PHYSICAL CHEMISTRY 2022

16th International Conference
on Fundamental and Applied Aspects of
Physical Chemistry

Proceedings
Volume II

September 26-30, 2022
Belgrade, Serbia

Title: PHYSICAL CHEMISTRY 2022, 16th International Conference on Fundamental and Applied Aspects of Physical Chemistry (Proceedings) **ISBN** 978-86-82475-41-5
Volume II: ISBN 978-53-82475-43-9
Editors: Željko Čupić and Slobodan Anić
Published by: Society of Physical Chemists of Serbia, Studentski Trg 12-16, 11158, Belgrade, Serbia
Publisher: Society of Physical Chemists of Serbia
For Publisher: S. Anić, President of Society of Physical Chemists of Serbia
Printed by: "Jovan", <Printing and Publishing Company, Ilije Đuričića 19, Belgrade, 200 Copies
Number of pages: 6+320, Format A4, printing finished in December 2022

Text and Layout: "Jovan"

200 - *Copy printing*

CONTENT

PHYSICAL CHEMISTRY 2022

16th International Conference on Fundamental and Applied Aspects of Physical Chemistry

Organized by

The Society of Physical Chemists of Serbia

in co-operation with

Institute of Catalysis Bulgarian Academy of Sciences

and

Boreskov Institute of Catalysis Siberian Branch of Russian Academy of Sciences

and

University of Belgrade, Serbia:

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RADIOACTIVITY IN SOIL FROM REGION DONJI MILANOVAC, NP ĐERDAP IN 2018-2020

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ABSTRACT

From June 2018 to 2020, 87 soil samples were collected from 10 locations in the National Park Đerdap, region of Donji Milanovac. The radionuclide content (Bq kg^{-1}) in collected soil was: for ^{40}K 80.6-1005; ^{238}U 7.4-60.2 and ^{232}Th 5.3-13.1. The apsorbed dose rate in air (nGy h^{-1}) on the territory of NP Đerdap is in the range of 18.5 to 98.8, with an average value of 53.6. Values of the external gamma dose were in the range of expected values and close to the average values in the world. The mean value of the annual effective dose in the region Donji Milanovac is 0.066 mSv and is lower than the mean value in the world.

INTRODUCTION

NP Đerdap is located in the North-Eastern part of Serbia and covers part of the area of the Đerdap gorge (Iron Gate) in the middle course of the Danube. It includes parts of the Severni Kučaj, Miroč and Štrbac massive 2-10 km wide, and also a part of the Danube that belongs to the Republic of Serbia. The very complex relief in NP Đerdap, specific climate, a large number of relic species and phytocenosis, and also a great variety in the lithological composition of rocks, genetic affiliation, and geological age have caused the formation of a variety of soil types with different properties and production potential [1]. The land is a dynamic system in which different physic-chemical and biological processes occur. It is composed of two components: mineral and organic. Rocks that are part of the Earth's crust contain a certain concentration of natural radionuclides (uranium, radium, thorium, and potassium) that are also present in the soil formed when they decompose and their contribution to natural radioactivity in the environment is the highest [2]. Primordial radionuclides such as ^{238}U, ^{232}Th and ^{40}K have a long physical half-life and significantly differ in physical and geochemical properties from other radionuclides. Radionuclides such ^{238}U, ^{232}Th and ^{40}K are present more homogeneously in the environment than manmade ones with worldwide average activity concentrations in soil 400 Bq kg^{-1}, 30 Bq kg^{-1}, and 35 Bq kg^{-1}, respectively [3]. Knowledge of their distribution and concentration plays a significant role in radiation protection.

EXPERIMENTAL

Soil samples (87) were collected in the NP Đerdap, the Donji Milanovac region, from 10 management units (MU) (Boljetinka (*1*), Crni vrh (*2*), Pecka bara (*3*), Kosovica (*4*), Manastirički gaj (*5*), Prapežešće (*6*), Brzujka (*7*), Zlatica (*8*), Boljetinska reka (*9*), Porečke šume (*10*)), up to the depth of 10 cm, in June from 2018 to 2020. Localities were carefully chosen based on the results obtained for bioindicator radioactivity in previous years [4]. After arrival at the laboratory, the samples were cleaned by removing visible impurities, dried, mechanically chopped, homogenized, and packed into Marinelli's vessels with a volume of 0.5 L, hermetically sealed with paraffin, and left to sit for 40 days to establish radioactive stability of post-radon series members ^{238}U, prior to gamma spectrometric analysis. The ^{238}U content was determined based on gamma lines: ^{234}Th (63 and 93 keV) and ^{234}Pa (1001 keV). The ^{232}Th content was determined based on gamma lines ^{228}Ac (338, 911 and 969 keV). The ^{40}K content was determined based on the gamma line at 1460 keV. The sample mass was up to 600g. Detector calibration was performed using three different radioactive reference materials in the Marinelli geometry: 1) Silicone resin (Czech Metrological Institute Praha (CMI Praha), Cert. No. 1035-SE-40517-17, Type MBSS 2 (^{241}Am, ^{109}Cd, ^{139}Ce, ^{57}Co, ^{60}Co, ^{137}Cs, ^{113}Sn, ^{85}Sr, ^{88}Y, ^{51}Cr), 490.0g, density: 0.98 ± 0.01 gcm^3, vol. 500.0 ± 5.0 cm^3ref. date 1.9.2017); 2) silicone resin CMI Praha, Cert. No. 1035-SE-40661/14, Type MBSS 2 (^{241}Am, ^{109}Cd, ^{139}Ce, ^{57}Co, ^{60}Co, ^{137}Cs, ^{113}Sn, ^{85}Sr, ^{88}Y, ^{51}Cr), 490.0g, density: 0.98 ± 0.01 g/cm^3, vol. 500.0 ± 5.0 cm^3, ref. date 1.10.2014). All samples were measured for 60000 s. A semiconducting germanium high purity detector of the n-type, ORTEC – AMETEK, USA, with 8192 channels, resolution of 1.65 keV, and relative efficiency of 34% at 1.33 MeV for ^{60}Co was used for detection. Spectra were analyzed using the Gamma Vision 32 software package [5]. The total standard error of the method was estimated to be around 20%. The absorbed dose rate in air (nGy h^{-1}) and the annual effective dose calculations were performed according to the recommendations of UNSCEAR [6].

RESULTS AND DISCUSSION

Table 1 shows the mean value obtained from measuring the content of radionuclides (^{40}K, ^{232}Th and ^{238}U) in soil, collected from 2018 to 2020 on the territory of the D. Milanovac region. Also, values of the apsorbed dose rate in air D (nGy h^{-1}) and annual effective dose D_E (mSv) are given in Table 1. The mean value (Bq kg^{-1}) of the radionuclide content in soil collected on the region D. Milanovac (in 2018, 2019, 2020) was ^{40}K 498 (536, 497, 470), ^{238}U 32.1 (33.4, 35.5, 27.9) and ^{232}Th 29.6 (34.4, 32.4, 23.2). The content (Bq kg^{-1}) in soil collected in region Donji Milanovac in 2018 (2019, 2020) was: ^{40}K 106-887 (80.6-918, 245-1005), ^{238}U 16.9-60.2 (8.8-53.9, 7.4-46.1) and ^{232}Th 13.1-60.6 (8.2-55.7, 5.3-45.3). These values are in the range determined in our previous research and in the worldwide research [6].

The values of Pearson's coefficient for U-Th are 0.891, which indicates a very strong correlation and common origin; while for K-U 0.489 and K-Th 0.571 indicate a correlation.

The apsorbed dose rate in air (nGy h^{-1}) radiation originating from activity of radionuclides in soil can be calculated using the following equation:

$$D(nGyh^{-1}) = 0.462xC_{Ra} + 0.604xC_{Th} + 0.0417xC_K \quad (1)$$

where C_{Ra}, C_{Th}, C_K are the radionuclide content in soil, while according to recommendations of UNSCEAR, corresponding conversion coefficients are: 0.462 nGy h^{-1}/(Bq kg^{-1}), 0.604 nGy h^{-1}/(Bq kg^{-1}), 0.0417 nGy h^{-1}/(Bq kg^{-1}), respectively [3]. The apsorbed dose rate in air (nGy h^{-1}) in 2015 on the territory of NP Đerdap is in the range from 9.8 to 70.5, while in 2016 it was from 4.6 to 66.3 [7]. The mean value of the apsorbed dose rate in air (nGy h^{-1}) in the period from 2018 to 2020 is 58.8, 56.8, and 46.7. The mean value of the apsorbed dose rate in air (nGy h^{-1}) is in the range of 23.1 to 98.8. These values are in the range of values obtained in the previous research globally [6].

The annual effective dose was determined as

$$D_E\,(mSv) = Dx0.7x0.2x365x24 \quad (2)$$

The annual effective dose (mSv) in 2015 was from 0.014 to 0.087, while in 2016 it was from 0.006 to 0.081 and they are the same order of magnitude as values determined on other locations in Serbia [7]. The mean value of the annual effective dose in the region Donji Milanovac is in the range from

0.023 to 0.121 mSv. The average value of the annual effective dose (mSv) in soil collected in the period from 2018 to 2020 is 0.072, 0.070, and 0.057. These values are within the measurement range of the mean value globally determined (0.070 mSv).

Table 1. Mean value radionuclide content (Bq kg^{-1}) in soil collected from 2018 to 2020 in the Donji Milanovac region and values of the apsorbed dose rate in air D (nGy h^{-1}) and annual effective dose D_E (mSv)

MU* (samples)	Year	^{40}K (Bq kg^{-1})	^{238}U (Bq kg^{-1})	^{232}Th (Bq kg^{-1})	D (nGy h^{-1})	D_E (mSv)
1 (3)		229	23.7	18.3	31.6	0.039
2 (9)		503	38.4	38.6	62.2	0.076
3 (4)		793	39.6	47.1	80.1	0.098
4 (2)		502	33.4	35.8	58.1	0.071
5 (2)	2018.	211	18.7	14.8	26.4	0.032
6 (2)		710	34.1	33.4	65.7	0.081
7 (2)		823	27.4	33.6	67.5	0.083
1 (6)		425	27.4	24.0	45.00	0.055
2 (14)	2019.	478	41.9	50.8	62.5	0.077
3 (3)		788	46.6	45.2	81.9	0.101
8 (3)		503	27.2	24.0	48.2	0.059
9 (5)		457	25.8	23.7	45.4	0.056
1 (4)		344	22.5	21.5	37.8	0.046
2 (9)	2020.	510	39.3	36.7	61.8	0.076
3 (3)		706	42.2	41.8	74.4	0.097
8 (7)		454	20.2	11.6	35.4	0.043
9 (4)		353	16.5	9.90	28.5	0.035
10 (5)		474	22.9	16.0	40.2	0.049

*MU management unit

Based on the Guidelines [3,6] the annual effective dose for the population is increased if it is higher than 1 mSv for a year. The calculated average values show that the effective dose for the population in the Donji Milanovac region is low.

CONCLUSION

Radionuclides ^{40}K, ^{238}U, and ^{232}Th were detected and measured in all investigated samples. The average values of radionuclide content in soil collected from 2018 to 2020 are in the range of average values of radionuclide content in the soil worldwide.

The apsorbed dose rate in air originating from radionuclide activity in soil was calculated. Total and annual effective doses were calculated and they are in the range of average values throughout the world.

Acknowledgment

The research presented in this work was performed with the financial backing of the Ministry for Education, Science and Technological Development of the Republic of Serbia, as part of financing scientific research at the Institute for the Application of Nuclear Energy – INEP, contract number 451-03-68/2022-14/200019.

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