

Root uptake of Cs-137 by natural grasses as a function of properties of soils

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Resumen

Este trabajo estudia la dependencia de la absorción radicular de Cs-137 en la estructura de un ambiente natural, especialmente sobre las propiedades de suelos, bajo condiciones controladas. Se realizaron investigaciones a varios niveles de contaminación con Cs-137 (de 20 hasta 1000 kBq/m²), con cinco tipos diferentes de suelos, los cuales difieren en textura y composición granulométrica. Los resultados muestran que los valores del factor de transferencia de Cs-137 (TF) difieren hasta 5 veces respecto a la cobertura seminatural del pasto. La correlación entre los valores de TF de Cs-137 y la composición granulométrica del suelo fue determinada tanto para suelos minerales automórficos como hidromórficos.

Abstract

This work studies the dependence of Cs-137 root uptake on the structure of landscape, especially on the properties of soils, under controlled conditions. Researches were carried out at various levels of Cs-137 contamination (from 20 up 1000 kBq/m²), with five different types of soils, which differ in texture and granulometric composition. The results showed that transfer factor (TF) values of Cs-137 differ 5 times for the natural grassy coenoses. The correlation between Cs-137 TF values and granulometric composition of soil was determined for both automorphic and hydromorphic mineral soils.

1. Introduction

Among the long-living radionuclides, Cs-137 is the most widespread (or prevalent) as a result of nuclear or radioactive accidents and this nuclide plays an important role in the definition of radioecological situation in various countries. It can be considered as a main factor of the internal dose formation (80-95% of total dose) for the population of any radioactively contaminated territory. The dose formation is based mainly on the consumption of agricultural products, especially by the rural population, from radiopolluted lands. Therefore soil-to-plant link is the most important element of the Cs-137 pathway along the food chain.

Nowadays, significant experience exists in field studies and in the estimation of certain factors of the radionuclide root uptake by plants. In fact, the consideration of the radionuclides behavior in soil and their biological availability to plants has been investigated in earlier works [1]. Special attention was also paid to the transfer factor dynamics [2], the influence of soil characteristics [3] and the biological

properties of plants [4]. Consequently, it is possible to assume that the basic mechanisms of the soil-to-plant Cs-137 transfer are well known. However, the researches carried out till now have embraced quite a limited number of natural factors. Therefore, a problem of further parameterization of these natural mechanisms and the specification of existing models is still open.

Taking into consideration the multifactorial character of the soil-plant system in nature, it is necessary to note the lack of data that would allow to allocate the role of separate factors and to estimate the influence of different combinations of the latter as quantitative parameters. In a number of experiments inconsistent data have been received, showing an increase in radionuclides accumulation by plants [5] or their decrease [6].

In nature, the estimation of radionuclides migration mechanisms is to be carried out not only taking into account separate natural factors, but also for complete geocosystem,

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which is an element of the landscape of the investigated territory, with the complete set of relatively stable and variable factors.

In this aspect, the basic task of this work consists in the substantiation of the dependence between Cs-137 root uptake and the structure of a landscape, especially texture and moisture of soils, in artificial conditions.

A landscape is considered as an environment of chemical elements circulation. The soil, as an important landscape component, may be proposed to have a key role in the formation of the migration conditions of radionuclides.

2. Material and Methods

2.1. Experimental set-up

In order to estimate the Cs-137 migration parameters in the soil-to-plant link in nature, a referent sampling net was established. The sampling plots were positioned at representative semi-natural coenoses, at various levels of Cs-137 contamination, on typical elements of landscape structure, with different soil varieties, which differ in texture, granulometry and moisture.

During sampling, the landscape characteristic of the experimental plots regarding their position at the relief was carried out. For each of the plots, a soil profile was described.

2.2. Analytical methods

Plant samples were dried in air conditions, cut into small pieces and homogenized. Soil samples were also air-dried, pounded and sieved through 1 mm sieve. All samples were put in marinelli cups.

Cs-137 content in soil and plants was determined using the high effective gamma-spectrometer EG&ORTEC, with low background, equipped with a solid scintillation detector BICROM of NaI(Tl) 3x3" (energetic resolution of Co-60 line: 65 keV). The time of detection provided results with reliability more than 10%. The counting error ranged from 2 to 10% depending on the intensity of the measured activity. The concentration of Cs-137 in the samples was expressed in Bq/kg air-dry mass.

2.3. Definition of transfer factor (TF)

The soil-to-plant aggregated transfer factor

(TF) was defined as follows [7]:

$$TF = \frac{SAP}{SAS}$$

Where:

SAP: specific activity in plant (Bq/kg dry weight)

SAS: specific activity in soil (Bq/kg dry weight).

TF values of plant samples were averaged for the same soil variety. According to their distribution, the different soil varieties were represented by a minimum of 4 and a maximum of 10 samples.

The conditions of this research have allowed to study in detail the influence of the landscape factors on biological availability of Cs-137 in a soil-plant system separately and in aggregation on a wide range of the contamination density.

3. Results and Discussion

The results of this study showed that TF values of Cs-137 for the different soils in various landscapes range from 0.2 for soddy-podzolic loamy soil to 3.7 for non-drained (wet) peat bog soil, showing a difference of 19 times for the natural grassy coenoses.

The correlation between Cs-137 TF values and granulometric composition of soil was determined and shown in Fig.1.

Obtained data on Cs-137 accumulation by grasses in natural coenoses have confirmed that the dependence of TF on the contents of clay is successfully described by the following power function:

$$TF_{j,i} = TF_0 x G^{-\lambda_j}$$

Where $TF_{j,i}$ is the transfer factor of radionuclide from i-th soil into j-th crop; TF_0 the possible value of $TF_{j,i}$, if $G=1$; G the content of clay in the soil; and λ_j is the parameter of a degree of dependence for j-th crop.

In fact, in the range of mineral soils (automorphic and hydromorphic) of an identical degree of moisture, Cs-137 TF values significantly differ depending on the soil granulometry.

Cs-137 TF values are consistently reduced in the following order: sandy soils (<10% of

clay) >loamy-sandy soil (10-15% of clay)> loamy soil (> 15% of clay).

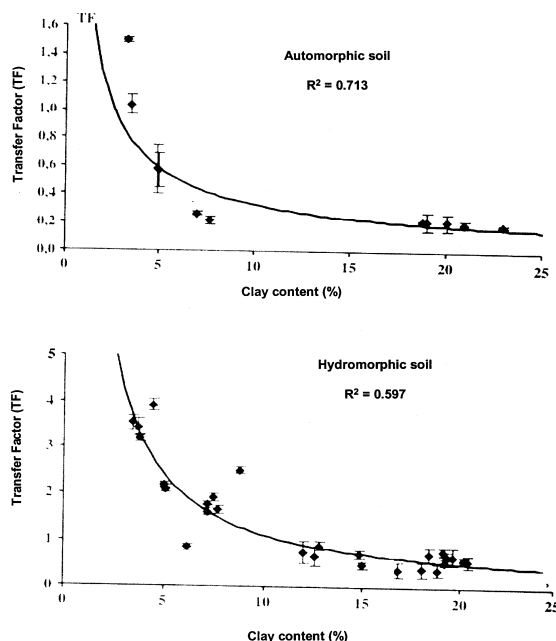


Figure 1. Correlation between Cs-137 TF values and granulometric composition of soil.

Table 1 shows the average values of Cs-137 transfer factor for the semi-natural coenoses on different soils. As to the influence of the soil hydromorphism (moisture of soil) on Cs-137 root uptake, for soils of the same granulometry, the differences in TF values can reach the order of 5-10%.

The obtained results, allow assuming that the soil hydromorphism influences the TF Cs-137 values via, both, soil structure and botanical characteristic of phytocoenoses.

Table 1. Average values of Cs-137 Transfer factor on different soils.

Soil Variety		Transfer Factor (TF)	Uncertainty (K=2)
Organic bog soil	Drained	0.48	0.029
Alluvial soddy soil	Sandy	0.47	0.035
	Loamy	0.22	0.024
Soddy-podzolic soil	Sandy	0.35	0.010
	Loamy-sandy	0.26	0.011
	Loamy	0.12	0.006

4. Conclusions

The approach proposed in this work provides a combination of qualitative and quantitative criteria of evaluation of Cs-137 absorption by plants and shows the dependence between the Cs-137 TF values in grass and the stable

landscape factors, such as texture and moisture of soil, which define to a great extent the fertility of soil.

On the basis of obtained results, it could be assumed that Cs-137 TF values are consistently reduced in the following order of soil varieties: sandy > loamy-sandy > loamy. The correlation between Cs-137 TF values and clay content in soil is described by a power function.

Therefore, such quantitative parameter, as Cs-137 TF value, could be used as a criterion for the estimation of the landscapes radioecological criticality. The revealing of the most vulnerable landscape areas, from the radioecological point of view, will allow to improve their practical use and to define the rational strategy of human interference in the radiopolluted environments.

5. References

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