Bioremediation of polluted soils: status and challenges

Sapienza University of Rome

Andrea Ceci

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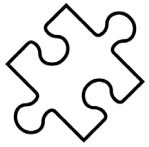
- Present and future challenges 

Soil contamination

- Hazardous persistent organic pollutants and potentially toxic elements (PTEs) constantly enter soil ecosystems, causing severe environmental and health problems
- Anthropogenic processes associated with domestic, municipal, agricultural, industrial and military activities as major sources
- Co-contamination due to mix of inorganic and organic pollutants
- Metals and mineral oil contribute jointly to around 60% of soil contamination in Europe

The global dimension of the problem

- In 1991 22 million hectares were estimated to be affected by soil pollution by ISRIC and UNEP (Rodríguez-Eugenio et al., 2018)
- More than 40% of the US National Priority List sites are co-contaminated by organic and inorganic pollutants (Ceci et al., 2018)
- In China, 16% of all soils (19% of agricultural soils) are polluted (CCICED, 2015)
- In Australia estimated ~80 000 polluted sites (DECA, 2010)
- Local soil contamination in 2011 was estimated at 2.5 million potentially contaminated sites in the EEA-39 (estimated ~342 000 contaminated sites) (EEA, 2014)

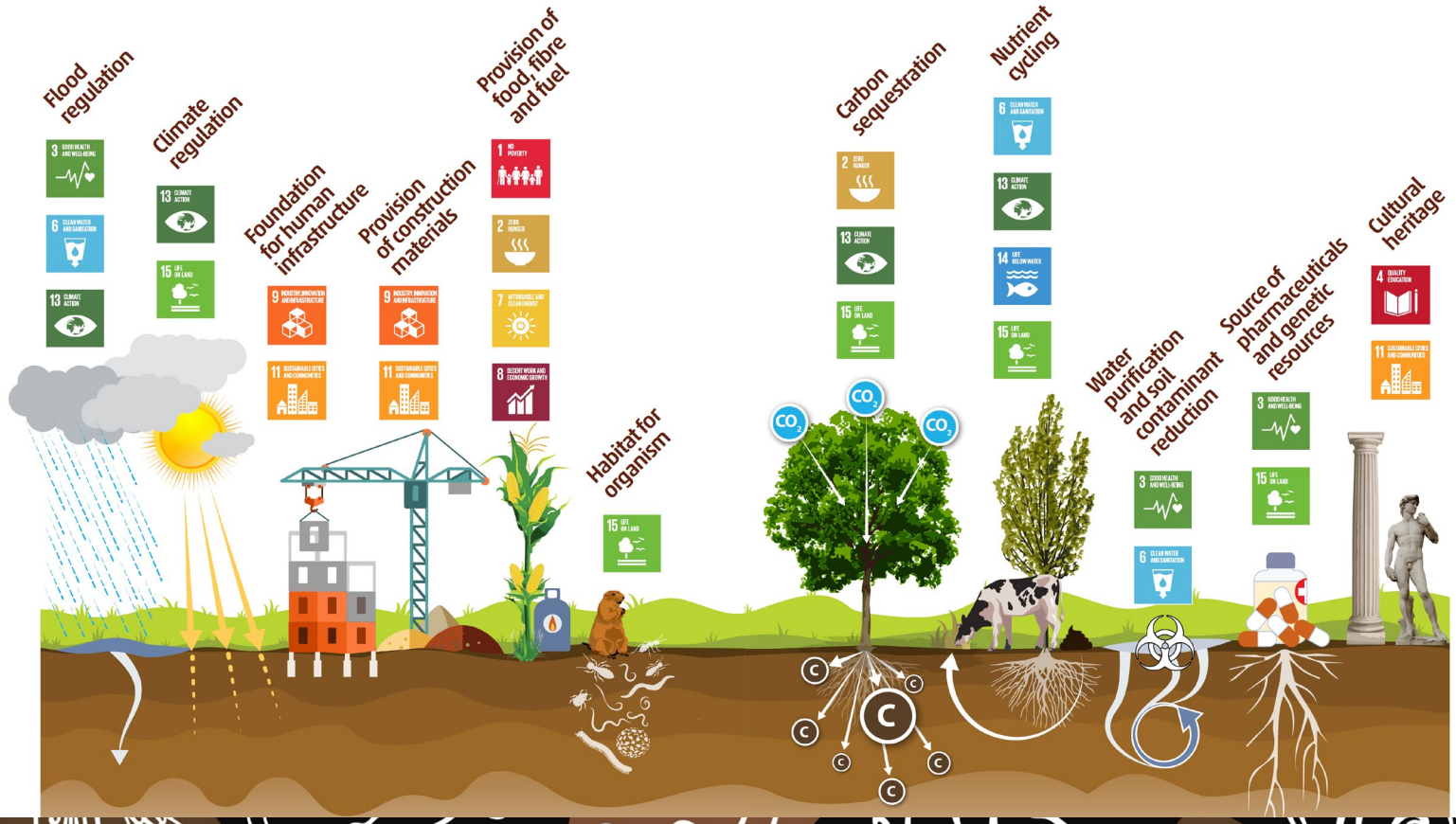
Soils and their global importance

- «Soils are fundamental to life on Earth but human pressures on soil resources are reaching critical limits.» (Preamble of the revised World Soil Charter)
- « Soils are a key enabling resource, central to the creation of a host of goods and services integral to ecosystems and human well-being.» (Principle 1 of World Soil Charter)
- « Soils are a key reservoir of global biodiversity, which ranges from micro-organisms to flora and fauna .» (Principle 6 of World Soil Charter)

Soils Biodiversity

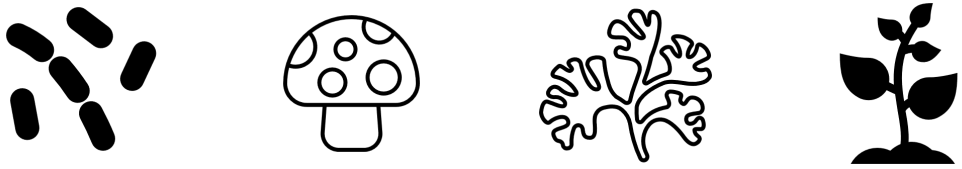
- providing ecosystem services
- meeting the Sustainable Development Goals (SDGs) of UN 2030 Agenda
- supporting human well-being and ecosystems

"A healthy soil is capable of providing most ecosystem services and therefore achieving compliance with SDGs and human well-being" (FAO, ITPS, GSBI, CBD and EC. 2020. State of knowledge of soil biodiversity - Status, challenges and potentialities, Report 2020. Rome, FAO)



Soil Biodiversity and Soil Pollution

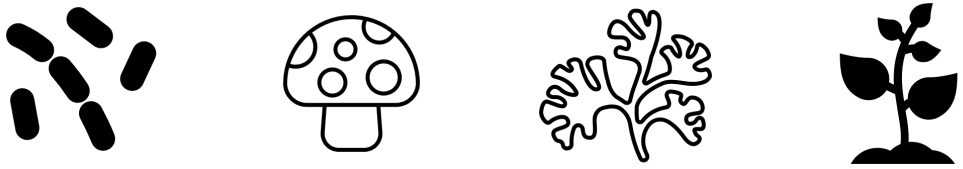
- Soil biodiversity can help in soil remediation
- Soil remediation: physicochemical and biological methods
- Bioremediation and phytoremediation as nature-based solutions for restoration of soil health and biodiversity preservation
- Bioremediation is «the process whereby contaminants are biologically degraded under controlled conditions that enhance plants' or microorganisms' growth and enzymatic activities» (FAO, ITPS, GSBI, CBD and EC, 2020)



Bioremediation

"Bioremediation is involved in degrading, removing, altering, immobilizing or detoxifying various contaminants from the environment through the action of bacteria, fungi and plants." (FAO, ITPS, GSBI, CBD and EC. 2020).

- Environmentally friendly, cost-effective, relatively simple in implementation
- High public acceptance, sustainable, use of natural processes to reduce the toxicity of harmful pollutants
- Known many taxa belong to different groups of organisms (e.g. bacteria, fungi, plants, algae, invertebrates) with potential applications in soil bioremediation

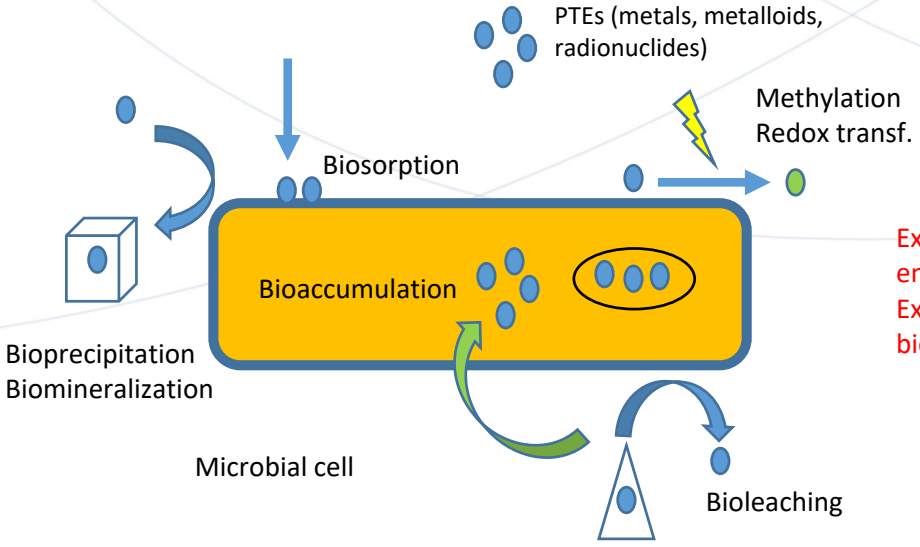


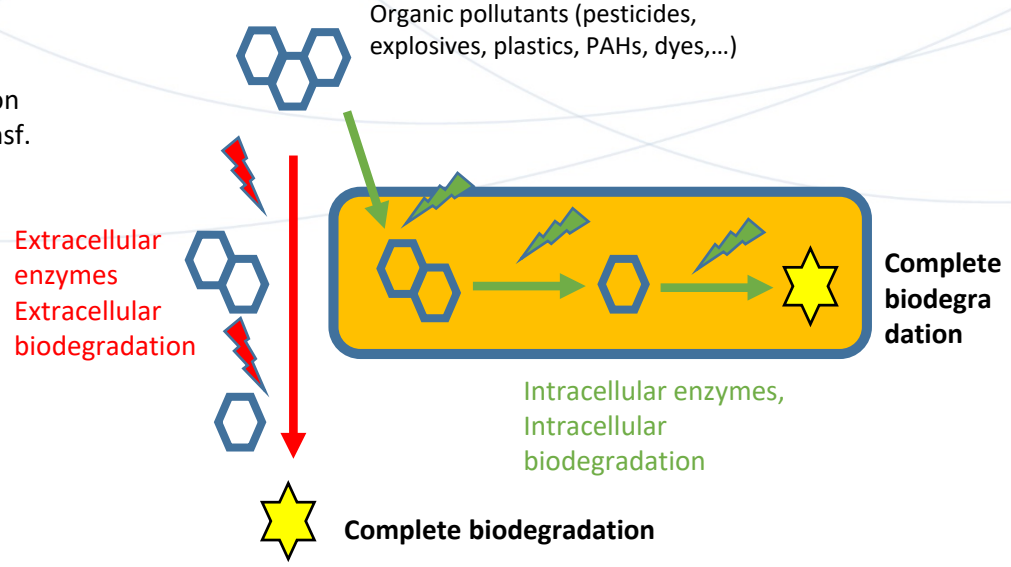
Microbial bioremediation

Bacteria, algae and fungi play fundamental ecological and geological roles

Biodegradation of persistent organic pollutants by enzymes

Biotransformation of PTEs in less toxic forms, bioaccumulation, biorecovery

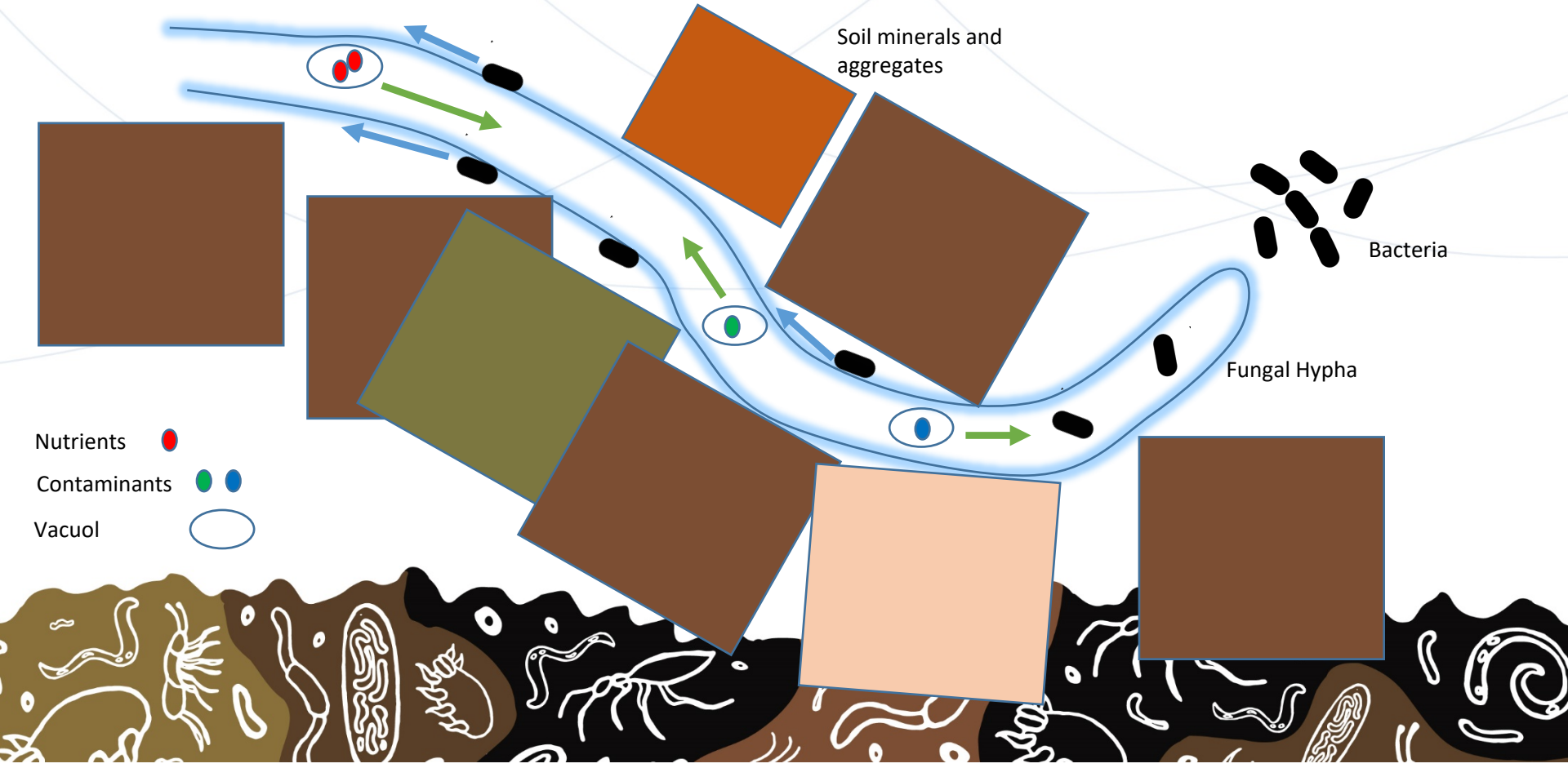




Fungal trasportation networks

Fungal hyphae as “highways” for bacterial dispersal and “pipelines” for vacuolar transport of nutrients and pollutants

Water transport and chemical diffusion in the soil hydrosphere (Harms et al., 2012)



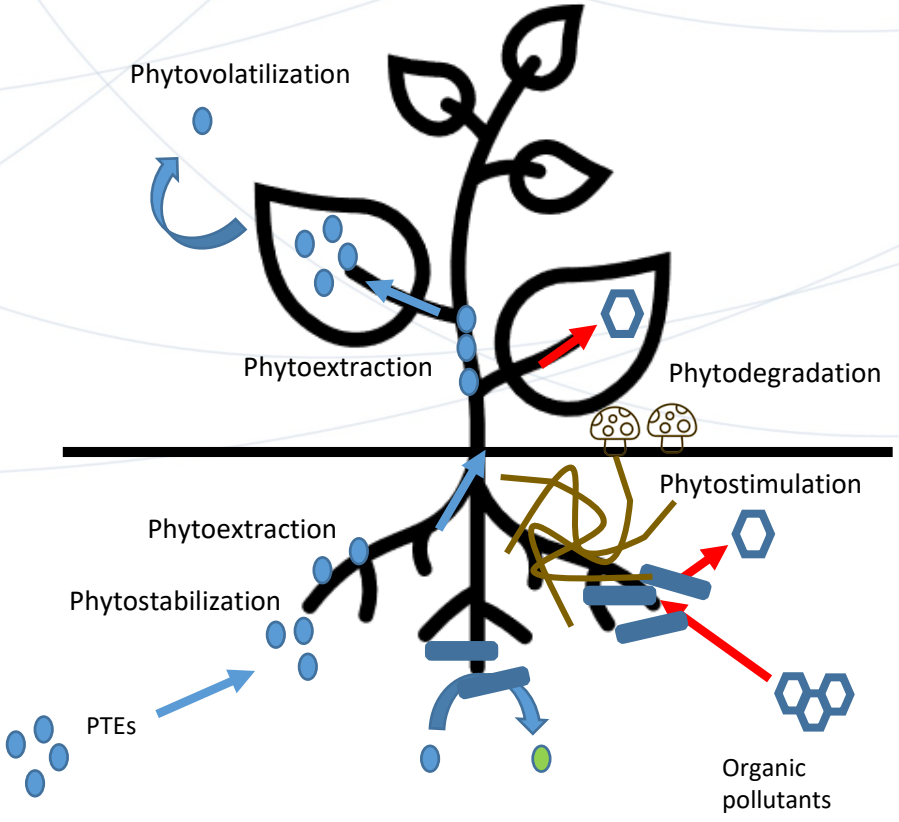
Phytoremediation

Plants in bioremediation of PTEs and organic xenobiotics

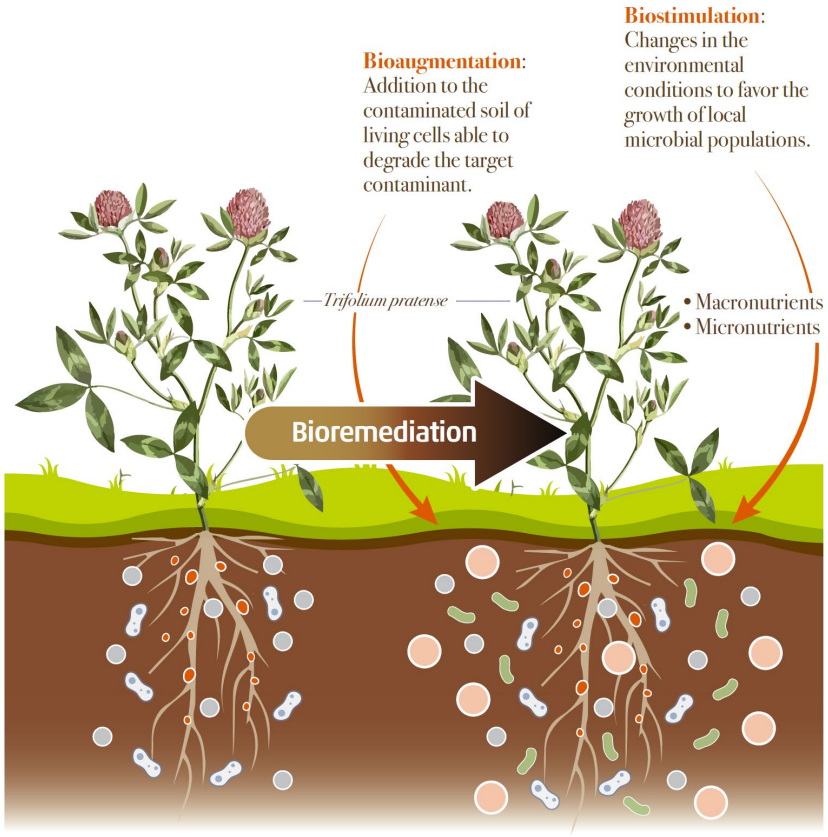
Interactions with soil microbial community and endophytic and symbiotic bacteria and fungi

PTEs can be bioaccumulated and recover as bio-ores

~500 taxa as hyperaccumulators in several families (e.g. Brassicaceae)

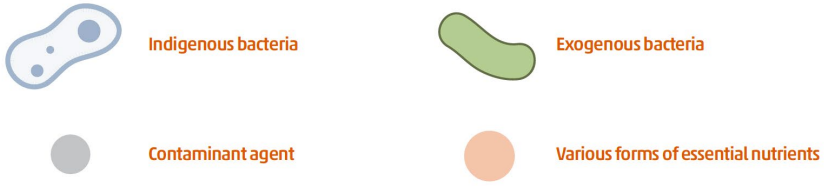


Bioremediation methodologies *in situ* and *ex situ*



Bioremediation methodologies
Microbial activity
Landfarming
Biopilling
Composting
Bioreactor
Bioleaching
Plant activity
Phytostabilisation
Phytoexstraction
Phytodegradation

Biological remediation methodologies (Rodríguez-Eugenio, N., McLaughlin, M. and Pennock, D. 2018. Soil Pollution: a hidden reality. Rome, FAO)



Bioaugmentation and biostimulation (FAO, ITPS, GSBI, CBD and EC. 2020.)

Bioremediation: Limitations

Environmental conditions (soil moisture, nutrients, oxygen and electron acceptors, T, pH, soil types and other soil features)

Contaminants (PTEs and/or organic pollutants): chemical nature and concentrations, bioavailability, spatial and vertical distribution in soil

Ecological interactions between native microbial community of soil and microorganisms used in bioremediation

Limitations in biotransformation of organic pollutants

Long period of time required

Bioremediation: Challanges

New technological integrated multidisciplinary approaches to overcome limitations (omics, modeling, new species, genetically engineered microorganisms)

Gain a better understanding on the metabolic cooperation among the microbial communities

Integration of physico-chemical and biological methodologies for soil remediation

Nanobioremediation

New emerging pollutants

Overcome economic, political, social and industrial issues

Conclusion

Bioremediation is sustainable, environmentally friendly, cost-effective approach to remediate soil pollution

Bioremediation provides nature-based solutions to overcome soil contamination thanks to the activities of microorganisms and plants

New integrated multidisciplinary approaches can help to overcome limitations of bioremediation and face the future challenges to protect soil functionality and biodiversity


Thank you for
your attention