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Caesium-137 root uptake by agricultural and wild crops in post-Chernobyl landscape: the possibilities for phytoremediation?

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In spite of long term period after Chernobyl fallout (≈25 years after the accident) the level of Cs-137 in soils of contaminated landscapes remains several times more than radiation safety standard (= 37 kBq/m2). In particular, within the area of Plavsk radioactive hot spot (Tula region, Russia) current Cs-137 activities in soil are 460-500 Bq/kg (170-200 kBq/m2) on watershed, 580-680 Bq/kg (200-220 kBq/m2) in arable lower parts of slopes and 620-710 Bq/kg (210-280 kBq/m2) in untilled foots of slopes and river floodplains.

To estimate the process of Cs-137 root uptake and incorporation of the radionuclide in plant tissues 6 agricultural crops of typical field rotation (spring barley, maize, summer rape, galega, potatoes, amaranth) as well as natural ecosystems of dry and wet meadows were selected for the detailed study. Total bioproductivity of agricultural crops varies between 1.7-3.9 kg/m2, natural grass ecosystems – 1.9-2.2 g/m2, and is obviously unaffected by radioactive land contamination. At the same time Cs-137 activity in total biomass slightly increases with Cs-137 activity in soil (correlation coefficient r=0.45) and with total biomass (correlation coefficient r=0.51) in the row: rape (5 Bq/kg) < amaranth, galega (17-19 Bq/kg) < barley, potatoes (31-37 Bq/kg) < maize (58 Bq/kg) < dry meadow (73 Bq/kg) < wet meadow (120 Bq/kg).

Commonly, Cs-137 activity in vegetation of natural ecosystems with predominance of perennial grasses is significantly higher than in agrosystems with annual crops. But a substantial portion of Cs-137 in meadow vegetation is associated with belowground biomass, where the radionuclide's activity is 3-5 times greater than in the aboveground part. The distribution of Cs-137 activities between above- and belowground parts of agricultural crops greatly varies depending on the biological characteristics of plants: barley and maize (Gramíneae family) are also characterized by elevated Cs-137 concentrations in belowground parts (12-14 times higher than in shoots); rape (Brassicaceae family) and potatoes (Solanaceae family) are characterized by similar Cs-137 concentrations in the structural parts (but note, that belowground part of the last is mostly represented by modified shoots); while galega and amaranth (Fabaceae and Amaranthaceae families respectively) are characterized by higher Cs-137 activity in aboveground part (4-6 times more than in roots).

Therefore, meadow grasses and cereals that are true accumulators of Cs-137 seem to be useless for phytoremediation purposes, as 86-97% of the radionuclide inventory is associated with roots and remains in soil after cutting of aboveground parts. On the other hand, galega and amaranth could be considered as agricultural crops potentially being used for phytoremediation, since 87-93% of Cs-137 inventory is located in shoots. Potatoes having rather high aboveground biomass and easily removed from soil underground part could be also used for phytoremediation. However, it should be clearly understood that in total Cs-137 inventory in "soil-plant" system the annual amount of the radionuclide's consumption (that may be alienated when harvesting) is less than 0.01%, while the rate of Cs-137 radioactive decay is estimated as about 2% per year.

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