Transfer of 137Cs from soil to vegetative crops

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Transfer of ^{137}Cs from soil to vegetative crops

Prelaz ^{137}Cs iz zemljišta u neke žitarice

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The researches for the transfer of radio-nuclides from the soil to the plant have great importance in terms of assessment of radiation risk, for formation of preventive measures in accidents as well as for eventual decontamination of the land by growing certain plants.Taking into consideration the importance of the distribution and the transfer of radionuclides from the soil to the vegetative crops, in this work an attempt was made to calculate the transfer factor of 137Cs from soil to plant.Data have been used about concentrations of activities of soil from certain locations in the surrounding area of Skopje, their mean value has been taken, while the values of the transfer factors of radio-nuclides from soil to plant have been taken from international scales, for grain and corn. It is assumed that in Macedonia they represent most commonly used vegetative crops, so the grain and the stem of the plant have been separately analyzed. The radiometric analysis of these samples were performed by using of gamma spectrometer supplied with germanium of high purity (HPGe), detector with 30% relative efficiency and energetic resolution (FWHM) of 1.8 keV for 1.33 MeV reference point of 60Co. The software applied for obtaining data is Canberra software package, Genie-2000, including search of maximal value and modules for identification of nuclides. The results indicate that 137Cs is accumulated more in the root than in the grain which would imply control of the radioactivity in the agricultural land. Also these data may represent a basis for assessment of a dose that the population receives by ingestion of produced food, which required knowledge about the average annual intake for every plant separately.

INTRODUCTION

During the accident in Chernobyl, the radioactive pollution with radio-nuclides that reached Macedonia, Anovski et al. (1986,1996) as well, was a consequence of a tropospheric radioactive dust (Greek Atomic Energy Commission, 1988) and the crops after the accident or later – up to today – were polluted with radio-nuclides almost strictly through their root system. Further on, the threat of accidents with nuclear weapons enhanced the needs to understand how radionuclides move through the environment after release, particularly in the plants that are part of the food chain. The level of radioactive contamination with ^{137}Cs in plant organisms that include the agricultural products, that is, food products with plant origin, depends on the intensity and the radiation, the meteorological, hydrological, agrochemical and other factors.

Also, the level of radioactive contamination in separate plant organisms (flower, leaf, stem, root) is not equal. It primarily depends on the differences in the chemical compositions and the direction of the ion transport (from the vegetative to the generative organs, from the root system to the overhead organs and vice versa). However, the rate of movement of the radionuclides through the terrestrial ecosystems depends on physical and biological processes. The first ones have radionuclide dependence, while the second ones have high rate of dependence on the element and its chemical form. Some of the more important physical processes include (Bodensky D.Robin MA. 1987) capture of radionuclides in the air and rain from vegetation, (UNSCEAR: 1988.), the loss of radionuclides from vegetative surfaces, (IAEA Report ,1990) resuspension of radionuclides from terrestrial surface and deposition on the vegetation. The distribution of ^{137}Cs has been researched in many plants. From the researches it has been determined that the plants that have shallow root absorb more radionuclides, than the ones with a deeper root. This occurrence can be explained with the fact that most of the radionuclides (85%) are retained on the surface layer at a depth of 5cm.

[Guricic G Popovic D. 1994]. Between the separate plant species there are significant differences in the sensitivity of the transfer of ^{137}Cs from the soil to the plant. For example, the wheat is more sensitive compared to the barley, and the root has greater tendency to accumulate radiocesium than the grain (Coughtrey P.J. & Thorne M.C., 1983). In the plant the radiocesium follows the same route as potassium. Co ^{137}Cs is transferred to the most active parts of the plant and 50% can be expected to be transferred to the growing parts as well (Forsberg S., 2000).
Weather conditions also affect the intake of radiocesium in the plant. During long and dry years, the root system enters in bigger depths in order to reach the moisture, which would imply intake of less ^{137}Cs. The opposite would happen in conditions of higher humidity level, since the root system would be shallower and in this manner the roots will be present in the upper layer where most of this pollutant is found (Mascanzoni D., 1988).
(H. Tsukada and H. Hasegawa 2002) have been working on determining the transfer factor of different radionuclides in the agricultural farms in Japan.
(Pulhani VA, Dafauti S 2005) measured the transfer factor of the grain in India and discovered that large part of ^{137}Cs is retained in the plant's root.
In Vojvodina (I. Bikit, N. Todorović 2011) were working on determination of the transfer factor of grain cultures and comparisons of transfer of ^{137}Cs in the grain and root.

MATERIALS AND METHODS

During the period from January to May 2012, in the surrounding of Skopje, 84 samples of soil were collected from surface soil (0-5 cm, 5-10 cm, 10-15 cm). All samples were separately analyzed and the concentration of the activity of ^{137}Cs was determined. Simultaneously, barley and corn were analyzed from the same locations, as the most commonly used vegetative crops in R. Macedonia. Every plant was taken by careful digging of the soil in order to collect the entire plant (root, grain) and the soil that is around the roots. The plants were collected as ripe crops, from open fields. They were air-dried for two days in a laboratory and then in an oven at a temperature of 90°C. Their dry weight was measured and they were burned at a temperature of 500°C in an oven for at least 24 hours in order to get white ash. This was made since Cs in a certain quantity of ash is 8-9 times more than Cs in the same quantity of dry plant.
The radiometric analysis of these samples was conducted by applying spectrometer for γ-rays with germanium with high purity (HPGe), detector with 30% relative efficiency and energy resolution (FWHM) of 1.8 keV for 1.33 MeV reference point of ^{60}Co. The software that has been used for obtaining data is Canberra software package Genie-2000, including search of maximal value and modules for identification of nuclides. The system was regularly calibrated in terms of energy and efficiency.
The testing was in accordance with the method from the IAEA Technical Report 295. The time of measurement of each sample is 10800 s, and the relative error of the measurement i.e. the measurement uncertainty is less than 10%.
Upon termination of the measurement the software of the instrument gives a written report with already calculated values of the activity of radionuclides that are checked in the program EXCEL.

RESULTS AND DISCUSSION

In order to be able to make quantitative measurement of the transfer of radionuclides from one link to the chain of another, the transfer factor TF is being used.

$$TF = \text{activity of } ^{137}Cs \text{ in dry plant} / \text{activity of } ^{137}Cs \text{ in dry soil}$$

IAEA made an extensive database of transfer factor values.

In our research for taking the mean values for the activities of ^{137}Cs for the given locations, and use of the international values for transfer factors from soil to plant, we calculated the transfer factor for ^{137}Cs for barley and corn, see Tab. 1. and Fig.1.

Table 1: Transfer factor of ^{137}Cs from soil to vegetative crops (barly, corn)

Location	^{137}Cs activity of soil [Bq/kg]	Part of plant	Concentration of activity of ^{137}Cs in vegetative crops [Bq/kg]			
			Barley		Corn	
			Grain	Stem	Grain	Stem
Petrovec	15.20		0.44	2.28	0.50	1.10
Belimbegovo	11.98		0.34	1.80	0.39	0.87
Aracinovo	18.41		0.53	2.76	0.60	1.34
Radisani	18.75		0.54	2.81	0.61	1.36
Cucer	11.20		0.32	1.68	0.36	0.81
Vizbegovo	11.43		0.33	1.71	0.37	0.83
Bardovci	15.42		0.45	2.31	0.50	1.12
Saraj	13.49		0.39	2.02	0.44	0.98
Nerezi	10.75		0.31	1.61	0.35	0.78
Lisice	7.42		0.21	1.11	0.24	0.54
Dracevo	7.64		0.22	1.15	0.25	0.55
Pintija	11.31		0.32	1.69	0.37	0.82
Batinci	11.36		0.32	1.70	0.37	0.82
Volkovo	10.31		0.29	1.55	0.34	0.75
Transfer factor Fv			2.9×10^{-2}	1.5×10^{-1}	3.3×10^{-2}	7.3×10^{-2}

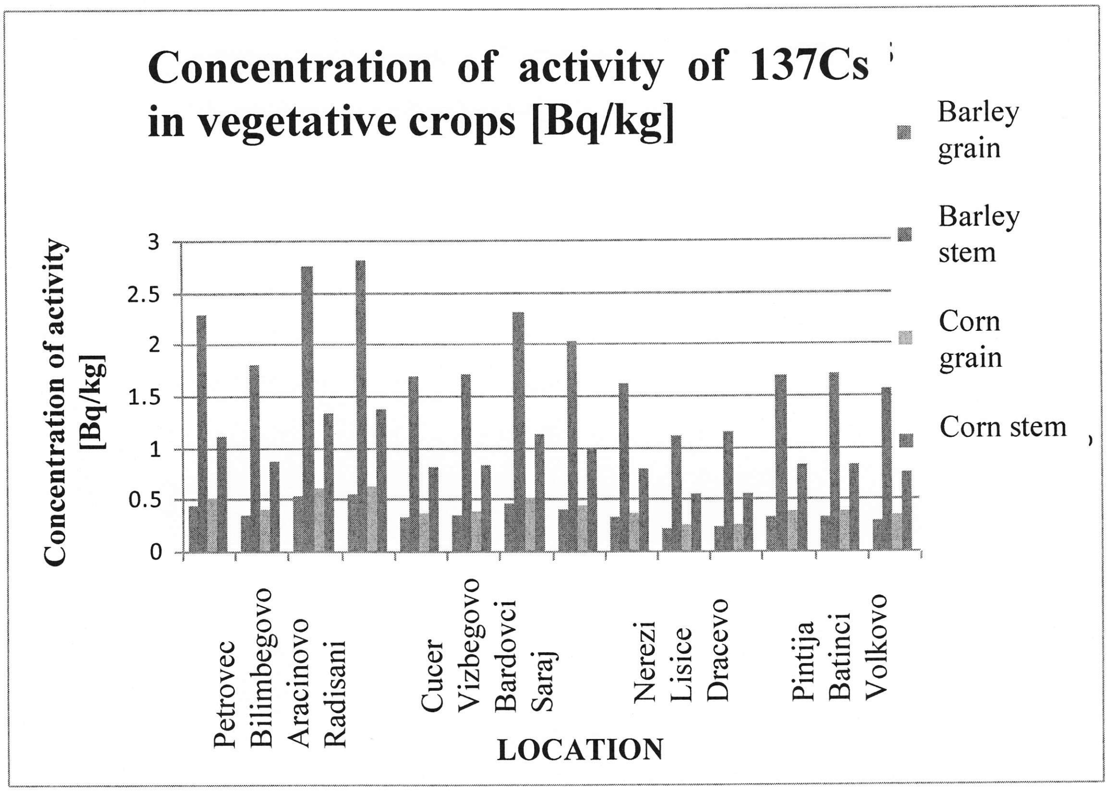

Figure 1: Concentration of activity of ^{137}Cs in vegetative crops [Bq/kg]

The pollution of the soil with radiocesium has long-term radiological influence since it is easily transferred through the food chain to people. Comparing the level of ^{137}Cs into the Soil today 7-15 Bq/kg with these observed by Anovski et al. (1992) after the Chernobyle accident (up to 80 Bq/kg), it is evident for its decreasing, more or less according the the law for radioactive decay.The intake from plants is the main route of its migration to the human nutrition.

The assessed values of the transfer factors for the vegetative crops represent maximal values that can be found in the dry parts of the plants cultivated at agricultural land. One can notice that the accumulation of ^{137}Cs is importantly higher in the root than in the grain in both crops, which indicates the monitoring of the activity of the agricultural land. From the chart one can also notice a difference in the transfer at both crops. At the barley there is greater transfer because it is a matter of a culture with shallower roots, and this implies easier and more accessible accumulation of ^{137}Cs from the soil itself (Mascanzoni D., 1988). At the same time it is necessary to monitor the radioactivity in agricultural land appropriate for accumulation of radionuclides, after strong winds, torrential rains etc. In order to reduce ^{137}Cs in vegetative crops, the scientists recommend its treatment with a fertilizer that contains potassium which can reduce its intake in the plant, thus reducing the intake dose for about 5% from the levels before the treatment. During the preparation and the processing of the agricultural food products, the washing itself reduces the quantity of radioactive substances.

CONCLUSION

To avoid any wider contamination of the Environment and possible consequences on the area of interest, it is necessary to perform extensive radio-ecological investigations, all in order to minimize possible undesirable adverse effects on the populations.

Although at the current level of radioactive contamination there is no need for special decontamination procedures, however, the familiarity with the methods related to the reduction of the radiological activity in the technological processes of food industry, may be useful in the processing of the vegetable raw materials with eventually higher level of radiological contamination.

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