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Behavior of Trickle Bed Air Biofilter for VOCs Removal
: *Effect of Non-Use Periods*

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- **Objective**
- **Experimental Method**
- **Experimental Approach**
- **Results & Summary**
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Introduction

VOC: Volatile organic compounds

- Typical air contaminants
  - Environmental concern due to their toxicity
  - Serious health problems: cancer
  - Precursor of Ozone (O_3)

- Sources of VOCs
  - Chemical manufacturing
  - Dry cleaners,
  - Paint booths,
  - and other sources using solvent.

Introduction (cont'd)

VOC Control Technology

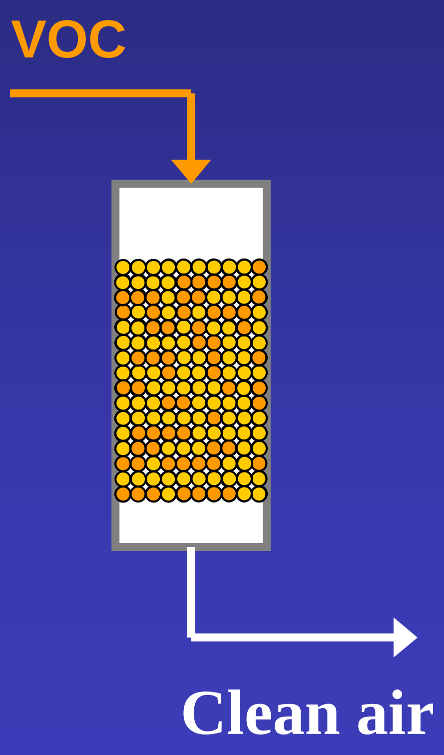
- Carbon adsorption,
- Liquid scrubbing,
- Condensation,
- Catalytic incineration,
- and Biological treatment.

Biofiltration !!!

Introduction (cont'd)

Biofiltration

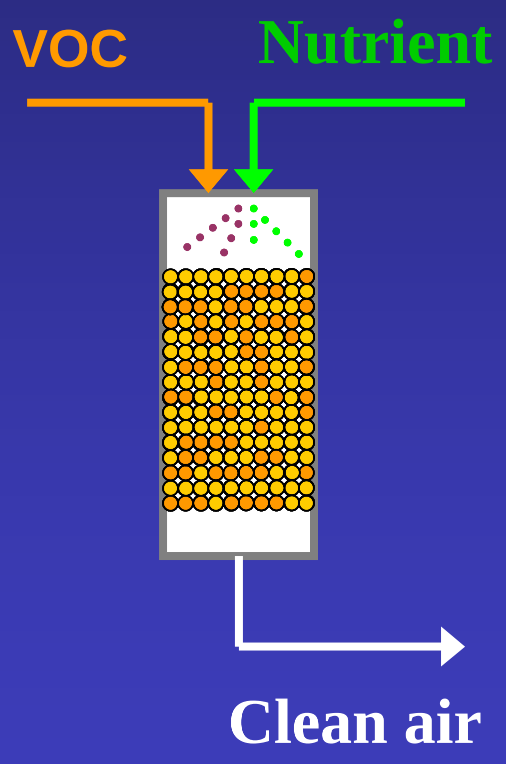
- Typical biological treatment process
- VOCs are removed through a biologically active media
- Natural organic media (soil, compost)
  $\rightarrow$ easily exhaust nutrient & buffer capacity
  $\rightarrow$ long term operation is impractical



Introduction (cont'd)

Trickle Bed Air Biofilter (TBAB)

- Nutrient & buffer control
- Synthetic & inorganic media
  - → Optimizing the contaminant utilizing kinetics for microorganisms
  - → Long term, high removal performance



Introduction (cont'd)

Trickle Bed Air Biofilter (TBAB)

- Advantages
  - ✓ Environmental friendly
  - ✓ Economical viable

- Disadvantage
  - ✓ Clogging of bed due to accumulation of biomass
  - ✓ Unclear performance under non-use periods : a shut down for equipment repair, during weekends and holidays
  - ✓ Unfavorable performance due to shock load & load fluctuation

Solvable problem !!

Introduction (cont'd)

Trickle Bed Air Biofilter (TBAB)

- Clogging of bed due to accumulation of biomass

  → Solution: biomass control

  Periodic *in-situ* upflow washing, backwashing

- Unclear performance under non-use periods

  → A purpose of this study

- Unfavorable performance due to shock load & load fluctuation

  → A purpose of the next study

Objective

- The main objective of this research is to investigate the performance of a TBAB under periodic stressed operating conditions (backwashing & non-use periods) as a function of toluene loading.

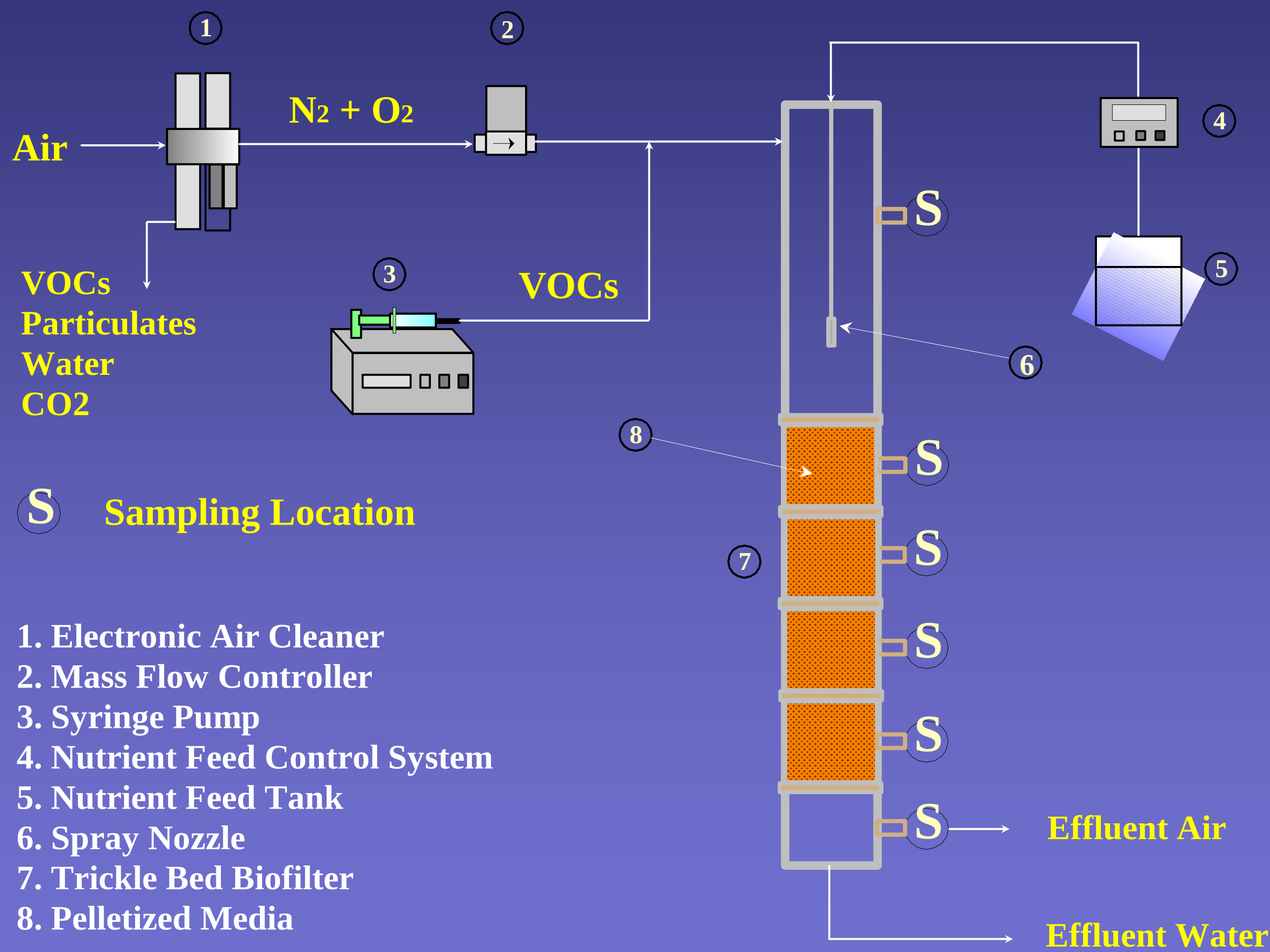
  ✓ To evaluate the effect of non-use periods (starvation & stagnant) on the performance of a TBAB for long-term operation.

  ✓ To compare TBAB operated under non-use periods against backwashing strategy.

Experimental Methods

- Target VOC: Toluene
- Reactor:
  independent lab-scale TBAB
- Media: pelletized biological support media

Schematic diagram



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

Experimental Approach (cont'd)

- Experimental Condition : 5 steps

  → Different inlet concentration & loading rate

	I	II	III	IV	V
Inlet Concentration, ppmv	*50*	*50*	*100*	*250*	*500*
Loading rate, kg COD/m³,day	*1.14*	*0.7*	*1.41*	*3.52*	*7.03*
EBRT, min	*0.76*	*1.23*	*1.23*	*1.23*	*1.23*

Experimental Approach

Experimental Strategy: backwashing, starvation, stagnant

- Backwashing: biomass control
  - ✓ Using nutrient solution
  - ✓ Frequency: 1 hour once per week for a period of 3 weeks
- Non-use period
  - ✓ Starvation: pure air with nutrient passing through the biofilter (without VOC loading)
  - ✓ Stagnant: no flow (VOC, nutrient, air) passing through the biofilter
  - ✓ Frequency: two days per week for a period of 3 weeks
  - ✓ Without backwashing as biomass control

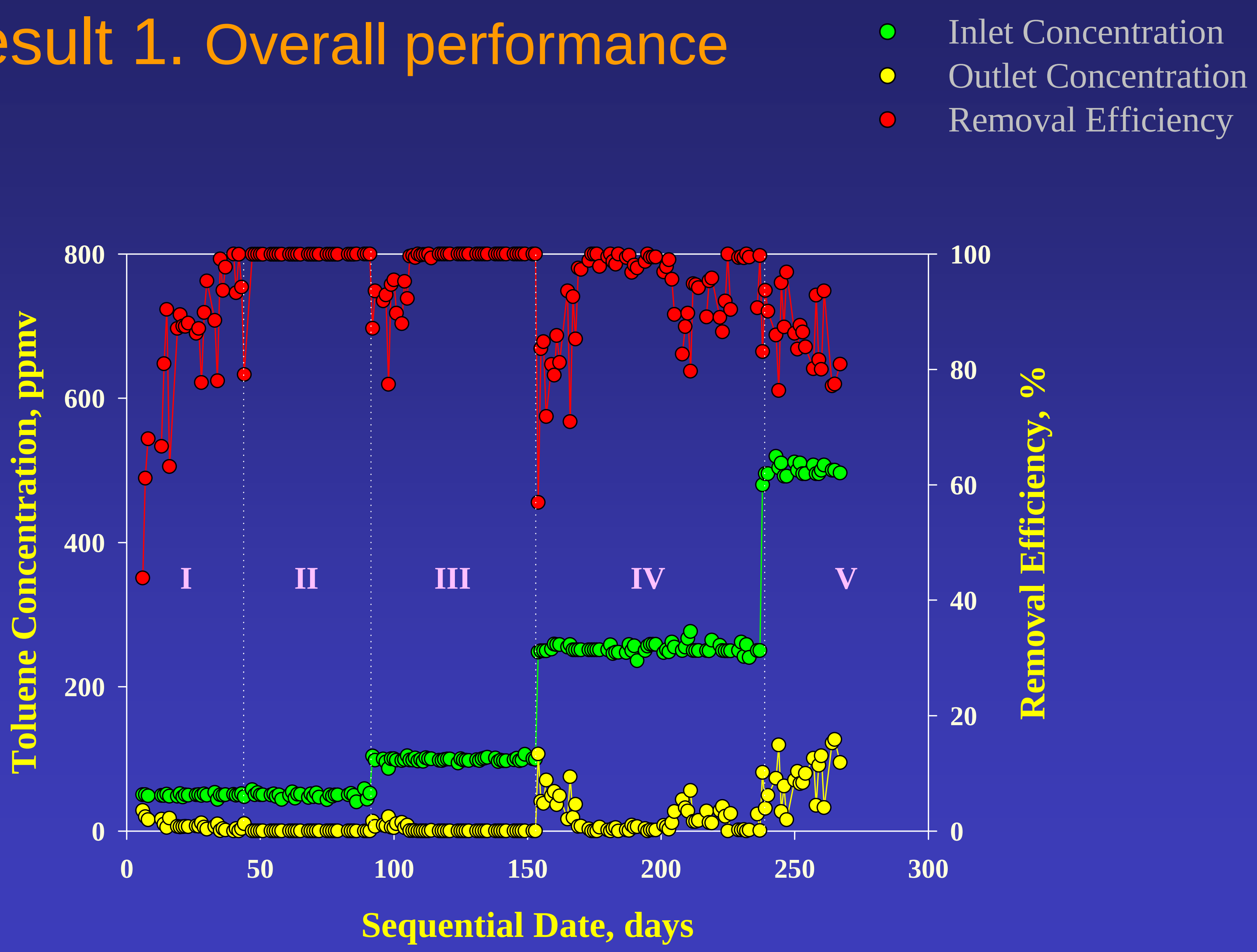
Results

- Biofilter performance
- Reacclimation
- Kinetic analysis

Result 1. Biofilter Performance

- Biofilter performance as a function of inlet VOC concentration and loading, and experimental strategies.

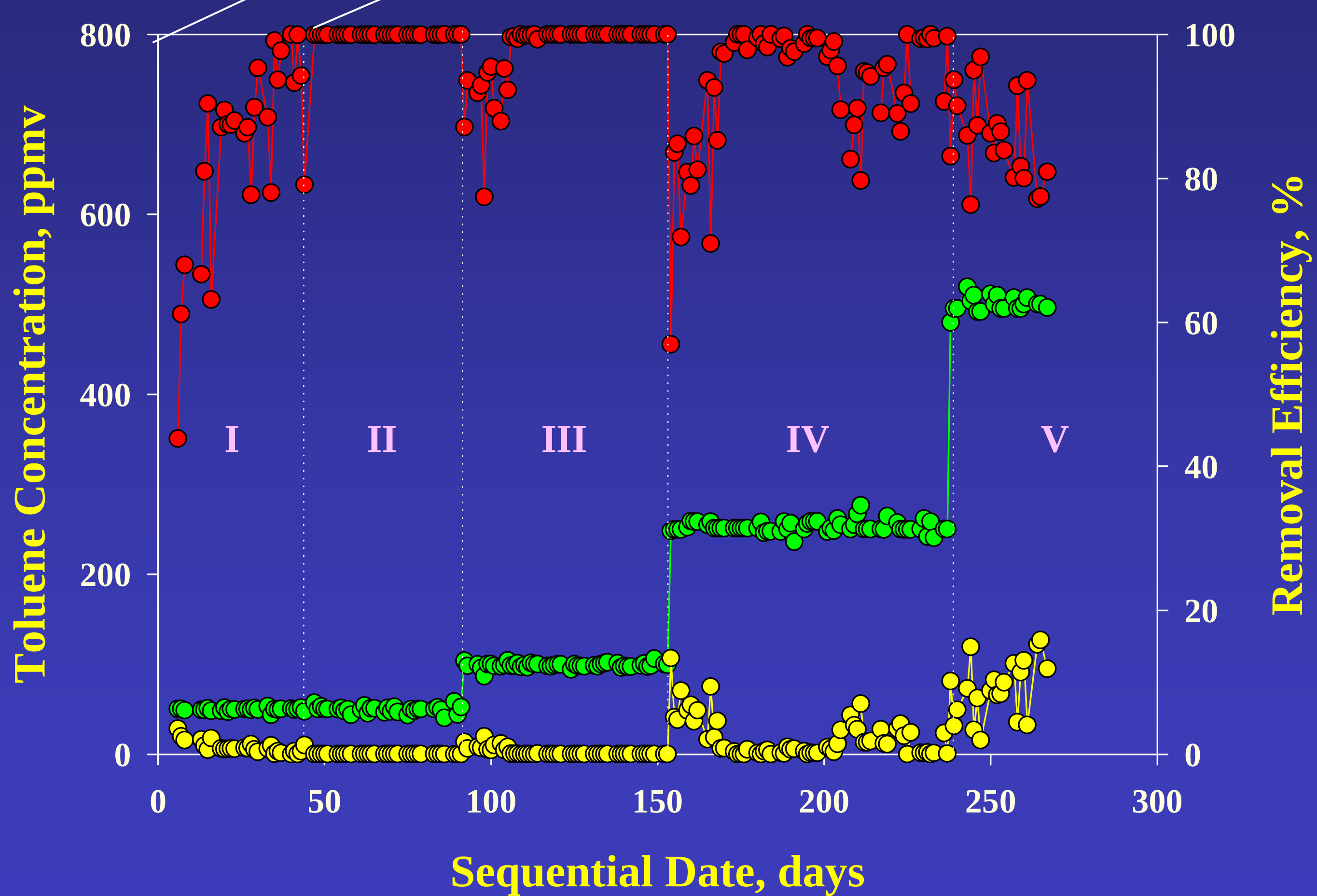
Result 1. Overall performance



Result 1 (cont'd)

	I
Inlet Conc., ppmv	*50*
Loading, kg COD/m^3,day	*1.14*

Step I: Start-up Period
• Backwashing

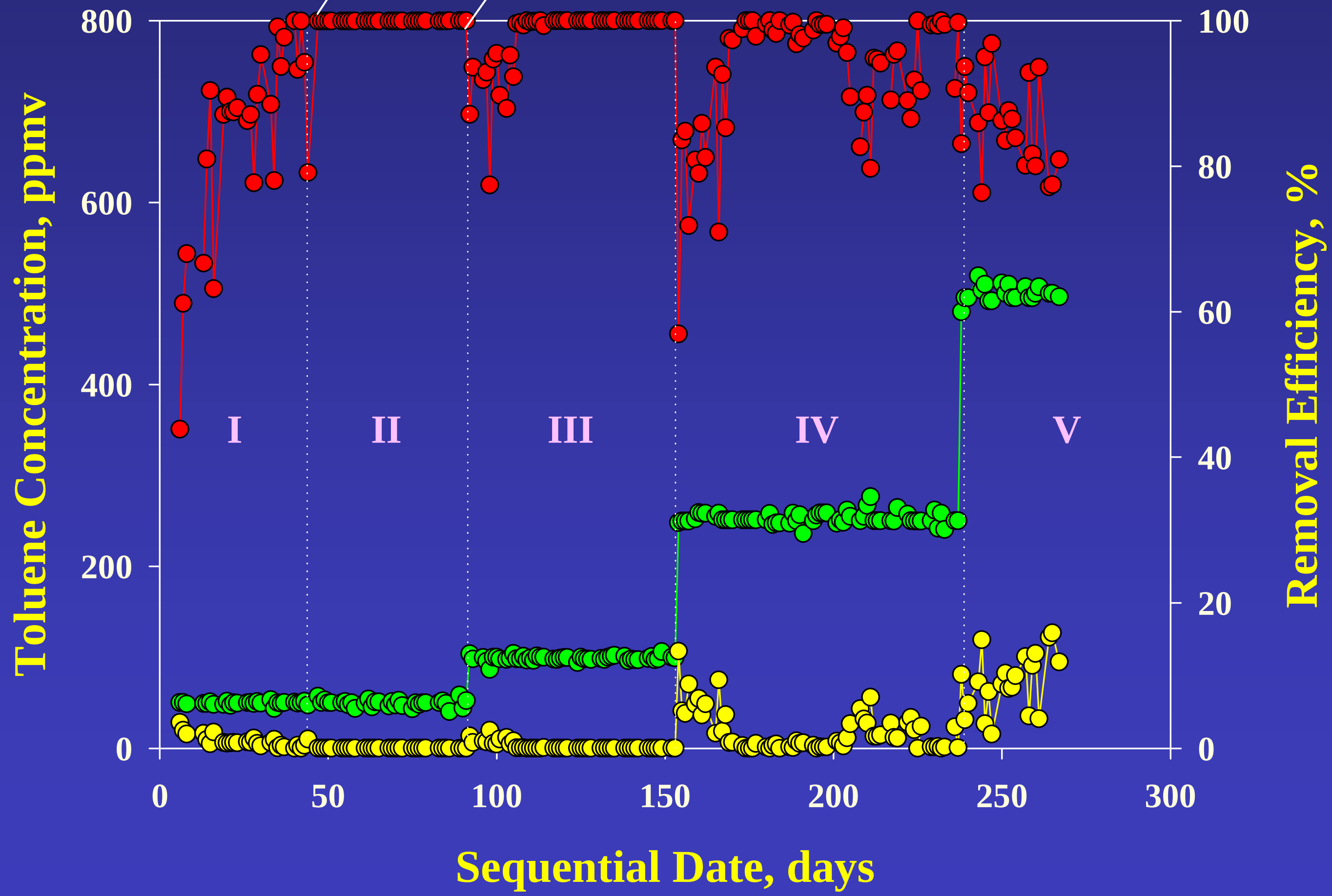


Result 1 (cont'd)

	II
Inlet Conc., ppmv	50
Loading, kg COD/m^3,day	0.7

Step II: Stable & efficient performance

- Backwashing
- Non-use periods

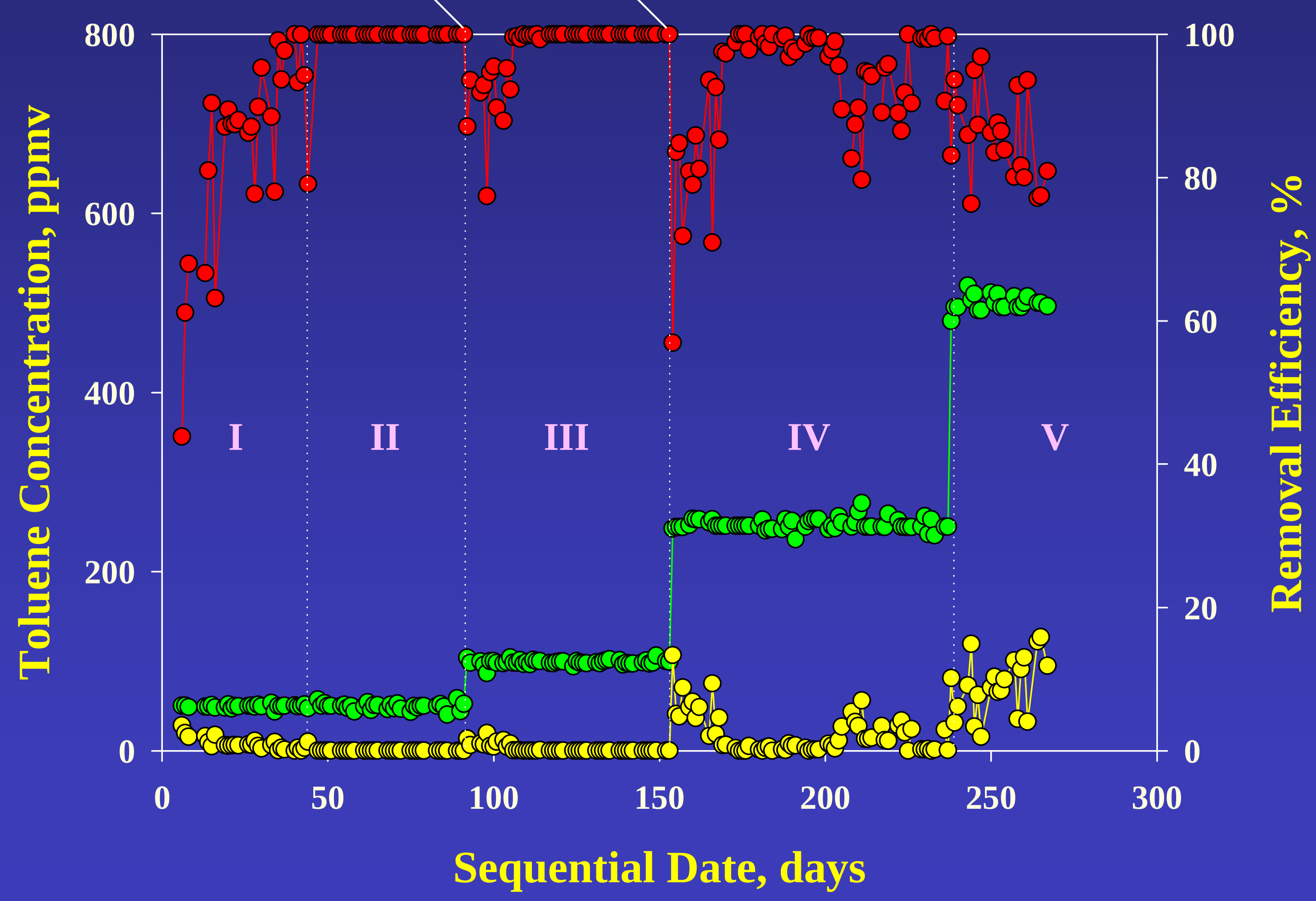


Result 1 (cont'd)

	III
Inlet Conc., ppmv	100
Loading, kg COD/m^3,day	1.41

Step III : Reacclimation (+10 days)

- Efficient performance (backwashing, non-use periods)



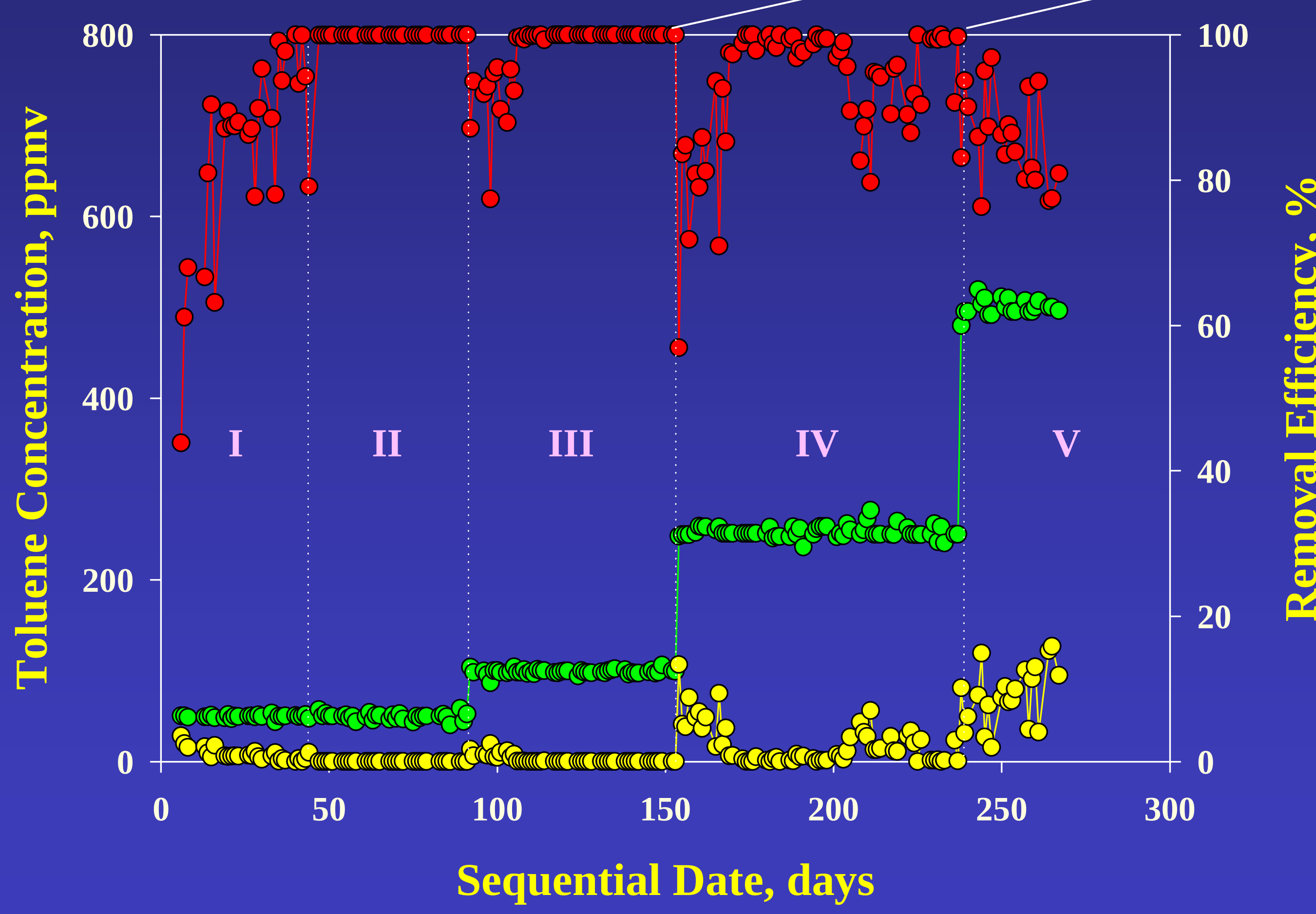
Result 1 (cont'd)

Step IV : Reacclimation (+20 days)

- backwashing: relatively stable
- non-use periods: unstable

  → need backwashing

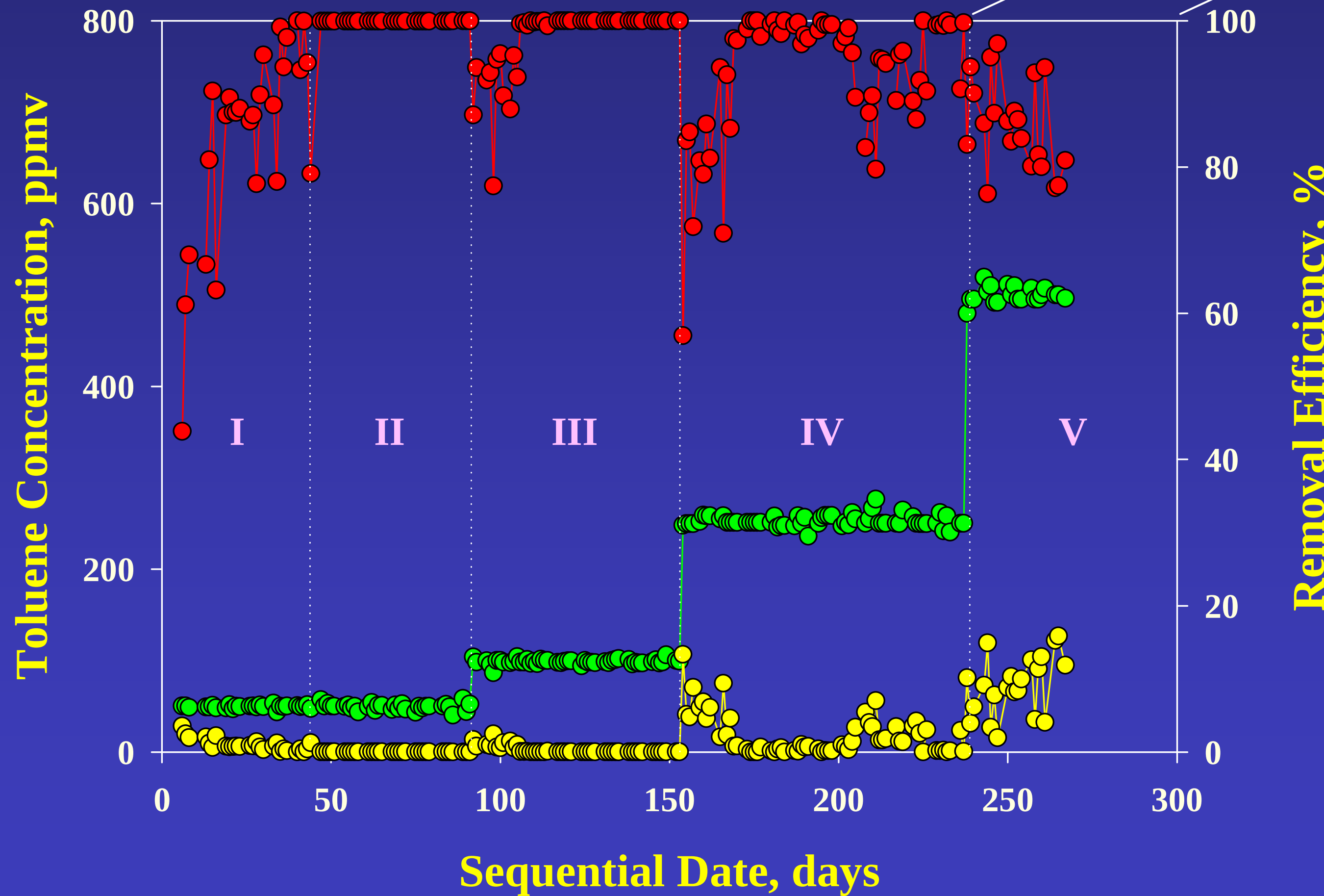
	IV
Inlet Conc., ppmv	***250***
Loading, kg COD/m³,day	***3.52***



Result 1 (cont'd)

Step V : Inefficient performance
(backwashing)
→ Oxygen limitation within biofim

	V
Inlet Conc., ppmv	***500***
Loading, kg COD/m³,day	***7.03***



<u>Result 1 (cont'd)</u>

Summary

- At 0.7 and 1.41 kg COD/m^3·day, TBAB provided the + 99 % removal efficiency for all strategies.
- For non-use periods at 3.52 kg COD/m^3·day, the removal efficiency dropped below 90 %.

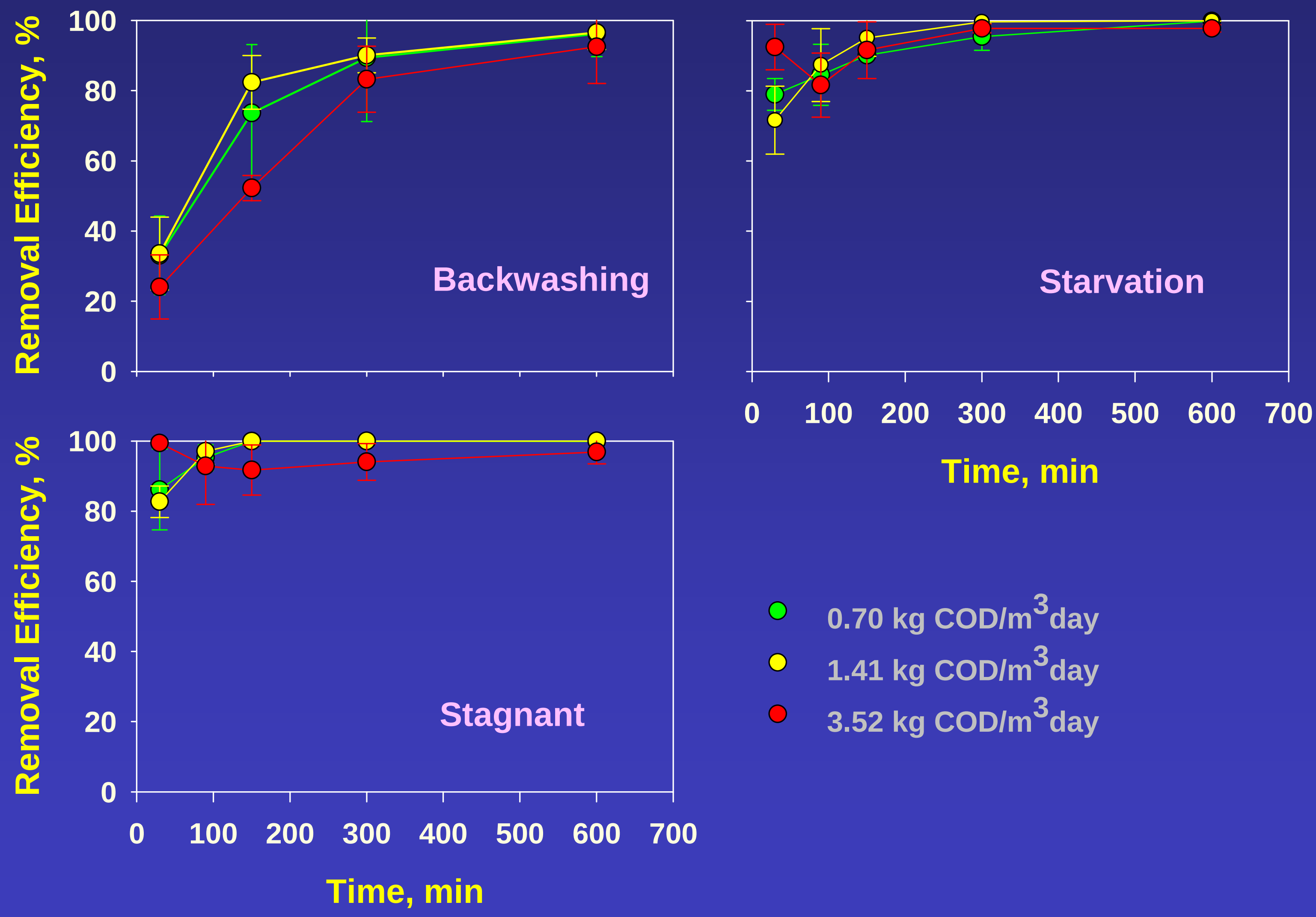
  $\rightarrow$ demanding Backwashing as biomass control
- An increase in loading rate needs much longer acclimation period.

Result 2. Reacclimation

- Reacclimation periods to reach at 99 % removal efficiency
  - After *backwashing* and
  - After *restart-up following the shut down for non-use periods*.

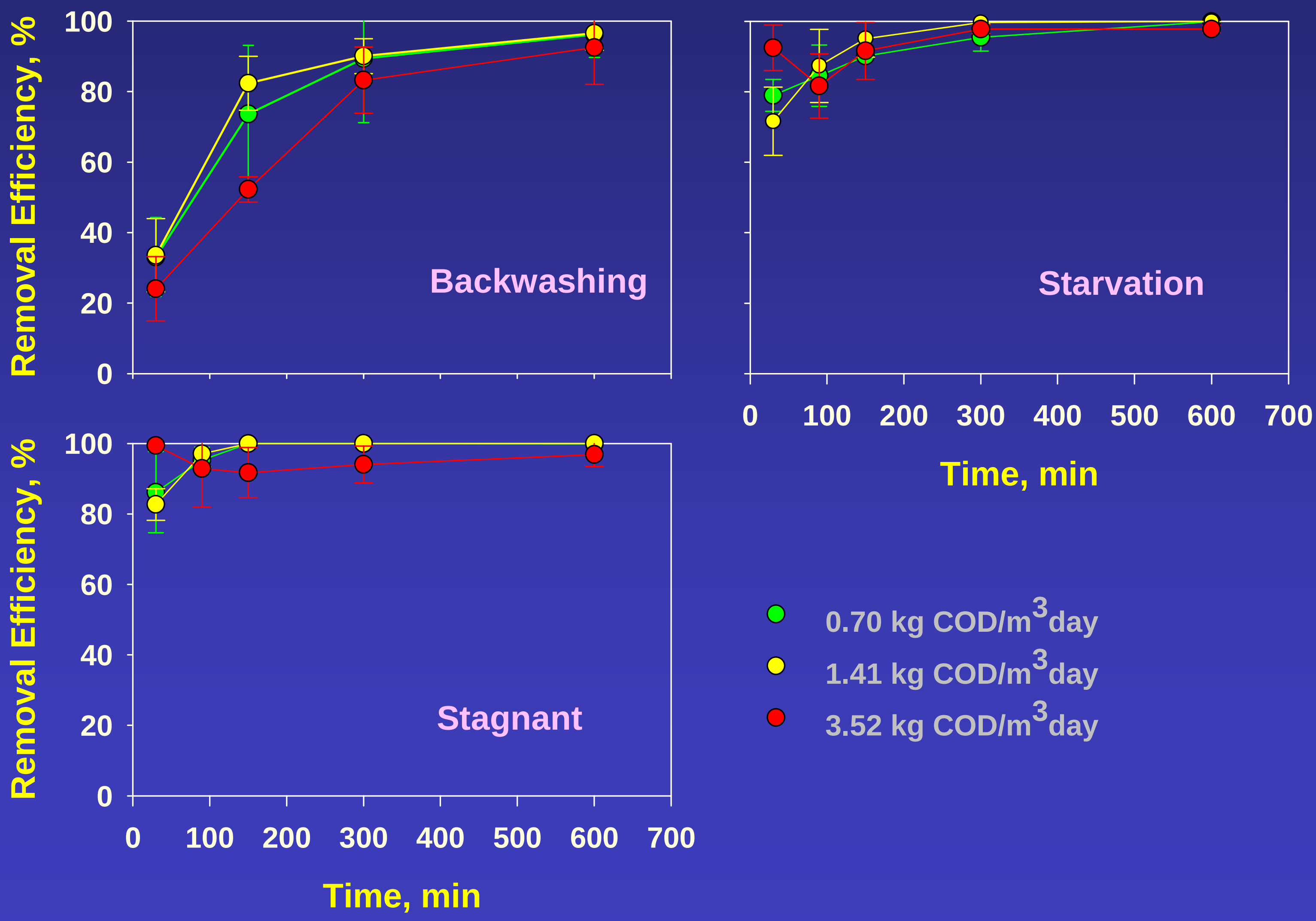
Result 2 (cont'd)

Result 2: Reacclimation



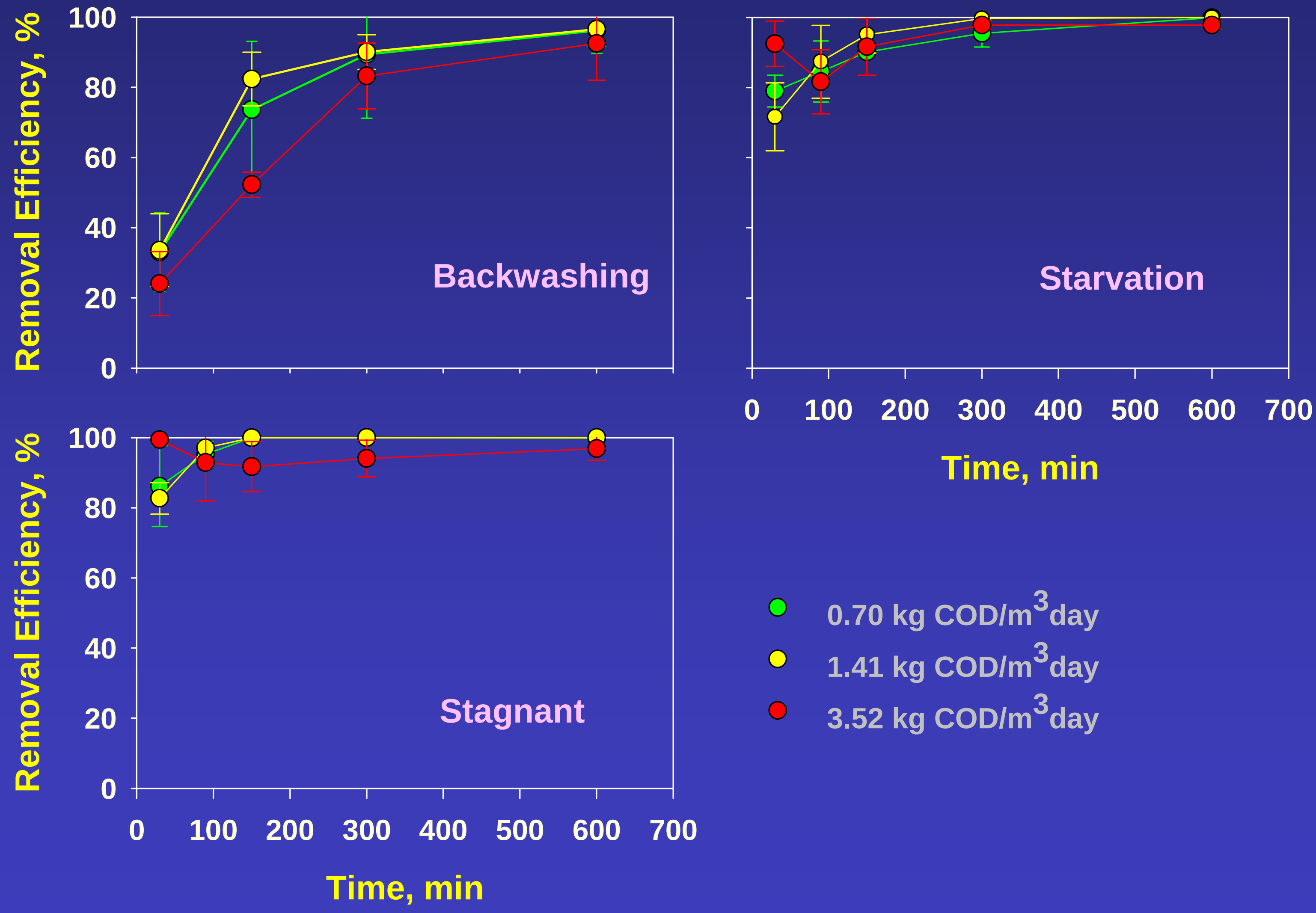
Result 2 (cont'd)

Summary 2-1. An increase in loading rate delayed reacclimation.



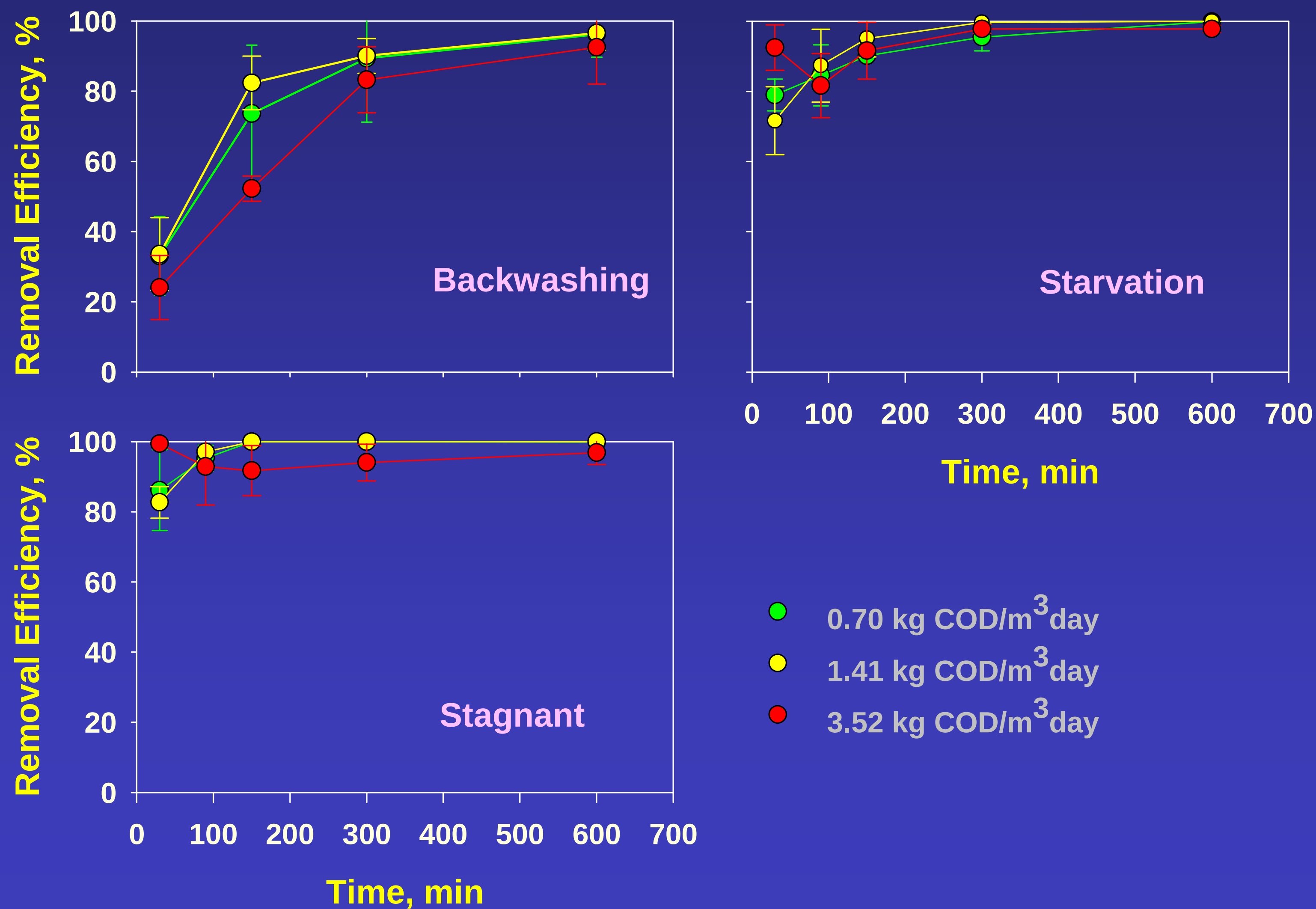
Result 2 (cont'd)

Summary 2-2. For backwashing strategy, much longer reacclimation period was required.
→ due to the loss of active biomass by conducting backwashing



Result 2 (cont'd)

Summary 2-3. For non-use period strategies, the biofilter response is different from that after backwashing.
→ the biomass played an important role in the reacclimation

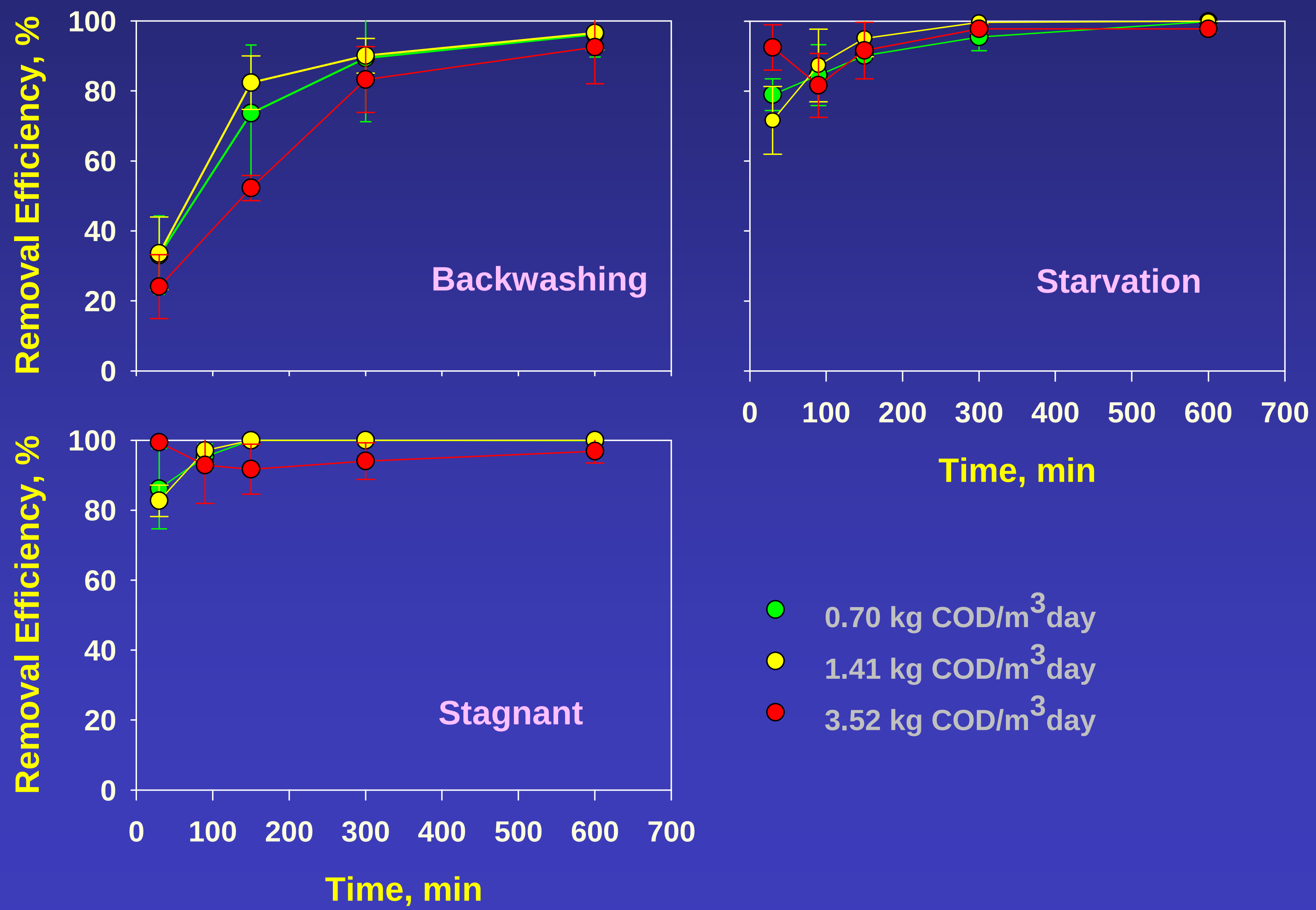


Result 2 (cont'd)

Summary 2- 4. At high loading rate for non-use periods,

→ initially, a likely breakthrough was observed

→ due to VOC adsorption on the biomass

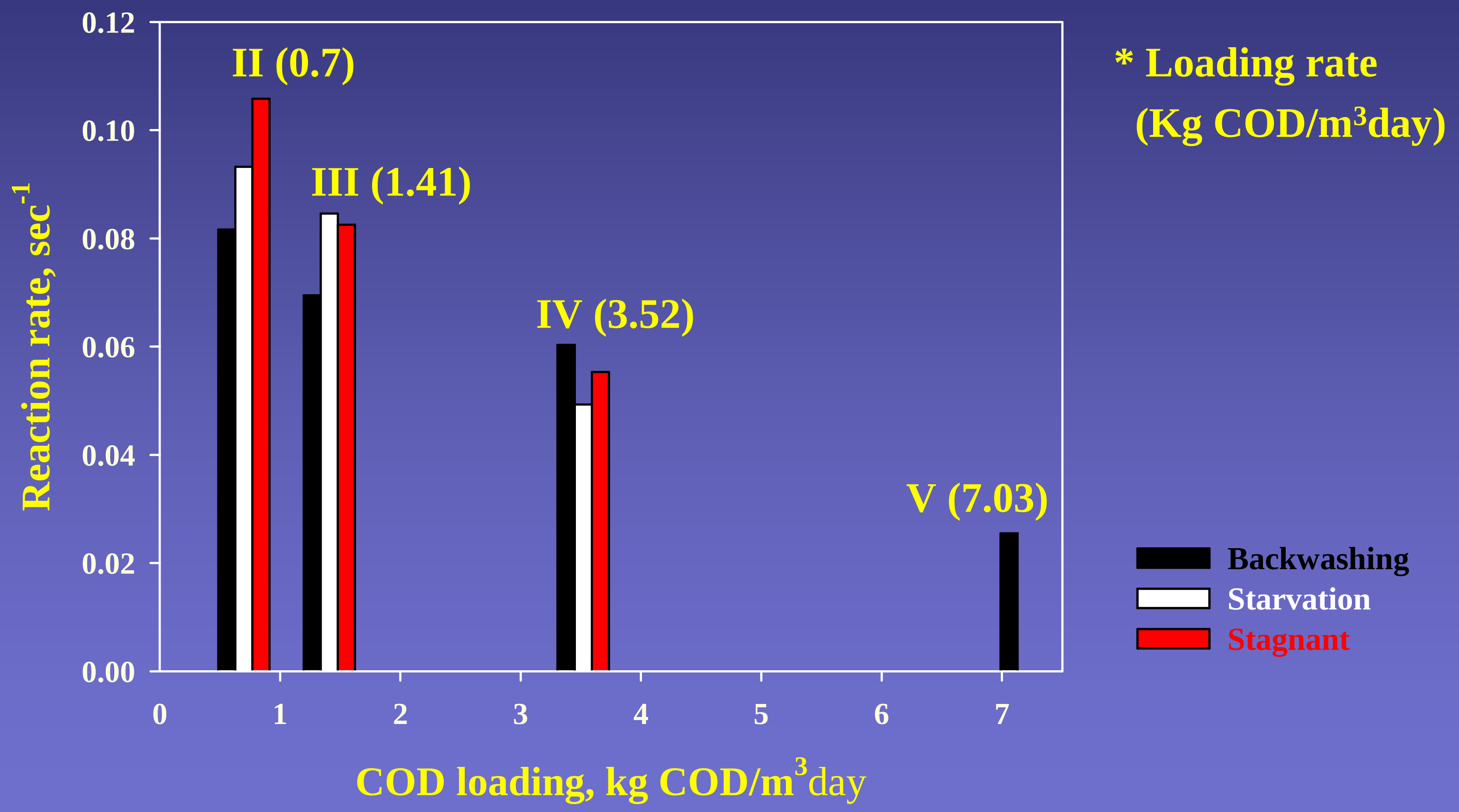


Result 3. Kinetic analysis

- Kinetic analysis for VOC removal
    - ✓ Based on a pseudo first order reaction rate as a function of depth in the biofilter

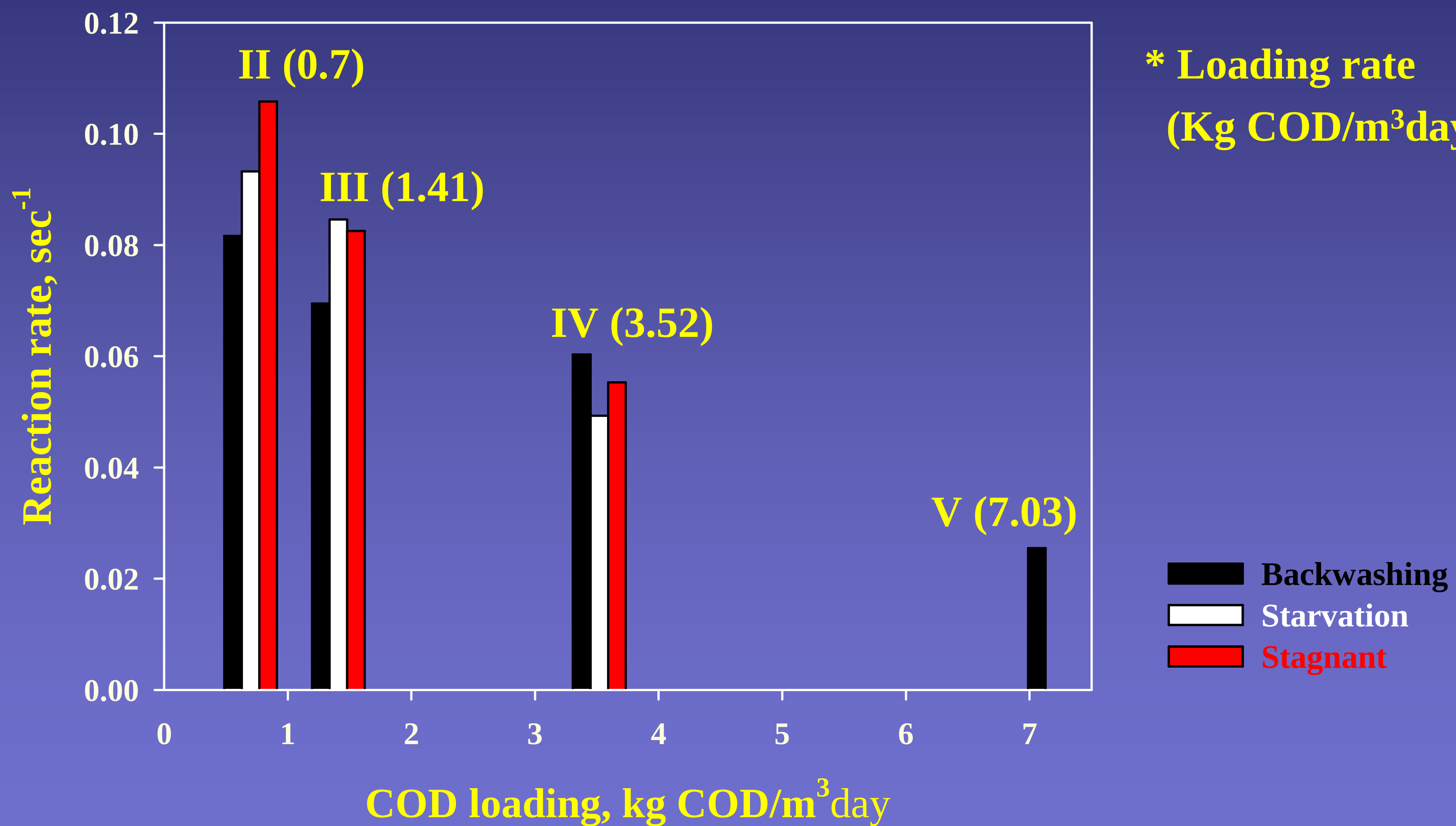
Result 3 (cont'd)

Result 3. Kinetic analysis



Result 3 (cont'd)

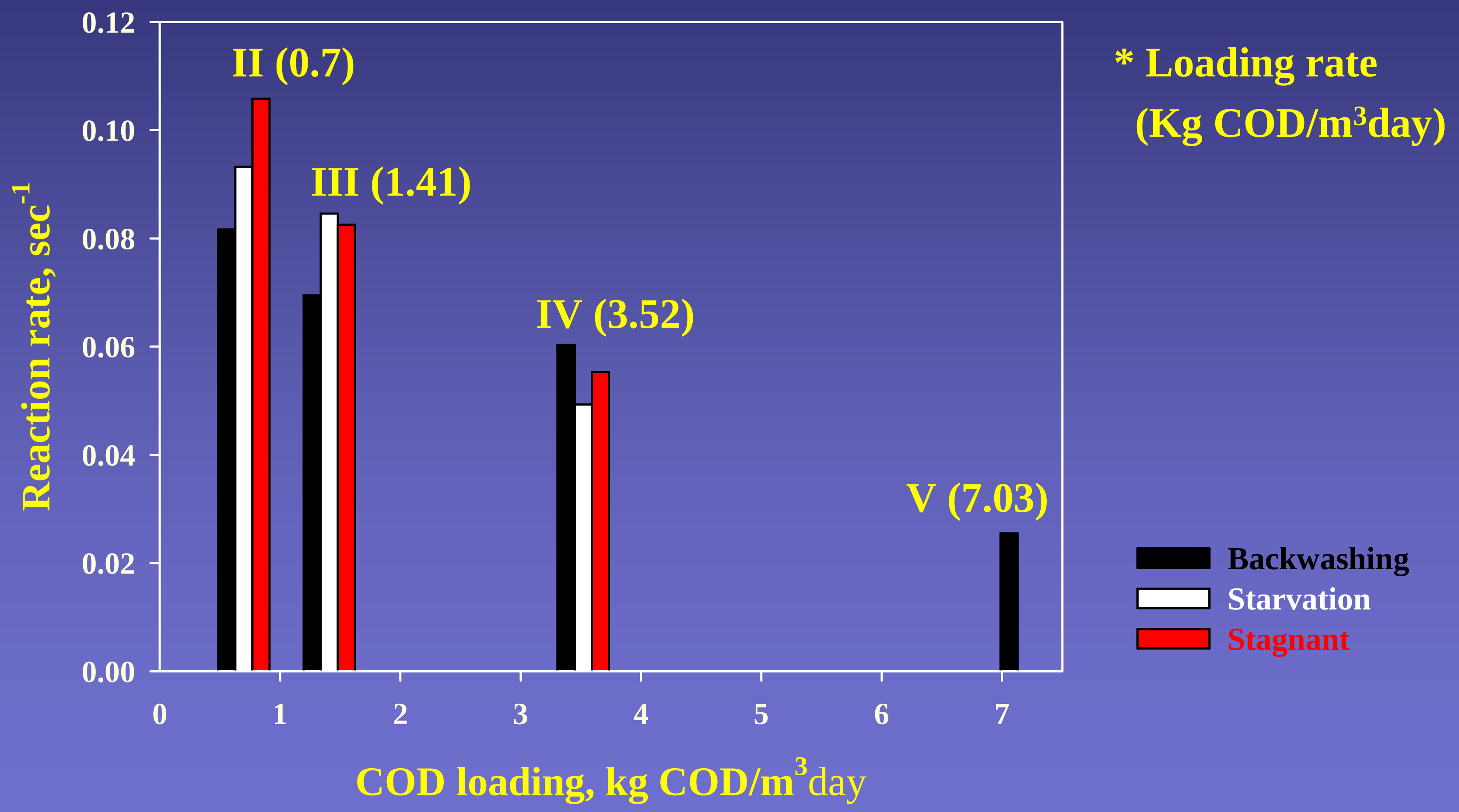
Summary 3-1. An increase in loading rate decreased reaction rates.



* Loading rate (Kg COD/m^3day)

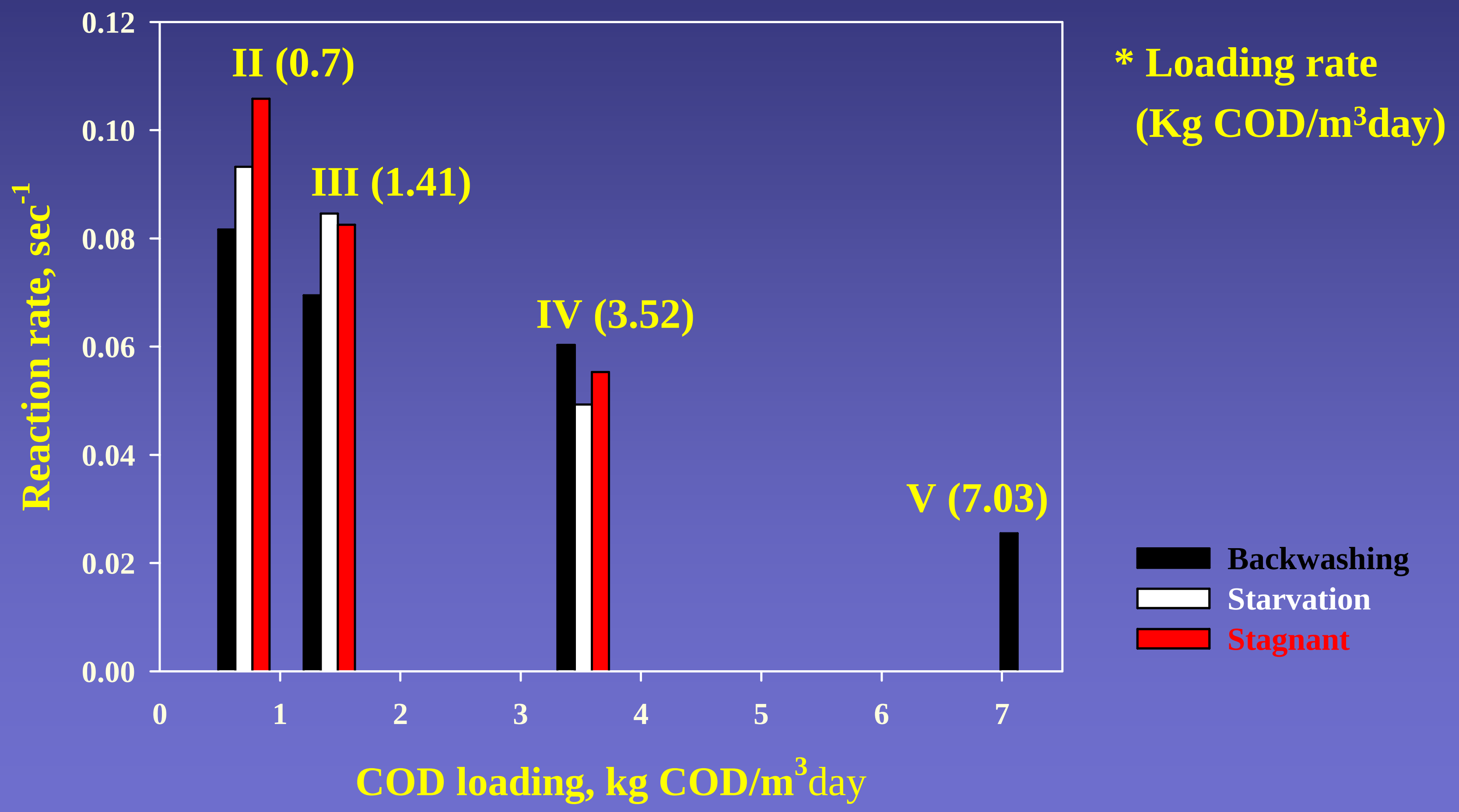
Result 3 (cont'd)

Summary 3-2. For low loading rate (0.7 and 1.41 kg COD/m^3day), non-use period strategies showed high reaction rates
→ might be due to availability of active biomass



Result 3 (cont'd)

Summary 3-3. For 3.52 kg COD/m^3day,
non-use period strategies showed low reaction rates
→ might be due to high accumulation of the biomass



Conclusion

- High performance of TBAB was observed for all experimental strategies up to 3.52 kg COD/m^{3}day (250 ppmv).
- However, during the reacclimation periods following backwashing and non-use period, the TBAB unit can not comply with emission regulations.

$\rightarrow$ the limitation of current TBAB system demands

novel VOCs control technology

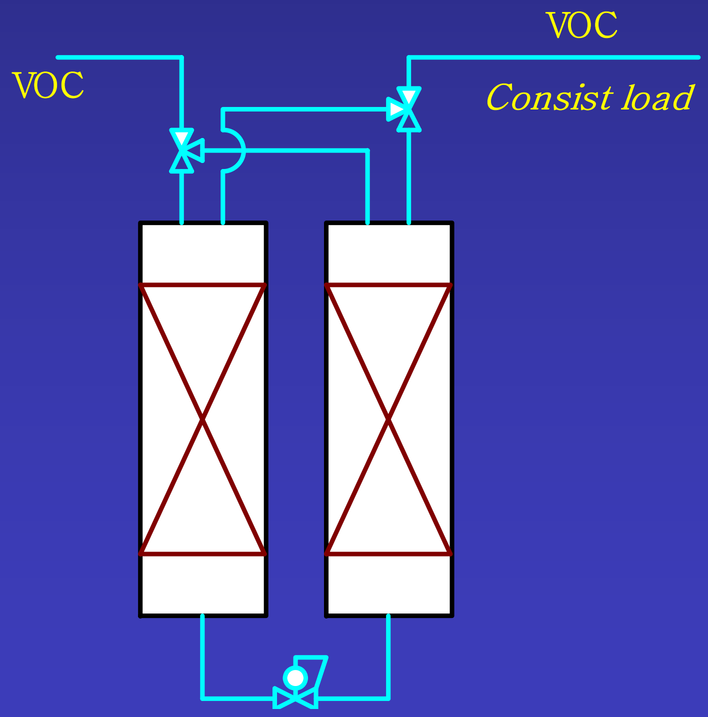
Future Works

- Issue
  - ✓ Need to decrease reacclimation periods
  - ✓ Need to mitigate shock load & load fluctuations
- Goal
  - ✓ Yield consistently high VOC removal efficiency
- Proposal
  - ✓ Employ a preliminary unit as a buffer

Future Works (cont'd)

Preliminary unit: Pressure swing adsorption (PSA) unit

✓Operated under long term adsorption/desorption cycles



Future Works (cont'd)

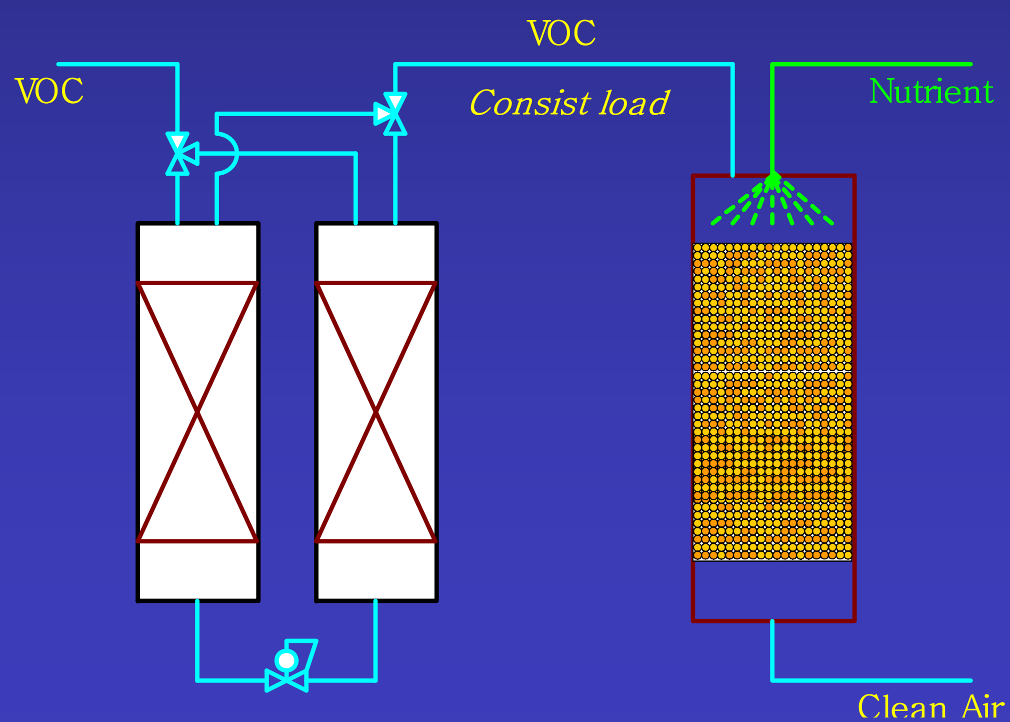
Combined Treatment : PSA + TBAB

→ Long term, high performance for VOC removal

Functions

During backwashing
for biofilter unit
→ PSA:
a sole unit of purification

During reacclimation period
for biofilter unit
→ PSA: a buffer unit



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