

Original Research

ANNUAL EFFECTIVE DOSE DUE TO INGESTION OF HERBAL INFUSIONS  
FROM ASTERACEAE MEDICINAL PLANTS

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Irina Vasić<sup>1,a\*</sup>, Igor Čeliković<sup>1,b</sup>, Aleksandra Samolov<sup>1,c</sup>, Tamara Milanović<sup>1,d</sup>,  
Aleksandar Kandić<sup>1,e</sup>, Mirjana Đurašević<sup>1,f</sup>

<sup>1</sup> „Vinča” Institute of Nuclear Sciences, National Institute of Republic of Serbia,  
University of Belgrade, Mike Petrovića Alasa 12–14, 11000 Belgrade, Serbia

<sup>a</sup> <https://orcid.org/0000-0002-9852-6742> <sup>b</sup> <https://orcid.org/0000-0002-5642-4393>

<sup>c</sup> <https://orcid.org/0000-0002-6912-2407> <sup>d</sup> <https://orcid.org/0000-0002-5948-851X>

<sup>e</sup> <https://orcid.org/0000-0002-7610-1663> <sup>f</sup> <https://orcid.org/0000-0002-1557-7414>

**Abstract**

Five medicinal herbs belonging to the Asteraceae family (chamomile, yarrow, marigold, dandelion, and elecampane) from Serbia purchased from a local health food store in Serbia were investigated to determine the activity concentrations of <sup>137</sup>Cs, <sup>210</sup>Pb, <sup>226</sup>Ra, <sup>228</sup>Ac, and <sup>40</sup>K and to assess the radiological risk associated with their consumption. The annual effective doses due to ingestion, assuming daily consumption of 200 mL of herbal infusion prepared from these plants, are estimated. The results showed that <sup>40</sup>K is the main contributor to the total radioactivity, <sup>210</sup>Pb and <sup>226</sup>Ra are moderate, although present across all samples. Among all radionuclides, <sup>210</sup>Pb and <sup>40</sup>K provided the highest contribution to the annual effective dose. The calculated annual effective doses for each sample were significantly below the recommended limit of 100 μSv/year.

**Keywords:** medicinal plants, radionuclides, radiological assessment, ingestion dose.

**INTRODUCTION**

Medicinal herbs are widely consumed throughout the world in the form of infusions, decoctions, and other traditional preparations, and are generally perceived as safe due to their natural origin. In Serbia, herbal infusions prepared from medicinal plants remain an important part of everyday dietary and therapeutic practice. However, like other plant-based food products, medicinal herbs can accumulate radionuclides (both natural and anthropogenic) from soil and atmospheric deposition, making their regular consumption a potential pathway of internal radiation exposure to humans [1]. Naturally occurring radionuclides such as <sup>210</sup>Pb, <sup>226</sup>Ra, <sup>228</sup>Ac, and <sup>40</sup>K are particularly relevant because of their environmental ubiquity and potential transfer into plant tissues, while <sup>137</sup>Cs is important as an anthropogenic radionuclide originating mainly from past nuclear fallout [2,3]. Species belonging to the Asteraceae family are of particular relevance in this context, as many are commonly used for the preparation of medicinal herbal infusions and may therefore contribute to radionuclide intake through ingestion. In addition, some representatives of the Asteraceae family have been reported to

\*irina.kandic@vin.bg.ac.rs

accumulate environmental contaminants, including radionuclides and trace elements, through soil - plant transfer processes, which may contribute to their transfer into consumable plant material [2,4,5]. *Taraxacum officinale* (dandelion), in particular, has been shown to accumulate elevated levels of environmental contaminants, especially in polluted environments [6]. Given their frequent use in traditional and everyday consumption, the occurrence of radionuclides in these medicinal plants may represent a relevant pathway of internal exposure for consumers. In this context, the determination of radionuclide activity concentrations and the estimation of annual effective dose due to ingestion are essential for evaluating their radiological significance.

The aim of this study was to determine the activity concentrations of  $^{137}\text{Cs}$ ,  $^{210}\text{Pb}$ ,  $^{226}\text{Ra}$ ,  $^{228}\text{Ac}$ , and  $^{40}\text{K}$  in selected medicinal herbs from the Asteraceae family (chamomile, yarrow, marigold, dandelion and elecampane) from Serbia purchased from a local health food store, and to estimate the annual effective dose associated with their daily consumption of 200 mL herbal infusions.

## MATERIALS AND METHODS

Five medicinal herb samples (chamomile, yarrow, marigold, dandelion, and elecampane) from Serbia were purchased from a local health food store. The corresponding common English and Latin names, botanical family, analyzed plant part, and recommended amount of dried material for the preparation of 200 mL of infusion are listed in Table 1. The samples, purchased in dried form, were ground and homogenized. The prepared material was then packed into standard cylindrical PVC containers (125 mL). Approximately 30 g of each sample was used, ensuring consistency with the working standard employed for detector calibration. The working standard was based on dried grass as a matrix of similar biological composition and was spiked with a radioactive solution containing a mixture of gamma-emitting radionuclides:  $^{210}\text{Pb}$ ,  $^{241}\text{Am}$ ,  $^{109}\text{Cd}$ ,  $^{139}\text{Ce}$ ,  $^{57}\text{Co}$ ,  $^{60}\text{Co}$ ,  $^{137}\text{Cs}$ ,  $^{113}\text{Sn}$ ,  $^{85}\text{Sr}$ , and  $^{88}\text{Y}$ , supplied by the Czech Metrology Institute (CMI) [7].

**Table 1** Investigated medicinal herbs, their English and Latin names, family affiliation, plant part used, and recommended amount of dried material for preparation of 200 mL of herbal infusion.

| English name      | Latin name                   | Familly   | Plant part | Recommended amount [2,8,9] |
|-------------------|------------------------------|-----------|------------|----------------------------|
| <b>Chamomile</b>  | <i>Matricaria chamomilla</i> | Asteracea | flower     | 2.5 g                      |
| <b>Yarrow</b>     | <i>Achillea millefolium</i>  | Asteracea | herb       | 2 g                        |
| <b>Marigold</b>   | <i>Calendula officinalis</i> | Asteracea | flower     | 3 g                        |
| <b>Dandelion</b>  | <i>Taraxacum officinale</i>  | Asteracea | leaf       | 1.5 g                      |
| <b>Elecampane</b> | <i>Inula helenium</i>        | Asteracea | root       | 1 g                        |

The working standard was prepared at the Laboratory for nuclear and plasma physics, “Vinča” Institute of Nuclear Sciences, University of Belgrade [10,11]. All samples were measured in a close to detector geometry using a coaxial HPGe spectrometer (Canberra GX5019) with a relative efficiency of 55% and an energy resolution of 1.9 keV for  $^{60}\text{Co}$

1332.5 keV. The gamma spectra of the medicinal herb samples were acquired and analyzed using Canberra Genie 2000 software. To ensure acceptable counting statistics, the samples were measured for up to 585,000 s. The activity concentrations of  $^{137}\text{Cs}$ ,  $^{210}\text{Pb}$ ,  $^{226}\text{Ra}$ ,  $^{228}\text{Ac}$ , and  $^{40}\text{K}$  in the medicinal plants samples were determined from the corresponding full-energy gamma peaks at 661.66 keV, 46.54 keV, 186.21 keV, 911.20 keV, and 1460.82 keV respectively, after applying background corrections. In the case of  $^{40}\text{K}$ , correction of the 1460.82 keV peak was also performed to eliminate the contribution of the adjacent  $^{228}\text{Ac}$  line at 1459.13 keV. The combined measurement uncertainty was estimated by applying the general law of uncertainty propagation. The dominant sources of uncertainty were counting statistics and efficiency calibration (contributing 5%), whereas the effect of sample mass uncertainty was considered negligible.

The annual effective dose for ingestion in the case of daily consumption of 200 mL of herbal infusion prepared from medicinal herbs was calculated based on the obtained values of specific activities of radionuclides  $^{137}\text{Cs}$ ,  $^{210}\text{Pb}$ ,  $^{226}\text{Ra}$ ,  $^{228}\text{Ac}$ , and  $^{40}\text{K}$ , using the following formula [12] (1):

$$E_{\text{ing}} = A_s H C_d D F_{\text{ing}} \quad (1)$$

where  $A_s$  is the specific activity in [Bq/kg],  $H$  is the amount of medicinal plant consumed in [kg/year],  $C_d$  is the dissolution coefficient of the radionuclide during the infusion preparation, and  $D F_{\text{ing}}$  is the coefficient of effective ingestion dose [Sv/Bq].

Radionuclide solubility coefficients,  $C_d$ , for herbal infusion preparation are: 0.6 for  $^{137}\text{Cs}$  [13], 0.5 for  $^{210}\text{Pb}$  [14], 0.2 for  $^{226}\text{Ra}$  [15], 0.0005 for  $^{228}\text{Ac}$  [16], and 0.9 for  $^{40}\text{K}$  [17].

The effective dose coefficients,  $D F_{\text{ing}}$ , used in the calculations are:  $1.310^{-8}$  Sv/Bq for  $^{137}\text{Cs}$ ,  $6.910^{-7}$  Sv/Bq for  $^{210}\text{Pb}$ ,  $2.8 \cdot 10^{-7}$  Sv/Bq for  $^{226}\text{Ra}$ ,  $4.3 \cdot 10^{-10}$  Sv/Bq for  $^{228}\text{Ac}$ , and  $6.210^{-9}$  Sv/Bq for  $^{40}\text{K}$  [16].

## RESULTS AND DISCUSSION

The activity concentrations of  $^{137}\text{Cs}$ ,  $^{210}\text{Pb}$ ,  $^{226}\text{Ra}$ ,  $^{228}\text{Ac}$ , and  $^{40}\text{K}$  in 5 selected medicinal plants collected from a local herbal store in Serbia, together with the associated measurement uncertainties at the  $1\sigma$  confidence level, are presented in Table 2.

**Table 2** Activity concentration of radionuclides in Asteraceae medicinal plants

| Plant species     | $^{137}\text{Cs}$ | $^{210}\text{Pb}$ | $^{226}\text{Ra}$ | $^{228}\text{Ac}$ | $^{40}\text{K}$ |
|-------------------|-------------------|-------------------|-------------------|-------------------|-----------------|
|                   | [Bq/kg]           |                   |                   |                   |                 |
| <b>Chamomile</b>  | < 0.3             | $9.4 \pm 1.0$     | $9.3 \pm 1.7$     | $4.7 \pm 0.9$     | $628 \pm 33$    |
| <b>Yarrow</b>     | < 0.3             | $13.3 \pm 2.0$    | $3.8 \pm 0.3$     | < 2.1             | $450 \pm 24$    |
| <b>Marigold</b>   | < 0.3             | $12.0 \pm 2.1$    | $17.2 \pm 1.6$    | < 2.1             | $753 \pm 39$    |
| <b>Dandelion</b>  | < 0.3             | $28.3 \pm 3.9$    | $3.2 \pm 0.3$     | $3.2 \pm 0.4$     | $874 \pm 45$    |
| <b>Elecampane</b> | $0.6 \pm 0.2$     | $7.3 \pm 0.7$     | $4.5 \pm 0.4$     | $3.0 \pm 0.4$     | $734 \pm 38$    |

The obtained results are in general agreement with the data reported in the available literature [2,18–20], indicating that the activity concentrations of the investigated

radionuclides fall within the expected ranges for medicinal plants. However, it should be emphasized that the amount of published data on  $^{210}\text{Pb}$  in such materials is relatively limited [2,8,20].

Table 3 presents the estimated individual annual effective doses resulting from the ingestion of  $^{137}\text{Cs}$ ,  $^{210}\text{Pb}$ ,  $^{226}\text{Ra}$ ,  $^{228}\text{Ac}$ , and  $^{40}\text{K}$ , assuming a daily consumption of 200 mL of herbal infusion. Due to the extremely low solubility coefficient of  $^{228}\text{Ac}$ , its contribution was considered negligible and therefore excluded from the estimation of the individual annual effective dose.

**Table 3** Estimated individual annual effective doses resulting from the ingestion of  $^{137}\text{Cs}$ ,  $^{210}\text{Pb}$ ,  $^{226}\text{Ra}$ ,  $^{228}\text{Ac}$ , and  $^{40}\text{K}$  in 200 mL of herbal infusion, including measurement uncertainties at the  $1\sigma$  confidence level

| Plant species     | $^{137}\text{Cs}$ | $^{210}\text{Pb}$ | $^{226}\text{Ra}$ | $^{40}\text{K}$ | Total annual effective doses |
|-------------------|-------------------|-------------------|-------------------|-----------------|------------------------------|
|                   | [nSv/year]        |                   | [μSv/year]        |                 |                              |
| <b>Chamomile</b>  | < 2.14            | $2.92 \pm 0.31$   | $0.48 \pm 0.09$   | $3.20 \pm 0.17$ | $6.60 \pm 0.57$              |
| <b>Yarrow</b>     | < 1.71            | $3.35 \pm 0.50$   | $0.16 \pm 0.01$   | $1.83 \pm 0.10$ | $5.34 \pm 0.61$              |
| <b>Marigold</b>   | < 2.56            | $4.53 \pm 0.78$   | $1.05 \pm 0.10$   | $4.60 \pm 0.24$ | $10.18 \pm 1.12$             |
| <b>Dandelion</b>  | < 1.28            | $5.35 \pm 0.73$   | $0.10 \pm 0.01$   | $2.67 \pm 0.14$ | $8.12 \pm 0.88$              |
| <b>Elecampane</b> | $1.71 \pm 0.57$   | $0.92 \pm 0.09$   | $0.09 \pm 0.01$   | $1.49 \pm 0.08$ | $2.50 \pm 0.18$              |

The individual annual effective dose due to ingestion of  $^{137}\text{Cs}$ ,  $^{210}\text{Pb}$ ,  $^{226}\text{Ra}$ , and  $^{40}\text{K}$  through the consumption of 200 mL of herbal infusion prepared from the investigated medicinal plants was found to be up to 1.71 nSv, 5.35 μSv, 1.05 μSv, and 4.60 μSv, for  $^{137}\text{Cs}$ ,  $^{210}\text{Pb}$ ,  $^{226}\text{Ra}$ , and  $^{40}\text{K}$ , respectively. The highest total annual effective dose was observed in the marigold sample. Among all radionuclides,  $^{210}\text{Pb}$  and  $^{40}\text{K}$  provided the highest contribution to the annual effective dose. Notably, the contribution of  $^{40}\text{K}$  is relatively uniform and reflects its natural abundance in plant tissues. This can be explained by the essential biological role of potassium in plants. In contrast,  $^{137}\text{Cs}$  exhibits a negligible contribution in all samples, likely due to low environmental levels or values below detection limits. Additionally,  $^{228}\text{Ac}$  does not contribute to the total dose, due to its very low solubility.

The total annual effective doses obtained for all investigated herbal infusions are considerably lower than the recommended limit of 100 μSv/year prescribed by *Regulation on limits of radionuclide content in drinking water, foodstuffs, feeding stuff, drugs, items of general use, building materials, and other goods to be placed on the market* [21]. This indicates that these herbal infusions are radiologically safe for use.

## CONCLUSION

Five medicinal herbs from the Asteraceae family were analyzed for the activity concentrations of  $^{137}\text{Cs}$ ,  $^{210}\text{Pb}$ ,  $^{226}\text{Ra}$ ,  $^{228}\text{Ac}$ , and  $^{40}\text{K}$ , and the corresponding annual effective doses due to ingestion were estimated for the daily consumption of 200 mL of herbal infusion. The calculated annual effective doses were significantly below the regulatory limit of

100  $\mu\text{Sv/year}$ , indicating that the investigated herbal infusions do not pose a significant radiological risk to consumers.

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