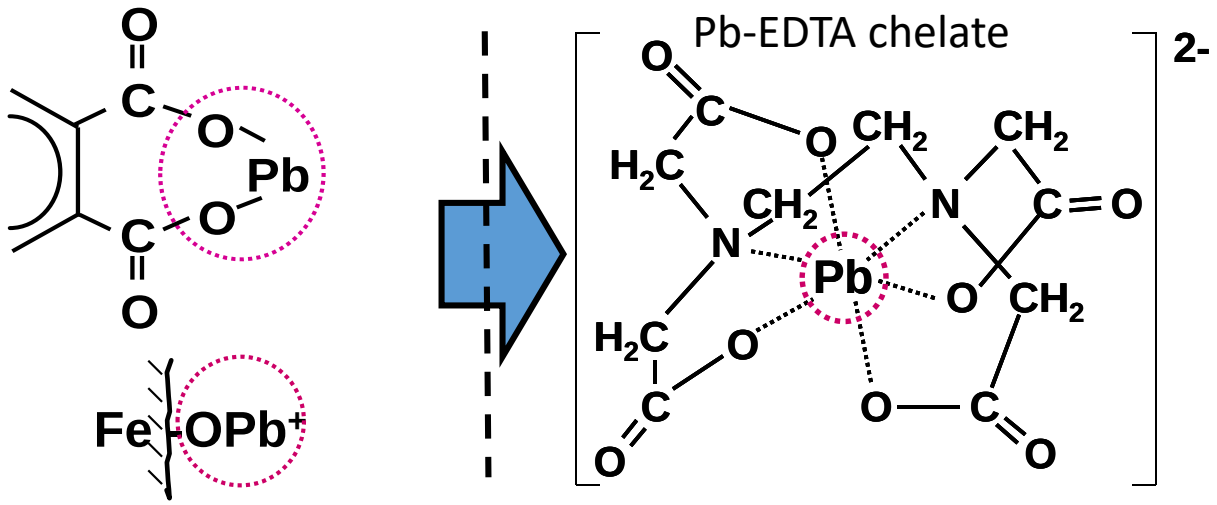
ReSoil

Problem to solve

- Contaminated urban and peri-urban areas
- Military and recreation shooting ranges
- Brownfields
- Contaminated agricultural soil

Only a fraction of soils contaminated with Pb and other toxic metals is treated due to the lack of efficient and environmentally sustainable technologies.

Technology summary: Prior & novel knowledge



Pb bound to soil solid phases

Pb in washing solution

Prior knowledge

Novel technology

Cleansed soil

ReSoil

EDTA, process waters recycling, emission curbing

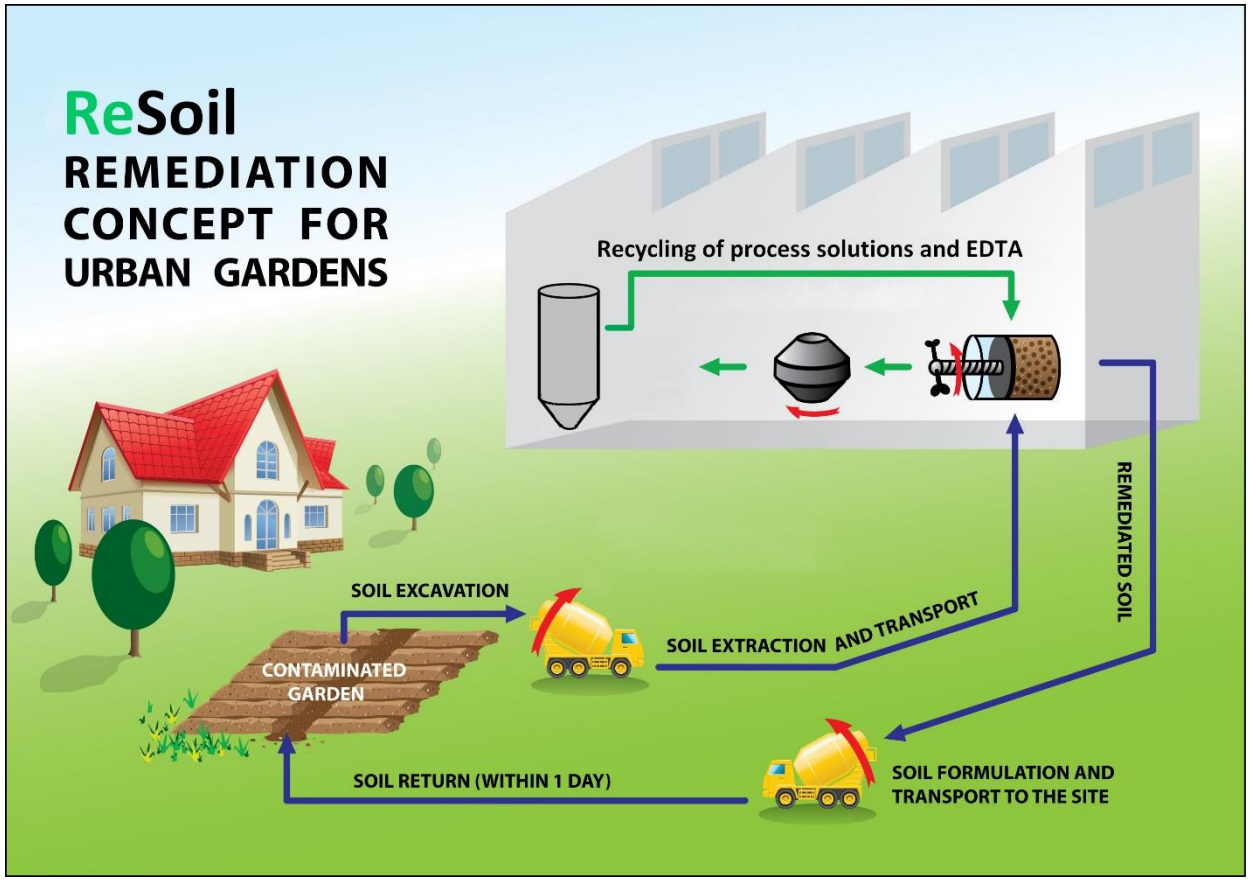
Solid wastes enriched with Pb and other toxic metals

EDTA-based soil-washing efficiently remove Pb and other toxic metals from soil. However, more than 20-years of research by many groups worldwide did not result in feasible solution for EDTA recycling, problems with vast amounts of waste waters and for toxic emission due to EDTA environmental persistence.

Technology summary: ReSoil is an *ex-situ* soil treatment

→ Soil excavation and transportation to remediation plant.
→ Soil extraction with EDTA solution.
→ Separation of solid and liquid phase.
→ Recycling of process solutions and EDTA in a closed loop.
→ Return of remediated soil.

ReSoil generates no waste-water and other emissions, produces only solid wastes and uses very little fresh water. Energy and infrastructural requirements for **ReSoil** are modest; mobile and on-site setting of the **ReSoil** remediation plant is feasible.



Technology details: Background chemistry

Chelant (EDTA) and process waters are recycled in an imposed pH gradient.

Alkaline phase:

The CaO, $Ca(OH)_2$ imposed alkalinity (pH >12) destabilizes EDTA chelates with toxic metals which are replaced in the chelate by Ca. Alkaline adsorption of released toxic metals on polysaccharide materials (i.e. waste paper) shift the chemical equilibrium towards products formation in the substitution/ adsorption/ precipitation reaction:

Recycled chelant

$$2Ca^{2+} + 4(OH)^{-} + 2Me\text{-}EDTA + R_3C\text{-}OH \leftrightarrow 2Ca\text{-}EDTA + Me(OH)_{2(s)} + R_3C\text{-}OH\text{-}Me(OH)_2^{-}{}_{(s.)}$$

Equilibrium

Acidic phase:

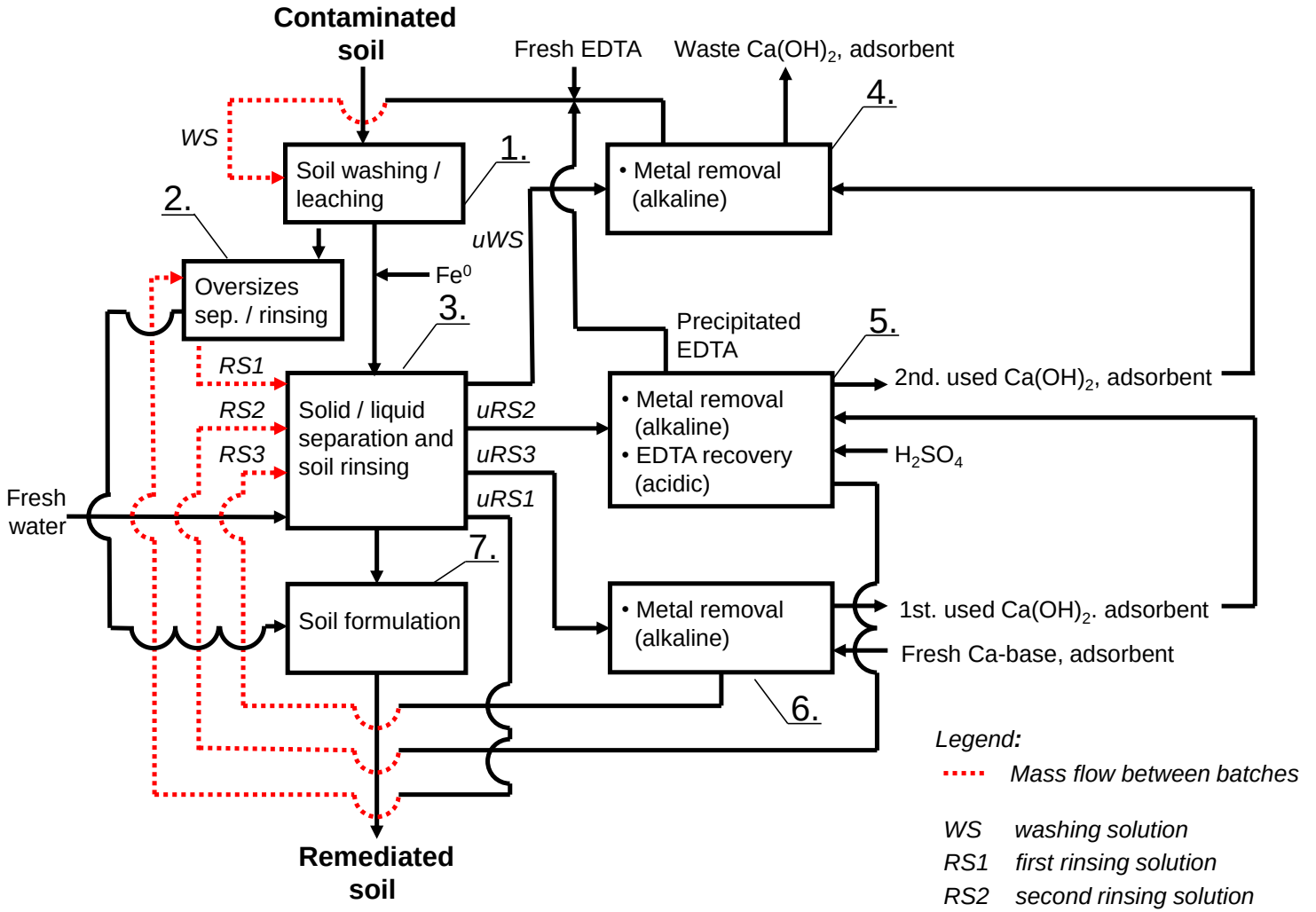
The alkaline part of the process yields >90% of recycled EDTA. The remaining EDTA is recycled as H_4EDTA (pK4 = 2.7) after H_2SO_4 addition (pH 2).

Reagents in excess:

Excess SO_4^{2-} from the acidic and Ca^{2+} from the alkaline part of the process forms insoluble $CaSO_4$, which is removed with the remediated soil. The build-up of salt ions and deterioration of process solutions through consecutive batches is thus prevented.

Technology details: Process flow

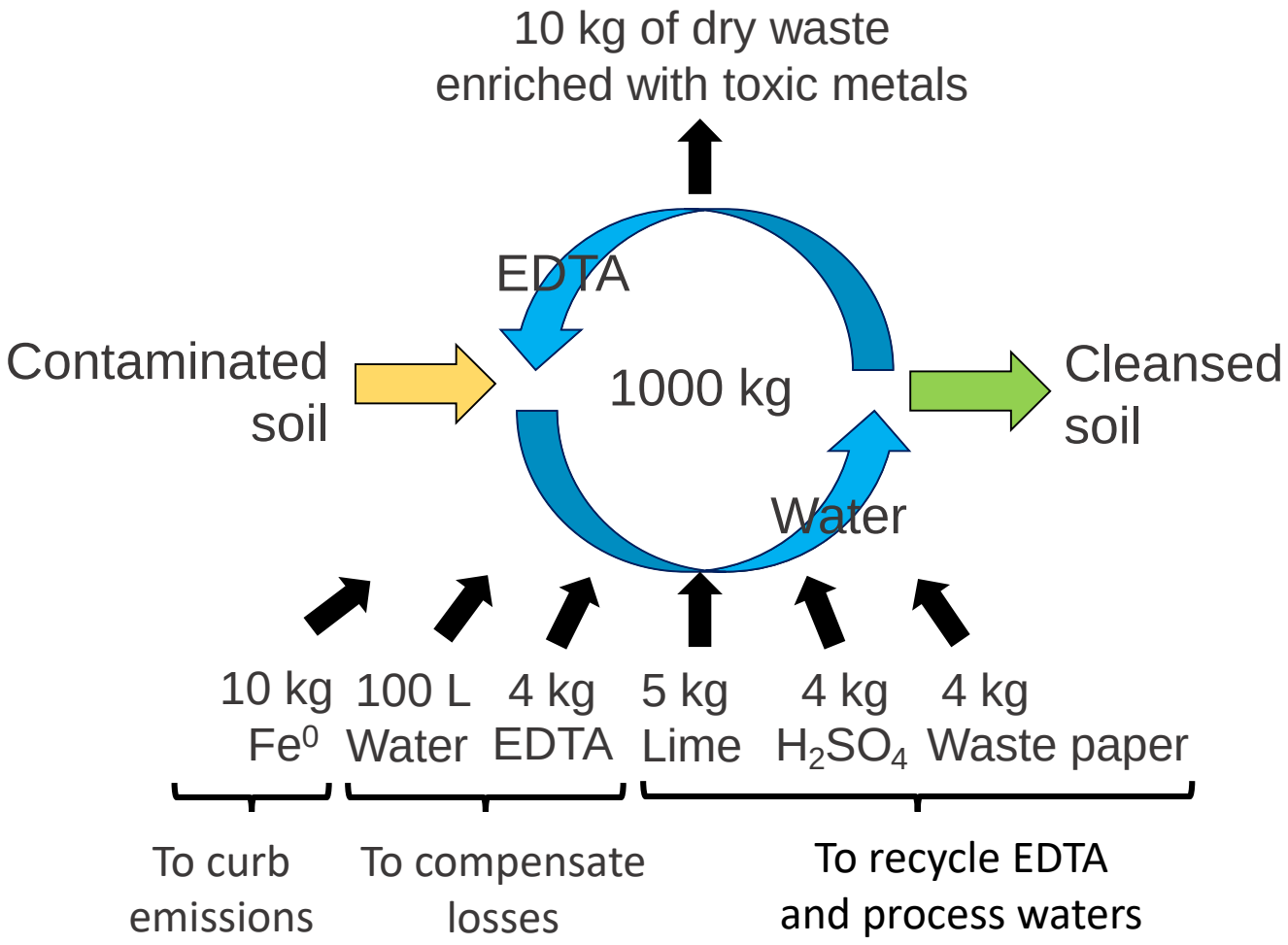
ReSoil is a batch-process technology. EDTA and process waters are treated/ reused in a closed cycles.



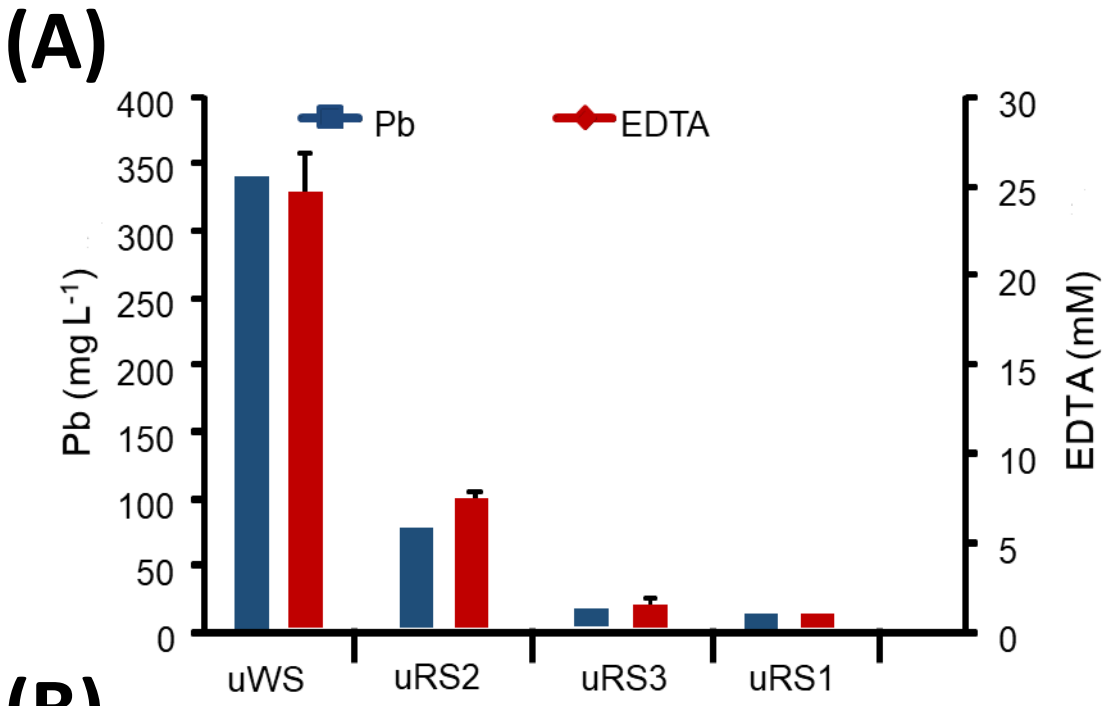
To remove residual Pb(Me)-EDTA the washed soil is 3-times rinsed with process waters generated and recycled from the previous batch, and with fresh water (to compensate the difference between moisture content in soils entering and exiting the process).

Technology details: Process material balance

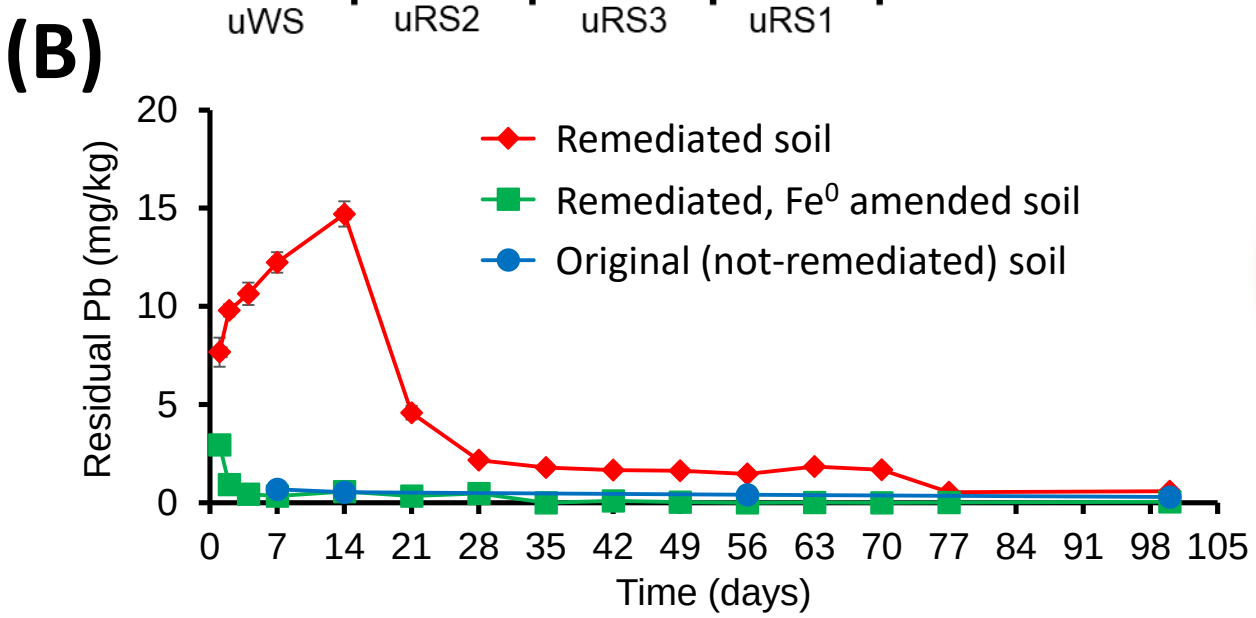
Material balance

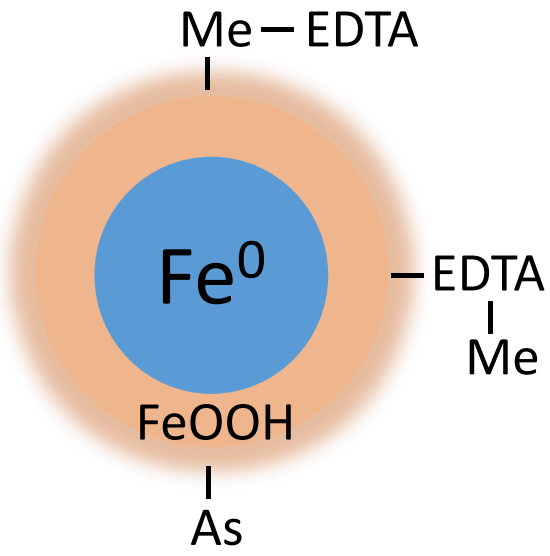


Technology details: Curbing toxic emissions from remediated soil



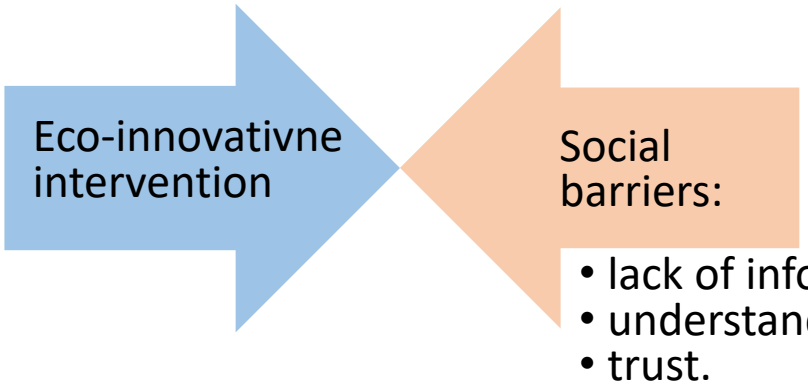
EDTA is slowly biodegradable and persist in the environment. Emissions of residual EDTA and toxic metals (Me) from remediated soils are curbed by:
(A) **ReSoil** patented EDTA recycling and soil rising and,
(B) **ReSoil** patent-pending addition of absorbent (Fe^0 = zero-valent iron) into the soil slurry.





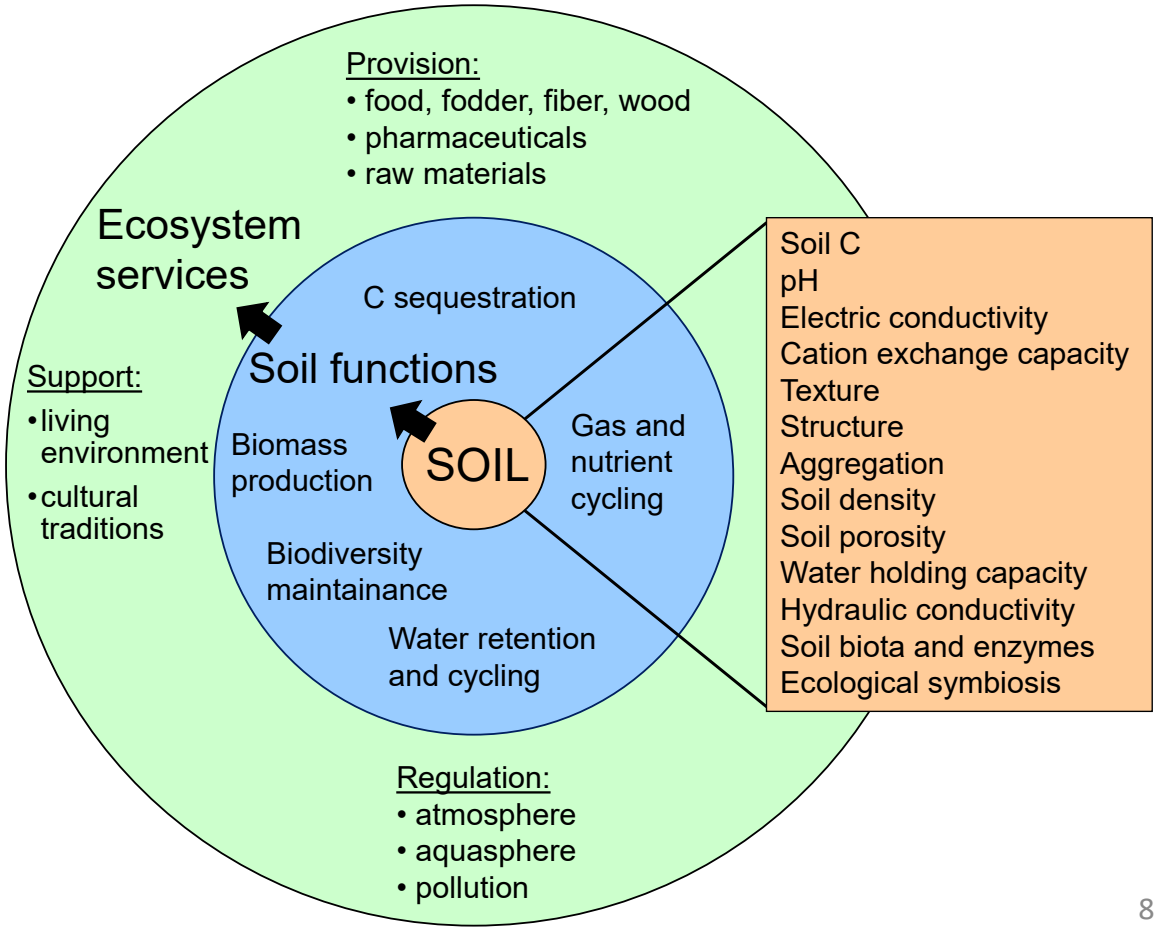
Technology adoption

Lay public and decision makers can be suspicious of »chemical« interventions.
Using natural means to fix man-inflicted environmental wounds is appealing, but is not always effective & feasible.



Extensive research lead by our project partner University of Ljubljana, Slovenia, demonstrated:

- **ReSoil** remediated / revitalised soil preserve chemical, physical and biological properties, soil functioning and ecosystem services.
- **ReSoil** is a “green and sustainable” soil remediation solution.



Sustainability: ReSoil preserves soil as a natural resource

ReSoil uniquely recycles chelant mainly as Ca-EDTA which is much less soil-aggressive than Na-EDTA.

- Insignificant changes in chemical properties (pH, soil organic matter, soil N, P, Fe, Ca content).
- Minor changes in soil texture and soil-water properties (mainly due to loss of soil structure and disaggregation of soil silt into clayish fractions).
- Transitional changes in soil biological properties (soil enzyme activities, microbial abundance and structure of population).
- No effect on the rate of mineralization of model organic material.
- Moderate impact on soil C and N cycles.

Artificial aggregates of remediated soil.

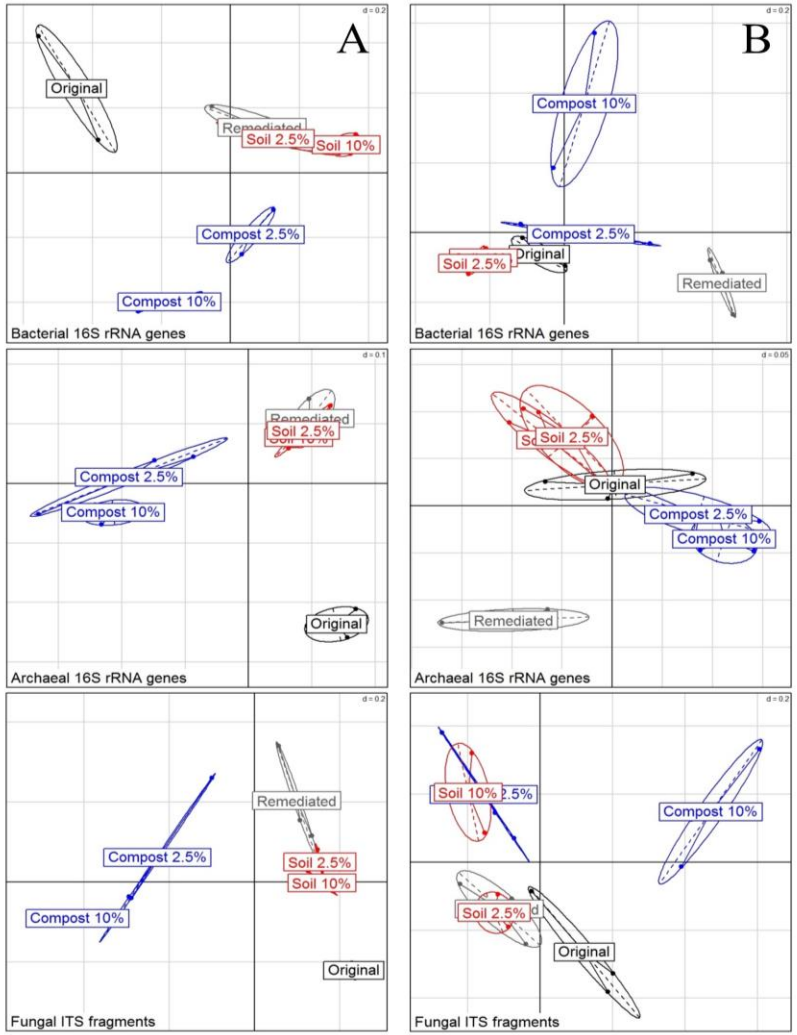


Fig. 5. Correspondence analysis based on relative abundance of bacterial 16S rRNA genes, archaeal 16S rRNA genes and fungal ITS T-RFLP fragments as affected by remediation and amendments (addition of 2.5% and 10% of healthy soil and compost) to remediated Arnoldstein (A) and Meza (B) soil. Situation after 7 weeks of experiment is depicted. Ellipses surround the replicates for each treatment (n = 3), showing that they cluster together.

Sustainability: ReSoil preserves soil as a plant substrate

Plants possess a basal tolerance to toxic non-essential metals: biomass yield on metal-contaminated soil is not affected. EDTA is nonspecific chelant and could reduce concentration of bio-available micronutrients essential for plant growth.

- We observed no or moderate (and transitional) effects of remediation on visual plant growth, biomass, and physiological processes (photosynthesis, stomatal conductance and evapotranspiration of water).
- Concentration of Pb in edible parts of vegetables cultivated on remediated soil is significantly reduced, often bellow the limit of quantification (by AAS).
- Fate of herbicides: isoproturon, bentazon, s-metolachlor, mecoprop is not significantly altered.

Original (not-remediated soil) Remediated soil

ReSoil remediated soil possess restored soil quality and provide ecosystem services including safe food production.

ReSoil: Technology readiness level

Based on scientific data proving technology feasibility and safety the permission to built demonstrational remediation plant in city of Prevalje, Slovenia (region contaminated by Pb mining and smelting) was issued in 2016 by Slovenian Environmental Agency.

- **ReSoil** technology prototype is currently demonstrated in operational environment; planned max. capacity: 6.000 kg of soil day^{-1}
- Technology Readiness Level: TRL 7 (EU, NASA).
- Technology uses commonly used process equipment.

ReSoil economics: Remediation cost

EDTA recycling, no waste-waters, use of inexpensive and non-toxic auxiliary materials and chemicals and use of common process equipment makes economics of **ReSoil** technology cost-effective and the economy of scale: soil remediation cost decrease with the remediation plant capacity.

ReSoil economy indicators

Contact us for further information

ReSoil, overview and conclusions

ReSoil is available remediation option which efficiently removes Pb and other toxic metals from contaminated soils and preserves soil as a natural resource.

- ✓ Up to 75- and 95% of Pb and co-contaminating metals (i.e. Pb, Zn, Cd, Cu) are removed from contaminated calcareous and acidic soils.
- ✓ Recycles EDTA and process waters using inexpensive and waste materials as auxiliary reagents: lime, waste polysaccharides, H_2SO_4 **(patent family EP 3153246B)**.
- ✓ Closed-loop operation ensures for effective soil washing and rinsing, no liquid wastes are generated **(patent family US 9108233B2)**.
- ✓ Produces only solid wastes: up to 1.5% (wt.).
- ✓ Produces no emissions.
- ✓ Uses zero-valent Fe (Fe^0) to prevent leaching of EDTA and EDTA chelates with toxic metals from remediated soil **(patent application GB 1720126.0)**.
- ✓ Enables effective immobilization of EDTA-resistant co-contaminants, i.e. oxy-anion forming As, by addition of immobilizators (i.e. Fe^0) into the soil slurry.
- ✓ Recycles EDTA mainly in soil-friendly Ca-EDTA form. Preserves remediated soil as a natural resource, i.e. for safe food production in urban agriculture.
- ✓ Low operation and remediation cost.