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REMEDIATION OF RADIOISOTOPIC WASTE USING MICROORGANISMS

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Introduction

Isotopes are atoms of an element with the same number of protons but different numbers of neutrons. Some of these isotopes are unstable, making these atoms radioactive that decay spontaneously, emitting energy in the form of electromagnetic waves or particles. Radioactive decay involves the emission of alpha particles, beta particles, or gamma rays. Gamma rays are the most energetic and therefore most likely to ionize whatever they strike, they can damage DNA, protein, and various human tissues. These wastes can affect human health and the environment, so their safe management has received considerable attention worldwide.

Technetium, Cesium (Cs), Plutonium (Pu), Strontium (Sr), Uranium are some of the commonly used radioactive elements. Of the naturally occurring radionuclides, only uranium and radium are found in substantial amounts. Most radionuclides are produced artificially in nuclear reactors or in particle accelerators, others are produced during radioactive decay of other radionuclides. A large quantity of radioactive waste is being generated and dumped into the environment, and if the general population is exposed to it, may cause serious life-threatening disorders and acute health effects that begin with nausea, vomiting and headaches. With increased exposure a person may also experience fatigue, weakness, fever, hair loss, dizziness disorientation, diarrhoea, blood in stool, low blood pressure and ultimately death. Therefore, treatment of radioactive wastes is receiving considerable attention worldwide for the protection of human health and the environment from the adverse effect of radiation associated with these wastes.

There exists no reservations that microbes, specifically bacteria and archaea, possess tremendous knack to not only withstand extreme conditions but also carry out important biotechnological processes. Contrary to their microscopic size, they have relentlessly shown to carry out certain vital and unique processes without which other life might not be able to sustain or even exist. Using microorganisms for radioactive waste remediation is an important area of interest gaining attention among scientists and research groups.

Uses/Importance in various sectors

Radioisotopes are useful in various sectors **(Figure 1).** They are used in carbon dating, as tracers within living organisms for diagnostic purposes, radiation in radioisotopes is useful in treating certain types of illnesses, particularly cancerous tumors. Radiolabelled pesticides are used to monitor the persistence of their residues in food items, soil, ground water and environment. These studies have helped to trace and minimize the side effects of pesticides and insecticides. Besides, different types of radiation can be used to induce mutations to develop desired mutants line that are resistant to disease, are of higher quality, allow earlier ripening, and produce a higher yield**.** This technique of utilizing radiation energy for inducing mutation in plants has been widely used to obtain desired or improved characters in number of plant varieties.

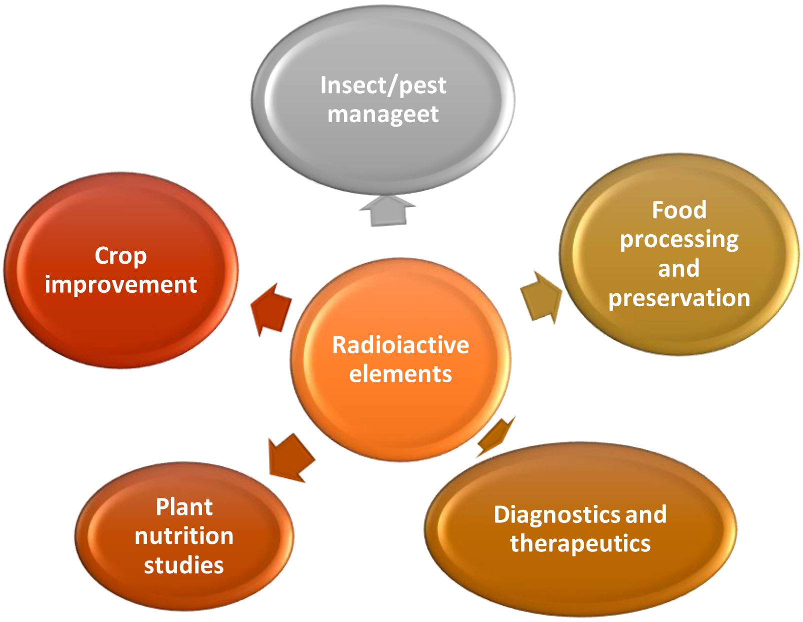

Figure 1 : Uses of radionucleotides in any sectors

Treatment of radioactive waste

Treatment is an important phase in the management of radioactive wastes, it aims to reduce the volume of generated wastes to enhance the safety and/or reduce the costs of further management phases. After the treatment phase, the wastes split to two portions, the first is a small volume of concentrate that contain the bulk of radionuclides is kept in the management system and the second is a large volume portion that have low radioactivity that allow its discharge to the environment after meeting the regulatory requirements.

Radionuclides form complexes with natural organic ligands such as humic substances. The solubility of these complexes varies with the pH of the natural aquifers in which they occur. Radionuclides also can form complexes with inorganic materials such as carbonate and sulfate. Natural organic matter (NOM) constitutes an important pool of ligands for complexing radionuclides and metal ions, and can play a role in their migration in subsurface environments.

Bioremediation has been viewed as the ecologically responsible alternative to environmentally destructive physical remediation. Microorganisms carry endogenous genetic, biochemical and physiological properties to reduce, eliminate, contain, or transform to benign products contaminants present in soils, sediments, water, or air, it has become widely accepted that microorganisms, and to a lesser extent plants, can transform and degrade many types of contaminants. Attempts have been made to develop native or genetically engineered (GE) microbes for the remediation of environmental contaminants including radionuclides. Microorganism-mediated bioremediation can affect the solubility, bioavailability and mobility of radionuclides. Therefore, we aim to unveil the microbial-mediated mechanisms for biotransformation of radionuclides under various environmental conditions as developing strategies for waste management of radionuclides.

This technology includes intrinsic bioremediation, which relies on naturally occurring processes, and accelerated bioremediation, which enhances microbial degradation or transformation through the addition of nutrients (biostimulation) or inoculation with microorganisms (bioaugmentation). Certain organic compounds, however, can play a central role in metal and radionuclide bioremediation strategies. The synthetic chelators (EDTA) and nitrilotriacetic acid (NTA) were commonly used as cleaning agents during industrial processing of nuclear fuels at DOE and have formed stable, soluble complexes with certain metals and radionuclides in the subsurface. These chelators may be inherently toxic, and when combined with radionuclides. The increased solubility of the radionuclides to move much farther in the subsurface than normal, thereby increasing their probability of reaching risk receptors (drinking water wells and surface waters, e.g., rivers). Bioremediation is an alternative to traditional remediation technologies such as landfilling or incineration. Although prokaryotes, Bacteria and Archaea are usually the agents responsible for most bioremediation strategies, eukaryotes such as fungi and algae also can transform and degrade contaminants. Microorganisms already living in contaminated environments are often well-adapted to survival in the presence of existing contaminants and to the temperature, pH, and oxidation–reduction potential of the site. These indigenous microbes tend to utilize the nutrients and electron acceptors that are available in situ, provided liquid water is present. The bulk of subsurface microbial populations are associated with the solid phase. Water acts as a vehicle to transport both microorganisms and dissolved substances, including contaminants and their breakdown products. biodegraded. However, microorganisms can interact with these contaminants and transform them from one chemical form to another by changing their oxidation state through the adding of (reduction) or removing of (oxidation) electrons. In some bioremediation strategies, the solubility of the transformed metal or radionuclide increases, thus increasing the mobility of the contaminant and allowing it to more easily be flushed from the environment. In other strategies, the opposite will occur, and the transformed metal or radionuclide may precipitate out of solution, leading to immobilization.

For bioremediation of metals and radionuclides, first step may be to increase contaminant mobility for extraction or the choice may be to immobilize the metal through sequestration, complexation, or changes in speciation that reduce solubility. **Figure 2** represents some of the strategies aoted by microorganisms for radionucleotide bioremediation which involve, the enzymatic bioreduction of radionuclides through direct or indirect reduction of soluble contaminants in sedimentary and subsurface environments by metal reducing or sulfate-reducing microorganisms.

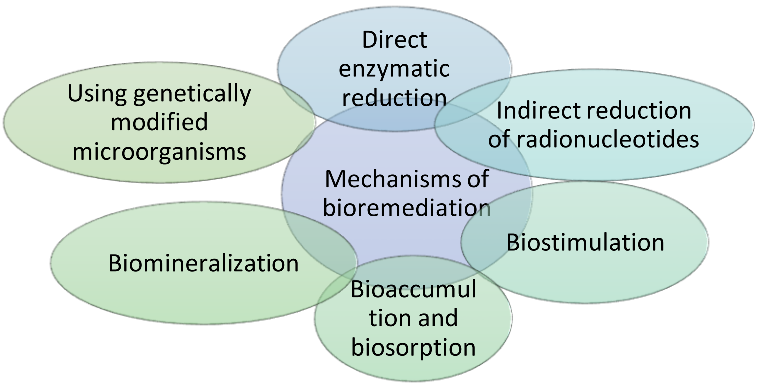

Figure 2 : Mechanisms used by microorganisms for radionucleotide remediation

Biosorption is the sequestration of positively charged metal ions to the negatively charged cell membranes and polysaccharides secreted on the outer surfaces of bacteria through slime and capsule formation. Biostimulation using specific communities of microorganisms is another mechanism to enhance the bioremediation of radionuclides. Microorganisms can interact with metal ions and immobilize them to transformation.

Genetic engineering (GE) and recombinant DNA technology have been employed to generate character-specific microorganisms for efficient removal of radionuclides by sorption. Different protein constructs have been generated in which the bacterial cell surface is equipped with metal binding polypeptides by fusion-binding domains to outer-membrane-anchored proteins that include metallothioneins.

Challenges and future prospects

The microbes have shown their ability to undergo genetic manipulations and carry out their recombinant phenotypic traits. It is also interesting to note that the interaction mechanisms with radionuclides, as discussed above, are akin to those of metals. Recently, the biotechnological applications of recombinant bacteria have shown encouraging results in remediation of radio waste. It seems only prudent to make use of those microbes that are indigenous to radionuclide containing natural samples, such as soil, air or water, and subject them to extreme scrutiny for exploring their capabilities. True potential of these microbial processes can be unlocked by frequent and sustaining collaborations with various fields of science and technology and, once characterized completely, these microscopic beings can be used, in isolation or as a consortia, for removal of high concentrations of radiowaste. The removed radionuclide can be further used as substrate for other commercial applications. The beauty of using microbes for the job lies in their reusability. Such an approach could lead to the development of an eco-friendly way for treatment as well as extraction and/or recovery of precious radionuclides.

References

Atlas R M, Philp J (2005) *Bioremediation.* Applied microbial solutions for real-world environmental cleanup. ASM press.

Kumar R, Singh S, and Singh O V (2007). Bioremediation of radionuclides: emerging technologies. Omics: a journal of integrative biology, 11(3): 295-304.

Sathiyamoorthy P, and Golan-Goldhrish A. (2005). Low-cost bioremediation of heavy metals and radionuclides of contaminated soils. Advanced Biotech, *4*(3):17-23.