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Original article

Botanical survey and screening of plant species which accumulate ^{226}Ra from contaminated soil of uranium waste depot

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Abstract

A geobotanical study was performed of the wild plants growing in the area of the old uranium mill tailings waste depot of a former uranium ore reprocessing factory in South Bohemia and the distribution of ^{226}Ra in selected plants was determined. The distribution of ^{226}Ra in contaminated soil was found to be extremely variable (from 7 to 32 Bq ^{226}Ra g^{-1} of DW). The differences in plant distribution were caused by factors of disturbance, soil properties (nutrients and salt content, water supply), and successional stage. No direct relation was proved between plant species characteristics and their radioactivity content. The results showed a great range of variation in the accumulation of ^{226}Ra by the plant species found. The highest activity of ^{226}Ra was found in *Potentilla reptans* (4.09 Bq ^{226}Ra g^{-1} of DW), *Mentha arvensis* (4.00 Bq ^{226}Ra g^{-1} of DW), and *Daucus carota* (3.70 Bq ^{226}Ra g^{-1} of DW). About half of the plant species are used as medicinal plants and some of them are accumulators of ^{226}Ra. However, no plants suitable for phytoextraction of ^{226}Ra contaminated substrates were discovered.

Keywords: Uranium; Uptake; Radium; Mill tailings; Radiophytoremediation; Plant distribution

1. Introduction

Elements from the uranium and thorium decay chain are the most problematic pollutants resulting from mining, reprocessing and disposal activities related to the nuclear industry. For these reasons, to study such an environment and the possibility of its decontamination is important. One of the promising strategies for treating large-scale low-level contamination is the use of phytoremediation techniques for these purposes, taking into consideration some special

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requirements for radiophytoremediation in comparison with phytoremediation of toxic metals [27]. Initially, it is necessary to study the basic mechanisms influencing the uptake of the above-mentioned radionuclides by plants. It is surprising that the soil-plant relationships of U, Th and some other daughter radionuclides, notably ^{226}Ra, are not well understood [18]. Most studies have been concerned with soil sampling and mapping of contamination, the relative uptake of these radionuclides by various plant species, improvement of uptake by adding of fertilizers and transfer of radionuclides to animals [5].

Willett and Bond [29] performed field and column experiments to determine the fate of radionuclides (^{238}U, ^{226}Ra and ^{210}Pb) and Mn, when applied in uranium mine waste water sprayed on highly weathered soil near Ranger uranium mine at Jabiru, Northern Territory, Australia. They found that more than 14% of ^{226}Ra in the surface soils in contrast with other radionuclides was in the exchangeable form which may be available for uptake by roots. Hakam et al. [9] analyzed 42 natural water samples which could be a potential risk for public health in Morocco. They found 150 times higher ^{226}Ra activity in mineral water than the highest activity of ^{226}Ra in well water. Plant uptake of uranium under controlled conditions was studied in different plant species. Huang et al. [12] used *Brassica juncea* and *Brassica chinensis* and reported an increase of shoot uranium concentrations from less than 5 mg/kg to more than 500 mg/kg in citric acid-treated soils. Increased uranium uptake was also reported by Ebbs et al. [7] who tested 12 different plant species and cultivars. Two beet plants (*Beta vulgaris* and *Phaseolus acutifolius*) were selected and two soil amendments, HEDTA and citric acid, were tested. Citric acid was more effective, decreasing the soil pH to 5.0 and increasing uranium accumulation. The hairy root cultures of *Brassica juncea* and *Chenopodium amaranticolor* were used for the experiments to study their potential for rhizofiltration of uranium. Different concentrations and the medium with and without phosphates were used. The result indicated that the hairy roots could remove uranium from aqueous solution within a short period of incubation [6].

Uranium or ^{226}Ra uptake by plant species on naturally contaminated sites was also investigated. Bhatti et al. [2] tested uranium accumulation by *Raphanus* sp. and they found more than 5 mg U_3O_8 per kg of dry weight basis. To reduce the dispersion of natural radionuclides into the environment, some dams in the Urgeirica mine (north Portugal) were revegetated with trees (*Eucalyptus globosus* and *Pinus pinea*) and shrubs (*Cytisus* spp.). Differences in the ^{226}Ra uptake by plants were observed. In the trees, ^{226}Ra concentration ratios decreased at low radium concentrations in the tailings and appeared relatively constant at higher radium concentrations. In the shrubs, concentration ratios increased at higher tailings concentrations, approaching a saturation value [16]. Soil-plant transfer of ^{226}Ra was studied also by Markose et al. [17] on tomato and by Blanco Rodriguez et al. [21] on grass-pasture (*Fabaceae*, *Poaceae*, *Asteraceae*, etc.). They found that uptake of uranium, thorium and radium be mainly associated with concentration of iron in the plant and the phosphorus and alkaline earths in the substrate. Sam [23] studied the uptake of ^{226}Ra by cultivated crop plants in uncontaminated regions of purely natural radioactivity in Western Sudan. Among the species analyzed, purslane (*Portulaca oleracea*) displays a higher affinity for radium uptake relative to other species. Chen et al. [4] tested also crop plants in the experiments in southeastern China. The plant samples were divided on the roots and shoots and the activity of ^{238}U, ^{226}Ra and ^{232}Th were determined. The results show ten times higher activity of all three nuclides in roots than in the shoots. The highest activity was found in the roots of *Lolium multiflorum* (more than 5 Bq ^{226}Ra g^{-1} of DW). The wheat plants were tested in the India by Pulhani et al. [20] on uptake of uranium, thorium, radium and potassium. For the ^{226}Ra they published transfer factor in the range of 0.009 to 0.016, that about 54–75% of total ^{238}U, ^{232}Th and ^{226}Ra activity is concentrated in the roots and only about 1–2% was distributed in the grains. Vera Tomé et al. [28] studied the activity concentrations of natural uranium and thorium isotopes and ^{226}Ra in soil and plant samples from a disused uranium mine located in the Extremadura region in the southwest of Spain. The plant samples (aerial fraction of vegetation from several m^2) at each point were collected from the locations where the soil samples were taken. The concentration levels were much smaller than those found in the corresponding soil but the results showed decrease of the activity. Plant and soil samples were collected from a uranium mill tailings site and control sites in South Dakota by Rumble and Bjugstad [22]. ^{226}Ra in plants from the mill tailings averaged 107.3 mBq g^{-1} as compared to 1.4 mBq g^{-1} from the control sites. ^{226}Ra concentrations in soils averaged 4107.0 mBq g^{-1} and 66.6 mBq g^{-1} from the mill tailings and control sites, respectively. Concentration ratios (amount in plant/amount in soil) of radionuclides indicated two grasses (*Agropyron cristatum* and *Sporobulus airoides*) and one forb (*Kochia scoparia*) were not concentrating uranium or ^{226}Ra. Kozak et al. [14] developed one-