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# Migration of Radionuclides in the Soil-Crop-Food Product System and Assessment of Agricultural Countermeasures

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**Abstract.** Studies on dynamics of redistribution of radionuclides through of profile of the different soils on uncultivated agricultural lands of Belarus during the 1986-1995 period show that vertical migration occurs with low rate. In arable soils the radionuclides are distributed in comparatively uniform way through the whole depth of the 25-30 cm cultivated layer. Investigations on migration of radionuclides with wind erosion on the drained series of wet sandy and peat soils and water erosion on sloping lands show that one should take into consideration the secondary contamination of soils while forecasting a possible accumulation of radionuclides in farm products.

## 1. Introduction

Radionuclides in the topsoil are potentially available for uptake by plant roots, although plant uptake of many radionuclides is controlled by variety of factors. The rate of uptake differs substantially for different radionuclides and soil types and depends on the physicochemical processes in the soil that govern their availability and on the physiological requirements of the plant.

The amount of information for various radionuclides concerning their behaviour in soil varies greatly. Studies on the dynamics of redistribution of radionuclides through the profile of the different soils, on the transport of radionuclides with wind and water erosion and the effect of soil moisture on the processes of migration of  $^{137}\text{Cs}$  and  $^{90}\text{Sr}$  in the soil-crop system are of actuality to the population of Belarus.

## 2. Results and Discussion

### 2.1 Vertical migration of radionuclides in soils

Studies on the character and rates of migration processes of the long-lived radionuclides  $^{137}\text{Cs}$  and  $^{90}\text{Sr}$  were conducted on the main typical soil series of the Gomelskaya and Mogilevskaya regions, uncultivated areas of pastures, hayland and lealand. On each site the initial characteristics of morphological properties, granulometric, mineralogic and bulk chemical composition and of agro-chemical properties of all genetic horizons of soil cross sections have been established. Annual measurements of the exposure dose and determinations of the levels of radionuclides in relation to 1 cm and 5 cm soil layers were performed.

Vertical and horizontal migration of  $^{137}\text{Cs}$  and  $^{90}\text{Sr}$  in arable soils is studied in field experiments. The forms of radionuclides in soils and accumulation of those in the yields were determined. Studies on dynamics of redistribution of radionuclides through the

depth of a soil profile on uncultivated agricultural lands during the 1986-1995 period show that vertical migration occurs with a low rate. Practically all the radionuclides are in the upper active part of a root layer of soil humus horizons. The greatest quantity of  $^{137}\text{Cs}$  and  $^{238-240}\text{Pu}$  (80-90%) appears to be in the upper 5 cm layer, i.e. in the sod. And only on the soils being cultivated before the accident (ploughing, grassland establishment) a more appreciable movement of radionuclides to the 5-15 cm depth has been found (Fig. 1).

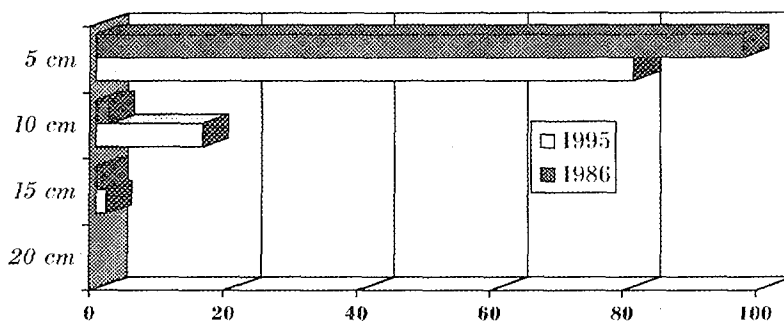


Fig. 1. Dynamics of migration of  $^{137}\text{Cs}$  through the profile of sod-podzolic loamy sands (in % of the total level)

The mean rate of migration of  $^{137}\text{Cs}$  from the upper 5-cm layer was within a range of 1.6-5.2% per year.  $^{90}\text{Sr}$  is more mobile, the level in the 0-5 cm layer decreasing with a rate of 2.8-6.4% per year. In all uncultivated soil the 20-25 cm layer is characterised by background level of radioactivity. Notwithstanding some peculiarities, vertical distributions of  $^{137}\text{Cs}$ ,  $^{90}\text{Sr}$  and  $^{238-240}\text{Pu}$  are much similar in character; this fact is probably conditioned by a predominantly biomechanic transfer of radionuclides with soil particles.

In arable soils  $^{137}\text{Cs}$  and  $^{90}\text{Sr}$  are distributed in a comparatively uniform way through the whole depth of the 25-30 cm cultivated layer. Their movement to 30-50 cm depth is significant.

## 2.2 Horizontal transport radionuclides with water and wind erosion

Transport of radionuclides with processes such as wind erosion has been studied on the drained series of wet sandy and peat soils used for growing field crops. According to the direction of prevailing winds profiles were laid down, the space between them being 100 metres. Over a four-year period since 1991 in spring, summer and autumn from each profile in accordance with the motion of an air flow, composite soil sample have been taken and analysed for  $^{137}\text{Cs}$ . The results obtained were compared with the

initial levels of radiocaesium in soils according to the data of the 1987 measurements. It has been found that various sites of the fields investigated differ greatly for the levels of radiocaesium in the arable horizon of soils. The levels of  $^{137}\text{Cs}$  increased normally by 1.5-2 times in the direction from the central part of the field to the tract of forest and at the edge of the forest the levels of  $^{137}\text{Cs}$  were 2-3 times higher than the initial levels of contamination. This fact is due to the transport of contaminated dust particles; it is confirmed by the presence of deflation material in dusters designed by Bagnold and in plotting boards installed according to the motion of an air flow.

Studies on transport of radionuclides with water erosion were conducted on sloping lands. These studies are underlain by quantitative indices of a solid flow during 1991-1994 in the Gomelskaya region. It has been found that most of the lands subjected to washout are represented by areas having a potential average annual washout that ranges between 2.5 and 10 t/ha. Thus, in Vetkovsky district one can observe a natural increase in the levels of  $^{137}\text{Cs}$  in the middle and particularly in the lower part of the slope up to 1.5-2.0 times comparing with the upper part while cultivating grain and tilled crops. On the lands under four-year old perennial grasses, where practically a solid flow was absent, there was no significant differentiation in the density of contamination of soils according to units of a slope. On the sloping lands, with an intensity of a solid flow of 10-20 t/ha per year, a more significant accumulation of  $^{137}\text{Cs}$  in the arable horizon of soils of the lower part of the slope has been found.

Thus, one should take into consideration the secondary contamination of soils while forecasting a possible accumulation of radionuclides in farm products. It is obvious that there is a need for taking regular measures focused on soil conservation, because in the zone of radioactive contamination more than half of the arable land represented by sandy and drained peat bog soils and also by sloping soils can be subjected to erosion.

### 2.3 The degree of soil moistening and processes of migration of radionuclides in the soil-crop system

Due to contradictions of data in the literature a need has appeared for studying the effects of soil moisture on the processes of migration of radionuclides in the soil-crop system. As the degree of soil moistening increased the share of radiocaesium fractions available to plants increased by a factor five and the transfer of radionuclides into hay, by a factor twenty. Taking into account the natural increase in yield on sod-gley sandy soils the total removal of  $^{137}\text{Cs}$  has increased by a factor 76 in comparison with overmoistened soils.

The availability of  $^{137}\text{Cs}$  to plants is significantly declining in the course of time due to the processes of "ageing" and its fixation in soil. During the period 1987-1992, the share of mobile radiocaesium decreased in different soils from 29-74% to 5-29% of the total or on an average more than 3 times. At the same time a corresponding reduction in the transfer of  $^{137}\text{Cs}$  into the yields occurred.

On the contrary,  $^{90}\text{Sr}$  is characteristic of predominance of easily available exchangeable and water-soluble forms that as a whole account for 50-87% of the total level. As for the share of the fixed fraction extracted by 6M HCl it is not high and varies within a range of 2 to 19%. Overmoistening of soils also results in the increase in the share of mobile fractions of  $^{90}\text{Sr}$ . But this process is accompanied by a significantly lower increase in the transfer of  $^{90}\text{Sr}$  into perennial grasses than for  $^{137}\text{Cs}$ . Accumulation of strontium in plants to a higher degree depends upon the agrochemical properties of soils than on the moisture regime.

## 2.4 Assessment of agricultural countermeasures

The protective measures in farming industry are carried out in two stages : the 1st stage -- 1986-1991 and the 2nd stage -- since 1992. The highly contaminated lands, where obtaining farm products having permissible levels of radionuclides have been removed from crop rotations; there liming and fertilisation of acid soils using phosphorous and potash fertilizers have been performed on waterlogged soils, drainage and deep ploughing of the sod were done, grass establishment and regrassing of hayland and pastures was done. All the measures made it possible to reduce the entry of radiocaesium into farm products by 3.5 times.

There exists only random monitoring concerning the levels of  $^{90}\text{Sr}$  in farm products. Approximately, the entry of radiostrontium into food products over the postaccident period has decreased twice. The availability of  $^{90}\text{Sr}$  to plants remains high with a trend towards increase.

### **Conclusion**

In Belarus one can see apparent comparatively high effectiveness of large-scale protective agricultural measures that have been taken mainly in the public sector. However, the problems of safe residence for population and obtaining quality food products are still far from being solved.