

RADIOACTIVE CONTAMINATION OF FOOD CHAIN AROUND COAL MINE AND COAL-FIRED POWER STATIONS

by

**Gordana S. VITOROVIĆ^{1*}, Branislava M. MITROVIĆ¹, Velibor Dj. ANDRIĆ¹,
Mirjana D. STOJANOVIĆ², Mirjana V. LAZAREVIĆ-MACANOVIĆ¹,
and Duško P. VITOROVIĆ³**

¹Department of Radiology and Radiation Hygiene, Faculty of Veterinary Medicine, University of Belgrade, Belgrade, Serbia

²Institute for Technology of Nuclear and other Mineral Raw Materials, Belgrade, Serbia

³Institute of Animal Sciences, Faculty of Agriculture, University of Belgrade, Belgrade, Serbia

Short paper

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The main aim of this study was to investigate the impact of the coal mine in Lazarevac, and the coal-fired power stations in Obrenovac, on the activity concentrations of radionuclides ^{40}K , ^{238}U , ^{232}Th , and ^{137}Cs in some parts of human food chain of people living in the surrounding area. The obtained results showed that natural environment around the examined coal mine and the coal-fired power stations are not significantly affected by the emission of primordial radionuclides. The activity concentrations of ^{238}U in the soil around the open coal mine and the coal processing installations (66.4-76.0 Bq/kg) and in the soil around the coal-fired power stations (55.5-61.2 Bq/kg) were not significantly higher than the average values in Serbia. The significant increase in the activity concentrations of natural radioisotopes in the samples of soil, vegetation, and animal products, was not confirmed. Food of animal origin used in human consumption is safe, *i. e.* not contaminated by radiation.

Key words: food chain, radioactivity, coal mine, coal-fired power station

INTRODUCTION

Worldwide use of nuclear energy, coal combustion, production and application of phosphorus fertilizers, mining industry and radioactive waste production, all contribute to distribution of natural radioactivity [1].

Energy production from coal is one of the major sources of increased exposure of man to artificially perturbed natural radioactivity. Coal contains trace quantities of all primordial radionuclides and their decay products, in particular ^{40}K and the decay series headed by ^{232}Th and ^{238}U . The radioactivity in coal is comparable with that in other environmental materials. However, all the stages of the coal fuel cycle including mining, combusting, and utilization or disposal of ash, cause minor perturbation of the natural radiation. The radioactive contamination of the environment from the above source, is expected to be concentrated around the centres of extraction and utilization of coal [2, 3]. The problem associated with the use of coal is very high ash content. Therefore, the problem for the future should be addressed from radio-ecological and pollution points of view [4].

Coal-fired power station spreads around the pollution and moves the radioisotopes to local ecosystem at a distance of several kilometres [5]. Dust emitted to the atmosphere by the coal-fired power station is a dangerous and serious problem for the environment [6]. However, the significant increase in the activity concentrations of natural radioisotopes in the samples of air, soil or vegetation have not been detected experimentally, nor even in the territories surrounding coal-fired power plants. In general, the activity concentrations of primordial radioisotopes in coal are of the same order as those in common rock and soils, on average 35 Bq/kg for ^{238}U [7]. Occasionally, a high concentration of uranium can be found in coal. Mining and utilization of uraniumiferous coal resulted in considerably elevated activity concentration of ^{238}U , ^{226}Ra in the soil, through the deposition of fly ash and slag. It was documented that the soil around a coal-fired plant can be contaminated with a measurable amount of radioactivity [8, 9]. The activities of natural radionuclides, which are discharged to the atmosphere from a coal-fired power plant depend on a number of factors. One of them is the efficiency of the filtering system.

The main pathways through which the population living in the vicinity of a coal-power plant, are ex-

* Corresponding author; e-mail: radijacija@net.bg.ac.rs

posed to the enhanced level of natural radionuclides are inhalation and ingestion, following deposition of the activity on the ground. Therefore, the activity concentrations of radionuclides in the soil and food chain should be examined. The results of our previous research [10], during years 2007 and 2008 showed that the samples of feedstuffs, animal products, and meat of wild animals from natural environment around Belgrade, where the most food for human consumption originates from, are safe for human consumption regarding radioactivity.

The aim of this paper was to determine the activity concentration of radionuclides ^{40}K , ^{238}U , ^{232}Th , and ^{137}Cs in the samples of soil, feedstuffs and animal products collected from the people living on the territory around the coal mine in Lazarevac and the coal-fired power plants in Obrenovac.

MATERIALS AND METHODS

The samples were collected during 2011 in the area of three regions (Šopići, Stepojevac, and Vreoci) in the vicinity of Lazarevac open coal mine and the installation for coal processing (washing, drying *etc.*), and in the area of two locations (Konatica and Ušće) around Obrenovac, in the vicinity of the coal-fired power plants.

From all these sites, 3 samples of each sampling type were taken for analysis. The soil samples, in amount of 3 to 5 kg were collected from a depth of 10-29 cm, homogenized, dried at the temperature of 105 °C and put in 1 L Marinelli beakers. The feedstuffs (alfalfa and maize) samples were collected, dried at air temperature, ground and put in 1 L Marinelli beakers. The samples of milk, cheese, meat, and eggs were collected and put in 1 L Marinelli beakers in fresh weight.

All the samples were kept for 40 days prior to measurements, in order to achieve a radioactive equilibrium.

Radionuclides activity concentration was determined by gamma spectrometric measurement on HPGe detector (ORTEC, USA), with relative efficiency of 30% and energy resolution of 1.85 keV (1332.5 ^{60}Co). Radioactive measurements were performed according to the procedure described in our previous work [11].

All obtained results were expressed as means standard deviation.

RESULTS AND DISCUSSION

Table 1. represents the average values of measured results in locations of Šopići, Stepojevac, and Vreoci, around Lazarevac. It shows the activity concentrations of investigated radionuclides, in the samples of food chain collected in the vicinity of the open coal mine and the coal processing installation, and tab. 2. shows the average values of the measured results in locations of Konatica and Ušće, around Obrenovac, in the vicinity of the coal-fired power plants.

^{40}K represents the most dominant natural radioactive element. The detected average activity concentrations of this radionuclide, were high in both the samples of soil (cultivated and uncultivated) and alfalfa, while in the samples of maize the activity concentrations were significantly lower.

The activity concentrations of ^{238}U in the soil around the open coal mine and the coal processing installations (66.4-76.0 Bq/kg) and in the soil around the coal-fired power stations (55.5-61.2 Bq/kg) were not significantly higher from the average values in Serbia [1, 10] and from food chain samples in Belgrade environment [11]. Similar results were obtained for ^{226}Ra and ^{232}Th activity concentrations in the soil. One

Table 1. ^{40}K , ^{238}U , ^{226}Ra , ^{232}Th , and ^{137}Cs activity concentrations in the soil, feedstuffs, milk, cheese, eggs, and meat of domestic animals, in Lazarevac, around the open coal mine (average values for locations Šopići, Stepojevac, and Vreoci)

Samples	^{40}K [Bq kg ⁻¹]	^{238}U [Bq kg ⁻¹]	^{226}Ra [Bq kg ⁻¹]	^{232}Th [Bq kg ⁻¹]	^{137}Cs [Bq kg ⁻¹]
Soil cultivated	680 21	66.4 3.2	58.7 4.1	57.0 1.9	33.2 1.3
Soil non-cultivated	660 20	76.0 5.1	69.0 2.6	60.8 1.7	61.9 1.8
Alfalfa	760 10	<5.6	1.1 0.2	<1.2	1.1 0.2
Maize	120 4	<1.2	<1.3	<0.2	<0.1
Cow milk	55 2	<1.2	<1.5	<0.2	<0.1
Goat milk	73 3	<1.2	<1.3	<0.3	1.3 0.1
Cow cheese	40 2	<1.2	<1.5	<0.3	<0.1
Eggs (chicken)	41 2	<1.4	<1.7	<0.3	<0.1
Beef meat	96 3	<1.4	0.7 0.2	<0.3	<0.1
Sheep meat	92 4	<2.5	<1.5	<0.3	<0.1
Pork meat	99 3	<1.3	0.4 0.1	<0.2	<0.1
Chicken meat	73 3	<1.4	0.5 0.1	<0.3	<0.1

Table 2. ^{40}K , ^{238}U , ^{226}Ra , ^{232}Th , and ^{137}Cs activity concentrations in the soil, feedstuffs, milk, cheese, eggs, and meat of domestic animals, in Obrenovac, around the open coal-fired power stations (average values for locations Konatica and Ušće)

Samples	^{40}K [Bq kg ⁻¹]	^{238}U [Bq kg ⁻¹]	^{226}Ra [Bq kg ⁻¹]	^{232}Th [Bq kg ⁻¹]	^{137}Cs [Bq kg ⁻¹]
Soil cultivated	590 22	61.2 7.4	67.8 5.2	68.1 2.1	25.3 0.9
Soil non-cultivated	650 19	55.5 3.3	50.8 2.8	55.3 1.7	42.6 1.2
Alfalfa	980 14	<1.5	<2.3	<0.3	<0.1
Maize	105 4	<1.1	<1.5	<0.3	<0.1
Cow milk	41 2	<1.1	<1.3	<0.2	<0.1
Goat milk	56 3	<1.5	<1.5	<0.2	<0.1
Cow cheese	44 2	<3.4	<0.7	<0.3	<0.1
Eggs (chicken)	401 2	<1.1	0.6 0.1	<0.2	<0.1
Beef meat	97 3	2.1 0.2	<1.5	<0.4	<0.1
Sheep meat	99 4	<1.5	<1.5	<0.3	<0.1
Pork meat	99 4	<1.5	<1.5	<0.3	<0.1

of the possible reasons for these results is that the activity of natural radionuclides, which are discharged to the atmosphere from the coal-fired power plant, depends on the efficiency of emission control devices and the efficiency of the filtering system [9].

The activity concentrations of ^{137}Cs in the soil samples ranged from 25.3-33.2 Bq/kg in cultivated, to 42.6-61.9 Bq/kg in uncultivated soils. Activity is almost 2 times higher in non-cultivated soils. This results stand in accordance with the results of authors [10, 11] who have suggested that applying of agro-technical procedures (ploughing, manuring) are measures which are undertaken to decrease the concentration of ^{137}Cs in soil.

In the samples of feedstuffs, which are mostly present in diet of animals (alfalfa, maize) low level activity of primordial radionuclides was measured while ^{137}Cs was on a border of the detection range.

In the examined samples of animal products (milk, cheese, meat, and eggs) originated from the regions around the coal mine and the coal-fired power stations, low level of activity concentration of primordial radionuclides was identified and ^{137}Cs was near the detection limit. The obtained results suggested that the examined animal products are safe for human consumption.

The significant increase in the activity concentrations of natural radioisotopes in the samples of soil or vegetation has not been found both in the territories surrounding coal-fired power plants and in the coal mine, which stands in accordance with UNSCEAR 2000 Report [7].

CONCLUSIONS

Based on the results obtained in our research we can conclude that the natural environment around the examined coal mine (in Lazarevac) and the coal-fired power stations (in Obrenovac) is not significantly af-

ected by the emission of primordial radionuclides. The significant increase in the activity concentrations of natural radioisotopes in the samples of soil, vegetation, and animal products was not confirmed. Food of animal origin used in human consumption is safe, *i. e.* not contaminated by radiation.

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AUTHOR CONTRIBUTIONS

Theoretical analysis was carried out by G. S. Vitorović and samples were collected by B. M. Mitrović, and D. P. Vitorović. All authors analysed and discussed the results. The manuscript was written by G. S. Vitorović, D. P. Vitorović, V. Dj. Andrić, B. M. Mitrović, and M. V. Lazarević-Macanović and translation of the work made by M. D. Stojanović, V. Dj. Andrić, and M. V. Lazarević-Macanović.

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**Гордана С. ВИТРОВИЋ, Бранислава М. МИТРОВИЋ, Велибор Ђ. АНДРИЋ,
Мирјана Д. СТОЈАНОВИЋ, Мирјана В. ЛАЗАРЕВИЋ-МАЦАНОВИЋ,
Душко П. ВИТРОВИЋ**

**РАДИОАКТИВНА КОНТАМИНАЦИЈА ЛАНЦА ИСХРАНЕ У
ОКОЛИНИ РУДНИКА УГЉА И ТЕРМОЕЛЕКТРАНА НА УГАЉ**

Циљ овог истраживања био је да се испита утицај процеса вађења и прераде угља из отвореног рудног копа у Лазаревцу, као и сагоревања угља током производње електричне енергије у термоелектранама у Обреновцу, на присуство радионуклида ^{40}K , ^{238}U , ^{232}Th као и ^{137}Cs у ланцу исхране људи који живе у околини ових постројења. Ниво испитиваних радионуклида мерен је гамаспектрометријски, у узорцима земљишта, сточне хране (луцерка, кукуруз), млека крава и коза, крављег сира, јаја и меса говеда, оваца, свиња и живине. Узорци су узимани од локалног становништва и то по три узорка на сваком локалитету. На подручју Лазареваца, узорковање је извршено на локалитетима Конатица и Ушће. Добијени резултати показали су да се ниво активности ^{238}U у земљишту, на подручју око рудника угља (Лазаревац) кретао у распону 66,4-76,0 Вq/kg, а на подручју око термоелектрана у Обреновцу 55,5-61,2 Вq/kg. Ове, као и вредности добијене за остале радионуклиде, нису биле значајно више од просечних вредности за Србију. У узорцима сточне хране и анималних производа, ниво активности, испитиваних радионуклида био је веома низак и често на граници детекције. На основу свега, може се закључити да рудник угља, постројења за прераду угља као и термоелектране, немају значајног утицаја на повећања нивоа активности примордијалних радионуклида у животној средини Лазареваца и Обреновца.

Кључне речи: ланац исхране, радиоактивност, рудник угља, термоелектрана