



ЗБОРНИК РАДОВА



XXXII Симпозијум Друштва за заштиту од зрачења Србије и Црне Горе

**04-06. октобар 2023. године
Будва, Црна Гора**

**ДРУШТВО ЗА ЗАШТИТУ ОД ЗРАЧЕЊА
СРБИЈЕ И ЦРНЕ ГОРЕ**



ЗБОРНИК РАДОВА

XXXII СИМПОЗИЈУМ ДЗЗСЦГ

**Будва, Црна Гора
04-06. октобар 2023. године**

**Београд
2023. године**

**RADIATION PROTECTION ASSOCIATION OF
SERBIA AND MONTENEGRO**



PROCEEDINGS

XXXII SYMPOSIUM RPASM

**Budva, Montenegro
4th-6th October 2023**

**Belgrade
2023**

ЗБОРНИК РАДОВА

XXXII СИМПОЗИЈУМ ДЗЗСЦГ

04-06.10.2023.

Издавачи:

Институт за нуклеарне науке „Винча“
Друштво за заштиту од зрачења Србије и Црне Горе

За извршног издавача:

Проф. Др Снежана Пајовић

Уредници:

Др Милица Рајачић
Др Ивана Вуканац

ISBN 978-86-7306-169-6

© Institut za nuklearne nauke „Vinča“

Техничка обрада:

Милош Ђалетић, Милица Рајачић

Електронско издање:

Институт за нуклеарне науке „Винча“, Мике Петровића Аласа 12-14,
11351 Винча, Београд, Србија

Година издања:

Октобар 2023.



Овај Зборник као и сви радови у њему подлежу лиценци:

Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License, <https://creativecommons.org/licenses/by-nc-nd/4.0/>

Ова лиценца дозвољава само преузимање и дистрибуцију дела, ако/док се правилно назначавача име аутора, без икаквих промена дела и без права комерцијалног коришћења дела.

**XXXII СИМПОЗИЈУМ ДРУШТВА
ЗА ЗАШТИТУ ОД ЗРАЧЕЊА
СРБИЈЕ И ЦРНЕ ГОРЕ**

Будва, 04-06.10.2023. године

Организатори:

ДРУШТВО ЗА ЗАШТИТУ ОД ЗРАЧЕЊА СРБИЈЕ И ЦРНЕ ГОРЕ

Институт за нуклеарне науке „Винча“

Лабораторија за заштиту од зрачења и заштиту животне средине „Заштита“

Центар за екотоксиколошка испитивања Подгорица д.о.о, ЦЕТИ

Организациони одбор:

Председник:

Ивана Вуканац

Чланови:

Милица Рајачић, Институт за нуклеарне науке „Винча“, Београд

Александра Милатовић, ЦЕТИ, Подгорица, Црна Гора

Никола Свркота, ЦЕТИ, Подгорица, Црна Гора

Ранко Зекић, ЦЕТИ, Подгорица, Црна Гора

Гордана Пантелић, Институт за нуклеарне науке „Винча“, Београд

Милош Ђалетић, Институт за нуклеарне науке „Винча“, Београд

Никола Кржановић, Институт за нуклеарне науке „Винча“, Београд

Наташа Сарап, Институт за нуклеарне науке „Винча“, Београд

Јелена Станковић Петровић, Институт за нуклеарне науке „Винча“, Београд

Ивана Коматина, Институт за нуклеарне науке „Винча“, Београд

Јелена Влаховић, Институт за нуклеарне науке „Винча“, Београд

Зорица Обрадовић, Институт за нуклеарне науке „Винча“, Београд

Игор Челиковић, Институт за нуклеарне науке „Винча“, Београд

Јелена Крнета Николић, Институт за нуклеарне науке „Винча“, Београд

Александра Самолов, Институт за нуклеарне науке „Винча“, Београд

**XXXII СИМПОЗИЈУМ ДРУШТВА
ЗА ЗАШТИТУ ОД ЗРАЧЕЊА
СРБИЈЕ И ЦРНЕ ГОРЕ**

Будва, 04-06.10.2023. године

Научни одбор:

др Владимир Удовичић, Институт за физику, Земун, Универзитет у Београду

др Војислав Станић, Институт за нуклеарне науке „Винча“, Универзитет у Београду

др Душан Мрђа, Природно математички факултет, Универзитет у Новом Саду

др Ивана Вуканац, Институт за нуклеарне науке „Винча“, Универзитет у Београду

др Игор Челиковић, Институт за нуклеарне науке „Винча“, Универзитет у Београду

др Јелена Крнета Николић, Институт за нуклеарне науке „Винча“, Универзитет у Београду

др Јелена Пајић, Институт за медицину рада Србије "Др Драгомир Карајовић",
Београд

др Јелица Грујић, Институт за медицинска истраживања, Универзитет у Београду

др Јована Николов, Природно математички факултет, Универзитет у Новом Саду

др Маја Еремић-Савковић, Директорат за радијациону и нуклеарну сигурност и
безбедност Србије

др Марија Јанковић, Институт за нуклеарне науке „Винча“, Универзитет у Београду

др Мирјана Ђурашевић, Институт за нуклеарне науке „Винча“, Универзитет у
Београду

др Мирјана Раденковић, Институт за нуклеарне науке „Винча“, Универзитет у
Београду

др Невена Здјеларевић, ЈП Нуклеарни објекти Србије, Београд

др Оливера Митровић Ајтић, Институт за медицинска истраживања, Универзитет у
Београду

др Софија Форкапић, Природно математички факултет, Универзитет у Новом Саду

др Србољуб Станковић, Институт за нуклеарне науке „Винча“, Универзитет у
Београду

Организацију су помогли:

Институт за нуклеарне науке „Винча“, Лабораторија за заштиту од зрачења и заштиту животне средине „Заштита“

Мике Петровића Аласа 12-14

11351 Винча, Београд, Србија

<https://www.vin.bg.ac.rs/>

Центар за екотоксиколошка испитивања Подгорица д.о.о, ЦЕТИ

Булевар Шарла де Гола бр. 2

81000 Подгорица, Црна Гора

<https://mne.ceti.me/>

МОЈ ЛАБ

ул. Московска бр. 2б

81000 Подгорица, Црна Гора

<https://mojlab.me/>

ФАРМАЛАБ

Булевар Михаила Лалића бр. 8

81000 Подгорица, Црна Гора

<https://farmalab.me/>

ГЛОСАРИЈ ДОО

ул. Војисављевића бр. 76

81000 Подгорица, Црна Гора

<https://www.glosarij.me/me/pocetna>

Излагачи:

Canberra Packard Central Europe GmbH.

Wienersiedlung 6

2432 SCHWADORF, Austria

Phone: +43 (0)2230 3700-0

Fax: +43 (0)2230 3700-15

Web: <http://www.cpce.net/>

LKB Vertriebs doo Beograd-Palilula

Свијићева 115

11120 Beograd, Srbija

Tel: +381 (0)11 676 6711

Faks: +381 (0)11 675 9419

Web: www.lkb.eu

Овај Зборник је збирка радова саопштених на XXXII Симпозијуму Друштва за заштиту од зрачења Србије и Црне Горе који је одржан у Будви, Црна Гора, 04-06.10.2023. године. Радови су према обрађеној проблематици груписани у једанаест секција. Сви радови у Зборнику су рецензирани од стране Научног одбора, а за све приказане резултате и тврдње одговорни су сами аутори.

*Југословенско друштво за заштиту од зрачења основано је 1963. године у Порторожу, а од 2005. носи име "Друштво за заштиту од зрачења Србије и Црне Горе". На XXXII Симпозијуму, ове године обележавамо веома значајан јубилеј - **60 година организоване заштите од зрачења на нашим просторима.***

Од оснивања, Симпозијуми Друштва за заштиту од зрачења представљају прилику да се кроз стручни програм прикажу резултати истраживања у области заштите од зрачења, представе различите области примене извора и генератора зрачења, анализирају актуелна дешавања, размене искуства са колегама из региона, дефинишу проблеми и правци даљег унапређивања наше професионалне заједнице.

Поред тога, Симпозијуми друштва представљају и прилику да у мање формалном маниру сретнемо старе и упознамо нове пријатеље и колеге, обновимо старе и започнемо нове професионалне сарадње.

Ауторима и коауторима научних и стручних радова саопштених на XXXII Симпозијуму се захваљујемо на уложеном труду и настојању да квалитетним радовима заједно допринесемо остваривању циљева и задатака Друштва и наставимо традицију дугу импозантних 60 година.

Посебно се захваљујемо свима који су подржали одржавање овог Симпозијума.

Свим члановима Друштва, сарадницима и колегама честитамо овај значајан јубилеј!

Организациони одбор XXXII Симпозијума ДЗЗСЦГ

FLY-ASH FOR USAGE IN THE BUILDING MATERIAL INDUSTRY

Nataša MLADENOVIĆ NIKOLIĆ¹, Katarina TRIVUNAC², Miloš NENADOVIĆ³,
Sabina DOLENEC⁴, Maruša MRAK⁴, Ivana VUKANAC⁵, Snežana NENADOVIĆ¹,
Ljiljana KLJAJEVIĆ¹

- 1) „Vinča“ Institute of Nuclear Sciences – National Institute of the Republic of Serbia, University of Belgrade, Department of Materials, Belgrade, Serbia
- 2) Faculty of Technology and Metallurgy, University of Belgrade, Department of Analytical Chemistry and Quality Control, Belgrade, Serbia
- 3) „Vinča“ Institute of Nuclear Sciences – National Institute of the Republic of Serbia, University of Belgrade, Department of Atomic Physics, Belgrade, Serbia
- 4) Slovenian National Building and Civil Engineering Institute, Dimčevaulica 12, 1000 Ljubljana, Slovenia
- 5) „Vinča“ Institute of Nuclear Sciences – National Institute of the Republic of Serbia, University of Belgrade, Department of Radiation and Environmental Protection, Belgrade, Serbia

Corresponding author: Ljiljana KLJAJEVIĆ, ljiljana@vin.bg.ac.rs

ABSTRACT

In this study, fly ash (FA) from the active and passive cassette TENT A (Nikola Tesla power plant, Obrenovac) is characterized from physicochemical and radiological aspects. Samples of FA consisted of amorphous phase followed by quartz, mullite, plagioclase, K-feldspar, hematite and calcite. As indicated by laser granulometry, the fraction D₅₀ of investigated samples are about 80µm, so based on the above, they belong to coarse ashes. Very important parameter which defines chemical composition of the fly ash as precursor material of clinker or alkali activated materials is presence of organic matter which is expressed by total organic content (TOC). Assessment of radiation exposure during coal combustion depends on the concentration of radioactive elements in the coal and in the resulting fly ash. Fly ash as industrial waste contains certain concentrations of natural radionuclides that are considered naturally occurring radioactive materials (NORM). The results showed that fly ash has satisfactory radiological properties and can be used as an addition to clinkers, but also as a potential precursor of a new class of alkaline activated materials that can be used in the construction sector.

Introduction

Fly ash is a by-product material produced in the combustion process of coal used in power stations. It is a fine grey coloured powder having spherical glassy particles that rise with the flue gases. As pozzolanic material fly ash is used in concrete, mines, landfills and dams. There has been an increasing attempt for fly ash utilization in different sectors. Loya and Rawani [1] identified top areas for the quantity of fly ash utilization as 44.19% in cement and concrete sectors, 15.25% of ash in roads, embankments and ash dyke raising, followed by 12.49% in reclamation of low lying areas and land filling, 8.84% in mine filling, 7.61% in bricks, blocks and tiles, 2.47% in agriculture and 9.14% in others. Since 316 individual minerals and 188 mineral groups are recognized in fly ash, it is one of the most complex materials in terms of characteristics [2]. However, all fly ash includes substantial amounts of

silicon dioxide (SiO_2) (both amorphous and crystalline), aluminum oxide (Al_2O_3) and calcium oxide (CaO), the main mineral compounds in coal-bearing rock strata. Fly ash can be classified according to the type of coal from which the ash was derived and depending on pH value and calcium/sulphur ratio, fly ashes are classified as acidic ash (pH 1.2 up to 7), mildly alkaline ash (pH 8–9), and strongly alkaline ash (pH 11–13) [3]. The chemical properties of fly ash depend not only on the type of coal used in a process but also on the techniques used to burn the coal. Specifically, properties of fly ash depend on: (a) boiler configuration, (b) burning condition and temperature of the boiler, (c) the particle size of the coal, and (d) the gas cleaning equipment [4]. The use of industrial by-products, fly ash of the coal combustion process, disposed in landfills near thermal power plants which represent a burden on the environment is nowadays an important task for scientists.

In the thermal power plants (TE) of "Elektroprivreda Srbije" (JP EPS) whose boilers burn lignite, around 6 million tons of fly ash are produced annually as a waste which is deposited in an open waste disposal, taking up an area of around 400 hectares. Depositing ash in open spaces can be very damaging to the environment due to the potentially deleterious effects of ash particles. Dispersal of ash particles by wind and water erosion and the leaching of substances such as salts and heavy metals can be hazardous for the surrounding terrain and underground waters. Fly and bottom ash are produced as a by-product in the process of burning Kolubara lignite (Coal mine basin Kolubara, Serbia) are the basic raw material in the technological process of collecting, preparing, transporting and disposing of ashes by their nature they belong to non-hazardous waste. A potential market for the use of fly ash exists and for now, it is used exclusively by cement factories [5]. The production of construction materials using or re-using local industrial waste alumina-silicate materials is a cost-benefit, environmental-friendly and sustainable technology [6, 7].

In order the ashes found in landfills to continue to be used as raw materials in the production of concrete, cement, clinker, and some new materials, for example alkaline-activated materials that would find their application in the construction sector, it is necessary to examine, among others, physico-chemical, mineralogical, and radiological characteristics of FA. The radioactivity of FA can be one of the important reasons against its wider use in the construction industry of Serbia [3]. The presented research is a contribution to the potential solution of environmental protection through the synthesis of potential construction materials based on FA or applications FA as Al-rich by-products in the building industry.

Materials and methods

Materials

Selected samples of FA were taken from ash dumps TENT A. Location of TENT A is on the right bank of the Sava river, about 40 km upstream of Belgrade between settlements of Krtinska and Urovci, about 3 km west of Obrenovac. Fly ash disposal: The cassette 1 of the ash dump of the TENT A in Obrenovac is covered with earth. The cassette 2 is active and the ash dumped into this cassette is mixed with water, while the cassette 3 is passive and recultivated, with planted grass [8].

The sample S1 was taken from the passive cassette number 1 from TENT A. The creation of a passive cassette differs from an active cassette in the part when the subject cassette ceases to be actively used. After the end of its active use, there is a period of aging of the cassette, which implies exposure exclusively to environmental influences. The sample is brownish with some impurities in it. Particle size and granulation are within expectations for the ash sample. Since it is a passive cassette, which has been inactive for several years, sampling was performed by the method of random sampling from several places. The composite sample

thus obtained was later mixed, dried and homogenized. The sample S2 was taken from active cassette from TENT A. The sample is dark almost black in color and shows the presence of impurities. The granulation of the powder is within the expected range. Since it was sampled from the active cassette, the reliability of the results may be better than that of the samples from the passive cassettes.

Due to the size of the active cassette, as well as the fact that part of the cassette is covered with water from the sprinklers, for sampling a representative part of the active cassette that can best represent the entire process that takes place in the active cassette was selected[8].

Methods

Among physical characteristics moisture content, granulometry, BET specific surface area, particle density were performed.

The specific surface area of the fly ash samples were determined using the BET (Brunauer-Emmet-Teller) method using Micromeritics ASAP-2020 analyser, by nitrogen adsorption measurements at 77 K. The samples were pre dried for 60 min at 105 °C. Specific density analysis of flyash samples was determined according to EN 1097-7 [9], by pycnometer method. Moisture measurements were determined by drying sample in an oven SP-440 (max. T 300 °C) on 105 °C for 24 h. Moisture content is given with the relation $\% mc_{wb} = (w_w - w_d / w_w) \times 100$ where mc is expressed on wet basis (w_w is wet weight and w_d is dry weight)

The X-ray powder diffraction (XRD) was performed to determine the phase composition of the FA samples using a PANalytical Empyrean X-ray diffractometer equipped with CuK α radiation with $\lambda = 1.54$ Å. The samples were scanned at 45 kV and a current of 40 mA, over the 2θ range from 4° to 70°, at a scan rate of 0.026° 2θ min⁻¹ and step time 172 seconds. The obtained XRD patterns were analysed using X'Pert High Score Plus diffraction software v. 4.8 from PANalytical, using PAN ICSD v. 3.4 powder diffraction files. All Rietveld refinements were performed using the PANalytical X'Pert High Score Plus diffraction software, using the structures for the phases from ICDD PDF 4+ 2016 RDB powder diffraction files. Amorphous content was determined using the external standard method (NIST SRM 676a) [10]. The chemical composition of FA was determined by X-ray fluorescence (XRF). The XRF analysis was performed with a wavelength dispersion (WD XRF) spectroscope ARL Perform X manufactured by Thermo Scientific with a power of 2500 W, 5 GN Rh X-ray tube, 4 crystals (AX03, PET, LiF200 and LiF220), two detectors (proportional and scintillation), and computer program UniQuant. The samples were quartered, dried at 105 °C and calcined at 950 °C.

Total organic compound (TOC) analyzed by Analizator CW-800M "Multiphase", ELTRA by dry incineration method, detection of products with IR detector.

The contents of naturally occurring radionuclides in the FA were determined by gamma spectrometry. The samples of FA placed in PVC cylindrical containers (125 ml and 250 ml), sealed with beeswax and left for six weeks. The equilibrium between radon and its progenies realized in this way. Radiological analysis was performed by means of a coaxial semiconductor high purity germanium (HPGe) detector (Canberra 7229N-7500-1818 with 20% relative efficiency and 1.8 keV resolution for ⁶⁰Co at the 1332 keV line) associated with standard beam supply electronics units. The method has been shown previously and described by Nenadović, et al. [11] and Mirković et al. [12] Quoted uncertainties (the confidence level of 1 σ) were calculated by error propagation calculation. The combined standard uncertainties included the statistical uncertainties of the recorded peaks, efficiency calibration uncertainty and the uncertainty of measured mass.

European Commission [13] recommends that the reference level for building materials should be of the order of 1 mSv/y or less expressed as effective dose caused by external gamma radiation to members of the public. A common screening method the dose caused by building materials is the use of an Activity Concentration Index (I), the value of which is calculated on the basis of the concentrations of Ra-226, Th-232 and K-40. The index ACI is related to the gamma radiation dose in a building and was calculated according to equation 1 [14]:

$$(1) \quad ACI = \frac{A_{C,Ra-226}}{300} + \frac{A_{C,Th-232}}{200} + \frac{A_{C,K-40}}{3000}$$

where $A_{C,Ra-226}$, $A_{C,Th-232}$ and $A_{C,K-40}$ are the activity concentrations in Bq/kg.

Besides the activity concentration index, in order to estimate a possible health effect due to the exposure to natural radionuclides present in the measured samples, radium equivalent activity, Ra_{eq} [Bqkg⁻¹], the external hazard index, Hex [Bqkg⁻¹], total external absorbed gamma dose rate D [nGyh⁻¹], and annual effective dose EDR [mSv] can be calculated. The radium equivalent activity can be used to estimate the hazard associated with materials that contain 226-Ra, 232-Th, and 40-K. The external radiation hazard index reflects the external radiation hazard due to the emitted gamma radiation. The values of these indicators of exposure can be calculated according to eqs. from Vukanac et al. [15]. The value of this index must be less than unity to keep the radium equivalent activity and annual dose under the permissible limits of 370 Bqkg⁻¹ and 1 mSv, respectively.

The external absorbed gamma dose rate, \dot{D} (nGy/h), in air 1m above the ground due to radionuclides 226-Ra, 232-Th, and 40-K in measured samples was calculated [16]:

$$(2) \quad \dot{D} = 0.462A_{Ra} + 0.604A_{Th} + 0.0417A_K$$

In order to estimate the health risks, the annual effective dose rates was calculated using the conversion coefficient from the absorbed dose in air to the effective dose (0.7 Sv/Gy), the indoor occupancy factor (0.8) - assuming that people spend approximately 80% of the time indoors, and 8760 h (1 year) annual exposure time as proposed by UNSCEAR (1993). The annual effective dose (EDR) was calculated from the formula [17]:

$$(3) \quad EDR(\text{mSv}) = \dot{D}(\text{nGy/h}) \times 8760(\text{h/y}) \times 0.8 \times 0.7 (\text{Sv/Gy}) 10^{-6}$$

Results

Physico-chemical properties of FA

Table 1 shows the particle density, bulk density, BET and moisture content of FA samples.

Table 4: Particle density, bulk density, BET and moisture content of FA

Sample	Particle density (g/cm ³)	Bulk density (kg/m ³)	BET (m ² /g)	Moisture content (%)
S1	2.20	681	8.0	31.22
S2	2.05	659	17.9	25.92

The characteristic values D_{10} , D_{50} and D_{90} are shown in Table 2 and corresponding PSD curves are presented on Figure 1.

Table 2: Results of laser granulometry

Sample	D ₁₀ (μm)	D ₅₀ (μm)	D ₉₀ (μm)
S1	13.4	78.7	203.4
S2	21.5	85.9	144.1

XRD analysis

Table 3 shows phase composition of investigated samples determined by XRD analysis.

Table 3: Phase composition of ash samples

Sample	Amorphous (%)	Mineral composition (%)						
		Quartz	Mullite	Plagioclase	K-feldspar	Hematite	Calcite	SUM
S1	68.0	14.2	9.2	6.8	1.2	0.2	0.4	100.0
		16.5	6.5	4.6	0.7	0.1	/	100.0
S2	71.6	14.2	9.2	6.8	1.2	0.2	0.4	100.0
		16.5	6.5	4.6	0.7	0.1	/	100.0

XRF analysis

Table 4 shows chemical composition of all samples determined by XRF analysis.

Table 4: XRF results of chemical composition of all samples

Sample	L.O.I.	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	Na ₂ O	K ₂ O	SO ₃	MnO	TiO ₂	P ₂ O ₅	Cr ₂ O ₃	SUM
	(%)													
S1	3.00	57.65	23.46	5.28	5.82	1.98	0.32	1.39	0.04	0.07	0.84	0.05	0.05	100.04
S2	5.90	57.92	22.72	6.30	2.99	1.43	0.30	1.29	0.34	0.06	0.72	0.05	0.03	100.10

Table 5 showstotal organic compounds (TOC) in samples of FA.

Table 5: Results of TOC measurements

Sample	TOC (%)
S1	0.56
S2	0.71

Radiological Characterizations

For assessing the specific dose rate, more elaborate methods need to be used in order to consider the actual concentrations and locations of a certain building material in a building. European Commission [13] recommends the model represents by Markkanen in reference [18]. A protection strategy should be established with the aim to promote building materials that do not exceed the reference level.

Radiological characteristics of the ash samples – specific activity (Bq/kg) were presented in Table 6.

Table 6: Activity concentration of natural radionuclides in the investigated samples with associated measurement uncertainties (k = 1).

Sample	Specific activity (Bq/kg)						
	²¹⁰ Pb	²²⁶ Ra	²³² Th	⁴⁰ K	¹³⁷ Cs	²³⁸ U	²³⁵ U
S1	89±8	72±3	61±4	246±17	<0.1	81±8	5.5±0.4
S2	29±3	51±2	38±3	211±15	<0.1	47±5	2.8±0.2

Table 7 shows radium equivalent activity (Raeq), external radiation hazard index (Hex), the external gamma radiation absorbed dose rate (Ḑ) and effective dose rate (EDR) of fly ashes.

Table 7: Radium equivalent activity (Ra_{eq}), external radiation hazard index (H_{ex}), the external gamma radiation absorbed dose rate (\dot{D}) and effective dose rate (EDR) of fly ash samples

Sample	Ra_{eq} (Bq/kg)	H_{ex} (Bq/kg)	\dot{D} (nGy/h)	EDR (mSv/y)	ACI
S1	348.65	0.4813	80.4	0.394	0.627
S2	267.81	0.328	55.3	0.271	0.430

Discussion

Mineral composition of the samples was determined. Samples consisted of amorphous phase followed by quartz, mullite, plagioclase, K-feldspar, hematite, calcite. Quartz amount in both sample of FA from passive and active case is approximately the same. Also, amount of amorphous phase is slightly higher for S2 sample. Such a high % of the amorphous phase indicates a good reactivity of FA in further processes of use as a component in the production of clinker or alkali-activated materials. During the burning process, the mineral substances from the coal change into the crystalline and amorphous phases that make up the ash. For example, calcite is thought to mostly transition to CaO, which in some cases can react with SO₂ and CO₂ to form anhydrite and again calcite. Clay matter, like feldspar, melts and transforms into glass, sometimes with the action of solvents such as FeO and CaO. Kaolinite usually passes into mullite, glass and sometimes cristobalite, while the other types of clay and feldspar transition to glass [19]. Quartz partially melts, but some quartz grains remain. In this way, in addition to the amorphous phase that is characteristic of fly ash, crystalline mineral species mainly include quartz, mullite, K- and Ca-type feldspars, calcite, gellenite, hematite. The spherical particles that make up the glassy (amorphous) part of the ash are mostly thin, hollow, ceramic microspheres and are called cenospheres. These spheres are created under specific conditions, as molten drops of clay minerals, mica, feldspar and quartz. Spheres are usually charged gases resulting from combustion of organic matter, decomposition of carbonates, dehydration clay minerals and pore water evaporation. These are mainly CO₂, N₂, O₂ and H₂O. It is assumed that these spheres are formed at temperatures between 1230 and 1400°C [20].

According to particle size, ashes are divided into fine and coarse fraction. The fine fraction includes ash whose particle size is below 45 µm, while ashes with particle sizes above that belong to coarse ash. Ashes from bituminous coals have finer particles compared to ashes produced by burning lignite coals [19]. As a result of laser granulometry, the fraction D₅₀ of both samples are about 80 µm, so based on the above, they belong to coarse ashes.

Among chemical parameters which are analyzed SiO₂ amount is almost the same (~58%) for the S1 and S2 sample. The values for CaO is lower for the S2—2.99 %—almost twice value of S1.

Very important parameter, which defines chemical composition of the fly ash as precursor material of clinker or alkali activated materials, is presence of organic matter. It is expressed by total organic content (TOC). It effects mainly emissions, as in unstable operating conditions the presence of TOC in clinker raw mixture can contribute to the CO₂ emissions.

The behavior of natural radionuclides in the process of burning coal depends on a number of factors, such as the type and characteristics of coal, ash content in coal, calorific value of coal, combustion temperature, chemical and physical form in which the radionuclides are found coal and others. In the combustion process, the organic component is eliminated thus that there is an increase in the concentration of radionuclides in ash compared to coal. Change in natural radioactivity as a consequence of the operation of thermal power plants it can also affect the food chain, soil-plant-animal-human. Considering that EDR , H_{ex} and ACI are less

than 1, FAs are safe from the aspect of external exposure with the limitation of the duration of exposure to less than 20% of hours per year.

Conclusion

Physico-chemical characteristics of samples led to conclusion that these ashes are heterogeneous materials.

Accordingly, the criteria $Ra_{eq} < 370$, $H_{ex} < 1$, FA from bouthcasete can be freely re-used as raw materials for building materials.

This researching offer a good basis for further investigations, considering possible utilization of these ash in production new materials which can be applied in the construction sector.

Acknowledgment

This work was financially supported by the Ministry of Science, Technological Development and Inovation of the Republic of Serbia on the research program, record number: 451-03-47/2023-01/200017, and grant No. 1702302 Vinča Institute of Nuclear Sciences, National Institute of the Republic of Serbia, University of Belgrade, Serbia, and from the European Institute of Innovation and Technology (EIT), a body of the European Union, under Horizon 2020, the EU Framework Programme for Research and Innovation (RIS-ALiCE, project no. 18258). The Metrology Institute of the Republic of Slovenia is acknowledged for the use of XRF.

Reference

- [1] M.I.M. Loya, A.M. Rawani. A review: promising applications for utilization of fly ash, *Int. J. Adv. Technol. Eng. Sci.*, Vol.2, 2014, 143-149. ISSN:
- [2] S.V. Vassilev, C.G. Vassileva. A new approach for the classification of coal fly ashes based on their origin, composition, properties, and behaviour, *Fuel.*, Vol.86 No.10-11, 2007, 1490-1512. ISSN:
- [3] S. Gaffney, N.A. Marley. The impacts of combustion emissions on air quality and climate – from coal to biofuels and beyond, *Atmos. Environ.*, Vol.43, No.1, 2009, 23-36. ISSN:
- [4] A.B. Mukherjee, R. Zevenhoven, P. Bhattacharya, K.S. Sajwan, R. Kikuchi. Mercury flow via coal and coal utilization by-products: a global perspective *Resour. Conserv. Recycl.*, Vol.52, No.4, 2008, 571-591. ISSN:
- [5] D. M. Kisić, S. R. Miletić, V. D. Radonjić, S. B. Radanović, J. Z. Filipovic, I. A. Gržetić. Prirodnaradioaktivnostuglja i letećegpepela u termoelektrani „Nikola Tesla B“, *Hem. Ind.* Vol. 67, No.5, 2013, 729–738. ISSN:
- [6] Miloš T. Nenadović, Claudio Ferone, Ljiljana M. Kljajević, Miljana M. Mirković, Bratislav Ž. Todorović, Ivana S. Vukanac, and Snežana S. Nenadović, Alkali Activation of Different Type of Ash as a Production of Combustion Process Nuclear Technology & Radiation Protection, Vol. 36, No. 1, 2021, 66-73. ISSN:
- [7] S. S. Nenadović, Lj. M. Kljajević, S. B. Marković, M.O. Omerasević, U.D. Jovanović, V.Đ. Andrić, I.S. Vukanac, Natural diatomite (Rudovci, Serbia) as adsorbent for removal Cs from radioactive waste liquids, *science of Sintering*, Vol. 47 No. 3, 2015, 299-309. ISSN:

- [8] https://www.researchgate.net/publication/274826992_Potential_usage_of_fly_and_bottom_ash_from_thermal_power_plant_Nikola_Tesla_landfill_Serbia [accessed Jun20th2023].
- [9] EN 1097-7: Tests for mechanical and physical properties of aggregates. Determination of the particle density of filler. Pycnometer method (2008).
- [10] J. P. Cline, et al. Addressing the Amorphous Content Issue in Quantitative Phase Analysis: the Certification of NIST Standard Reference Material 676a. *Acta Cryst*, A67, 2011, 357-367.
- [11] S. Nenadović, C. Ferone, M. Nenadović, R. Cioffi, M. Mirković, I. Vukanac, Lj. Kljajević. Chemical, physical and radiological evaluation of raw materials and geopolymers for building applications, *J Radioanal Nucl Chem* Vol. 325 No.2, 435-445. ISSN:
- [12] M. Mirković, Lj. Kljajević, S. Nenadović, S. Dolenc, K. Šter, L. Žibret, M. Rajačić. Fly ash as a raw material for low-carbon cement clinkers and its radiological properties, *Journal of Radioanalytical and Nuclear Chemistry*, Vol. 328, 2021, 1391-1398. ISSN:
- [13] European Commission (EC), Radiation protection 112-Radiological Protection Principles concerning the Natural Radioactivity of Building Materials, Directorate-General Environment, Nuclear Safety and Civil Protection, 1999
- [14] Directive 2013/59/EUROATOM 5-December 2013, Official European Union 17/01/2014, 2013
- [15] I. Vukanac, et al. Assessment of Natural Radioactivity Levels and Radon Exhalation Rate Potential from Various Building Materials, *Nucl Technol Radiat* Vol.35, No.1, 2020, 64-73. ISSN:
- [16] R.C. Bhangare, M. Tiwari, P.Y. Ajmal, S.K. Sahu, G.G. Pandit. Distribution of natural radioactivity in coal and combustion residues of thermal power plants, *Journal of Radioanalytical and Nuclear Chemistry*, Vol.300, 2014, 17-22, ISSN: 0236-5731
- [17] United Nations Scientific Committee on the Effects of Atomic Radiation. Sources, Effects and Risks of Ionizing Radiation (UNSCEAR) Report to the General Assembly with Annex A: Exposures from Natural Sources of Radiation; United Nations: New York, 1993.
- [18] M. Markkanen. Radiation Dose Assessments for Materials with Elevated Natural Radioactivity, Report STUK-B-STO 32, Radiation and Nuclear Safety Authority – STUK, 1995.
- [19] W.L. Daniels, B. Stewart, K. Haering, C. Zipper. 'The Potential for Beneficial Reuse of Coal Fly Ash in Southwest Virginia Mining Environments', 2002., Virginia Cooperative Extension, Knowledge for the Commonwealth.
- [20] S. Vassilev, R. Menendez. Phase-mineral and chemical composition of coal fly ashes as a basis for their multicomponent utilization. 4. Characterization of heavy concentrates and improved fly ash residues, *Fuel*, Vol. 84, No. 7-8, 2005, 973-991. ISSN:

UPOTREBA LETEĆEG PEPELA U INDUSTRIJI GRAĐEVINSKOG MATERIJALA

Nataša MLADENOVIĆ NIKOLIĆ¹, Katarina TRIVUNAC², Miloš NENADOVIĆ³,
Sabina DOLENEC⁴, Maruša MRAK⁴, Ivana VUKANAC⁵, Snežana NENADOVIĆ¹,
Ljiljana KLJAJEVIĆ¹

- 1) *Institut za nuklearne nauke „Vinča“, Institut od nacionalnog značaja za Republiku Srbiju, Univerzitet u Beogradu, Laboratorija za materijale, Beograd, Srbija*
- 2) *Tehnološko-metalurški fakultet, Katedra za analitičku hemiju i kontrolu kvaliteta, Univerzitet u Beogradu, Beograd, Srbija*
- 3) *Institut za nuklearne nauke „Vinča“, Institut od nacionalnog značaja za Republiku Srbiju, Univerzitet u Beogradu, Laboratorija za atomsku fiziku, Beograd, Srbija*
- 4) *Slovenački nacionalni građevinski institut, Dimčeva ulica 12, 1000 Ljubljana, Slovenija*
- 5) *Institut za nuklearne nauke „Vinča“, Institut od nacionalnog značaja za Republiku Srbiju, Univerzitet u Beogradu, Laboratorija za zaštitu od zračenja i zaštitu životne sredine, Beograd, Srbija*

REZIME

Procena izloženosti zračenju pri sagorevanju uglja zavisi od koncentracije radioaktivnih elemenata u uglju i u letećem pepelu koji nastaje. Uzorci letećeg pepela se sastoje od amorfne faze praćene kvarcom, mulitom, plagioklasom, K-feldspatom, hematinom, kalcitom. Kao rezultat laserske granulometrije, frakcija D50 za ispitivane uzorke je približno 80 µm, tako da na osnovu navedenog, leteći pepeli predstavljaju pepele krupnih čestica. Veoma važan parametar je prisustvo organske materije koje se izražava ukupnim organskim sadržajem. Leteći pepeli kao industrijski ostaci sadrže određene koncentracije prirodnih radionuklida koji se smatraju prirodnim radioaktivnim materijalima (NORM). U ovoj istraživanju, leteći pepeo iz aktivne i pasivne kasete TENT A (termoelektrana Nikola Tesla, Obrenovac) karakteriše se sa radiološkog i fizičko-hemijskog aspekta. Rezultati su pokazali da leteći pepeo ima zadovoljavajuća radiološka svojstva i da se može koristiti kao dodatak klinkerima, ali i kao potencijalni precursor nove klase alkalno aktiviranih materijala koji se mogu primeniti u građevinskom sektoru.

САДРЖАЈ

ОПШТИ ПРОБЛЕМИ ЗАШТИТЕ ОД ЗРАЧЕЊА GENERAL PROBLEMS OF RADIATION PROTECTION 1

OPRAVDANOST, OPTIMIZACIJA I REFERENTNI NIVOI U SITUACIJAMA POSTOJEĆEG IZLAGANJA 2

JUSTIFICATION, OPTIMIZATION AND REFERENCE LEVELS IN EXISTING EXPOSURE SITUATIONS 8

METROPOEM PROJEKAT – METROLOGIJA ZA HARMONIZACIJU MERENJA ZAGADJIVAČA ŽIVOTNE SREDINE U EVROPI 9

METROPOEM – METROLOGY FOR THE HARMONISATION OF MEASUREMENTS OF ENVIRONMENTAL POLLUTANTS IN EUROPE 14

РАДИОЕКОЛОГИЈА И ИЗЛАГАЊЕ СТАНОВНИШТВА RADIOECOLOGY AND POPULATION EXPOSURE 15

RADIOLOŠKA KARAKTERIZACIJA POLJOPRIVREDNOG ZEMLJIŠTA NA TERITORIJI VOJVODINE 16

RADIOLOGICAL CHARACTERIZATION OF AGRICULTURAL SOIL IN THE TERRITORY OF VOJVODINA 23

MONITORING RADIOAKTIVNOSTI I PROCENA RADIJACIONOG RIZIKA U OKOLINI TERMOELEKTRANA U REPUBLICI SRBIJI U 2021. I 2022. GODINI 24

RADIOACTIVITY MONITORING AND RADIATION RISK ASSESSMENT IN THE SURROUNDINGS OF THERMAL POWER PLANTS IN THE REPUBLIC OF SERBIA IN 2021 AND 2022 29

GRAMON BAZA PODATAKA: DESETOGODIŠNJA MERENJA SPECIFIČNE AKTIVNOSTI BERILIJUMA-7 U VAZDUHU 30

GRAMON DATABASE: TEN YEARS OF BERYLLIUM-7 SPECIFIC ACTIVITY MEASUREMENTS 35

ISPITIVANJE SADRŽAJA RADIONUKLIDA U VODI I SEDIMENTU, REKA SAVA 36

RADIONUCLIDES IN WATER AND SEDIMENT, SAVA RIVER 41

RADIOLOŠKA ANALIZA NEKIH VRSTA LEKOVITOG BILJA SA PODRUČJA GUČEVA I PROCENA GODIŠNJE EFEKTIVNE DOZE USLED INGESTIJE 42

RADIOLOGICAL ANALYSIS OF SOME TYPES OF MEDICINAL PLANTS FROM THE GUČEVO AREA AND ESTIMATION OF ANNUAL EFFECTIVE DOSE DUE TO INGESTATION 48

PRIMENA JONOIZMENJIVAČKIH SMOLA ZA GAMA SPEKTROMETRIJSKO ODREĐIVANJE RADIJUMA U VODI 49

APPLICATION OF ION EXCHANGE RESINS FOR GAMMA SPECTROMETRIC DETERMINATION OF RADIUM IN WATER 55

ODREĐIVANJE VEŠTAČKIH I PRIRODNIH RADIONUKLIDA U UZORKU ZEMLJIŠTA U SVRHU INTERKOMPARACIJE IAEA-TERC-2022-02 56

DETERMINATION OF GAMMA-EMITTING ANTHROPOGENIC AND NATURAL RADIONUCLIDES IN SOIL SAMPLE FOR THE PURPOSE OF PROFICIENCY TEST IAEA-TERC-2022-02 ALMERA 61

RASPODELA KONCENTRACIJA AKTIVNOSTI PRIRODNIH RADIONUKIDA U UZORCIMA ŽIVOTNE SREDINE KAO POSLEDICA RADA TERMOELEKTRANE “KOLUBARA” U PERIODU 2010 – 2022. GODINE 62

THE ACTIVITY CONCENTRATION DISTRIBUTIONS OF NATURALLY OCCURRING RADIONUCLIDES IN THE ENVIRONMENTAL SAMPLES AS A RESULT OF THE OPERATION OF THE “KOLUBARA” COAL-FIRED POWER PLANT IN THE PERIOD OF 2010 – 2022. 70

RADIOLOGICAL CHARACTERIZATION OF ALKALI ACTIVATED MATERIALS CONTAINING WOOD AND FLY ASH 71

RADIOLOŠKA KARAKTERIZACIJA ALKALNO AKTIVNIH MATERIJALA KOJI SADRŽE DRVENI I LETEĆI PEPEO	79
POTENCIJALNI ODNOS IZMEĐU KONCENTRACIJE TRICIJUMA U KIŠNICI I REKAMA.....	80
RELATIONSHIP BETWEEN TRITIUM CONCENTRATIONS IN PRECIPITATION AND RIVERS.....	85
ANALIZA TRENDA PROMENE UKUPNE ALFA I UKUPNE BETA AKTIVNOSTI U POLJOPRIVREDNOM EKOSISTEMU.....	86
ANALYSIS OF TREND OF THE GROSS ALPHA AND GROSS BETA ACTIVITY IN THE AGRICULTURAL ECOSYSTEM.....	92
AKUMULACIJA RADIONUKLIDA IZ ZEMLJIŠTA U PLODOVIMA LEŠNIKA	93
ACCUMULATION OF RADIONUCLIDES FROM SOIL IN HAZELNUT FRUITS.....	102
REZULTATI MERENJA PRIVATNE MERNE STANICE U POŽAREVCU ZA KONTINUALNO MERENJE AMBIJENTALNOG EKVIVALENTA DOZE ZA 2021. I 2022. GODINU.....	103
MEASUREMENT RESULTS OF PRIVATE MEASURING STATION IN POŽAREVAC FOR CONTINUOUS MEASUREMENT OF AMBIENT DOSE EQUIVALENT FOR 2021 AND 2022	109
ISPITIVANJE KONCENTRACIJE RADIONUKLIDA U SEDIMENTU PODMORJA CRNE GORE	110
CONCENTRATION OF RADIONUCLIDES IN THE SUBMARINE SEDIMENT OF MONTENEGRO	115
SADRŽAJ RADIONUKLIDA I DOZA INGESTIJOM ZA ČAJEVE SPRAVLJENE OD LEKOVITOG BILJA SA TERITORIJE REPUBLIKE SRBIJE.....	116
RADIONUCLIDE CONTENT AND INGESTION DOSE FOR TEA MADE FROM MEDICINAL HERBES FROM THE THERITORY OF REPUBLIC OF SERBIA	121
ANALIZA FRAKTALNE PRIRODE SPECIFIČNE AKTIVNOSTI BERILIJUMA-7 U PRIZEMNOM SLOJU ATMOSFERE MERENE U BEOGRADU, SRBIJA (1991-2022)	122
ANALYSIS OF THE FRACTAL NATURE OF THE SPECIFIC ACTIVITY OF BERYLLIUM-7 IN THE NEAR-SURFACE LAYER OF THE ATMOSPHERE MEASURED IN BELGRADE, SERBIA (1991–2022)	127
FLY-ASH FOR USAGE IN THE BUILDING MATERIAL INDUSTRY	128
UPOTREBA LETEĆEG PEPELA U INDUSTRIJI GRAĐEVINSKOG MATERIJALA	136
IZBOR REFERENTNOG DATUMA ZA PREZENTOVANJE AKTIVNOSTI RADIONUKLIDA U VREMENSKI KOMPOZITNIM UZORCIMA.....	137
SELECTION OF REFERENCE DATE FOR PRESENTATION OF RADIONUCLIDE ACTIVITY IN TIME-COMPOSITE SAMPLES.....	142
SADRŽAJ RADIONUKLIDA I TEŠKIH METALA U OTPADNOM TALOGU OD PREČIŠĆAVANJA RASTVORA ZA ELEKTROLIZU CINKA U “ZORKI” ŠABAC	143
CONTENT OF RADIONUCLIDES AND HEAVY METALS IN THE WASTE PRECIPITATE FROM THE PURIFICATION OF THE SOLUTION FOR THE ELECTROLYSIS OF ZINC IN "ZORKA" ŠABAC	152
SOIL TO PLANT TRANSFER OF CS-137, SR-90, RA-226, PB-210 AND K-40 IN DIFFERENT AGRICULTURAL PRODUCTS IN CROATIA.....	153
PRIJENOS CS-137, SR-90, RA-226, PB-210 I K-40 IZ TLA U BILJKU U RAZLIČITIM POLJOPRIVREDNIM KULTURAMA U HRVATSKOJ	159
РАДОН RADON.....	160
MERENJE RADIOAKTIVNOSTI I EKSHALACIJE RADONA IZ KONCENTRATA ARSENA KORIŠĆENOG U INDUSTRIJI CINKA „ZORKA” ŠABAC	161
MEASUREMENTS OF RADIOACTIVITY AND RADON EXHALATION FROM THE ARSENIC CONCENTRATE USED IN THE ZINC INDUSTRY "ZORKA" ŠABAC	171
RADON U SREDNJIM ŠKOLAMA U CRNOJ GORI.....	172

RADON IN SECONDARY SCHOOLS IN MONTENEGRO.....	177
RAZVOJ METODOLOGIJE ZA BRZU DIJAGNOSTIKU POVIŠENIH NIVOVA RADONA I ANALIZU GEOLOŠKIH FAKTORA U RADONOM UGROŽENIM PODRUČJIMA	178
DEVELOPMENT OF METHODOLOGY FOR RAPID DIAGNOSTIC OF ELEVATED RADON LEVELS AND ANALYSIS OF GEOLOGICAL FACTORS IN RADON PRIORITY AREAS.....	185
MERENJE KONCENTRACIJE RADONA U ZATVORENOM PROSTORU – PRIKAZ JEDNOG SLUČAJA.....	186
INDOOR RADON CONCENTRATION MEASUREMENT - CASE STUDY	195
TRACERADON PROJEKAT – PREGLED NAJVAŽNIJIH REZULTATA.....	196
TRACERADON PROJECT – AN OVERVIEW OF SCIENTIFIC ACHIEVEMENTS	205
MONITORING KONCENTRACIJE RADONA U RADNOM PROSTORU, LABORATORIJA PMF-A U KOSOVSKOJ MITROVICI	206
MONITORING OF RADON CONCENTRATION IN THE WORKPLACE, LABORATORY OF FACULTY IN KOSOVSKA MITROVICA.....	211
ISPITIVANJE KONCENTRACIJE AKTIVNOSTI RADONA SA VODOIZVORIŠTA U CRNOJ GORI	212
INVESTIGATION OF RADON ACTIVITY CONCENTRATION FROM WATER SOURCES IN MONTENEGRO	218
METODE DETEKCIJE I MERNA INSTRUMENTACIJA DETECTION METHODS AND MEASUREMENT INSTRUMENTATION	219
PONOVLJIVOST ODREĐIVANJA AKTIVNOSTI RADIONUKLIDA CS-137 IZ CILINDRIČNOG RADIOAKTIVNOG IZVORA.....	220
REPEATABILITY OF CS-137 RADIONUCLIDE ACTIVITY DETERMINATION FROM CYLINDRICAL RADIOACTIVE SOURCE	224
VARIJACIJE FONA HPGE DETEKTORA	225
BACKGROUND VARIATIONS OF HPGE DETECTORS	231
INTERNA KONTROLA KVALITETA HPGE GAMASPEKTROMETRIJSKOG SISTEMA.....	232
INTERNAL QUALITY CONTROL OF HPGE GAMMA SPECTROMETRY SYSTEM.....	237
ODREĐIVANJE SADRŽAJA PRIRODNIH RADIONUKLIDA U UZORCIMA MINERALNIH ĐUBRIVA.....	238
DETERMINATION OF THE CONTENT OF NATURAL RADIONUCLIDES IN SAMPLES OF MINERAL FERTILIZERS.....	244
GODIŠNJA KONTROLA DETEKTORA INSPECTOR 1000 I RADEYE PRD	245
ANNUAL CONTROL OF INSPECTOR 1000 AND RADEYE PRD DETECTORS.....	251
UPOTREBA FRAM SOFTVERA U ANALIZI GAMA SPEKTARA NUKLEARNIH MATERIJALA	252
FRAM SOFTVER	252
THE USE OF FRAM SOFTWARE IN THE ANALYSIS OF GAMMA SPECTRA OF NUCLEAR MATERIALS	258
REZULTATI ISPITIVANJA SONDE S1 SA KOMPENZACIONIM FILTEROM ZA MERENJE AMBIJENTALNOG EKVIVALENTA DOZE ZA UREĐAJ DMRZ-M15	259
TEST RESULTS OF PROBE S1 WITH COMPENSATION FILTER FOR MEASURING THE AMBIENT EQUIVALENT DOSE USED WITH DMRZ-M15 SURVEY METER.....	264
MERNA NESIGURNOST AMBIJENTALNIH FOTONSKIH DOZIMETARA U IMPULSNOM REŽIMU RADA SA POSEBNIM OSVRTOM NA UTICAJ OSETLJIVOSTI DETEKCIJE I VREMENA MERENJA	265

MEASUREMENT UNCERTAINTY OF AMBIENT PHOTON DOSIMETERS IN PULSE MODE OPERATION WITH SPECIAL EMPHASIS TO THE INFLUENCE OF DETECTION SENSITIVITY AND MEASUREMENT TIME	271
PRIPREMA RADIOAKTIVNIH STANDARDA ZA KALIBRACIJU GAMA SPEKTROMETARA	272
PREPARATION OF RADIOACTIVE STANDARDS FOR CALIBRATION OF GAMMA SPECTROMETER	279
ODREĐIVANJE SR-89 I SR-90 ČERENKOVLJEVIM BROJENJEM.....	280
DETERMINATION OF SR-89 AND SR-90 BY CHERENKOV COUNTING.....	286
ANALIZA FLUKSA I DOZNIH EFEKATA TERESTRIJALNOG SKYSHINE ZRAČENJA	287
ANALYSIS OF FLUX AND DOSE EFFECTS OF TERRESTRIAL SKYSHINE RADIATION	292
KALIBRACIJA LSC DETEKTORA U OKVIRU RAZVOJA METODE ZA MERENJE URANIJUMA U PODZEMNIM VODAMA	293
CALIBRATION OF LSC DETECTOR FOR THE DEVELOPMENT OF METHOD FOR MEASURING URANIUM IN GROUNDWATER.....	297
ЗАШТИТА ОД ЗРАЧЕЊА У МЕДИЦИНИ RADIATION PROTECTION IN MEDICINE.....	298
ANALIZA RASEJANJA ZRAČENJA OD ZAUSTAVLJAČA SNOPA KOD LINEARNIH MEDICINSKIH AKCELERATORA	299
ANALYSIS OF RADIATION SCATTERING FROM BEAM STOPPERS AT LINEAR MEDICAL ACCELERATORS.....	305
UNAPREĐENJE ZAŠTITE MEDICINSKOG OSOBLJA KOJE UČESTVUJE U FLUOROSKOPSKI VOĐENIM INTERVENTNIM PROCEDURAMA UVOĐENJEM POLUAUTOMATSKOG SISTEMA UPRAVLJANJA VISEĆIM ZAŠTITNIM EKTRANOM.....	306
IMPROVING THE PROTECTION OF MEDICAL STAFF PARTICIPATING IN FLUOROSCOPICALLY GUIDED INTERVENTIONAL PROCEDURES BY INTRODUCING A SEMI-AUTOMATIC SYSTEM FOR MANAGING A CEILING-SUSPENDED PROTECTIVE SCREEN.....	312
NOVI PRISTUP U KONSTRUKCIJI ZAŠTITE U BRAHITERAPIJI-BRAHITERAPIJSKA KOMORA	313
A NEW APPROACH IN THE CONSTRUCTION OF PROTECTION IN BRACHYTHERAPY – BRACHYTHERAPY CHAMBER.....	320
EKSPERIMENTALNI MODEL ZA PROCENU MOGUĆEG RADIOPROTEKTIVNOG EFEKTA BILJNOG EKSTRAKTA	321
EXPERIMENTAL MODEL FOR ASSESSING THE POSSIBLE RADIOPROTECTIVE EFFECT OF PLANT EXTRACT	327
CT PROTOKOL I VRIJEDNOSTI DOZA ZA PREGLED UROGRAFIJE.....	328
CT PROTOCOL AND DOSE VALUES FOR UROGRAPHY EXAMINATION.....	334
STANJE RENDGEN-APARATA U DIJAGNOSTIČKOJ RADIOLOGIJI U CRNOJ GORI.....	335
THE CONDITION OF X-RAY MACHINES IN DIAGNOSTIC RADIOLOGY IN MONTENEGRO	341
VALIDACIJA ITLC METODE ZA ODREĐIVANJE SADRŽAJA RADIOHEMIJSKE NEČISTOĆE C U ^{99m} Tc-MIBI INJEKCIJI	342
VALIDATION OF AN ITLC METHOD FOR THE DETERMINATION OF RADIOCHEMICAL IMPURITIES C IN ^{99m} Tc-MIBI INJECTION.....	349
METODA ISPITIVANJA FIZIOLOŠKE RASPODELE ^{99m} Tc-DPD.....	350
METHOD FOR INVESTIGATION OF PHYSIOLOGICAL DISTRIBUTION OF ^{99m} Tc DPD	355
AUTOMATIZACIJA PROCESA PROIZVODNJE RADIOFARMACEUTIKA U CILJU SMANJENJA DOZE ZRAČENJA OPERATERA.....	356

AUTOMATION OF THE PRODUCTION OF RADIOPHARMACEUTICAL WITH THE AIM TO REDUCE THE OPERATOR'S RADIATION DOSE	360
ДОЗИМЕТРИЈА DOSIMETRY	361
USPOSTAVLJANJE ETALONSKOG POLJA ZA MALE VREDNOSTI JAČINE DOZNOG EKVIVALENTA.....	362
ESTABLISHING CALIBRATION FIELD FOR SMALL VALUES OF DOSE EQUIVALENT RATE....	368
EVALUATION OF DIAGNOSTIC RADIOLOGY DETECTOR PERFORMANCE IN REFERENCE MAMMOGRAPHY RADIATION FIELDS	369
EVALUACIJA PERFORMANSI DETEKTORA ZA DIJAGNOSTIČKU RADIOLOGIJU U REFERENTNIM POLJIMA ZRAČENJA ZA MAMMOGRAFIJU	375
PROVERA RADIOTERAPIJSKIH USTANOVA SRBIJE OD 2019. DO 2022. GODINE POŠTANSKOM DOZIMETRIJOM U VELIČINI APSORBOVANA DOZA U VODI.....	376
POSTAL DOSIMETRY AUDIT OF RADIOTHERAPY CENTERS IN SERBIA FOR THE PERIOD FROM 2019. TO 2022. IN TERMS OF ABSORBED DOSE TO WATER	381
THE INFLUENCE OF COMPRESSION PADDLE POSITIONING ON HVL MEASUREMENTS IN MAMMOGRAPHY	382
UTICAJ POZICIJE KOMPRESIJE PAPUČICE NA HVL MERENJA U MAMMOGRAFIJI	386
PRIMENA TL DOZIMETARA ZA ISPITIVANJE TAČNOSTI ISPORUČENE DOZE U OZRAČIVAČU KRVU	387
APPLICATION OF TL DOSIMETERS FOR TESTING THE ACCURACY OF DELIVERED DOSE IN BLOOD IRRADIATOR.....	393
БИОЛОШКИ ЕФЕКТИ ЈОНИЗУЈУЋИХ ЗРАЧЕЊА BIOLOGICAL EFFECTS OF IONIZING RADIATION	394
SINTEZA LUTECIJUMA(III) KOMPLEKSA SA POLIAZAMAKROCIKLIČNIM LIGANDOM	395
SYNTHESIS OF LUTETIUM(III) COMPLEX WITH A POLYAZAMACROCYCLIC LIGAND.....	400
ANTIOKSIDATIVNI I RADIOPROTEKTIVNI EFEKAT FLAVONOIDA NA UČESTALOST MIKRONUKLEUSA U HUMANIM LIMFOCITIMA	401
ANTIOXIDATIVE AND RADIOPROTECTIVE EFFECT OF FLAVONOIDS ON FREQUENCY OF MICRONUCLEI IN HUMAN LYMPHOCYTES.....	405
PROMENE GENETIČKOG MATERIJALA U LIMFOCITIMA PERIFERNE KRVU IZLOŽENIH U VANREDNOM DOGAĐAJU NA GRANIČNOM PRELAZU BEZDAN.....	406
CYTOGENETIC CHANGES IN PERIPHERAL BLOOD LYMPHOCYTES OF THE EXPOSED PERSONS IN THE EMERGENCY EVENT AT THE BORDER CROSSING BEZDAN	410
ANALIZA ZDRAVSTVENOG STANJA RADNIKA NA CARINSKOM PRELAZU AKCIDENTALNO IZLOŽENIH RADIOAKTIVNOM ZRAČENJU	411
ANALYSIS OF THE HEALTH CONDITION AFTER THE EMERGENCY EVENT AT BEZDAN BORDER CROSSING	416
THE EFFECT OF HONEY ON MALONDIALDEHYDE LEVEL IN PLASMA EXPOSED TO A THERAPEUTIC DOSE OF RADIATION.....	417
DELOVANJE MEDA NA NIVO MALONDIALDEHIDA U PLAZMI IZLOŽENOJ TERAPIJSKOJ DOZI ZRAČENJA.....	423
OKSIDATIVNI STATUS KOD PACIJENATA OBOLELIH OD DOBRO DIFERENTOVANIH KARCINOMA ŠTITASTE ŽLEZDE NAKON TERAPIJE ¹³¹ I.....	424
OXIDATIVE STATUS IN PATIENTS SUFFERED FROM WELL DIFFERENTIATED THYROID CARCINOMA AFTER ¹³¹ I THERAPY.....	429

РАДИОАКТИВНИ ОТПАД И ДЕКОНТАМИНАЦИЈА RADIOACTIVE WASTE AND DECONTAMINATION.....430

BEZBEDNO UPRAVLJANJE ZATVORENIM IZVORIMA JONIZUJUĆEG ZRAČENJA: MOGUĆI PRISTUPI, RUKOVANJE, KONDICIONIRANJE I SKLADIŠTENJE	431
SAFE MANAGEMENT OF SEALED RADIOACTIVE SOURCES: POSSIBLE APPROACHES, HANDLING, CONDITIONING AND STORAGE	438
EFIKASNOST I KAPACITET SORPCIJE JONA BA^{2+} ZEOLITOM 4A I PRIRODNIM KLINOPTILOLITOM I UTICAJ KOMPETICIJE SA JONIMA SR^{2+}	439
EFFICIENCY AND CAPACITY OF BA^{2+} IONS SORPTION BY ZEOLITE 4A AND NATURAL KLINOPTILOLITE AND INFLUENCE OF COMPETING SR^{2+} IONS.....	444
PREGLED POTENCIJALNIH PRIMENA OTPADNOG STAKLA EKRANA U MALTER-MATRIKSU ZA IMOBILIZACIJU TEČNOG RADIOAKTIVNOG OTPADA	445
OVERVIEW OF POTENTIAL APPLICATIONS OF SCREEN WASTE GLASS IN MORTAR-MATRIX FOR LIQUID RADIOACTIVE WASTE IMMOBILIZATION	451
ПРОБНИ РАД ПОСТРОЈЕЊА ЗА ПРЕРАДУ РАДИОАКТИВНОГ ОТПАДА БЕЗ РАДИОАКТИВНИХ И НУКЛЕАРНИХ МАТЕРИЈАЛА	452
TRIAL OPERATION OF THE RADIOACTIVE WASTE PROCESSING FACILITY WITHOUT RADIOACTIVE AND NUCLEAR MATERIALS	460
UPRAVLJANJE RADIOAKTIVNIM OTPADOM INSTITUTA ZA ONKOLOGIJU I RADIOLOGIJU SRBIJE	461
RADIOACTIVE WASTE MANAGEMENT OF THE INSTITUTE FOR ONCOLOGY AND RADIOLOGY OF SERBIA	468

РЕГУЛАТИВА, ЕДУКАЦИЈА И ЈАВНО ИНФОРМИСАЊЕ REGULATION, EDUCATION AND PUBLIC INFORMATION.....469

PRIMENA KAZNENIH MERA U INSPEKCIJSKOM NADZORU	470
APPLICATION OF PENALTIES IN INSPECTION OVERSIGHT	476
TERMINOLOGIJA U OBLASTI RADIJACIONE I NUKLEARNE SIGURNOSTI I BEZBEDNOSTI – IZAZOVI.....	477
TERMINOLOGY IN THE FIELD OF RADIATION AND NUCLEAR SAFETY AND SECURITY – CHALLENGES	482
BEZBEDNOSNI IZAZOVI USLED POJAVE FALSIFIKOVANIH, LAŽNIH I SUMNJIVIH PREDMETA U LANCU NUKLEARNOG SNABDEVANJA	483
SECURITY CHALLENGES DUE TO THE APPEARANCE OF COUNTERFEIT, FAKE AND SUSPICIOUS ITEMS IN THE NUCLEAR SUPPLY CHAIN.....	488
UNAPREĐENJE REGULATORNOG OKVIRA U OBLASTI PRIMENE IZVORA ZRAČENJA U MEDICINI.....	489
IMPROVEMENT OF THE REGULATORY FRAMEWORK IN THE FIELD OF APPLICATION OF RADIATION SOURCES IN MEDICINE.....	495
GENERALNA PREVENCIJA ILEGALNE TRGOVINE RADIOAKTIVNIH MATERIJALA	496
GENERAL PREVENTION OF RADIOACTIVE MATERIALS ILLICIT TRAFFICKING.....	508

НЕЈОНИЗУЈУЋА ЗРАЧЕЊА NON-IONIZING RADIATION509

UTICAJ EVOLUCIJE MOBILNIH TEHNOLOGIJA NA IZLAGANJE LJUDI EM POLJIMA.....	510
THE INFLUENCE OF THE EVOLUTION OF MOBILE TECHNOLOGIES ON THE EXPOSURE OF PEOPLE TO EM FIELDS.....	518
ФОТОТЕРАПИЈА ЗА НЕОНАТАЛНУ ХИПЕРБИЛИРУБИНЕМИЈУ	519
PHOTOTHERAPY FOR NEONATAL HYPERBILIRUBINEMIA	525