Phytoremediation 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 their 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.

**Phytoremediation**

- Phytostabilization
- Phytoextraction
- Rhizofiltration

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

**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 amphi-euhalophytes and mycorrhizal symbiosis (between fungi and plants) may help to answer these unknowns.

Moreover, the potential of GMOs is limited by biophysical 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 produces chromosome abnormalities, cause 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.

**Bacterial remediation**

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

**Biosorption**

Biosorption is based on passive sequestration of positively charged radionuclides by adsorption/desorption 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.

**Bacterial remediation**

Bacterial remediation 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 cleaves phosphate molecules and promotes the generation of chernovikite crystals.