

Coupling Biological Reductive Dechlorination and Adsorption for TCE Removal Exploiting Raw Polyhydroxyalkanoates (PHA) from Organic Waste as Electron Donor and Pine Wood Biochar (PWB)

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DIPARTIMENTO DI CHIMICA



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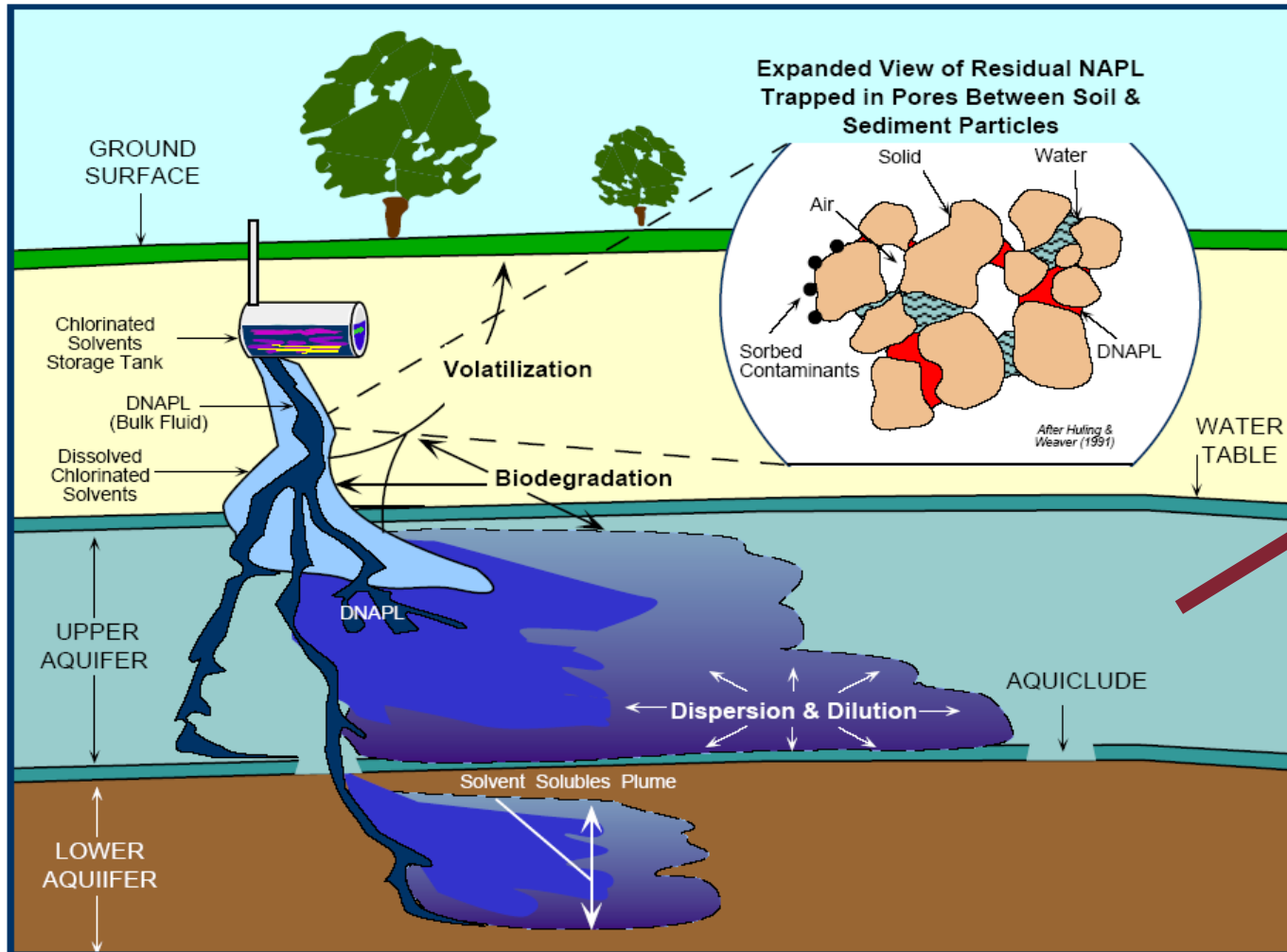
2024 Chlorinated Conference

June 2-6, 2024 | Denver, Colorado

battelle.org/chlorcon | [#Chlorinated2024](https://twitter.com/Chlorinated2024)

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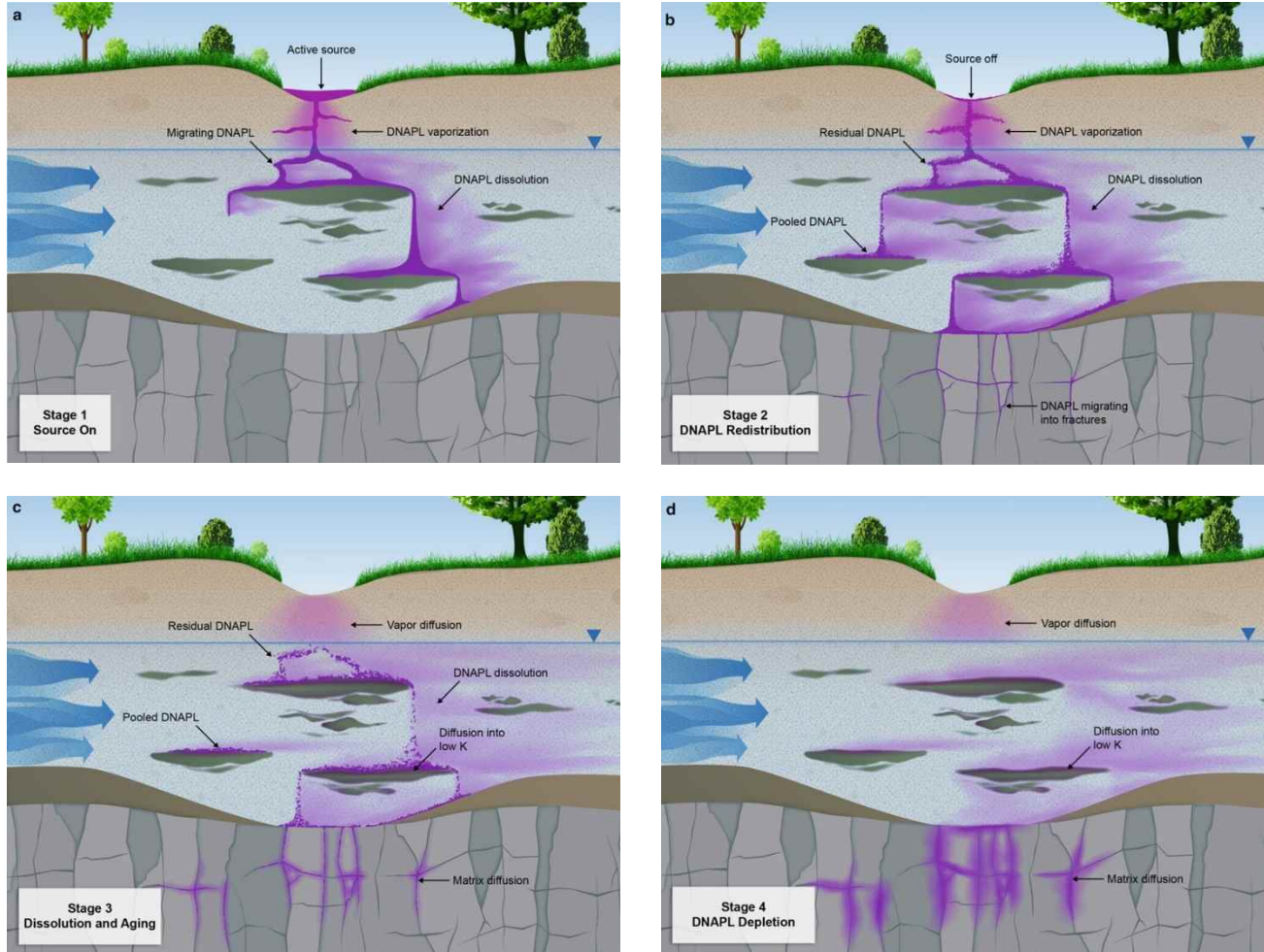
Typical DNAPL contamination scenario (the chlorinated solvent problem)



Due to higher density than water, DNAPLs migrate vertically also in the saturated zone (aquifer). Depending on the soil heterogeneity and spilled amount, contamination could reach significant depth.

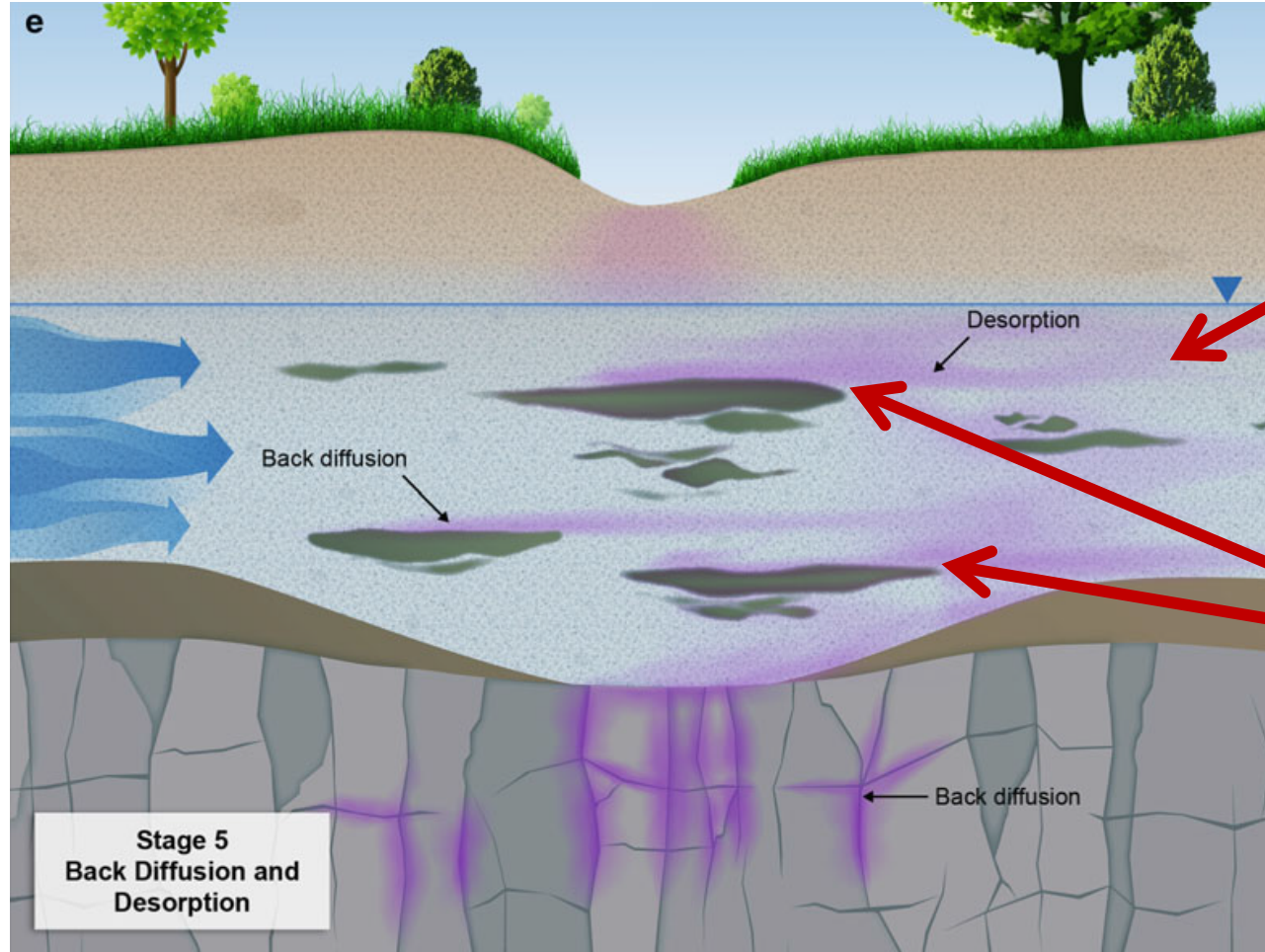
Significant aging of the secondary sources

Aging of the contamination source (DNAPLs)



- **Initially**, particularly **mobile** separate phase associated to the zones with **higher permeability**
- **Progressive depletion** of the separated phase by volatilization, solubilization and degradation
- **Progressive "concentration"** of the residual fraction in the zones with **lower permeability** (due to slow molecular diffusion)

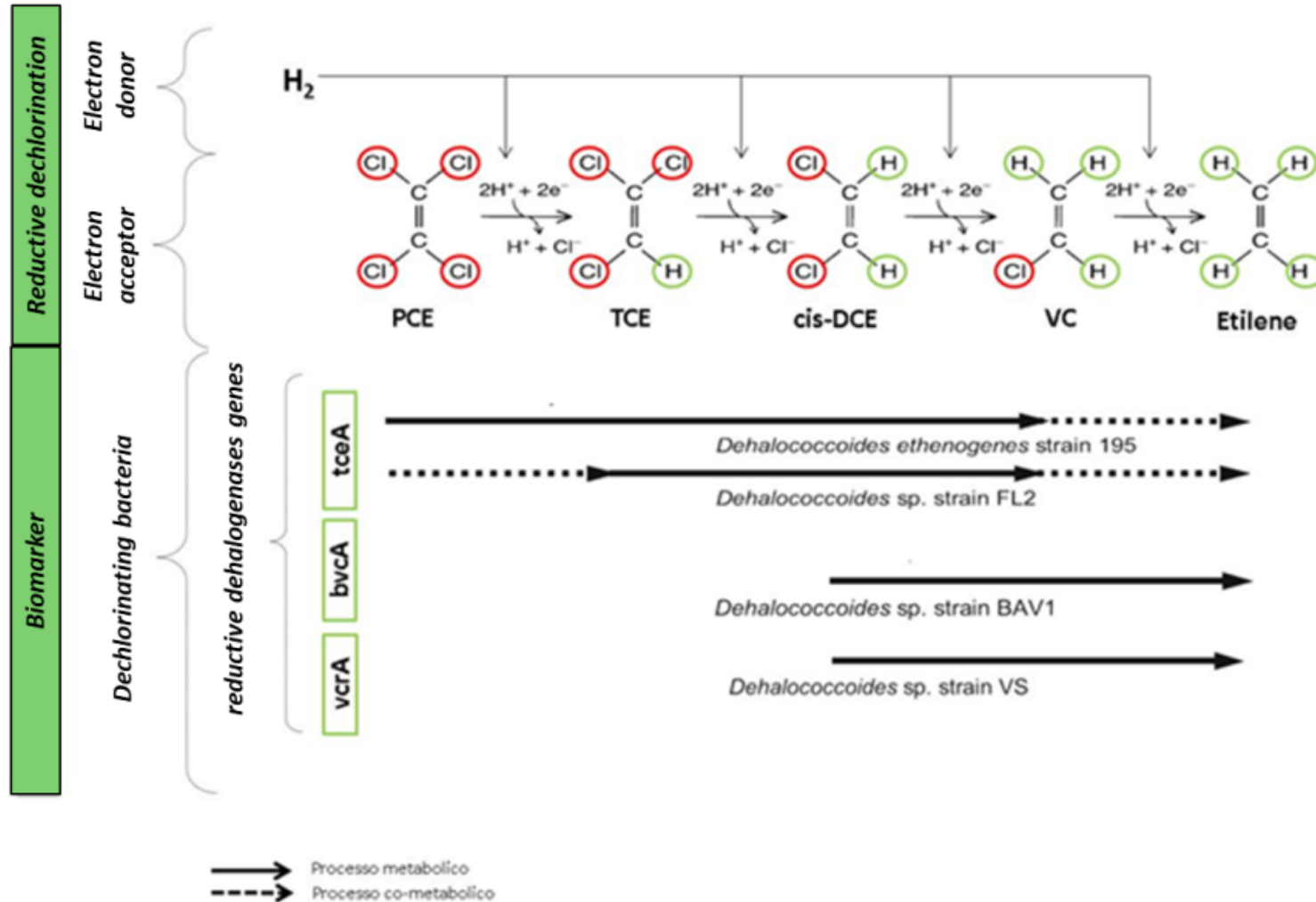
Strategies for the remediation of contaminated soil/groundwater from NAPLs (management of the source and the plume)



«Sustainable» management
of the persistent plumes of
contamination

«Effective » technologies
in the removal of active
secondary sources
(strictly related to the
aging stage)

in-situ Enhanced Bioremediation



Some limiting factors

- Lack of electron donor
- **Low residence time**

NINTH INTERNATIONAL CONFERENCE ON REMEDIATION OF CHLORINATED AND RECALCITRANT COMPOUNDS

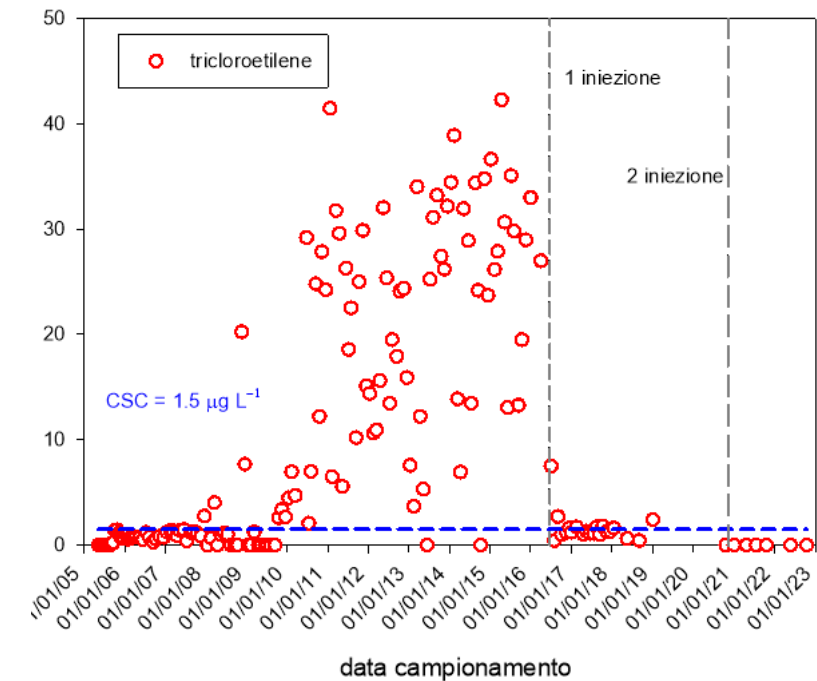
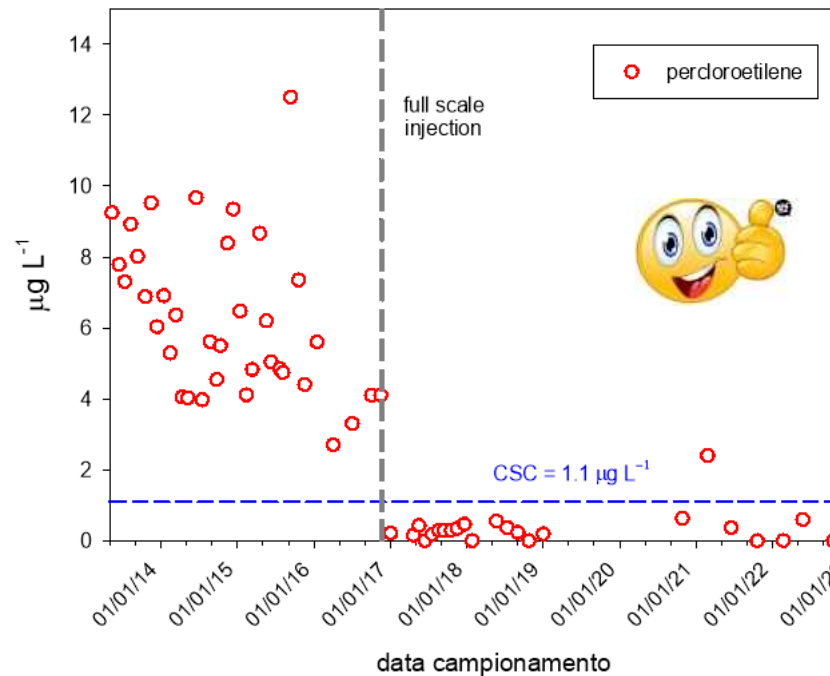
May 19-22, 2014 | Monterey, California

What is PlumeStop™?

- Non-toxic, Liquid Activated Carbon
- Very fine particles of activated carbon (1-2 μm)

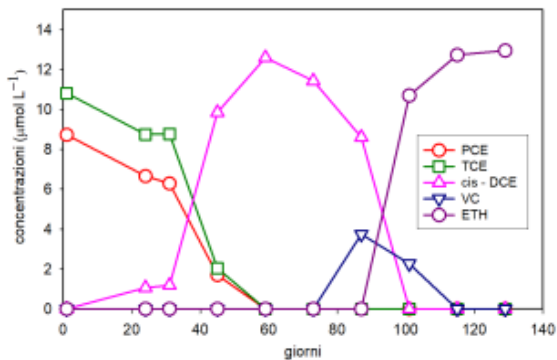
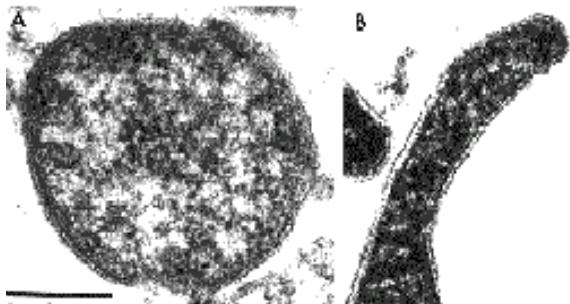
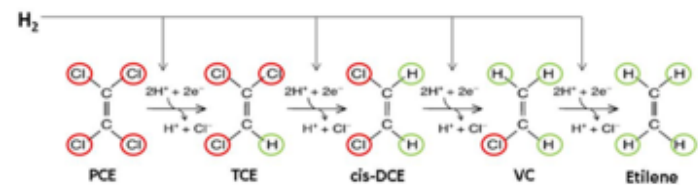


First Full-Scale Application in Europe (2016) High-Speed Railway Station (Bologna)

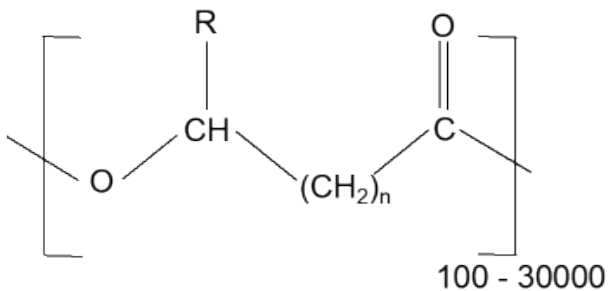


Combination of processes for sustainable approach at CAH remediation

Biological reductive dechlorination

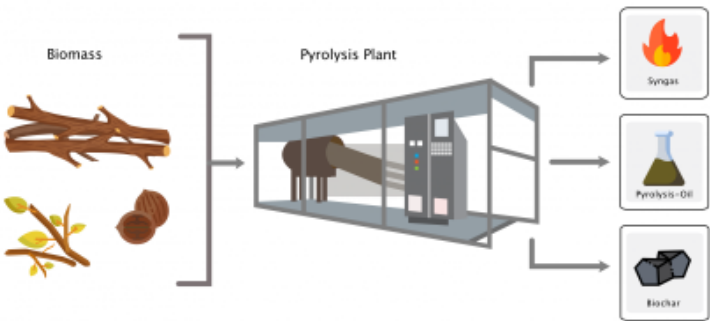


Biodegradable plastics from waste valorization



Poly-Hydroxy-Alcanoate, PHA

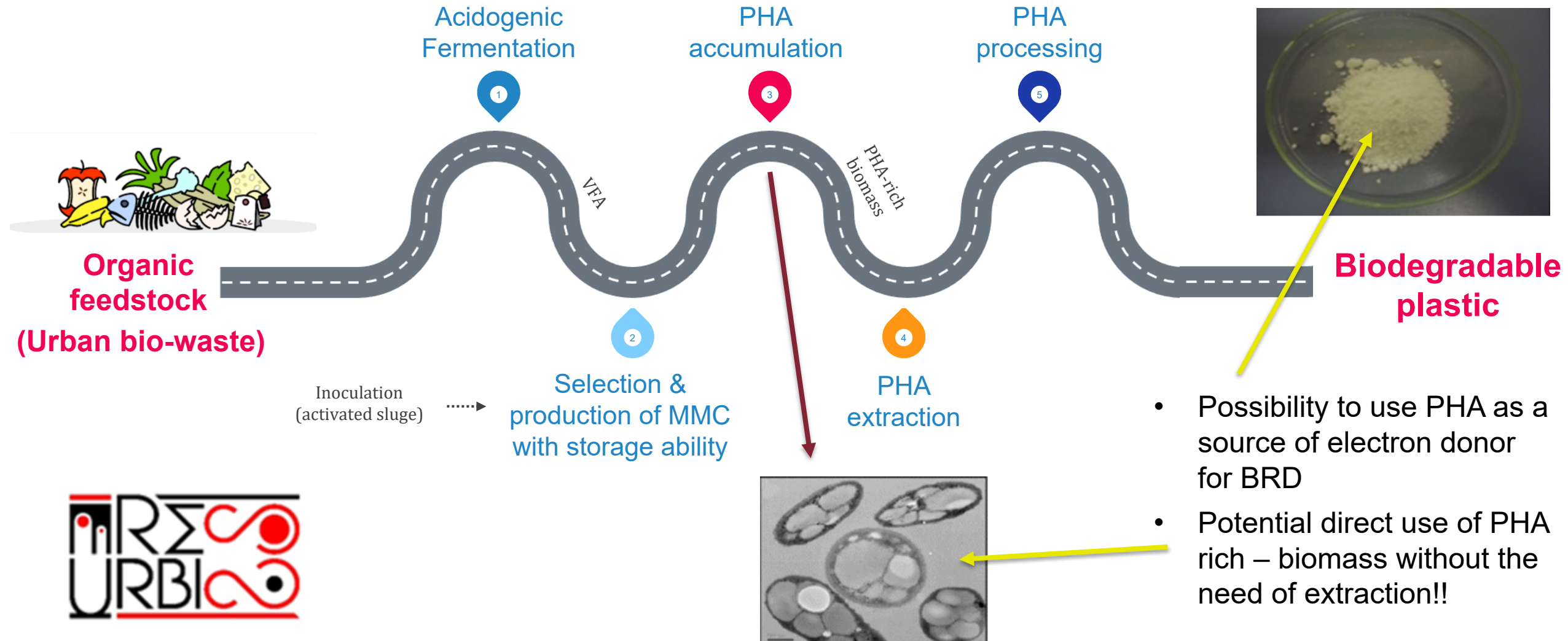
«low cost» sorbent materials (biomass valorization)



biochar



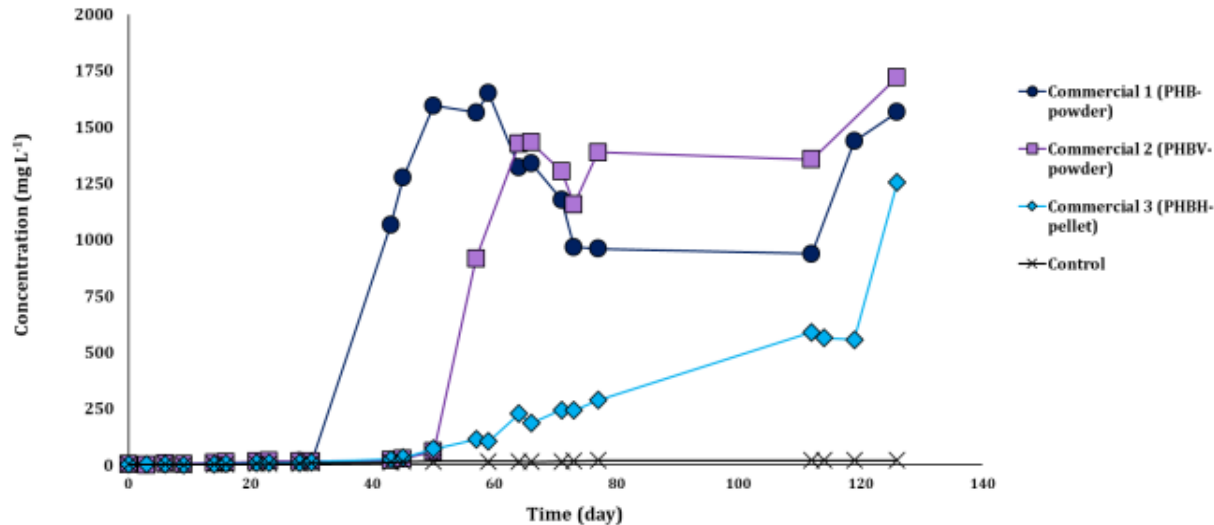
Production of PHA from Mixed Microbial Cultures (MMC)



PHA batch fermentation tests

(commercial vs MMC products)

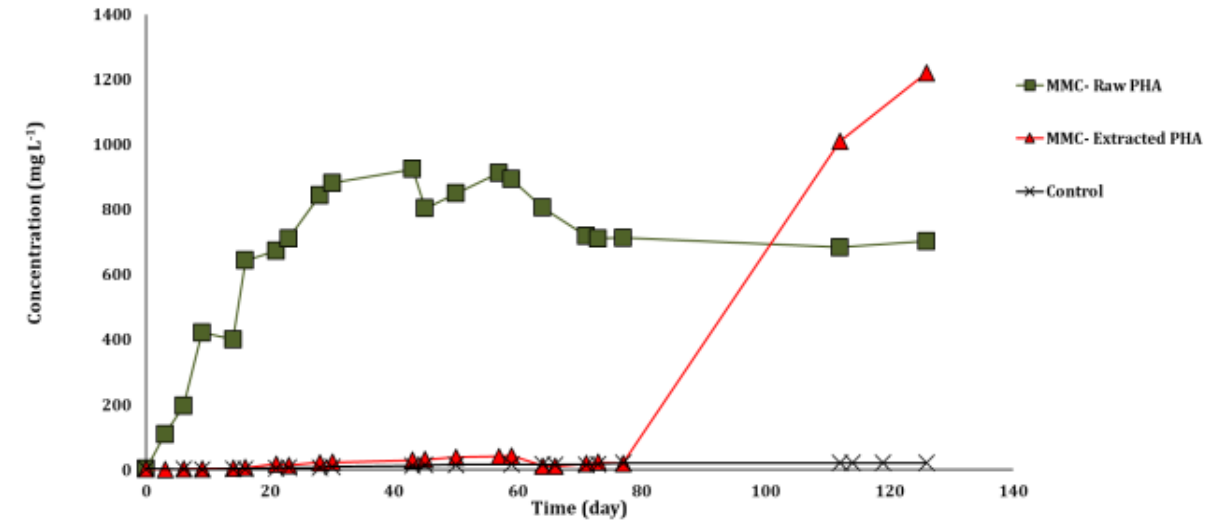
Total VFA Totali (mg L⁻¹) - Commercial Products



Different behavior in fermentation:

- Difference in particle size
- Difference in composition of materials

Total VFA Total (mg/L) - Products from RES URBIS project

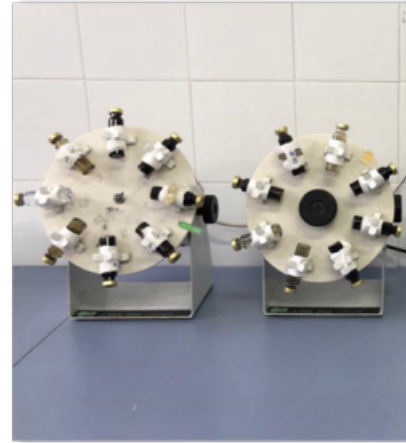
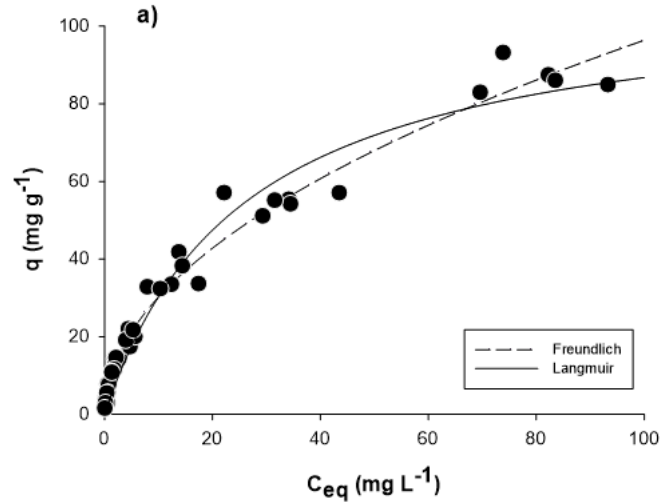


Raw PHA :

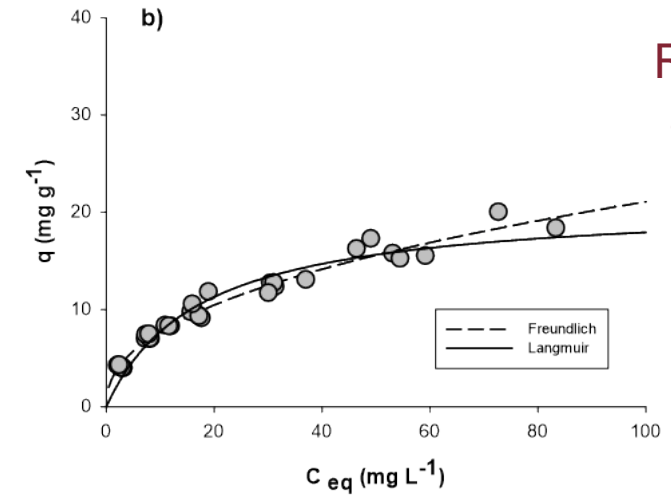
- Total VFA concentration comparable with that of other materials
- Almost immediate fermentation (after 5 days)
- Economic and environmental advantage (does not undergo the extraction and purification phase)

TCE adsorption onto biochars (batch test – isotherms)

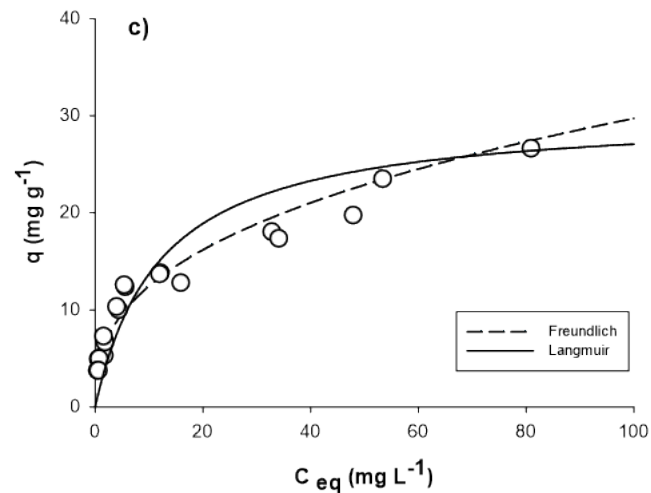
Pine wood
343 m² g⁻¹



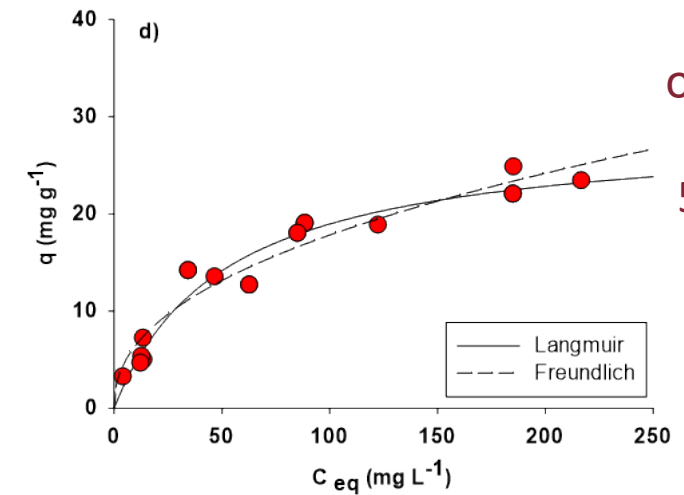
Rice husk
81 m² g⁻¹



Iron enriched
Eupatorium
97 m² g⁻¹

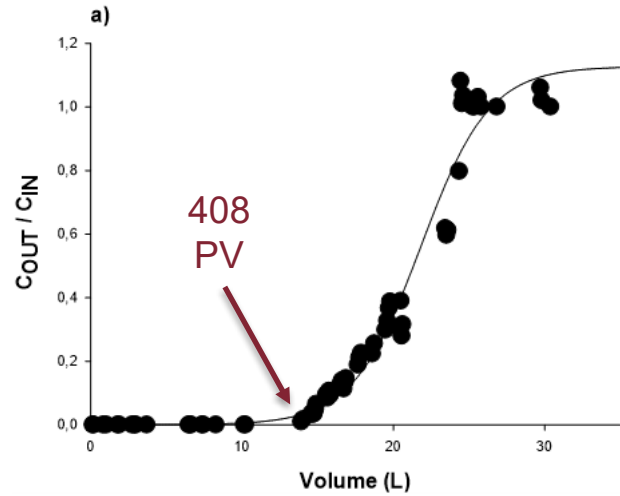


char from
tyres
58 m² g⁻¹

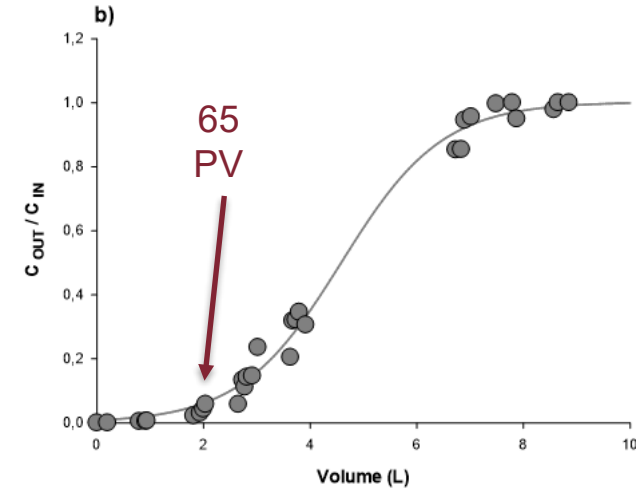


TCE adsorption onto biochars (column tests)

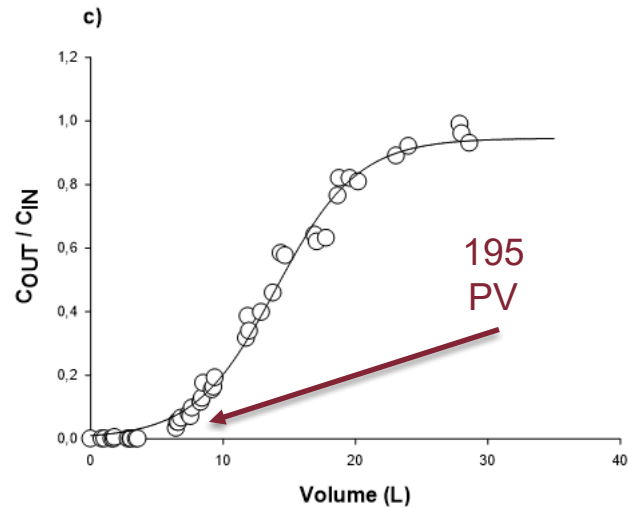
Pine wood



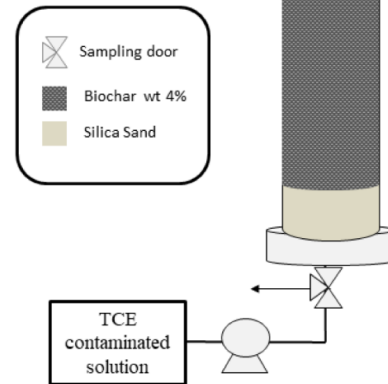
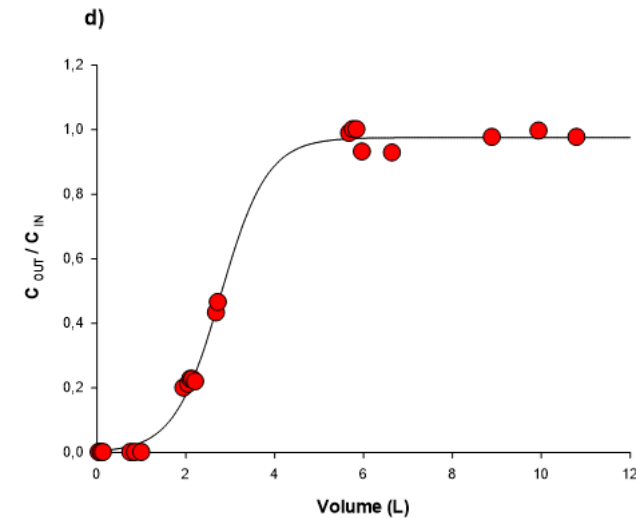
Rice husk



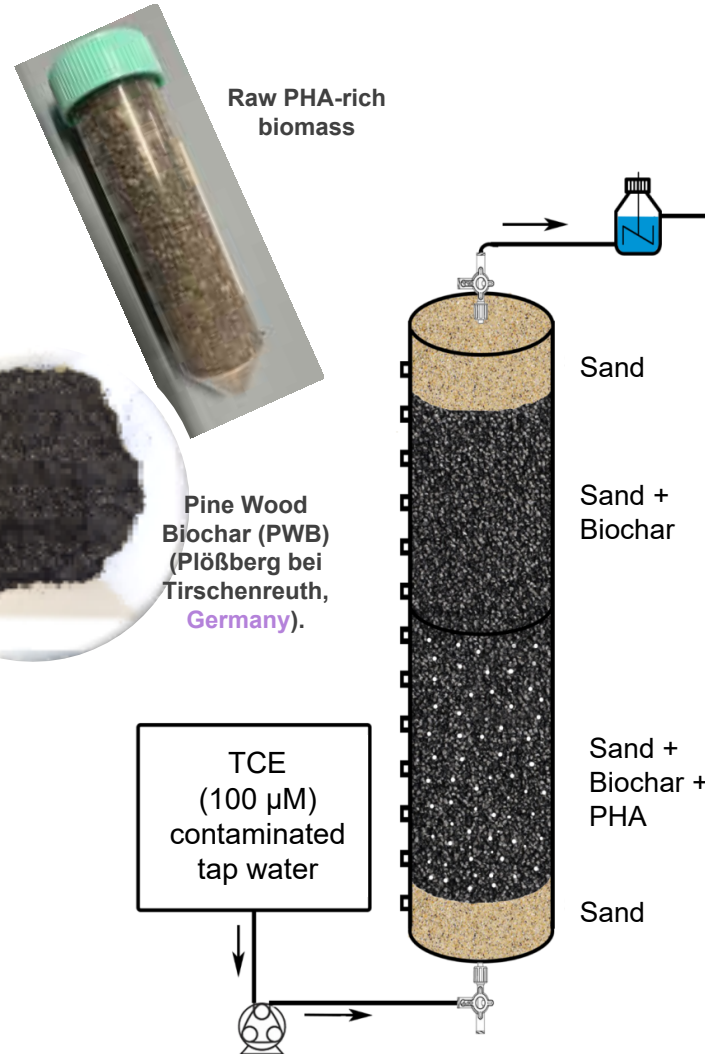
Iron enriched
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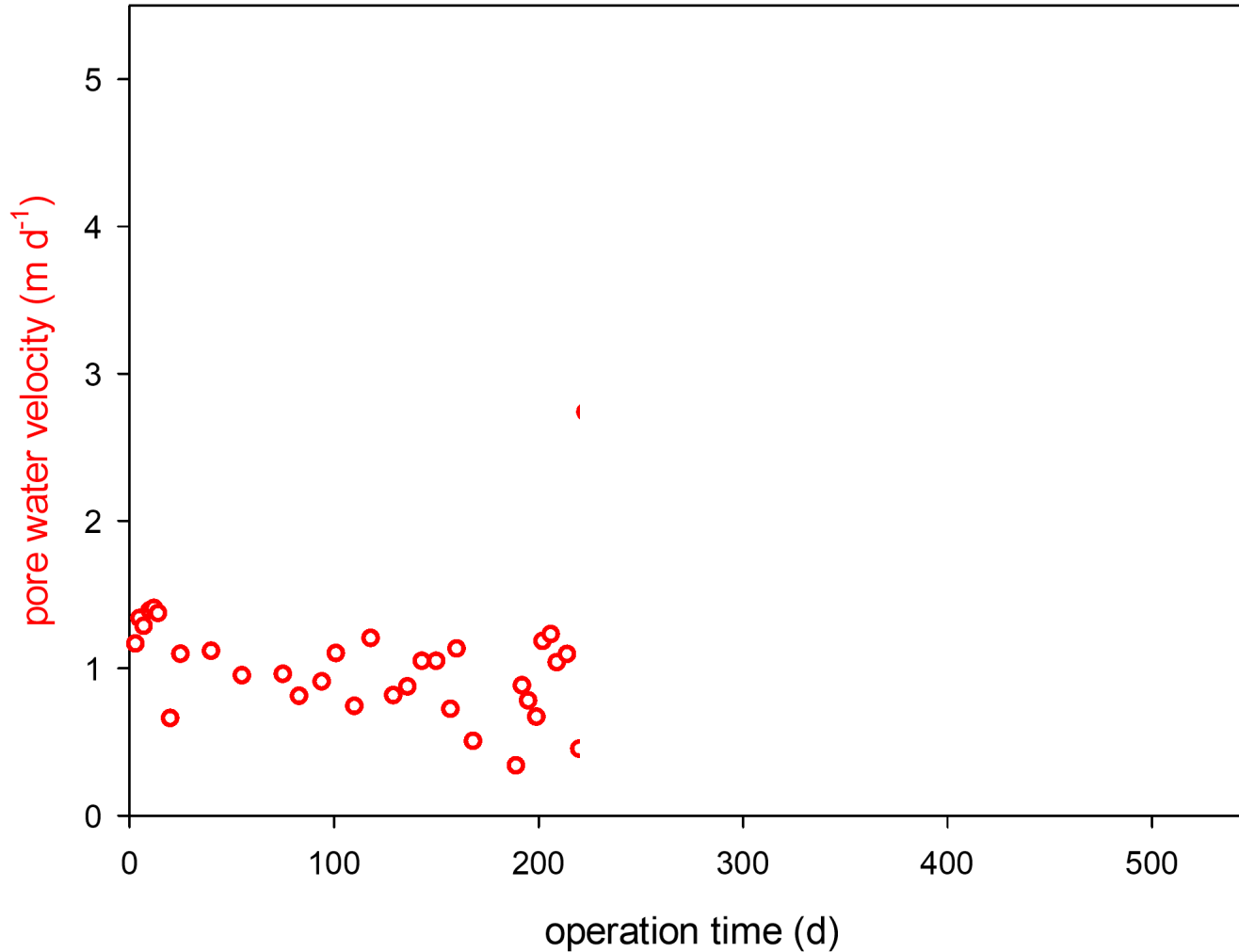


The combined strategy (BRD-biochar adsorption-raw PHA as ED)



- **Column**
 - Height: 144 cm
 - Diameter: 10 cm
 - 4 %wt of PHA e PWB
- **Gates 1 and 13**
 - Sand
- **Gates 2-7**
 - 250 g raw PHA
 - 250 g PWB
- **Gates 8-12**
 - 300 g PWB
- Dechlorinating culture recirculated for inoculating the whole column

Operating conditions (linear velocity)



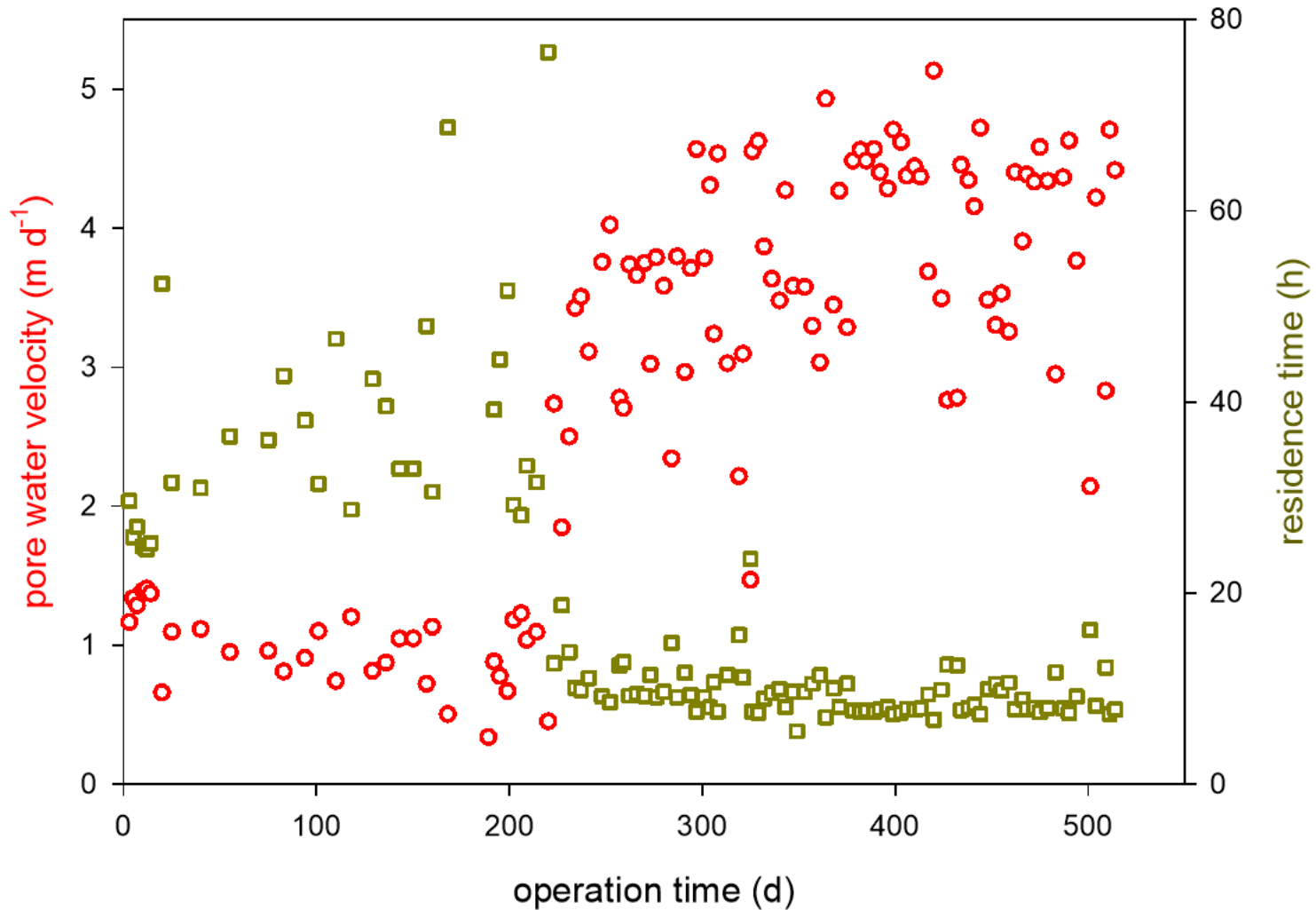
Average linear velocity during the first period (until day 230):

1.1 m/d

Average linear velocity during the second period (since day 231):

3.8 m/d

Operating conditions (Hydraulic Residence Time)



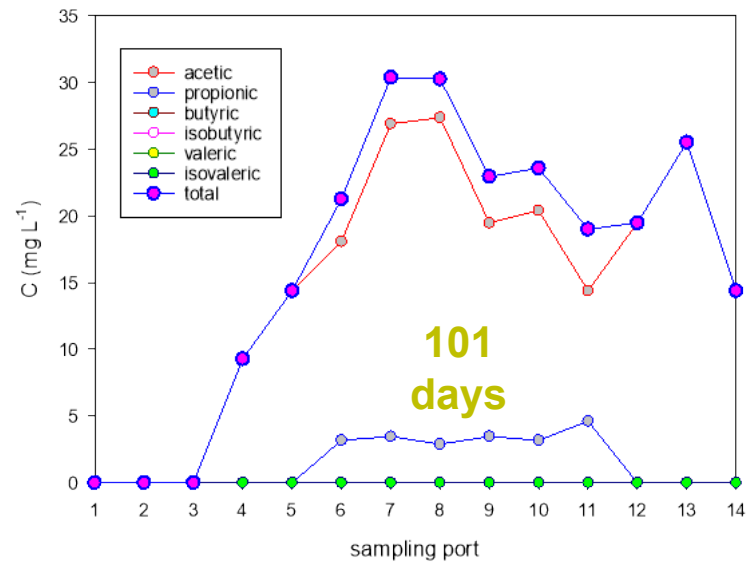
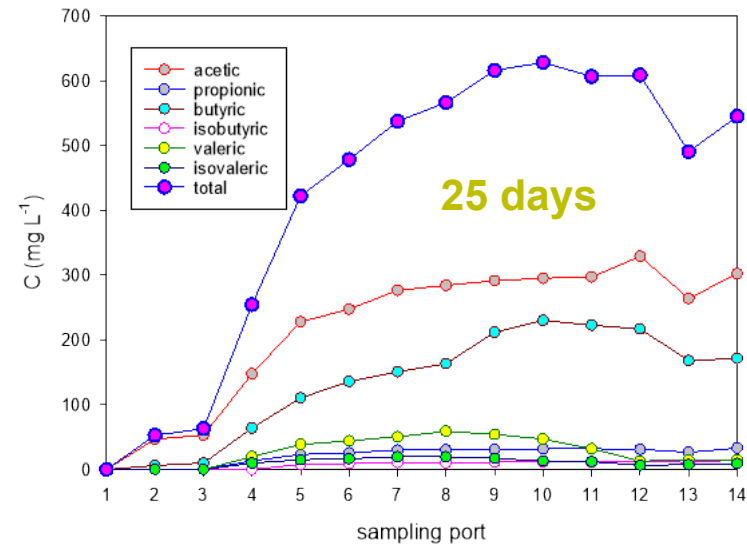
Average HRT during the first period (until day 230):

Around 40 hours

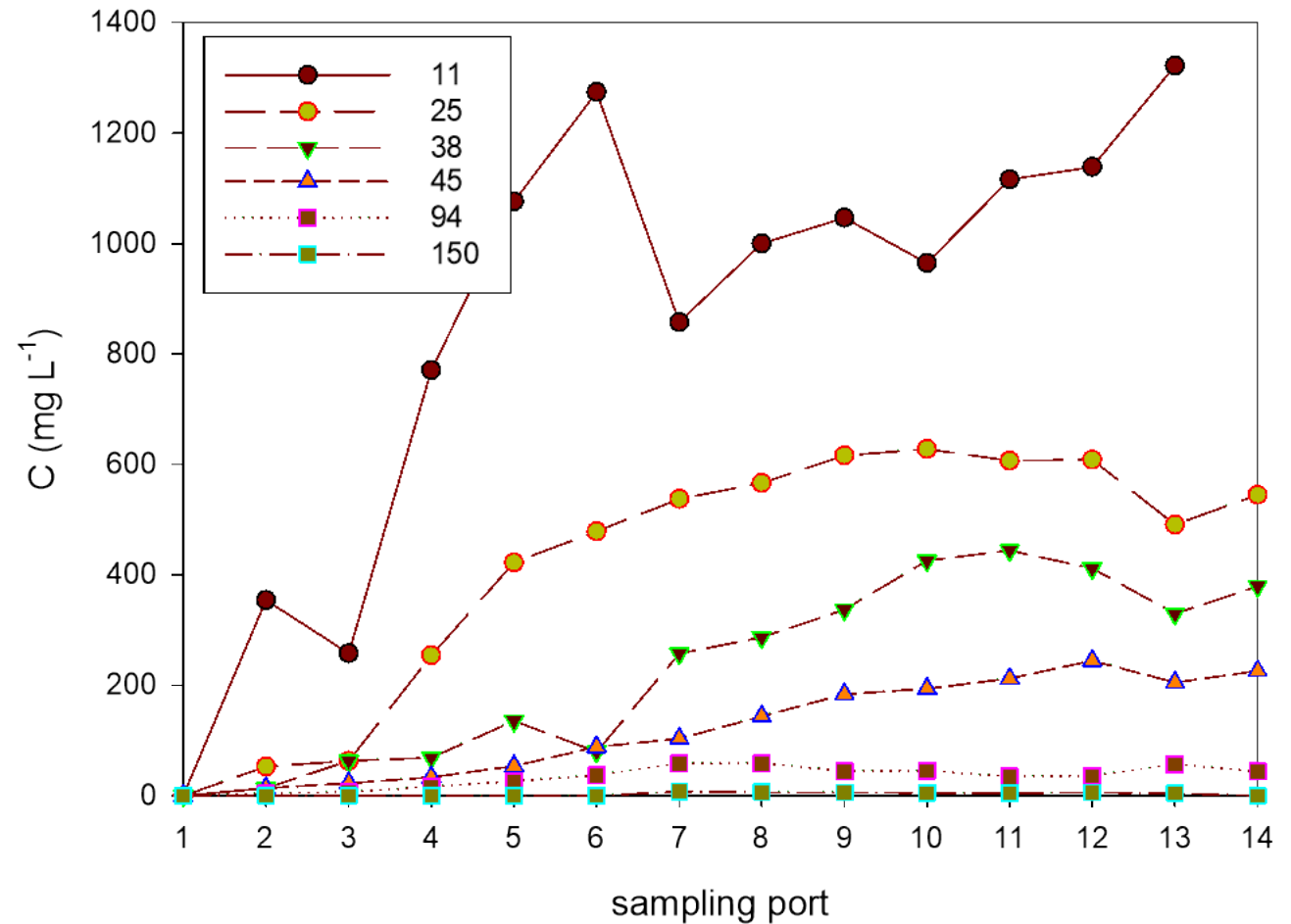
Average HRT during the second period (since day 231):

Around 8 hours

VFA production during operating time



Total VFA along the column profile

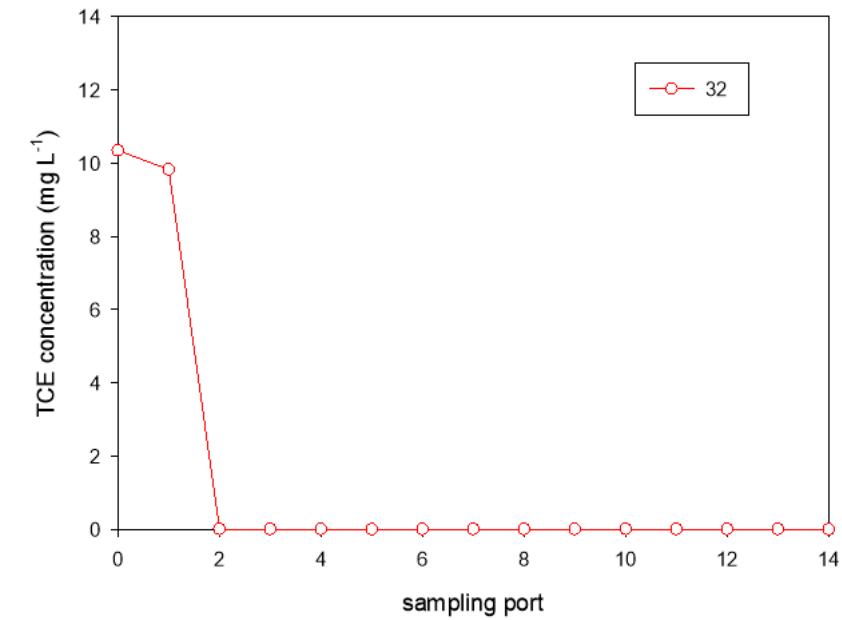
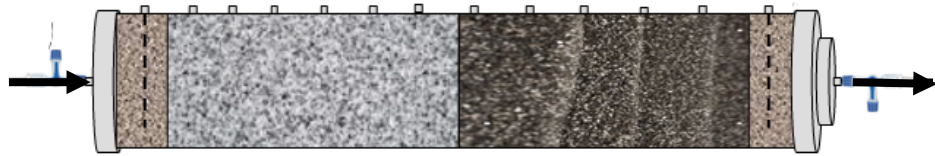


The combined strategy (column profiles at different operative days)

TCE

Biochar/PHA

Biochar

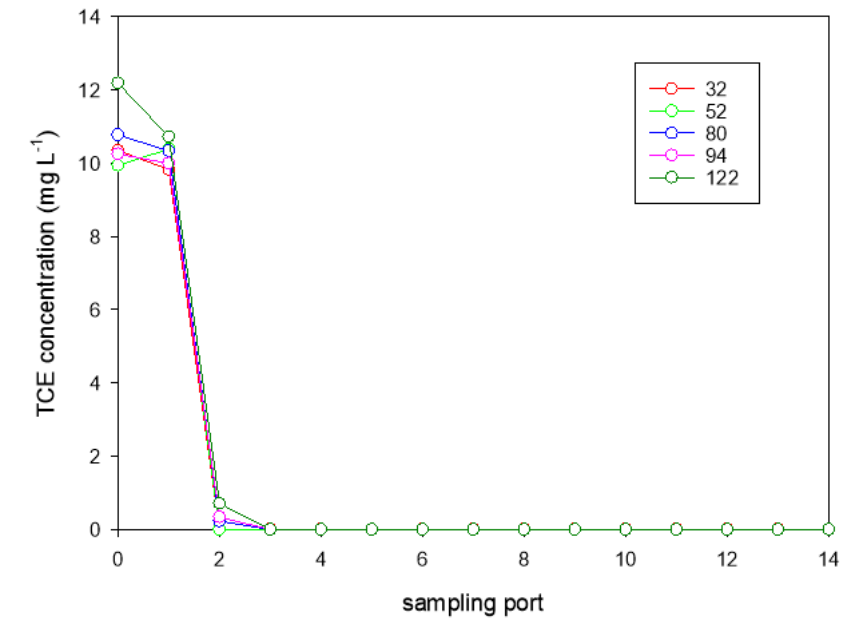
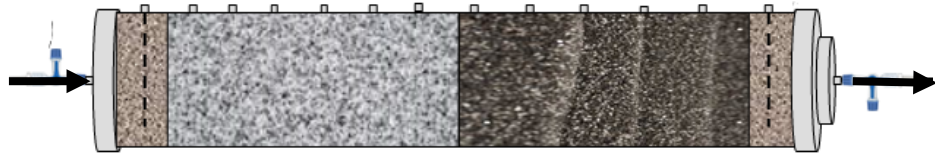


The combined strategy (column profiles at different operative days)

TCE

Biochar/PHA

Biochar

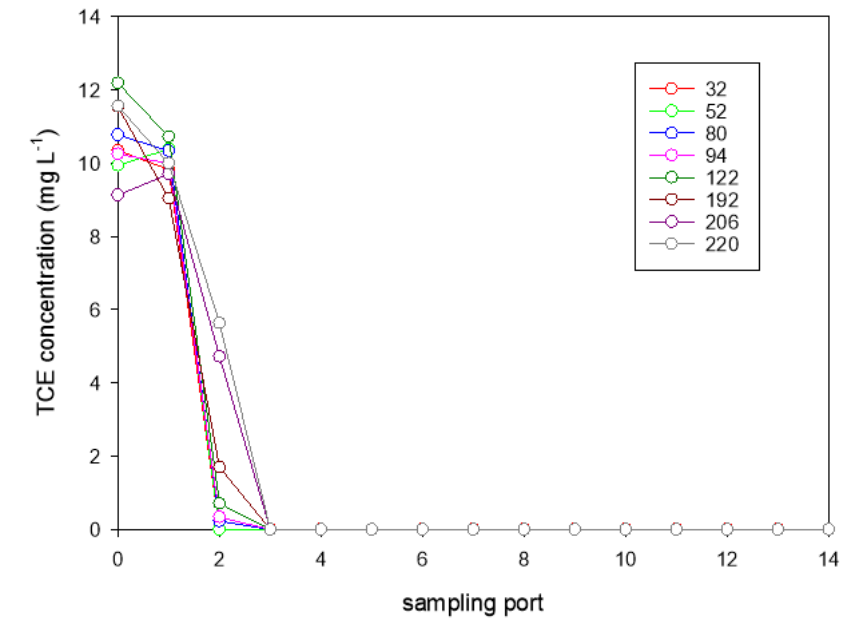
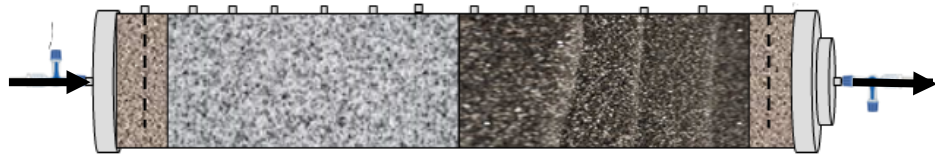


(column profiles at different operative days)

TCE

Biochar/PHA

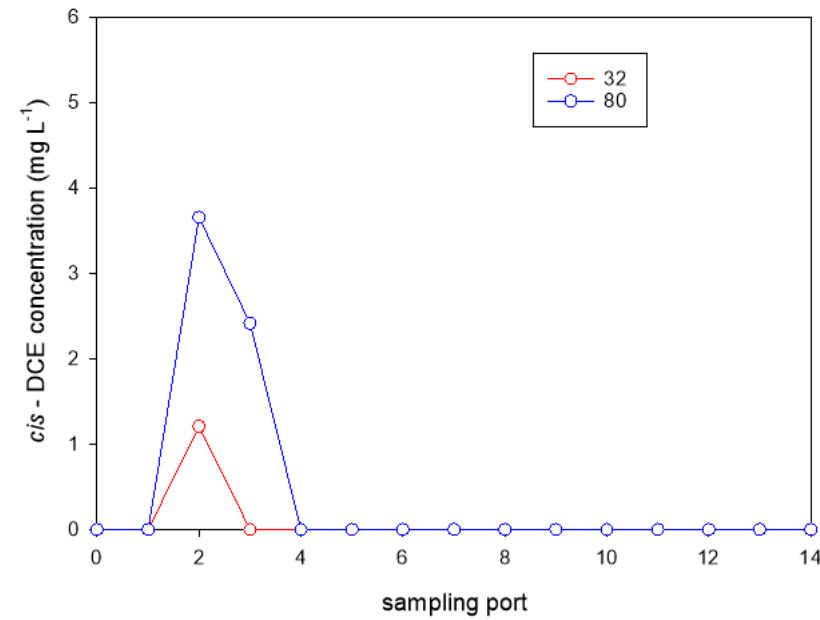
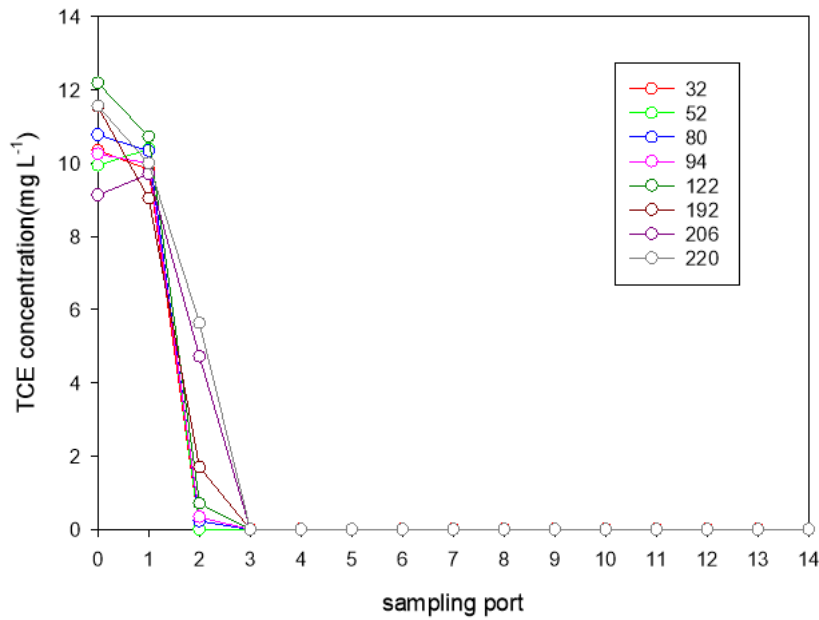
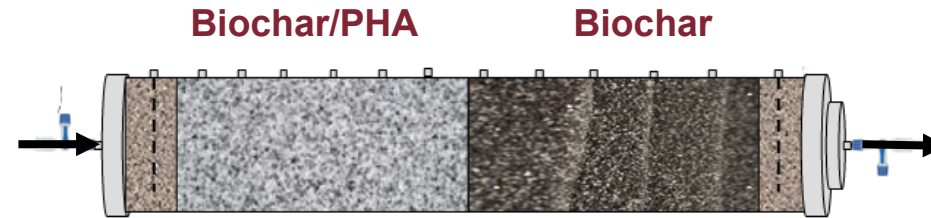
Biochar



The combined strategy (column profiles at different operative days)

TCE

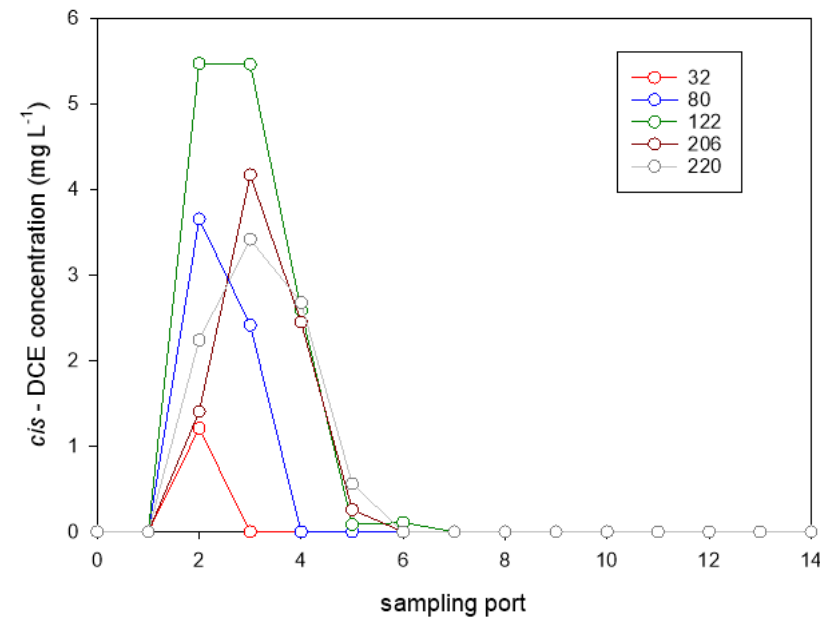
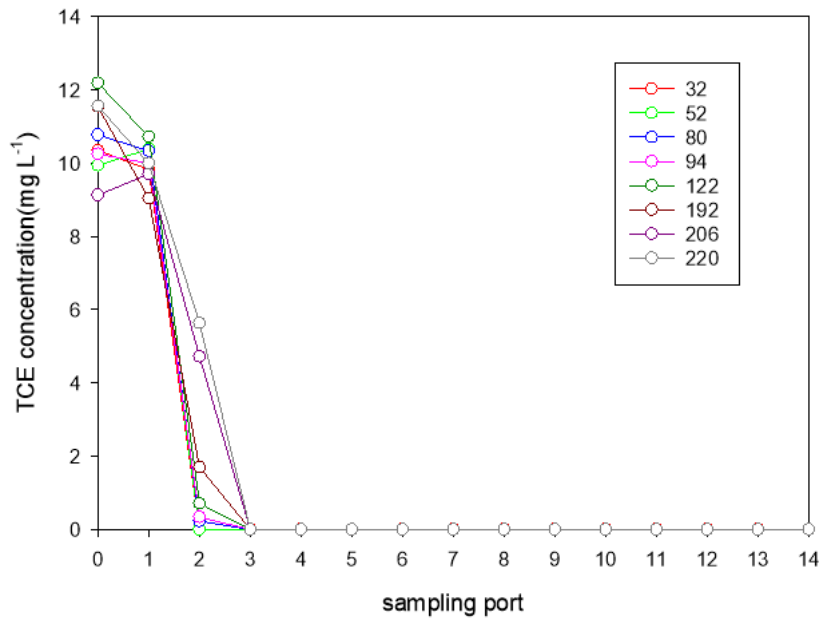
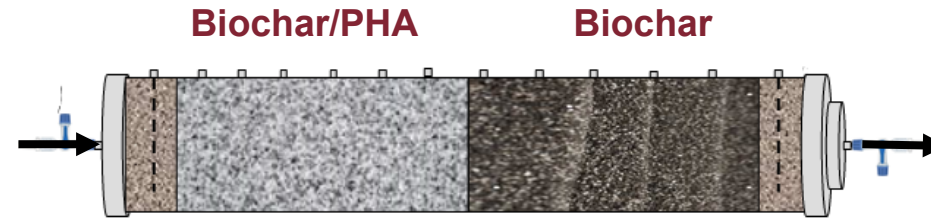
cis - DCE



The combined strategy (column profiles at different operative days)

TCE

***cis* - DCE**

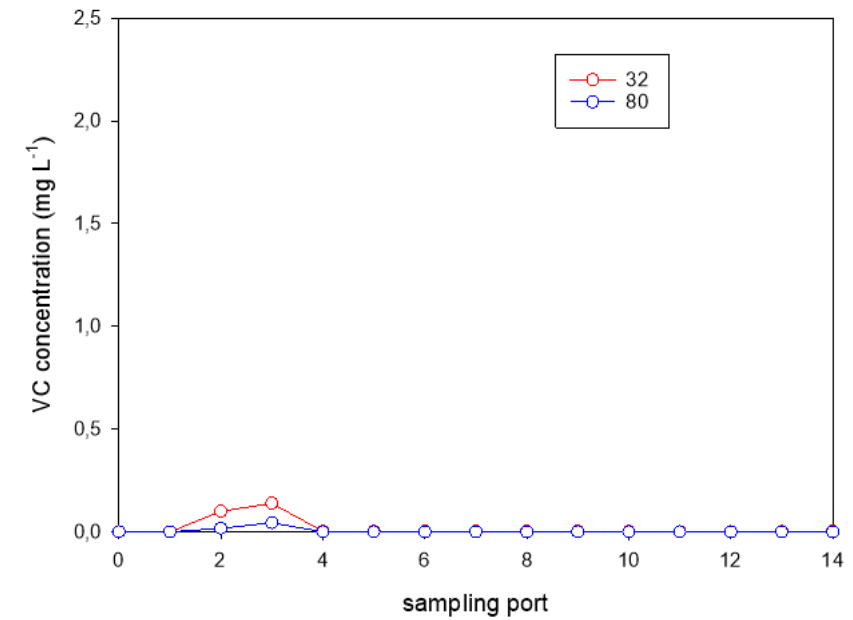
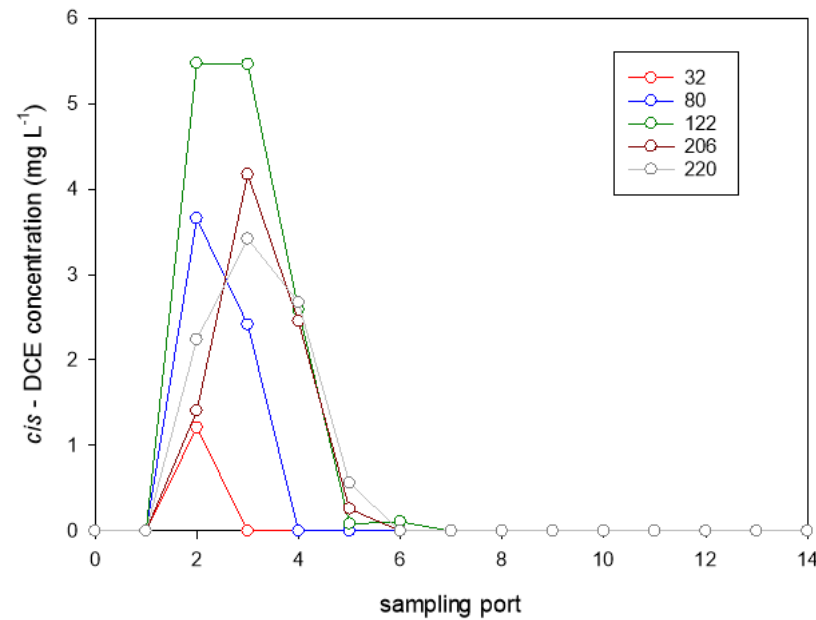
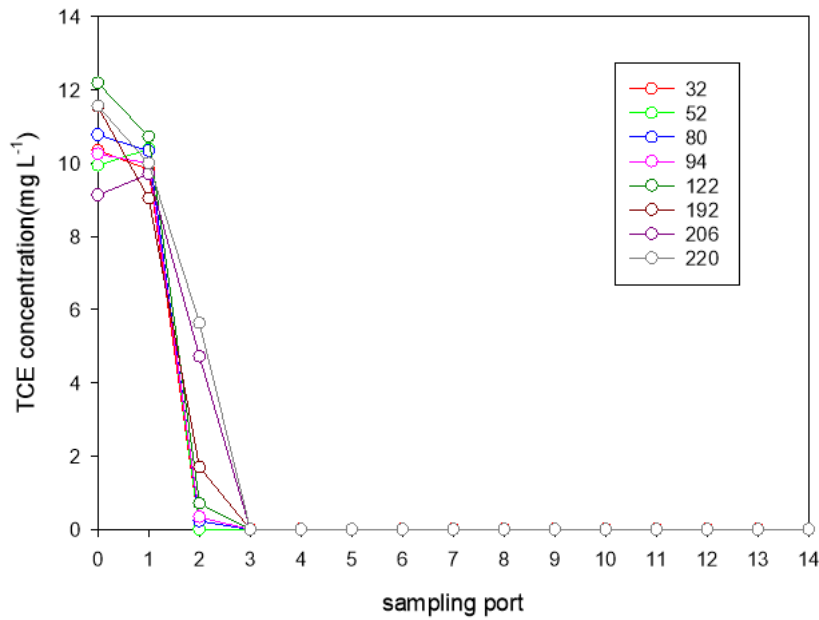
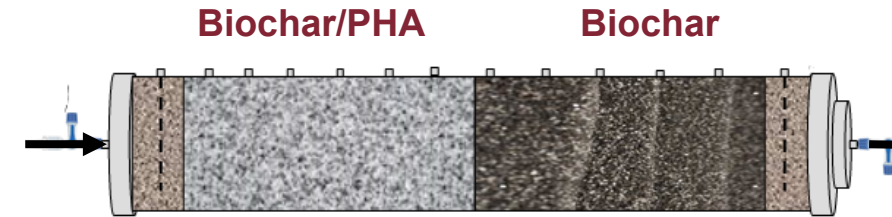


The combined strategy (column profiles at different operative days)

TCE

***cis* - DCE**

VC

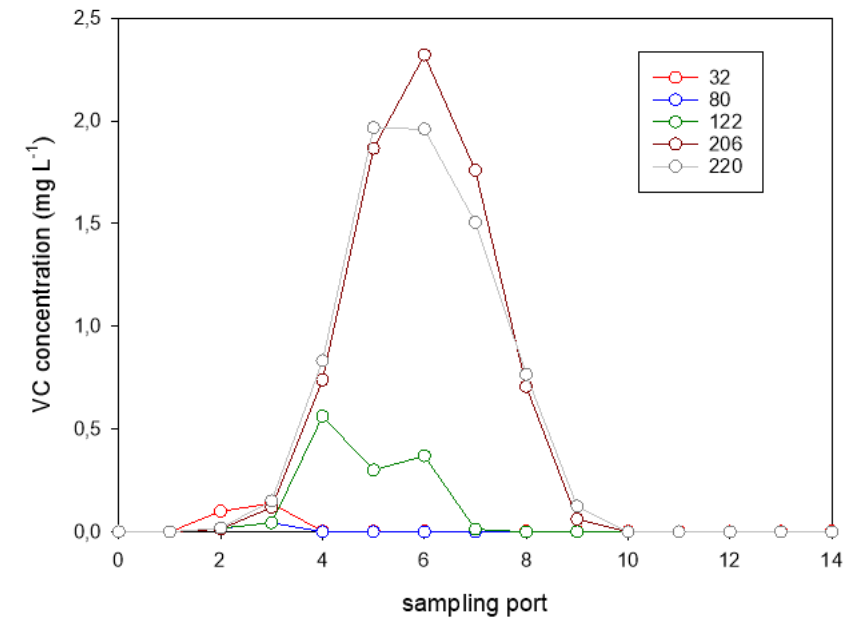
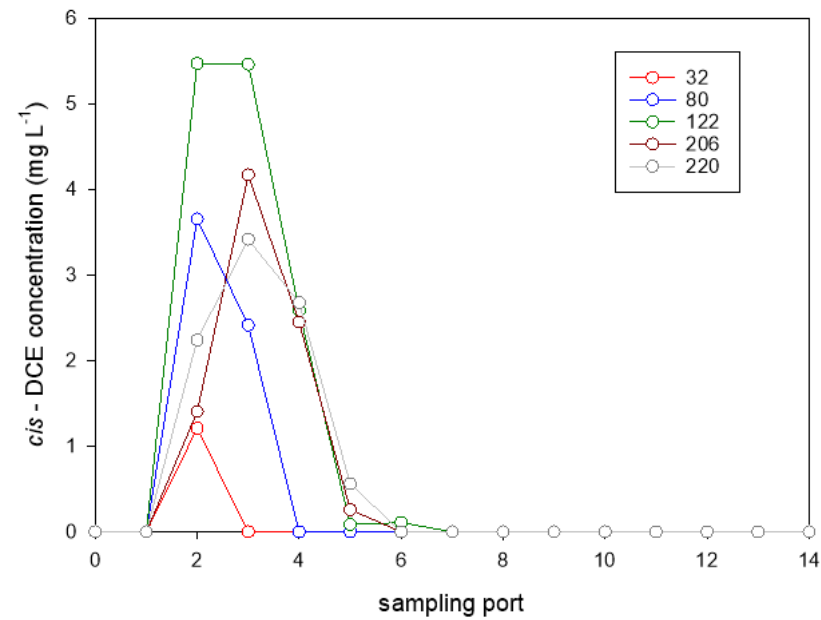
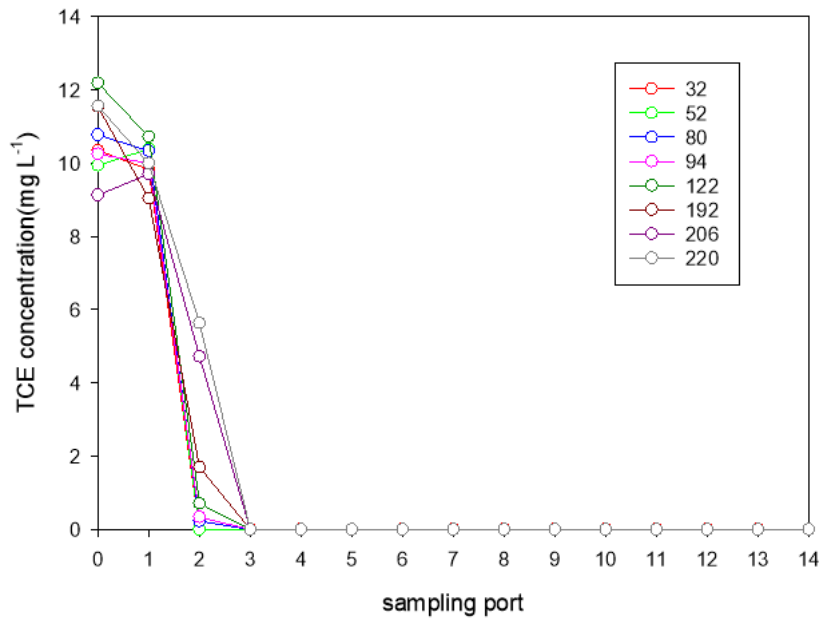
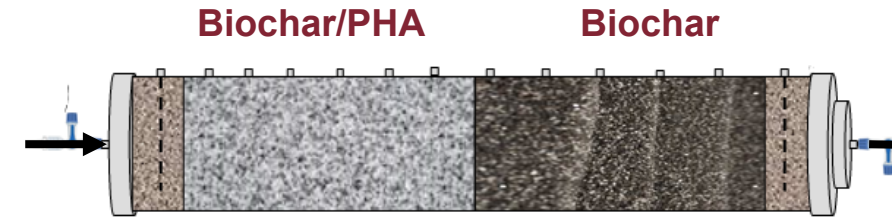


The combined strategy (column profiles at different operative days)

TCE

cis - DCE

VC

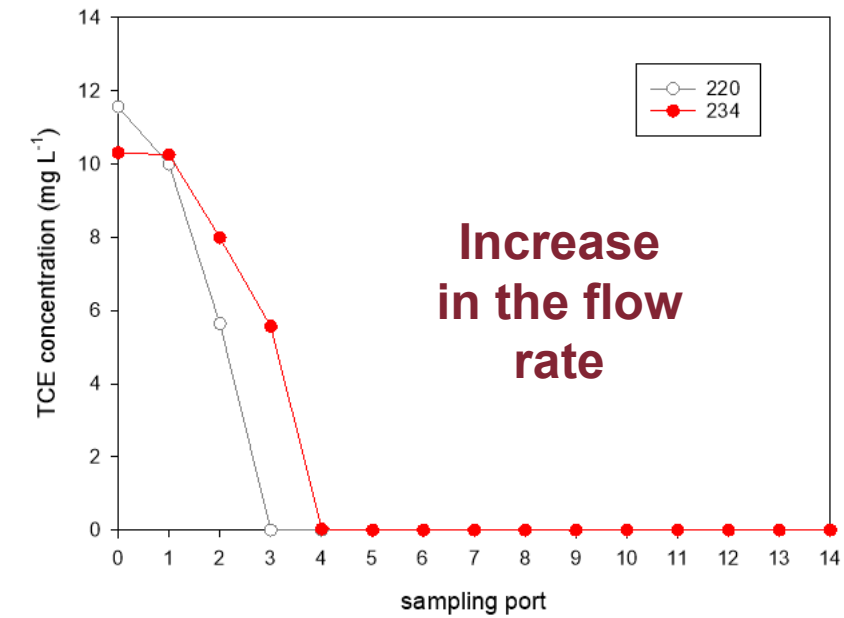
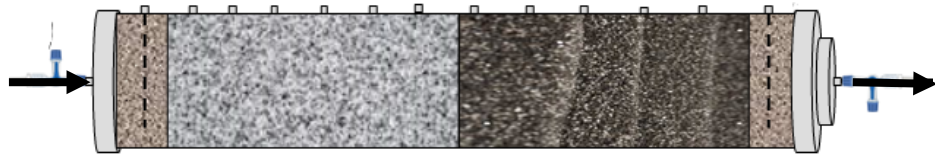


The combined strategy (column profiles at different operative days)

TCE

Biochar/PHA

Biochar

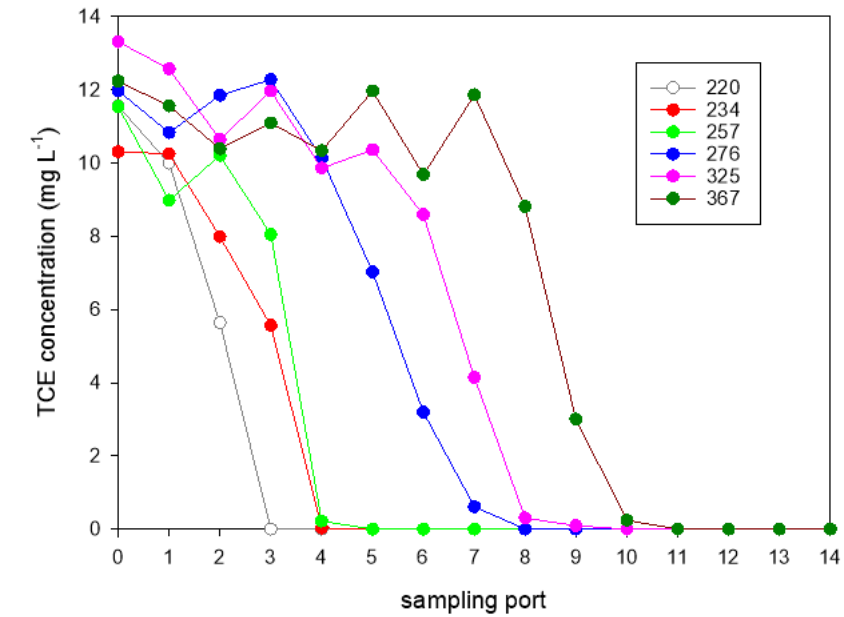
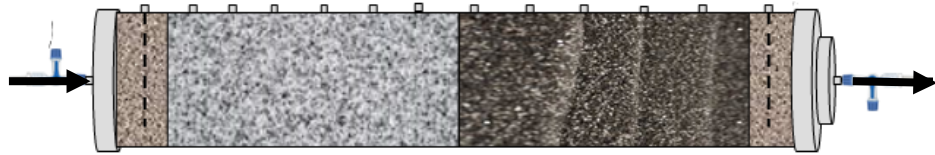


The combined strategy (column profiles at different operative days)

TCE

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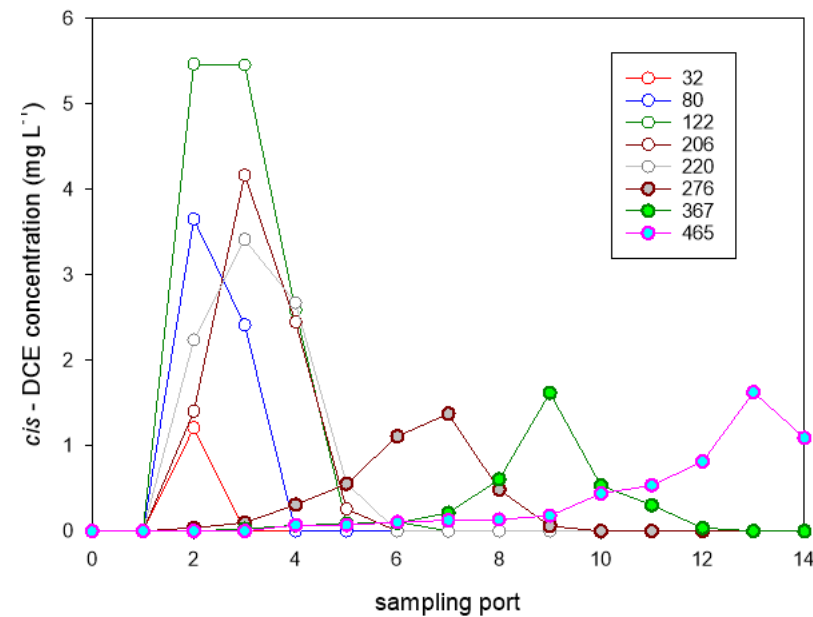
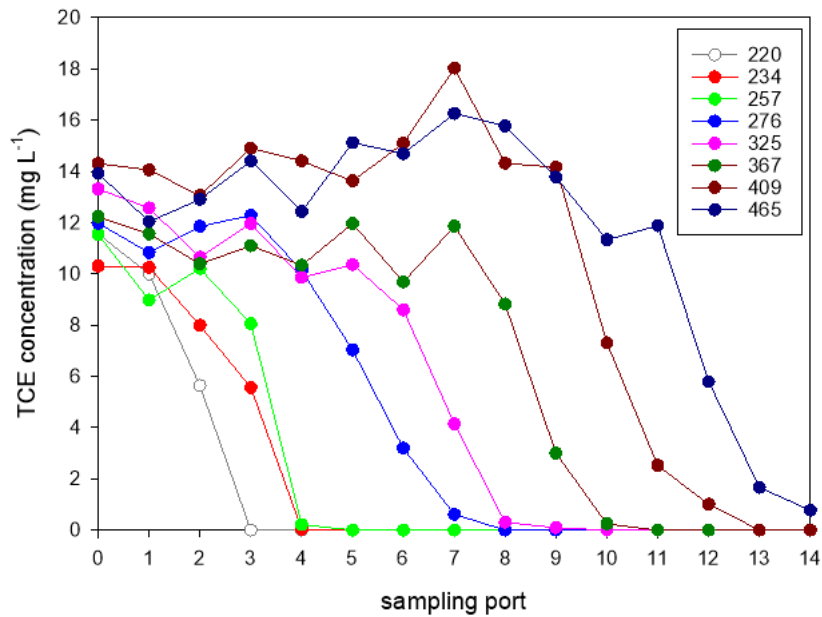
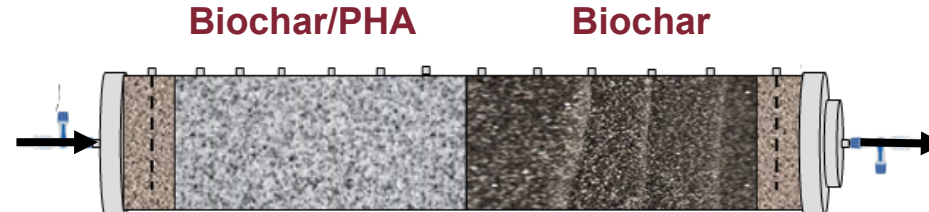
Biochar



The combined strategy
(column profiles at different operative days)

TCE

cis - DCE

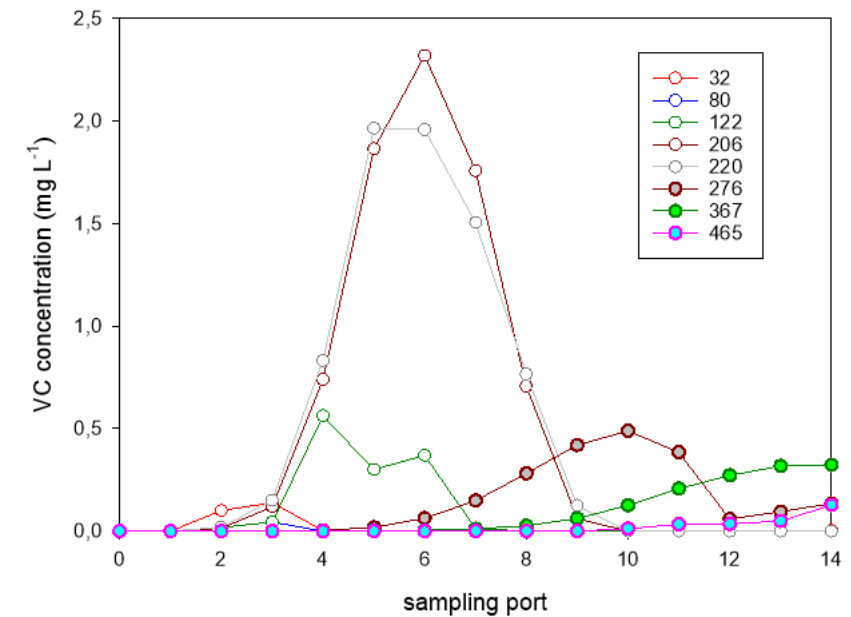
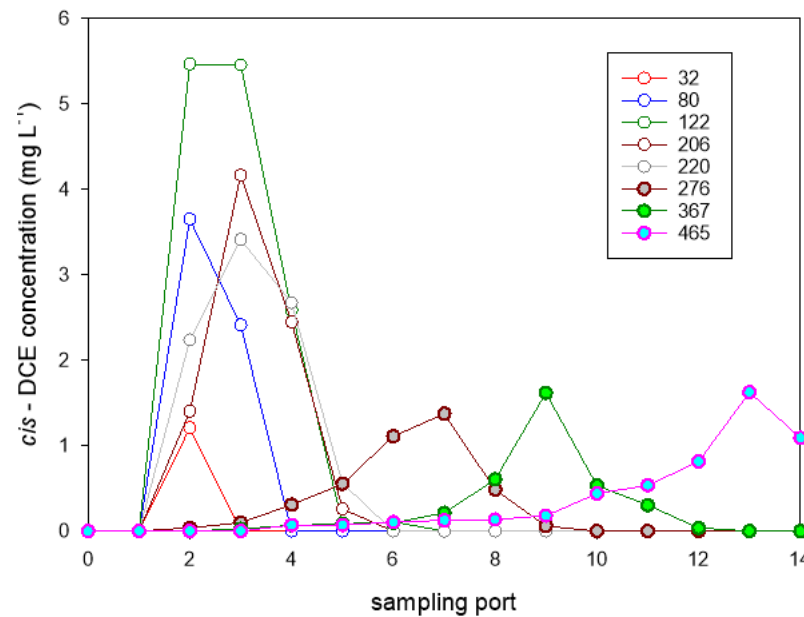
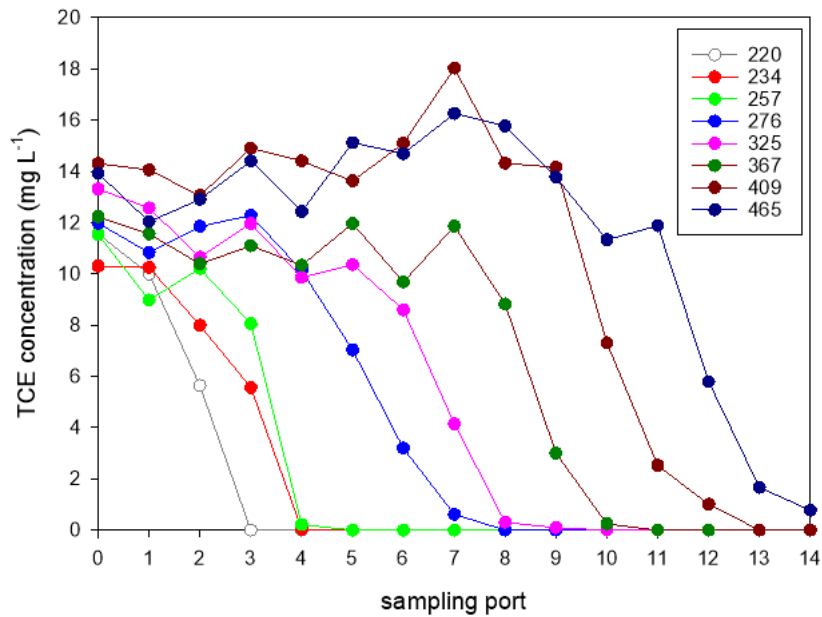
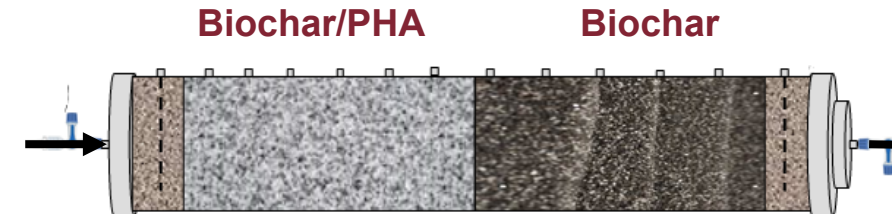


The combined strategy (column profiles at different operative days)

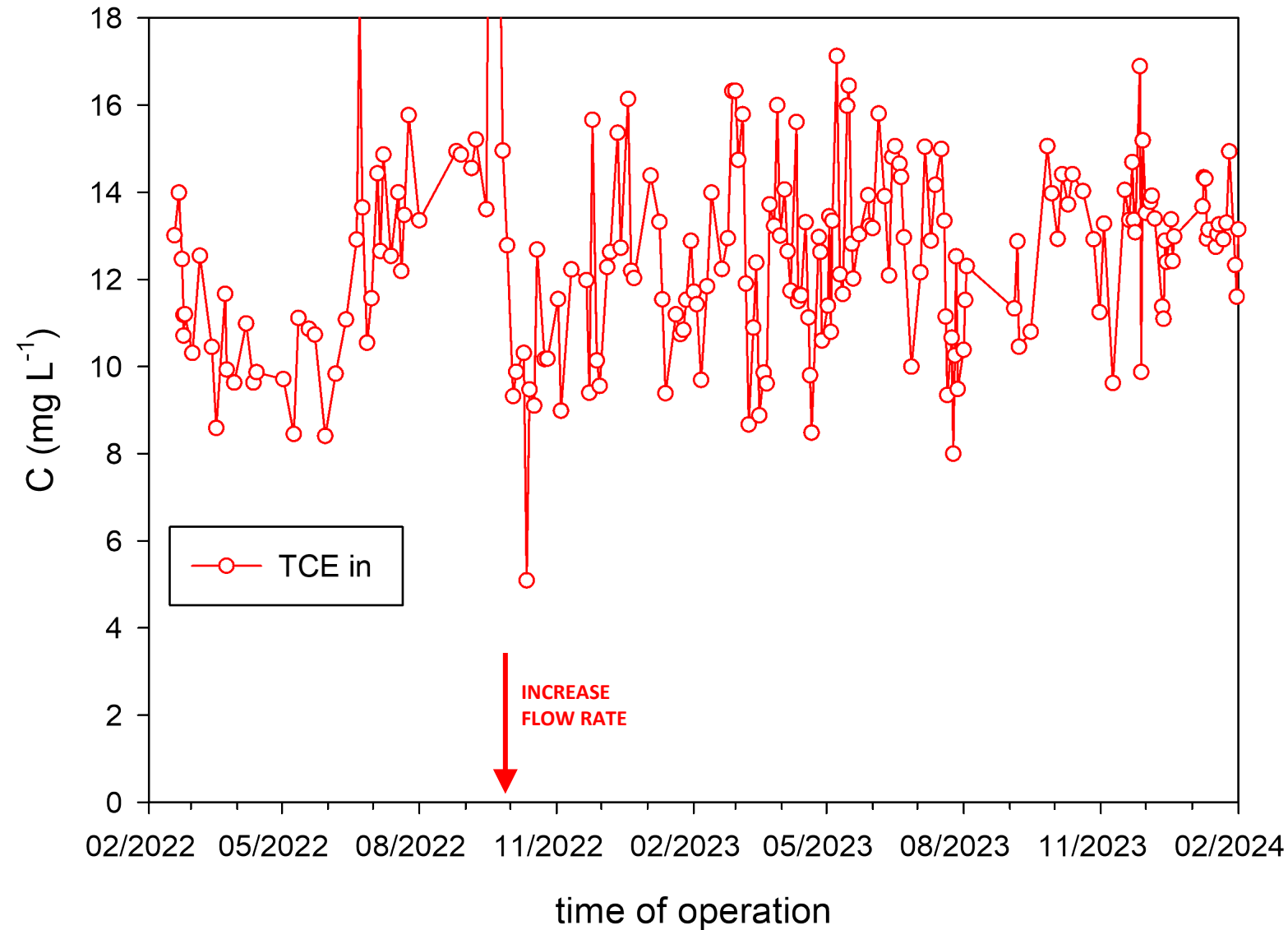
TCE

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VC

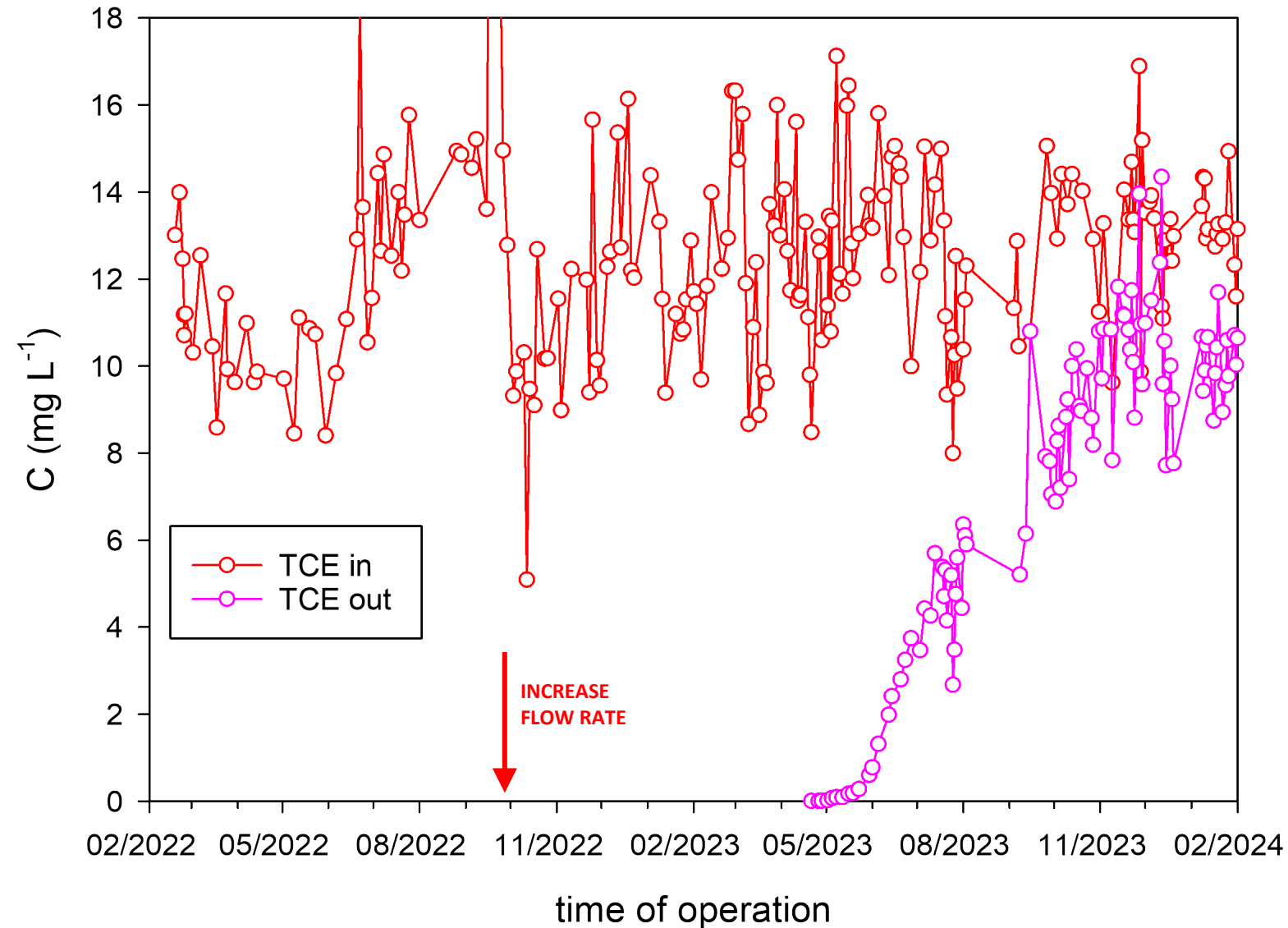


The combined strategy (column outlet)



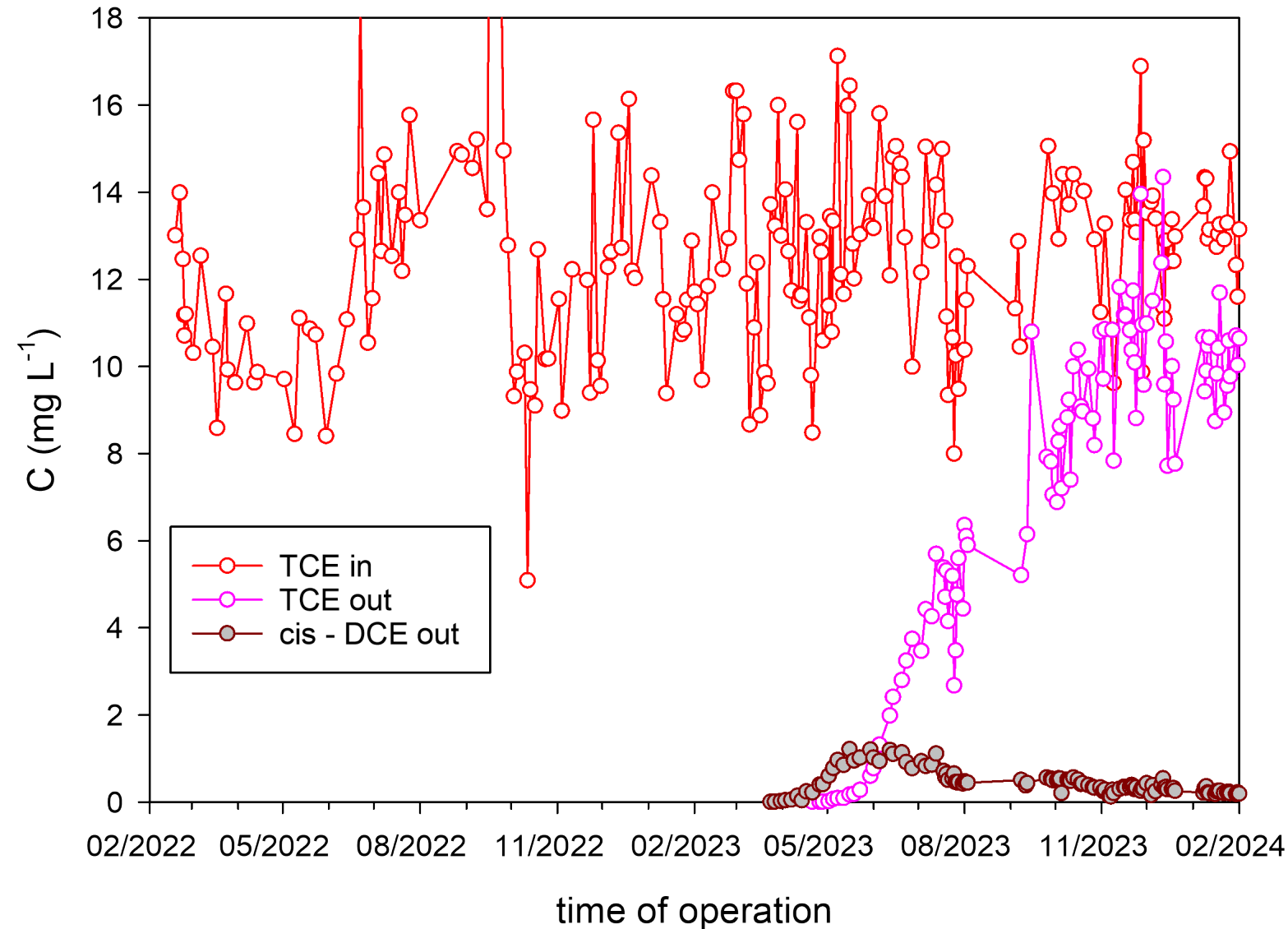
• 5140 L of treated water (1285 PV)

The combined strategy (column outlet)



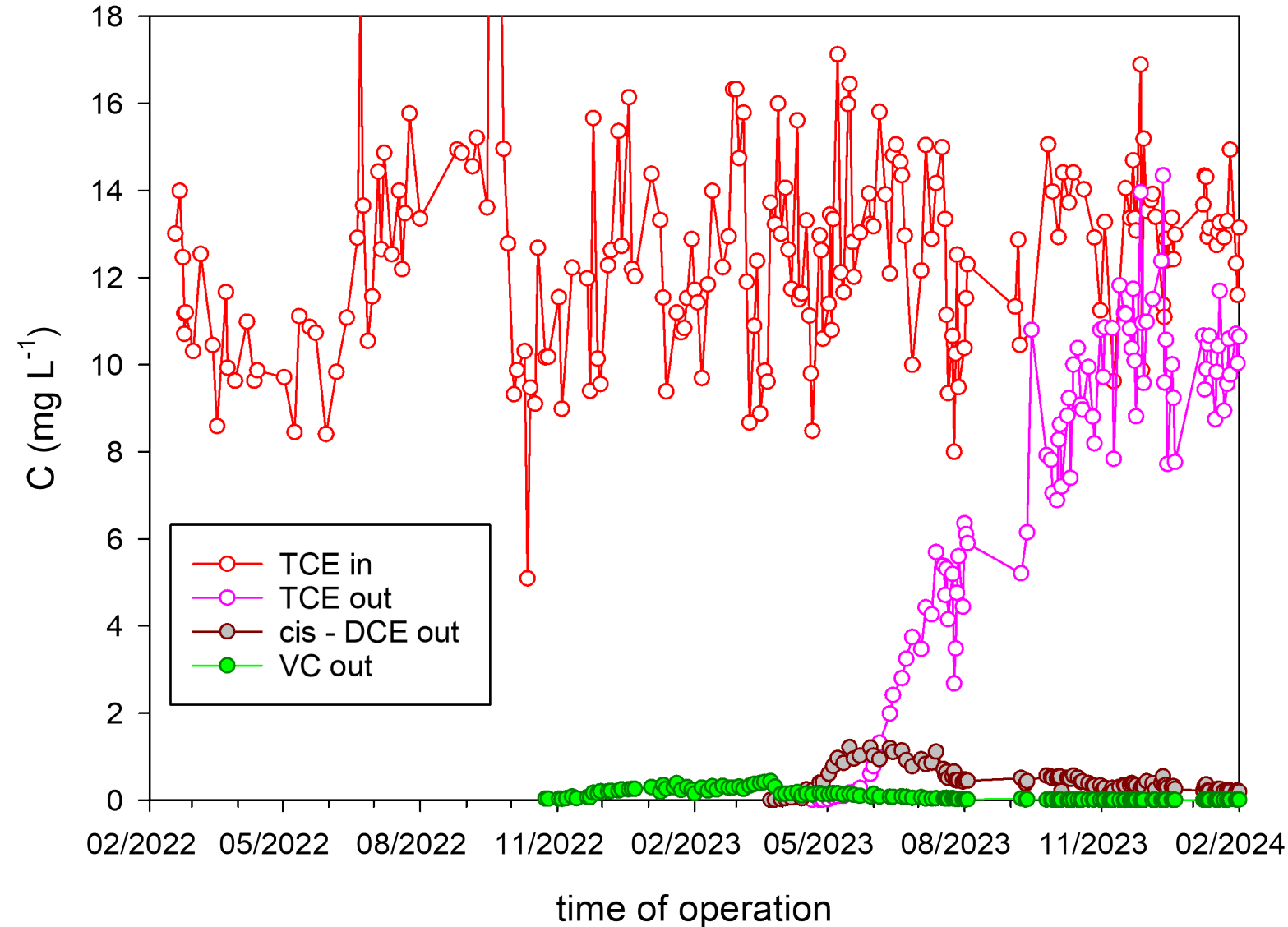
- 5140 L of treated water (1285 PV)
- Complete TCE removal until day 480 (810 PV)
- 51 g of TCE removed
- 17 g of TCE theoretically adsorbed

The combined strategy (column outlet)



- **5140 L of treated water (1285 PV)**
- **Complete TCE removal until day 480 (810 PV)**
- **51 g of TCE removed**
- **17 g of TCE theoretically adsorbed**

The combined strategy (column outlet)



- 5140 L of treated water (1285 PV)
- Complete TCE removal until day 480 (810 PV)
- 51 g of TCE removed
- 17 g of TCE theoretically adsorbed

Concluding remarks

- Feasible use of Biochar as specific *Dhc* biofilm support
 - The CAB process as an example of synergic effect: create a better habitat for the biofilm and prolong the lifespan of the material
 - The novel reactor should simulate a PRB, or a treatment in a fixed-bed reactor (high contaminant load)
- ❖ ***Circular Economy*** approach: using the raw PHA-rich biomass produced from MMC and organic waste closes the loop and enhances the sustainability

Thanks for your attention



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There are known knowns.

These are things we know that we know.

There are known unknowns.

That is to say, there are things that we know we don't know.

But there are also unknown unknowns.

These are things we don't know we don't know.

Donald Rumsfeld (2002)

email: Marco.Petrangelipapini@uniroma1.it