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ИЗСЛЕДВАНЕ НА НЯКОИ ЕСТЕСТВЕНИ РАДИОНУКЛИДИ В РАПИЦА (*BRASSICA NAPUS*)

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RESEARCH ON SOME NATURAL RADIONUCLIDES IN RAPESEED (*BRASSICA NAPUS*)

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Abstract
This study presents the gamma spectrometric analysis of winter oilseed rape (Brassica napus) plants and associated soil samples collected from the area "The Orchard" in the Divdyadovo district, Shumen municipality, Bulgaria, located near the Golyama Kamchiya River. A total of 10 samples were collected and analyzed during two distinct vegetation periods – spring and summer – including different plant organs (roots, stems, leaves, pods, seeds) and soil. The investigation focused on the distribution and activity levels of naturally occurring radionuclides belonging to the uranium-radium and uranium-actinium decay series. The aim was to assess potential radiological risks and understand radionuclide uptake by plants from the soil.
Keywords: natural, radionuclides gamma, spectrometry, *Brassica napus*, environmental radioactivity, crop contamination.

INTRODUCTION

Rapeseed (*Brassica napus*) is a globally important oilseed crop with a long history and wide-ranging applications in agriculture, food production, and industry. Cultivated since at least 4000 BCE, its origins can be traced to the Mediterranean and West African regions. Belonging to the Brassicaceae family [1], rapeseed was among the earliest domesticated crops, although it was initially mistaken for related cruciferous species. In Europe, it was extensively grown from the Middle Ages through the 19th century, primarily for its oil, which was used in cooking, lighting, and lubrication [2]. The rise of petroleum-based alternatives caused a decline in rapeseed cultivation, but interest resurged in the late 20th century due to advancements in oil processing and increasing demand for renewable energy sources like biofuels.

Today, rapeseed is cultivated on more than 26 million hectares globally, with major producers including the European Union, Canada, China, and India [3]. In Bulgaria, winter rapeseed is mainly grown in the northeastern regions and ranks as the second most important oil crop after sunflower [4].

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Modern cultivation of rapeseed focuses on its dual-purpose output: oil and protein-rich meal. Rapeseed oil is highly valued in the food industry for its favorable fatty acid profile and antioxidant content, making it a healthy cooking oil [5]. The meal, a by-product of oil extraction, serves as a high-protein feed for livestock.

EXPOSITION

In the modern world, the peaceful use of nuclear energy carries the risk of accidents leading to radioactive contamination of the environment [6]. The uptake and accumulation of radionuclides in plants occur mainly through foliar absorption and root uptake from soil [7]. Radionuclides deposited on leaves may subsequently reach the soil through erosion or leaching. Plant species differ in their capacity to absorb and retain radionuclides, as well as in their radiosensitivity, which correlates with factors such as chromosomal volume and polyploidy level. For example, polyploid crops like rapeseed tend to exhibit higher radiation resistance compared to more sensitive species. Plants serve as environmental monitors for radionuclides, detecting both short-lived isotopes and indicating long-term radionuclide deposition trends. Since plants form the base of the food chain, radionuclide accumulation in crops poses potential risks to animal and human health even if the plants themselves show no damage [8].

Sampling Location

Sample collection of winter oilseed rape (Brassica napus) was conducted on the land of the agricultural cooperative “PK Divdyadovo,” located in the area known as “The Orchard” (“Ovoshtnata gradina”), within the municipality of Shumen, near the Divdyadovo district and close to the Golyama Kamchiya River. The site is at an altitude of 100 meters above sea level, with GPS coordinates: N 43° 20' 63.2", E 26° 89' 29.9".

Samples

Detailed information regarding the collected samples, including their type, collection sites, and sampling times, is presented in Tables 1 and 2.

Table 1 Collected materials

First sampling (March):	**Second sampling (July):**
1. Young rapeseed plants sown in autumn of the previous year 2. Soil from the rapeseed field 3. Soil from the border area adjacent to the field	1. Soil from the field 2. Whole mature rapeseed plants, including: • Roots • Leaves • Stems • Pods • Seeds

Seeds for sowing and harvested seeds from the field (total area: 240 decares) were also collected.

Table 2 Information regarding the collected samples, including their type, collection sites, and sampling times

Sample Code	**Sample Type**	**Sampling Notes**
Soil 1	Soil	From plot with young rapeseed, March
Soil 2	Soil	After rapeseed harvest, July
Leaves 1	Leaves	From young rapeseed plant, March
Leaves 2	Leaves	From mature rapeseed plant, July
Stem 2	Stem	From mature rapeseed plant, July
Seeds 0	Seeds	Rapeseed sowing material, September
Seeds 2	Seeds	From mature rapeseed plant, July
Roots 1	Roots	From young rapeseed plant, March
Roots 2	Roots	From mature rapeseed plant, July
Pods 2	Pods	From mature rapeseed plant, July

Sample Preparation

Samples were cleaned of impurities. Plant samples were separated into leaves, stems, roots, and fruits (pods and seeds). Samples were dried in a laboratory dryer at 30–40°C, finely ground using an electric mill, and stored in appropriate containers for gamma spectrometric analysis.

Gamma spectrometric method for determination of radionuclides in plant and soil samples

Gamma spectrometric analysis was performed at the Laboratory of Nuclear Physics and Radioecology, Konstantin Preslavsky University of Shumen. The system includes:

- Ge(Li) semiconductor detector (60 cm³, 1 kV, 4.5% relative efficiency for 137Cs, E=661.66 keV)
- Preamplifier
- Analog-to-digital converter with multichannel analyzer
- High-voltage power supply
- Linear pulse amplifier
- Computer for data recording
- Low-background multilayer shielding (Al, Cd, Pb, polyethylene cover).

Gamma Spectrum Processing

The gamma spectra were processed with ANGES software [9], which performs Gaussian peak area approximation, energy and efficiency calibration, and background correction [10].

The activity (A) of the emitting radionuclides was calculated using the following equation [11]:

$$A = \frac{S}{\varepsilon I t} \quad (1)$$

where: S is the net peak area; ε is the detector efficiency; t is the spectrum acquisition time; I is the quantum yield.

The specific activity was calculated using formula [12]:

$$A_{sp} = \frac{A}{m} \quad (2)$$

where m is the mass of the sample, and A is the activity of the respective radionuclide.

Results

The obtained specific activities for the radionuclides ^{226}Ra, ^{228}Ac, ^{214}Pb, ^{208}Tl and ^{214}Bi are presented in Figures 1 to 6.

The specific activities of natural radionuclides in the soil samples ranged from 25 to 130 Bq/kg, with the lowest values observed for ^{208}Tl and the highest for ^{226}Ra. In both samples, the measured values were similar, falling within the range of experimental uncertainty (Fig. 1).

The specific activities of natural radionuclides in the seed samples ranged from 30 to 320 Bq/kg. The lowest values were observed for ^{214}Pb and ^{208}Tl in the seeds used for sowing (Seeds 0), while the highest was recorded for ^{226}Ra. In the newly harvested seeds, the specific activities of ^{214}Pb, ^{208}Tl, and ^{226}Ra were approximately twice as high as those measured in the sowing seeds. The changes in specific activities of ^{228}Ac and ^{214}Pb were minimal and within the range of experimental uncertainty (Fig. 3).

The specific activities of radionuclides in rapeseed leaves ranged from 40 to 480 Bq/kg. The lowest activity was detected for ^{208}Tl in a sample of young leaves, while the highest was observed for ^{228}Ac, also in young leaves. The specific activity of ^{228}Ac in young leaves was four times higher than that measured in the leaves of mature plants (Fig. 3).

The specific activities of ^{214}Pb, ^{208}Tl, and ^{214}Bi in the root samples of both young and mature plants were similar, falling within the range of experimental uncertainty. A difference was observed for ^{226}Ra, with higher activity in the roots of the young plant. No activity was detected for ^{228}Ac in the roots of the young plant (Fig. 4).

In mature plants, ^{228}Ac predominantly accumulated in the pods, while ^{226}Ra showed higher accumulation in both the stems and pods (Fig. 5).

In young plants, the radionuclide ^{228}Ac is detected exclusively in the leaves. For the other radionuclides, the lowest specific activities were observed in the soil, while the highest were found in the roots (Fig. 6).

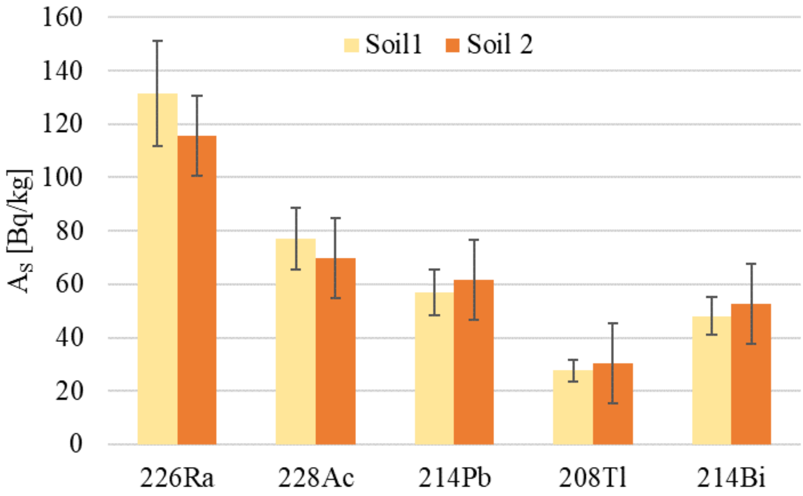

Fig. 1. *Graphical representation of the specific activities of ^{226}Ra, ^{228}Ac, ^{214}Pb, ^{208}Tl and ^{214}Bi in soil samples*

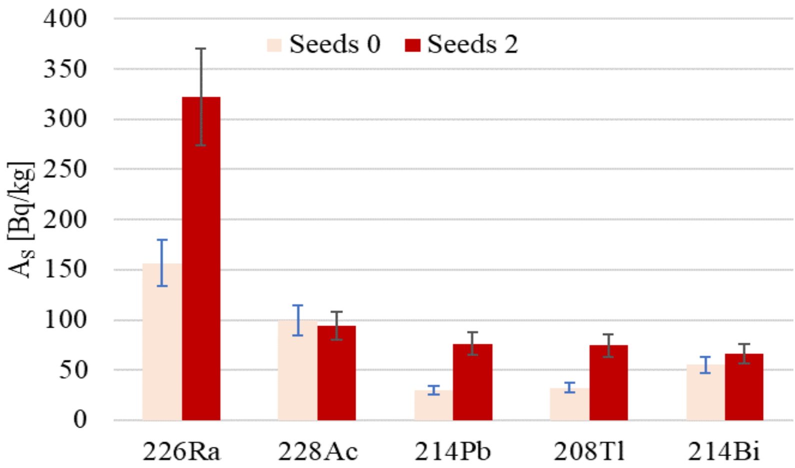

Fig. 2. *Graphical representation of the specific activities of ^{226}Ra, ^{228}Ac, ^{214}Pb, ^{208}Tl and ^{214}Bi in Seeds of winter oilseed rape samples*

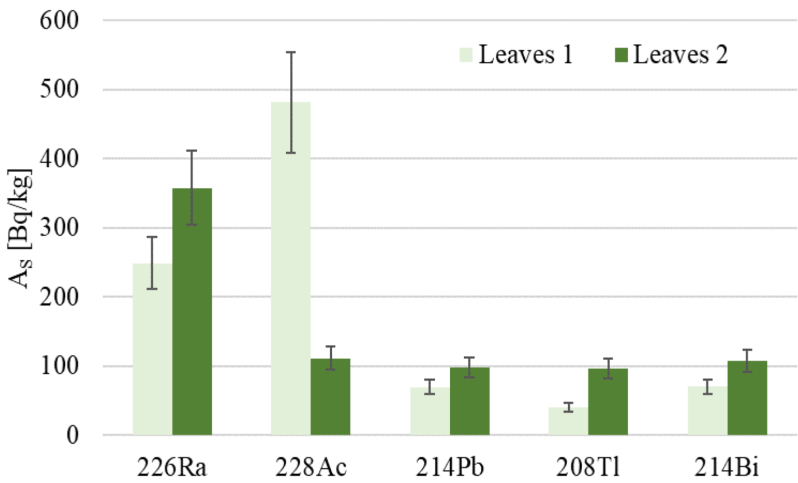

Fig. 3. *Graphical representation of the specific activities of ^{226}Ra, ^{228}Ac, ^{214}Pb, ^{208}Tl and ^{214}Bi in Leaves of winter oilseed rape samples*

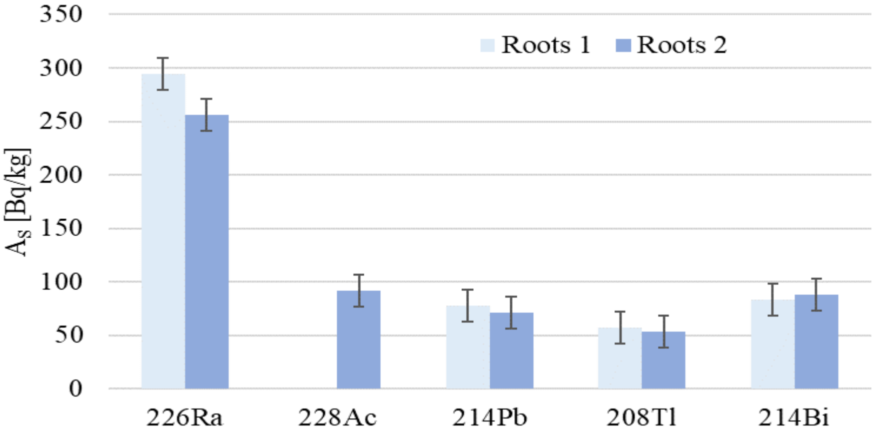

Fig. 4. *Graphical representation of the specific activities of ^{226}Ra, ^{228}Ac, ^{214}Pb, ^{208}Tl and ^{214}Bi in Roots of winter oilseed rape samples*

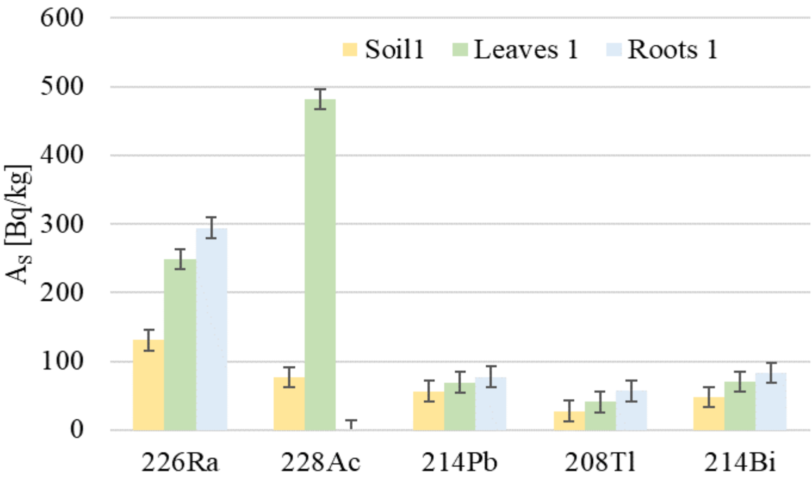

Fig. 5. *Graphical representation of the specific activities of ^{226}Ra, ^{228}Ac, ^{214}Pb, ^{208}Tl and ^{214}Bi in Leaves and Roots of winter oilseed rape and soil sample collected in March*

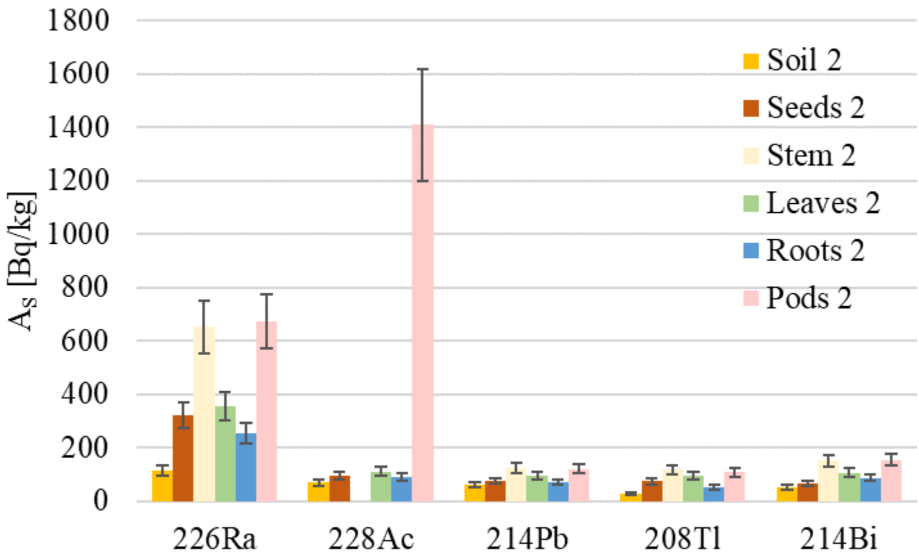

Fig. 6. *Graphical representation of the specific activities of ^{226}Ra, ^{228}Ac, ^{214}Pb, ^{208}Tl and ^{214}Bi in Leaves, Seeds, Stem,Pods and Roots of winter oilseed rape and soil sample collected in July*

CONCLUSION

In this study, gamma-spectrometric analysis was conducted on soil samples and oilseed rape (Brassica napus) plantations. A total of 10 samples were collected, prepared, and analyzed from a plot located in the "Ovoshtna Gradina" area, Divdyadovo district, Shumen municipality, near the Golyama Kamchiya River. The site is situated at an altitude of 100 meters, with GPS coordinates N 43° 20' 63.2", E 26° 89' 29.9". The radionuclides present in the samples and their specific activities were determined.

Based on the analysis, the following conclusions were drawn:

- The specific activities of ^{228}Ac, ^{214}Bi, and ^{208}Tl remained unchanged between the seeds used for sowing and those from the new harvest.
- ^{228}Ac: During early spring, accumulation of this radionuclide was observed in the foliage, while its presence in the root system was detected only during the summer.
- The specific activities of ^{226}Ra and ^{214}Pb in seeds from the new harvest were found to be twice as high as those in the seeds used for planting.

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