

Effect of Different Treatments on ^{85}Sr Plant Uptake in Various Soil Types

E. Koblinger-Bokori and P. Szerbin
"Frédéric Joliot-Curie" National Research Institute for Radiobiology and Radiohygiene
P.O.Box 101, H-1775 Budapest, Hungary

ABSTRACT

In the recent years radioecological studies are concentrated on the investigation of restoration possibilities of contaminated ecosystems. These studies are aimed to develop methods for decreasing the bio-availability of the radionuclides released to the environment.

Radionuclides of long half-lives, such as ^{90}Sr and ^{137}Cs , are of special importance from the point of human health, since these nuclides can enter the human body via the food-chain and increase the radiation burden for many years. ^{90}Sr and ^{137}Cs contamination of the environment may occur as a result of atmospheric releases during nuclear accidents. For instance, considerable amounts were released to the atmosphere during the Chernobyl reactor accident.

In the presented study strontium plant uptake from different types of soil was investigated. To avoid the difficulties related to ^{90}Sr determination, the gamma-emitting strontium isotope ^{85}Sr is used at the experiments (no isotopic effect takes place). The plant selected is yellow leguminous bean.

Most typical Hungarian soils (leached Ramann brown forest soil, alluvial soil, chernozem-light sandy soil and calcareous chernozem soil) were selected for the experiments carried out under laboratory conditions. Results are presented in relation to major soil characteristics. Effects of two different treatments: lime and organic matter fertilizations on plant uptake are given.

The highest uptake was found in bean grown on leached Ramann brown forest soil, whereas the lowest value was measured in the plant grown in calcareous chernozem soil. Organic fertilization significantly reduced the uptake of radiostrontium in all investigated types of soil. The largest factor of reduction was found to be as high as 3.5. Lime fertilization was less effective.

Our study clearly demonstrates that carefully selected post-accident treatments (e.g. organic fertilization following strontium contamination) can significantly reduce the environmental consequences of radioactive releases. Methods to be developed on the basis of such studies could be used for remedial actions of agricultural lands polluted with radioactive substances.

INTRODUCTION

Accidental releases of radioactive material into the environment have promoted the research for effective soil-based chemical treatments to reduce the transfer of radionuclides along food-chains. A simple laboratory method has been applied for determination of concentration factors after contamination. The effects of different soil treatments, which may influence the radionuclide availability for plant, are also studied. Protection of agricultural environment is usually directed towards the longer-lived radioisotopes, such as radiocaesium and radiostrontium, since these are readily transferred to man via food-chains.

It is known that the soil type and a large number of environmental factors can affect the processes in the soil and plant (1,2,3). Therefore, data from experiments carried out under field conditions and under controlled conditions show different results. However, for soil based treatments, studies carried out under laboratory condition are more effective, because in this case the effects on the plant uptake of different treatments in various soil types can be separately investigated.

A review of the previous studies showed that with the addition of different fertilizers (K , Ca , NH_4^+) to soil a large reduction of radioisotope uptake can be achieved, especially in the cases of caesium and silver. The reduction rate does not exceed a factor of two in the case of strontium (4,5,6,7). Therefore, it is very important to find a method for strontium remediation.

The overall objective of this work is to develop a methodology that can be used after an accident to reduce the availability of radionuclides by plants.

MATERIAL AND METHODS

Soil selection and characterizing

Four different soil types, representative of the most important agricultural soils in Hungary, were selected. The soil samples were taken from surface down to a depth of 30 cm on each sampling site.

Table 1 shows the physical and chemical characteristics of soils which were determined according to standard methods (8).

Table 1. Physical and chemical characteristics of soils

soil types	leached Ramann forest soil	alluvial soil	chernozem light sandy soil	calcareous chernozem soil
location	Gödöllő	Foktő	Örbottyán	Nagyhörcsök
pH (KCl)	5.0	7.5	7.6	7.8
organic matter (%)	1.05	1.53	1.26	3.40
cation exchange capacity T (me/100g)	8.98	11.3	11.00	32.2
changeable K (me/100g)	0.35	0.37	0.12	0.28
changeable Ca (me/100g)	1.43	8.57	4.09	10.32
coarse sand (%)*	32.9	0.4	11.9	0.8
fine sand (%)*	41.0	50.0	79.4	15.7
silt (%)*	17.8	43.1	49	60.4
clay (%)*	8.3	6.5	3.8	23.1

*per cent of mineral content

The dried, homogenized and sieved (with a sieve hole width of 1.25 mm) soils were artificially contaminated with ^{85}Sr in form of nitrate (without carrier, with an activity concentration of 18.5 MBq/ml). All the investigations were carried out using the particles having diameters less than 1.25 mm.

Plant uptake

The plant uptake was investigated with pot experiments under laboratory conditions.

Each pot was filled with 1 kg labeled soil. From each type of soil 2 pots of control and 2 pots of treated soil were prepared. Yellow leguminous bean was selected for the investigations and plants were sampled at the end of the vegetation time. After sampling the plants were separated into edible (crop) and unpalatable portions (the root and the unit comprising the stem-and-leaves). All parts of the plants were dried at 105°C. ^{85}Sr activity concentrations were measured in the crop, roots and stem, separately.

^{85}Sr activity measurements were performed by an NK-350 type one-channel gamma-spectrometer (Gamma Works, Hungary) with a Na(Tl) scintillation detector. Radionuclide activities were corrected according to radioactive decay.

The soil-to-plant concentration factor (CF) characterizing the uptake is given by

$$CF = C_p/C_s,$$

where C_p and C_s are the activity concentrations in the plant (by wet weight) and soil (by dry weight), respectively.

Soil treatments

It is known from the literature that strontium uptake is influenced by organic matter content of the soil (6,7). On the other hand, uptake of strontium depends on the calcium content (9).

Two commercial fertilizers were selected for this study: compost and garden lime. In the first case one

part of compost was mixed with two parts of soil (300 g/kg). This treatment is equivalent to a 200 Mg/ha fertilization. In the case of lime treatment, fertilizer was mixed into the soil (10 g/kg) leading to a fertilization of 3.3 Mg/ha Ca (as $\text{Ca}(\text{OH})_2$). The soil treatments are given in Mg/ha, to convert the data given in units g/kg, the chemicals are assumed to have been distributed over the top 5 cm of soil with a density of 1.25 kg/dm^3 (10). These fertilizations are higher than usual in agricultural practice. The soil humidity was set to 25 % and, during the experiment, pots were watered with 50 ml distilled water three times a week. It corresponds to a 650 mm yearly precipitation, representative in Hungary.

RESULTS AND DISCUSSION

^{85}Sr plant uptake in various types of soil

The ^{85}Sr activity-concentrations and concentration factors vary significantly according to plant properties and soil types. The results obtained from plant uptake experiments carried out on labeled soil without treatment (controls) are shown in figures 1 and 2.

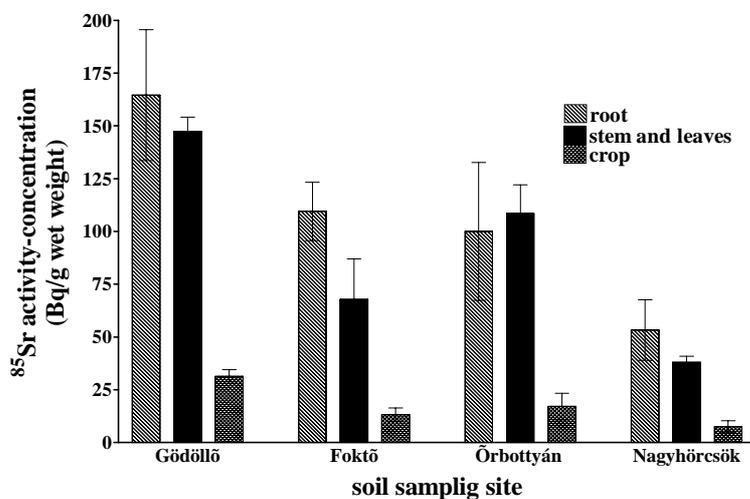


Figure 1. ^{85}Sr distribution in plant

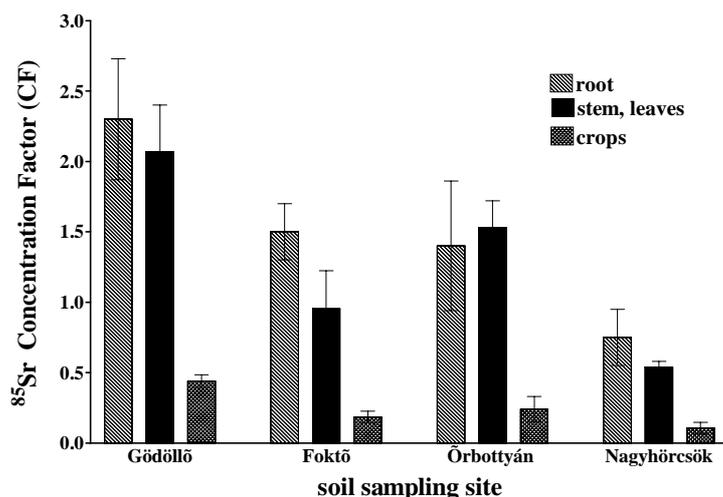


Figure 2. ^{85}Sr concentration factors in various plant parts

Results show that the ^{85}Sr concentrations in the root and stem-leaves are 5 times higher than that in the crops.

Concentration factors, calculated from the activity concentrations measured in the soil and in the plant, vary between 2.07 ± 0.4 and 0.54 ± 0.04 in vegetative portion and between 0.44 ± 0.05 and 0.11 ± 0.04 in crops.

The smallest concentration factor is found in the soil with the largest organic matter content: calcareous chernozem soil (Nagyhörcsök), whereas the largest concentration factor is found in leached Ramann forest soil (Gödöllő). There is a factor of 3.5 between the largest and smallest concentration factors.

Effect of compost treatment on ^{85}Sr plant uptake

Application of compost for soil treatment leads to a decrease in uptake of ^{85}Sr by plant. Figures 3 and 4 show the effect of compost treatment.

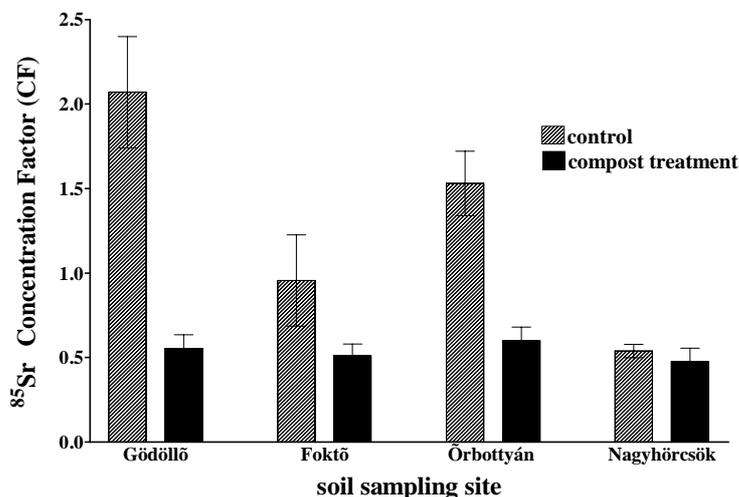


Figure 3. Effect of compost treatment on ^{85}Sr concentration factor in stem and leaves

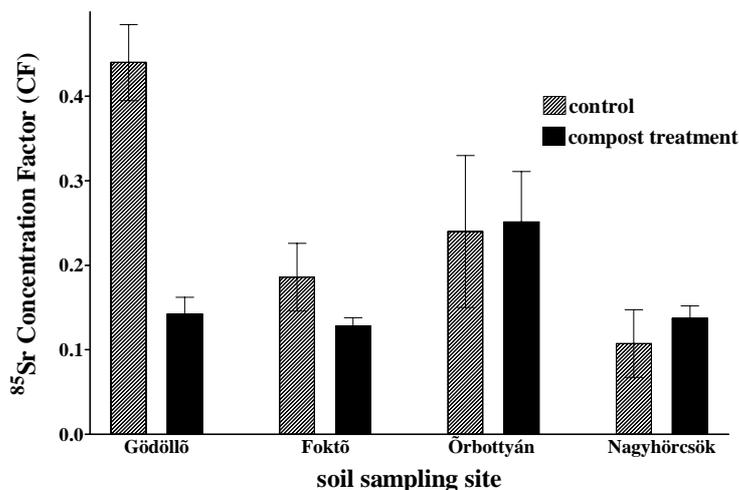


Figure 4. Effect of compost treatment ^{85}Sr concentration factor in crop

The treatment is most effective in the leached Ramann forest soil (Gödöllő), i.e. in the soil with the smallest organic matter content. It is known that the bio-availability and mobility of radionuclide in soil depend on the chemical form and association with different soil phases (12). One portion of strontium in the soil is in a readily exchangeable form, i.e. available for uptake by plant. The other part is complexed with organic matter and is associated with high molecular weight species, i.e. not readily taken into solution. The high molecular weight organic matter content is enhanced in the soil by the compost treatment and this leads to the decrease in the availability of the strontium, especially in soils with low organic matter content. The effect of compost treatment could be measured in unpalatable portion of plants grown on soils with a low organic matter content (*leached Ramann forest soil, chernozem light sandy soil, alluvial soil*) and in edible portion of plants grown on soils with the lowest organic matter content (*leached Ramann forest soil*).

Effect of garden lime treatment on ⁸⁵Sr plant uptake

The treatment with calcium, in the form of garden lime, is less effective as compost fertilization. Figures 5 and 6 show the effect of Ca treatment.

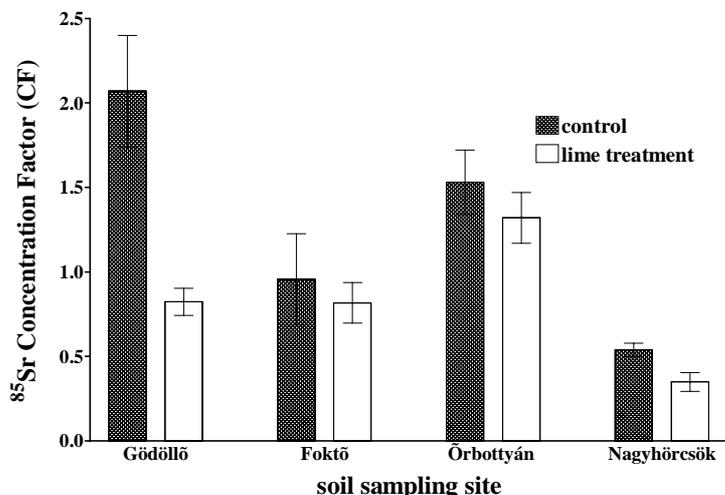


Figure 5. Effect of lime treatment on ⁸⁵Sr concentration factors in stem and leaves

The smallest amount of exchangeable Ca and the smallest cation exchange capacity were found in the leached Ramann forest soil (Gödöllő). The respective values are about 1.5 me/100g and 9 me/100g. These amounts of Ca and exchangeable cations are low enough to reduce the uptake of strontium by further addition of Ca. The uptake of strontium is decreased by a factor of 2.5 as a result of garden lime treatment with the rates applied in this study. Such a decrease was achieved only on the leached Raman forest soil. In the case of the other soil types the treatments lead to smaller effects on uptakes.

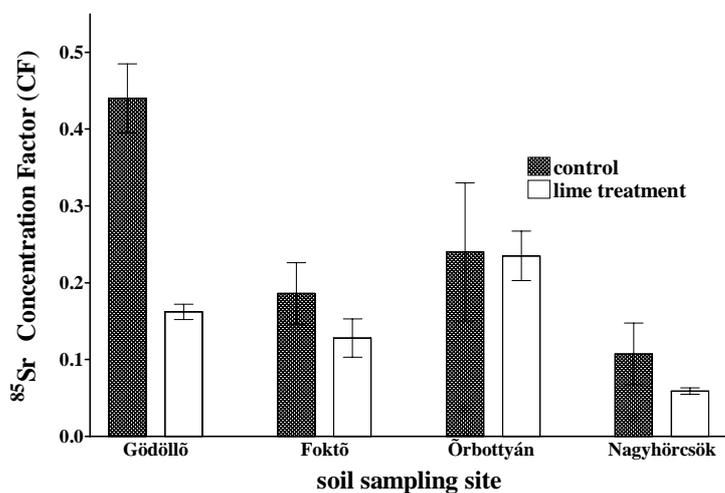


Figure 6. Effect of lime treatment on ⁸⁵Sr concentration factor in crop

SUMMARY AND CONCLUSIONS

The variation of the ^{85}Sr uptake with soil type

The concentration factors decreased in the following order:

*leached Ramann forest soil > chernozem light sandy soil >
alluvial soil > calcareous chernozem soil.*

Results are summarized in Table 2.

Table 2. Soil to plant concentration factors (CF) for ^{85}Sr , pot experiments

	leached Ramann forest soil	alluvial soil	chernozem light sandy soil	calcareous chernozem soil
	Gödöllő	Foktő	Örbottyán	Nagyhörcsök
CF (stem and leaves)	2.07 ± 0.4	0.96 ± 0.3	1.53 ± 0.2	0.54 ± 0.04
CF (crop)	0.44 ± 0.04	0.19 ± 0.04	0.24 ± 0.09	0.11 ± 0.04

The observed concentration factor for most plant parts (stem, leaves and root) are around one or exceeding it, except for plants grown on calcareous chernozem soil.

The observed concentration ratio in the edible portion lies between 0.11 and 0.44. The ratios of concentration factors in unpalatable parts to those in the corresponding edible parts are between 5 and 6 for each soil type.

The activity concentrations in non-edible parts are greater than those in the edible portions. This discrimination against large divalent cations by the grain is well recognised. (11).

Effect of treatments (compost and garden lime)

An uptake decrease of about 3.5 can be reached by compost treatment in the case of leached Raman forest soil. The decrease factor in the other soils is not more than 1.2 – 2. The effect decreases with increasing organic matter content.

The lime treatment is effective only on the soil with the smallest exchangeable calcium content. The maximum decrease is about 2.5, compared to control.

Table 3. Strontium concentration factors in plants after treatments

		leached Ramann forest soil	alluvial soil	chernozem light sandy soil	calcareous chernozem soil
treatment		Gödöllő	Foktő	Örbottyán	Nagyhörcsök
compost	CF (stem, leaves)	0.55	0.51	0.60	0.48
	CF (crops)	0.14	0.13	0.25	0.14
garden lime	CF (stem, leaves)	0.82	0.82	1.32	0.35
	CF (crops)	0.16	0.13	0.24	0.06

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