RADIOACTIVITY IN WILD-GROWING MUSHROOMS IN THE TERRITORY OF ALBANIA

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Abstract

This study evaluates the levels of radioactivity in wild mushrooms collected from various regions of Albania using total gamma spectrometry. Fungi are sensitive indicators of radioactive pollution due to their capability to absorb radionuclides from their environment. Samples were collected from forest areas in Puka, Bajram Curri, Korçë, and Fier to measure the concentrations of cesium-137 and lead-210, which may have resulted from the Chornobyl nuclear accident. The average radioactivity level found in Albanian mushrooms was 48.80 ± 7.20 Bq/kg, significantly below the European maximum limit of 370 Bq/kg. These results indicate that wild mushrooms in Albania do not pose a public health risk and are safe for consumption. This study's findings are crucial for food safety and for understanding the processes of radionuclide transfer in the food chain. Consequently, continuous monitoring is recommended to assess potential risks to communities affected by radioactive pollution.

Key words: radionuclide, radioactivity in foods, radioactivity in mushrooms, total gamma measurement, gamma radiation.

Përmbledhje:

Ky studim ka vlerësuar nivelet e radioaktivitetit në kërpudha të egra të mbledhura nga zona të ndryshme të Shqipërisë, duke përdorur metodën e spektrometrisë gama totale. Kërpudhat janë indikatorë të ndjeshëm të ndotjes radioaktive për shkak të aftësisë së tyre për të absorbuar radionuklide nga mjedisi. Në këtë studim janë analizuar mostrat e mbledhura nga zonat pyjore të Pukës, Bajram-Currit, Korçës dhe Fierit, me qëllim për të përcaktuar përqendrimet e radionuklidëve të ceziumi-137 dhe plumbi-210, të cilat mund të jenë pasojë e ndotjes nga aksidenti bërthamor i Cernobilit. Vlera mesatare e radioaktivitetit të matur në kërpudhat shqiptare ishte 48.8 ± 7.2 Bq/kg, një vlerë që është dukshëm më e ulët se kufiri maksimal i lejuar nga standardet *evropiane prej 370 Bq/kg. Rezultatet tregojnë se kërpudhat e egra në Shqipëri nuk paraqesin rrezik për shëndetin publik dhe janë të sigurta për konsum. Këto gjetje janë të rëndësishme për sigurinë ushqimore dhe për kuptimin e proceseve të transferimit të radionuklidëve në zinxhirin ushqimor. Studimi rekomandon monitorim të vazhdueshëm për të vlerësuar rreziqet e mundshme për komunitetet e prekura nga ndotja radioaktive.*

Fjalë kyçe: Radionuklide, radioaktiviteti në ushqime, radioaktiviteti në kërpudha, matje gama total, rrezatim gama.

Introduction

Fungi were once considered plants, are now recognized as a distinct biological kingdom. Unlike plants, they have no chlorophyll and take food from the surrounding environment, like animals. The visible part of the mushroom is only a small part of the organism, which primarily consists of a network of thread-like structures known as hyphae, forming the mycelium. Fungi reproduce through spores and creating the fruit body requires the union of two filaments from genetically different spores, making reproduction complex.

In Albania, mushrooms are predominantly harvested from the wild rather than cultivated. According to a study by the Ministry of Agriculture, the weight of mushrooms collected in the country ranges from 20 to 40 tons (Maho, 2022). Among the main places where they collect mushrooms are Puka, the hilly areas of Lezha, Prespa, the mountainous regions of Korca, and Librazhd. These areas are known for the diversity and quality of wild mushrooms, which include species as diverse as Boletus edulis, Cantharellus cibarius, Craterellus cornucopioides, Morchella conica, and Amanita Caesarea. Mushrooms are also known for their rich mineral content. Raw fungus ash contains seven main mineral elements: calcium, chlorine, magnesium, phosphorus, potassium, sodium, and sulfur. Cultivated mushrooms typically contain 5-12 g of ash per 100 g, while wild species may have higher content. Potassium and phosphorus are the main components of fungus ash, while the sodium and calcium content are lower. (Kalac, 2019). However, certain species can accumulate high levels of harmful trace elements, including arsenic, cadmium, lead, and mercury (Kalac, 2019).

Mushrooms are also efficient absorbers of radioactive elements from their environment, making them critical indicators of radioactive contamination, several factors influence the level of radioactivity in mushrooms, such as soil, pH, atmospheric conditions, and types of fungi. (Yoshida, 1994). The differences observed between different types of mushrooms about the rate of absorption of radionuclides may also be due to the degree of contamination of the chosen sample site, the feeding mechanism, the depth of the mycelium, the climate, and the bioavailability of radon. (Caridi, 2017). In the years following the disaster at the Chornobyl nuclear power plant, numerous studies were conducted to assess the level of mushroom radioactivity in Europe.

(Zarubina, 2004). because some wild mushroom species showed higher levels of radioactivity than any plant grown in the wild. Because of this explosion, the risk to the population from the consumption of mushrooms increased to a very high level from the Chernobyl accident, recent estimates of the total releases to the atmosphere from the accident using all the information now available remain consistent with the total release of 131-I being within the range of about 100 to about 500 PBq, and that of 137-Cs being within the range of 6 to 20 PBq (UNSCEAR, 2022). One of the best-known researchers who worked on the assessment of radioactivity content in mushrooms was Yoshida, who found that the levels of 137-Cs in the studied mushrooms ranged from 6.1 to 2824.8 Bq/kg. (Yoshida, 1994) He noted that levels of 137-Cs activity in wild mushrooms rose significantly after the Chornobyl nuclear accident.

Various techniques have been employed over time to lower the radioactivity levels of mushrooms. When cooking slices of Badius and Chrysenteron, it was observed that 80% of the radiation was released into the cooking water after just 5 minutes. After 20 minutes, up to 87% of 137-Cs was released into the cooking water., (Kla´n, 1988). Another technique used for cooking Stropharia rugusoannulata in a 2% table salt solution for 15 minutes reduced radiocaesium levels by 36–63%. However, these techniques, even though they are effective, cannot be applied even when the level of radiation is high.

This indicates that radiation levels would remain very high, even with an 80% reduction, making mushrooms unsafe for public consumption. Over the years, there has been a decrease in the values of radionuclides measured in mushrooms (UNSCEAR, 2022). Thus, for example, in the Czech Republic, in the years 2000-2004, from the testing of 33 samples of different analyzed types, it resulted that the average radiation value was 100 Bq/kg (Szántó, 2007). In some border states such as Ukraine, where the impact of the explosion was higher, the values measured in the samples vary from 834 to 1290 Bq/kg.

Another situation is reported in Poland, in the hot zone in the region of "Opole". In this area, contamination from the Chornobyl explosion reached up to 60,000 Bq/m2 in 1993 (Kalač, 2010). In a study conducted in 2006-2007 in which 70 different species of mushrooms were considered, the measured values were between 30 and 54070 Bq/kg. The primary aim of this paper is to assess the radionuclide content in wild mushrooms found in various regions of Albania, including the forested areas of Puka, Korça, Fieri, and the Tropoja Mountains. By evaluating these levels, the study seeks to determine whether these mushrooms, which are widely consumed by the local population and exported as complementary food, pose a potential health risk. Photographs of mushrooms grown in the mountains of Puka are shown in Figures 1 and 2.

Figure 1&2: Photos from the expedition in the forests of Puka, showcasing a Boletus edulis mushroom found in the forested massif.

Methodology

The Institute of Applied Nuclear Physics (IANP) is the only known Institution in Albania from the Radiation Protection Office (RPO) to measure radioactivity in solid, liquid, and air materials. For export reasons, different companies are obliged to certify their products regarding the doses of radioactive exposure. One of these products is mushrooms. The samples collected from various regions of Albania are brought to the Institute of Applied Nuclear Physics.

The mushrooms are prepared for absorption dose assessment following a specific procedure outlined in the measurement preparation manual. Gamma spectrometric methods perform measurements in the same geometry, with the corresponding calibration. (ISHP, 2014). The calibration coefficient is K = 70 Bq/kg*ips and the calibration is performed once a year. To perform the calibration of the Geiger-Müller (GM) detector, we use a source 137 Cs with a known activity of 2100 Bq/kg. We position the source on the detector to have a geometry 360^{o}. After I activated the GM, I counted the pulses for 60 seconds and repeated the measurement several times to get an accurate average (ISHP, 2014).

$$K=\frac{N}{A*t} \tag{1}$$

1. K is the calibration coefficient for GM,
2. N is the number of pulses I recorded,
3. A is Cs-137 source activity,
4. t is time measured in seconds

Figure 3 illustrates the device used for gamma total measurements, which consists of a lead chamber containing a gamma radiation detector and a control panel.

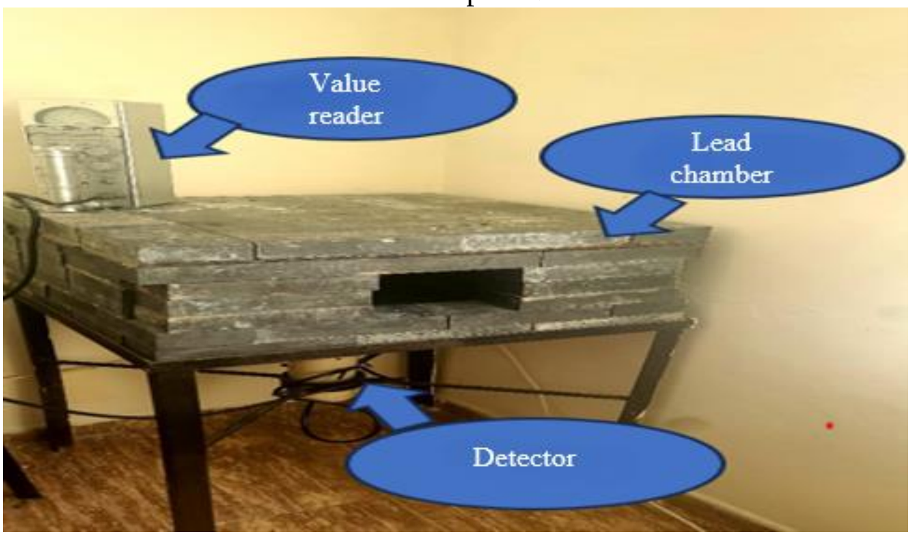

Figure 3: Gamma radiation measuring device equipped with a photomultiplier tube. This setup is used for detecting and quantifying gamma radiation in samples.

The sample that is evaluated for the presence of radioactive contamination is placed in a Marinelli beaker by cutting, crushing, grinding, or disintegrating it. The packaging of the sample is done with roughly the same level of compaction as during the gamma spectrometric calibration of the

methodology for the specific measuring-detecting device. The Marinelli beaker shown in Figure 4, after being filled with the sample material, is placed on the radiation detector in the lead chamber (Figure 4).

According to the protocol, to determine the activity (Asp), we consider the uncertainties in the counting rates 'N' (sample measurement) and 'F' (background measurement). Since radiation measurements follow Poisson statistics, the standard uncertainty in the counting rate 'N' or 'F' is the square root of each count rate. For measurements taken over a time 't', the uncertainty in each rate is proportional to $N^{1/2}/t$ and $F^{1/2}/t$ respectively.

The specific activity Asp is calculated as: where 'K' is the calibration factor (assumed to have negligible uncertainty in this case). The uncertainty in the specific activity 'Asp' can now be calculated as:

$$Asp = (N - F) \times K \quad (2)$$

$$\sigma_{Asp} = K \times \sigma_D \quad (3)$$

When D =N-F and the uncertainty of D is:

$$\sigma_D = \frac{\sqrt{N+F}}{t} \quad (4)$$

Final Formula for Uncertainty in Specific Activity:

$$\sigma_D = K \times \frac{\sqrt{N+F}}{t} \quad (5)$$

Figure 4, The Marinelli container used for gamma measurements. The container ensures consistent geometry for accurate determination of radionuclide concentrations in sample materials.

the specific activity, Asp, is compared with the allowable levels of total Caesium content in specified goods set by the Radiation Protection Commission. Depending on the destination of the goods (for children or adults), a decision is made regarding the permission to use the goods or their blocking for further checks using gamma spectrometric methods at IFBZ. Finally, certification of the goods is carried out for the presence or absence of radioactive contamination. (ISHP, 2014).

Results and discussions

Figure 5 presents the results obtained from the measurements conducted on mushroom samples collected from various areas, such as the forests in the regions of Puka, Fier, and Korça.

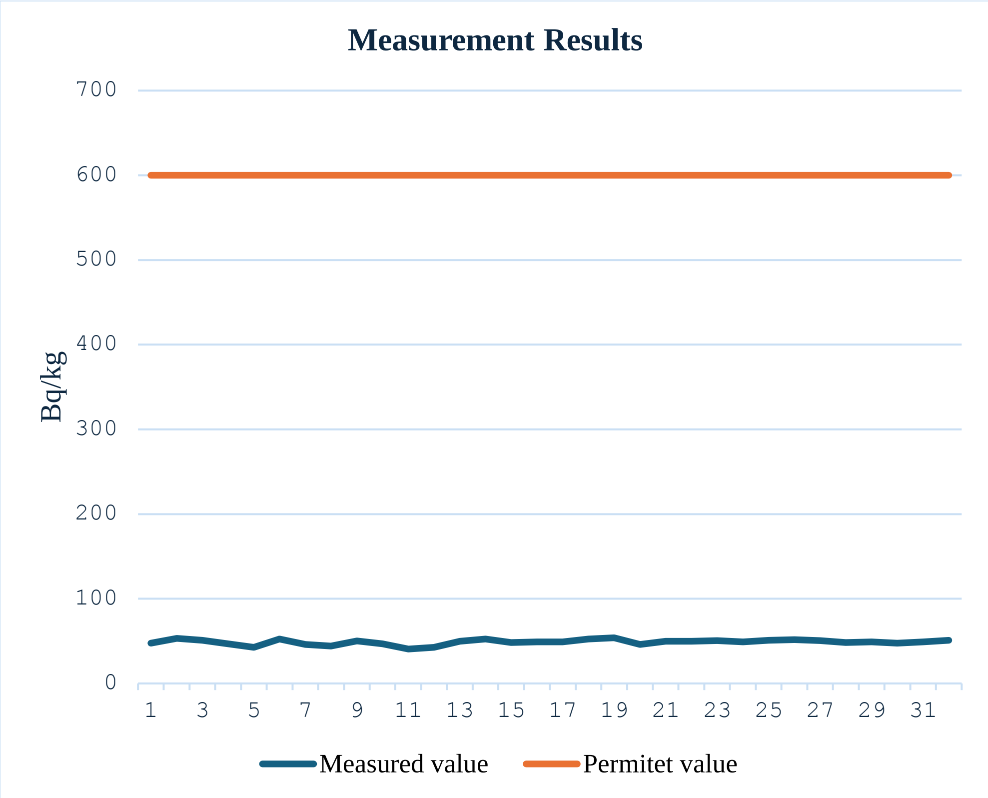

Figure 5: Measurement results for radionuclide concentrations in wild mushrooms. Blue bars represent the observed values, while orange bars indicate the permissible limits for consumption as defined by European standards.

The results obtained show that the radiation level in wild mushrooms collected in the territory of Albania is approximately twelve times lower than the permissible consumption limit in the European market.

Meanwhile, Table 2 provides data regarding exposure rates in various European countries. The data indicate significant differences between regions.

Name	Average value in Bq/Kg	Number of measurements
Cantharellus Cibarius	48.98 ± 7.35	6
Boletus Edulis	48.11 ± 7.20	15
Morchella Conica	50.10 ± 7.51	7
Amanita Caesarea	49.18 ± 7.36	4

Table 1: The table presents the measurements conducted on different varieties of mushrooms and the average value for each.

For example, in Belgium and the Czech Republic, the concentration of radionuclides reaches much higher values, with a maximum of 150,700 Bq/kg in the Czech Republic and up to 135,575 Bq/kg in Italy. These regional differences may result from various factors, including soil composition, the affinity of different mushrooms for radionuclides, and the extent of exposure of areas to radioactive contamination from previous accidents. Previous studies show that mushrooms have a unique ability to accumulate radionuclides, particularly cesium-137, making them indicators of environmental radioactive contamination (Yoshida, 1994).

In Albania, the measured value is at the level of 48.8 Bq/kg. This indicates relatively low contamination from radionuclides. This value is comparable to the lower range values in Bulgaria 41 Bq/kg and Romania, 70 Bq/kg. (Szántó, 2007). At the same time, there are countries with a much higher maximum value, such as Belgium, the Czech Republic, and Italy, indicating large regional variations in radioactive contamination. However, considering the sensitive nature of mushrooms in absorbing radionuclides from the environment, it is important to conduct periodic monitoring of these levels, especially in areas that may have been exposed to radioactive pollution sources such as Chornobyl.

State	Value in Bq/Kg	Reference
Austria	148-37370	(Teherani, 1987)
Belgian	160-102000	(Szántó, 2007)
Bulgaria	41-990	(Szántó, 2007)
Czech	50-150700	(Szántó, 2007)
Denmark	212-13343	(Strandberg, 2004)
France	2.5-5595	(Loaiza, 2012)
Germany	90-11290	(Zibold, 2001)
Hungary	0.6-714	(Szántó, 2007)
Italy	95-135575	(Marzano, 2001)
Romania	70-360	(Tanase, 2009)
Slovakia	323-966	(Petr, 2006)
Türkiye	9.89-401	(Özlem, 2007,)

Table 2: The table presents radiation values in mushrooms for different countries.

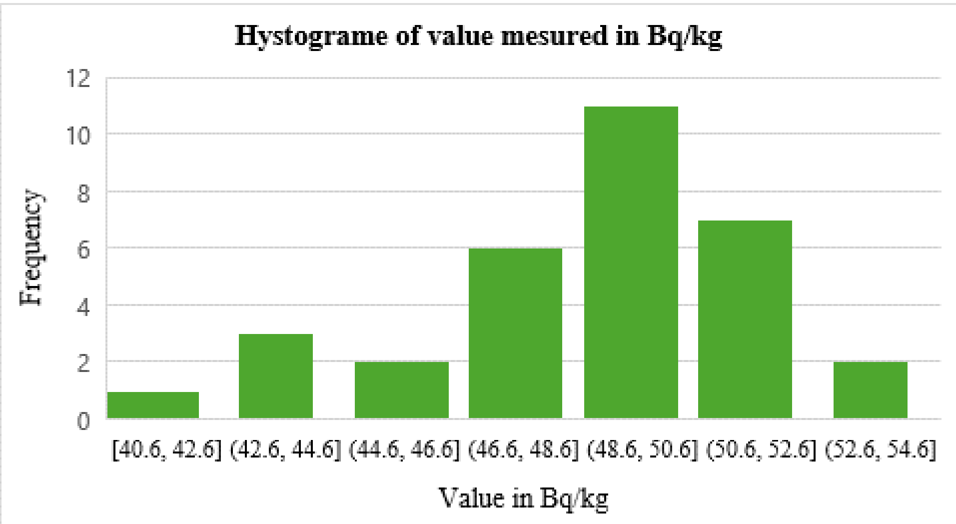

Figure 6: Histogram of the value measured in Bq/kg for mushrooms in Albania.

Conclusions

In Figure 6, the distribution of frequency values for the measurements is presented. A notable peak appears in the range of [48.60-50.60] Bq/kg, indicating that most measured values fall within this interval. The interval with the highest frequency, approximately 12, is [48.60, 50.60]. The following range, [50.60, 52.60], also shows a significant frequency of around 7. In contrast, the frequencies at both the far left and right extremes of the distribution are much lower, highlighting that the values are primarily concentrated in the central range.

The intervals [40.60, 42.60] and [52.60, 54.60] exhibit the lowest frequencies, further confirming that most measured values for mushrooms fall between 42.60 ± 6.39 and 54.60 ± 8.19 Bq/kg. In conclusion, the average concentration of these radionuclides in Albanian mushrooms is very low compared to that in most European countries, suggesting that the consumption of mushrooms does not pose a risk to the population. Although current measurements indicate no immediate risks, the bioaccumulate properties of mushrooms warrant continuous monitoring, particularly in areas susceptible to environmental changes or historical contamination.

Regular assessments will help maintain food safety standards and provide early warnings of potential public health risks. The results of this study contribute valuable data to the broader understanding of radionuclide behavior in food chains and support the implementation of effective environmental and food safety policies in Albania and beyond.

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References

F. Caridi, G. B. (2017). Radioactivity in wild-growing mushrooms of the Calabria region, south of Italy. Cogent Physics, 4:1, 1354957.

doi: https://doi.org/10.1080/23311940.2017.1354957

G. Zibold, J. D. (2001). Time-dependence of the radiocaesium contamination of roe deer: measurement and modeling, Journal of Environmental Radioactivity, Volume 55, Issue 1, 5-27.

doi:10.1016/S0265-931X(00)00184-3

Holmberg, P., & Marklund, H. (2013). The Pocket Guide to Wild Mushrooms. 307 West 36th Street, 11th Floor, New: Skyhorse Publishing, Inc.

ISHP, Ministria e Shendetesise. (2014, 10 24). Gjetur në Instituti i Shëndetit Publik: https://www.ishp.gov.al/wp-content/uploads/2019/07/U.Nr_.6097.5-dat%C3%AB-24.10.2014-Metodika-e-kontrollit-t%C3%AB-mallrave.pdf

Kalač, P. (2010). Trace element contents in European species of wild growing edible mushrooms: A review for the period 2000–2009. Elsevier, 2–15.

Kalac, P. (2019). Mineral Composition and Radioactivity of Edible Mushrooms. Nw P. Kalac, Mineral Composition and Radioactivity of Edible Mushrooms (fv. 5-7). 125 London Wall, London EC2Y 5AS, United Kingdom: Elsevier Inc.

Kla´n, J. R. (1988). Investigation of. Cˇeska´ Mykologie, 158–169.

Marzano FN, B. P. (2001). Radioactive and conventional pollutants accumulated by edible mushrooms (Boletus sp.) are useful indicators of species origin. Environ Res, 260-264. doi:10.1006/enrs.2001.4233

Morten Strandberg. (2004). Long-term trends in the uptake of radiocesium in Rozites apparatus, Science of The Total Environment, Volume 327, Issues 1–3, 315-321. doi:10.1016/j.scitotenv.2004.01.022.

N.Maho. (2022, 02 02). Monitor. Gjetur në Monitor: https://www.monitor.al/kerpudhat-grumbullojme-mes-20-40-tone-studimi-investimi-ne-perpunim-do-rriste-dukshem-vleren-e-shtuar/

Özlem, K. G. (2007,). Dynamic equilibrium of radiocesium with stable cesium within the soil–a mushroom system in a Turkish pine forest, Environmental Pollution, Volume 148, Issue 1, 316-324. doi:10.1016/j.envpol.2006.10.042.

P. Loaiza, V. B.-L. (2012). Air radioactivity levels following the Fukushima reactor accident measured at the Laboratoire Souterrain de Modane, France, Journal of Environmental Radioactivity, volume 144, 66-70. doi:0.1016/j.jenvrad.2012.03.003

Petr, D. V. (2006). Exponential drop of radiocesium activity in mushrooms due to the effect of acetic acid. Eur Food Res Technol, 139–143. doi:10.1007/s00217-005-0127-6

Polese, J.-M. (2005). The Pocket Guide to Mushrooms. Në J.-M. Polese, The Pocket Guide to Mushrooms (fv. 24-26). Slovakia: LOSANGE - 63400 Chamalières - France.

Tanase, C. P. (2009). Translocation of radioactivity from substrate to macromycetes in the Crucea (Romania) uranium mining area. J Radioanal Nucl Chem, 563-567. doi:10.1007/s10967-009-0035-5

Teherani, D. K. (1987). Accumulation of103Ru,137Cs and134Cs in fruitbodies of various mushrooms from Austria after the Chernobyl incident. J.RADIOANAL.NUCL.CHEM, 69-74. doi:10.1007/bf02165314

UNSCEAR. (2022). *Official Records of the General Assembly, Seventy-sixth Session, Supplement No. 46 (A/76/46).* New York: UNITED NATIONS PUBLICATION. doi: https://www.unscear.org/unscear/uploads/documents/unscear-reports/UNSCEAR_2020_21_Report_Vol.I.pdf

Yoshida, S. M. (1994). Concentrations of radiocesium and potassium in. Environ. Sci. 7, 63-70. doi:https://doi.org/10.11353/sesj1988.7.63

Zarubina, N. (2004). The content of accidental radionuclides in mushrooms from the 30-km zone of Chornobyl Nuclear Power Station. Mikologiya I Fitopatologiya, 36-40.

Zs. Szántó, *. M. (2007). Current radioactivity content of wild edible mushrooms: Journal of Radioanalytical and Nuclear Chemistry, Vol. 273, No.1, 167–170. doi: 10.1007/s10967-007-0730-z