ASSESSMENT OF THE ANNUAL EFFECTIVE DOSE FROM SOME CEREAL CROPS COMMONLY USED IN LOCAL MARKETS OF TIRANA CITY

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Abstract

About fifteen samples of cereal crops commonly used in Albania were collected from the local markets of Tirana city for this study. Radionuclides are found everywhere in the environment, therefore some radionuclides are transferred to the cereal crops and further enter our bodies by different pathways. This study aimed to assess the total annual effective dose from these cereal crops. The HPGe detector was used for the measurements and the activity concentration for radionuclides of ^{226}Ra, ^{232}Th, ^{40}K and ^{137}Cs was calculated before assessing the total annual effective dose. Radionuclide of ^{40}K has the highest value of the activity concentration for all samples and then they follow from ^{226}Ra, ^{232}Th and ^{137}Cs. The activity concentration of the artificial radionuclide of ^{137}Cs was detected only in four samples at a low level. The total annual effective dose, based on intake of ^{40}K, ^{226}Ra, ^{232}Th and ^{137}Cs in cereal crops, was found to be 350.68 μSv/year. The main contributors to the total dose come by radionuclides ^{40}K and ^{226}Ra, while two other radionuclides ^{232}Th and ^{137}Cs have a minor contribution. The total annual effective dose in this study falls within the global range defined by UNSCEAR reports and was lower than the recommended limit value of 1 mSv y^{-1} by WHO and ICRP for adults. Therefore, results indicated that consumption of cereal *crops by the people of the study region is safe, with acceptable radiological risk and no harmful health effects are expected for living things.*

***Key words**: Radionuclide, Activity Concentration, Cereal Crop, Annual Effective Dose.*

Përmbledhje

Rreth pesëmbëdhjetë kampione të kulturave të drithërave bujqësore të përdorura zakonisht në Shqipëri ishin zgjedhur nga marketet lokale të qytetit të Tiranës për këtë studim. Radiobërthamat gjenden kudo në mjedis, prandaj disa radiobërthama transferohen në kulturat e drithërave dhe më tej hyjnë në trupin tonë në rrugë të ndryshme. Ky studim synonte të vlerësonte dozën totale efektive vjetore nga këto kultura drithërash. Për matjet ishte përdorur detektori HPGe dhe ishte llogaritur përqendrimi i aktivitetit për radiobërthamat e ^{226}Ra, ^{232}Th, ^{40}K dhe ^{137}Cs përpara se të vlerësohej doza totale efektive vjetore. Radiobërthama e ^{40}K ka vlerën më të lartë të përqendrimit të aktivitetit për të gjitha kampionet dhe më pas ato pasojnë nga ^{226}Ra, ^{232}Th dhe ^{137}Cs. Përqendrimi i aktivitetit të radiobërthamës artificiale të ^{137}Cs u gjet vetëm në katër mostra në një nivel të ulët. Doza totale efektive vjetore, bazuar në marrjen e ^{40}K, ^{226}Ra, ^{232}Th dhe ^{137}Cs në kulturat e drithërave bujqësore, ishte gjetur të jetë 350.68 µSv/vit. Kontribuesit kryesorë në dozën totale vijnë nga radiobërthamat e ^{40}K dhe ^{226}Ra, ndërsa dy radiobërthamat të tjera ^{232}Th dhe ^{137}Cs kanë një kontribut të vogël. Doza totale efektive vjetore në këtë studim bie brenda intervalit global të përcaktuar nga raportet e UNSCEAR dhe ishte më e ulët se vlera kufi e rekomanduar prej 1 mSv/vit nga OBSH dhe ICRP për të rriturit. Prandaj, rezultatet treguan se konsumi i këtyre drithërave nga banorët e rajonit të studimit është i sigurt, me rrezik të pranueshëm radiologjik dhe nuk priten efekte të dëmshme shëndetësore nga konsumimi i tyre.

***Fjalë kyçe:** Radiobërthamë, Përqëndrimi i Aktivitetit, Kulturat e Drithërave, Doza Efektive Vjetore.*

1-Introduction

The exposure of human beings to ionizing radiation from natural sources is a continuing feature of life on the earth and for most individuals, exceeds that from all man-made sources combined. This exposure comes by cosmic ray particles from the atmosphere and radionuclides that originate in the earth's crust (UNSCEAR, 2008). Thus, radionuclides are present everywhere in the environment, including the human body itself. All peoples in the world are also exposed to radiation resulting from releases to the environment of radionuclides from man-made sources. The annual average dose that is exposed from natural radiation sources has been reported by the United Nations Scientific Committee on the Effect of Atomic Radiation and is about 2.4 mSv y^{-1} per person (UNSCEAR, 2008).

The radionuclides of natural series such as ^{238}U, ^{232}Th, and non-series ^{40}K which are ordinarily long-lived and with a half-life hundred million years have the main contribution of natural radiation, and are everywhere, in environment, atmosphere, water and foodstuffs (UNSCEAR, 2000). However, a contribution to consider in several areas comes from artificial radionuclides released into the environment by man-made sources, such nuclear power plants, tests and accidents, also industrial and medicinal waste. Many artificial radionuclides were released into the environment from the factors mentioned above, with high levels of activity, where more important by the artificial radionuclides it's ^{137}Cs with long half-life of about 30 years (IAEA, 2006).

An amount of radioactivity can enter into the human body by the ingestion and inhalation pathway and can cause a long exposure inside the human body. Plants take the most of radionuclides through the roots and leaves, whereas humans and animals acquire radionuclides through the consumption of these plants **(**Zakariya et al., 2021). Soils and plants are the primary pathway of natural radionuclides entering into different types of cereal crops and after ingestion, can enter directly or indirectly into the human body through the food chain (Tettey-Larbi et al., 2013). Radionuclides of ^{40}K, ^{226}Ra, ^{232}Th and ^{137}Cs have transfer factors from soil to plants the values 0.17, 0.07, 0.16 and 0.23, respectively. The radionuclides of ^{137}Cs and ^{40}K have a high transfer factor, but the abundance of ^{40}K it is much higher into in the environment **(**Cengiz et al., 2021). Many studies of natural and artificial radioactivity have been investigated in different types of plants in different countries of the world, while in Albania there is very little information on the radioactivity and dose levels (Spahiu et al., 2019).

Therefore, in this study determining the radioactivity levels and assessment of the total annual effective dose of cereal crops consumed by human beings is of great importance for human health in Albania. Our results were compared with several international reference values such as the International Commission on Radiological Protection (ICRP), United Nations Scientific Committee on the Effect of Atomic Radiation (UNSCEAR) and World Health Organization (WHO) which have reported guidelines for radioactivity levels and annual effective dose limit in foodstuff.

2-Materials and methods

2.1 Sampling and sample preparation

In total, fifteen samples of cereal crops consumed in Albania were collected from some local markets of Tirana city. Some of them are produced in Albania, while others are imported by other countries. These samples were opened in the air for drying on trays for a week and then in the oven were dried at a temperature of about 80^0C for 14 hours until a constant mass was obtained and as much as possible moisture was removed (IAEA, 1989). Some cereal crops are in the form of grains, while others are the form of flour and the mass is accurately weighed. Each sample was put in a 250 ml Marinelli beaker, then stored in tight plastic containers for about 30 days to allow radioactive equilibrium to be reached between parents and their daughter, concretely to parents ^{226}Ra and ^{232}Th and their daughters, before the measurements to have been performed. An empty Marinelli beaker similar to others was also counted under the same conditions to determine the background.

2.2 Measurements and sample analysis

The measurements were performed by using the High Purity Germanium (HPGe) detector and the activity concentration was determined by gamma-ray spectrometry method (Genie 2000 software). The HPGe detector is connected with Multichannel Analyzer (MCA) of 8192 channels and equipped with a carbon epoxy window to protect the upper part of the detector during the measurements. Also, the detector has an energy resolution (FWHM) of 1.8 keV for 1.33 MeV γ-energy of ^{60}Co and 40% relative efficiency on the peak. To avoid radiation from outside and other fluctuations, the detector was shielded by three layers of lead, copper and cadmium. The counting time interval was 86400 s for each sample, to have a better statistical of counts. The energy calibration was performed in the range from 50 keV to 2000 keV by a mathematical model Software of LabSOCS. The range of absolute efficiency uncertainties was calculated on each peak, however, these varies from 10% at low energies to 4% at high energies (Shyti, 2019). Calculations of the activity concentration (A in Bq kg^{-1}) were taken by the following formula (1):

$$A(Bq\ kg^{-1}) = \frac{N}{\varepsilon(E_\gamma) \cdot P_\gamma \cdot t \cdot m} \qquad (1)$$

where N is the net peak area of peak after background subtracted, $\varepsilon(E_\gamma)$ is the absolute efficiency in the corresponding peak at energy $E\gamma$, P_γ is the gamma-ray yield, t is the counting live time and m is sample mass in kilogram (Dovlete et al., 2004). By the formula (1), the activity concentration of radionuclides ^{226}Ra, ^{232}Th, ^{40}K and ^{137}Cs were determined for every sample, respectively. From secular equilibrium, the activity concentration of ^{226}Ra was calculated indirectly, by averages of activities of decay daughters ^{214}Pb and ^{214}Bi, in energy peaks 295.2 and 351.9 keV for ^{214}Pb, while for ^{214}Bi energy peaks are taken 609.3 keV and 1120.29 keV. The activity concentration of ^{232}Th was calculated by the activity of ^{228}Ac in energy peaks 338.4 and 911.2 keV. The activity concentration of ^{40}K was calculated in the key line 1460.8 keV and for artificial radionuclide ^{137}Cs in the key line energy 661.7 keV. All gamma emission yields and gamma lines energy were taken from the Nuclide-LARA library (Bé et al., 2008).

Minimum detectable activity (MDA) was performed by using the Currie method (Currie, 2004).

1. Results and discussion

3.1 Activity concentration in the cereal crop samples

The values of activity concentration of radionuclides ^{226}Ra, ^{232}Th, ^{40}K and artificial ^{137}Cs radionuclides for cereal crops and uncertainty ($\pm 1\sigma$) are presented in Table 1 (Spahiu et al., 2023). Minimum Detectable Activity (MDA),) for radionuclides of ^{226}Ra, ^{232}Th, ^{40}K and ^{137}Cs were found to be

4.66, 0.03, 0.11 and 0.01 Bq kg^{-1}, respectively. The average values of activity concentration for ^{226}Ra, ^{232}Th and ^{40}K were found to be 5.35, 1.2 and 178.17 Bq kg^{-1}. The activity for ^{137}Cs was below MDA for most of them, where 0.65 Bq kg^{-1} highest value was found for Kidney white beans. The ranges of activity were found: 0.91 to 10.34 Bq kg^{-1} for ^{226}Ra, from <MDA to 2.2 Bq kg^{-1} for ^{232}Th and 28.35 to 446.36 Bq kg^{-1} for ^{40}K.
The radionuclide of ^{40}K is the main contributor to the activity concentration for all samples. The highest value was found to Bean sprouts and the lowest was for the rice sample. Radionuclide of ^{137}Cs was detected in four samples as shown in Table 1.

Table 1. Activity concentration of ^{226}Ra, ^{232}Th, ^{40}K and ^{137}Cs for 15 cereal crops consumed in Albania

	Activity concentration ±1σ (Bq kg^{-1})				
No.	Sample ID	^{226}Ra	^{232}Th	^{40}K	^{137}Cs
1	Green pea	4.99 ± 0.23	1.48 ± 0.16	359.03 ± 15.49	<MDA
2	Barley grain	0.91 ± 0.11	1.43 ± 0.15	115.29 ± 5.51	<MDA
3	Beige beans	4.24 ± 0.18	2.09 ± 0.22	303.08 ± 12.96	<MDA
4	Kidney white beans	2.54 ± 0.21	<MDA	363.16 ± 15.66	0.65 ± 0.22
5	Bulgur wheat	7.03 ± 0.56	<MDA	81.22 ± 4.01	<MDA
6	Wheat grain	0.93 ± 0.18	1.62 ± 0.18	117.30 ± 2.46	0.35 ± 0.04
7	Wheat flour	7.89 ± 0.50	1.21 ± 0.14	31.36 ± 5.41	<MDA
8	Bean sprouts	8.66 ± 0.64	1.32 ± 0.16	446.36 ± 19.04	<MDA
9	Corn grain	6.92 ± 0.57	1.36 ± 0.16	70.33 ± 3.54	<MDA
10	Corn flour	9.36 ± 0.78	2.20 ± 0.24	35.88 ± 2.60	<MDA
11	Rice	2.56 ± 0.16	<MDA	28.35 ± 2.08	0.58 ± 0.21
12	Oat grain	10.34 ± 1.17	2.10 ± 0.18	105.23 ± 5.59	<MDA
13	Rye grain	2.11 ± 0.15	1.42 ± 0.16	112.63 ± 5.28	0.46 ± 0.06
14	Lentil Greece	6.84 ± 0.56	1.19 ± 0.13	255.60 ± 10.63	<MDA
15	Lentil Canada	4.92 ± 0.44	0.52 ± 0.08	247.70 ± 10.72	<MDA

The highest values of ^{40}K were expected because it is naturally high in abundance in environment and from soil fertilization used by farmers, also, its high mobility in soil. The average values of this study for activity concentrations are lower than the worldwide average values of 35 Bq kg^{-1}, 30 Bq kg^{-1} and 400 Bq kg^{-1} for ^{226}Ra, ^{232}Th and ^{40}K, defined by the UNSCEAR (2000) report.

3.2 Estimation of annual effective dose for cereal crops

The ingestion dose due consumption of cereal crops varies depending on the amount of them and the activity concentration of the radionuclides. Thus, the annual effective dose (AED) for each sample by intake of radionuclides was estimated using the following formula (2), defined from the UNSCEAR (2008) report,

$$(AED)_s = \sum_i I_s \times A_{is} \times C_i \qquad (2)$$

where (AED)s is expressed in μSv y^{-1} and s refers to the corresponding sample, Ais is the activity concentration to radionuclide i in Bq kg^{-1}. Is is the annual consumption rate of cereal crops in kg/year and Ci is the dose conversion factor for each radionuclide in μSv Bq^{-1}.

The annual consumption rate was taken at 25 kg/year for samples of Wheat, 10 kg/year for Rice and 5 kg/year for all the others as part of the human diet (UNSCEAR, 2008). The dose conversion factors for radionuclides ^{40}K, ^{226}Ra, ^{232}Th and ^{137}Cs are taken, 0.0062 μSv Bq^{-1}, 0.28 μSv Bq^{-1}, 0.23 μSv Bq^{-1} and 0.013 μSv Bq^{-1} (ICRP, 2012). The values of the annual effective dose are presented in Table 2 for each type and the end at the total annual dose was found.

Table 2. The values of annual effective dose and the total dose

No.	Sample ID	AED (μSv y^{-1})
1	Green pea	19.82±0.61
2	Barley grain	6.49±0.29
3	Beige beans	17.73±0.54
4	Kidney white beans	14.85±0.57
5	Bulgur wheat	61.76±3.98
6	Wheat grain	34.09±1.83
7	Wheat flour	67.01±3.62
8	Bean sprouts	27.47±1.08
9	Corn grain	13.43±0.82
10	Corn flour	16.74±1.13

11	Rice	9.00±0.47
12	Oat grain	20.15±1.66
13	Rye grain	8.11±0.32
14	Lentil Greece	18.86±0.87
15	Lentil Canada	15.16±0.71
	Total AED	350.68±6.39

The main contribution of dose for each sample comes from radionuclides of ^{40}K and ^{226}Ra, while ^{232}Th and artificial radionuclides of ^{137}Cs have a minor contribution. The highest value of dose was for the Wheat flour sample with 67.01 μSv y^{-1} and the lowest for the Barley grain sample with 6.49 μSv y^{-1}. The total annual effective dose was found to be 350.68 μSv y^{-1}.

The international reference values for the total annual dose from basic foodstuffs are in the range 200-1000 μSv y^{-1} by the report UNSCEAR (2008), 200–500 μSv y^{-1} by WHO (2021) and the allowable limits of 1000 μSv y^{-1} by the report ICRP (2007) for all age groups. The radiation dose from the consumption of cereal crops fall within the range of international reference values, therefore, these are safe for consumption in our country and do not pose a radiological risk to public health.

Conclusions

In this study, the annual effective dose in 15 cereal crops commonly used in Albania was determined. The average values of activity concentration for ^{226}Ra, ^{232}Th and ^{40}K were found to be 5.35, 1.2 and 178.17 Bq kg^{-1}. ^{137}Cs was detected only in four samples with the highest value of activity 0.65 Bq kg^{-1}. Our results of the activity concentration are lower than the worldwide average values of 35 Bq kg^{-1}, 30 Bq kg^{-1} and 400 Bq kg^{-1} for ^{226}Ra, ^{232}Th and ^{40}K.

The values of the annual effective dose were estimated for each type and at end the total annual dose was found. The total annual effective dose was found to be 350.68 μSv y^{-1}. The main contribution of dose for each sample comes from radionuclides of ^{40}K and ^{226}Ra.

The total annual effective dose in this study falls within the global range defined by the UNSCEAR 2008 report and was lower than the recommended limit value of 1 mSv y^{-1} by reports of WHO 2021 and ICRP 2007. Therefore, results indicated that consumption of cereal crops in Albania is safe, with acceptable radiological risk and no harmful health effects are expected for living things.

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