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Research Note

Phytoextraction of Radioactive Cesium and Strontium: A Brief Synopsis

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Abstract

Improper handlings of nuclear materials and accidental nuclear disasters have resulted in radionuclide contamination of soil and groundwater around the world. Radioactive contamination of soil is a potential health hazard. Following the world's two worst nuclear disasters, Chernobyl (Ukraine) in 1986, and Fukushima (Japan) in 2011, concerns about accumulation of radioactive materials in soil and water have led to the public awareness to look at natural ways to clean human habitats of possible radiation contaminations. One method worthy of consideration is phytoremediation. Clean up efforts at Chernobyl after 1986 nuclear explosion included the use of hemp (Charkowski, 1989) and sunflower (McDonough-Horton, 2011) that absorbed radionuclides through their roots. The success of phytoremediation of radioactive hazards at Chernobyl, gives promise to the use of this technology at Fukushima and at other sites contaminated with radioactive materials.

Keywords: Phytoremediation, radioactive contamination, radionuclide, cesium, strontium.

Phytoremediation is an innovative, green technology that uses plants to remediate contaminants from the environment. As the plants ability of cleaning up various metal contaminated soils has been extensively investigated (Gerard *et al.*, 2000; Saygideger, 2000; Addae *et al.*, 2010; Lopez-Chuken, 2010; Purakayastha and Chhonkar, 2010; Shumaker *et al.*, 2011; Zaman and Zereen, 2011), uptake of radionuclides by plants has caught the attention of the scientific community as well (Huang *et al.*, 1998; Westhoff, 1999; Fuhrmann *et al.*, 2002; McGrath, 2002; Dushenkov, 2003: Shirong and Willey, 2003; Epen *et al.*, 2006; Willey and Collins, 2007; Roongtanakita *et al.*, 2010; Eskander *et al.*, 2011).

Radionuclides have been linked to various cancers including bone, breast, lung, thyroid, leukemia, etc. Following Chernobyl nuclear disaster in 1986, as of 1988, 237 confirmed cases of grim illness and 31 fatalities were reported in the then Soviet Union (Anspaugh et al., 1988). The two primary radionuclides which are the most common fission products are cesium-137 (^{137}Cs) and strontium-90 (^{90}Sr) with half-lives of 30.17 and 28.8 years, respectively (Westhoff, 1999). The half-life is the time required for a radioisotope to decompose by half, and the rate of decay is not affected by anyknown environmental agents or conditions. These radionuclides have been found at nuclear weapon production facilities, various nuclear reactor sites, and on a vast land following the Chernobyl nuclear power plant accident in 1986 (Fuhrmann, 2000). Both of these radionuclides can enter the food chain and deliver internal doses of radiation.

Cesium is the heaviest of the alkali (atomic number: 55, atomic weight: 132.905) and the most reactive of all elements. Strontium is another highly reactive alkaline metal (atomic number: 38, atomic weight: 87.62). Plant absorption of ^{137}Cs is low as Cs strongly binds to soil minerals and thus remains less available for plant uptake. The ability of a plant to take up a contaminant can be measured by the Concentration Ratio (CR) which is the concentration of the contaminant in dried plant tissue divided by its concentration in dried soil. The higher the CR, the greater is the plant's ability of contaminant uptake.

In experiments conducted with three plant species: Redroot pigweed (*Amaranthus retroflexus*),

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Indian mustard (*Brassica juncea*), and tepary bean (*Phaseolus acutifolius*) to evaluate their potential to extract ^{137}Cs and ^{90}Sr from contaminated soil, it was observed that the CR for ^{137}Cs for redroot pigweed, Indian mustard, and tepary bean were 2.58, 0.46, and 0.17, respectively. For ^{90}Sr, they were substantially higher: 6.5, 8.2, and 15.2, respectively. The pigweed had the greatest accumulation of both ^{137}Cs and ^{90}Sr, even though its CR for ^{90}Sr was the lowest, because of its relatively large biomass. It was estimated that the time required for removal of 50% of the two contaminants, assuming two crops of redroot pigweed per year, were 7 years for ^{90}Sr and 18 years for ^{137}Cs (Fuhrmann *et al.*, 2002).

Studies with cabbage plants (*Brassica oleracea*) and redroot pigweed indicated that cabbage plants extracted considerable amounts of ^{137}Cs with CRs ranging from 2 to 3 from soil. In red root pigweed, CRs ranged from 2.2 to 3.2. From this study it was estimated that about 3% of the ^{137}Cs in the soil could be removed by each crop and with two crops harvested per year, it would take approximately 10–15 years to meet soil cleanup goals. In field studies on a contaminated lake bed, okra (*Hibiscus esculentus*) was observed to have high uptake, with CRs averaging 6.8 (Fuhrmann, 2000).

Experiments to induce Cs absorption by chelating agents showed that application of ammonium nitrate (NH_4NO_3) solutions (up to 80 millimoles/kg of soil) increased CR by 12 folds as compared to control plants (Fuhrmann, 2000). However, presence of high potassium (K) in soil inhibited plant's absorption of cesium due to competition for uptake into plants as the chemical behavior of K was very much like that of Cs. Fertilizers rich in K tended to inhibit Cs uptake. Like K, the presence of ammonium (NH_4) in soil would also compete for plant uptake and make the phytoremediation process slow. Similar results were observed with the presence of calcium (Ca) and magnesium (Mg) in soils. However, presence of organic matters in soil appeared to enhance Cs uptake (Fuhrmann, 2000).

Since soils in a variety of geological, geographical and climatic conditions could be contaminated by radionuclides, scientists have to identify plants that are adaptive to various conditions and are with higher CR values and greater mass. Chelating agents that are environmentally friendly are to be carefully studied to determine their potential to help induce greater uptake of radionuclides by plants.

Phytoremediation is a rapidly developing field both in the developed and developing countries. During the past two decades, a lot of field applications were studied involving various plant species and various organic, inorganic and radionuclide contaminants. Results of these investigations indicate that it is a sustainable and inexpensive process and a viable alternative to other conventional remediation methods. With its rapid development and growing acceptability, it is reasonably rational to expect that in the near future, commercial application of this innovative technology will be widely available.

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