Chromium (VI) and vanadium (V) in groundwater: investigating bioremediation solutions

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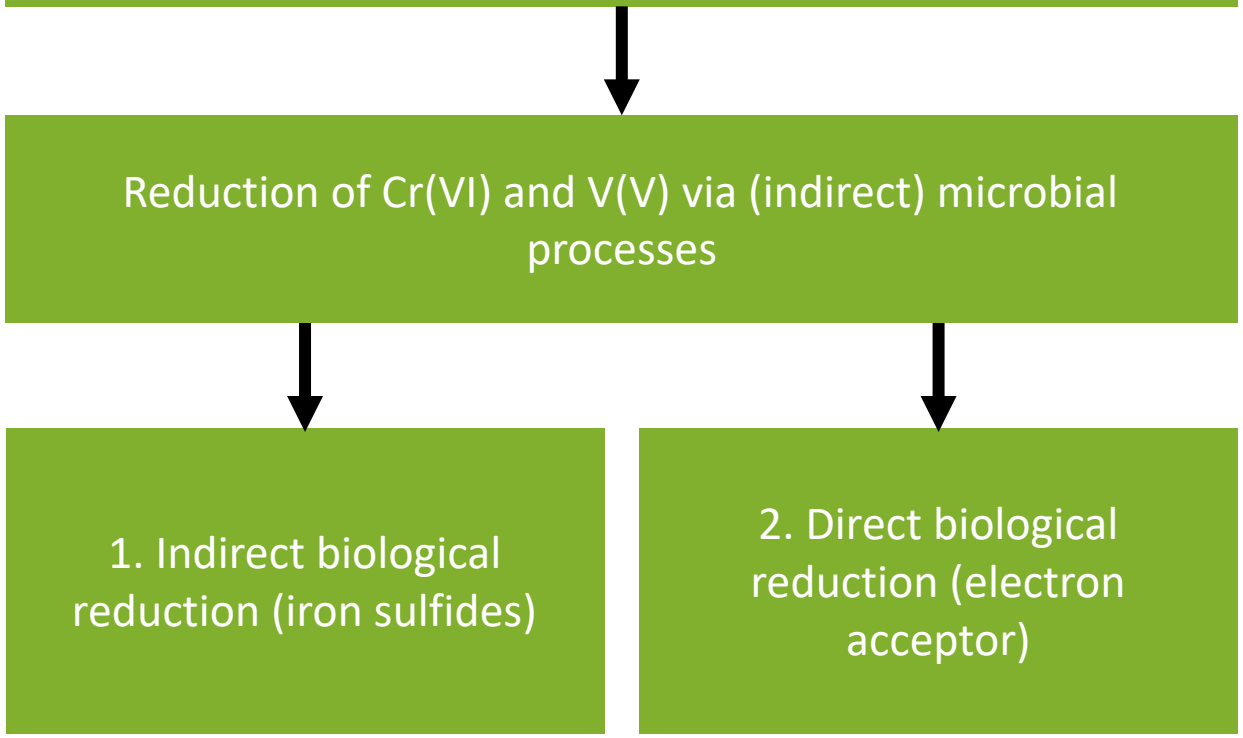
Microbial reduction of metals

Mainly Cr(VI) and Cr(III)

Chromium (Cr) and vanadium (V) exist as different species: Cr(VI) and V(V) most toxic and mobile

V(V), V(IV), V(III) and V(II)



Site

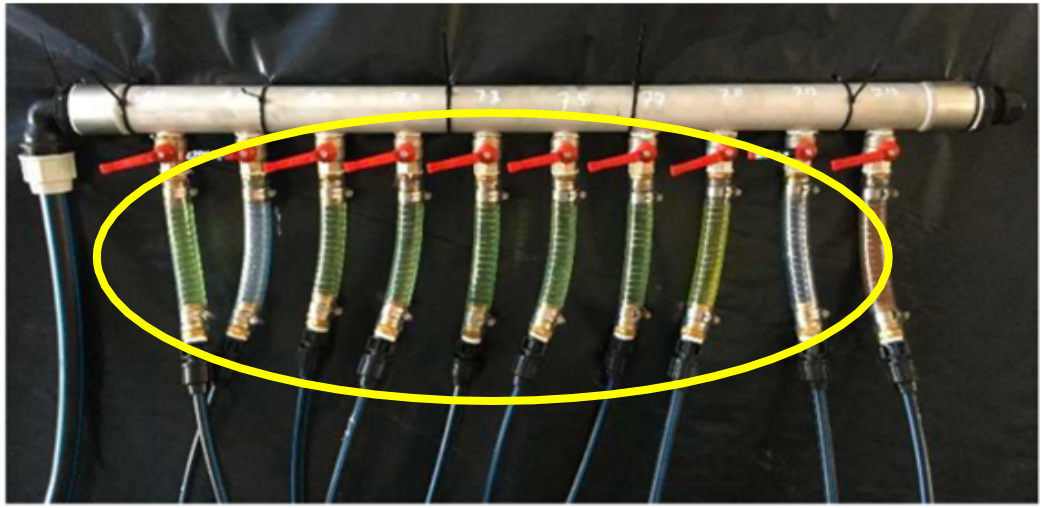
In-situ remediation of cVOC and Cr(VI) contamination at an urban site

- Former galvanizing plant in The Netherlands; urban area + significant part of the contamination is located under a monumental building.
- Concentrations groundwater: ±1000 mg/L Cr(VI), ±100 mg/L cVOCs
- Anaerobic in-situ bioremediation: injections of electron donor to dechlorinate cVOCs and reduce Cr(VI) to Cr(III)

Chromium (VI) in-situ remediation

Source treatment

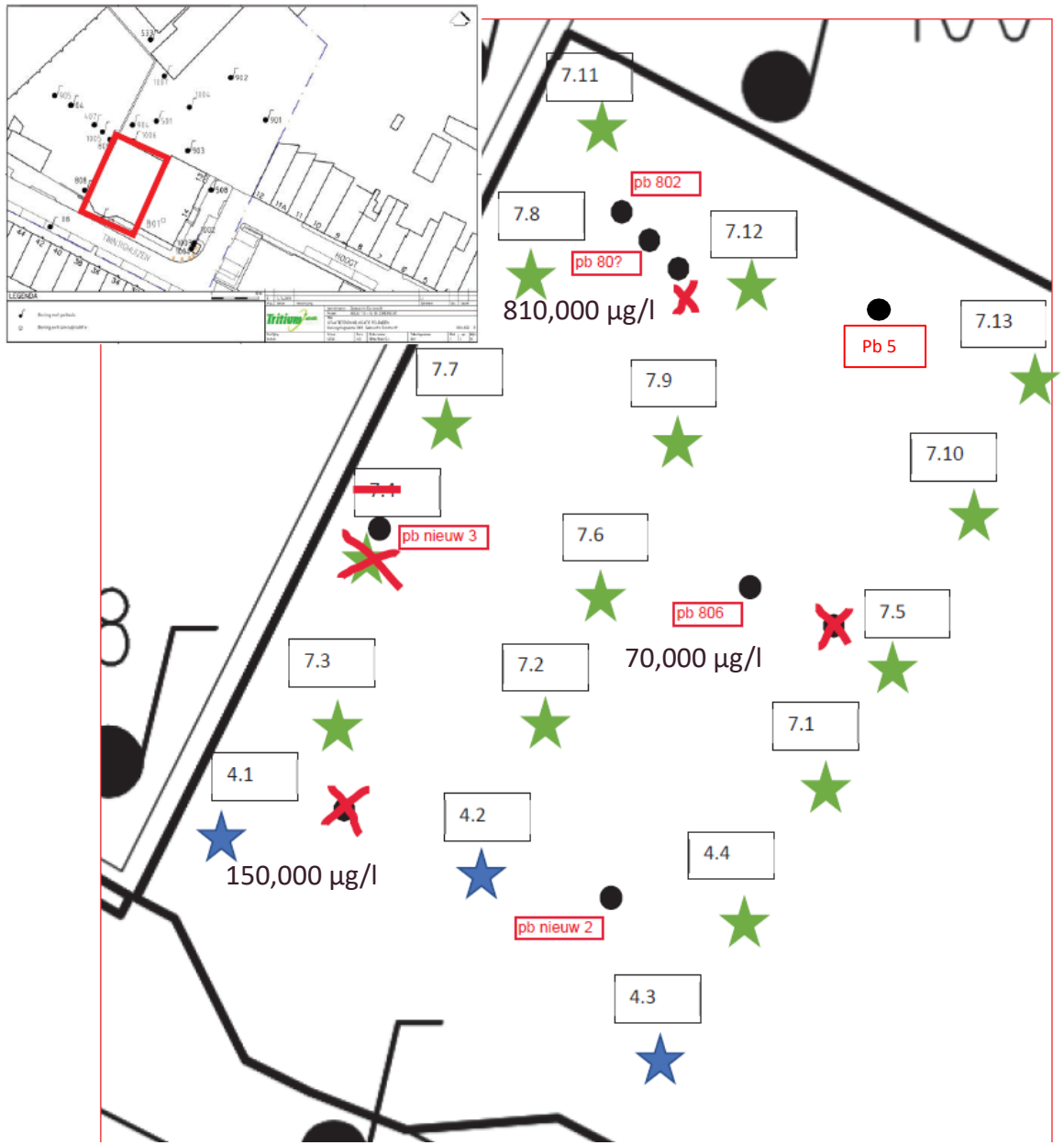
- Circulations system (flushing)
  - 10 filters
  - Extraction strongly contaminated water
  - Infiltration clean water
  - Removal 13 tonnes highly contaminated material
- Direct injections in cellar
  - 18 injection of 8 m3 electron donor solution



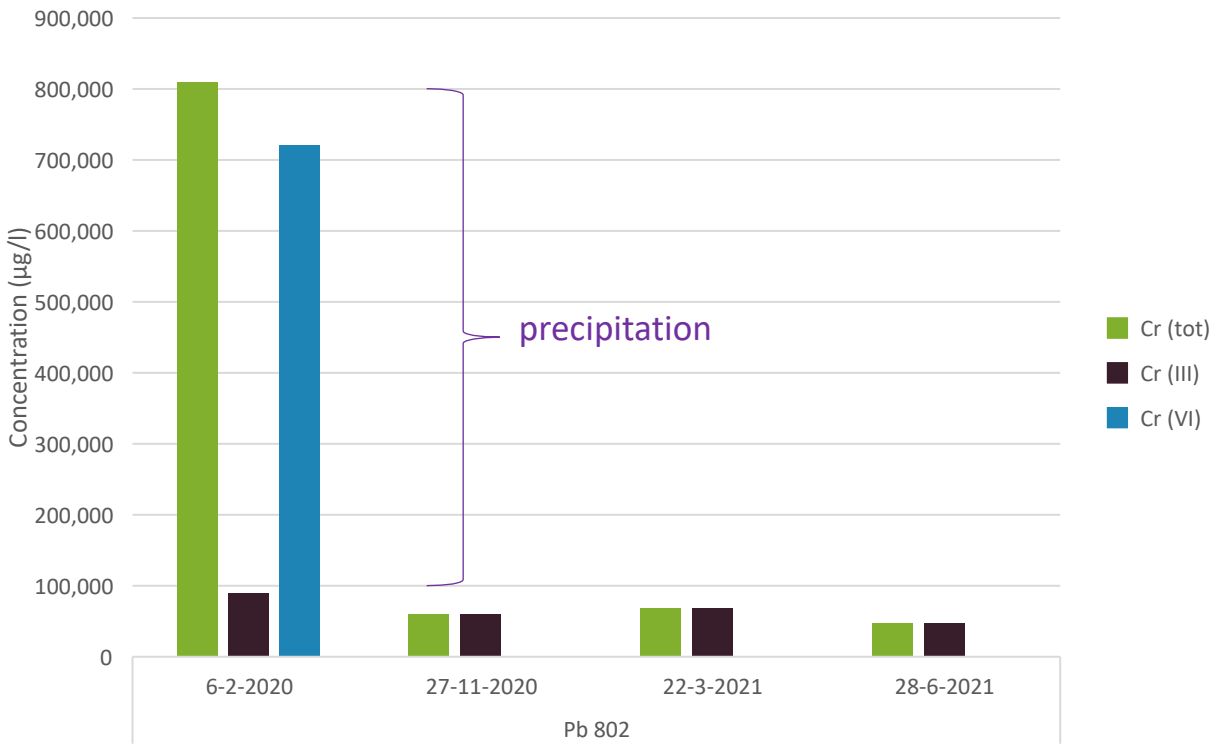
Chromium (VI) in-situ remediation

Treated area	
Volume	2,500 m^3
Depth (layer)	7 m-bgl

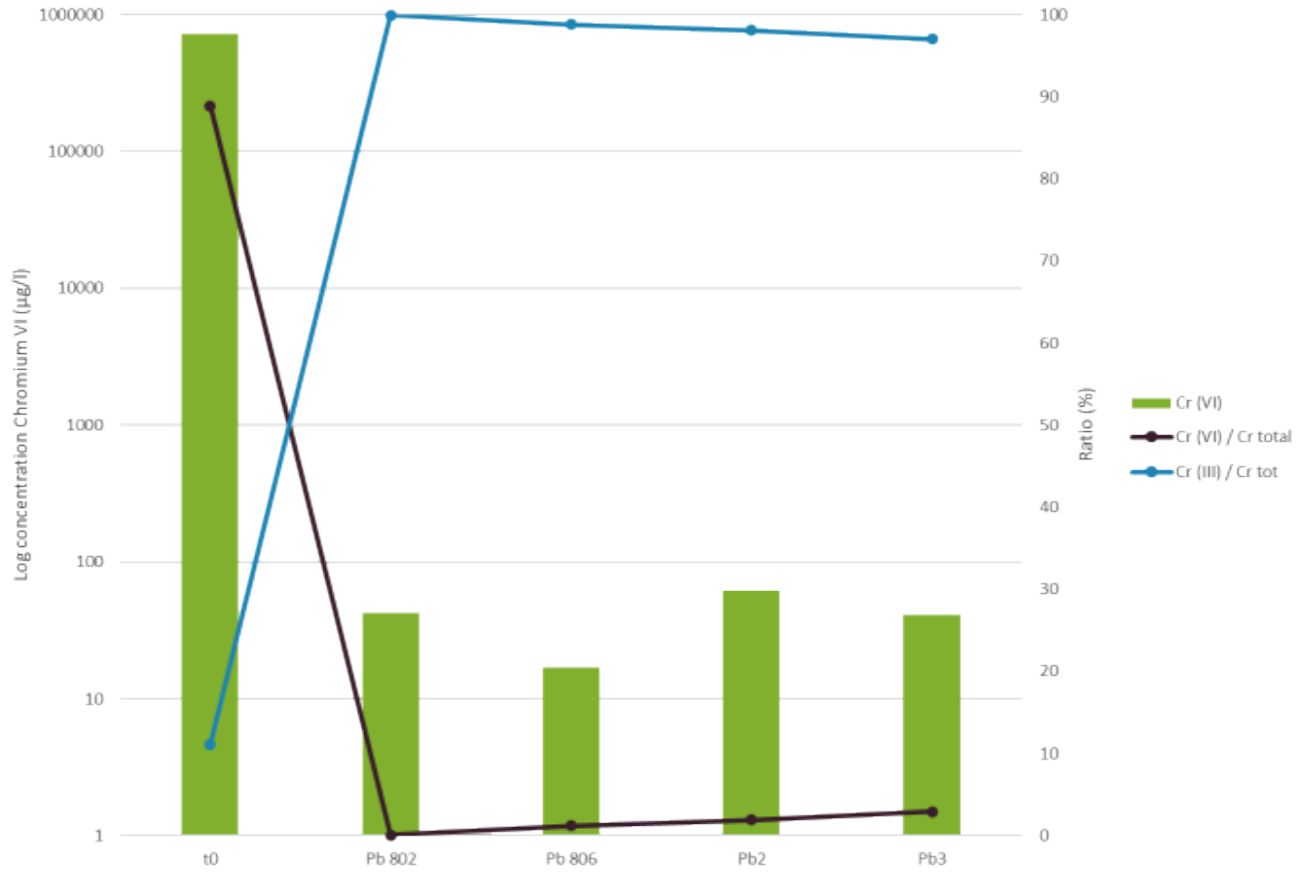
Max groundwater concentration	
Cr (VI)	1,000,000 µg/l
TCE	100,000 µg/l
*c*DCE	53,000 µg/l
VC	3,600 µg/l
SO_4^{2-}	1,500 mg/l



Chromium (VI) in-situ remediation



Chromium (VI) in-situ remediation



After 1 year

- No limits for Cr defined: risk based
- Long term stability: followed up by monitoring (natural redox conditions are reducing)

Site

Vanadium (V) and sulphate contamination in the groundwater at a former mining and production site

- Former vanadium mine/production site. Currently intended for agricultural use.
- Concentrations: ±1,000 mg/L V(V), ± 5,000 mg/L sulphate (leaching dump)
- Microbially mediated reduction of vanadium (V) to less mobile and toxic forms was investigated as a viable option.

1st laboratory test: results

- Vanadium reduction took place in the beginning of the test; no correlation with sulphate reduction
- Based on NGS, *P. putida* (obligate aerobic bacteria) possible candidate for vanadium reduction - 8 % of total bacteria + described in literature as being able to reduce Vanadium
- Starting material likely contained dissolved oxygen to some extend (presence of iron (hydr)oxides upon arrival)

2nd Laboratory test: Aerobic and anaerobic

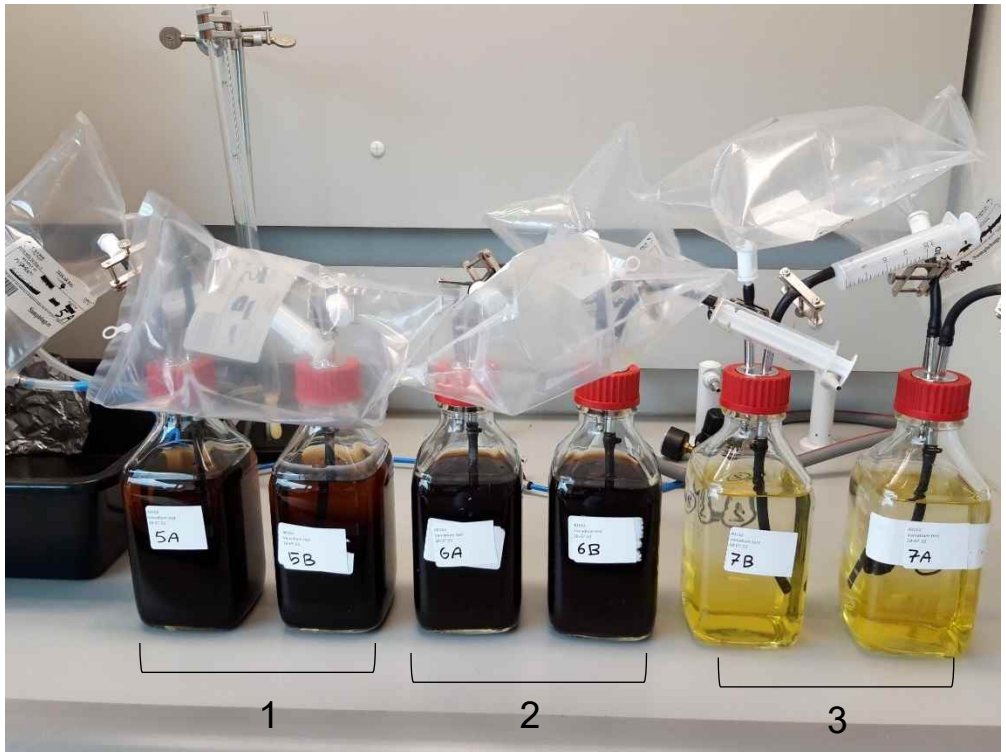
- Incubation under aerobic condition (+ growth substrate) to test if V reduction can take place under aerobic conditions **-> No reduction**

- Incubation under anaerobic conditions with strict anaerobic (new) material

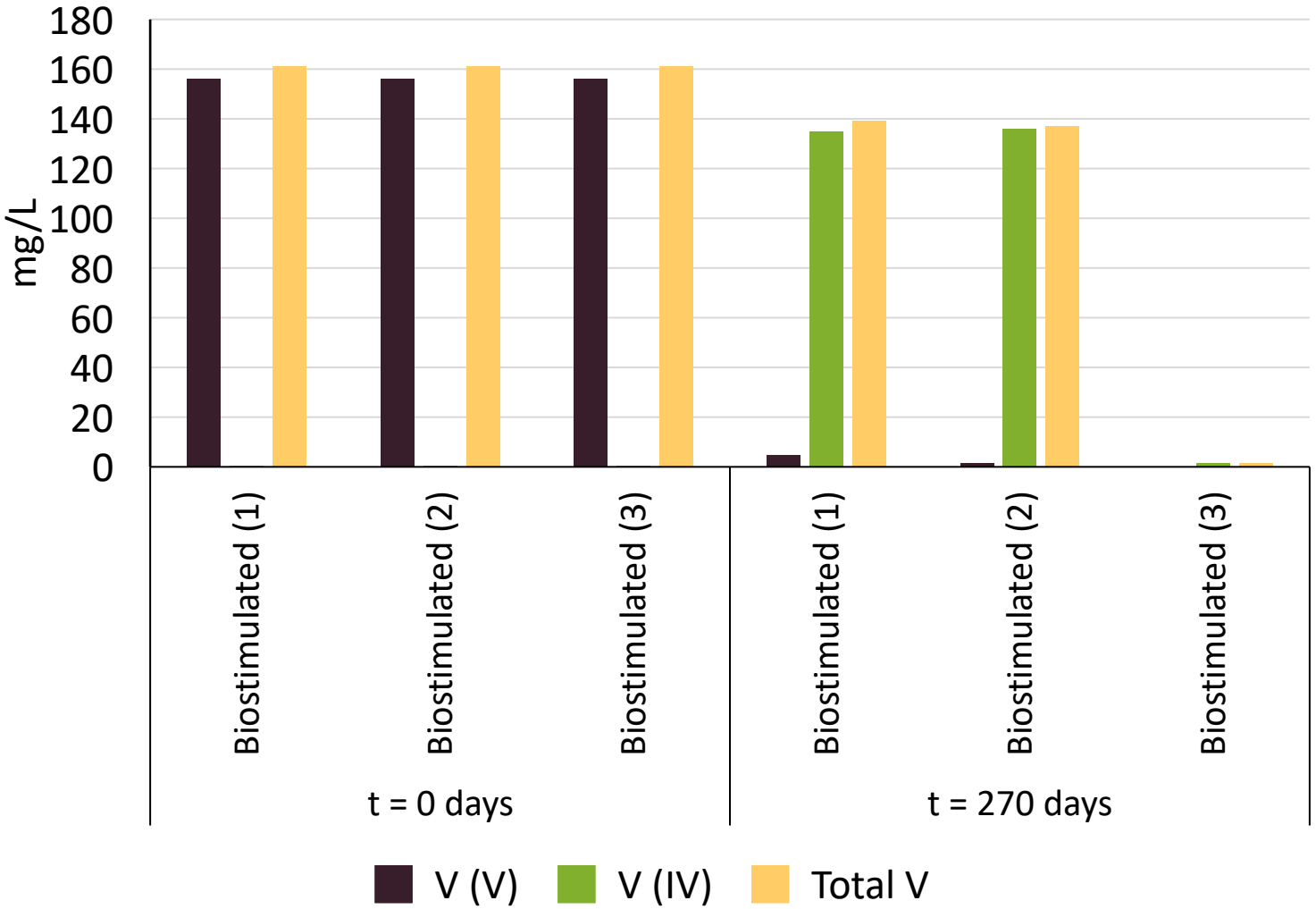
Anaerobic test: set up

- Complex organic substrate (Dehalo GS) and lactate as electron donors
- Iron sulphate might enhance sulfide and vanadium precipitation
- Lactate as substrate for better visible observations (colorless)

	Conditions	Amendments
1	Biostimulated 1	groundwater + electron donor Dehalo GS
2	Biostimulated 2	groundwater + electron donor + FeSO4
3	Biostimulated 3	groundwater + lactate + N/P



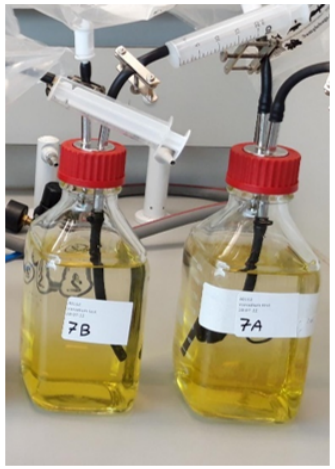
Anaerobic test: results



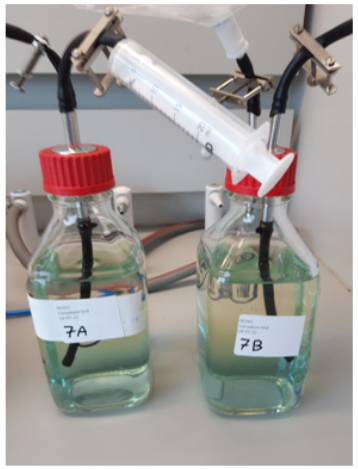
- 95-99% of total V was reduced
- >99% of total dissolved V was precipitated in lactate/phosphate condition

Anaerobic test: vanadium color changes

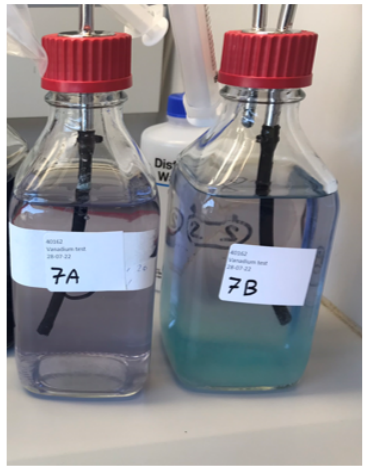
t = 0



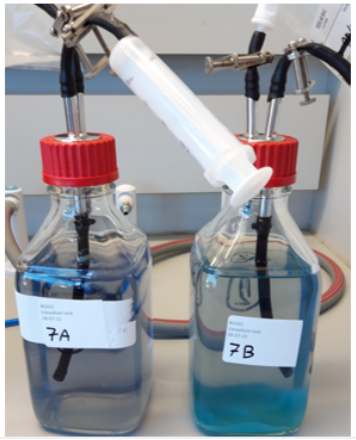
7 days



26 days

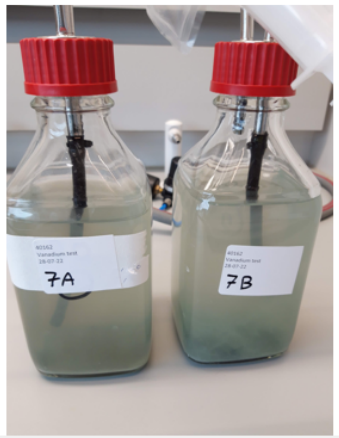


40 days

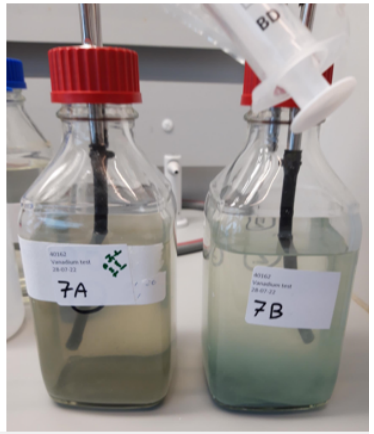


63 days

89 days



180 days



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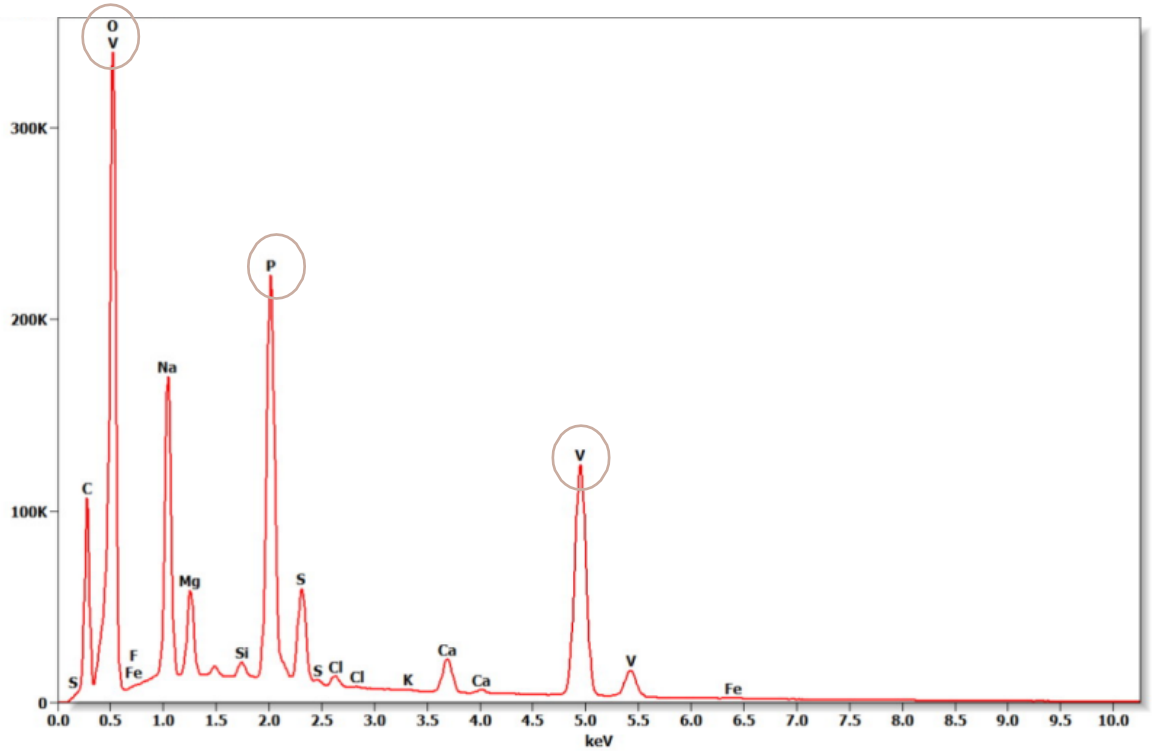
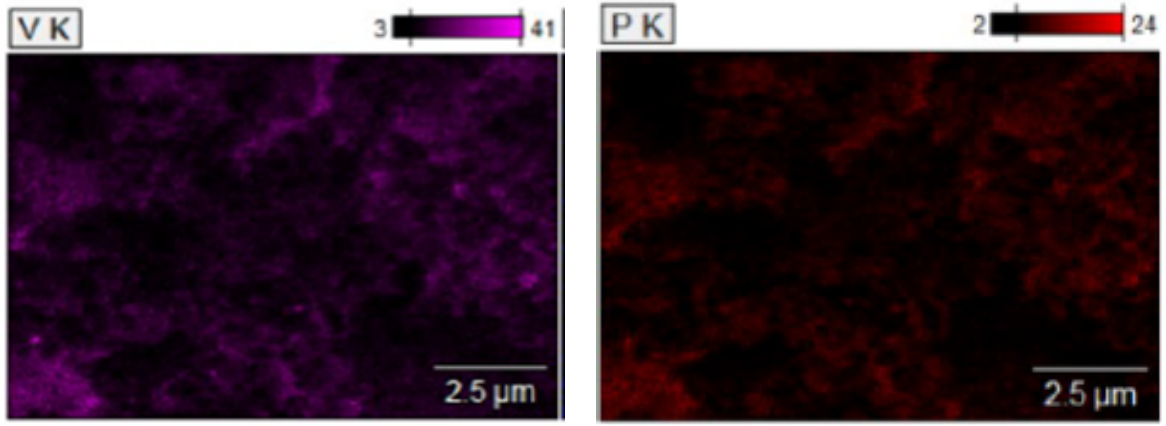
Anaerobic test: precipitation analyses



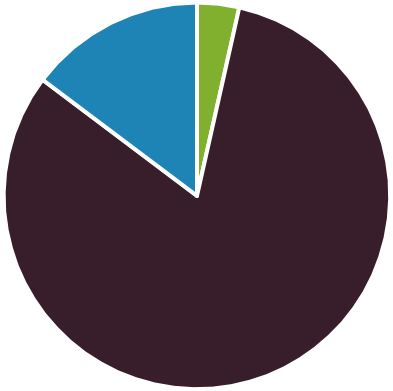
- Vanadium/phosphate complex?



SEM-EDX

Anaerobic test: results

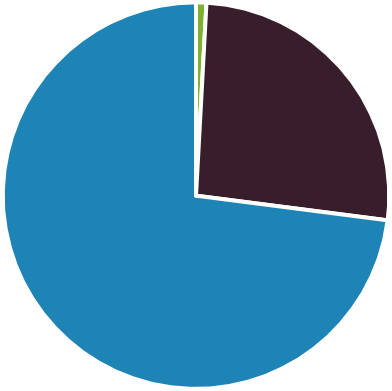
5: Dehalo-GS



% aq. V(V) % aq. V(IV) % precipitated V

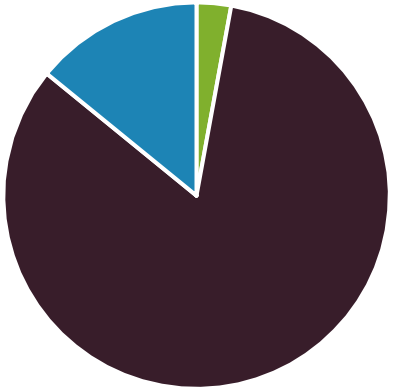
+ PO_4

5b: Dehalo-GS + PO4



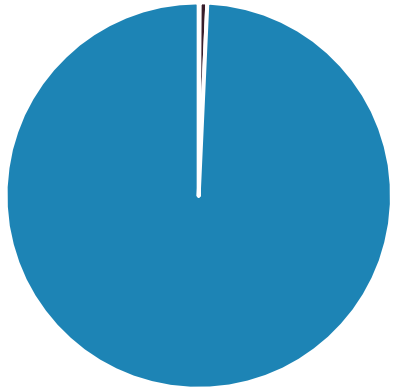
% aq. V(V) % aq. V(IV) % precipitated V

6: Dehalo-GS + Fe2+



% aq. V(V) % aq. V(IV) % precipitated V

7: Lactate + PO4 buffer



% aq. V(V) % aq. V(IV) % precipitated V

- >99% of total dissolved V was precipitated in lactate/phosphate condition

Anaerobic test: microbial analyses (NGS)

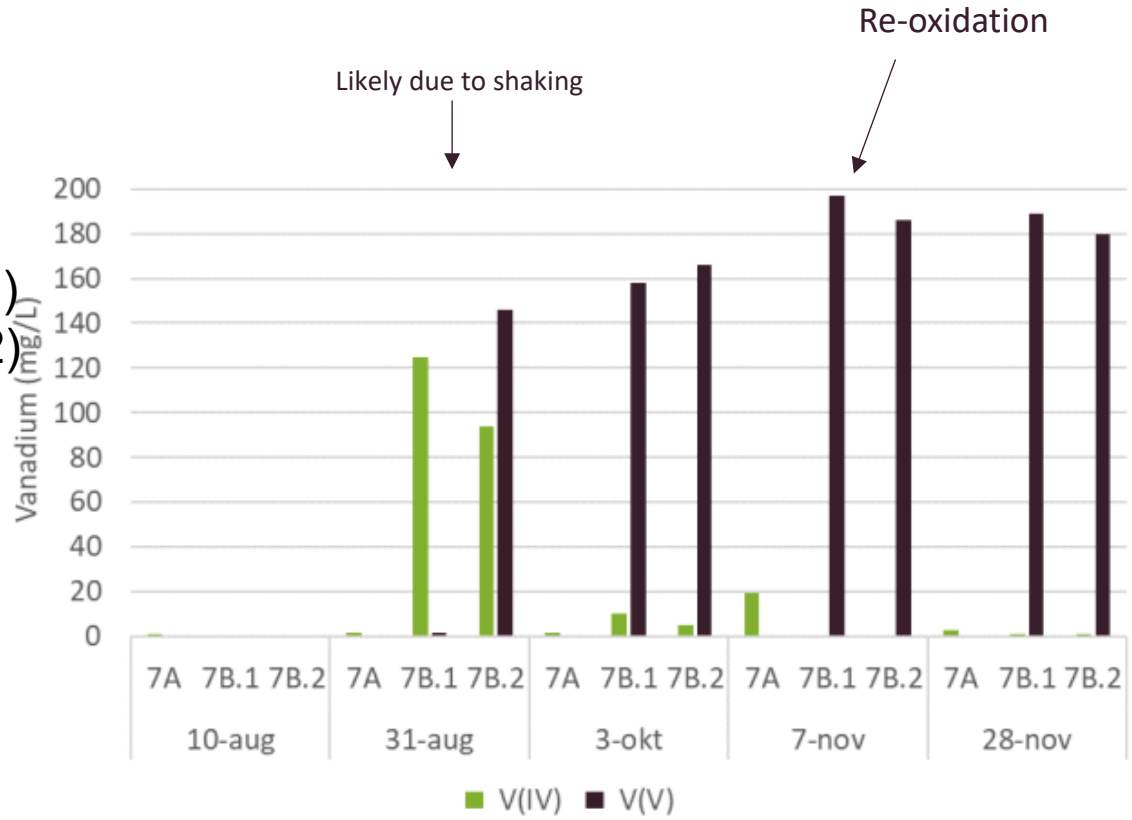
- potential Cr(VI) reducing bacterial species (Pseudomonas stutzeri)
- Sulphate reducing bacteria (variety of Desulfosporosinus)
- Fermenting bacteria (Clostridia
- Other

- Different species than first test (also different material)
- Vanadium likely used as electron acceptor (literature: vanadate (VO_4^{3-}) as electron acceptor for *Pseudomonas aeruginosa* etc)

Long-term stabilization of reduced Vanadium

- Investigate stability of precipitated, reduced Vanadium under three conditions for 3 months

1. Anaerobic (7A)
2. Worst-case 1; headspace flushed once (7B.1)
3. Worst-case 2 headspace flushed weekly(7B.2)



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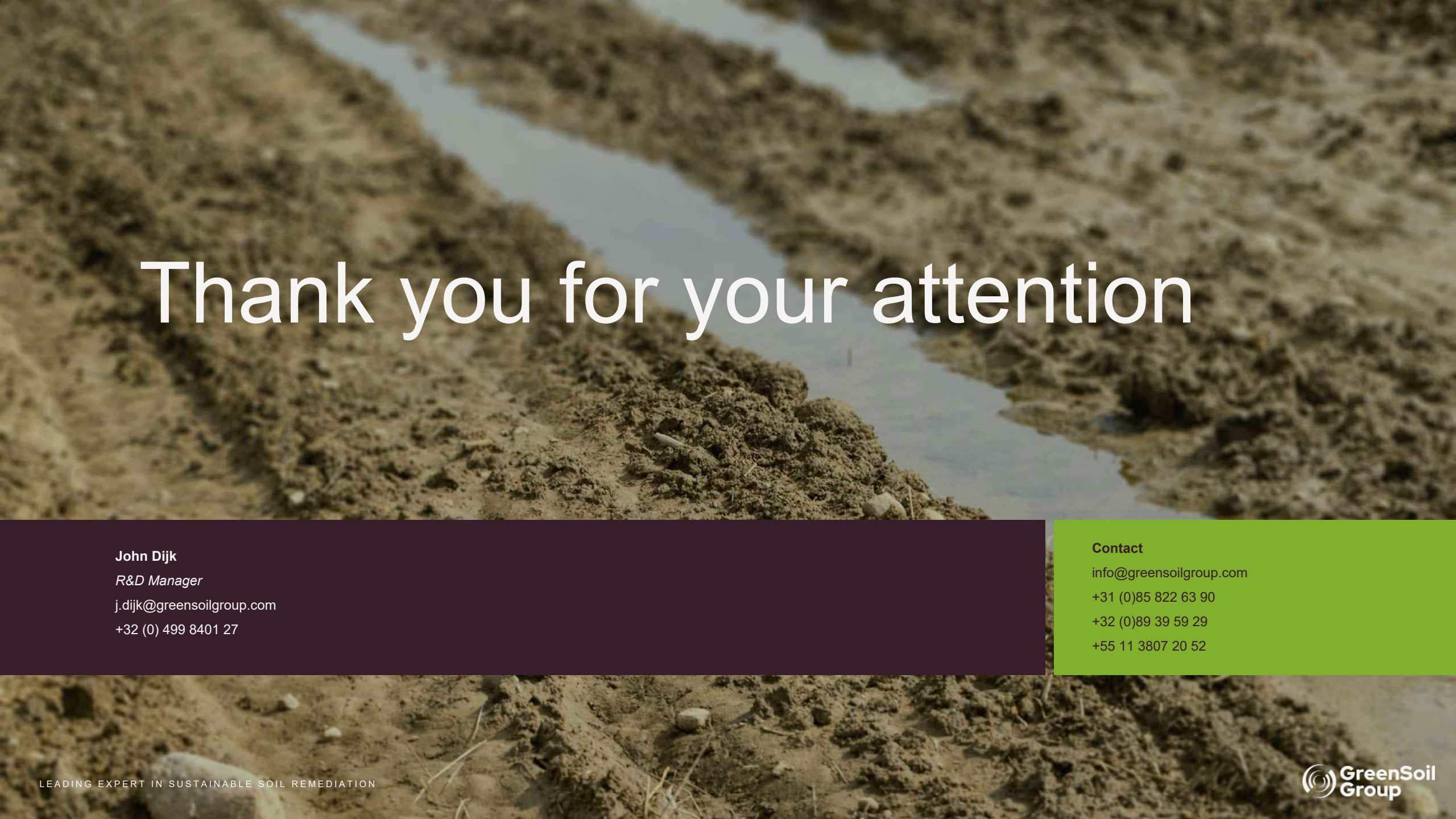
Conclusions

- Up to 99% reduction of V(V) to V(IV) in the presence of growth substrate under anaerobic (likely nitrate reducing) conditions. Biological process!
- Up to 99% precipitation in the presence of sufficient phosphate
- Vanadium reduction reversible process. Quick re-oxidation in worst-case scenario, but no re-oxidation under anaerobic conditions
- Next steps: field conditions different than laboratory conditions (low DO, no shaking) -> test under field conditions



Thank you for your attention

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