Ash radioactivity level and ambient dose equivalent rate in the vicinity of the TPP „Kosovo B“ Obilić

Nivo radioaktivnosti u pepelu i jačina ambijentalnog doznog ekvivalenta u okolini TE “Kosovo B” Obilić

Ljljana Gulan[1], Stanimirka Jovanović[1], Marija Mitrović[2,*], Jelena M. Stajić[3]

[1]*University of Priština in Kosovska Mitrovica,Faculty of Sciences and Mathematics, Lole Ribara 29,38220 Kosovska Mitrovica, Serbia*

[2]*School of Electrical and Computer Engineering,Vojvode Stepe 232, 11000 Belgrade, Serbia*

[3]*University of Kragujevac, Institute for Information Technologies, Department of Science, Jovana Cvijica bb, 34000 Kragujevac, Serbia*

[*] *Corresponding_author: marijam@viser.edu.rs*

Abstract

In this paper, the specific activities of radionuclides in ash and ambient dose equivalent rate of gamma radiation in the air in the vicinity of the thermal power plant (TPP) "Kosovo B", Obilić were measured. Five samples for determination the activity of radionuclides in the ash by gamma spectrometric method were taken from the ash dump of the TPP "Kosovo B". The specific activities of the radionuclide ^{226}Ra in the ash are in the range of 9.5 ± 0.6 Bq/kg - 22.4 ± 0.8 Bq/kg. The specific activity of ^{232}Th is in the range of 9.7 ± 0.7Bq/kg - 13.42 ± 0.8 Bq/kg, and the specific activity of ^{40}K is in the range of 22 ± 2Bq/kg - 65 ± 3 Bq/kg. The radiation risk index based on the obtained values is 0.48. The results of measuried ambient dose equivalent rate of gamma radiation on the ground and at a height of 1 m from the ground, at 40 locations, show that the values are within the permitted limits of the world average in the wider study area. The obtained values were measured with the RADEX RD1053+ detector, and ranged from 0.12-0.25 μSv/h on the ground, and 0.11-0.21 μSv/h at the height of 1 m. From the radiological point of view, there are no significant exceedances of the level of radioactivity in the vicinity of the TPP "Kosovo B", Obilić.

Keywords:*radioactivity; ash; ambient dose equivalent rate;radiation risk;thermal power plant*

Izvod

U ovom radu izmerene su specifične aktivnosti radionuklida u pepelu i jačine ambijentalnog doznog ekvivalenta gama zračenja u vazduhu u okolini termoelektrane (TE) „Kosovo B“, Obilić. Pet uzoraka za određivanje aktivnosti radionuklida u pepelu gamaspektrometrijskom metodom uzeto je sa deponije pepela TE „Kosovo B“. Specifične aktivnosti radionuklida ^{226}Ra u pepelu su u opsegu 9,5 ± 0,6Bq/kg – 22,4 ± 0,8 Bq/kg. Specifična aktivnost ^{232}Th je u opsegu 9,7 ± 0,7Bq/kg – 13,42 ± 0,8 Bq/kg, a specifična aktivnost ^{40}K je u opsegu 22 ± 2Bq/kg - 65 ± 3 Bq/kg. Indeks radijacionog rizika na osnovu dobijenih vrednosti je 0,48. Rezultati merenja jačine ambijentalnog doznog ekvivalenta gama zračenja na tlu i na visini od 1 m od tla, na 40 lokacija, pokazuju da se vrednosti kreću u dozvoljenim granicama svetskog proseka u širem istraživanom prostoru. Dobijene vrednosti merene su detektorom RADEX RD1053^{+} i kreću se u opsegu 0,12-0,25 μSv/h na tlu, i 0,11-0,21 μSv/h na 1 m visine. Sa radiološke tačke gledišta nema značajnih prekoračenja nivoa radioaktivnosti u okolini TE „Kosovo B“, Obilić.

Ključne reči: *radioaktivnost; pepeo; jačina ambijentalnog doznog ekvivalenta; radijacioni rizik; termoelektrana*

Introduction

Natural radiation in the environment is constant and inevitable. Since the formation, the planet Earth has been a permanent reservoir of radioactivity. The most of primordial radionuclides belongs to one of the three natural radioactive series ^{238}U, ^{235}U and ^{232}Th, which have a very long half-life. Natural radionuclides ^{226}Ra, ^{232}Th and ^{40}K are present in all soils and rocks. They have a significant impact on the environment and public health, so monitoring of their concentrations in the environmental samples is necessary. Concentrations of radionuclides in soil and atmosphere depend on several factors: mineral composition of the substrate, permeability and porosity of the soil, brittleness of rocks, atmospheric condition (temperature, pressure, wind, moisture, etc). The range of values of the total annual exposure of the population to natural radiation sources is 1-13 mSv, which depends mainly on the geological area; the worldwide average activity concentrations of ^{238}U (^{226}Ra), ^{232}Th, and ^{40}K in soil are 33, 45, and 412 Bq/kg, respectively [1].

The industrial development has led to an increase of radioactivity levels in the environment, which is manifested as a development of the nuclear industry, production and testing of nuclear weapons, emission and distribution of radioactive substances, ore and mineral exploitations, use of fertilizers, etc. The increased content of natural radionuclides can occur as a result of using the raw materials from industrial processes, since radionuclides are released into the biosphere by exploitation and processing. All building materials contain natural radionuclides in a greater or lesser extent, mostly in the permitted values.

The Republic of Serbia is rich in ores and has coal reserves for decades. This has led to the construction of TPPs in the basins of Kosovo and Metohija, in the municipality of Obilić. The presence of TPPs "Kosovo A" and "Kosovo B", surface mines Belaćevac and Dobro Selo and ash dumps in Kruševac and Plemetina, poses a risk to the population of nearby settlements. The construction of the TPP "Kosovo B" began in 1977, where two units were built with the total power of 680 MW. Based on previous research, Kosovo and Metohija has significant reserves of lignite on its territory. Coal is the most important energy resource of Kosovo and Metohija, which accounts for about 97% of total electricity production. The annual production of coal is about 6.5 million tons. For the production of electricity, the TPP "Kosovo B" uses lignite from the surface mines Belaćevac and Dobro Selo. Lignite is extracted by excavators and transported by two conveyor belts to the separation (capacity between 1400 t/h - 33,000 tons per day per strip). Lignite is deposited near the TPP "Kosovo B" [2]. The water supply of TPP "Kosovo B" is through the Ibar-Lepenac canal, and it is discharged into the River Sitnica.The ash obtained by lignite burning is disposed near the TPP "Kosovo B". This ash dump is often flooded, causing pollution of the Sitnica riverbed.

It is always desirable and useful to measure the gamma dose rate in an area in order to have preliminary information about radioactivity levels in the environment. A continuous monitoring of environmental radioactivity is necessary to determine exceedances. Due to radiation cumulative effect, no exposure is without risk. Therefore, in order to assess the radioactivity levels around the TPP "Kosovo B", the aim of this paper was to determine the specific activity of natural radionuclides ^{226}Ra, ^{232}Th and ^{40}K in ash samples from the nearby dump and to measure the values of ambient dose equivalent rate in the air at 40 locations.

Materials and methods

The study area is the vicinity of the TPP "Kosovo B", Obilić, not far from the city of Priština, which is the central part of Kosovo and Metohija. The investigations were performed in the settlements nearby TPP "Kosovo B": Plemetina, Obilić, Kruševac, Kosovo Polje, Kuzmin and Dobri Dub (Figure 1).

Ash samples for gamma spectrometric measurements were taken from the ash dump of the TPP "Kosovo B", not far from the TPP itself in the setllement Plemetina. Gamma spectrometric method is often used for radioactivity monitoring of various samples in the environment according to the

adopted sampling protocols. Ash samples were collected at five locations from the ash dump of the TPP "Kosovo B" in May 2021. Samples were collected from a depth of 0-10 cm, packed in plastic bags and transported to the laboratory. The weight of the sample ranges from 369.5 g to 481.9 g. Ash samples were sealed in the Marinelli beakers for 30 days to establish a radioactive equilibrium between radium and its progenies. For the purpose of measurement, HPGe, coaxial germanium detector, model GEM30-70 (ORTEC) was used. The energy resolution of the detector (Full Width at Half Maximum - FWHM) is 1.85 keV at 1.33 MeV (^{60}Co) and 725 eV at 122 keV (^{57}Co), and the relative efficiency of the detector is 32% at 1.33 MeV (^{60}Co). To reduce the natural background, detector is shielded with a 10 cm thick lead. Standard mixture of gamma-emitting isotopes (MBSS 2) provided by the Czech Metrology Institute was used for system calibration. After recording the spectrum, which lasted 21600 s for each sample and for the background, the previously recorded background for the detector was subtracted. Analysis of photo peaks according to the energies of the corresponding radionuclides was done using the MAESTRO 32 program; specific activities of natural radionuclides ^{226}Ra, ^{232}Th and ^{40}K in the ash samples were determined using the intensities and gamma lines of radionuclides given in Table 1.

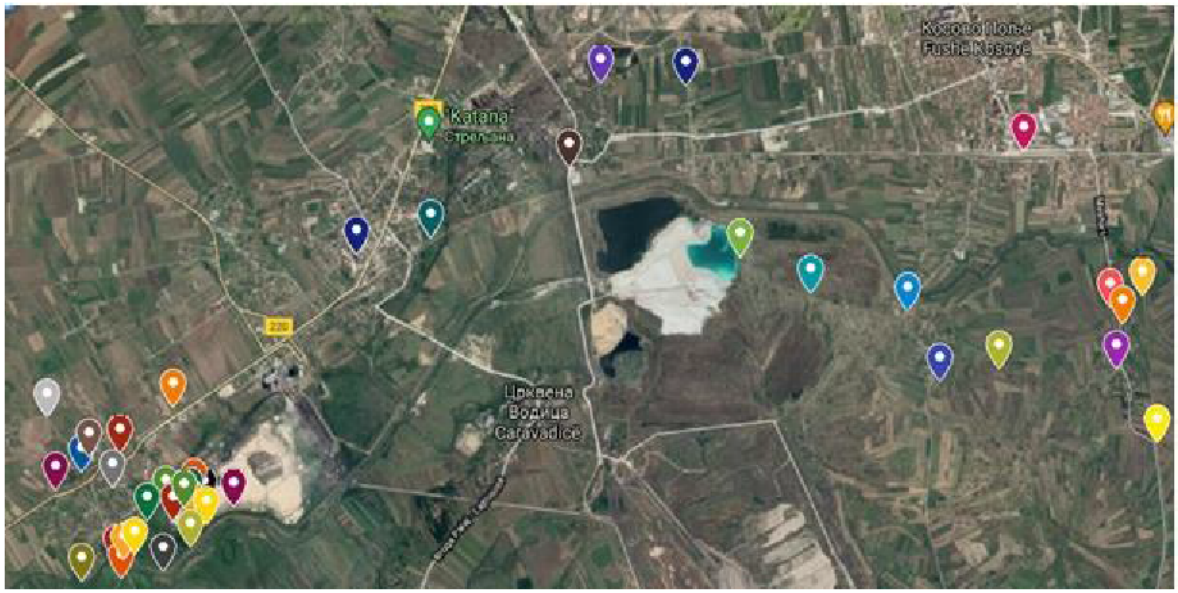

Figure 1. *Study area and marked locations in vicinity of TPP "Kosovo B"*

Table 1. Intensities and gamma lines of radionuclides

Radionuclide	Progeny	Gamma energy (keV)	Intensity (%)
^{226}Ra	^{214}Pb	351.9	37.6
	^{214}Bi	609.3	46.1
^{232}Th	^{228}Ac	911.1	25.8
	^{228}Ac	968.9	15.8
	^{208}Tl	583.0	84.5
	^{208}Tl	860.6	12.4
^{40}K		1460.7	10.7

To determine the specific activities of radionuclides the following formula was used:

$$A_E = \frac{N_E}{m \cdot t \cdot \varepsilon_E \cdot I_\gamma} \quad (1)$$

where N_E - number of counts under the photopeak at energy E, m - mass of sample (kg), t - spectrum recording time (s), ε_E- efficiency of detector for gamma line at energy E, I_γ - absolute intensity of gamma line at energy E.

In the same time, the measurements of ambient dose equivalent rate were performed at 40 locations, including five locations at ash dump. Measurements were performed during May 2021, in time intervals from 12:00 to 15:00. During the measurements, as well as two days earlier, there was no precipitation. Geiger-Miller counter, type RADEX model RD 1053^+ was used for ambient dose equivalent rate measurements [3]. RADEX RD 1053^+ is a detector of ionizing radiation used to measure gamma dose rate of natural radiation of terrestrial origin and radiation in the air originating from radionuclides from the decay of radon; it can measure outdoor and indoor radiation and in material. The measurement cycle is 40 seconds for ambient gamma dose in the range of 0.05 to 9.99 μSv/h. The values are constantly averaged by the detector - this is normal, because the background of natural radiation changes. RADEX RD 1053^+ detector was calibrated using the isotope ^{137}Cs. The measurement uncertainty for gamma radiation is ±15%.

Results and discussion

The obtained values of specific activity of radionuclides in the ash samples from ash dump of the TPP "Kosovo B" are given in Table 2. The specific activity of ^{226}Ra in the samples is in the range of 9.5 ± 0.6 - 22.4 ± 0.8 Bq/kg. A mean concentration of ^{226}Ra in ash samples from dump is 15.9 Bq/kg. The specific activity of ^{232}Th in the samples is in the range of 9.7 ± 0.7 - 13.42 ± 0.8 Bq/kg. The mean ^{232}Th concentration is 11.4 Bq/kg for ash dump.The specific activity of ^{40}K in the samples is in the range of 22 ± 2 - 65 ± 3 Bq/kg. The mean ^{40}K concentration is 46.4 Bq/kg.

Ash samples show low activity concentrations of natural radionuclides. Due to low radioactivity, ash can be used in the construction and chemical industries.

A study conducted in the municipality of Obilić around TPPs in 1997 showed the presence of radionuclides ^{226}Ra, ^{232}Th and ^{40}K in ash samples in the range: 15-32 Bq/kg, 15-61 Bq/kg and 208-245 Bq/kg, respectively [4]. Subsequently, in 2013, the values of ^{226}Ra, ^{232}Th and ^{40}K in ash samples were in range: 26-35Bq/kg, 27-34 Bq/kg and 104-146 Bq/kg, respectively [5]. The ranges of radionuclide values in the ash samples obtained in this paper are much lower compared to the TPP "Nikola Tesla": 91-152 Bq/kg, 71-104 Bq/kg and 311-509 Bq/kg, respectively for ^{226}Ra, ^{232}Th and ^{40}K [6]; these are also lower ranges compared to other studies of radionuclides in ash samples in the vicinity of TPPs in Serbia, "Nikola Tesla" and "Kolubara": 45-270 Bq/kg, 29-121 Bq/kg and 174-489 Bq/kg, respectively for ^{226}Ra, ^{232}Th and ^{40}K [7].

Table 2. Specific activity of radionuclides in ash and ambient dose equivalent rate

Sample	Specific activity of radionuclides (Bq/kg)			Ambient dose equivalent rate (μSv/h)	
	^{226}Ra	^{232}Th	^{40}K	On the dump	1 m above dump
Ash 1	9.5 ± 0.6	11.3 ± 0.7	57 ± 3	0.21	0.18
Ash 2	22.4 ± 0.8	10.9 ± 0.8	22 ± 2	0.22	0.20
Ash 3	22.3 ± 0.9	12 ± 1	50 ± 3	0.17	0.15
Ash 4	12.3 ± 0.6	9.7 ± 0.7	38 ± 2	0.14	0.12
Ash 5	12.9 ± 0.7	13.2 ± 0.8	65 ± 3	0.16	0.15

The radiation risk index due to external exposure is defined as external hazard index as follows:

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad (2)$$

where A_{Ra}, A_{Th}, A_K are activity concentrations (in Bq/kg) ^{226}Ra, ^{232}Th and ^{40}K, respectively. Based on the obtained results, the radiation risk index in the vicinity of the TPP "Kosovo B" is 0.48. Radiation risk due to external exposure is considered negligible if H_{ex} value is less than one, as in this case. A mean value of external hazard index H_{ex} from ash samples obtained in the vicinity of the TPP "Kosovo B" are lower than those obtained in TPPs in "Nikola Tesla A", "Nikola Tesla B", "Morava" and "Kolubara": 0.68, 0.64, 0.68 and 0.63, respectively, but higher than external hazard index calculated for ash samples from "Kostolac" [8].

Figure 2. presents the measured values of ambient dose equivalent rate, outdoors on the ground and at 1 m above the ground around the TPP "Kosovo B". Humidity was in the range of 37-47%, and the air temperature was between 23 and 28 ºC. The ranges of values of ambient dose equivalent rate is 0.12-0.25 μS /h (mean 0.16 μSv/h) and 0.11-0.21 μSv/h (mean 0.14 μSv/h), respectively on the ground and at 1 m of height. The results of ambient dose equivalent rate of gamma radiation in the studied area are within the world average. Value on the ground were always higher than in the air, which is expected since the soil is the main source of radioactivity. Pearson corelation coefficient, r = 0.95 is obtained between measurements conducted in the ground and at 1 m above ground. As mentioned, they depend on the geological characteristics, soil type and terrain on which the measurements were made.

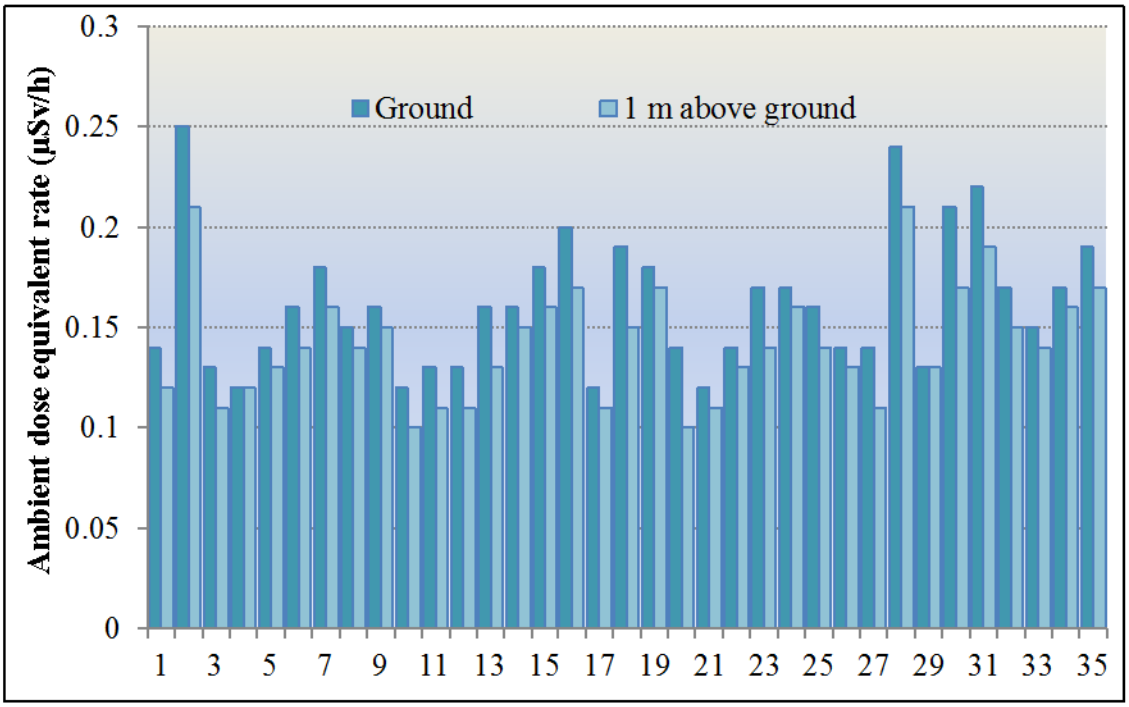

Figure 2. *Ambient dose equivalent rate at 35 locations in the vicinity of TPP "Kosovo B", Obilić*

Conclusion

Based on obtained results, there are no significant exceedances of the level of radioactivity in the vicinity of the TPP "Kosovo B", Obilić. Results of ambient dose equivalent rate are within the worldwide average. From the radiological point of view, ash radioactivity of the TPP "Kosovo B" and mean external hazard index are lower than those in TPPs in Serbia.

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References

1. UNCSEAR. (United Nations Scientific Committee on the Effects of Atomic Radiation), Report to the general assembly with Scientific Annexes. Annex B: Exposure of the public and workers from various sources of radiation. New York, USA, 2010.
2. Izvršni rezime, Projekat Tehničke Pomoći za Centralu sa Pogonom na Lignit (LPTAP), Grant Svetske banke: IDA H 254 KOS/H 318 KOS, Strateška Ekološka i Socijalna Procena, Public Disclosure Authorized, E1367 VOL.5 ,2008.
3. RADEX. 2017. Radiation Detector RD1503+. Retrieved from https: https://www.quarta-rad.ru/en/catalog/dozimetrradiometr-radon/dozimetr-radex-rd1503/
4. Adrović, F.D., Todorović, D., Ninković, M.M., Prokić, M.,. Investigation of the contents of natural radionuclides in coal and ashes from Kosovian power plant. In: Proceedings of the IRPA Symposium on Radiation Protection, Prague, 1997, pp. 334-336.
5. F.Hasani, F. Shala, G. Xhuxha, M.K.Xhixha, G. Hodolli, S.Kadiri, E. Bylyku, F.Cfarku, Naturally occurring radioactive materials (NORMs) generated from lignite-fired power plants in Kosovo, Journal of Environmental Radioactivity 138, 2014, 156-161.
6. Miletić S., Radonjić V., Radanović S., Filipovic J., Gržetić I. Prirodna radioaktivnost uglja i letećeg pepela u termoelektrani „Nikola Tesla B“ Hem. Ind.67(5), 2013, 729–738.
7. Janković M., Rajačić M., Todorović D., Sarap N., Nikolić J., Pantelić G., Krstić M. Study of radioactivity in environment around power plants TENT A and Kolubara due to coal burning for 2015. RAD Conference Proceedings, vol. 1, 2016, 84-89.
8. M.M. Janković, D.J. Todorović, J.D. Nikolić, Analysis of natural radionuclides in coal, slag and ash in coal-fired power plants in Serbia, University of Belgrade, Institute Vinča, Radiation and Environmental Protection Departman. Belgrade, 47 (2) B (2011), 149-15.