A SUSTAINABLE APPROACH FOR TCE CONTAMINATED GROUNDWATER REMEDIATION: POLYHYDROXYALKANOATES (PHA) FROM WASTE AS ELECTRON DONOR FOR BIOLOGICAL REDUCTIVE DECHLORINATION

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DIPARTIMENTO DI CHIMICA

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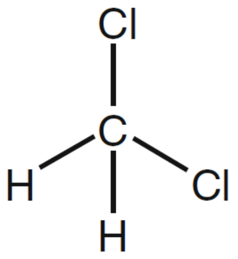
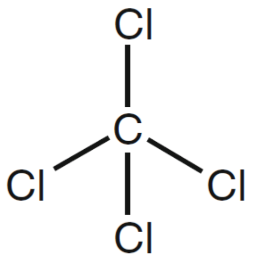
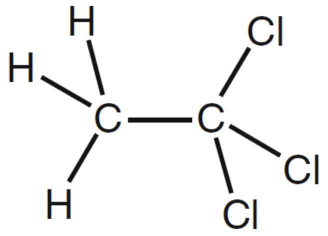
Chlorinated solvents are a group of substances called **Chlorinated Aliphatic Hydrocarbons** (CAHs), largely used as solvents and degreasing agents.
CAHs belong to the **Dense Non-Aqueous Phase Liquids (DNAPLs)** contaminants category



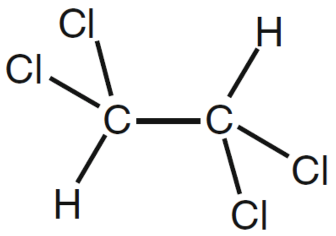
dichloromethane
(DCM)



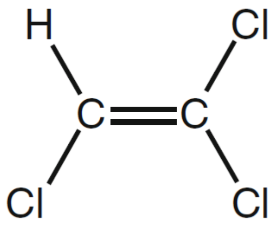
carbon tetrachloride
(CT)



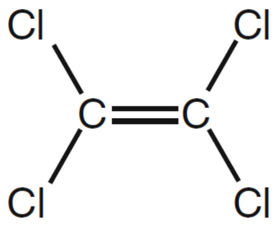
1,1,1 - trichloroethane
(1,1,1-TCA)



1,1,2,2 - tetrachloroethane
(1,1,2,2-TeCA)



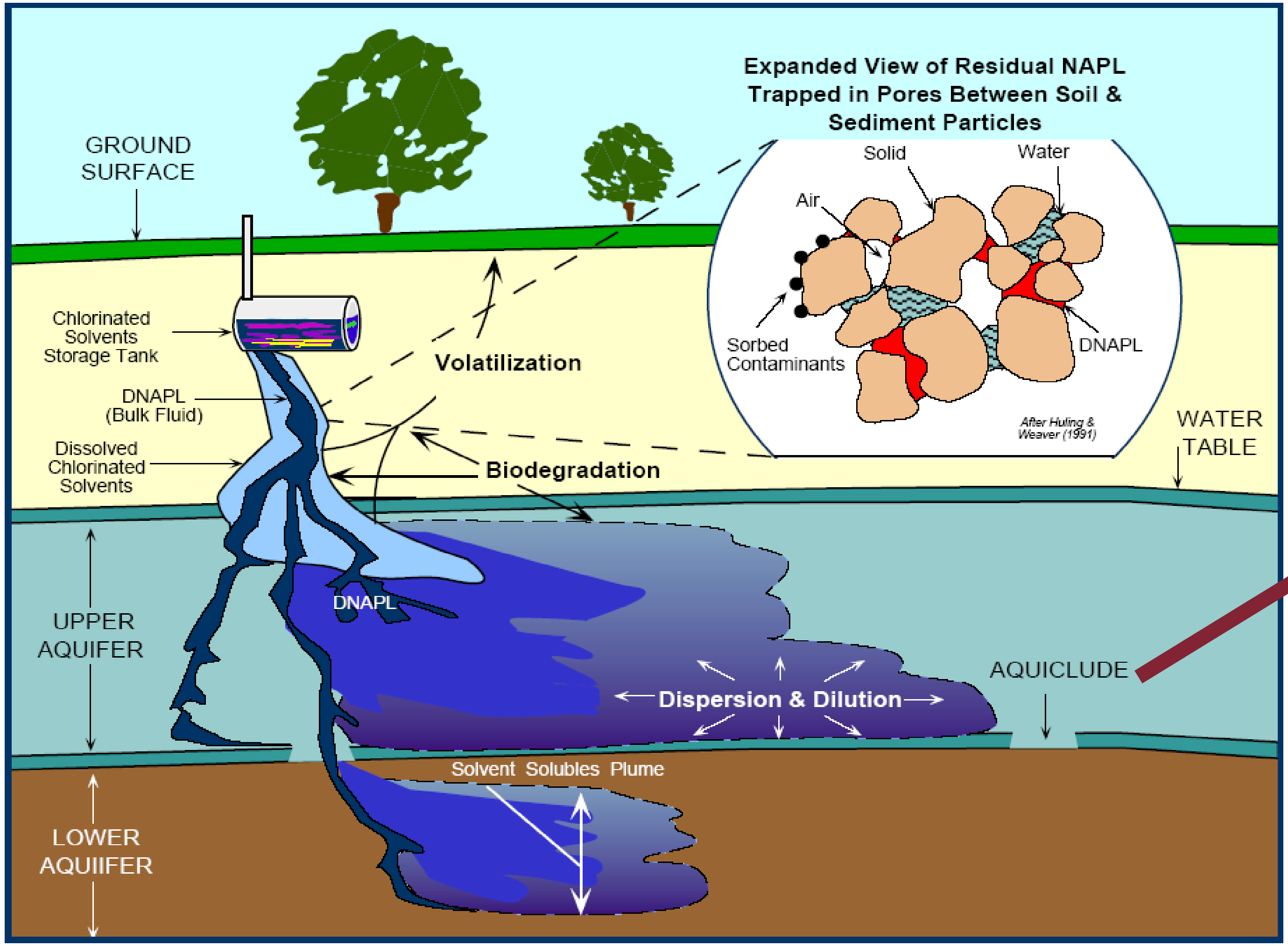
trichloroethene
(TCE)



perchloroethene
(PCE)

Typical DNAPL contamination scenario

(the chlorinated solvent problem)

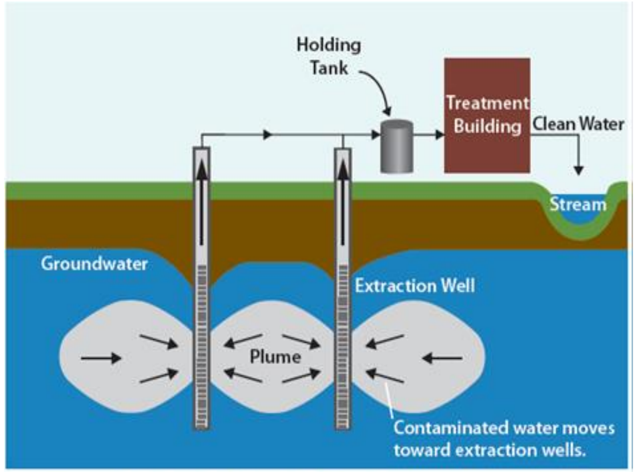


Due to higher density than water, DNAPLs migrates vertically also in the saturated zone (aquifer). Depending on the soil heterogeneity and spilled amount, contamination could reach significant depth.

Significant aging of the secondary sources

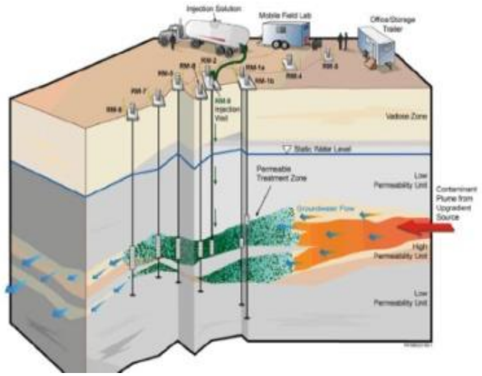
Chlorinated Solvents remediation strategies

Pump-and-Treat

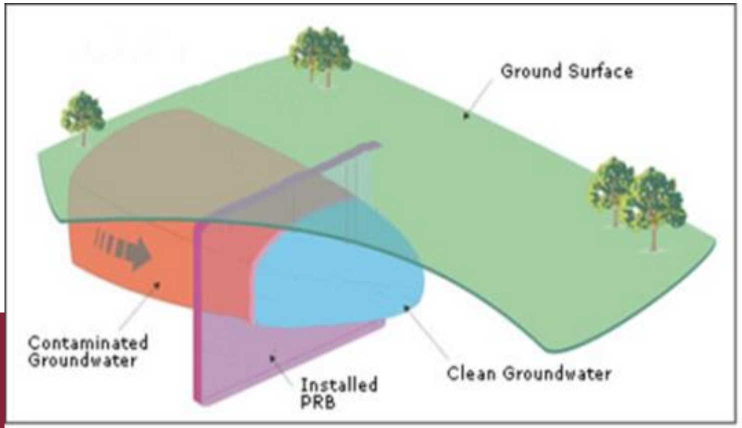


Example of a Pump and Treat System with Two Extraction Wells.

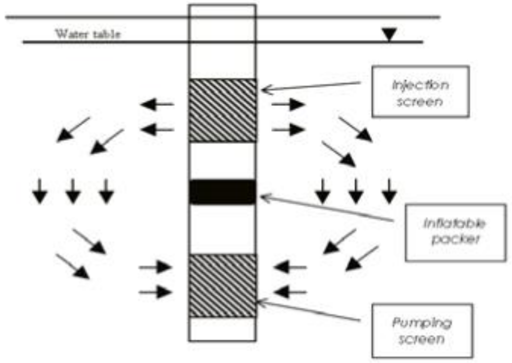
In-Situ Chemical Oxidation/Reduction

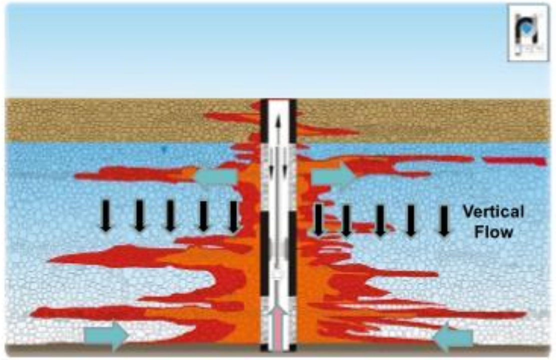


Permeable Reactive Barriers: PRB

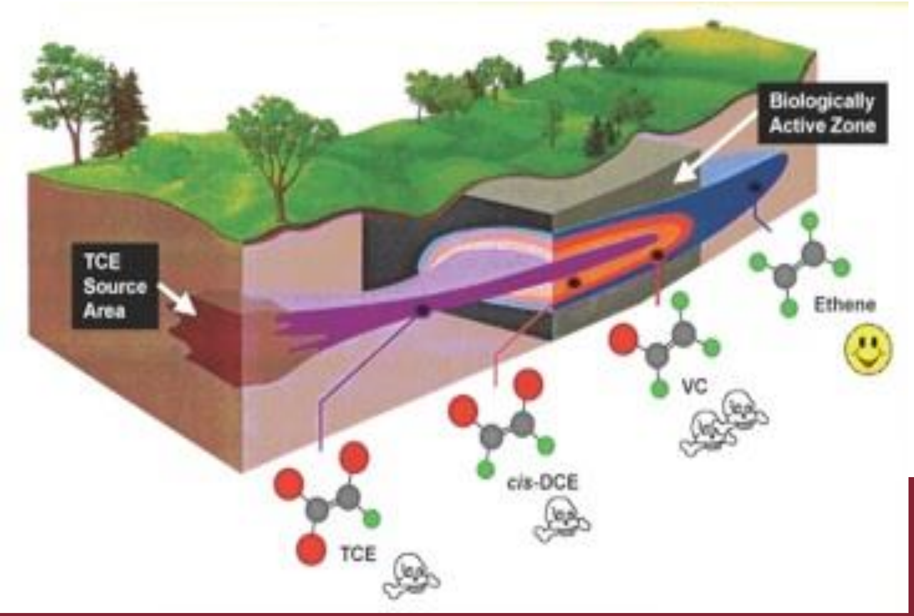


Groundwater Circulation Well: GCW

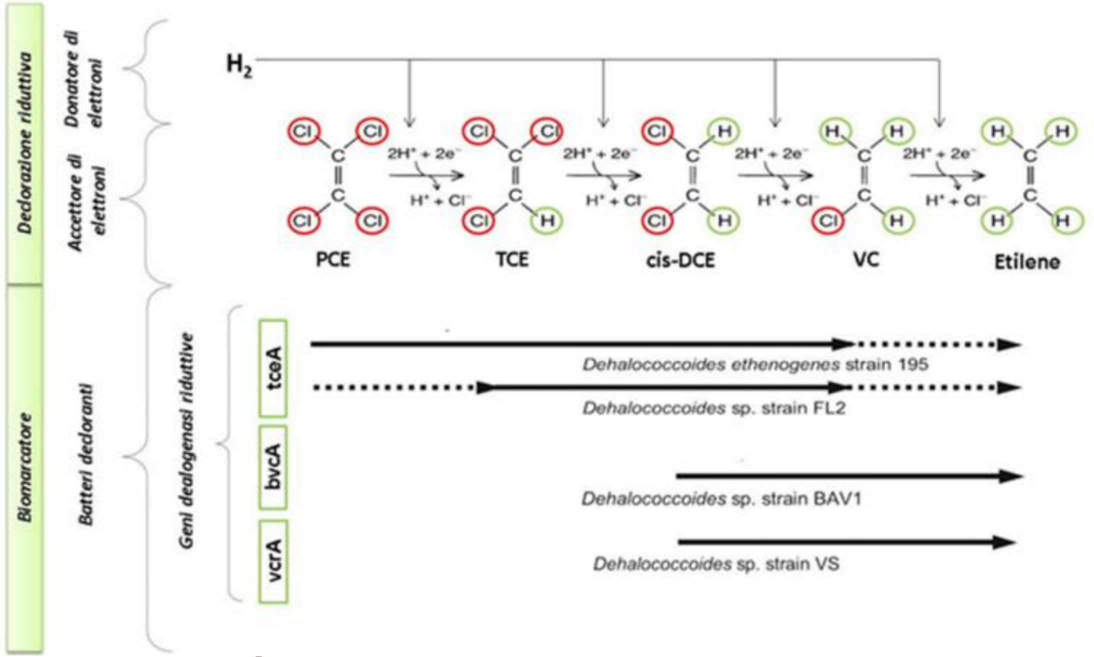




In-Situ Bioremediation



In-Situ Enhanced Bioremediation



Advantages

- ✓ No transfer to other matrix (gas or liquid) to be treated
- ✓ Conversion in nontoxic compound
- ✓ Direct action in the aquifer

Disadvantages

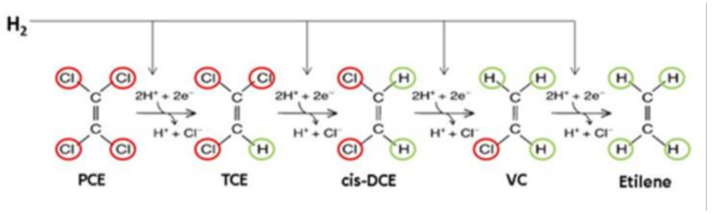
- Insufficient electron donor supply
- Interspecies H_2 competition,
- The presence of alternative terminal electron acceptors
- The presence of inhibitory substances

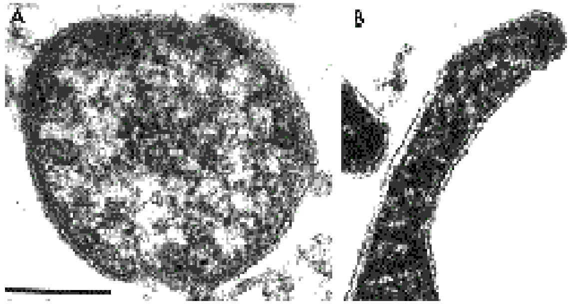
Substrate	Typical Delivery Techniques	Form of Application
Soluble Substrates		
Lactate, Propionate, and Butyrate	Injection wells or recirculation systems	Acids or salts diluted in water
Methanol and Ethanol	Injection wells or recirculation systems	Diluted in water
Sodium Benzoate	Injection wells or recirculation systems	Dissolved in water
Molasses, High Fructose Corn Syrup	Injection wells	Dissolved in water
Whey (soluble or slurry)	Direct injection or injection wells	Dissolved in water or slurry
Slowly Soluble Viscous or Low Viscosity Fluids		
Hydrogen Release Compounds®	Direct injection	Straight injection of product
Emulsified Vegetable Oil	Direct injection or injection wells	Low oil content (<10%) oil-in-water microemulsions
Vegetable Oils	Direct injection or injection wells	Straight oil injection with water push, or high oil:water content (>10% oil) emulsions
Solid Substrates		
Mulch and Compost	Trenching or excavation	Trenches, excavations, *in situ* bioreactors, or surface amendments
Chitin (solid)	Trenching or injection of a chitin slurry	Solid or slurry
Gaseous Substrates		
Hydrogen	Biosparging wells	Gas injection

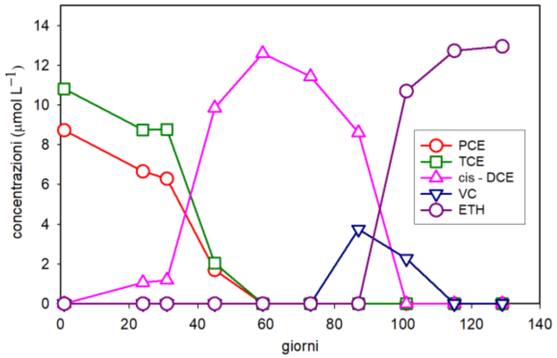
Book "In Situ Remediation of Chlorinated Solvent Plumes Series Editor : C . Herb Ward , Rice University

Combination of processes for sustainable approach at CAH remediation

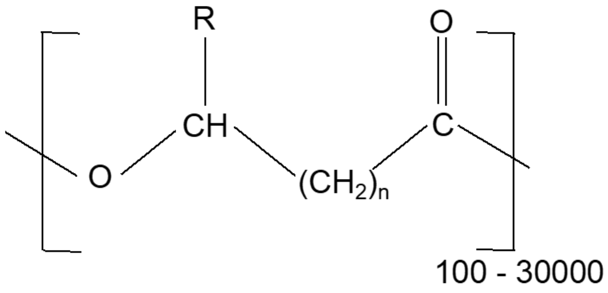
Biological reductive dechlorination

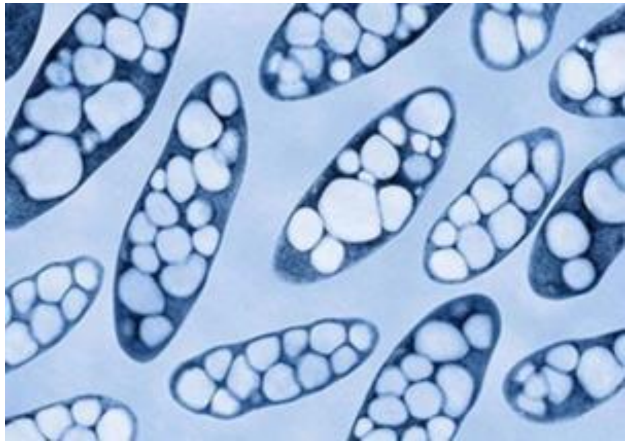






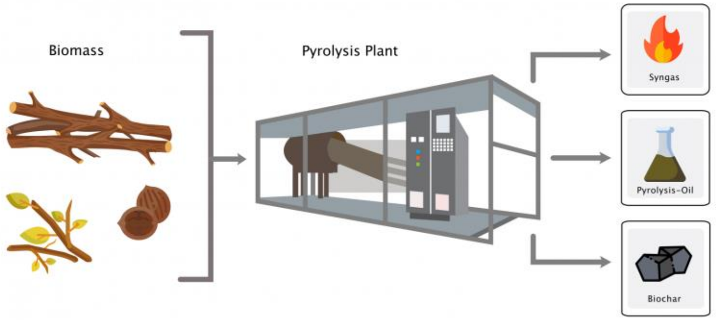
Biodegradable plastics from waste valorization





Polyhydroxyalcanoates, PHA

«low cost» sorbent materials (biomass valorization)



Biochar

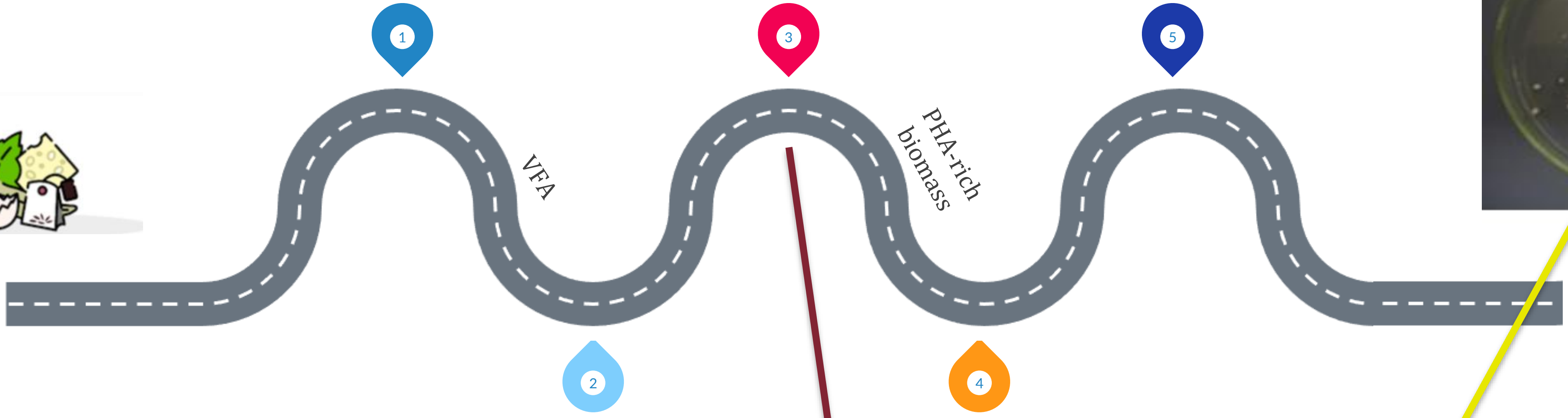
Production of PHA from Mixed Microbial Cultures (MMC)

Organic feedstock

Acidogenic Fermentation

PHA accumulation

PHA processing

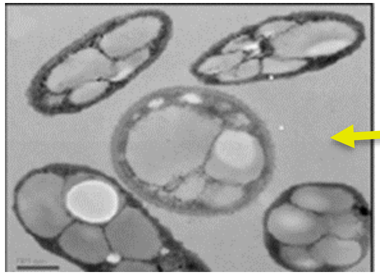


Inoculation (activated sluge)

Selection & production of MMC with storage ability

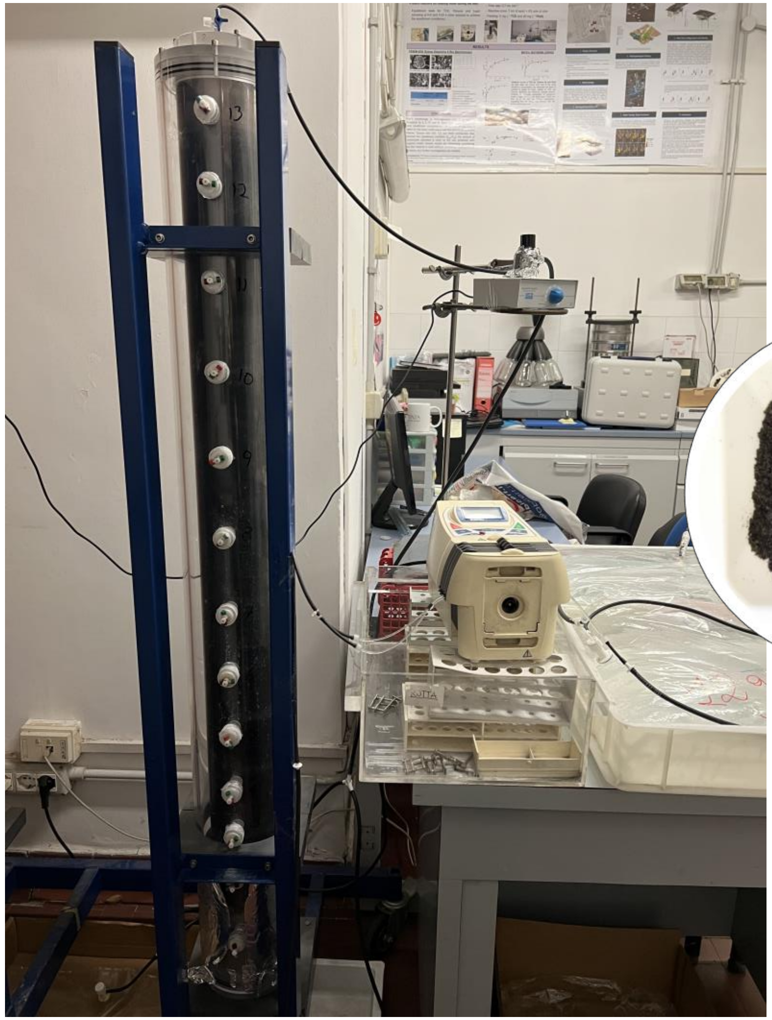
PHA extraction

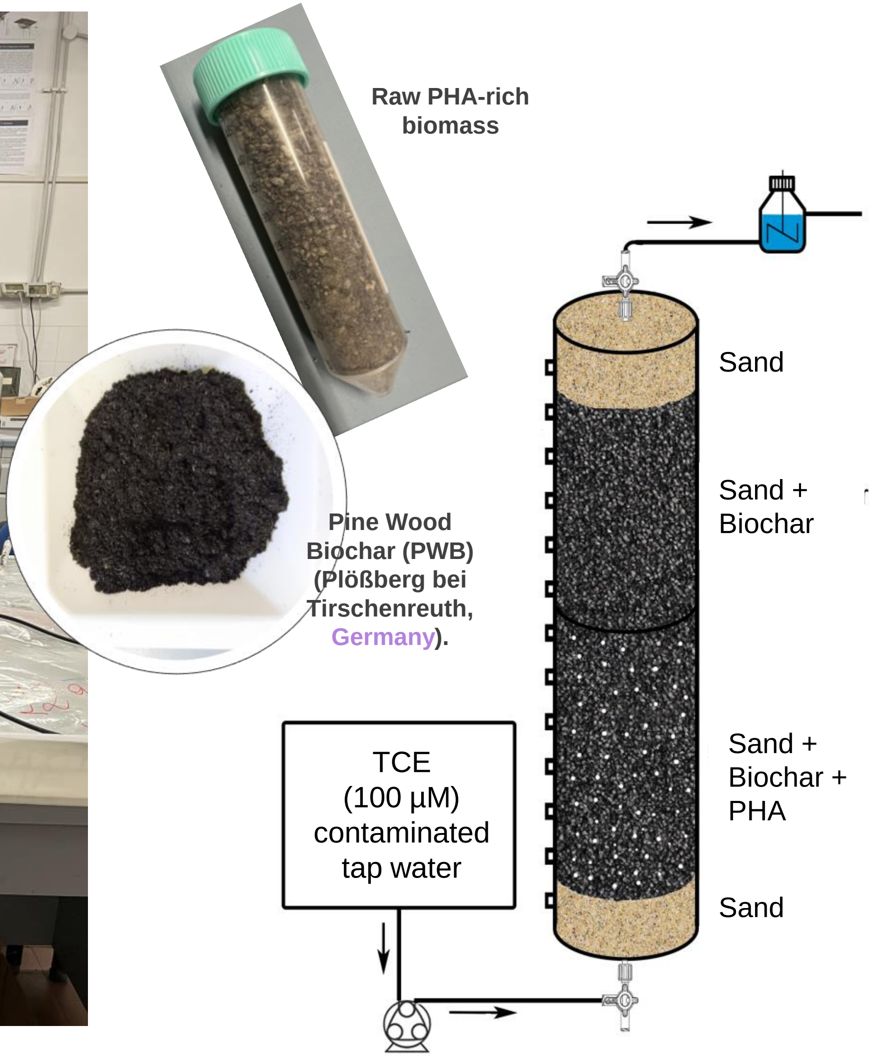
Biodegradable plastics



- Possibility to use PHA as a source of electron donor for BRD
- Potential direct use of PHA rich – biomass without the need of extraction!!

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





- **Reactor**

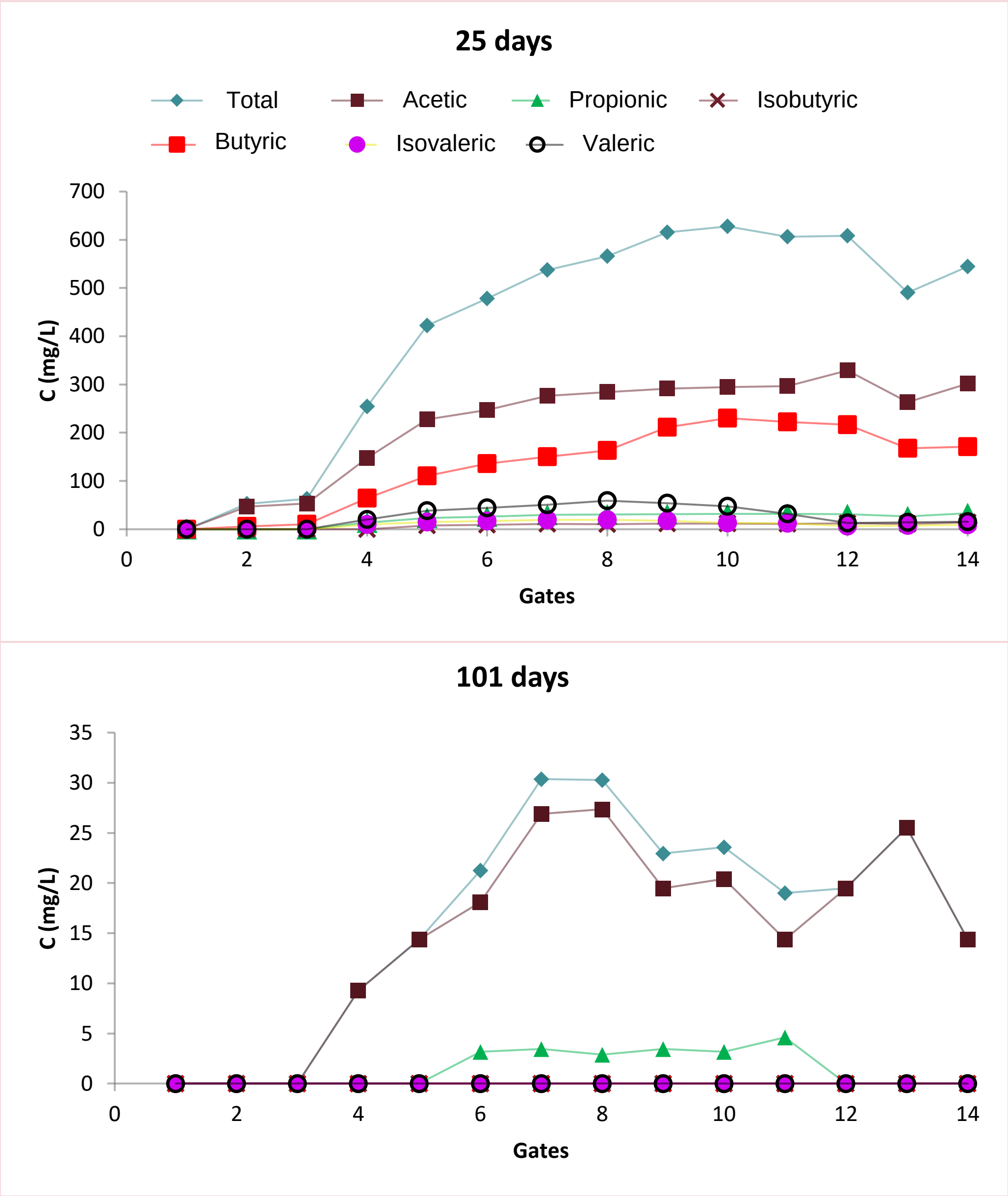
- Height: 144 cm

- Diameter: 10 cm

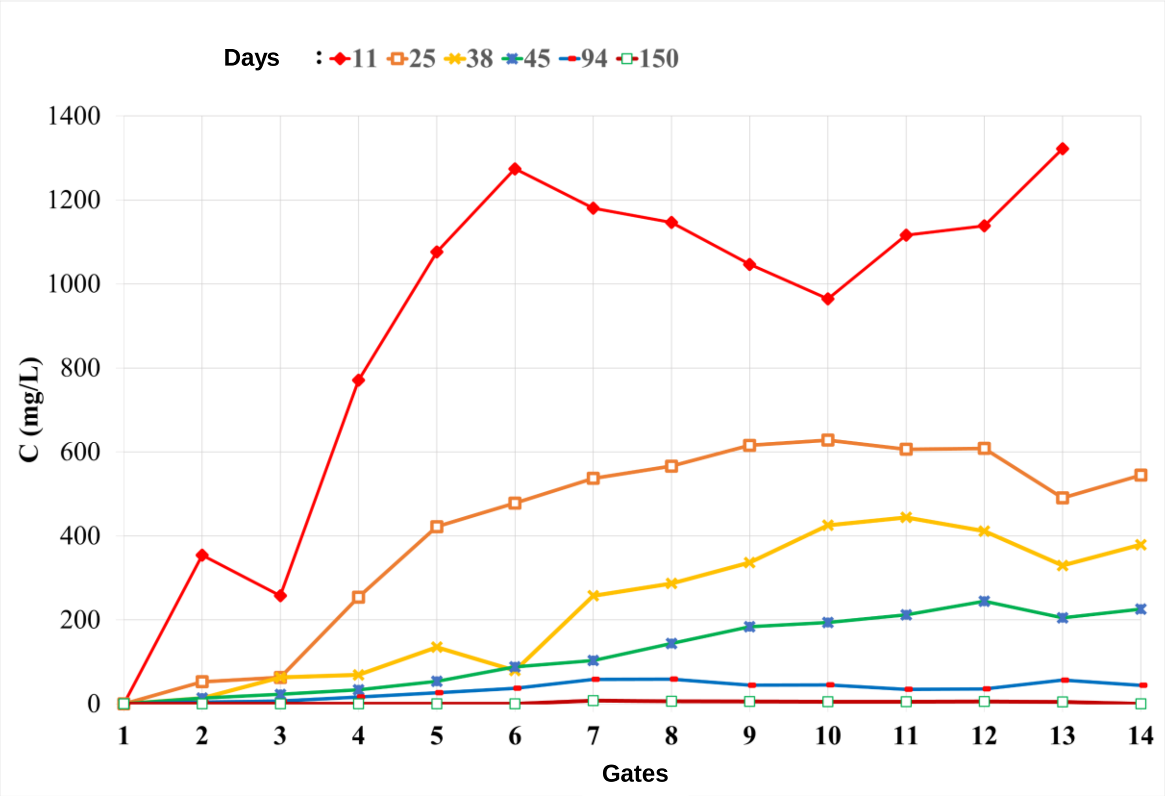
- 4 %wt of PHA e PWB

- **Gates 1 and 13**: Sand
- **Gates 2-7**:
  - 250 g raw PHA
  - 250 g PWB
- **Gates 8-12:**
  - 300 g PWB
- Dechlorinating culture recyrculated for inoculating the whole column

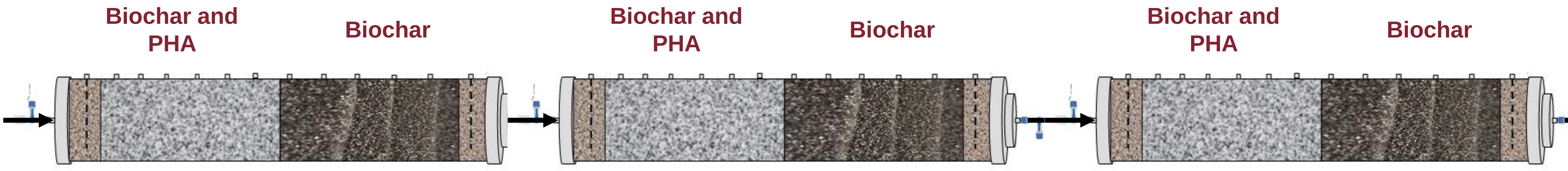
VFA production during operating time

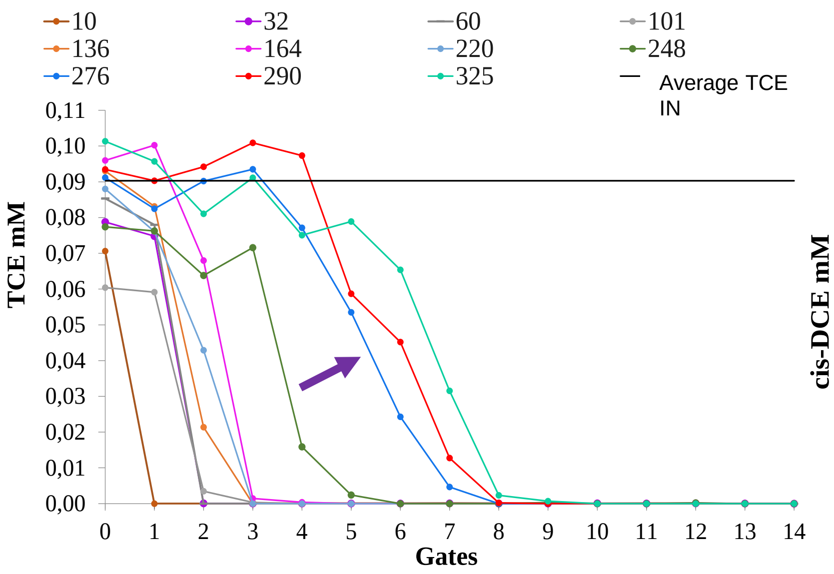


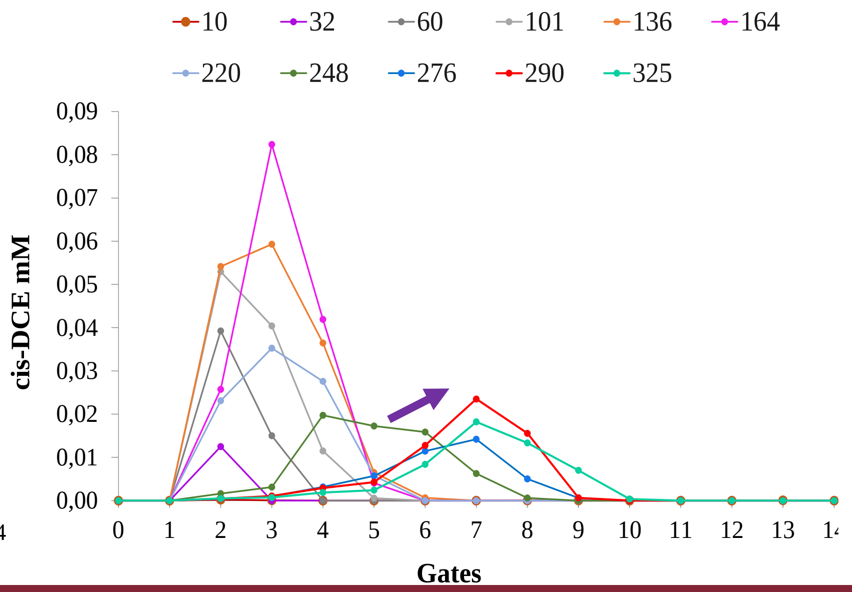
Total VFA along the column profile

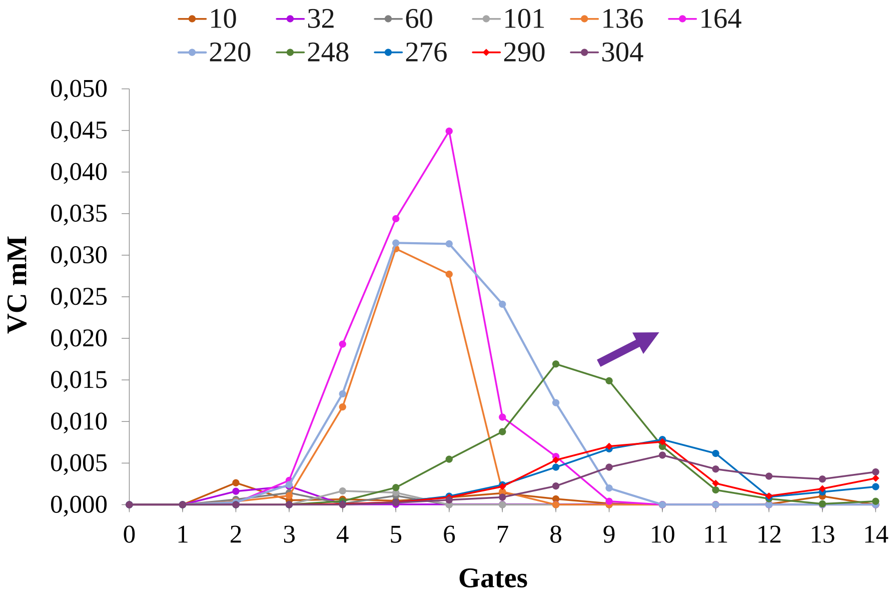


The combined strategy – Some results
(column profiles at different operative days)

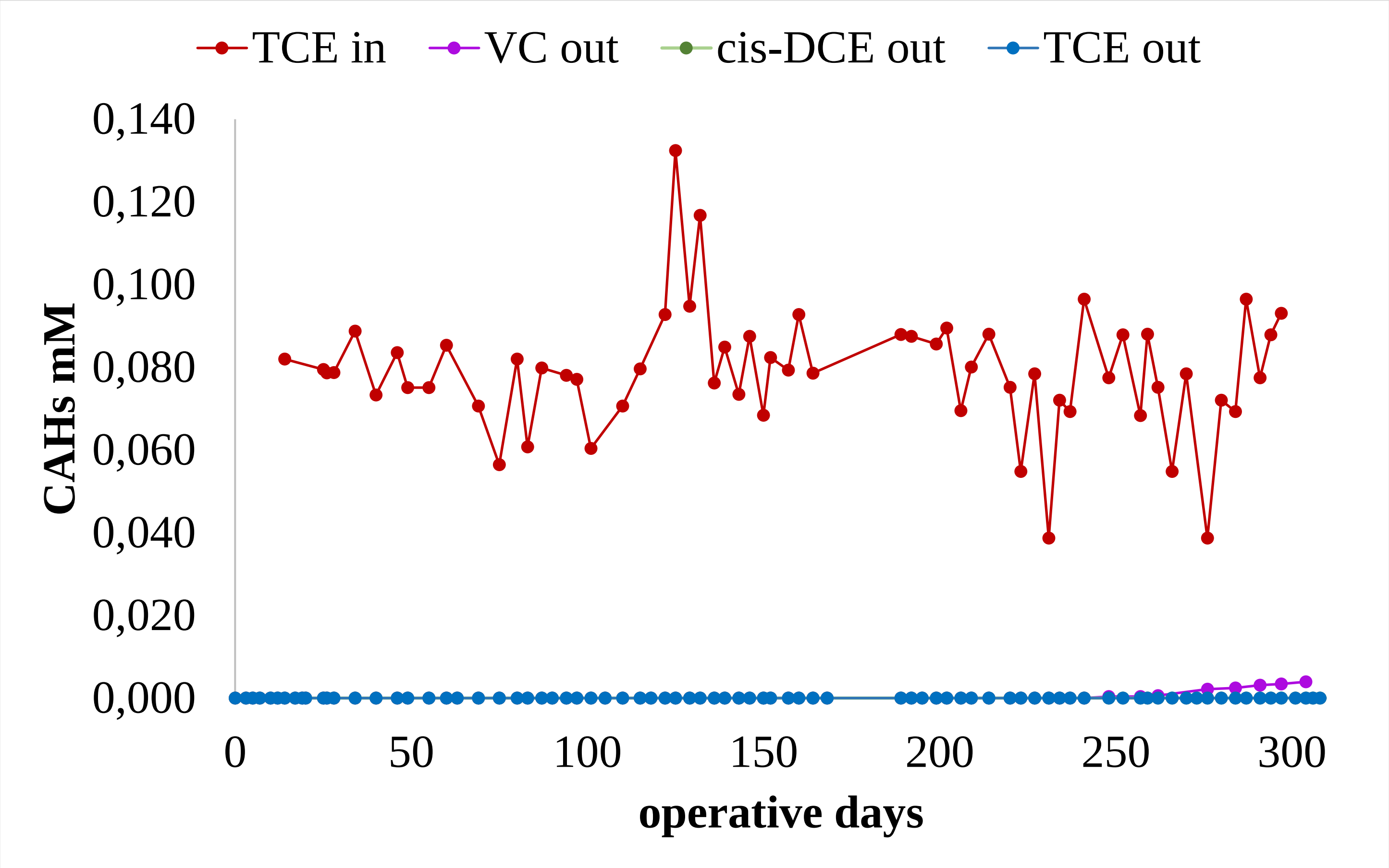








The combined strategy – Some results (column outlet)



- 1350 L of treated water (337 PV)
- Complete TCE removal
- 10 g of TCE removed
- Complete VC conversion until ED was available

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 kind attention!

Special thanks to

Prof. Mauro Majone
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www.resurbis.eu