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ОЦЕНКА НА СЪДЪРЖАНИЕТО НА ЕСТЕСТВЕНИТЕ РАДИОНУКЛИДИ В МЪРТВА КОПРИВА (*LAMIUM PURPUREUM*)

Сениха Салим*, Теодора Димова, Татяна Димитрова, Димитрина Радева, Нина Архангелова

ШУ „Епископ Константин Преславски“, ул. „Университетска“ №115, Шумен, България
**кореспондиращ автор: e-mail s.salim@shu.bg*

ASSESSMENT OF NATURAL RADIONUCLIDES IN PURPLE DEAD-NETTLE (*LAMIUM PURPUREUM*)

Seniha Salim*, Teodora Dimova, Tatyana Dimitrova, Dimitrina Radeva, Nina Arhangelova

Konstantin Preslavsky University of Shumen, 115, Universitetska str., Shumen, Bulgaria
**Corresponding author: e-mail s.salim@shu.bg*

Abstract
Plants serve as effective bioindicators for monitoring environmental contamination, in detecting the presence and distribution of radionuclides. This study investigates the accumulation of radionuclides in Lamium purpureum (purple dead-nettle), a widespread medicinal plant, with the aim of identifying the radionuclides present and determine their concentrations in the different organs of the plant. The study evaluates the plant's potential for long-term radiological monitoring. The results provide valuable insights into the role of plants in detecting environmental contamination and the associated risks of human exposure through the food chain.
Keywords: natural radionuclides, gamma spectrometry, *Lamium purpureum*, environmental radioactivity.

INTRODUCTION

Lamium purpureum, commonly known as purple dead-nettle, has traditionally been used in folk medicine for its anti-inflammatory, mildly antiseptic, and astringent properties [1, 2]. It has been applied externally to support the healing of wounds, minor bleeding, and skin irritations, particularly due to its ability to help stop bleeding [2]. In addition to its topical uses, the plant has occasionally been consumed as a mild diuretic and digestive aid within traditional herbal remedies.

Modern scientific studies have shown that extracts of *Lamium purpureum* contain significant amounts of flavonoids, phenolic acids, and may also include other bioactive compounds responsible for antioxidant activity [3]. While preliminary research supports its anti-inflammatory potential, the antimicrobial properties remain less extensively studied and warrant further investigation [3, 4].

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EXPOSITION

Monitoring environmental contamination, particularly the radionuclide presence, is essential for understanding both ecological health and human exposure risks. Living organisms, including plants, serve as effective bioindicators due to their ability to absorb and accumulate environmental pollutants [5]. The concentration of radionuclides in living organisms is typically proportional to their levels in the surrounding environment [6]. The extent of accumulation varies among species, depending on factors such as the mechanisms of radionuclide retention and absorption, as well as the plants' sensitivity to ionizing radiation [7]. Understanding how plants accumulate radionuclides and the factors that influence this process is critical for assessing the environmental and health risks associated with radioactive contamination [8]. Medicinal and edible plants, in particular, provide a valuable opportunity for long-term monitoring of radiological pollution [9].

This study focuses on purple dead-nettle (*Lamium purpureum*) as a bioindicator of radionuclide contamination. Its wide distribution and use in herbal medicine make it a suitable candidate for assessing its ability to accumulate radionuclides from different environmental sources, including soil, water, and air. The study aims to identify and quantify the radionuclides present in plant tissue, monitor changes in their concentration over time, and evaluate the potential of purple dead-nettle as a natural bioindicator for radiological environmental assessments. The aim of the present study is to identify which radionuclides accumulate in the selected medicinal plant, as well as to track changes in their concentration over the years.

Samples

Sampling was conducted in the area surrounding Konstantin Preslavsky University of Shumen, at an average altitude of 222 meters above sea level.

Purple dead-nettle samples were collected each March over a five-year period. The collected samples were cleaned of impurities and dried in a laboratory oven at up to 40°C. Plant samples were separated into flowers, corollas, leaves, stems. The dried samples were ground into a fine powder, and portions weighing between 18 and 25 g were placed into 75 ml cylindrical containers suitable for gamma spectrometric analysis.

Gamma spectrometric method for determination of radionuclides.

To determine the radionuclide content in purple dead-nettle, gamma spectrometric analysis was performed. The measurements were conducted using a low-background gamma spectrometry system located at the Laboratory of Nuclear Physics and Radioecology, Konstantin Preslavsky University of Shumen. The setup features a Ge(Li) semiconductor detector enclosed in a multilayer shielding assembly designed to meet the standards for low-background gamma measurements.

Radionuclide identification and determination of specific activities in the Lamium purpureum (purple dead-nettle) samples were based on the gamma spectrometry results. The activity (A) of the detected radionuclides was calculated using the equation [11]:

$$A = \frac{\mathrm{S}}{\varepsilon \mathrm{I} \mathrm{t}} \tag{1}$$

where A is the activity in becquerels [Bq], S is the net peak area, I is the gamma emission probability, ε is the detector efficiency, and t_L [s] is the live time for spectrum acquisition.

Specific activity was calculated as the ratio of radionuclide activity (A) to sample mass (m), according to the equation [12]:

$$\mathrm{A}_{sp} = \frac{\mathrm{A}}{m} \tag{2}$$

The result is expressed in becquerels per kilogram (Bq/kg).

Results

Results of gamma spectrometric analysis for purple dead-nettle samples collected in March over a five-year period is summarized in Figures 1–2 and Table 1. The concentrations of the natural radionuclides ^{238}U, ^{232}Th, ^{40}K, ^{228}Ac, ^{214}Pb, ^{208}Tl, and ^{214}Bi were measured. The lowest concentrations of all radionuclides were recorded in the first year, while the highest were observed in the fourth year, except for ^{228}Ac, which showed a continuous increase.

The specific activity of ^{40}K in the samples ranged from 1090 to 1950 Bq/kg, with an average value of 1520 Bq/kg (Table 1).

Table 1 Minimum, maximum, and mean specific activity of natural radionuclides in purple dead-nettle samples over five years

radionuclides	A_{sp} [Bq/kg]		
	min	max	mean
^{214}Pb	22,55	45,55	29,99
^{208}Tl	8,12	18,36	11,25
^{214}Bi	27,98	55,51	36,5
^{228}Ac	26,12	54,3	35,85
^{238}U	25,54	51,04	33,57
^{232}Th	13,09	22,35	17
^{40}K	1090,82	1947,26	1520,06

The measured specific activities of the radionuclides ^{238}U, ^{232}Th, ^{40}K, ^{228}Ac, ^{214}Pb, ^{208}Tl, and ^{214}Bi in the various organs of purple dead-nettle are presented in Fig. 3, Fig. 4, and Table 2.

The distribution of radionuclides across different plant organs was examined. Lead-214 (^{214}Pb) was found to accumulate equally in the flowers and stems, with lower concentrations in the leaves and corollas. Thallium-208 (^{208}Tl) showed accumulation levels close to the average in the flowers, corollas, and leaves, but was present in smaller amounts in the stems. Bismuth-214 (^{214}Bi) accumulated equally in the flowers and leaves, while lower levels were observed in the corollas and stems. Actinium-228 (^{228}Ac) was most concentrated in the flowers, followed by the leaves, and appeared in smaller but relatively similar amounts in the corollas and stems. Uranium-238 (^{238}U) showed high accumulation in all plant parts, though the lowest levels were detected in the flowers. Thorium-232 (^{232}Th) was most concentrated in the flowers, equally present in the corollas and leaves, and least accumulated in the stems (Fig. 3).

The highest concentration of ^{40}K was found in the stems, followed by the flowers, while the lowest levels were observed in the leaves and corollas (Fig. 4).

Table 2 Minimum, maximum, and mean specific activity of natural radionuclides in different plant organs

radionuclides	A_{sp} [Bq/kg]		
	min	max	mean
^{214}Pb	25,29	36,50	31,25
^{208}Tl	7,28	13,79	11,12
^{214}Bi	24,49	39,65	31,62
^{228}Ac	19,12	53,91	32,16
^{238}U	24,85	36,14	31,45
^{232}Th	10,05	22,36	16,04
^{40}K	1115,90	2388,53	1629,03

The collected data were statistically analyzed using IBM SPSS Statistics 19 [13]. Cluster analysis revealed distinct groupings of radionuclides based on their accumulation patterns in different organs of the purple dead-nettle plant. Radionuclides ^{214}Pb, ^{214}Bi, and ^{238}U formed a tightly associated cluster, indicating similar behavior, likely resulting from a common origin and comparable physicochemical properties. A second group, comprising ^{208}Tl, ^{232}Th, and ^{228}Ac, demonstrated moderate but still significant interrelationships, possibly reflecting differences in mobility or binding affinity within plant tissues. Potassium (^{40}K) appeared as a separate cluster, emphasizing its distinct biological status as an essential nutrient and its markedly different distribution profile compared to the other radionuclides.

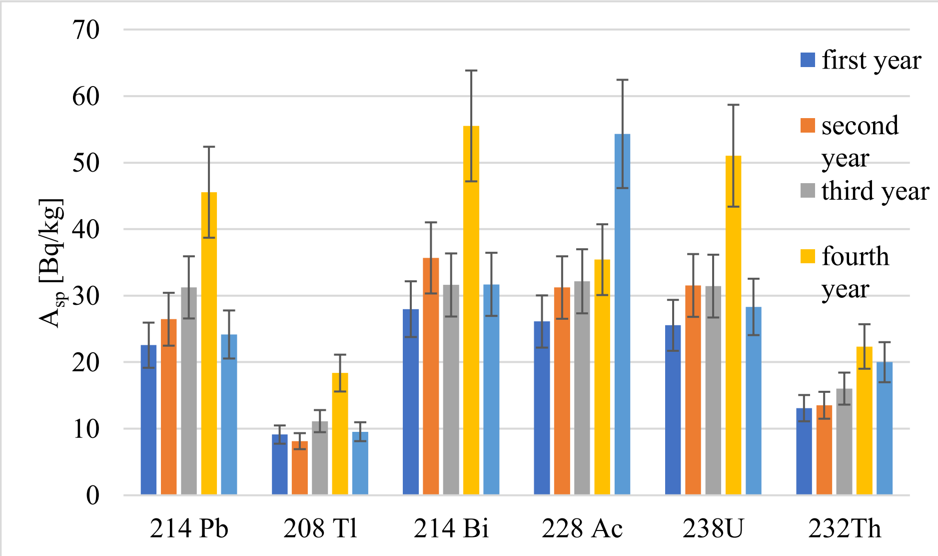

Fig. 1. *Graphical representation of the specific activities of ^{228}Ac, ^{214}Pb, ^{208}Tl, ^{214}Bi, ^{238}U and ^{232}Th in samples collected over the five-year period*

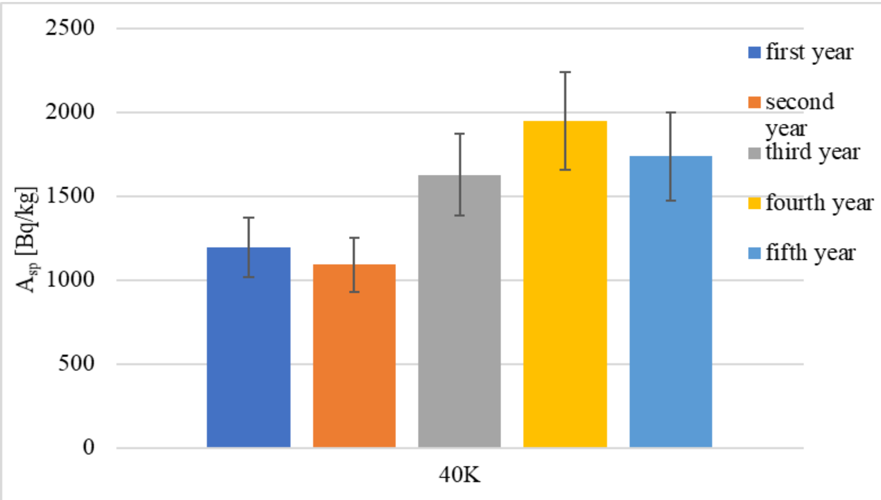

Fig. 2. *Graphical representation of the specific activities of ^{40}K in samples collected over the five-year period*

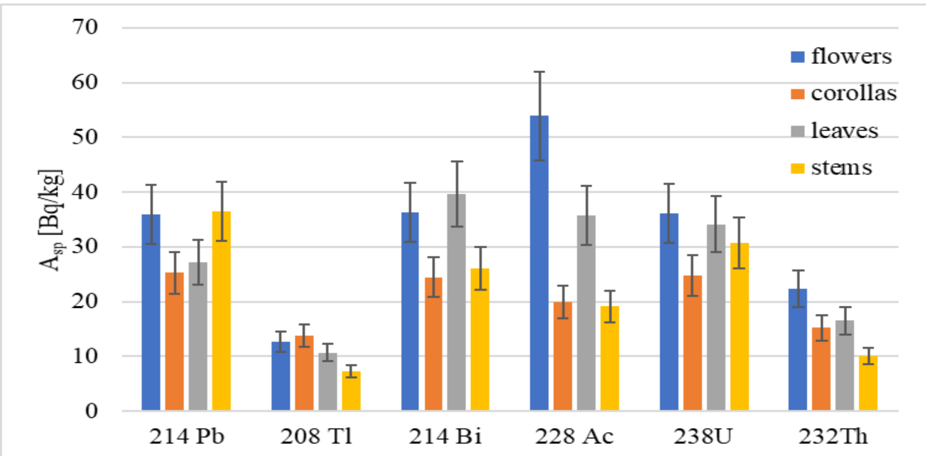

Fig. 3. *Graphical representation of the specific activities of ^{228}Ac, ^{214}Pb, ^{208}Tl, ^{214}Bi, ^{238}U and ^{232}Th in flowers, corollas, leaves and stems samples*

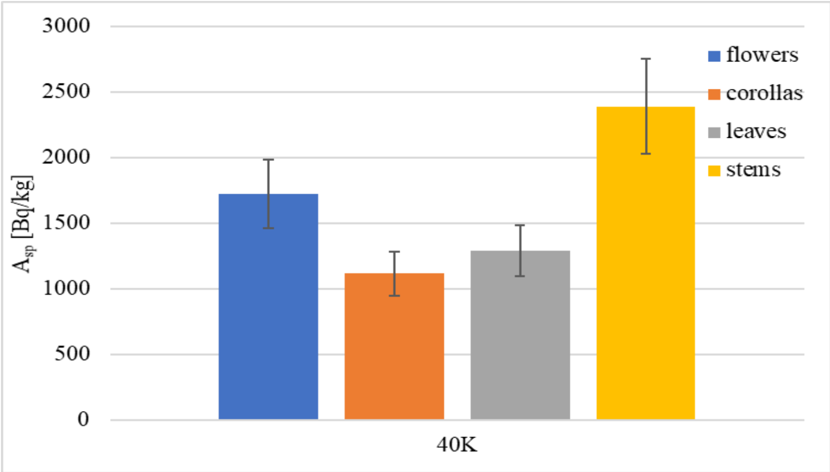

Fig. 4. *Graphical representation of the specific activities of ^{40}K in flowers, corollas, leaves and stems samples*

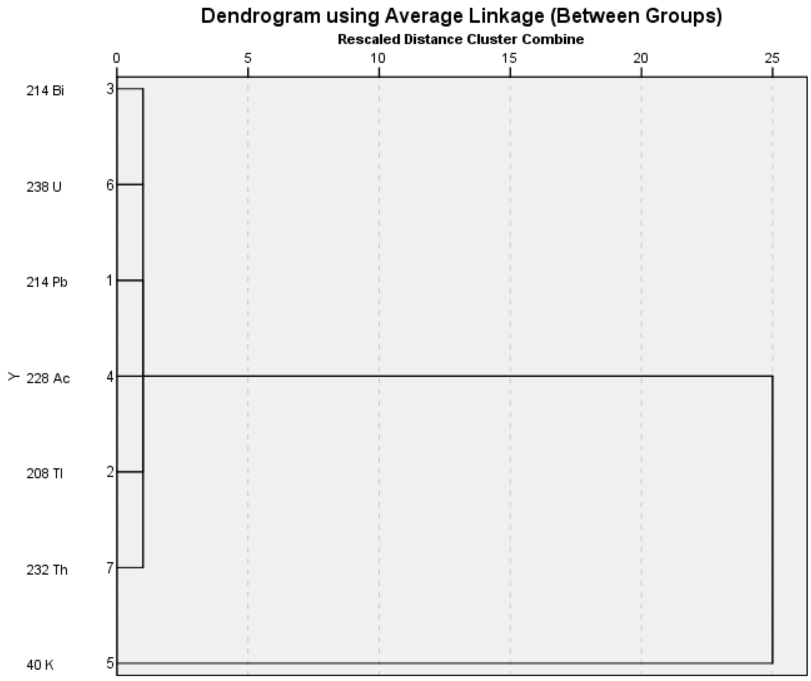

Fig. 5. *Dendrogram of the specific activities of ^{238}U, ^{232}Th, ^{228}Ac, ^{214}Pb, ^{208}Tl, ^{214}Bi and ^{40}K, in purple dead-nettle samples*

CONCLUSION

In this study, gamma-spectrometric analysis was performed on samples of purple dead-nettle (*Lamium purpureum*). The samples were collected annually over a five-year period in March from the grounds of Shumen University. The radionuclides present in the samples were identified, and their specific activities were determined.

Based on the analysis, the following conclusions were drawn:

- The specific activity of all radionuclides peaked in the fourth year of sampling, with the exception of ^{228}Ac, whose concentration showed a continuous increase over the years.
- ^{228}Ac accumulates most significantly in the flowers of the plant.
- ^{214}Pb is found in similar concentrations in both the flowers and stems.
- ^{214}Bi tends to accumulate in greater amounts in the flowers and leaves.
- ^{40}K is most concentrated in the stems of the plant.

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