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Bioremediation of heavy metals through Microbial-Induced Calcite Precipitation in the presence of organic contaminants

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WORLD CHANGING GLASGOW

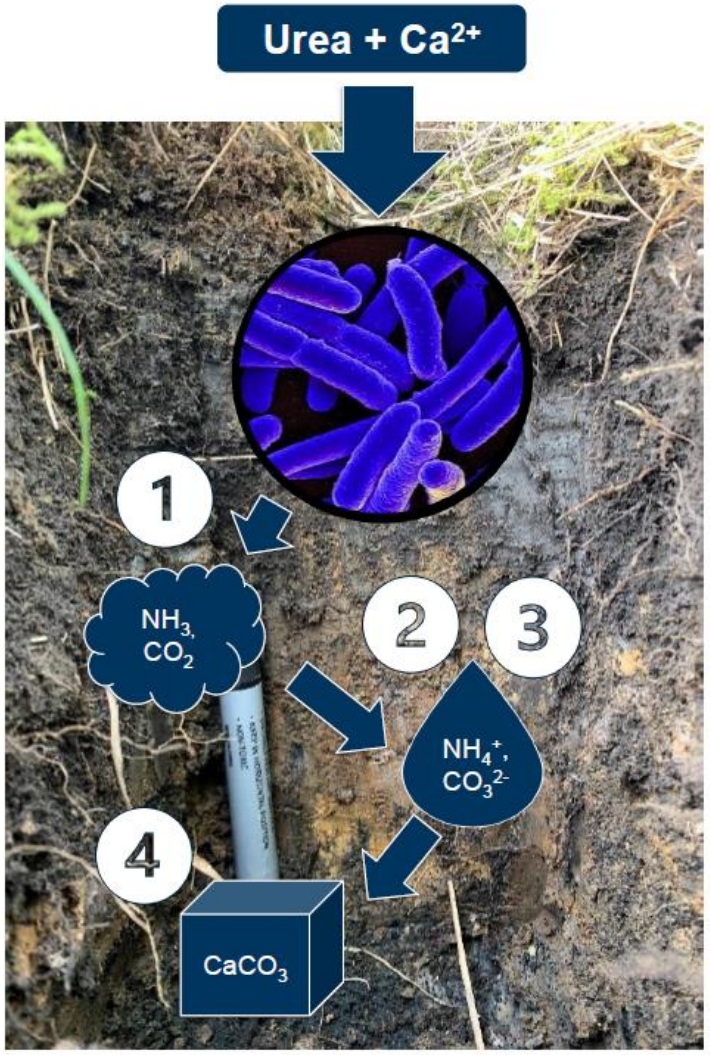





Microbial-Induced Calcite Precipitation (MICP) for simultaneous CCS and toxic element mineralisation

Conditions for soil carbonation:

- CO_3^{2-}
- pH >8.5



1 Urea hydrolysis: ammonia (NH_3) and CO_2 production

$$Urea \rightarrow 2NH_3 + CO_2$$

2 NH_3 and CO_2 dissolution in water (pH increase)

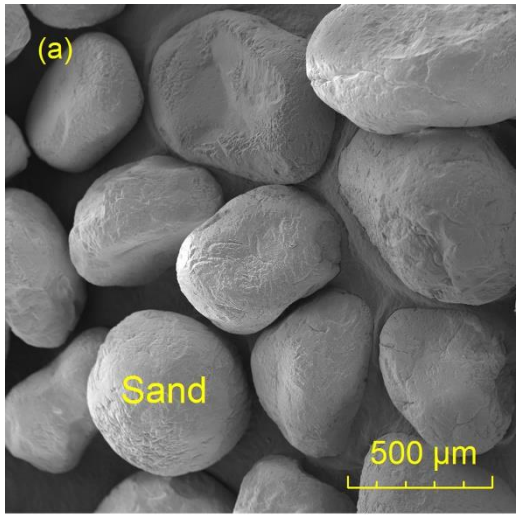
$$2NH_3 + 2H_2O \leftrightarrow 2NH_4 + 2OH^-$$
$$CO_2 + H_2O \leftrightarrow HCO_3^- + H^+$$

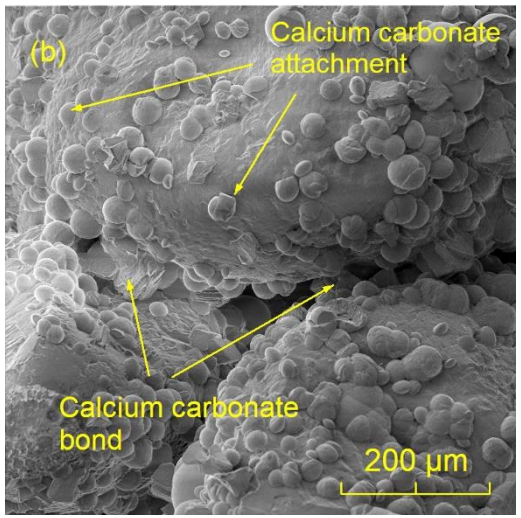
3 Production of carbonates (pH driven)

$$HCO_3^- \leftrightarrow CO_3^{2-} + H^+$$

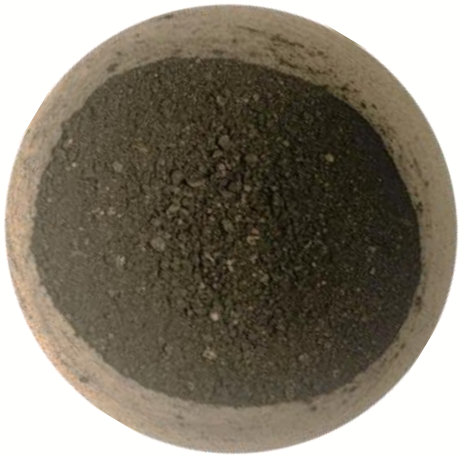
4 CO_2 and heavy metal mineralisation

$$Ca^{2+} + CO_3^{2-} \leftrightarrow CaCO_3 (\downarrow)$$
$$Cd^{2+} + CO_3^{2-} \leftrightarrow CdCO_3 (\downarrow)$$



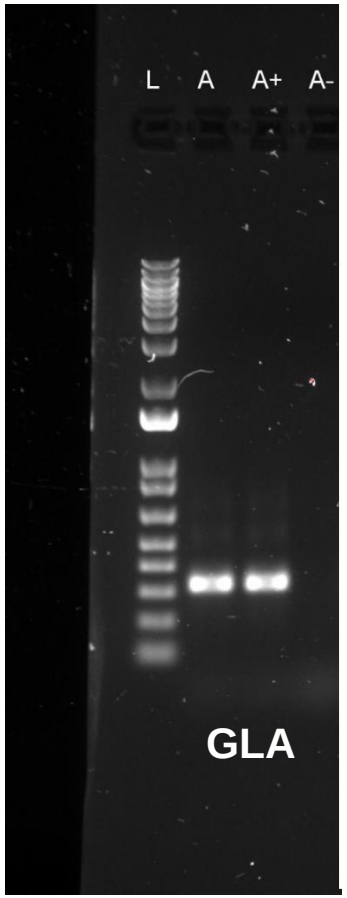


Bioremediation of heavy metals through indigenous Microbial-Induced Calcite Precipitation- Soil 1

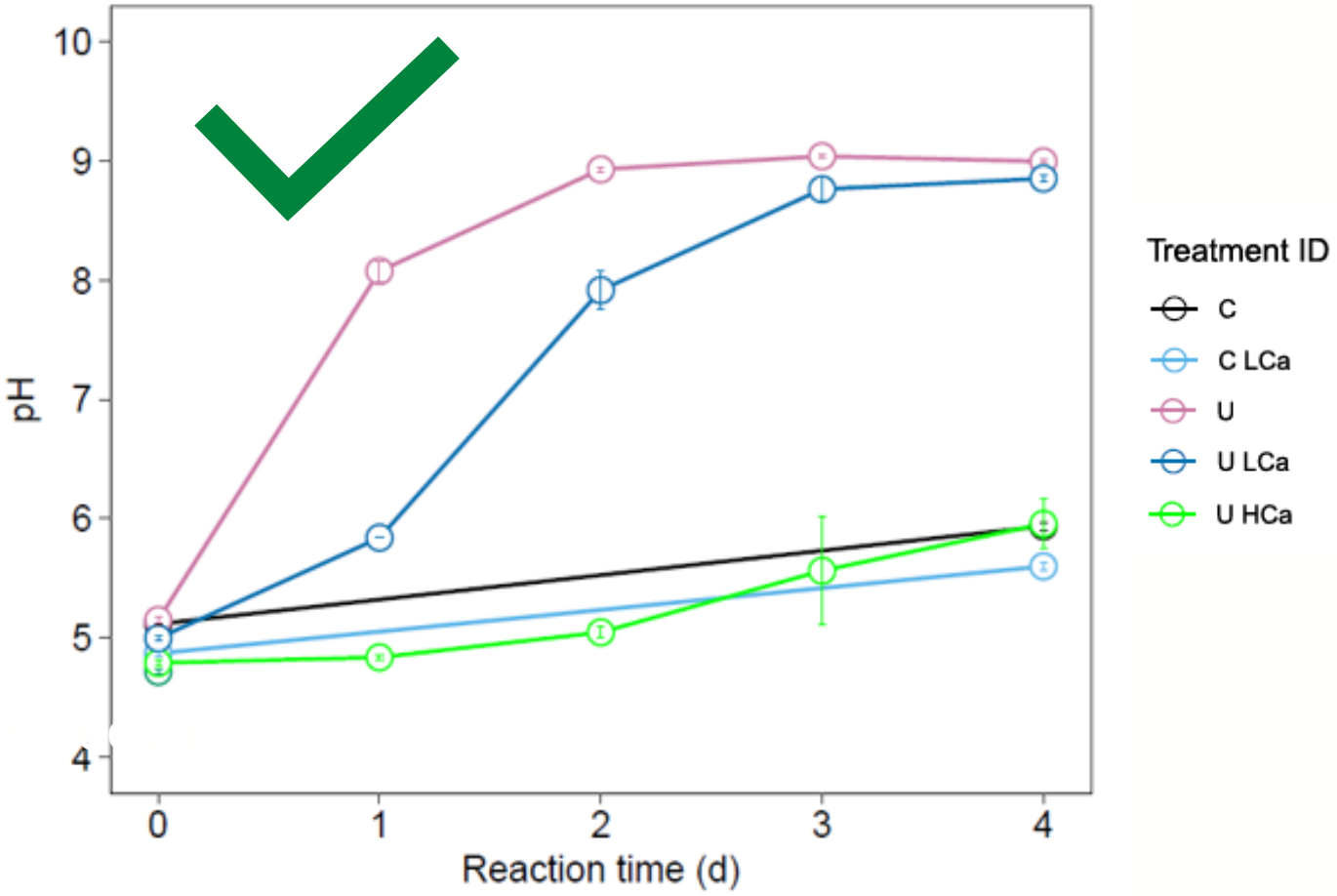


Soil 1

ureC gene

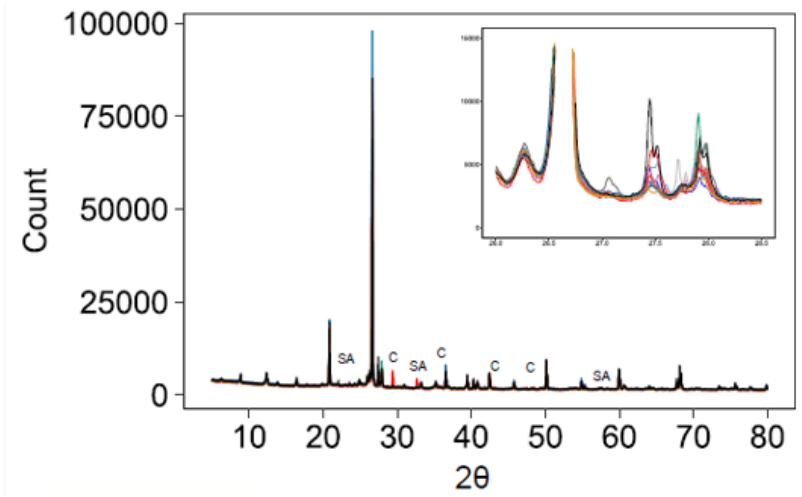


Urea hydrolysis

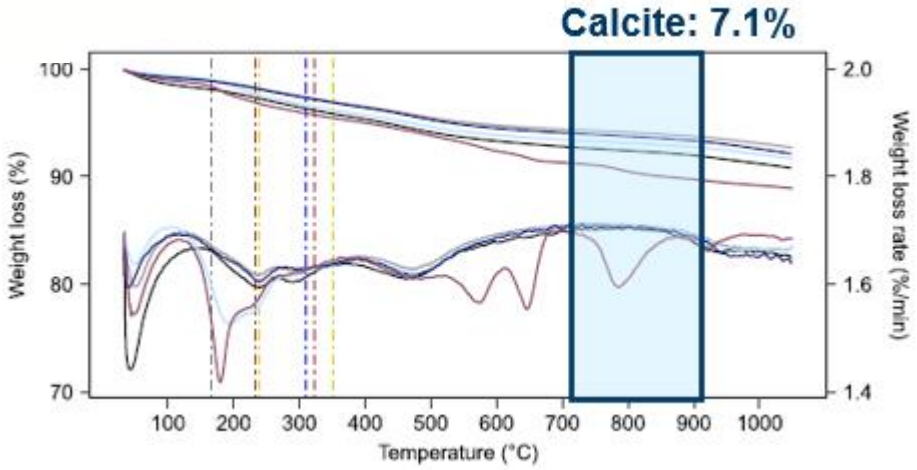


Bioremediation of heavy metals through indigenous Microbial-Induced Calcite Precipitation- Soil 1

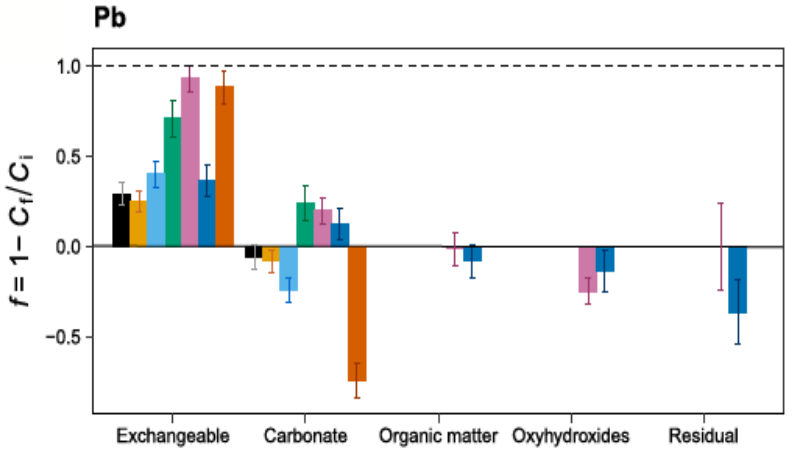
XRD

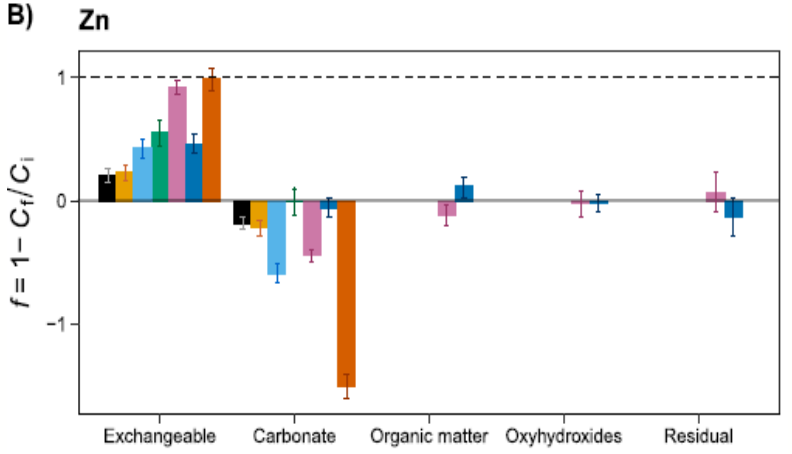


TG



Element partition

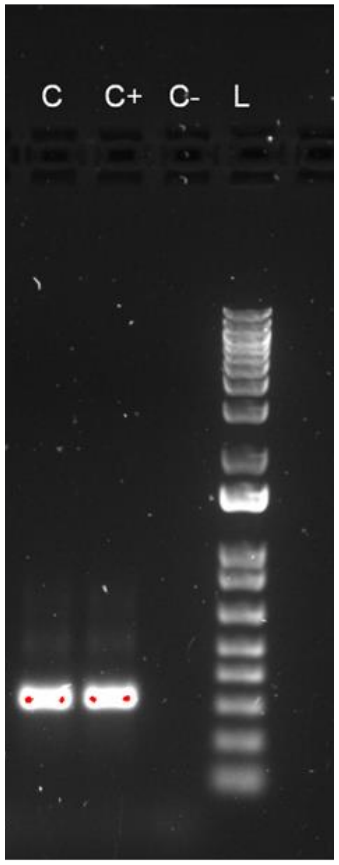




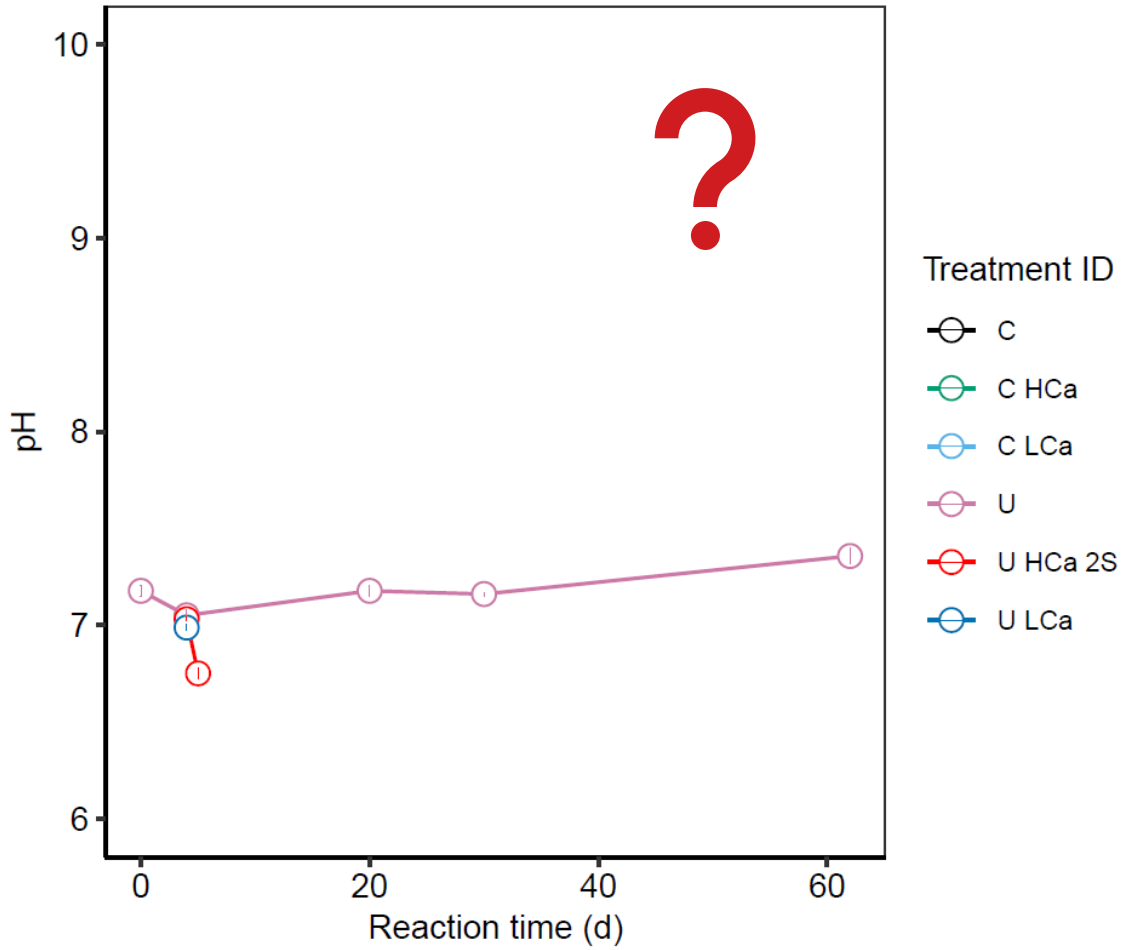
Bioremediation of heavy metals through indigenous Microbial-Induced Calcite Precipitation- Soil 2

Soil 2

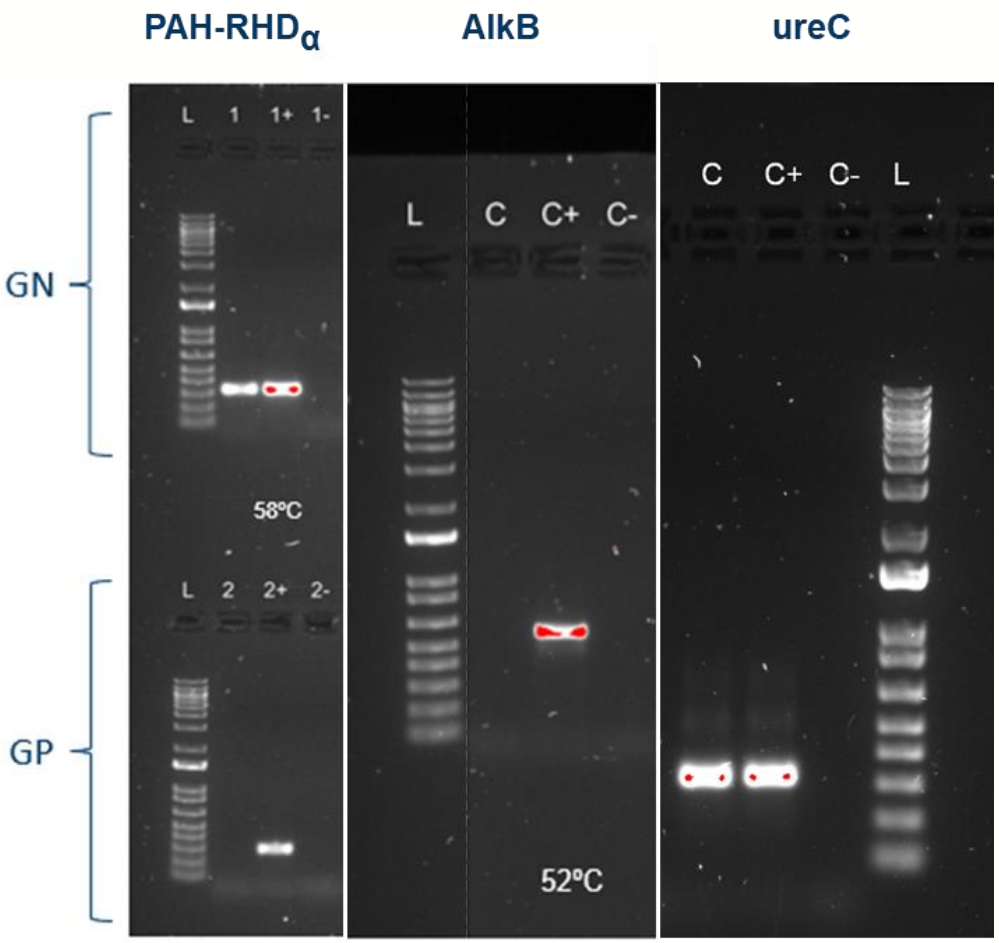
ureC gene



Urea hydrolysis



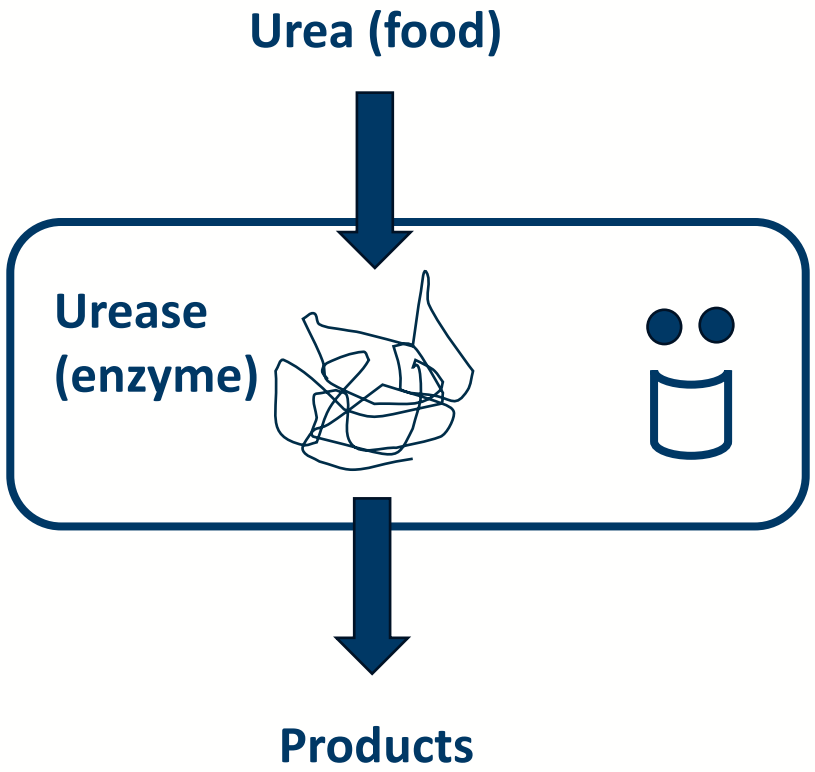
Soil genetic potential for bioremediation

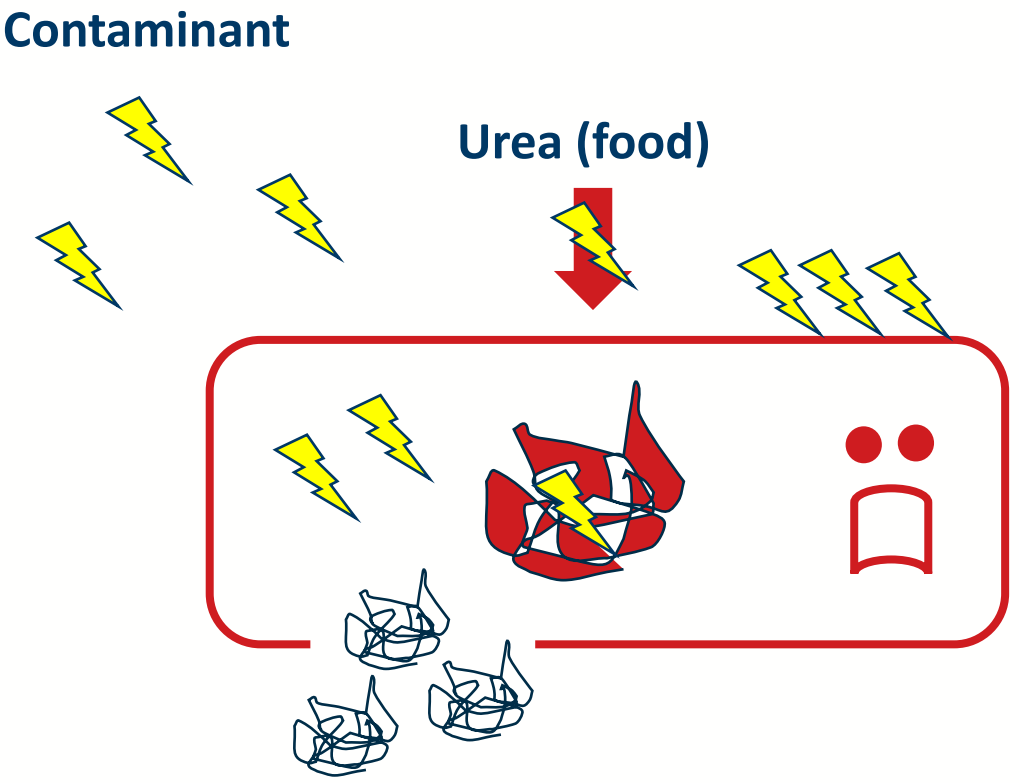


Organics

Heavy metals

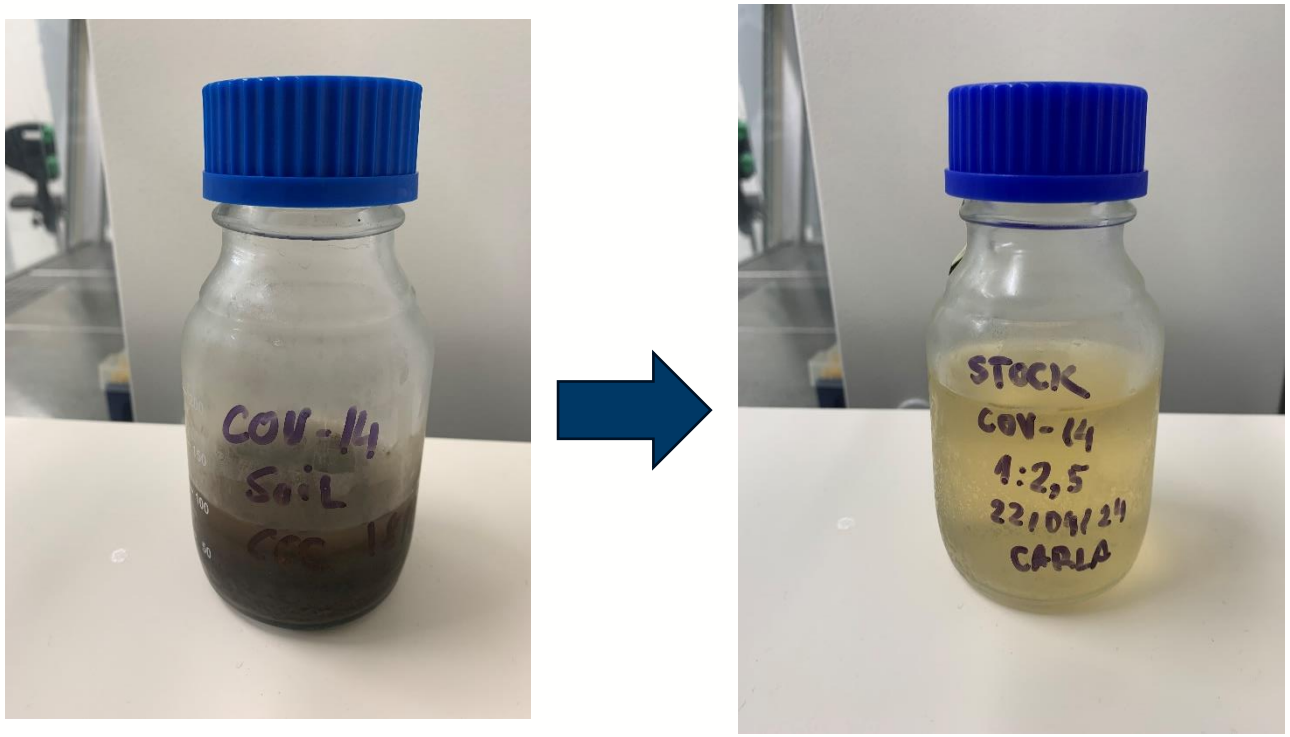
Research questions





Experimental plan

1. **Soil extraction**
2. Enzyme extraction
3. Bacteria culture
4. Urease activity assay
5. Bacteria viability



Experimental plan: urease activity inhibition

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2. **Enzyme extraction**
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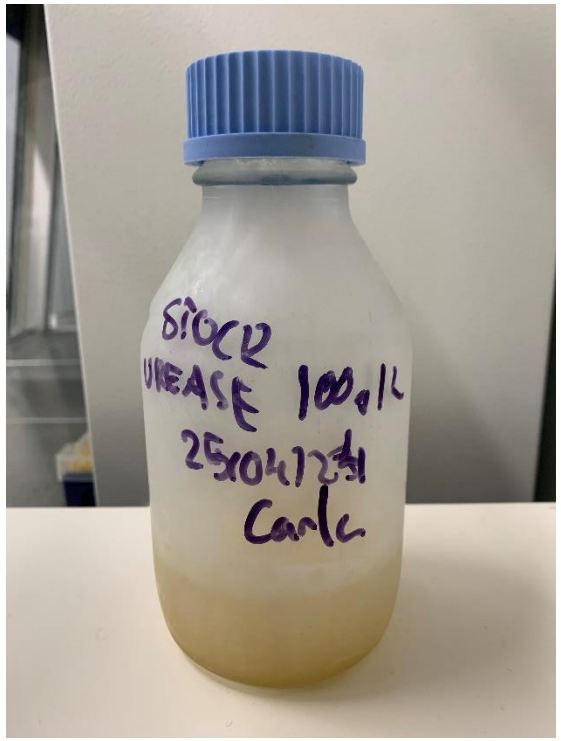
5. Bacteria viability



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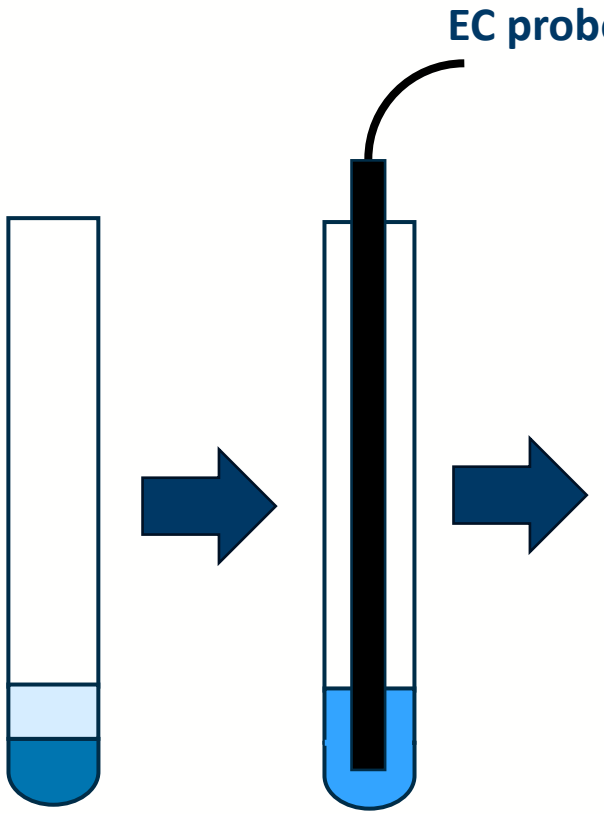
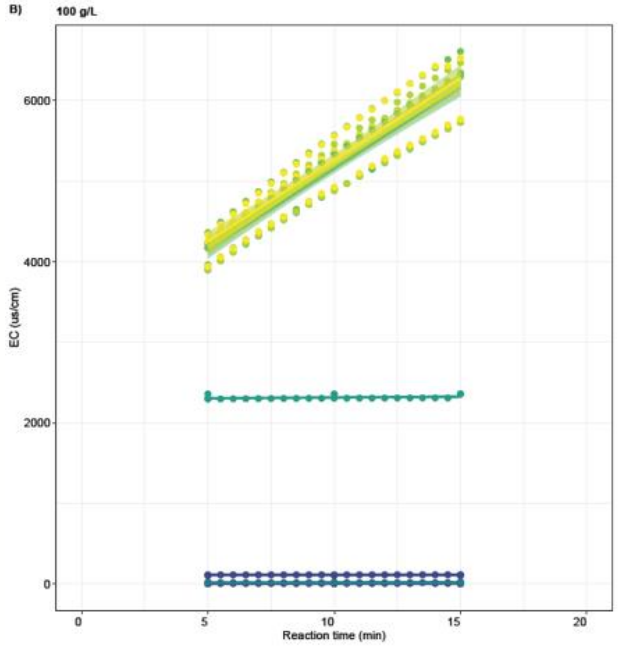


EC (*t*)



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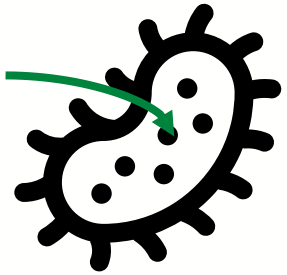
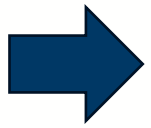
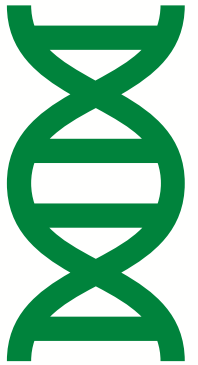
Flow cytometry

Total cell count

Dye 1

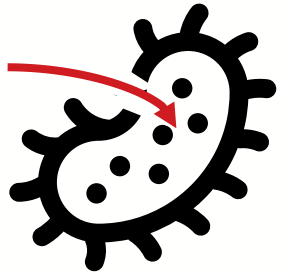


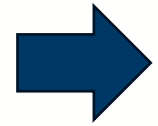


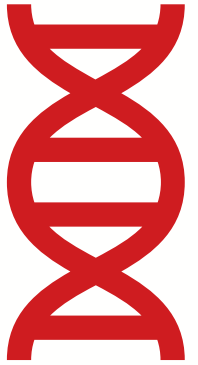


Intact cell count

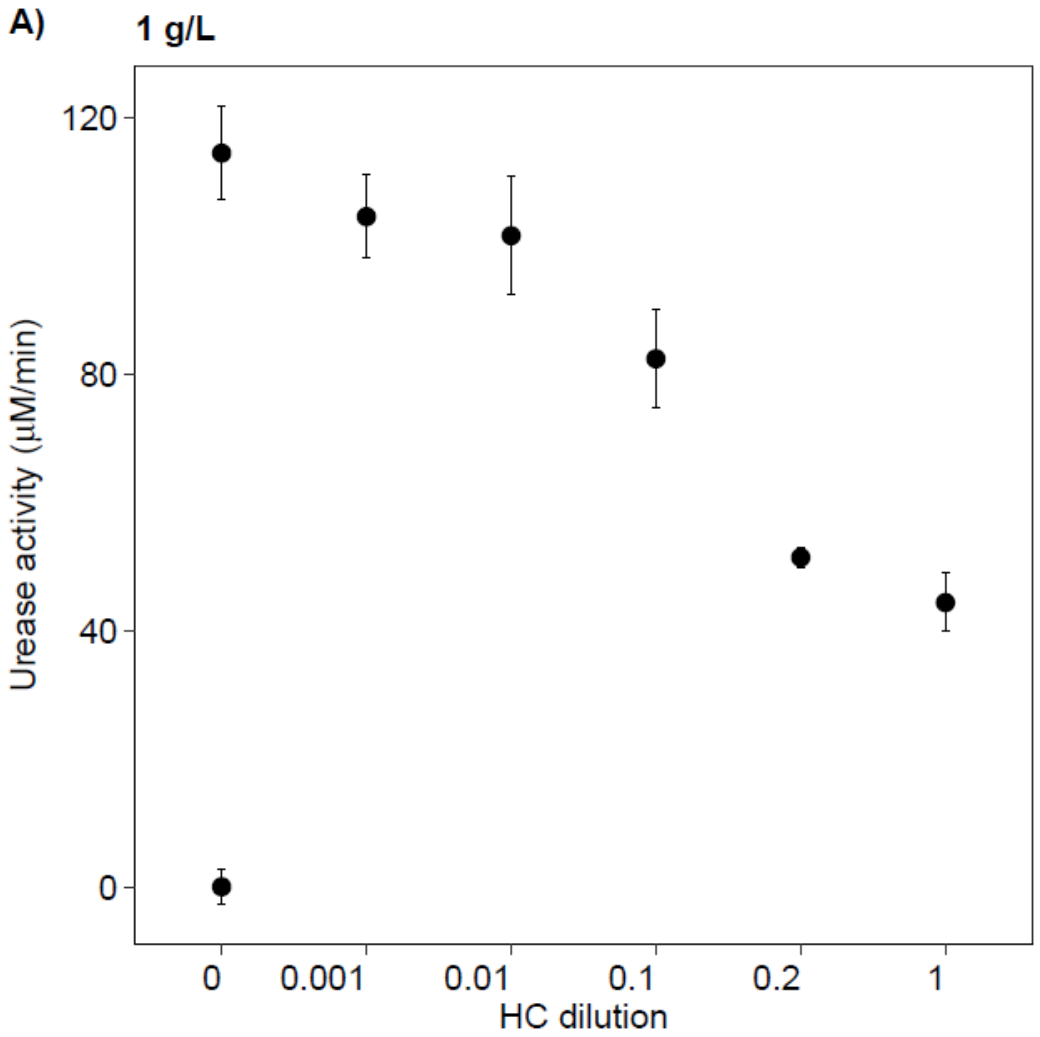
Dye 2

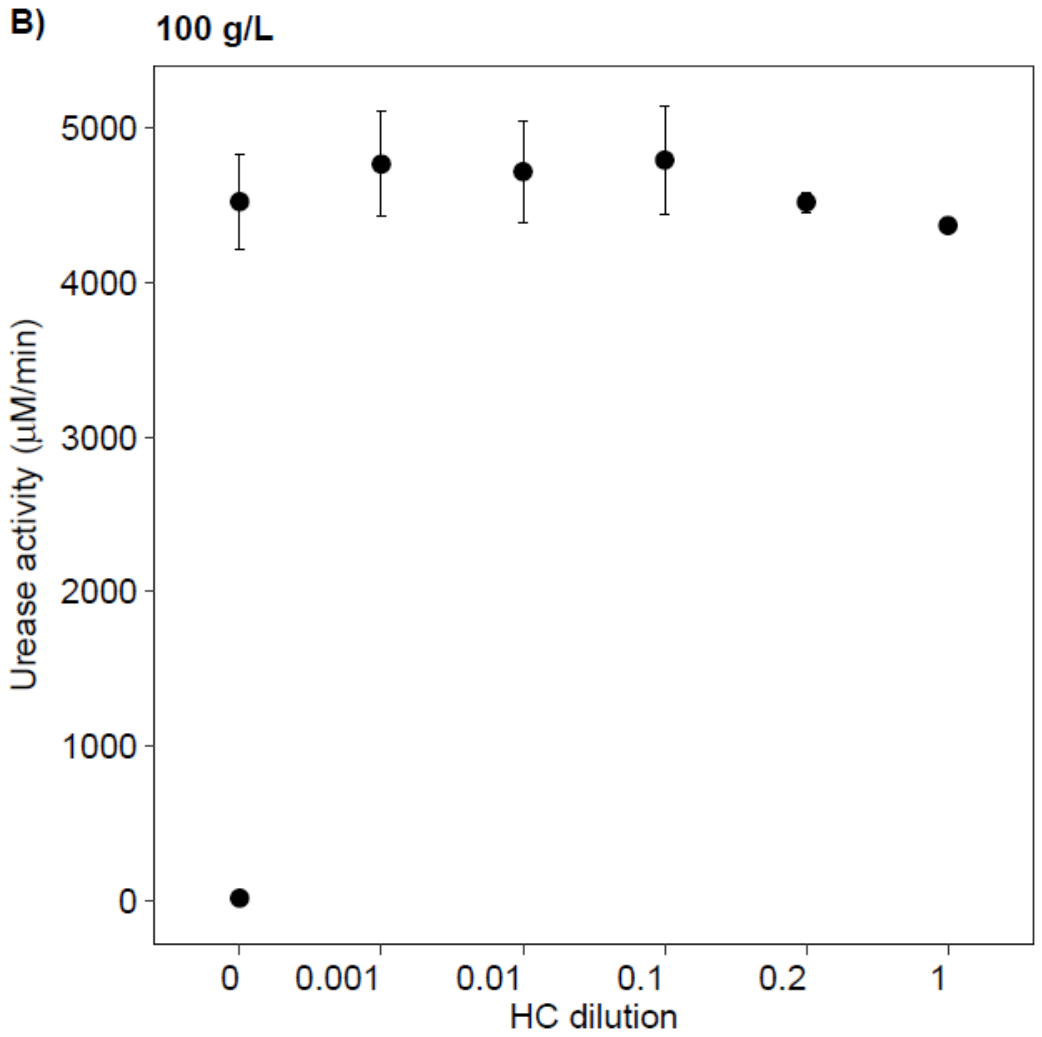






Urease activity of soya bean urease enzyme





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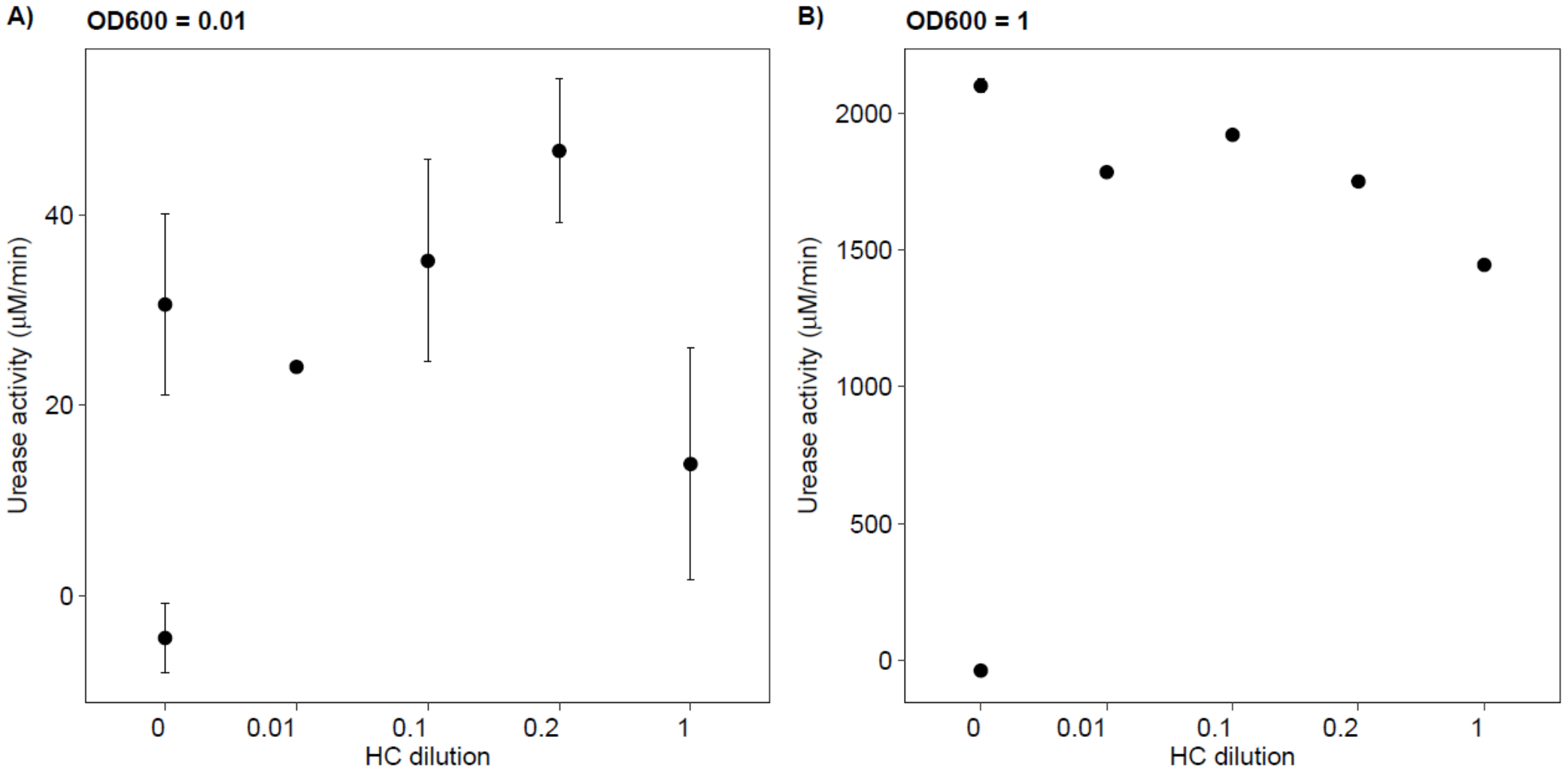
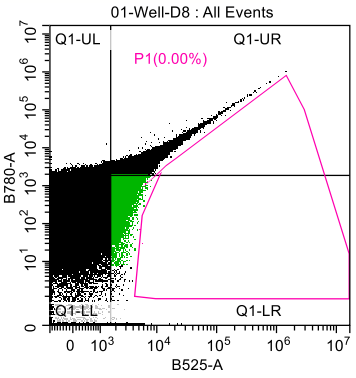
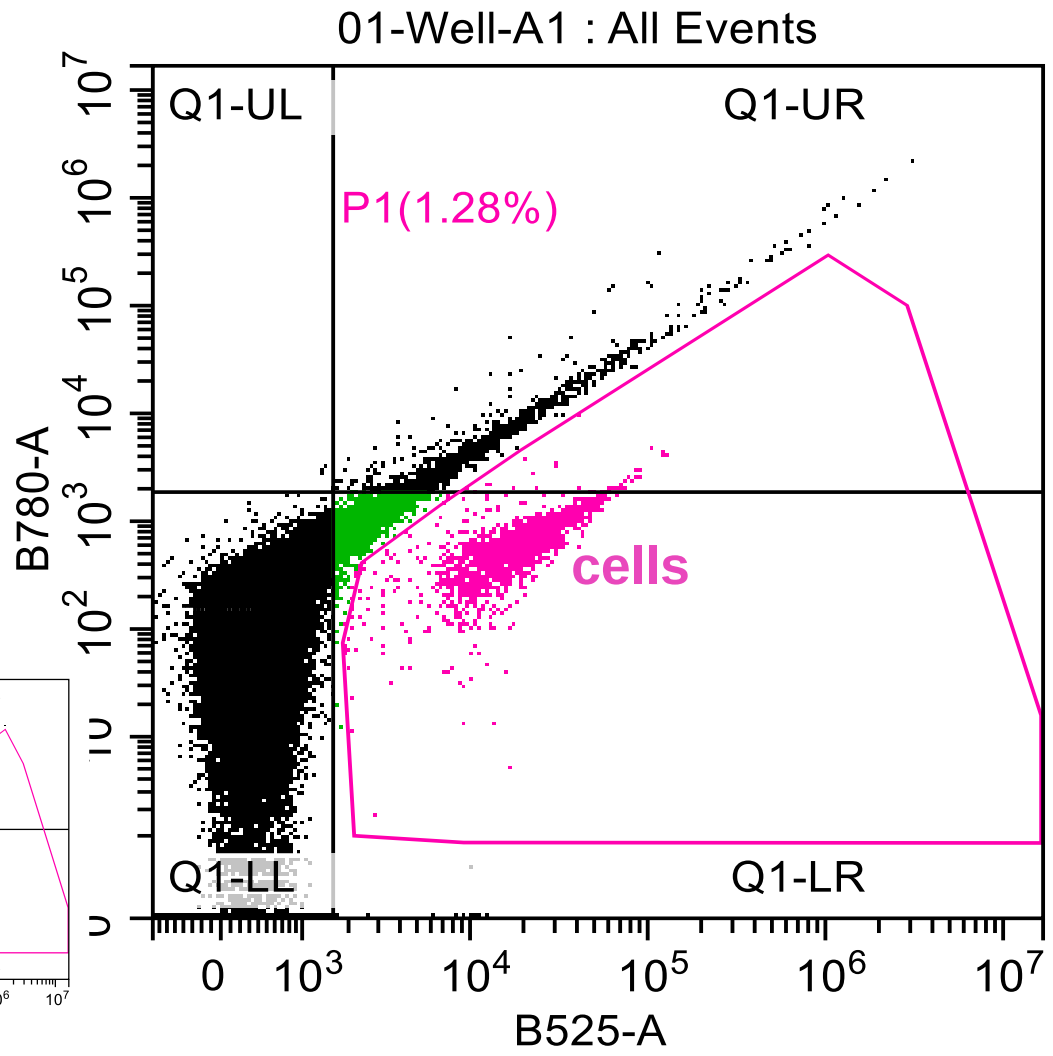
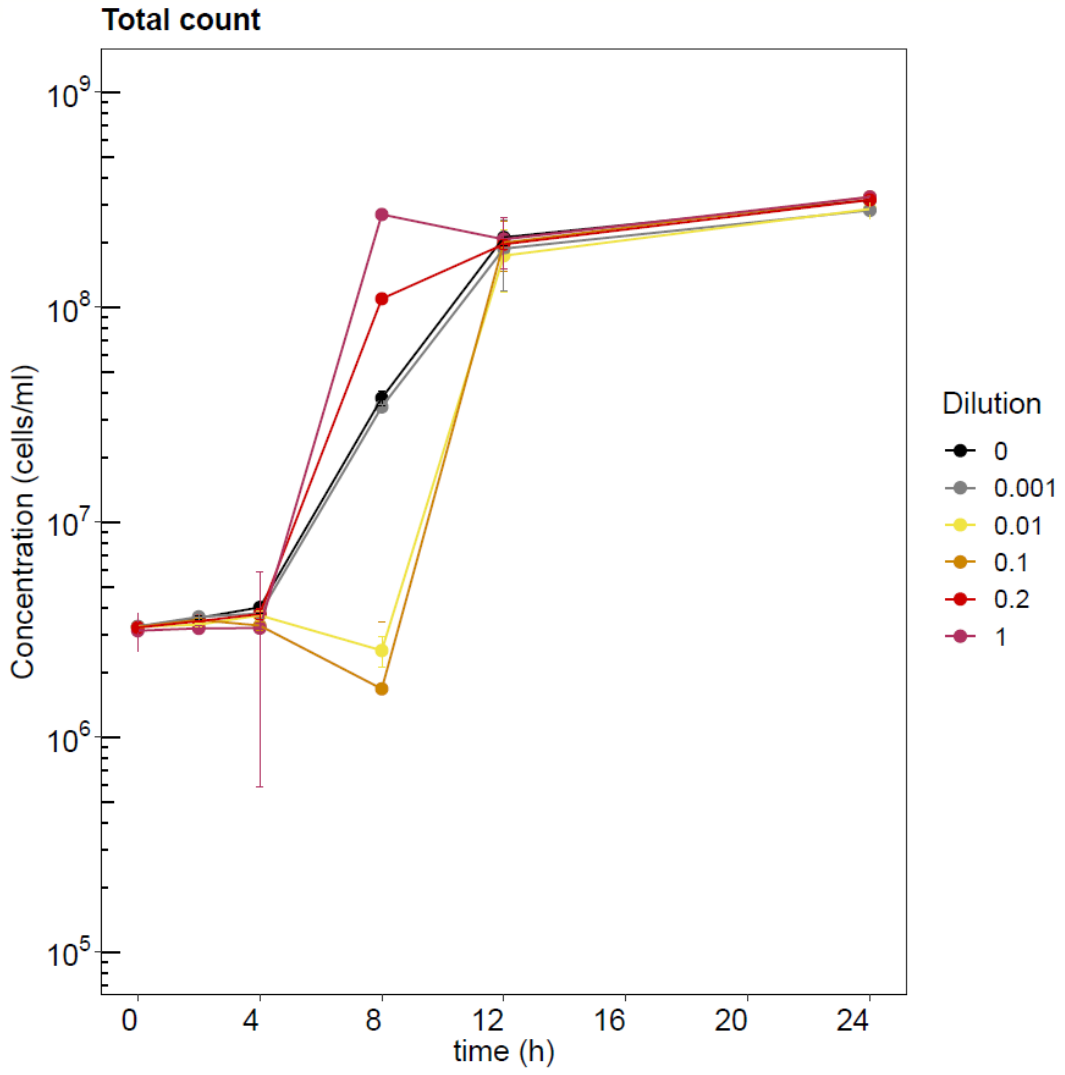
Urease activity of *Sporosarcina Pasteurii*



S. pasteurii growth in HC extract







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In absence of organic contaminants, indigenous bacteria can induce MICP to mineralise CO_2 and heavy metals.

High levels of PAH in soils inhibit biostimulation of urea hydrolysis. Inhibition occurs at both cell and enzyme level.

Bioaugmentation approaches with *S pasteurii* seem possible.

Bioremediation of contaminants might be necessary for biostimulation approaches.

What are we trying to do? Negative Carbon Remediation!!






Thank you!

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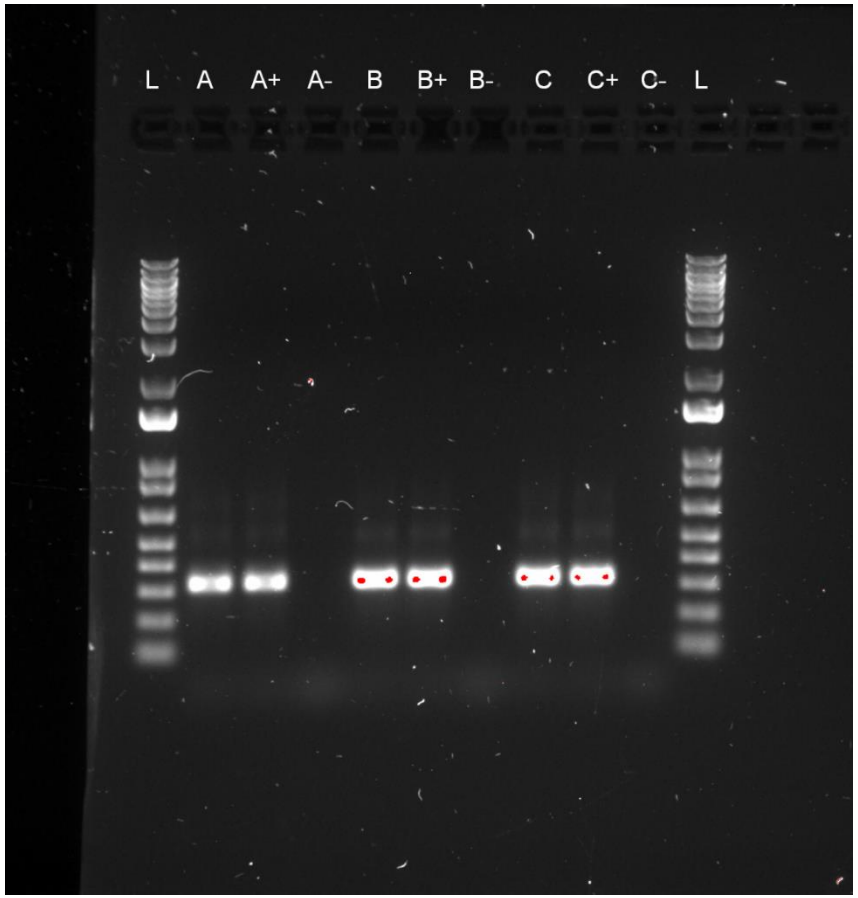
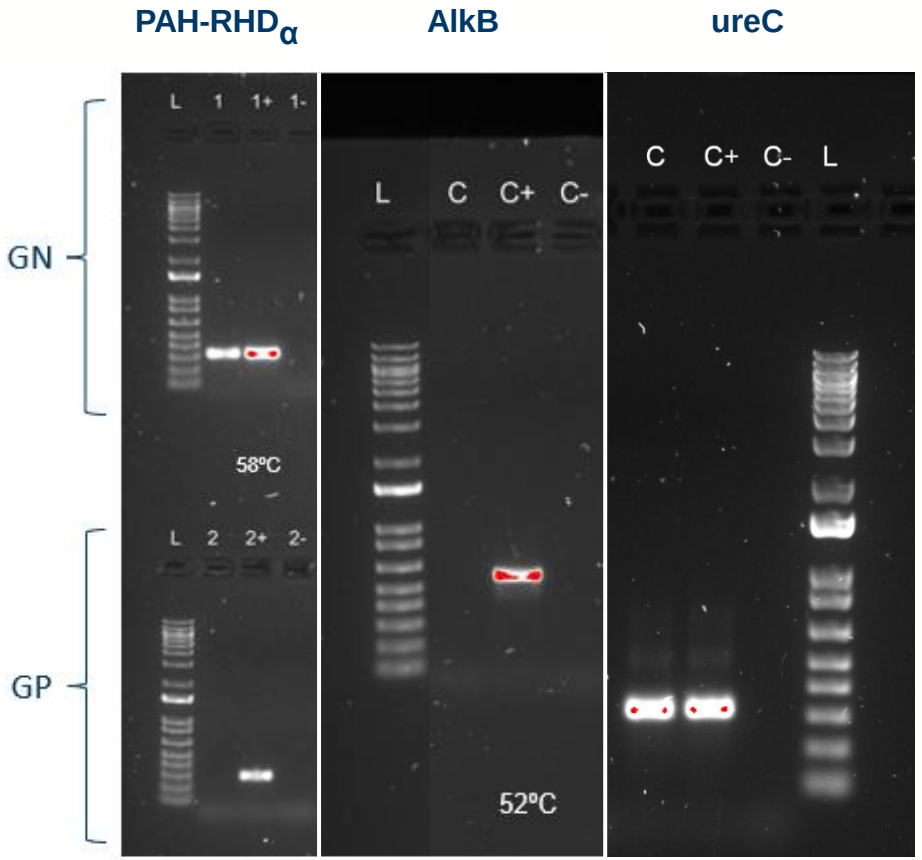
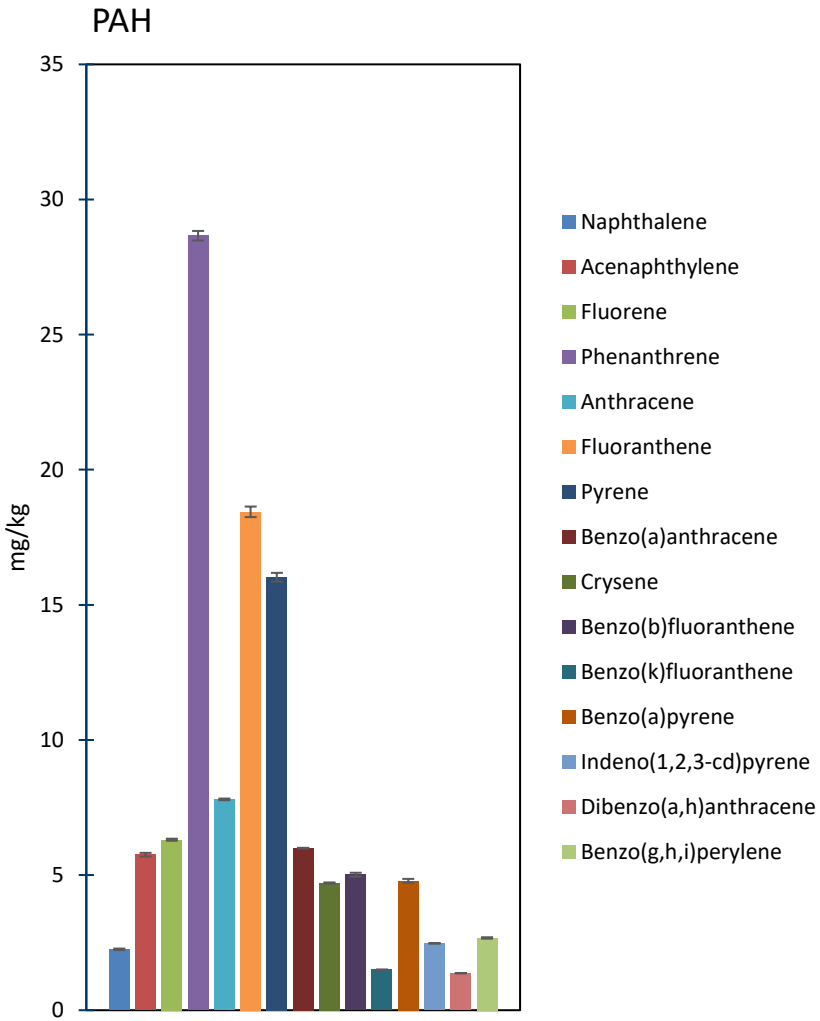
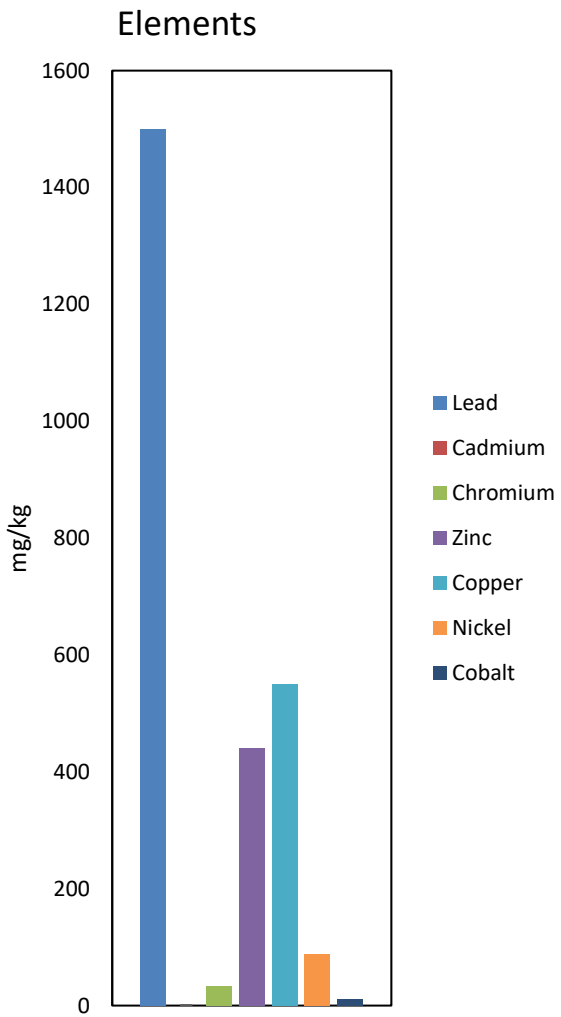

L A A+ A- B B+ B- C C+ C- L

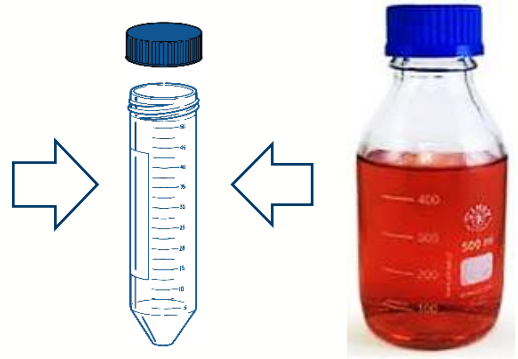

PAH-RHDα
AlkB
ureC
GN
GP
L 1 1+ 1-
58ºC
L 2 2+ 2-
L C C+ C-
52ºC
C C+ C- L

Soil properties and treatment strategy





Urea : Ca^{2+} (mM)	Application
333 : 0	Agriculture
333 : 50	Bioremediation
333 : 333	Engineering



Solution:
- Ureolysis (pH)