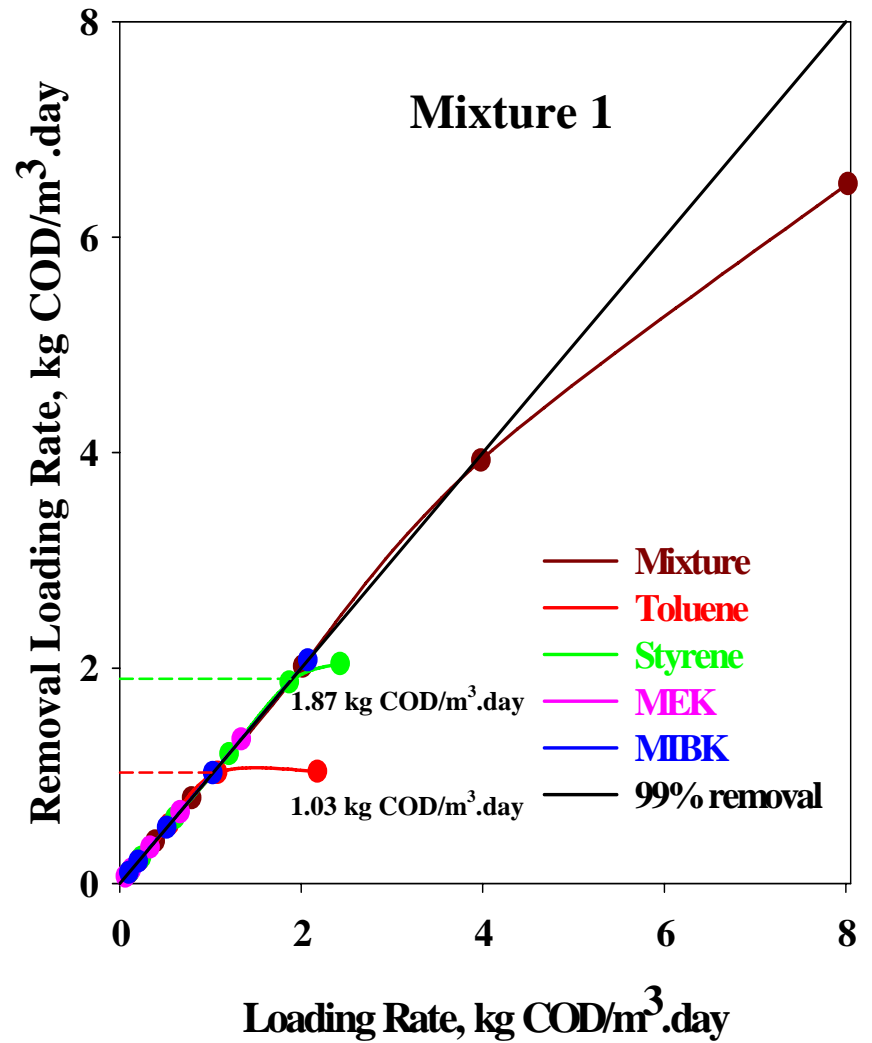
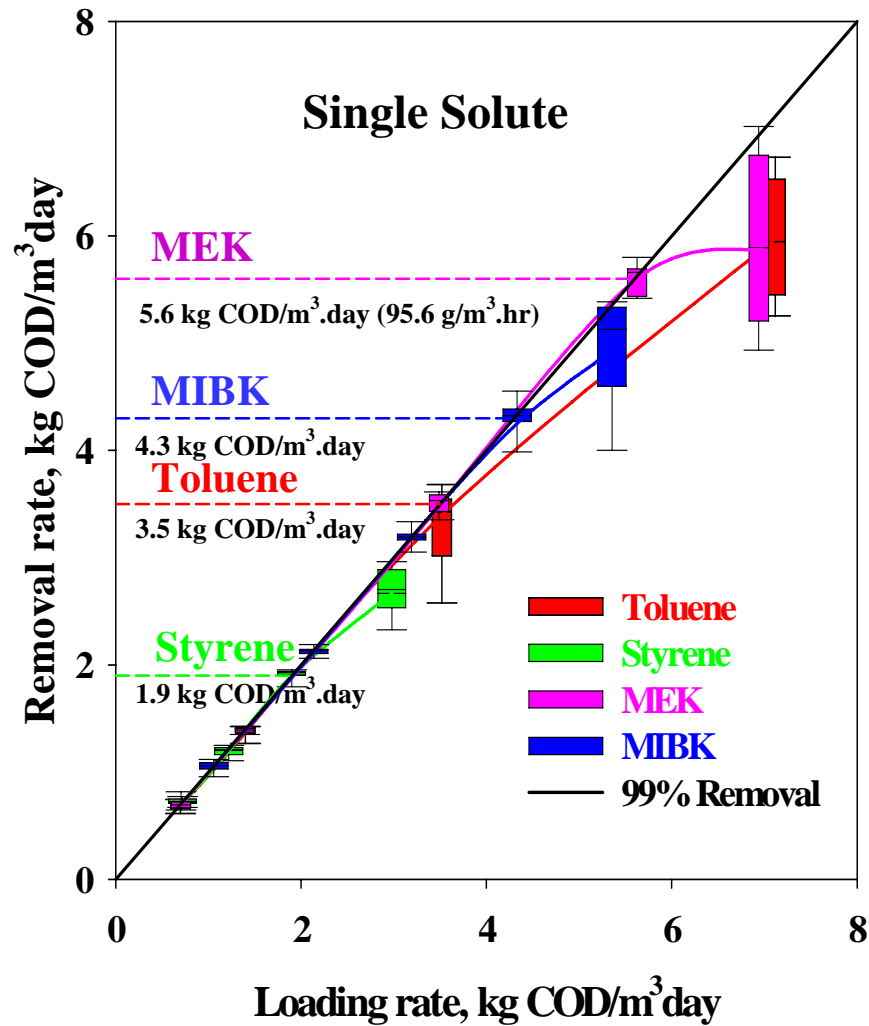
Results : MIBK in Mixture 2



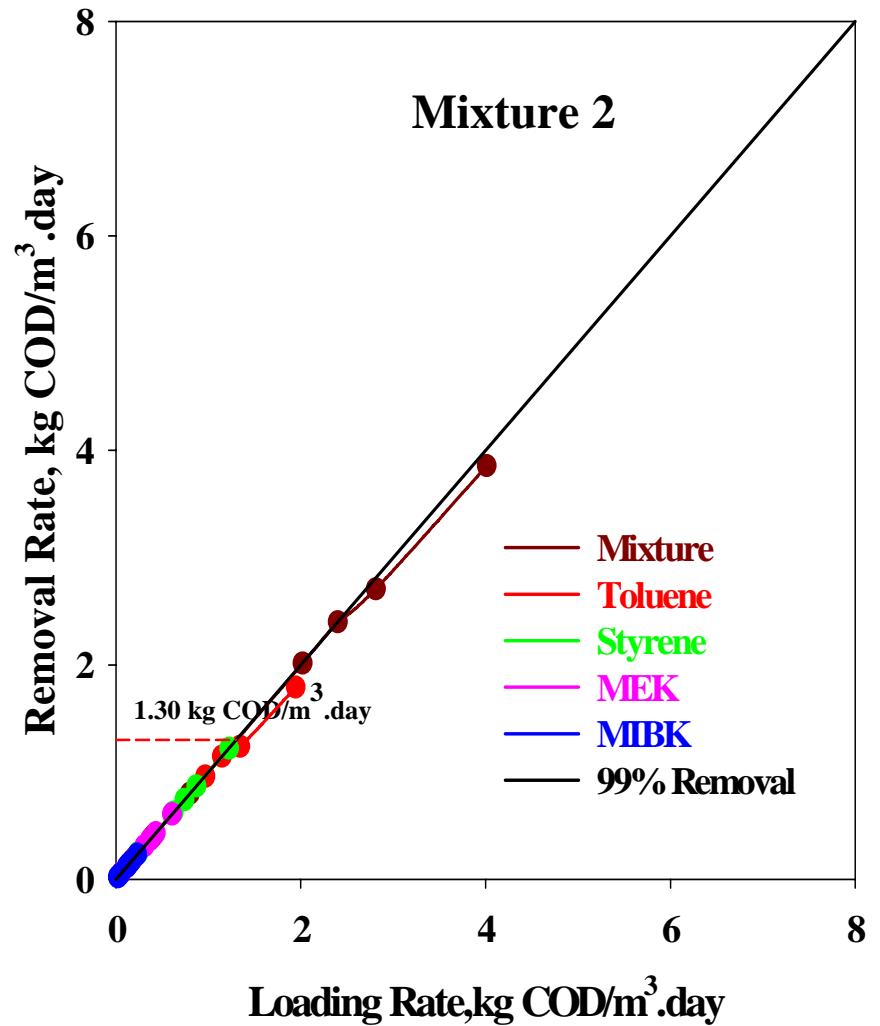
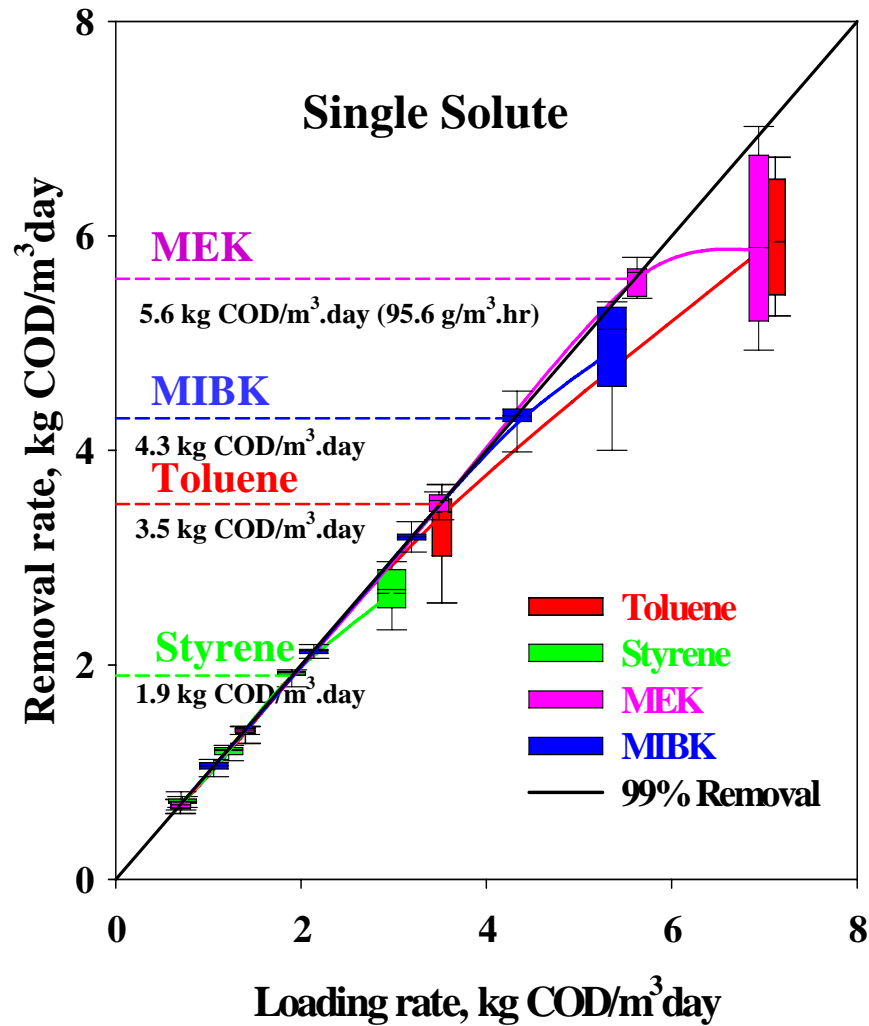
Results : MIBK in Mixture 2



Results : Elimination Capacity for Mixture 1



Results : Elimination Capacity for Mixture 2



Results : Mixture 1

➤ Biofilter Response for Step Change in Conc.

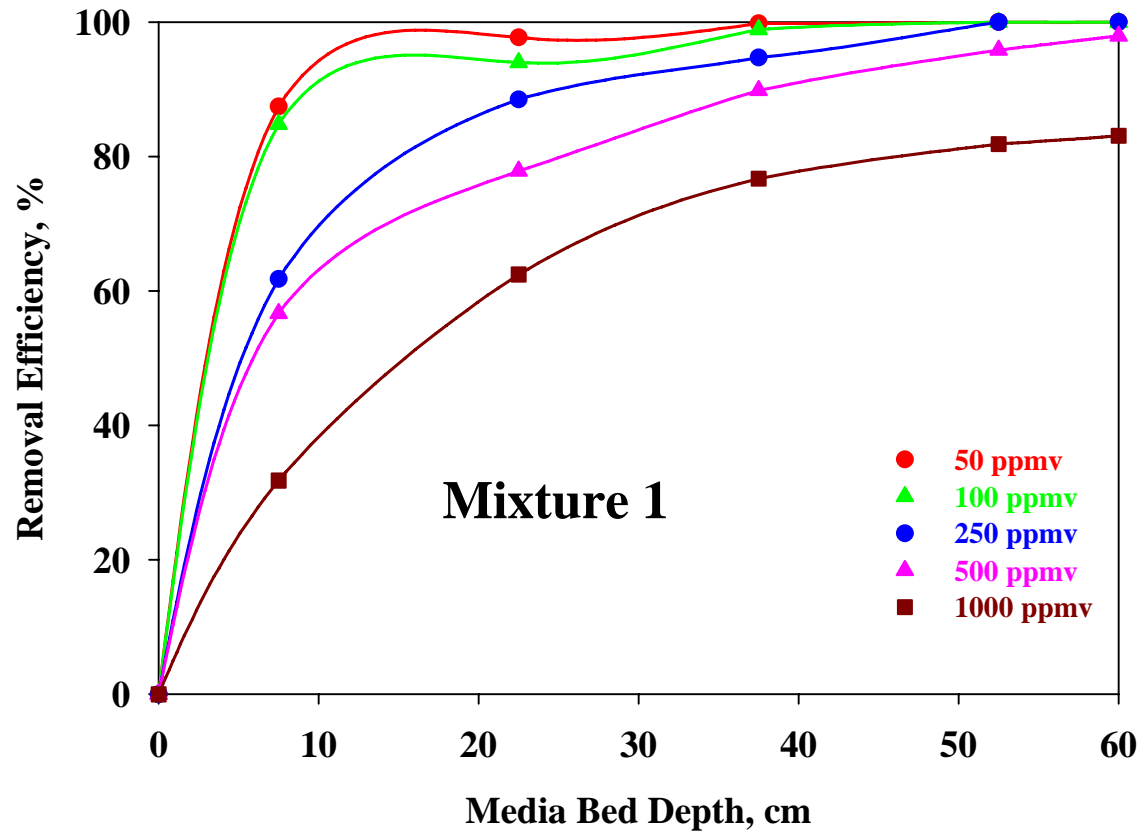
Time, min	50 ppmv	100 ppmv	250 ppmv	500 ppmv	1000 ppmv
30	86.8	84.8	81.8	80.6	79.0
60	95.3	89.2	86.6	84.0	80.3
300	99.9	99.2	99.3	98.6	80.6
600	99.9	99.9	99.9	99.5	84.7
1200	99.9	99.9	99.9	99.9	81.6
2880	99.9	99.9	99.9	99.9	82.5

Results : Mixture 2

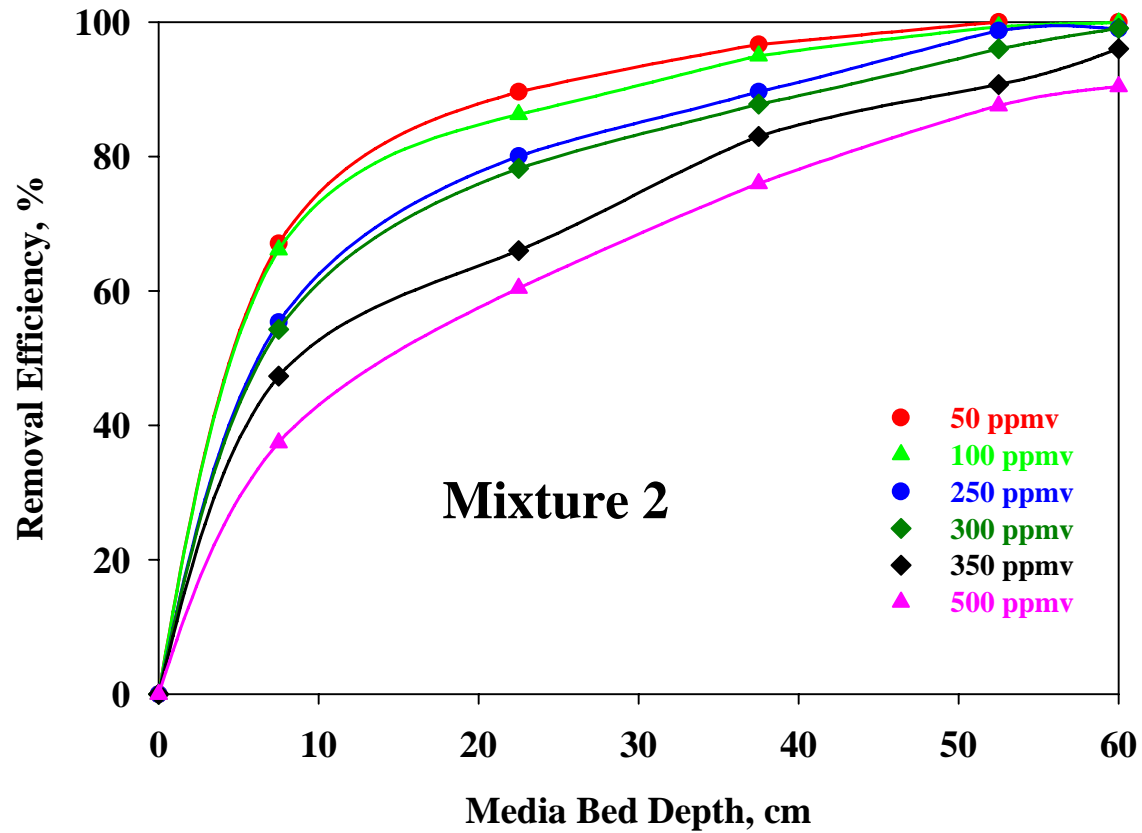
➤ Biofilter Response for Step Change in Conc.

Time, min	50 ppmv	100 ppmv	250 ppmv	300 ppmv	350 ppmv	500 ppmv
30	82.7	77.8	75.9	74.9	72.1	71.4
60	93.6	88.4	82.2	82.2	68.8	74.9
300	97.5	95.2	93.1	91.9	89.2	86.7
600	99.9	98.6	98.5	99.3	94.2	88.6
1200	99.9	99.9	99.9	99.9	95.5	92.1
2880	99.9	99.9	99.9	99.9	97.3	90.2

Results : Removal Profile along Bed Depth



Results : Removal Profile along Bed Depth



Conclusions

- **Over 99% removal efficiency could be maintained at inlet concentrations up to 500 ppmv for mixture 1 and 300 ppmv for Mixture 2.**
- **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.**
- **Biofilter depth utilization increased with increase of inlet concentrations for both biofilters. MEK and MIBK in the mixtures were removed in the upper biofilter depth, and removal of styrene and toluene utilized more biofilter depth.**
- **Toluene content in the mixture played a major role in the biofilter overall performance. And removal of toluene efficiency decreased with increase of content of MEK and MIBK in the mixtures.**

Acknowledgement

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

ATOs-11

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Questions?

Department of Civil and Environmental Engineering

UNIVERSITY OF
Cincinnati

The logo of the University of Cincinnati, featuring a stylized red 'UC' monogram.