Adsorption-Enhanced Phytoremediation

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Abstract: A series of inorganic ion exchangers, EDTA, natural and synthetic mineral adsorbents, activated carbons and adsorbent composites were studied together with plants on the land contaminated with radionuclides in the Chernobyl zone (Polesye and Chernobyl districts). The experiments were carried out in 1997 - 2000. The selection of adsorbents was based on their ability to remove radiocesium from tap water, with K_d at least 1,000. Amount of adsorbent placed into the root zone of the plants was 50-150 g/m^2. The plants chosen for the study are known for their ability to accumulate heavy metals. Soil activity, mainly due to Cs-137, was 1-20 kBq/kg. Migration of radionuclides was studied by measuring radioactivity of soil, adsorbents and plant biomass. In the presence of ion exchangers and EDTA that strongly bind metal ions plants accumulated less radioactivity than in the adsorbent-free soil. However, it was found that, against our original expectations, addition of certain adsorbents (activated carbon and natural minerals) to the soil accelerated and increased 2-4-fold the amount of radioactivity accumulated in corn, rape, sunflower, lupin and potatoes. Although not fully understood, this synergetic effect could be used for cost-effective decontamination of soil from radionuclides.

Phytoremediation has been suggested as an efficient method for soil decontamination from radionuclides (Zhu and Shaw 2000), whereas sorbents have been widely used for water treatment (Kremlyakova and Komarevsky 1997). In this paper results of the combined use of plants and sorbents are presented.

A series of inorganic ion exchangers, EDTA, natural and synthetic mineral adsorbents, activated carbons and adsorbent composites were studied together with plants on the land contaminated with radionuclides in the 30-km Chernobyl zone (Polesye and Chernobyl districts). The experiments were carried out in 1997 - 2000. The selection of adsorbents was based on their ability to remove radiocesium from tap water, with K_d at least 1,000. Amount of adsorbent placed into the root zone of the plants was 50-150 g/m^2. Modified vermiculite was made by *in situ* precipitation of Prussian blue on vermiculite. Carbon-mineral sorbent was synthesised by precipitation of titanium silicate on activated carbon. Soil activity, mainly due to Cs-137, was 1-20 kBq/kg. Migration of radionuclides was studied by measuring radioactivity of soil, sorbents and plant biomass. The plants chosen for the study are known for their ability to accumulate heavy metals: sunflower, lupin, rape, artichoke, amaranthus, etc. Each type of plant was allocated a separate area with experimental sites of 1 m x 1 m in size, separated by 0.6 m distance. Each site was allocated for one type of sorbents. Sorbents were introduced into the soil in the amount of 50, 100 or 150 g/m^2. Seeds were sown by hand in rows, separated by 0.45 m distance. Before sowing a calculated amount of sorbent was dispersed in each row and covered

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with a thin layer of soil. Seeds were planted at the depth of 1.5 cm. Seeds were planted in May. They were not watered but were regularly de-weeded. The crop was gathered in August. Green mass was cut off at the level of 3-5 cm above the ground. Roots were collected separately, washed with tap water and air dried at room temperature. To measure their activity, green mass was cut into 1-3 mm pieces. Efficiency of phytoextraction was expressed in terms of the coefficient of accumulation calculated as the ratio of the activity of biomass to that of the soil.

The radioactivity uptake by the plants depends on the type of the sorbent as well as the plant (Table 1 and Table 2).

Table 1. Extraction of radiocaesium by biomass

Plant	Sample activity, Bq/kg	Degree of accumulation, %	Coefficient of accumulation, (Bq/kg)/(kBq/m^2)
Phytoextraction			
Corn	1,140	5.0	0.2
Jerusalem artichoke	5,350	24	0.8
Sunflower	4,400	20	0.7
Lupin	6,000	27	0.9
Rape	6,800	31	1.0
Potatoes	440	1.9	0.1
Potatoes (green mass)	1,410	6.0	0.2
Phytoextraction in the presence of carbon-mineral sorbent			
Corn	3,070	14	0.4
Jerusalem artichoke	6,200	28	0.9
Sunflower	11,700	53	1.8
Lupin	11,300	51	1.7
Rape	11,500	52	1.7
Potatoes	960	4.1	0.14
Potatoes (green mass)	3,500	15.2	1.1

Table 2. Influence of sorbent nature on radioactivity uptake by the green mass.

Sorbent	Activity of mustard, KBq/kg*	Activity of amaranthus, KBq/kg*	Activity of rape, KBq/kg**
None (control)	0.4	1.3	0.49
EDTA	0.2	1.1	
Activated carbon (AC)	0.5	1.8	0.27
Zeolite	0.4	1.3	0.52
Titanium silicate	0.2	1.1	
AC + zeolite	0.6	2.3	0.68
Vermiculite			0.30
Modified vermiculite	0.3	1.1	0.22

Soil activity 1.0 kBq/kg, ** Soil activity 2.2 kBq/kg

By their effect on phytoremediation, sorbents could be divided into three groups: (i) reducing (antagonistic effect), (ii) no effect, and (iii) increasing the radioactivity uptake by the plants (synergetic effect). The latter, rather unusual, effect is most significant in the case of the carbon-mineral adsorbent (Figure 1).

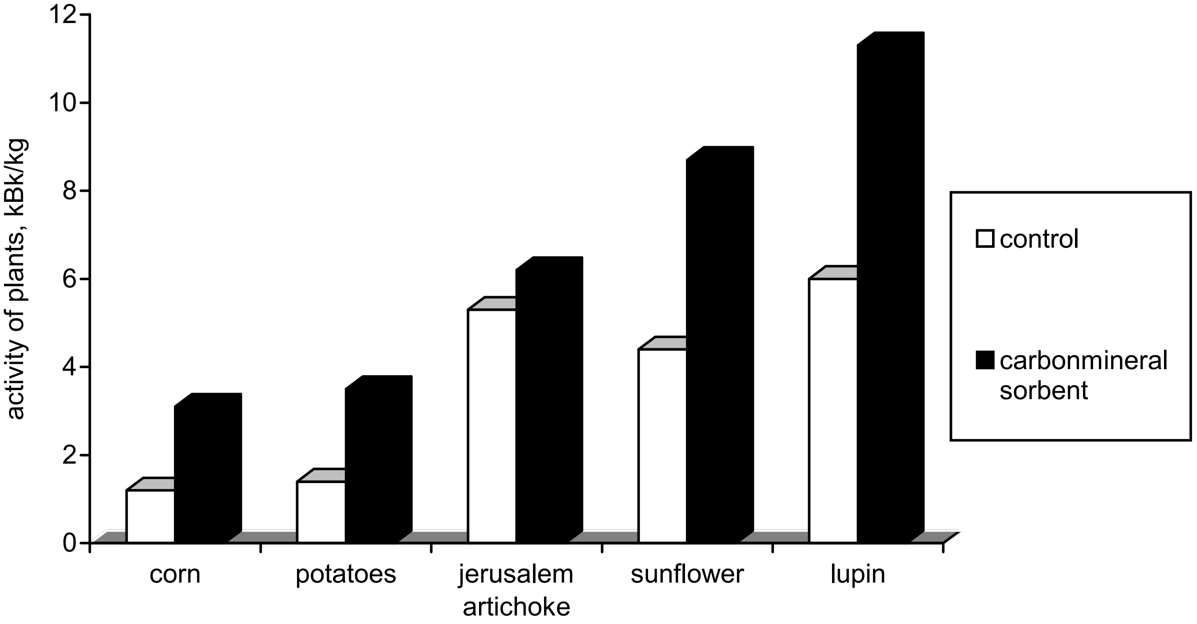

Figure 1 - Influence of the carbon-mineral sorbent on accumulation of radiocaesium by different plants (soil activity ~24 kBk/kg).

Sorbents in the soil may change local pH, as was shown in the model experiments. This effect can accelerate transformation of radionuclides from insoluble into soluble forms thus facilitating their migration to the root system of plants.

Although not fully understood, this synergetic effect could be used for cost-effective decontamination of soil from radionuclides.

References

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