BIOREMEDIATION of radioactive waste

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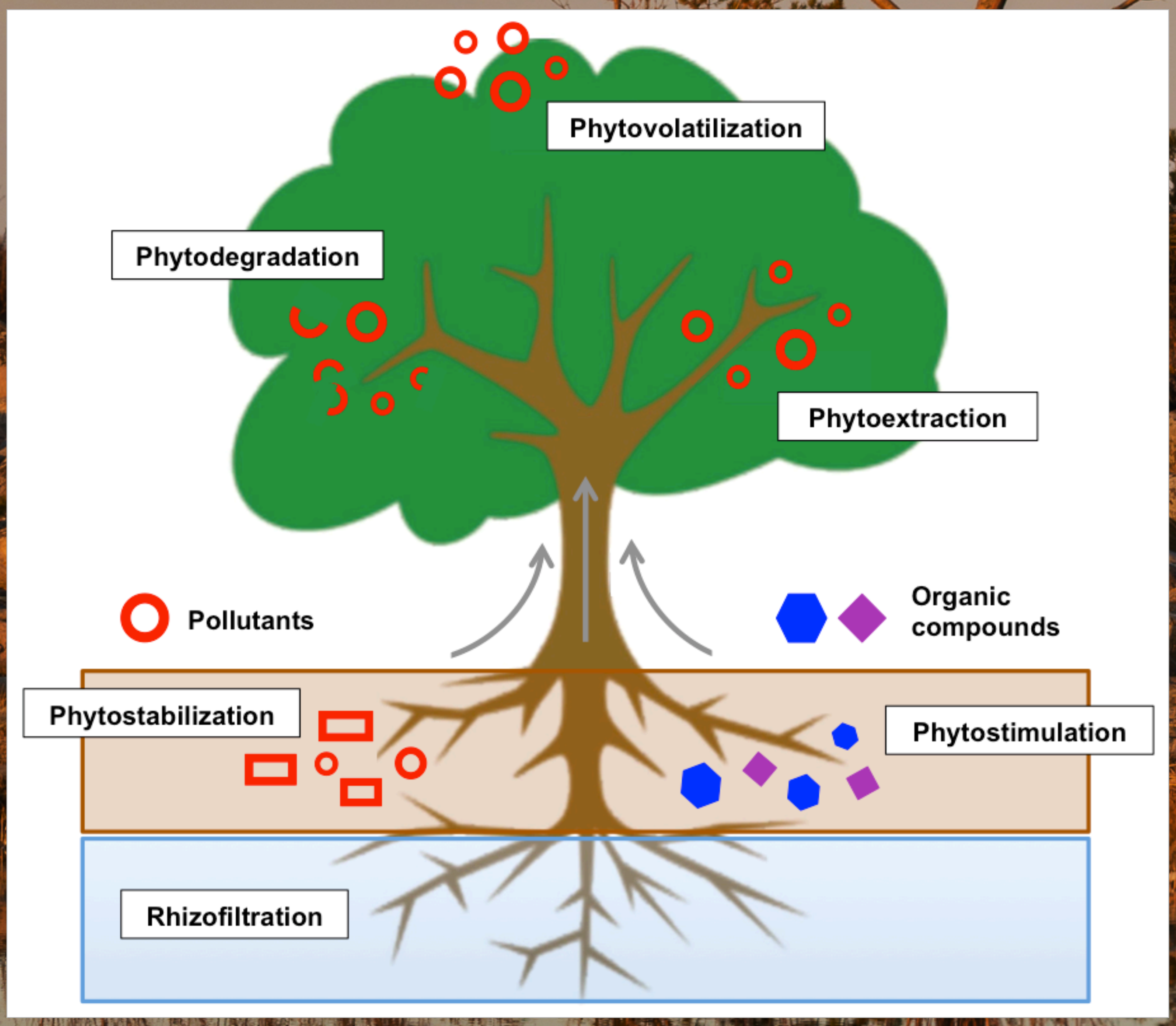
About

Bioremediation of radioactive waste is an application of bioremediation based on the use of bacteria, plants and fungi (natural or genetically modified) to catalyze chemical reactions that allow the decontamination of sites affected by radionuclides. These radioactive particles are by-products generated as a result of activities related to nuclear energy and constitute a pollution and a radiotoxicity problem due to its unstable nature of ionizing radiation emissions. The species involved in bioremediation processes are able to influence the properties of radionuclides such as solubility, bioavailability and mobility to accelerate its stabilization, and to do their function *in situ* or *ex situ*.

The diversity of bioremediation techniques are being set up as an ecological and economic alternative to conventional strategies, which are based on physical extraction and containment of waste with an estimated cost to be in excess of a trillion dollars in the US.

Injection of protein source (whey powder) to stimulate the growth of microorganisms in the Snake River Plain Aquifer (Idaho, US) and remove tritium.

Phytoremediation



Depiction of phytoremediation strategies. Radionuclides can not be phytodegraded but converted to more stable or less toxic forms.

The use of plants to remove radioactive waste from the environment or to render them less harmful is called **phytoremediation**. It is specially useful for long–lived radionuclides at low concentration. Genetic engineering and biostimulation (**phytostimulation**) procedures have improved these processes.

- **Phytoextraction** is the uptake of radioactive waste from the root system and its concentration in the biomass of shoots, for large polluted areas.
- **Rhizofiltration** is the adsorption and precipitation of soluble radionuclides in plant roots. It is the most efficient strategy in wetlands, and in the Chernobyl Exclusion Zone water sunflowers have removed up to 95% of uranium contamination.
- **Phytovolatilization** involves the capture and subsequent transpiration of radionuclides into the atmosphere. It is very useful for tritium treatments.
- **Phytostabilization** is a strategy based on the immobilization of radionuclides in the soil by the action of the roots. It ensures that waste can not be dispersed because soil erosion or leaching.

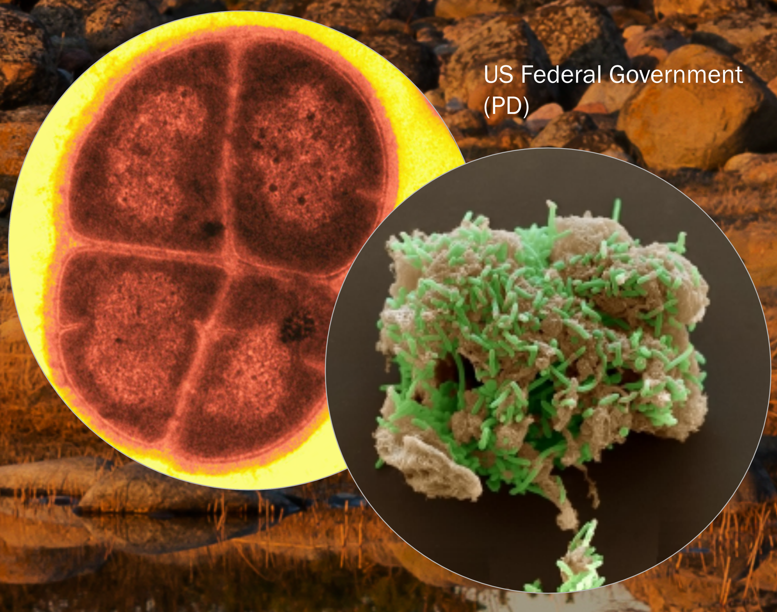
Ways of research

Current research is focused on the change of *ex situ* or laboratory processes to their real application *in situ*, in which soil heterogeneity and environmental conditions generate deficiencies of optimal biochemical status of the used species. The role of agrochemicals and mycorrizhae (symbiosis between fungi and plants) may help to answer these unknowns.

Moreover, the potential of GMOs is limited by bioethical issues. Therefore multidisciplinary research is focused on defining necessary genes and proteins to establish new free-cell systems which may avoid possible side effects on the environment by intrusion of transgenic or invasive species.

Classification and hazards

Two different kinds of radioactivity can be found in the Earth: natural (caused mainly by cosmic rays) and anthropogenic (from human sources). The **International Atomic Energy Agency** (IAEA) distinguishes six levels according to different parameters like heat released and half-life of the radionuclides. Long lived radionuclides with high activity are the most hazardous; they produce chromosome aberrations, cancer, reproductive deficiencies, reduced seed germination, burns and even death. So they need to be stored in deep, stable geological formations usually several hundred metres or more below the surface.

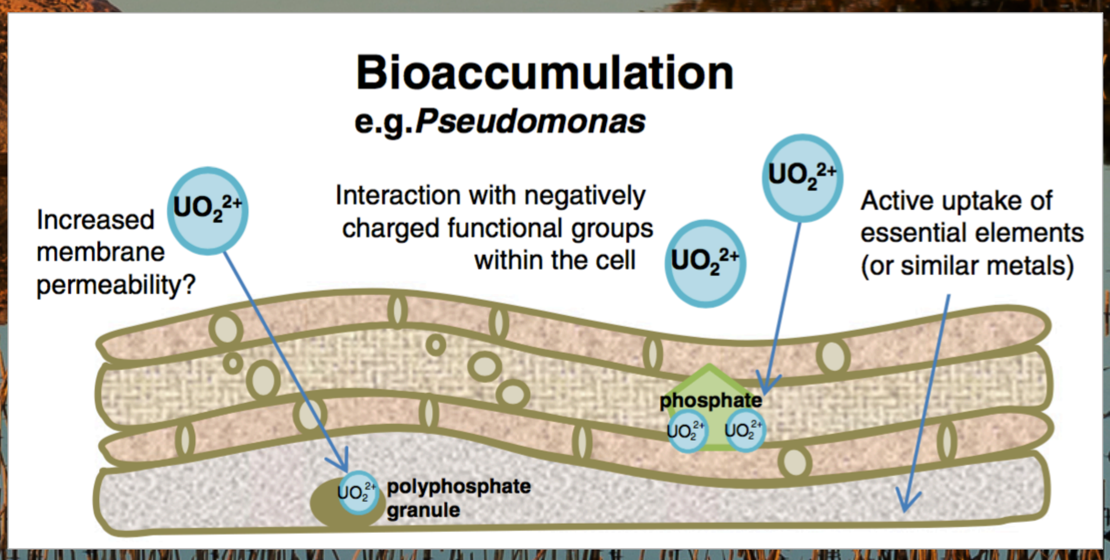


Deinococcus radiodurans (left) and *Geobacter sulfurreducens* (right) are widely used bacteria for bioremediation of radionuclides due to their capabilites.

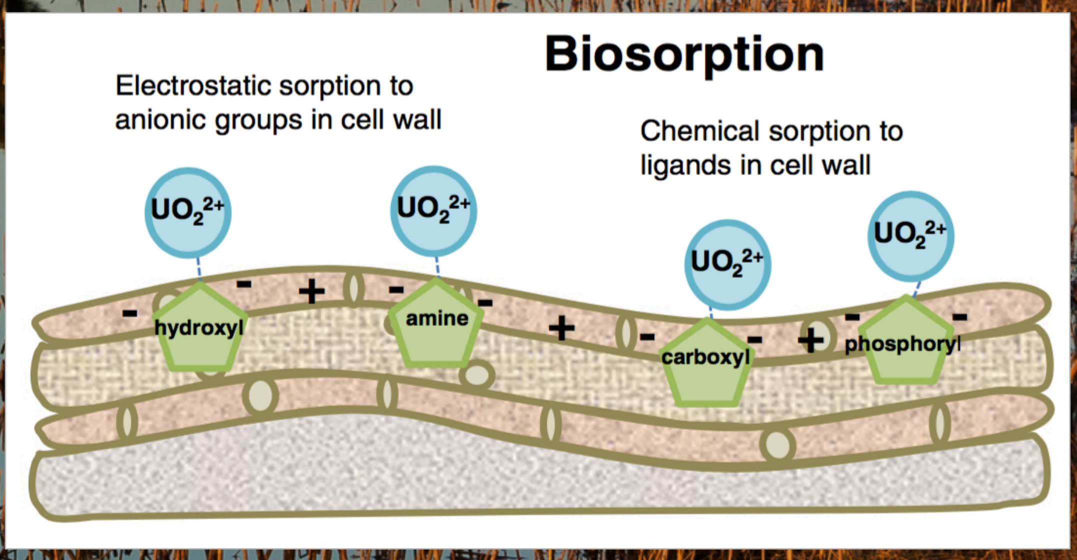
Bacterial remediation

Radioisotopes can be transformed directly through changes in valence state by acting as acceptors or by acting as cofactors to enzymes. They can also be transformed indirectly by reducing and oxidizing agents produced by bacteria, that cause changes in pH or redox potential. Other processes include precipitation and complexation, or chelating agents that bind to radioactive elements.

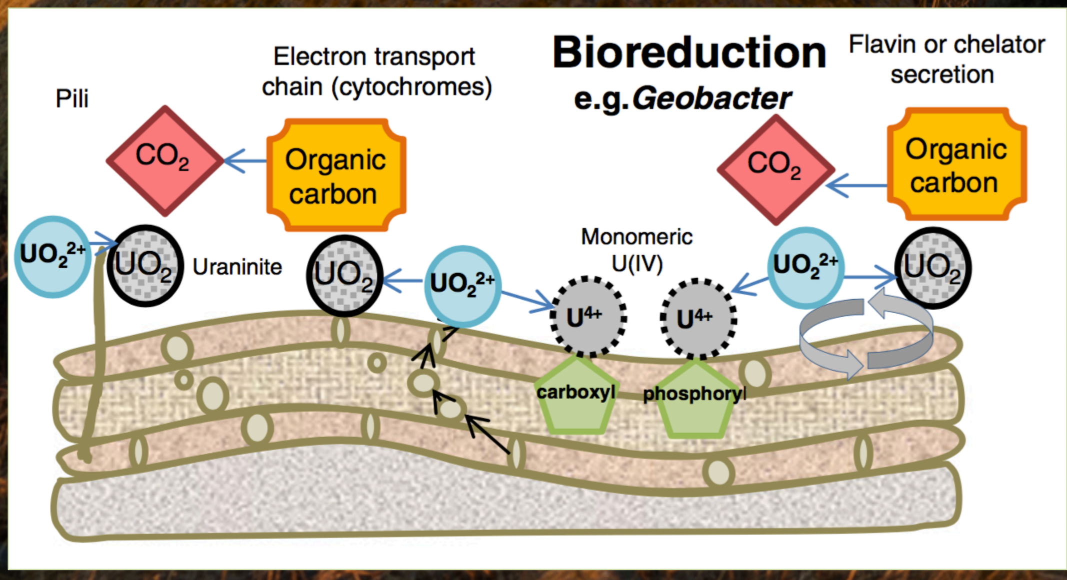
Human intervention, on the other hand, can improve these processes through **genetic and protein engineering**, and also by the omics. The injection of microorganisms (**biomagnification**) or nutrients (**biostimulation**) into the environment is a good strategy to accelerate them as well.



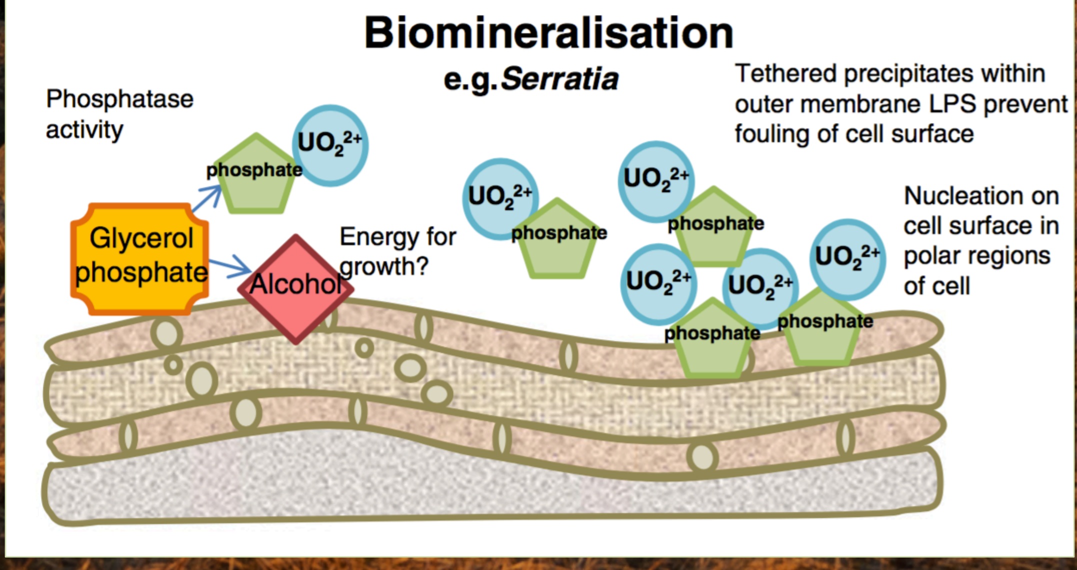
Bioaccumulation is the uptake and retainment of radionuclides into the cell by complexations with negatively charged intracellular components, precipitation or granules formations. They are often accumulated accidentally by bacteria because of its resemblance to dietary elements for metabolic pathways.



Biosorption is based on passive sequestration of positively charged radioisotopes by lipopolysaccharides on the cell membrane (negatively charged), either live or dead bacteria. It is a technique that requires high amounts of biomass to affect bioremediation and presents problems of saturation.



Bioreduction is an action in which organic carbon sources are used to reduce radionuclides to an insoluble and stable form thanks to cell surface cytochromes. Chelators and sequestering agents like siderophores also play an important role in bioreductions.



Biomineralisation is the precipitation of radionuclides through the generation of microbial ligands, resulting in the formation of biogenic minerals. Phosphatase enzyme is particularly relevant in uranium remediation, because cleavages phosphate molecules and promotes the generation of chernikovite crystals.

MAIN REFERENCES

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