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ESTIMATION OF EFFECTIVE DOSE IN INGESTION OF FOOD CROPS FOR ^{137}Cs

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INTRODUCTION

Radionuclides reach the surface of the soil in a form of solid particles or with the rains, in dissolved or undissolved state. The ones that come in a form of solid particles are mechanically retained on the surface, while the ones that are dissolved with the process of filtration, penetrate the soil and most of them connect to its surface layer. ^{137}Cs reaches the soil in a form that is soluble in water. Hence, after contamination, it has been determined that it is present on the surface layer with 85 %, from 5-10 cm: 12 %, and from 10-15 cm: 3 %. The accumulation of caesium on the ground depends on numerous factors (type of soil), and numerous researches have proved that it is mostly retained in the layer at 10 cm from the surface of the ground, because its penetration rate through the ground is 1-3 cm/g. Still, the speed will depend on the type of ground and the quantity of precipitation [1]. The transfer of ^{137}Cs in the ground is also affected by the form in which it is found. If it is present as part of the anion, the soil will poorly absorb it because it will migrate in plants intensively. This migration ability is also affected by potassium, as well as the stable caesium (their excess slows the migration). According to some data, it has been concluded that ^{137}Cs is mostly fixed on the ground permanently, whereby during the first year of its arrival, it is retained on the surface of the soil, and the speed of its migration according to depth is several cm per year, which is also conditioned by the type and the properties of the soil [2]. The radioactivity in the Earth's crust is transferred in small quantities in the plants that grow in different soils. The intake of ^{137}Cs in plants depends on different factors such as: soil type, texture, pH, conductivity, carbonate and sulphate contents etc. However, the radioactive contamination of the plant organisms is formed with continuous dynamical common action of the atmosphere, the pedosphere and the hydrosphere.

If radioactive surface occurs during the season of growth, the plants will be polluted directly on the leaves. Part of the pollutant will be absorbed through the leaves. The type of dust, i.e. wet or dry sediment, and the form, the structure, the leave surface and the development stage, all determine the contamination rate [3].

It is considered that these factors will lose their relevance as time goes by and the main contamination path will be by intake through the root of the soil [4]. Something that is quite important is that the specificity of ^{137}Cs is such that is acts in the human organism same as potassium, meaning that it is in every cell of the organism, i.e. it is equally distributed in all organs. This element is also the cause for great radiologic risks [5].

The measurement of radioactivity in soil provides information about the natural resources; thereby it is important for the measurement of the radiation dose for the general population and monitoring of radiation. The familiarity with the concentration of the radioactivity of our environment is essential in the assessment of the dose which is accumulated in the population and also for the formation of the basis for assessment of the level of radioactive pollution or environmental pollution in the future.

Taking into consideration the relevance of the distribution and the transfer of radionuclides from the soil to the crops, the objective of this paper was to assess the effective dose in ingestion of separate crops for ^{137}Cs. The effective dose was determined by means of already familiar transfer factors from the soil to the plants and measured concentrations of soil activities from specific locations in the surrounding of the city of Skopje. Agricultural crops that are most commonly used for analysis include vegetables, legumes and root crops in the R. Macedonia.

MATERIAL AND METHOD

In order to assess the effective dose in ingestion of specific crops for ^{137}Cs, primarily data were used from already calculated specific activity of ^{137}Cs for soil samples, taken from different locations in the surrounding of the city of Skopje. Each sample is taken by means of a special dosing container, including 3 - 4 samples according to the recommendations of IAEA [6]. The spectral analysis of the radionuclides of these samples was conducted by applying a spectrometer for γ-rays for high-purity germanium (HPGe) detector with 30 % relative efficiency and energy resolution (FWHM) of 1.8 keV for 1.33 MeV reference transition of ^{60}Co [7]. The effective dose was determined by means of already known transfer factors from the soil to the plants (F_v) and measured activity concentrations of soil

from specific locations in the surrounding of the city of Skopje (A_{ps}). Agricultural crops that are most commonly used for analysis include vegetables, legumes and root crops in the R. Macedonia.

The assessment of effective dose D_{ef} in the human body (Table 1) during ingestion of food products that contain a specific concentration of radionuclides is calculated according to the following equation: [8-10].

$$D_{ef} = \Sigma (A_{ps} \times F_v \times I_{af}) \times e \times 1000 \quad [\text{mSv/y}] \qquad (1)$$

where I_{af} is annual ingestion per person and e is the dose coefficient.

RESULTS AND DISCUSSION

The level of radioactive contamination with ^{137}Cs depends on the intensity and the radioactivity, the meteorological, the hydrological, the agrochemical and other factors. In addition, among the separate crops, there are important differences in the sensitivity to ^{137}Cs. The total dose of ^{137}Cs in this research is 0.0051 mSv/year. The assessed effective dose would imply for adults who intake the mentioned quantities that are produced in the mentioned locations, that is, in the region of Skopje.

Table 1. Assessed effective dose by ingestion of separate crops for ^{137}Cs

^{137}Cs						e (1.3E-8) for adults
Location	**Specific activities in soil** (Bq/kg))	**Specific activity in crops** (Bq/kg)				**Assessed effective dose** D_{ef} (mSv/year)
		Grains wheat wheat products etc.	**Vegetables** tomato cabbage peppers spinach, lettuce etc	**Legumes** beans peas lentils etc	**Root crops** potato onion carrot etc	
		$F_v = 2.9\times10^{-2}$	$F_v = 6.0\times10^{-1}$	$F_v = 4.0\times10^{-2}$	$F_v = 3.5\times10^{-2}$	
Petrovec	15.21	0.44	9.13	0.61	0.53	0.0060
Belinbegovo	11.98	0.35	7.19	0.48	0.42	0.0048
Aracinovo	18.42	0.53	11.05	0.74	0.64	0.0073
Radisani	18.75	0.54	11.25	0.75	0.66	0.0074
Cucer	18.13	0.53	10.88	0.73	0.63	0.0072
Vizbegovo	11.2	0.32	6.72	0.45	0.39	0.0044
Bardovci	11.43	0.33	6.86	0.46	0.40	0.0045
Saraj	15.39	0.45	9.23	0.62	0.54	0.0061
Nerezi	12.72	0.37	7.63	0.51	0.45	0.0051
Lisice	10.21	0.30	6.13	0.41	0.36	0.0041
Dracevo	7.58	0.22	4.55	0.30	0.27	0.0030
Pintija	8.15	0.24	4.89	0.33	0.29	0.0032
Batinci	10.67	0.31	6.40	0.43	0.37	0.0042
Volkovo	11.06	0.32	6.64	0.44	0.39	0.0044
Mean value	**12.92**	**0.37**	**7.75**	**0.52**	**0.45**	**0.0051**

Highest level of ^{137}Cs was found in the vegetables with mean value of 7.75 Bq/kg while the level is lowest in grains 0.37 Bq/kg. This occurrence is

explained by the fact that most of this radionuclide is retained on the surface part of the soil at a depth of 5 cm, whereby the vegetables have shallower root unlike the root crops and the grains [11]. If comparison is made regarding the accumulation of ^{137}Cs, in terms of its highest accumulation, the data is in accordance with the literature data [12].

Relevant data during the analysis of the transfer factor of ^{137}Cs include also the weather conditions during the year when research has been conducted. Since it was a matter of a dry year without a lot of precipitation, the root system penetrates in greater depths in order to reach moisture, which would imply lower intake of ^{137}Cs. The opposite would have happened under humid conditions because the root system will be shallower and in this manner, most part of the roots will be present in the upper layer where most of the pollutant is located. The intake of ^{137}Cs usually decreases as time goes by. The reduction is particularly noticed in soil with high clay content which is due to the fixation of caesium by clay minerals, still, the numerous organic matters increase caesium intake in the root, however they may also have an opposite effect; the excess of potassium dissolves the caesium ions, which decreases the intake, but that may also cause accumulation of fixed caesium which increases the intake. Hence, the very low quantity of caesium in the current research may be due to the high concentration of ^{40}K. Since ^{137}Cs is a synthetic element, its presence in plants may be dangerous. ^{137}Cs firmly attaches to clay mineral soil which is available for the plant. The cesium absorption rate is inversely proportional to potassium in the soil.

Table 2 shows the average annual intake for adults of separate crops, as well as the aggregate quantities represented by groups which are required for dose assessment.

Table 2. Average annual intake of separate crops for adults

Crops	Wheat (bread) kg	Wheat kg	Tomato kg	Pepper kg	Cabbage kg	Lettuce kg	Spinach kg	Beans kg	Peas kg	Lentils kg	Potato kg	Onion kg	Carrot kg
Average intake for adults	70.1	5.6	13.4	17.0	10.6	1.4	2.1	5.8	1.1	1.4	27.4	7.2	2.9
Groups	**Grains**		**Vegetable**					**Legumes**			**Root crops**		
Aggregate amounts per groups	75.7		44.5					8.3			37.5		

CONCLUSION

The different lifestyle and the different nutrition habits contribute for the differences in the assessment of the effective dose. From the very research and the presented tables, one may perceive that the level of radioactive contamination in different crops is not equal considering the fact that the crops have different TF. From radiological and health point of view, of all analysed crops, the most intensive accumulation of crops is present in vegetables, for all analysed radionuclides. However, the obtained total assessed effective dose is lower than the recommended dose of 1 mSv/year. It is worth mentioning that until recently it was considered that the flora and the fauna are protected if the human is protected.

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