Univerzitet Crne Gore
Prirodno-matematički fakultet

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Broj: 2027/01-348

Datum: 23. 02. 2023

UNIVERZITET CRNE GORE

SENATU

CENTRU ZA DOKTORSKE STUDIJE

U prilogu akta dostavljamo Odluku sa XCV sjednice Vijeća Prirodno-matematičkog fakuteta održane 21.02.2023. godine.

v.f dekana,
Prof. dr Mirjan Bigović

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Broj: 2023/01-196-1
Datum: 22.02.2023 god

Na osnovu člana 64 Statuta Univerziteta Crne Gore, a u vezi sa članom 34 stav 1 Pravila doktorskih studija, Vijeće Prirodno-matematičkog fakulteta je na XCV sjednici od 21.02.2023.godine utvrdilo

PREDLOG ODLUKE

o imenovanju komisije za ocjenu prijave doktorske disertacije

I

Imenuje se komisija za ocjenu prijave doktorske disertacije pod nazivom "Procjena zdravstvenog rizika unosa teških metala voćem i povrćem u industrijskom području – studija slučaja- Pljevlja, Crna Gora" kandidatkinje Nevene Cupara u sljedećem sastavu:

1. Prof. dr Slobodanka Pajević, redovni profesor Prirodno-matematičkog fakulteta Univerziteta u Novom Sadu (naučna oblast: Biologija, Ekologija, Fiziologija biljaka, Ekofiziologija biljaka),predsjednik;
2. Prof. dr Miljan Bigović, vanredni profesor na Prirodno-matematičkom fakultetu Univerziteta Crne Gore (naučna oblast: Organska hemija, Organska sinteza, Hemija životne sredine), član;
3. Prof. dr Dijana Đurović, docent na Univerzitetu Donja Gorica (naučna oblast: Analitička hemija, Bezbjednost hrane) član;
4. Prof. dr Irena Nikolić, redovni professor Metalurško tehnološkog fakulteta Univerziteta Crne Gore, komentor (naučna oblast: Zaštita životne sredine, Hemijski i tehnološki aspekti) i
5. Prof. dr Slađana Krivokapić, redovni profesor Prirodno-matematičkog fakulteta Univerziteta Crne Gore, mentor (naučna oblast: Bilogija, Botanika, Fiziološka ekologija).

II

Zadatak komisije je da podnese Izvještaj o ocjeni prijave doktorske disertacije Vijeću fakulteta u roku od 10 dana od dana javnog izlaganja studenta. Ukoliko komisija u navedenom roku ne podnese Izvještaj, imenovaće se nova komisija.

v.f. D E K A N-a
Prof. dr Miljan Bigović

ISPUNJENOST USLOVA DOKTORANDA

OPŠTI PODACI O DOKTORANDU	
Titula, ime, ime roditelja, prezime	Mr Nevena, Miroljub, Cupara
Fakultet	Prirodno - matematički fakultet
Studijski program	Biologija
Broj indeksa	1/19
NAZIV DOKTORSKE DISERTACIJE	
Na službenom jeziku	Procjena zdravstvenog rizika unosa teških metala voćem i povrćem u industrijskom području – studija slučaja: Pljevlja, Crna Gora
Na engleskom jeziku	Health risk assessment of heavy metal intake by fruits and vegetables in the industrial area - case study: Pljevlja, Montenegro
Naučna oblast	Fiziološka ekologija/zaštita životne sredine

MENTOR/MENTORI			
Prvi mentor	Dr Sladana Krivokapić, redovni profesor	Prirodno-matematički fakultet, Univerzitet Crne Gore, Crna Gora	Biologija/Botanika/ Fiziološka ekologija
Drugi mentor	Dr Irena Nikolić, redovni profesor	Metalurško-tehnološkifakultet, Univerzitet Crne Gore, Crna Gora	Zaštita životne sredine/hemijski i tehnološki aspekti

KOMISIJA ZA PREGLED I OCJENU DOKTORSKE DISERTACIJE		
Dr Slobodanka Pajević, redovni profesor, predsjednik	Prirodno-matematički fakultet, Univerzitet u Novom Sadu, Srbija	Biologija/Ekologija/Fiziologija biljaka/Ekofiziologija biljaka
Dr Dijana Đurović, docent, član	Fakultet za prehrambenu tehnologiju, bezbjednost hrane i ekologiju, Univerzitet Donja Gorica, Crna Gora	Analitička hemija/bezbijednost hrane
Dr Miljan Bigović, vanredni profesor, član	Prirodno-matematički fakultet, Univerzitet Crne Gore, Crna Gora	Organska hemija/organska sinteza/hemija životne sredine
Dr Irena Nikolić, redovni profesor, član, komentor	Metalurško-tehnološkifakultet, Univerzitet Crne Gore, Crna Gora	Zaštita životne sredine/hemijski i tehnološki aspekti
Dr Slađana Krivokapić, redovni profesor, član, mentor	Prirodno-matematički fakultet, Univerzitet	Biologija/Botanika/ Fiziološka ekologija

UCG

UNIVERZITET CRNE GORE

ObrazacD2: Ispunjenost uslova doktoranda

	Crne Gore, Crna Gora	
Datum značajni za ocjenu doktorske disertacije		
Sjednica Senata na kojoj je data saglasnost na ocjenu teme i kandidata		16.02.2021.
Dostavljanja doktorske disertacije organizacionoj jedinici i saglasanost mentora		10.02.2023.
Sjednica Vijeća organizacione jedinice na kojoj je dat prijedlog za imenovanje komisija za pregled i ocjenu doktorske disertacije		21.02.2023.

ISPUNJENOST USLOVA DOKTORANDA

U skladu sa članom 38 pravila doktorskih studija kandidat je cjelokupna ili dio sopstvenih istraživanja vezanih za doktorsku disertaciju publikovao u časopisu sa **SCI/SCIE** liste kao prvi autor.

Spisak radova doktoranda iz oblasti doktorskih studija koje je publikovao u časopisima sa SCI/SCIE liste

1. **Nevena Cupara**, Irena Nikolić, Dijana Đurović, Ivana Milašević, Darko Medin, Slađana Krivokapić, (2022). Heavy metals assessment in agricultural soils and vegetables in the vicinity of industrial pollutants in the Pljevlja municipality (Montenegro): ecological and health risk approach, *Environmental Monitoring and Assessment*.https://doi.org/10.1007/s10661-022-10445-6 , (**Q2** https://www.scimagojr.com/journalsearch.php?q=21482&tip=sid&clean=0)
2. **Nevena Cupara**, Dijana Đurović, Irena Nikolić, Ivana Milasević, Borko Bajić. Assesment of ecological and health risk in agricultural soil near the mine of lead and zinc in Pljevlja municipality (Montenegro), *Fresenius Environmental Bulletin*, Volume 31– No. 08B/2022 pages 9036-9044. https://www.prt-parlar.de/download_feb_2022/
3. Dijana Đurović, Irena Nikolić, **Nevena Cupara**, Ivana Milasević. Contamination and ecological risk assessment of heavy metals in agricultural soils in Pljevlja municipality (North Montenegro), *Fresenius Environmental Bulletin*, Volume 31– No. 04/2022, pp. 4536-4545. https://www.prt-parlar.de/download_feb_2022/

Obrazloženje mentora o korišćenju doktorske disertacije u publikovanim radovima

Kandidatkinja je u radu **Heavy metals assessment in agricultural soils and vegetables in the vicinity of industrial pollutants in the Pljevlja municipality (Montenegro): ecological and health risk approach** koristila veliki dio rezultata svoje doktorske teze, kojima je obuhvatila sadržaj teških metala u poljoprivrednom zemljištu i u odabranim biljnim vrstama, kao i procjenu rizika unosa teških metala putem kontakta sa zemljištem, ali i unosa ispitivanih biljnih vrsta.

U drugom autorskom radu **Assesment of ecological and health risk in agricultural soil near the mine of lead and zinc in Pljevlja municipality (Montenegro)**, kandidatkinja je stavila akcenat na analizu zagađenosti teškim metalima lokaliteta sa najvišim sadržajem teških metala (lokalitet u neposrednoj blizini rudnika olova i cinka) kroz poređenje sadržaja metala sa kontrolnim lokalitetom.

Koautorski rad kandidatkinje, **Contamination and ecological risk assessment of heavy metals in agricultural soils in Pljevlja municipality (North Montenegro)**, bazira se na procjeni ekološkog rizika poljoprivrednog zemljišta u opštini Pljevlja.

Napominjem da su svi rezultati objavljeni u prethodno navedenim radovima dio doktorske teze kandidatkinje i da su podijeljeni u segmente zbog obimnosti eksperimentalnog rada i dobijenih podataka.

Datum i ovjera (pečat i potpis odgovorne osobe)

UCG

UNIVERZITET CRNE GORE

ObrazacD2: Ispunjenost uslova doktoranda

U Podgorici,
10.02.2023.

MP

UNIVERZITET CRNE GORE Prirodno-matematički fakultet UCG

DEKAN

Prilog dokumenta sadrži:

1. Potvrdu o predaji doktorske disertacije organizacionoj jedinici
2. Odluku o imenovanju komisije za pregled i ocjenu doktorske disertacije
3. Kopiju rada publikovanog u časopisu sa odgovarajuće liste
4. Biografiju i bibliografiju kandidata
5. Biografiju i bibliografiju članova komisije za pregled i ocjenu doktorske disertacije sa potvrdom o izboru u odgovarajuće akademsko zvanje i potvrdom da barem jedan član komisije nije u radnom odnosu na Univerzitetu Crne Gore

Univerzitet Crne Gore
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Broj: 2023/02-187/1

Datum: 10.02.2023. god

Na osnovu člana 33 Zakona o upravnom postupku, nakon uvida u službenu evidenciju, Prirodno-matematički fakultet izdaje

P O T V R D U

MSc Nevena Cupara, student doktorskih studija na Prirodno-matematičkom fakultetu u Podgorici, dana 10.02.2023.godine dostavila je ovom fakultetu doktorsku disertaciju pod nazivom "Procjena zdravstvenog rizika unosa teških metala voćemi povrćem u industrijskom području - studija slučaja: Pljevlja, Crna Gora" na dalje postupanje.

V.f. D E K A N-a
Prof. dr Miljan Bigović

UNIVERZITET CRNE GORE

PRIRODNO-MATEMATIČKI FAKULTET

Na osnovu člana 37 Pravila doktorskih studija Univerziteta Crne Gore dajemo sljedeću

SAGLASNOST

Doktorska disertacija pod nazivom „*Procjena zdravstvenog rizika unosa teških metala voćem i povrćem u industrijskom području – studija slučaja: Pljevlja, Crna Gora*“ kandidatkinje MSc Nevene Cupare zadovoljava kriterijume propisane Statutom Univerziteta Crne Gore i Pravilima doktorskih studija, te smatramo da kandidatkinja istu može predati na ocjenu.

Podgorica, 10.02.2023.

Prof. dr Slađana Krivokapić

Prvi mentor

Prof. dr Irena Nikolić

Drugi mentor

europass

Europass Biografija

Lični podaci

Prezime; Ime(na)	**Cupara Nevena**
Adresa(e)	Slovačka bb, Podgorica
Telefonski broj(evi)	/
Broj mobilnog telefona	**+38268613196**
E-mail	ncupara@ymail.com
Državljanstvo	Crnogorsko
Datum rođenja	12/04/1993
Pol	Ženski

Radno iskustvo

Datumi	**April 2022-Trenutno**
Zanimanje ili radno mjesto	Analitičar u laboratoriji za gasnu hromatografiju
Glavni poslovi i odgovornosti	Analize vode, mzemljišta i voća i povrća na sadržaj teških metala, pesticida, PCB, PAH Razvijanje metoda za analize navedenih parametara tehnikama GC-MS, GCMSMS, ICP-OES, FAAS , DMA Obrada i analiza rezultata
Ime i adresa poslodavca	Institut za javno zdravlje Crne Gore, Džona Džeksona bb 81000 Podgorica

Datumi	**Jun 2019-Mart 2022**
Zanimanje ili radno mjesto	Zaposleni na naučnom projektu „Procjena zdravstvenog rizika u opštini Pljevlja na osnovu podataka dobijenih iz humanog biomonitoringa" kao doktorand Biologije na PMF UCG
Glavni poslovi i odgovornosti	Analize zemljišta i voća i povrća na sadržaj teških metala, pesticida, PCB, PAH Priprema uzoraka Razvijanje metoda za analize navedenih parametara tehnikama GC-MS, GCMSMS, ICP-OES, FAAS , DMA Obrada i analiza rezultata
Ime i adresa poslodavca	Institut za javno zdravlje Crne Gore, Džona Džeksona bb 81000 Podgorica

Datumi	**Maj 2018-Maj 2019**
Zanimanje ili radno mjesto	Analitičar na inovativnom projektu
Glavni poslovi i odgovornosti	-Priprema uzoraka za standardne testove izluženja -izvođenje standardnih testova izluženja (EPA metode: 1313, 1314, 1315, 1316) -hemijska analiza dobijenih eluata primjenom tehnika ICP-OES, AAS, GFAAS a po potrebi i GC i GC/MS
Ime i adresa poslodavca	Institut za javno zdravlje Crne Gore, Džona Džeksona bb 81000 Podgorica

Datumi	**2017**
Zanimanje ili radno mjesto	Analitičar pripravnik
Glavni poslovi i odgovornosti	- Analiza vode, hrane, zemljišta, predmeta opšte upotrebe - Analiza pesticida, THM, PAH-ova, PCB-a - Analiza teških metala
Ime i adresa poslodavca	Institut za javno zdravlje, Džona Džeksona bb 81000 Podgorica
Vrsta djelatnosti ili sektor	Medicina i zdravlje

Obrazovanje i osposobljavanje

Datumi	2019-trenutno
Studije	**Student doktorskih studija Biologije**
Ime i vrsta organizacije obrazovne institucije	Prirodno-matematički fakultet; Univerzitet Crne Gore
Datumi	2018
Naziv dodijeljene kvalifikacije	**Master biohemije**
Glavni predmeti / stečene profesionalne vještine	Odbranjen master rad na temu Optimizacija metode za ispitivanje antimikrobnog djelovanja fenolnih kiselina na bioluminiscentnoj E. coli / biohemija, eksperimentalna biohemija, rad u biohemijskoj laboratoriji
Ime i vrsta organizacije obrazovne institucije	Prirodno-matematički fakultet, Departman za hemiju, biohemiju i zaštitu životne sredine, Univerzitet u Novom Sadu
Nivo prema nacionalnoj ili međunarodnoj klasifikaciji	VII-2
Datumi	2016
Naziv dodijeljene kvalifikacije	**Diplomirani biohemičar**
Glavni predmeti/stečene profesionalne vještine	Biohemija, hemija, analitička hemija, organska, neorganska, instrumentalne metode u hemiji i biohemiji
Ime i vrsta organizacije obrazovne institucije	Prirodno-matematički fakultet, Departman za hemiju, biohemiju i zaštitu životne sredine, Univerzitet u Novom Sadu
Nivo prema nacionalnoj ili međunarodnoj klasifikaciji	VII-1

Lične vještine i kompetencije

OBUČENA ZA RAD NA RAZLIČITIM ANALITIČKIM TEHNIKAMA KAO ŠTO SU GC, GC/MS, HPLC/MC, LC, ICP-OES

Kursevi i seminari

[2020. godine] Obuka za korišćenje i održavanje Shimadzu uređaja- Gasni hromatograf GCMS-TQ8050NX i softver GCMS Solution, LabSolution Insight

[2019. godine] Obuka za korišćenje i održavanje Shimadzu uređaja- Spektrofotometar UV-1900 i softvera UVProbe
Obuka za korišćenje i održavanje Shimadzu uređaja- Gasni hromatograf GCMS-QP2020NX i softver GCMS Solution, LabSolution Insight

[2018. godine] Obuka za korišćenje i održavanje Shimadzu uređaja – Gasni hromatograf GCMS-QP2010Plus i softver GCMSSolution

Obuka za operatera na sistemu Agilent Technologies 7890 GC sa ECD detektorom i 7697A Headspace Samplerom sa OpenLab Chemstation softverom

Obuka za korišćenje Shimadzu uređaja: Gasni hromatograf GC-2030AF i softver LabSolution

Značaj i uloga balneologije u rehabilitaciji inflamatornih stanja; CENTAR ZA NAUČNO-ISTRAŽIVAČKI RAD INSTITUTA „DR SIMO MILOŠEVIĆ" Igalo

[2017. godine] Osnovni kurs iz ICP optičko-emisione Spektrofotometrije
Praktični kurs: ICP-OES na instrumentu SPECTRO ARCOS

Agilent Technologies 1260 HPLC system with 6120 Mass Selective detector LCMS system and Agylent Technologies Gas Chromatography system 789A" Organizator: Institut za javno zdravlje, Podgorica

[2016 godine] Summer Programme Chemistry Organizator: Institute of Biochemistry, Grac, Austrija

Maternji jezik(ci) **Srpski**

Drugi jezik(ci) **Engleski, Francuski**

Samoprocjena

Evropski nivo (*)

Razumijevanje				Govor				Pisanje	
Slušanje		Čitanje		Govorna interakcija		Govorna produkcija			
B2	Nezavisni korisnik	B2	Nezavisni korisnik	B2	Nezavisni korisnik	B2	Nezavisni korisnik	B2	Nezavisni korisnik

Razumijevanje				Govor				Pisanje	
Slušanje		Čitanje		Govorna interakcija		Govorna produkcija			
A2	Početnik	A2	Početnik	A2	Početnik	A2	Početnik	A2	Početnik

(*) Zajednički evropski referentni okvir za jezike

Računarske vještine i kompetencije Windows XP, Microsoft Office™ tools, Internet

Vozačka dozvola | B kategorija

Dodaci | Biografski podaci

MSc Nevena Cupara,

Nevena Cupara je rođena 12.4.1993. godine u Pljevljima. Osnovnu školu „Salko Aljković" završila je 2008. godine. Gimnaziju „Tanasije Pejatović" završila je 2012. godine takođe u Pljevljima, nakon čega upisuje Prirodno-matematički fakultet u Novom Sadu, Departman za hemiju, biohemiju i zaštitu životne sredine, smjer biohemija. Godine 2016. odlazi u Grac gdje u okviru Ljetnje škole hemije boravi šest nedelja na Departmanu za biotehnologiju Tehničkog univerziteta. Te iste godine upisuje master studije na istom departmanu i odlazi na studentsku razmjenu u Aveiro (Portugal), gdje radi ekperimentalni dio master rada, koji je odbranila 2018. godine.

Kao doktorand na projektu „Procjena zdravstvenog rizika u opštini Pljevlja na osnovu podataka dobijenih iz humanog biomonitoringa" bila je angažovana u periodu od 2019. – 2021. godine u okviru koga je odradila eksperimentalni dio doktorske teze.

Trenutno je angažovana kao analitičar u laboratoriji za gasnu hromatografiju na odjeljenju za Instrumentalnu dijagnostiku Instituta za javno zdravlje Crne Gore.

Bibliografija

Radovi publikovani u medjunarodnim časopisima (SCI/SCIE lista)

Nevena Cupara, Irena Nikolić, Dijana Đurović, Ivana Milašević, Darko Medin, Slađana Krivokapić, (2022). Heavy metals assessment in agricultural soils and vegetables in the vicinity of industrial pollutants in the Pljevlja municipality (Montenegro): ecological and health risk approach, *Environmental Monitoring and Assessment*.https://doi.org/10.1007/s10661-022-10445-6

Nevena Cupara, Dijana Durović, Irena Nikolić, Ivana Milasević, Borko Bajić (2022). Assesment of ecological and health risk in agricultural soil near the mine of lead and zinc in Pljevlja municipality (Montenegro), *Fresenius Environmental Bulletin*, Volume 31– No. 08B/2022 pages 9036-9044.

Dijana Durović, Irena Nikolić, **Nevena Cupara**, Ivana Milasević (2022). Contamination and ecological risk assessment of heavy metals in agricultural soils in Pljevlja municipality (North Montenegro), *Fresenius Environmental Bulletin*, Volume 31– No. 04/2022, pp. 4536-4545.

Radovi publikovani u zbornicima sa konferencijama

Nevena Cupara, Irena Nikolić, Dijana Đurović, Ivana Milašević, Sladjana Krivokapić, Heavy metals content in soil and vegetables in the vicinity of mine of lead and zinc (Montenegro): contamination of soil and health risk assessment, XII International Conference Industrial Engineering and Environmental Protection 2022 (IIZS 2022) October 06-07, 2022, Zrenjanin, Serbia, pp.283-288.

Milena Tadić, Irena Nikolić, Dijana Đurović, **Nevena Cupara**, Ivana Milašević, Kinetic and thermodynamic aproach of strontium adsorption onto electric arc furnace slag, XII International Conference Industrial Engineering and Environmental Protection 2022 (IIZS 2022) October 06-07, 2022, Zrenjanin, Serbia, pp.278-282

Nevena Cupara, Dijana Đurović, Ivana Milašević, Irena Nikolić, Health risk assessment in agricultural soils in a city of pljevlja (Montenegro), X International Conference of Social and Technological Development, STED 2021; Trebinje, 3-6 June, 2021., Bosnia and Hercegovina. Str. 19.

Milena Tadić, Irena Nikolić, Dijana Đurović, **Nevena Cupara**, Ivana Milašević, Industrial waste as a new adsorbent for Cu2+ removal from aquatic solutions, X International Conference of Social and Technological Development, STED 2021; Trebinje, 3-6 June, 2021., Bosnia and Hercegovina. Str. 16.

Slađana Krivokapić, Miljan Bigović, Dijana Đurović, **Nevena Cupara**, Irena Nikolić, Assessment of Ecological Risk of Heavy Metal Contamination in agricultural soil in Municipality Pljevlja (Montenegro), str. 6th International conference on environmental science and technology (ICOEST) October 21-25, 2020, Belgrade, Serbia.21-24

Miljan Bigović, Slađana Krivokapić, Dijana Đurović, **Nevena Cupara**, Irena Nikolić, Agricultural soil pollution by heavy metals in the municipality of Pljevlja, Montenegro, 27th International Conference Ecological Truth and Environmental Research, EcoTER 20, 16 - 19 June 2020, Kladovo, Serbia, str. 82-87.

Environ Monit Assess (2022) 194:819
https://doi.org/10.1007/s10661-022-10445-6

Heavy metal assessment in agricultural soils and vegetables in the vicinity of industrial pollutants in the Pljevlja municipality (Montenegro): ecological and health risk approach

Nevena Cupara · Irena Nikolić · Dijana Đurović · Ivana Milašević · Darko Medin · Slađana Krivokapić

Received: 10 February 2022 / Accepted: 30 August 2022

Abstract This paper aims to assess ecological and health risks associated with heavy metal (As, Hg, Cd, Pb, Cu, Zn, Cr) content in agricultural soils and vegetables (potato tuber, beetroot, onion bulb, carrot root) collected near the lead and zinc mine (MLZ), coal-fired power station (CFPS) and coal mine (CM) located in Pljevlja municipality (Montenegro). The ecological risk of soil was estimated using the ecological risk index (*RI*) and pollution load index (*PLI*). The health risk was evaluated through different soil exposure pathways (ingestion, inhalation, dermal contact) and vegetable consumption. The pollution indices *RI* and *PLI* indicated the highest contamination in MLZ study area followed by CM and CFPS areas. *RI* values revealed considerable contamination in MLZ and CM study areas, while CFPS area is moderately contaminated by heavy metals. According to *PLI*, soil in MLZ and CM areas is classified as polluted, while the soil in the vicinity of CFPS is classified as unpolluted. Non-carcinogenic and carcinogenic health risks through soil exposure were identified for both children and adults, in all investigated areas. Dermal contact was identified as the main contributor to carcinogenic risk. Dermal contact was also identified as the main exposure pathway for non-carcinogenic risk in MLZ area, while for CFPS and CM areas, ingestion was the main exposure route. As for vegetables, only Cu and Zn were detected in all examined vegetables. Non-cancerogenic health risk of edible vegetable consumption was found for children in all study areas, while there was no health risk for adults.

Keywords Heavy metals · Agricultural soil · Vegetables · Ecological risk · Health risk

N. Cupara (✉) · D. Đurović · I. Milašević
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N. Cupara · D. Medin · S. Krivokapić
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Introduction

Agricultural soil contamination by heavy metals (HMs) has attracted special attention due to their well-known effect on soil function in food production. Although heavy metal pollution of agricultural land has always been considered a major challenge in the scientific community, studies based on observing the state of the environment through monitoring heavy metal concentrations in the soil are considered

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important to prevent additional loads on agricultural soils (Turhan et al., 2020). Continual loading of agricultural soils with heavy metals due to the different industrial activity inevitably leads to soil dysfunction and decline in crop productivity but also affects human health through the food chain (Obiora et al., 2016). However, direct exposure of humans to polluted soil may also present a health risk since toxic heavy metals may be easily transferred from soil to the human body via ingestion, inhalation, or dermal contact. Moreover, agricultural soils polluted by HMs present a serious risk due to their accumulation by crops and transfer into the human body through food intake (Edelstein & Ben-Hur, 2018). Thus, it is of great importance to investigate the ecological and health risk assessment of HMs in agricultural soil.

Plants are responsible for primary organic production, during which they are able to transform inorganic into organic compounds (Pajević et al., 2018). One of the most dominant exposure pathways to heavy metals is through food consumption, especially vegetables. Locally grown vegetables are influenced by all contamination sources, and industrial contamination strongly impacts on their safety and quality (Zhong et al., 2018). With nutrients, heavy metals could easily be transported to upper plant parts, stored in different tissues, or affect different metabolic pathways (Osaili et al., 2016). Thus, health risk evaluation due to the vegetable consumption has also attracted a special attention.

The municipality of Pljevlja is located in the north of Montenegro. The soil quality in this municipality is greatly influenced by the industrial activities associated with the power production in a coal-fired power station (CFPS), coal mine (CM) and lead and zinc mine (MLZ) located in this town. Coal combustion in a coal-fired power station at high temperatures (above 1000 °C) leads to the transfer of HMs into the gas phase. Further, the decrease of temperature leads to HM deposition on the surface of ash particles in the gas path of coal-fired power stations (Ćujić et al., 2016). Thus, HMs reach the atmosphere mainly in form of aerosols and finally have been deposited in the soil through wet or dry deposition (Linnik et al., 2020). Mining activities also present a serious risk for surrounding soil pollution by HMs. Spilled ore tailings, emissions of dust containing HMs into the atmosphere and generation of a large number of acidic mine wastewaters that contain heavy metals are the main pathways for soil contamination by HMs caused by mining activities (Zhang & Wang, 2020).

In the last decade, many studies have been conducted to assess soil contamination by HMs due to the generation of electricity in the coal-fired power stations (George et al., 2015; Huang et al., 2017b; Legalley & Krekeler, 2013; Özkul, 2016; Iruretagoiena et al., 2015; Tang et al., 2013; Turhan et al., 2020) and coal and Zn-Pb mining activities (Cheng et al., 2018; Hua et al., 2018; Huang et al., 2017a; Liang et al., 2017; Lu et al., 2015; Obiora et al., 2016; Doležalová Weissmannová et al., 2019; Ying et al., 2016). These studies indicate that the presence of HMs in the soil is mainly the result of anthropogenic factors. However, to the best of our knowledge, there is no study conducted to assess agricultural soil pollution and in the municipality of Pljevlja in Montenegro and or in Montenegro at all.

Thus, this study aims to assess the potential of heavy metal (As, Hg, Cd, Pb, Cu, Zn, Cr) pollution of agricultural soils and vegetables (potato tuber, beet root, onion bulb, carrot root) in the vicinity of the pollution sources (MLZ, CFPS and CM) in the municipality of Pljevlja. Chemical analysis of the soil and plants included the analysis of the content of metals which were important with respect to the source of pollution. These kinds of vegetables were selected since they have mainly been cultivated in this area. To estimate heavy metal soil pollution, ecological risk index (*RI*) and pollution load index (*PLI*) were calculated, and possible sources based on Pearson's correlation analysis and principal component analysis were discussed. Health risks for children and adults were assessed through different soil exposure routes, ingestion, inhalation, dermal contact and vegetable consumption.

Materials and methods

Study area

Pljevlja is the industrially and agriculturally important town in the north of Montenegro, located in a valley surrounded by hills and mountains up to 2000 m altitude. In such conditions, naturally, Pljevlja is covered with thick fog for a large number of days a year but also with smog as a consequence of air pollution. The pollution of the municipality of Pljevlja comes

from several sources that are of interest for this study and in the vicinity of the sampling sites. A coal-fired power station (CFPS) (43°20′09.1″N, 19°19′34.6″E) uses lignite as fuel from the local coal mine, with the Maljevac industrial waste landfill, is located about 4 km from the city centre and surrounded by agricultural land in the nearby villages (Gornji and Donji Komini, Kalušići, Maljevac and Ljuće). The coal mine Pljevlja (CM) (43°20′25.0″N, 19°22′12.4″E) is another source of pollution in this municipality. It is a surface lignite mine located 3.5 km from the city centre. In its immediate vicinity, there are arable lands in several settlements: Potrlica, Mrzovići, Grevo, Otilovići and Crljenice. The third, important source of pollution is a mine of lead and zinc (MLZ) with a flotation tailings Gradac, located in Gradac village (43°23′57.4″N 19°09′02.7″E).

Chemical analysis and quality control

Soil samples were collected from a maximum of 20 cm of depth (Reimann et al., 2014) from agricultural fields in the vicinity of CFPS, MLZ and CM and were prepared according to the modified standard method EPA 3050b (US EPA, 1996) by wet digestion with aqua regia ($HCl:HNO_3 = 3:1$). To remove water, the samples were dried at 105 °C for 24 h in an air-blowing thermostatic oven. The dried samples were then sieved through a 2-mm sieve and prepared by the aforementioned method.

Edible vegetable sample such as potato (*Solanum tuberosum* L.), beet (*Beta vulgaris* L.), onion (*Allium cepa* L.) and carrot (*Daucus carota* L.) collected from the agricultural fields near sources of pollution were prepared according to the standard method MEST EN 13805:2009 which involves the use of a microwave system for digestion. Samples were washed and homogenized by grinding. After that, 0.5 g of sample was transferred to a microwave cuvette, and the digestion process was performed with 5 ml of concentrated HNO_3 and 2 ml of concentrated H_2O_2. After the digestion, samples were transferred in a volumetric flask (25 ml) and filled with distilled water to the line.

The total content of metals of interest (Cu, Cd, Zn, Cr, Pb) was determined by the technique ICP-EOS (inductively coupled plasma - optical emission spectrometry), brand SPECTRO ARCOS FHE12. The total arsenic content was determined by FAAS (flame atomic absorption spectrometry) (Perkin Elmer Analyst 300), while the total mercury content was determined directly by direct mercury analyser (DMA 80). The concentrations of metals were analysed in triplicates.

Calibration for all three techniques was performed by using metal standards (CPA chem) with five calibration points. Before determining the content of HMs, the blank sample was analysed, as well as the prepared spiked sample at two levels (LoQ and 5 times LoQ). Quality control was ensured by determining the content of HMs in the certified reference material (IAEA-158) containing the following significant metal concentrations: As (11.5 $mg \cdot kg^{-1}$), Cd (0.372 $mg \cdot kg^{-1}$), Cr (74.4 $mg \cdot kg^{-1}$), Cu (48.3 $mg \cdot kg^{-1}$), Pb (39.6 $mg \cdot kg^{-1}$), Zn (140.6 $mg \cdot kg^{-1}$) and Hg (0.132 $mg \cdot kg^{-1}$). The overall uncertainty of the analytical methods was below 10%.

Assessment of soil contamination by heavy metals

Soil contamination by HMs due to the anthropogenic activities was assessed by the evaluation of ecological risk index (*RI*) and pollution load index (*PLI*).

The potential ecological risk (*RI*) is determined as proposed by Hakanson and used to quantify the level of ecological risk degree of HMs in agricultural soils (Hakanson, 1980). *RI* is calculated as follows:

$$RI = \sum E_r \tag{1}$$

$$E_r = T_i \cdot C_f \tag{2}$$

$$C_f = \frac{C_i}{C_{ri}} \tag{3}$$

where E_r, C_f and T_i are ecological risk factor, contamination factor and toxic response factor of the element i, respectively. C_i and C_{ri} are the concentrations of the element i in the soil sample and the geochemical reference or background value of the element i in the Earth's crust, respectively. The values of T_i for As, Hg, Pb, Cd, Cu, Zn and Cr are 40, 10, 5, 30, 5, 1 and 2 and geochemical background concentrations 13, 0.4, 20, 0.3, 45, 95 and 90 $mg \cdot kg^{-1}$, respectively (Taylor, 1964). The degree of ecological risk can be categorized as follows: $RI < 150$, low risk; $150 \leq RI < 300$, moderate risk; and $RI \geq 600$, high contamination.

The pollution index (*PLI*), calculated using Eq. 4, provides the information on the overall level of HM pollution:

$$PLI = (C_{f1} \cdot C_{f2} \cdot C_{f3} \cdot .....C_{fn})^{1/n} \quad (4)$$

When $PLI > 1$, it means the soils are polluted by heavy metals, and when $PLI < 1$, it means the soils are unpolluted.

Assessment of health risk

Humans could be exposed to contaminants from soil via ingestion, inhalation or through dermal exposure and contamination via vegetable consumptions. Non-carcinogenic and carcinogenic risk for adults and children through each of exposure pathways to soil was calculated using the methodology proposed by the US EPA (US EPA, 1989, 2011).

The average daily doses (ADD_s) (mg·kg^{-1}·day^{-1}) of potentially toxic metals via soil ingestion (ADD_{ing}), soil inhalation (ADD_{inh}) and dermal contact with soil (ADD_{derm}) for both adults and children were estimated using the following eqs:

$$ADD_{ingestion} = \frac{C \cdot IngR \cdot EF \cdot ED}{BW \cdot AT} \cdot 10^{-6} \quad (5)$$

$$ADD_{inhalation} = \frac{C \cdot InhR \cdot EF \cdot ED}{PEF \cdot BW \cdot AT} \quad (6)$$

$$ADD_{dermal} = \frac{C \cdot SA \cdot SAF \cdot ABS \cdot EF \cdot ED}{BW \cdot AT} \cdot 10^{-6} \quad (7)$$

Factors used in the risk assessment equations are given in Table 1. C is the concentration of the contaminant in the soil; $IngR$ is the ingestion rate of the soil; EF is an exposure frequency; ED is an exposure duration; BW is an average body weight; AT is an averaging time; $InhR$ is an inhalation rate; PEF is a particle emission factor; SA is a surface area of the skin that contacts the soil; SAF is a skin adherence factor for the soil; ABS is a dermal absorption factor (chemical specific).

Non-carcinogenic effects of each HM present in a soil were assessed using the hazard quotient (HQ_i) and hazard index (HI) according to Eq. 8 and 9, while carcinogenic effects were assessed using the carcinogenic risk (CR_i) and total carcinogenic risk (TCR) by Eqs. 10 and 11:

$$HQ_i = \frac{ADD_i}{RfD_i} \quad (8)$$

$$HI = \sum HQ_i \quad (9)$$

$$CR_i = ADD_i \cdot SF \quad (10)$$

$$TCR = \sum CR_i \quad (11)$$

RfD_i is the reference dose which presents the maximum daily dose of each individual metal from a specific exposure pathway, for both adults and children that is believed not to lead to an appreciable risk of deleterious effects to sensitive individuals

Table 1 Factors used in the risk assessment equations

Factor	Value		Reference
	Children	Adults	
$IngR$ (mg·day^{-1})	200	100	US EPA (2002)
$InhR$ (m^3·day^{-1})	7.6	20	US EPA (2002)
EF (day·year^{-1})	350	350	US EPA (2009)
ED (years)	6	24	Hu et al. (2014); US EPA (2002)
BW (kg)	24.5	59.4	Ministry of Health (China) (2006)
AT (days) (non-carcinogens)	EF·ED	EF·ED	US EPA (1989)
AT (days) (carcinogens)	EF·70	EF·70	US EPA (1989)
PEF (m^3·kg^{-1})	$1.36 \cdot 10^9$	$1.36 \cdot 10^9$	Hu et al. (2014); US EPA (2002)
SA (cm^2)	2800	5700	Hu et al. (2014); US EPA (2002)
SAF (mg·cm^{-2}·day^{-1})	0.2	0.07	US EPA (2002)
ABS	0.001	0.001	US EPA (2011)
ABS (As)	0.03	0.03	US EPA (2011)

during a lifetime; CR_i is a cancer risk of each individual HM, SF is a slope factor for carcinogenic exposure, and TCR is a total cancer risk. Reference values of some parameters for health risk assessment of heavy metals in soils are given in Table 2. If $HI < 1$, there is no significant non-carcinogenic risk, while for $HI > 1$, there is a likelihood of adverse health effects. According to the US EPA regulatory, the tolerable cancer risk is in the range $1 \cdot 10^{-6}$ to $1 \cdot 10^{-4}$ (US EPA, 2015). The cancer risk is considered insignificant when TCR is less than $1 \cdot 10^{-6}$ and harmful when TCR is higher than $1 \cdot 10^{-4}$.

To assess the health risk due to the vegetable consumption, estimated daily intake (EDI), target hazard quotient (THQ), total hazard quotient ($TTHQ$) and hazard index (HI) were calculated according the following equations (Shaheen et al., 2016):

$$EDI = \frac{I_{Intake} \cdot Ef \cdot ED \cdot C_p}{BW \cdot AT} \cdot 10^{-3} \quad (12)$$

$$THQ = \frac{EDI}{RfD} \quad (13)$$

$$TTHQ_{(individualplant)} = THQ_{(metal1)} + THQ_{(metal2)} + ... + THQ_{meta\ ln)} \quad (14)$$

$$HI_{plant} = \sum TTHQ = TTHQ_{plant1} + TTHQ_{plant2} + ... + TTHQ_{plantn} \quad (15)$$

I_{intake} is a plant daily intake rate (223 g·day^{-1} for children and 366 g·day^{-1} for adults) (Hu et al., 2014; Ministry of Health (China), 2006); C_p is the concentration of the contaminant in a specific plant (mg·kg^{-1}of fresh weight). If the $THQ > 1$, there is a potential health risk, and if THQ < 1, there is no obvious risk from the substance over a lifetime of exposure.

Statistical analysis

The data obtained in this study were expressed as mean ± standard error of samples per examined location (mean values of metal concentrations at three locations MLZ, CPFS and CM in soil and vegetable samples). Data processing and statistical analysis were performed using Microsoft Excel 2003 (Microsoft, Redmond, WA, USA). SPSS v.20.0 for Windows (SPSS, Inc., USA) was used to perform Pearson's correlation analysis and principal component analysis (PCA). Oblimin with Kaiser normalization rotation was applied to extract PCs according to the eigenvalue with the variance > 10%.

Results and discussion

HM content in agricultural soil

Descriptive statistics of HM concentrations in agricultural soil is given in Table 3. As can be seen, Zn is the metal with the highest concentration in all soil samples. The mean concentration of HM varies in the range as follows: Zn (119.89–661.72 mg·kg^{-1}), Pb (33.77–660.60 mg·kg^{-1}), Cu (47.69–113.31 mg·kg^{-1}),

Table 2 RfD_i values (mg·kg^{-1}·day^{-1}) and slope factor (mg·kg^{-1}·day^{-1}) (Li et al., 2017)

Metal	RfD_{ing}	RfD_{inh}	RfD_{der}
As	3.00E-04	3.00E-04	1.23E-04
Hg	3.00E-03	8.57E-05	2.10E-05
Pb	3.50E-03	3.52E-03	5.25E-04
Cd	1.00E-03	1.00E-03	1.00E-05
Cu	4.00E-02	4.20E-02	1.20E-02
Zn	3.00E-01	3.00E-01	6.00E-02
Cr	3.00E-03	2.86E-05	6.00E-05
Metal	SF_{ing}	SF_{inh}	SF_{der}
$As_{(cancer)}$	1.50E+00	1.51E+01	1.50
$Pb_{(cancer)}$	8.50E-03	4.20E-02	8.50E-03
$Cd_{(cancer)}$	3.80E-01	6.30E+00	3.80E-01
$Cr_{(cancer)}$	5.01E-01	4.20E+01	20.00

Cr (23.53–36.87 mg·kg^{-1}), As (9.18–18.19 mg·kg^{-1}), Cd (1.48–2.64 mg·kg^{-1}) and Hg (0.078–0.35 mg·kg^{-1}). The highest concentrations of HMs were observed in the soil collected near the MLZ area ranked in descending order as Zn > Pb > Cu > Cr > As > Cd > Hg. The mean concentrations of Zn (661.72 ± 147.11 mg·kg^{-1}), Pb (660.60 ± 99.60 mg·kg^{-1}), Cu (113.31 ± 17.65 mg·kg^{-1}), As (18.19 ± 5.81 mg·kg^{-1}) and Cd (2.49 ± 0.56 mg·kg^{-1}) exceed their background values in the Earth's crust (Taylor, 1964) where the maximum allowable limits were 95 mg·kg^{-1} for Zn, 20 mg·kg^{-1} for Pb, 45 mg·kg^{-1} for Cu, 13 mg·kg^{-1} for As and 0.3 mg·kg^{-1} for Cd. Also, Zn, Pb and Cd exceed the maximum allowable concentrations (MAC) in soil according to the Montenegrin legislation (OG18/97, 1997) indicating considerable pollution in this study area. Similar studies were performed near lead and zinc mine in China (Li et al., 2006), where the concentrations of Pb, Zn, Cd and Cu were above permitted limits and this soil was described as unsuitable for agricultural use. On the other hand, the concentrations of Cr and Hg were below the limits for both MAC and background values. The lower content of metals compared to background values indicates the lithogenic source of metals. This is visible for Cr and Hg at all investigated areas. Furthermore, the mean concentrations of HMs in CFPS samples were below MAC, except for Pb (33.77 ± 5.74 mg·kg^{-1}). These results slightly differ from the study previously performed by Linnik et al. (Linnik et al., 2020) on soil near coal-fired power plant, pointing out the enrichment of soil with Pb, Zn and Cu. HM concentrations in CM sample groups were below MAC, except Pb and Cd. The mean concentrations of Pb and Cd in CM samples were 37.54 ± 5.67 mg·kg^{-1} and 2.64 ± 0.59 mg·kg^{-1}, respectively. It is obvious that high concentrations of Cd are a consequence of the work of the surface coal mine, since Cd high concentrations near this source of pollution were previously observed (Cao et al., 2009). The mean concentrations of HMs in CFPs and CM areas are ranked in a descending order, as Zn > Cu > Pb > Cr > As > Cd > Hg.

Statistical analysis

Pearson's correlation analysis

One of the most used methods to identify the connection between heavy metals and potential sources of heavy metals in soil samples is through Pearson's correlation coefficient. The results of this statistical

Table 3 Descriptive statistics of heavy metal content presented as mean ± standard error (mg·kg^{-1}) in agricultural soil from Pljevlja municipality (Montenegro) (values that exceed MAC are bolded)

Sample location	Parameter	Metal						
		As	Hg	Pb	Cd	Cu	Zn	Cr
	Background value	13.00	0.40	20.00	0.30	45.00	95.00	90.00
	MAC*	20.00	2.00	20.00	2.00	200.00	300.00	50.00
MLZ	Mean ± SE	18.19 ± 5.81	0.35 ± 0.11	**660.60 ± 99.60**	**2.49 ± 0.56**	113.31 ± 17.65	**661.72 ± 147.11**	23.53 ± 2.02
	Min	8.24	0.05	104.40	0.52	48.88	140.31	15.70
	Max	57.71	0.93	901.00	4.36	168.70	1150.29	29.10
	Median	12.91	0.27	780.70	2.94	128.31	815.27	25.39
CFPS	Mean ± SE	10.30 ± 0.66	0.08 ± 0.01	**33.77 ± 5.74**	1.48 ± 0.28	47.69 ± 4.19	119.89 ± 11.91	25.43 ± 2.42
	Min	3.55	0.03	8.53	0.17	23.13	54.65	12.26
	Max	14.43	0.16	139.59	6.29	112.68	300.01	60.59
	Median	10.96	0.06	26.64	1.11	39.70	102.61	22.90
CM	Mean ± SE	9.18 ± 0.68	0.33 ± 0.18	**37.54 ± 5.67**	**2.64 ± 0.59**	52.28 ± 6.45	121.19 ± 8.20	36.87 ± 3.36
	Min	4.55	0.05	9.28	0.84	5.67	81.98	20.56
	Max	12.63	2.01	61.96	6.47	79.26	170.49	55.57
	Median	9.83	0.09	35.25	2.29	57.02	119.77	40.76

*Maximum allowable concentration by Montenegrin legislation (OG18/97, 1997)

method are divided in three separate parts by pollution sources (Table 4).

In MLZ samples, a significant positive correlation at $p \leq 0.01$ of Zn was observed with Pb r (6)=0.908, p=0.002 indicating that Zn and Pb originate from the same source with high probability. This data shows that lead and zinc mine probably is the main source of soil pollution. Copper usually follows Pb and Zn minefields, and in this case, there is a significant positive correlation at $p \leq 0.05$ between Zn and Cu r (6)=0.748 at p=0.033 and Pb and Cu r (6)=0.685 at p=0.031.

Furthermore, in CFPS samples, a strong positive correlation of Pb was observed with Zn r (21)=0.748 at $p<0.001$ and Cu r (21)=0.745 at $p<0.001$. Zn also has a strong positive correlation with Cu r (21)=0.862 at $p<0.001$, while Cr showed strong positive correlation with Cd r (21)=0.770 at $p<0.001$. This might indicate the same source of these heavy metals. In some previous studies (Li & Sun, 2016; Singh et al., 2010), it was proven that Cr and Cd could originate from flying ash produced by the thermal power plant and migrate to agricultural soil. Some positive correlations at $p \leq 0.05$ were observed between Cr and Cu r (21)=0.519 at p=0.011 and Cr and Zn r (21)=0.505 at p=0.014. In this contamination zone, Pb, Zn and Cu had much lower mean values than in MLZ samples.

Table 4 Pearson's correlation of HM content in soil at examined locations

MLZ							
	As	Hg	Pb	Cd	Cu	Zn	Cr
As	1						
Hg	0.454	1					
Pb	0.353	−0.204	1				
Cd	0.283	0.501	0.337	1			
Cu	0.198	−0.098	**0.685***	0.611	1		
Zn	0.534	−0.132	**0.908****	0.249	**0.748***	1	
Cr	−0.145	0.464	0.258	0.569	0.143	0.048	1
CFPS							
	As	Hg	Pb	Cd	Cu	Zn	Cr
As	1						
Hg	−0.326	1					
Pb	−0.031	0.384	1				
Cd	0.410	−0.231	0.106	1			
Cu	0.160	0.198	**0.745****	0.391	1		
Zn	0.087	0.275	**0.748****	0.298	**0.862****	1	
Cr	0.327	−0.010	0.238	**0.770****	**0.519***	**0.505***	1
CM							
	As	Hg	Pb	Cd	Cu	Zn	Cr
As	1						
Hg	−0.019	1					
Pb	0.153	0.358	1				
Cd	0.180	0.124	**0.632***	1			
Cu	−0.135	0.287	0.091	−0.234	1		
Zn	0.149	0.324	0.585	0.462	0.555		
Cr	0.373	0.107	**0.806****	0.510	0.109	**0.705***	1

**Correlation is significant at the 0.01 level (2-tailed)

*Correlation is significant at the 0.05 level (2-tailed)

Finally, in CM samples, significant positive correlation was observed between Cr and Pb $r(9)=0.806$ at $p=0.003$ indicating the same source of their origin. In this case, it is an open coal mine, and there are previous studies confirming the presence of these elements in coal (Cui et al., 2019).

PCA (principal component analysis)

Further, heavy metal source was identified based on the PCA analysis, and two principal components were extracted with the eigenvalues > 1 accounting for 72.40%, 73.34% and 66.11% of the total variances for MLZ, CFPS and CM area (Table 5 and Fig. 1). For the purposes of determining inter-metal relationships, factor of loadings (> 0.75) was used. For MLZ study area (Fig. 1a), PC1 explained 47.07% of the total variance and was characterized by the high loading of Zn and Cu which suggested that Zn and Cu originated from the same source. These metals are otherwise typical markers for Pb/Zn mining (Liu et al., 2020). This is in an agreement with the results of Pearson's correlation of the content of heavy metals in the mining area. PC2 explained 25.33% of the total variance and was highly loaded by Cr, Pb, Cd and Hg. The concentration of Hg and Cr in investigated soil samples was below the referent background values which may indicate the lithogenic origin of these metals.

Concentrations of heavy metals should always be compared to local background values. However, since local background values for these metals are not available, the metal concentrations were compared with background concentrations of metals obtained from Taylor (1964). Lower concertation of some metals in comparison to their background values should indicate lithogenic origin of metals. However, in the absence of data on local background values of metals, such approach is especially problematic regarding the Hg and Cr content in soil, since intensive agriculture activities in Pljevlja municipality involve the use of pesticides and fertilizers which may also be important sources of Hg and Cr in soil (Yang et al., 2018). So, the content of Hg and Cr in soil might be rather the result of agricultural activities than lithogenic character. This dilemma imposes necessity to establish local background values for metals in soil. On the other hand, concentration of Pb and Cd were above respective background value, indicating anthropogenic influence and may originate from both, agricultural and mining activities (Liu et al., 2018). Pb and Cd are shared metals in PC1 and PC2 suggesting that the contribution of these metals is present in both components indicating origin from both mining and agricultural activities, but it is much more dominant in PC2.

For CFPS study area, PC1 and PC2 explained 44.07% and 27.27% of the total variance, respectively. The results obtained are presented in Table 5 and Fig. 1b. PC1 component was characterized by high loading of Zn, Cu and Pb which are the markers for soil pollution by the operation of CFPS (Iruretagoiena et al., 2015). PC2 component was highly loaded with As, Cr and Cd which probably originated from agricultural activities, as previously reported (Yang et al., 2018).

The results of PCA analysis for CM study area are given in Table 5 and Fig. 1c. Two principal components extracted can explain 66.11% of total variance. PC1 accounted for 44.29% of total

Table 5 Principal component analysis for heavy metals in agricultural soils from investigated areas in Pljevlja municipality. (Items of high loadings (> 0.75) were bolded))

Location	MLZ		CFPS		CM	
Component	PC1	PC2	PC1	PC2	PC1	PC2
Eigenvalues	3.30	1.77	3.23	1.91	3.11	1.53
Variance (%)	47.07	25.33	46.07	27.27	44.29	21.82
Cumulative (%)	47.07	72.40	46.07	73.34	44.29	66.11
Zn	**0.972**		**0.904**		0.571	0.654
Cu	**0.890**		**0.874**			**0.901**
As	0.621			0.728	0.509	
Cr		**0.878**	0.427	0.711	**0.862**	
Pb	0.510	**0.798**	**0.893**		**0.821**	
Cd	0.607	**0.763**		0.711	**0.821**	
Hg		**0.756**	0.552	0.569		0.606

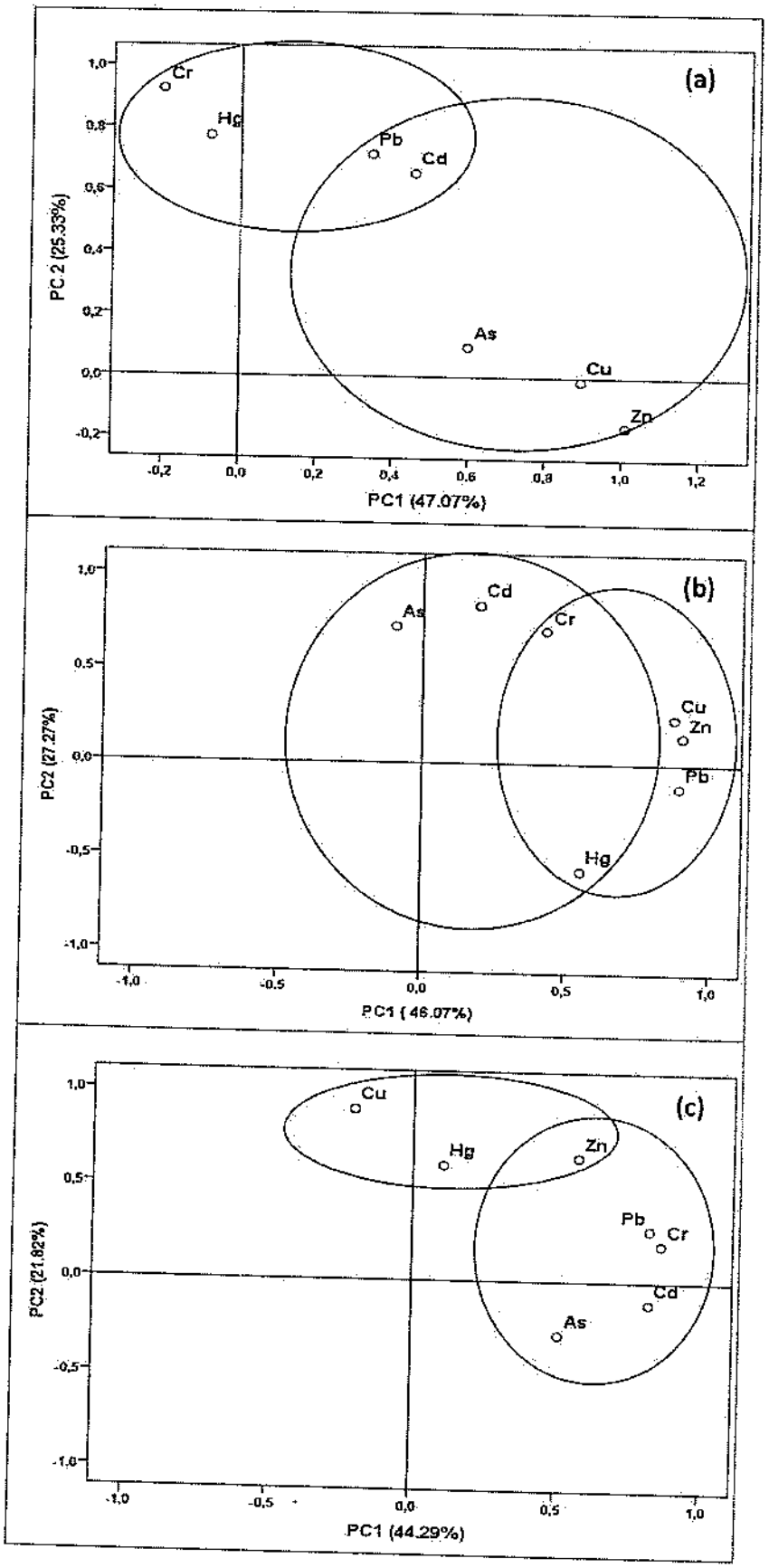

Fig. 1 PCA results in the two-dimensional space plot of loading of the first two principal components for different locations (a MLZ, b CFPS, c CM)

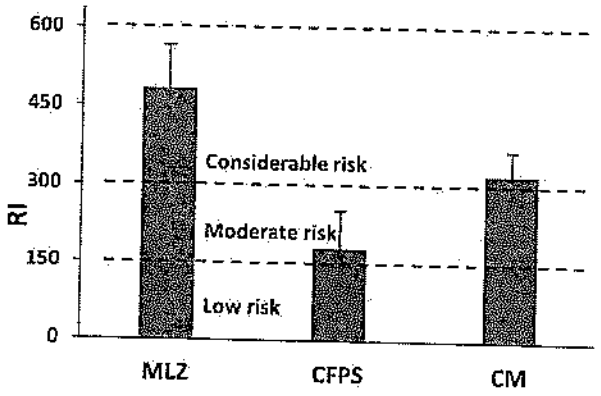

Fig. 2 Values of the potential ecological risk index (RI) for HMs in the agricultural soils collected near MLZ, CFPS, and CM areas (error bars represent standard deviation of results)

variance and mainly included Cr, Pb and Cd, while PC2 accounted for 21.82% and is characterized by the high loading of Cu (with loading > 0.75). Cr, Pb and Cd present in CM soil are a result of human factor and might originate from mining activities, specifically derived from coal mine effluents (Reza et al., 2015), while Cu originates from agricultural activities.

Therefore, anthropogenic factor is the main reason for agricultural soil load by heavy metals in Pljevlja municipality.

Assessment of HM soil pollution

The ecological risk index (*RI*) of HMs in the agricultural soils in the vicinity of industrial pollutants in the municipality of Pljevlja is given in Fig. 2. The values of *RI* for MLZ soil varied from 118.34 to 700.55 with an average value of 482.6 ± 83.08. This result is in the range of $300 \leq RI < 600$, indicating that the integrated potential ecological risk of HMs is at considerable risk. *RI* values for CFPS varied in the range of 37.89 to 662.40, with the average *RI* value 179.11 ± 71.99 that classifies this location as moderately contaminated by HMs. CM soil results for *RI* varied from 116.39 to 686.92, with the average *RI* values 321.62 ± 45.15, suggesting the considerable risk of soil contamination by HMs. Contribution of each metal to *RI* is given in Fig. 3. Cd concentrations showed the highest contribution in MLZ, CFPS and CM soils with the values of 54.4%, 82.0% and 78.6%, respectively. Significant contribution to *RI* was also observed for Pb in MLZ area (34.6%) followed by Hg (4.9%), Cu (2.7%), As (2.1%), Zn(1.3%) and Cr (0.1%). In CFPS area, the highest contribution of Cd was followed by Pb (5.0%) As (4.5%), Hg (4.4%), Cu (3.0%), Zn (0.7%) and Cr(0.3%), while in CM area, Hg has the highest prevalence after Cd with a value of 12.0%, followed by Pb (3.3%), As (3.2%), Cu (2.2%), Zn (0.5%) and Cr (0.3%).

The mutual contamination effects of the HMs are expressed by using *PLI*, and the results are given in Fig. 4. The highest value of *PLI* (2.59 ± 0.21) is observed for MLZ area followed by value *PLI* in CM area (1.09 ± 0.29) indicating the contaminated study areas. On the other hand, CFPS is characterized as unpolluted since *PLI* value was found to be 0.83 ± 0.09.

Health risk assessment of HMs through soil exposure

Non-carcinogenic health risk assessment

The non-carcinogenic health risks caused by the exposure to the soil from industrial pollutants for children and adults via ingestion, inhalation and dermal contact are given in Table 6. The results obtained indicate

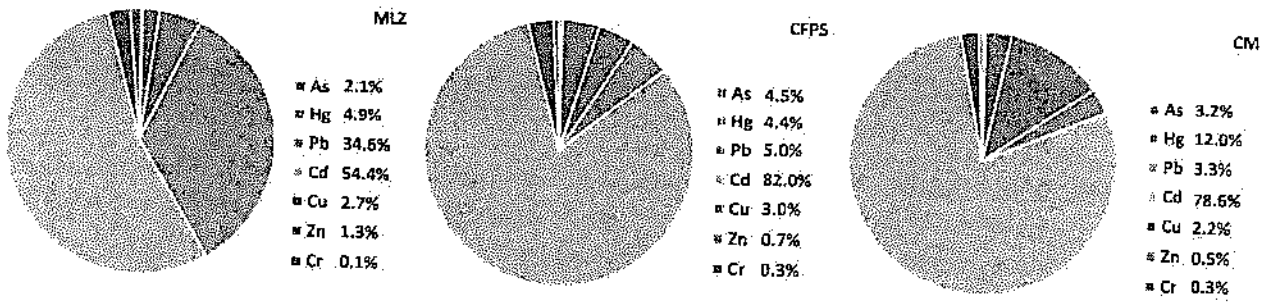

Fig. 3 Contribution of each analysed metal to RI

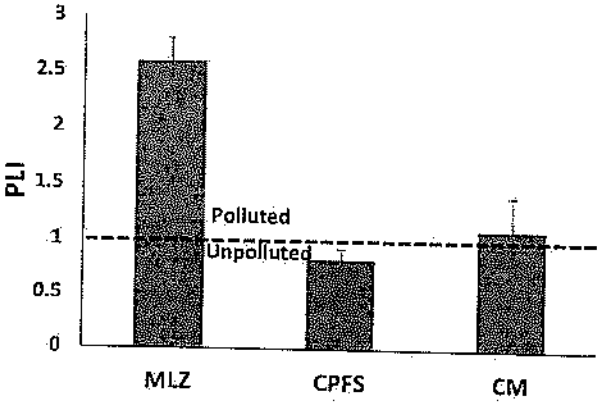

Fig. 4 Values of the pollution load index (PLI) for HMs in the agricultural soils collected at MLZ, CFPS, and CM areas (error bars represent standard deviation of results)

that children are at higher risk than adults. The highest health risk for humans was observed in MLZ study area followed by *HI* values for CM and CFPS areas, respectively. The values of non-carcinogenic hazard indexes for Hg, Cu and Zn are all lower than 1, in all study areas indicating that there are no non-carcinogenic risks of these metals for both children and adults through the soil exposure. On the other hand, hazard indexes for Cr, Pb, Cd and As are of concern since *HI* values of these metals were found to be higher than one. As shown in Table 6, the hazard indexes for children in MLZ study area exceed 1 for As (2.28E+00), Pb (1.28E+01), Cd (1.99E+00) and Cr (9.60E+00). It is evident that Cr and Pb show the highest health risk for children (MLZ). For adults, only Pb and Cr are of concern with *HI* values 2.65E+00 and 1.98E+00, respectively.

As for CFPS and CM study areas, the *HI* values higher than 1 were observed for Cr, As and Cd for children, while adults are faced with non-carcinogenic risks in these areas only with respect to Cr. The calculated values of *HI* for children in CFPS area were 1.29E+00, 1.19E+00 and 1.04E+01, for As, Cd and Cr, respectively. *HI* value for Cr for adult population was found to be 2.14E+00. In CM area, *HI* values for children were calculated to be 1.15E+00, 2.12E+00 and 1.50E+01 for As, Cd and Cr respectively, while for adults in this area, *HI* for Cr was 3.11E+00.

Table 6 Results of non-carcinogenic and carcinogenic risk of different pathways and metals (values of $HI > 1$ and $TCR > 1{\cdot}10^{-4}$ are bolded)

Sampling site	Metal	*HI*		*TCR*	
		Children	Adults	Children	Adults
MLZ	As	**2.28E+00**	4.87E-01	**2.79E-03**	**5.95E-04**
	Hg	1.65E-01	3.41E-02		
	Pb	**1.28E+01**	**2.65E+00**	**3.06E-04**	6.32E-05
	Cd	**1.99E+00**	4.12E-01	**1.38E-04**	2.85E-05
	Cu	1.17E-01	2.43E-02		
	Zn	1.21E-01	2.50E-02		
	Cr	**9.60E+00**	**1.98E+00**	**1.15E-02**	**2.38E-03**
CFPS	As	**1.29E+00**	2.75E-01	**1.58E-03**	**3.37E-04**
	Hg	3.53E-02	7.28E-03		
	Pb	6.56E-01	1.35E-01	1.56E-05	3.23E-06
	Cd	**1.19E+00**	2.45E-01	8.21E-05	1.70E-05
	Cu	4.95E-02	1.02E-02		
	Zn	2.20E-02	4.53E-03		
	Cr	**1.04E+01**	**2.14E+00**	**1.25E-02**	**2.58E-03**
CM	As	**1.15E+00**	2.46E-01	**1.41E-03**	**2.69E-04**
	Hg	1.54E-01	3.17E-02		
	Pb	7.29E-01	1.51E-01	1.73E-05	3.58E-06
	Cd	**2.12E+00**	4.37E-01	**1.46E-04**	3.01E-05
	Cu	5.42E-02	1.12E-02		
	Zn	2.22E-02	4.58E-03		
	Cr	**1.50E+01**	**3.11E+00**	**1.80E-02**	**3.72E-03**

The same contribution of different pathways to non-carcinogenic risk was obtained for both populations. Among the three different pathways of exposure to the soil for booth population in MLZ area (Fig. 5a), dermal contact was recognized as the main health risk (60.7%) followed by ingestion (31.5%) and inhalation (7.9%). On the other hand, in CFPS and CM areas, ingestion was the main health risk (around 54%), followed by dermal contact (around 42%) and inhalation pathway (3%).

Carcinogenic health risk assessment

As in the previous case, children are generally faced with a higher carcinogenic health risk than adults (Table 6). The results presented in Table 6 indicate the highest carcinogenic risk in MLZ study area, since the highest *TCR* values were obtained for this location. The children population in MLZ were under the serious carcinogenic risk due to the soil exposure since *TCR* values for As, Pb, Cd and Cr were 2.79E-03, 3.06E-04, 1.38E-04 and 1.15E-02, respectively. In CFPS area, only *TCR* values of As (1.58E-03) and Cr (1.25E-02) for children exceeded acceptable range, while in CM area, *TCR* values for As, Cd and Cr were 1.41E-03, 1.46E-04 and 1.80E-02, respectively, indicating that children are at risk caused by these metals. Adults in all investigated areas are faced with carcinogenic risk only by As and Cr. *TCR* values for these two metals in MLZ area were 5.95E-04 and 2.38E-03, respectively, in CFPS area 3.07E-04 and 2.58E-03 and in CM are 2.69E-06 and 3.72E-03, respectively.

As in the previous case, the contribution of different pathways to carcinogenic risk was similar for adults and children. The results presented in Fig. 5b show that the health risk posed by carcinogenic elements via ingestion for all investigated areas was the highest with the contribution to the total cancer risk of 70.6%, 69.2 and 68.5% for MLZ, CFPS

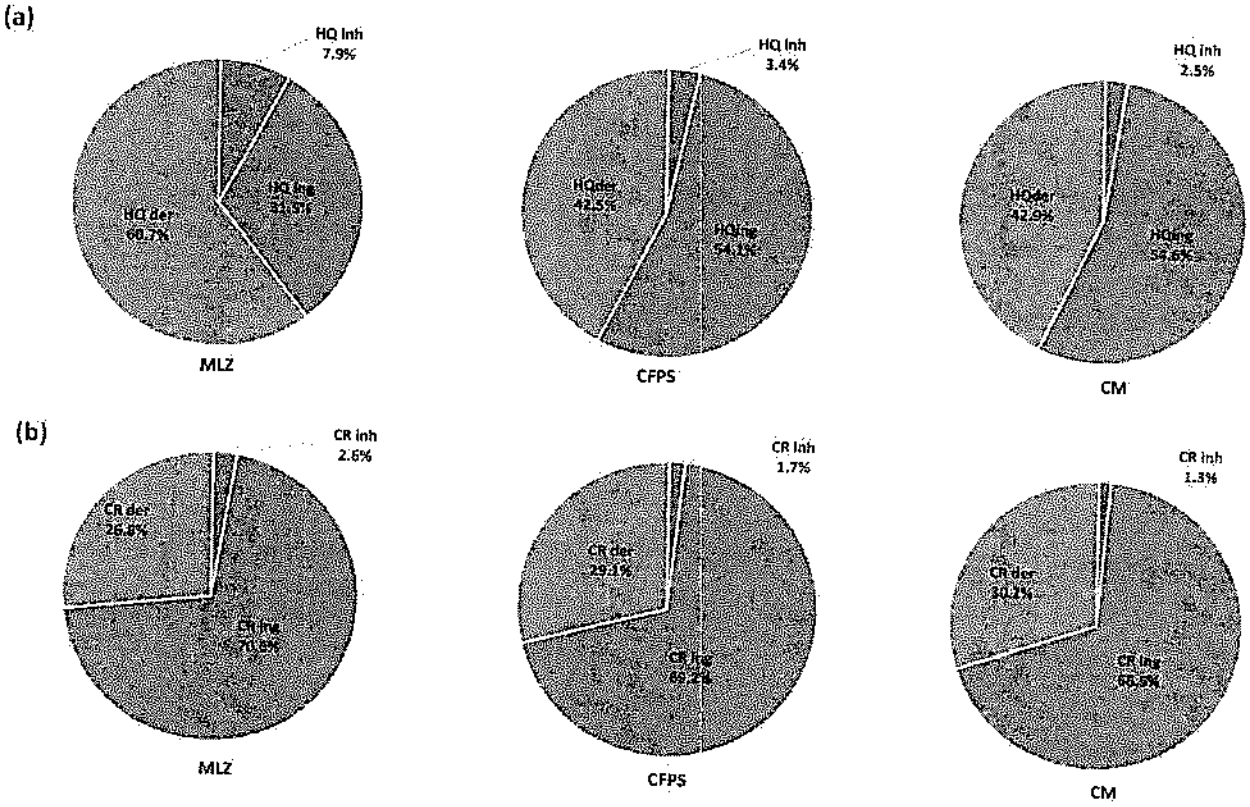

Fig. 5 **a** Contribution of each exposure pathway to non-carcinogenic health risk expressed as contribution of hazard quotient (HQi) to total hazardous index (HI) in MLZ, CFPS, and CM study areas. **b** Contribution of each exposure pathway to carcinogenic health risk expressed as contribution of carcinogenic risk (CRi) to total cancer risk (TCR) in MLZ, CFPS, and CM study areas

and CM area, respectively. Ingestion is followed by dermal contact with a contribution of 26.8%, 29.1% and 30.2% and small contribution arrives from inhalation pathway is with 2.6%, 1.7% and 1.3% for MLZ, CFPS and CM area, respectively.

HM concentrations in edible parts of vegetables

The results of descriptive statistics for metal content in edible parts of vegetables are given in Table 7. With the exception of Cu and Zn, chemical analysis of vegetable samples indicated concentrations of the majority of HMs (As, Hg, Pb, Cd and Cr) below the limits of detection. Thus, only the content of Cu and Zn in vegetable samples was discussed. The maximum allowable concentration for Zn in vegetable has not been proposed, while for Cu, this limit is 40 $mg{\cdot}kg^{-1}$ of fresh vegetable (FAO/WHO, 2011). The mean concentrations of Cu in all kinds of vegetables are far way below this limit. The highest mean value of Cu concentration was observed in CM potato samples (1.29 ± 0.15 $mg{\cdot}kg^{-1}$) followed by Cu content in MLZ potato tuber samples (1.27 ± 0.21 $mg{\cdot}kg^{-1}$). The mean concentrations of Cu in MLZ are ranked in descending order: potato > beet > carrot > onion, in CFPS area beet > potato > onion > carrot and in CM zone potato > beet > onion > carrot. Furthermore, the highest concentrations of Zn concentrations in al kind of vegetables were observed in MLZ study area. The highest accumulation of Zn was observed in beetroot (MLZ 5.47 ± 1.03 $mg{\cdot}kg^{-1}$ > CM 4.06 ± 0.65 $mg{\cdot}kg^{-1}$ > CFPS 2.89 ± 0.31 $mg{\cdot}kg^{-1}$). The mean concentration of Zn was ranked in descending order as follows: beet > potato > onion > carrot in CFPS and CM areas and beet > onion > carrot > potato in MLZ.

Although the content of some HMs (Pb, Cd) was high and above the maximum allowable concentrations in soil, these metals were under the limits of detection in vegetable samples. As previously published (Ye et al., 2015), the process of HM adoption by plants depends on soil and plant properties (pH of soil, soluble content of heavy metals in soil, growth stage of plant). Depending on the nature of plant and substance being absorbed, plants have different mechanisms to prevent the uptake of harmful compounds, such as heavy metals.

Table 7 Descriptive statistics of different HMs ($mg{\cdot}kg^{-1}$) in vegetable roots from Pljevlja municipality (Montenegro)

Analyte		Cu			Zn				
Sampling site		Potato *S. tuberosum*	Beet *B. vulgaris*	Onion *A. cepa*	Carrot *D. carota*	Potato *S. tuberosum*	Beet *B. vulgaris*	Onion *A. cepa*	Carrot *D. carota*
MLZ	Mean ± SE	1.27 ± 0.21	1.12 ± 0.06	0.49 ± 0.05	0.64 ± 0.09	2.61 ± 0.24	5.47 ± 1.03	3.40 ± 0.39	2.76 ± 0.56
	Max	1.88	1.22	0.62	0.9	3.31	7.62	4.38	3.93
	Min	0.94	0.94	0.37	0.43	2.24	3.13	2.47	1.21
	Median	1.12	1.17	0.49	0.61	2.44	5.58	3.39	2.94
CFPS	Mean ± SE	0.95 ± 0.08	1.04 ± 0.08	0.64 ± 0.07	0.57 ± 0.06	2.07 ± 0.13	2.89 ± 0.31	1.88 ± 0.14	1.72 ± 0.12
	Max	1.54	2.11	1.59	1.3	3.34	6.55	3.81	3.41
	Min	0.32	0.49	0.27	0.24	1.47	1.34	1.17	1.12
	Median	0.94	1.03	0.56	0.49	1.79	2.69	1.7	1.64
CM	Mean ± SE	1.29 ± 0.15	1.15 ± 0.20	0.53 ± 0.04	0.51 ± 0.02	2.77 ± 0.38	4.06 ± 0.65	1.89 ± 0.14	1.28 ± 0.09
	Max	2.15	2.28	0.75	0.6	4.93	7.86	2.61	1.55
	Min	0.82	0.71	0.36	0.38	1.57	2.22	1.36	0.8
	Median	1.16	0.92	0.5	0.55	2.69	3.97	1.86	1.3

Table 8 The *EDI* and *HQ* and *THQ* for heavy metals caused by consumption of vegetables

Sampling site	Analyte		Children				Adults			
			Potato *S. tuberosum*	Beet *B. vulgaris*	Onion *A. cepa*	Carrot *D. carota*	Potato *S. tuberosum*	Beet *B. vulgaris*	Onion *A. cepa*	Carrot *D. carota*
MLZ	Cu	*EDI*	0.010 ± 0.003	0.009 ± 0.002	0.004 ± 0.001	0.005 ± 0.001	0.007 ± 0.002	0.006 ± 0.001	0.003 ± 0.001	0.004 ± 0.001
		HQ	0.261 ± 0.058	0.228 ± 0.041	0.107 ± 0.021	0.136 ± 0.034	0.177 ± 0.042	0.154 ± 0.028	0.072 ± 0.010	0.092 ± 0.023
	Zn	*EDI*	0.022 ± 0.004	0.055 ± 0.018	0.030 ± 0.006	0.026 ± 0.009	0.015 ± 0.003	0.036 ± 0.012	0.020 ± 0.004	0.018 ± 0.006
		HQ	0.073 ± 0.012	0.175 ± 0.057	0.099 ± 0.020	0.086 ± 0.028	0.049 ± 0.008	0.119 ± 0.018	0.067 ± 0.014	0.059 ± 0.019
	THQ		0.334 ± 0.089	0.403 ± 0.039	0.206 ± 0.032	0.222 ± 0.031	0.226 ± 0.061	0.273 ± 0.026	0.139 ± 0.021	0.151 ± 0.021
CFPS	Cu	*EDI*	0.009 ± 0.003	0.009 ± 0.003	0.005 ± 0.001	0.005 ± 0.002	0.006 ± 0.002	0.006 ± 0.002	0.004 ± 0.002	0.003 ± 0.001
		HQ	0.232 ± 0.068	0.224 ± 0.079	0.135 ± 0.014	0.118 ± 0.036	0.157 ± 0.026	0.152 ± 0.024	0.091 ± 0.020	0.080 ± 0.018
	Zn	*EDI*	0.019 ± 0.006	0.025 ± 0.012	0.016 ± 0.006	0.015 ± 0.005	0.013 ± 0.004	0.017 ± 0.003	0.011 ± 0.003	0.010 ± 0.003
		HQ	0.062 ± 0.017	0.085 ± 0.040	0.054 ± 0.009	0.049 ± 0.014	0.042 ± 0.012	0.057 ± 0.017	0.037 ± 0.012	0.033 ± 0.010
	THQ		0.295 ± 0.071	0.308 ± 0.092	0.189 ± 0.032	0.222 ± 0.051	0.199 ± 0.048	0.209 ± 0.076	0.128 ± 0.018	0.151 ± 0.031
CM	Cu	*EDI*	0.011 ± 0.004	0.010 ± 0.004	0.005 ± 0.001	0.004 ± 0.001	0.007 ± 0.002	0.007 ± 0.003	0.003 ± 0.001	0.003 ± 0.001
		HQ	0.273 ± 0.027	0.252 ± 0.011	0.115 ± 0.026	0.112 ± 0.017	0.185 ± 0.039	0.171 ± 0.037	0.078 ± 0.018	0.076 ± 0.011
	Zn	*EDI*	0.024 ± 0.009	0.035 ± 0.015	0.016 ± 0.003	0.011 ± 0.002	0.016 ± 0.006	0.023 ± 0.010	0.011 ± 0.002	0.008 ± 0.001
		HQ	0.080 ± 0.019	0.116 ± 0.028	0.055 ± 0.011	0.037 ± 0.007	0.054 ± 0.019	0.078 ± 0.022	0.037 ± 0.007	0.025 ± 0.005
	THQ		0.353 ± 0.055	0.368 ± 0.102	0.170 ± 0.034	0.149 ± 0.019	0.239 ± 0.041	0.249 ± 0.046	0.115 ± 0.023	0.101 ± 0.013

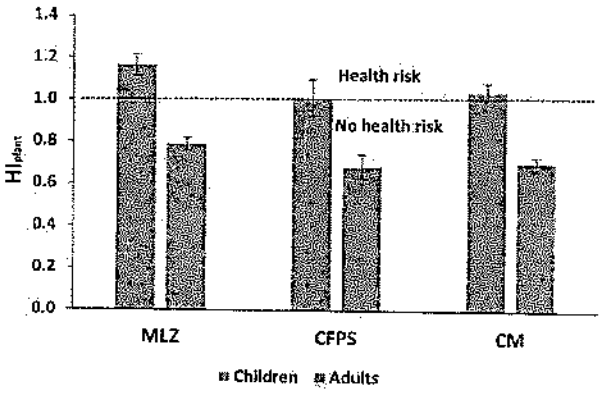

Fig. 6 Values of the hazard index (HI) for Cu and Zn in edible vegetable roots collected at MLZ, CFPS, and CM areas (error bars represent standard deviation of results)

Assessment of health risk of vegetable root consumption

To assess health risk due to vegetable consumption, the estimated daily intake (*EDI*), hazard quotient (*THQ*), total hazard quotient (*TTHQ*) and hazard index (*HI*) were calculated, and the results are given in Table 8 and Figs. 6 and 7. Only non-carcinogenic health risk was considered since these metals may promote only non-carcinogenic effect on human health. Among different vegetables (Table 8), the higher *EDI* values were observed for Zn in comparison to Cu, and these values were generally higher for children in comparison to adults. Moreover, the highest intake of HMs was observed in the consumption of potatoes and beet for all investigated study areas. However, the estimated *EDI* of Cu and Zn were below the tolerable *RfD* limits (Table 2). The *THQ* values of both metals were lower than one for all examined edible parts of vegetables for both populations. This indicates that inhabitants around the three main pollutants in Pljevlja municipality were not faced with health risk by the intake of single-metal Cu and Zn through vegetable consumption. There is also no health risk for inhabitants by the combined effect of Cu and Zn since TTHQ values for examined vegetables were less than one. Furthermore, results of *HI* values (Fig. 6) indicate that there is no potential health risk for adults in all investigated areas, while children are under the potential health risk by the consumption of vegetables cultivated in these areas. The highest risk ($HI = 1.65 \pm 0.05$) was observed for children in MLZ samples of vegetables, followed by CM ($HI = 1.09 \pm 0.04$) and CFPS ($HI = 1.00 \pm 0.08$) locations. The *HI* values in CM and CFPS areas were slightly above one, but if we take in account standard deviation, then children are considered to be at potential health risk from vegetable consumption.

Finally, the contribution of each kind of vegetable grown at specific locations to *HI* is given in Fig. 7. The highest contribution to *HI* was observed for beetroot with 34.6%, 30.4% and 35.3% in MLZ, CFPS and CM study area, respectively. Then it follows the potato tuber with contribution of 28.7%, 29.0% and 34.0%. The lowest contribution was observed for carrot root and onion bulb.

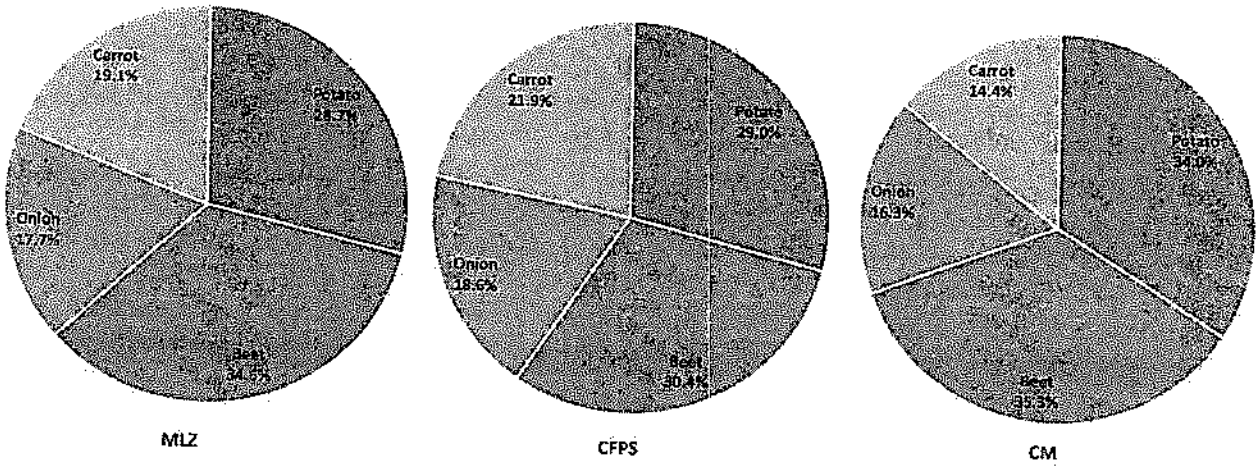

Fig. 7 Contribution of different vegetables to hazard index for different study areas

Conclusions

This study revealed high heavy metal accumulation in agricultural soils and vegetable roots in the vicinity of three main pollutants in Pljevlja municipality. The results obtained indicated that the main concentration of Pb, Cd and Zn in agricultural soil in the vicinity MLZ exceeded the maximum allowable concentration. The maximum allowable concentration of Cd in CFPS soil was higher than the prescribed limits, while in CM soil area, Pb and Cd were above the maximum allowable concentrations. The ecological assessment performed by *RI* showed a considerable risk of soil contamination by heavy metals in MLZ and CM zones and moderate risk in the CFPS zone. The values of *PLI* indicated polluted soil in MLZ and CM study areas, while soils in CFPS area are characterized as unpolluted.

Generally, the results of health risk assessment showed that children are exposed to higher health risk than adults. In MLZ area, the contribution of different soil exposure pathways to non-carcinogenic risk follows in descending order, dermal contact > ingestion > inhalation, while in CFPS and CM study areas, descending order is as follows: ingestion > dermal contact > inhalation. Among different exposure pathways, dermal contact was recognized as the main contributor to carcinogenic health risk, followed by ingestion and inhalation.

The presence of Cu and Zn was detected in the collected vegetable samples. Health risk assessed by estimated daily intake (*EDI*) of these metals through consumption of vegetables and hazard quotient (*THQ*) indicated no health risk for inhabitants in the vicinity of investigated study area. However, the overall hazard index (*HI*) indicated possible adverse health effects from vegetable consumption for children, while for adults, there is no health risk. Beetroot and potato tuber were recognized as the highest contributors to children health risk.

The results obtained in this study can be used to monitor the state of the environment, as well as the impact of changes due to continuous exposure to pollutants on the health of both Montenegrins and countries in the region, as the industrialization in the Western Balkans has led to similar patterns of pollution and potential health risks.

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Availability of data and material All data generated or analysed during this study are included in this published article (data set given in tables and figures).

Declarations

Competing interests D.Đ. is the leader of a project supported by the Montenegrin Ministry of Science under grant no. 01–799/2. Other authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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ASSESMENT OF ECOLOGICAL AND HEALTH RISK IN AGRICULTURAL SOIL NEAR THE MINE OF LEAD AND ZINC IN PLJEVLJA MUNICIPALITY (MONTENEGRO)

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ABSTRACT

Ecological and health risk assessments associated with heavy metal content in agricultural soils collected near the mine of lead and zinc located in Pljevlja municipality (Montenegro), were performed. Results obtained were compared with the results obtained for control study area. The ecological risk of soil was estimated using the index of geo-accumulation, (I_{geo}). The non-carcinogenic and carcinogenic health risks were evaluated through different soil exposure pathways (ingestion, inhalation and dermal contact). The results indicated polluted agricultural soil in the mining area while soil from control study area was characterized as unpolluted. The pollution indice (I_{geo}) indicated the ecological risk with respect to the soil pollution by Pb, Zn, Cd and Cu in mining area. A serious health non-carcinogenic and carcinogenic risks were identified in soil samples near lead and zinc mine for inhabitants through soil exposure. Pb was identified as the highest contributor to health non-carcinogenic risk while Cr highly contribute to carcinogenic risk. Ingestion was identified as the main contributor to carcinogenic risk while dermal contact presented the main exposure pathway for non-carcinogenic risk.

KEYWORDS:
Heavy metals, agricultural soil, index of geo-accumulation, health risk assessment

INTRODUCTION

Heavy metals pollution has become a global issue due to the rapid industrialization and possible contamination of water and soil. Thus, extensive research has been focused on environmental pollution caused by heavy metals since they are non-biodegradable and persist for many years posing a great risk to human health. Agricultural soils contaminated by heavy metals have attracted special attention due to well-known effect of heavy metals on the soil function in food production. Human beings may come into contact with heavy metals through soil exposure by ingestion, inhalation and dermal contact. Moreover, heavy metals from polluted soil may enter the agricultural crops and later into the food chain [1]. Inadequate disposal of waste and wastewater, former factory sites, landfills, uncontrolled use of agrochemicals, mining and various types of smelting, if performed inadequately, contrary to environmental standards, may become the sources of heavy metal pollution [2]. Thus, it is of great importance to investigate the ecological and health risk assessment of heavy metals in agricultural soil.

Mining activities represent one of the most important anthropogenic sources of heavy metal pollution. Spilt ore tailings, emissions of dust containing heavy metals into the atmosphere and the generation of a large number of acidic mine wastewaters that contain heavy metals are the main pathways for soil contamination by heavy metals caused by mining activities [3]. A numerous investigations indicated a soil pollution by heavy metals and so on health problems for local inhabitants in mining-affected areas [4-10].

Pljevlja is a municipality located in the north of Montenegro known for various mining activities, including the extraction of lead and zinc ore. Mining activities began in 1953 and were abandoned in the period between 2000 and 2006. After reopening in 2006, old flotation tailings were abandoned without reconstruction, and present a serious ecological risk since the agricultural fields and households in village Gradac are near the old flotation tailings. To the best of our knowledge, there is no study conducted to assess agricultural soil pollution by mining activities in the municipality of Pljevlja in Montenegro.

Thus, the aim of this study was to assess the potential heavy metal (As, Hg, Cd, Pb, Cu, Zn and Cr) pollution of agricultural soils located in the vicinity of mine of lead and zinc in Pljevlja. The ecological risk was assessed by the geo-accumulation index (I_{geo}). Non-carcinogenic and carcinogenic health risks for inhabitants through different soil exposure routes (ingestion, inhalation and dermal contact) were also assessed.

MATERIALS AND METHODS

Study area and chemical analysis. The analysed samples were divided into two groups, the mining area samples and the control area samples. The soil samples in the mining area were collected in the vicinity of the old flotation tailings of an old mine of lead and zinc in Gradac, Montenegro located in Pljevlja municipality (43° 23'57.4"N 19°09'02.7" E). The control area is approximately 30 km away from the mine (43°21'46.3"N 19°26'39.1"E). Soil samples were collected from a maximum of 20 cm of depth from agricultural fields and were prepared according to a modified standard method EPA 3050b (EPA, 1996) by wet digestion with aqua regia (HCl: HNO3=3:1). To remove water, the samples were dried at 105 °C for 24 hours in an air-blowing thermostatic oven. The dried samples were sieved through a 2 mm sieve and prepared by the aforementioned method. The total content of metals of interest (Cu, Cd, Zn, Cr, Pb) was determined by ICP-EOS technique (Inductively coupled plasma-Optical Emission Spectrometry); brand SPECTRO ARCOS FHE12. The total arsenic content was determined by FAAS-Flame Atomic Absorption Spectrometry (Perkin Elmer Analyst 300), while the total mercury content was determined directly by Direct Mercury Analyzer (DMA 80).

The calibration for all three techniques was performed using metal standards (CPA chem) with five calibration points. Before determining the content of heavy metals, the blank sample and the prepared spiked sample at two levels (LoQ and 5 times LoQ) were analysed. Quality control was obtained by determining the content of heavy metals in the certified reference material (IAEA-158) containing the following metal concentrations: As (11.5 mg kg-1), Cd (0.372 mg kg-1), Cr (74.4 mg kg-1)), Cu (48.3 mg kg-1), Pb (39.6 mg kg-1), Zn (140.6 mg kg-1) and Hg (0.132 mg kg-1). The overall uncertainty of the analytical methods was below 10%.

Assessment of soil contamination by heavy metals. Soil contamination by heavy metals due to the anthropogenic activities was assessed by the evaluation of index of geo-accumulation (I_{geo}).

$$I_{geo} = \log_2 \frac{C_i}{1.5 C_{ri}} \quad (1)$$

were C_i is the concentrations of the element i in the soil sample and and C_{ri} is the geochemical reference or background value of the element i in the earth's crust in mg·kg^{-1} (13.00 for As, 0.4 for Hg, 20 for Pb, 0.3 for Cd, 45 for Cu, 95 for Zn and 90 for Cr) [11]. The evaluated criteria of I_{geo} are summarized in Table 1.

Assessment of health risk. Humans could be exposed to contaminants from soil via oral intake, inhalation or through dermal exposure and contamination via vegetable consumptions. Non-carcinogenic and carcinogenic risk for inhabitants through each soil exposure pathway were calculated using the methodology proposed by USEPA [12, 13].

The average daily doses (ADDs) (mg·kg^{-1}·day^{-1}) of potentially toxic metals via soil ingestion (ADD_{ing}), soil inhalation (ADD_{inh}), and dermal contact with soil (ADD_{derm}) were estimated using the Eqs: (2, 3, 4)

$$ADD_{ingestion} = \frac{C \cdot IngR \cdot EF \cdot ED}{BW \cdot AT} \cdot 10^{-6} \quad (2)$$

$$ADD_{inhalation} = \frac{C \cdot InhR \cdot EF \cdot ED}{PEF \cdot BW \cdot AT} \quad (3)$$

C is the concentration of the contaminant in the soil; $IngR$ is the ingestion rate of the soil; EF is an exposure frequency; ED is an exposure duration; BW is an average body weight; AT is an averaging time; $InhR$ is an inhalation rate; PEF is a particle emission factor; SA is a surface area of the skin that contacts the soil; SAF is a skin adherence factor for the soil; ABS is a dermal absorption factor (chemical specific). Factors used in the risk assessment equations are given in Table 2.

Non-carcinogenic effects of each heavy metal in soil were assessed using the hazard quotient (HQ_i) for soil and hazard index (HI) according to Eq. 5 -7, while carcinogenic effects of heavy metals in soil were assessed using the carcinogenic risk (CR_i) and total carcinogenic risk (TCR) by Eq. 8 and 9.

$$ADD_{dermal} = \frac{C \cdot SA \cdot SAF \cdot ABS \cdot EF \cdot ED}{BW \cdot AT} \cdot 10^{-6} \quad (4)$$

TABLE 1
Terminologies for the assessment of agricultural soil contamination by heavy metals based on I_{geo}.

CLAS 0, unpolluted	$I_{geo} \leq 0$
CLASS 1, from unpolluted to moderately polluted	$0 < I_{geo} \leq 1$
CLASS 2, moderately polluted	$1 < I_{geo} \leq 2$
CLASS 3, from moderately to strongly polluted	$2 < I_{geo} \leq 3$
CLASS 4, strongly polluted	$3 < I_{geo} \leq 4$
CLASS 5, from strongly to extremely polluted	$4 < I_{geo} \leq 5$
CLASS 6, extremely polluted	$I_{geo} > 5$

TABLE 2
Factors used in the risk assessment equations.

Factor	Value	Reference
$IngR$ (mg·day^{-1})	100	[13]
$InhR$ (m^3·day^{-1})	17.5	[13]
EF (days·year^{-1})	350	[14]
ED (years)	30	[13]
W (kg)	59.4	[15]
AT (days) (Non-carcinogens)	EF·ED	[16]
AT (days) (Carcinogens)	EF·70	[16]
PEF (m^3·kg^{-1})	6.2·10^9	[13]
SA (cm^2)	5000	[13]
SAF (mg·cm^{-2} day^{-1})	0.07	[13]
ABS	0.001	[12]
ABS (As)	0.01	[12,13]

$$HQ_i = \frac{ADD_i}{R_f D_i} \quad (5)$$

$$THQ = \sum HQ_i \quad (6)$$

$$HI = \sum THQ_i \quad (7)$$

$$CR_i = ADD_i \cdot SF \quad (8)$$

$$TCR = \sum CR_i \quad (9)$$

RfD_i is reference dose which presents the maximum daily dose of each individual metal from a specific exposure pathway (mg·kg^{-1}·day^{-1}) , that is believed not to lead to an appreciable risk of deleterious effects to sensitive individuals during a lifetime; CR_i is a cancer risk of each individual heavy metal, SF is a slope factor for carcinogenic exposure (mg·kg^{-1}·day^{-1}) [17] and TCR is a total cancer risk.

For $HI \leq 1$, it is believed that there is no significant risk of non-carcinogenic effects while for $HI > 1$, it represents a great chance of non-carcinogenic effects. According to USEPA regulatory the tolerable cancer risk TCR is in the range from $1 \cdot 10^{-6}$ to $1 \cdot 10^{-4}$ [18].

Statistical analysis. The data obtained in this study were expressed as mean ±standard error of samples per examined location. Data processing and statistical analysis were performed using Microsoft Excel 2003 (Microsoft, Redmond, WA, USA). SPSS v.20.0 for Windows (SPSS, Inc., USA) was used to perform Pearson's correlation analysis and PCA (Principal Component Analysis).

RESULTS AND DISCUSSION

Heavy metal concentrations in agricultural soil collected in the vicinity of mine and lead and zinc and control area in Pljevlja municipality are given in Figure 1. It is evident that in control soil concentrations of all investigated metals were below their maximum allowed concentrations (MAC) in soil according to Montenegrin legislation [19]. On the other hand, mean concentrations of heavy metals in mining area were considerable higher compared with respective values in control area. Concentrations of heavy metals in mining area were ranked in descending order as Zn > Pb> Cu> Cr> As> Cd> Hg. The mean concentrations of Zn (661.72±147.07 mg·kg^{-1}), Pb (660.60±99.65 mg·kg^{-1}), Cu (113.33±17.65 mg·kg^{-1}) and Cd (2.49±0.56 mg·kg^{-1}), exceed their MAC values indicating considerable pollution by Pb and Zn with the mean concentrations around 13 and 2 times higer than their MAC values. The mean content of Cu and Cd slightly exceeded MAC value in this study area while concentrations of As, Hg and Cr were below the prescribed limits. The results obtained are in agreement with the previously reported results that Pb, Zn and Cd are major soil pollutants caused by the anthropogenic activities in the mines of Pb and Zn [20-22].

A potential source of heavy metals in investigated soil samples near the mining area in Pljevlja municipality was identified using Pearson's correlation coefficient analysis (Table 3) and principal component analysis (PCA) (Figure 2.) Pearson's correlation coefficients of heavy metals in soil samples near mining area are shown in Table 3. A significantly positive correlation of Zn was found with Cu (r=0.876, p<0.01) suggesting that these elements originate from the same sources.

Further, heavy metals source was identified based on the PCA analysis and two principal components were extracted with the eigenvalues >1 accounting for 72.40% of the total variances (Table 4 and Figure 2). PC1 explained 47.07% of the total variance and was characterized by the high loading of Zn and Cu which are typical markers for Pb/Zn mining [8]. This is in agreement with the results of Pearson's correlation of content of heavy metals in mining area. Moreover, PC1 component was loaded with As, Pb and Cd which are also related to mining activities. PC2 explained 25.33% of the total variance and was loaded by Cr, Pb, Cd and Hg. Cr and Hg probably originated from agricultural activities induced by the use of pesticides in this area [23].

while Pb and Cd may originate from both, agricultural and mining activities [24]. Pb and Cd are shared metals in PC1 and PC2 suggesting that contribution of these metals is present in both components, but it is much more dominant in PC2, indicating origin from both, mining and agricultural activities. Thus, PC2 represent the combination of mining and agricultural activities. Therefore, anthropogenic factor is the main reason for agricultural soil loaded with heavy metals.

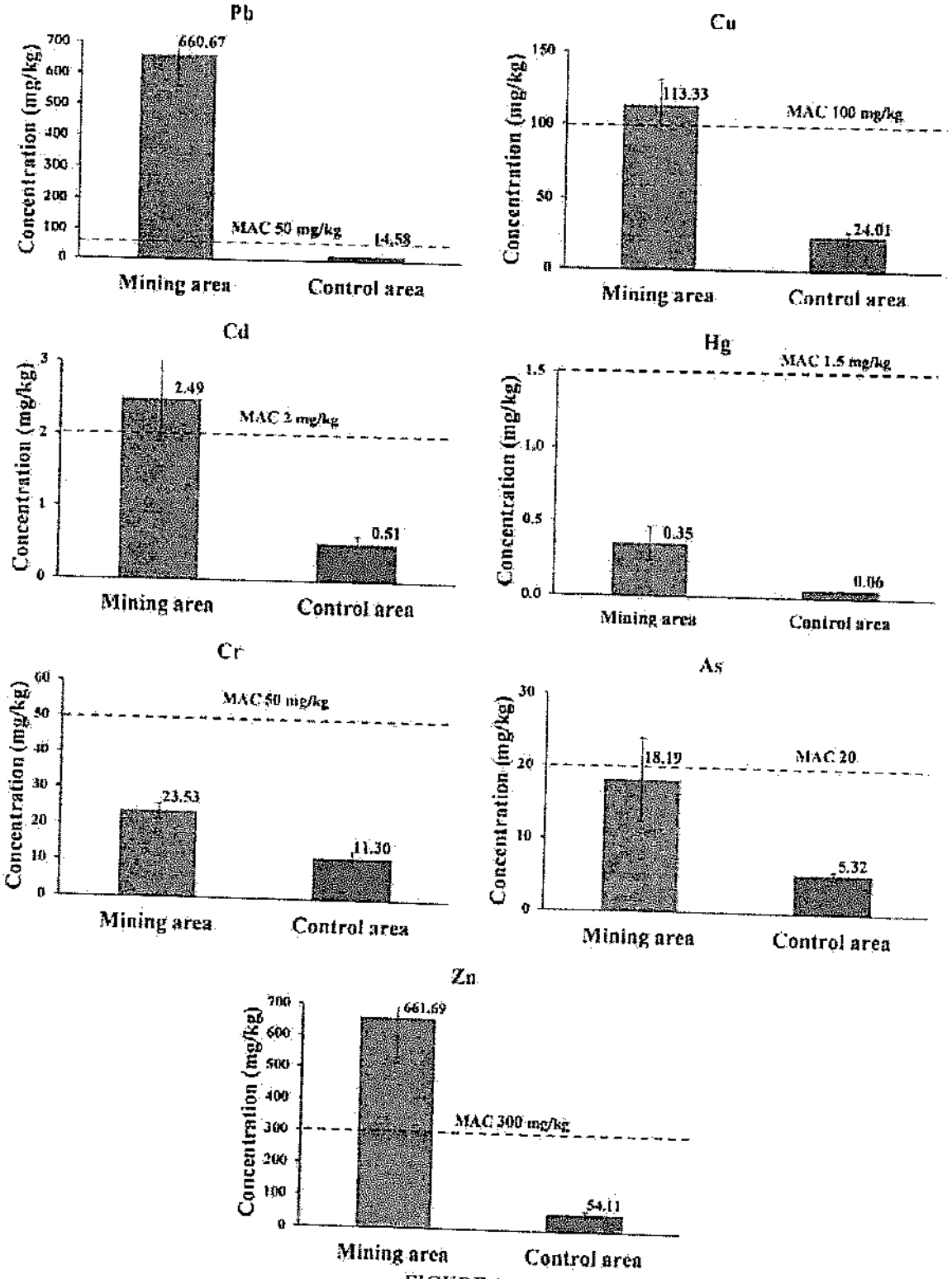

FIGURE 1
Heavy metal content in agricultural soil in mining and control areas

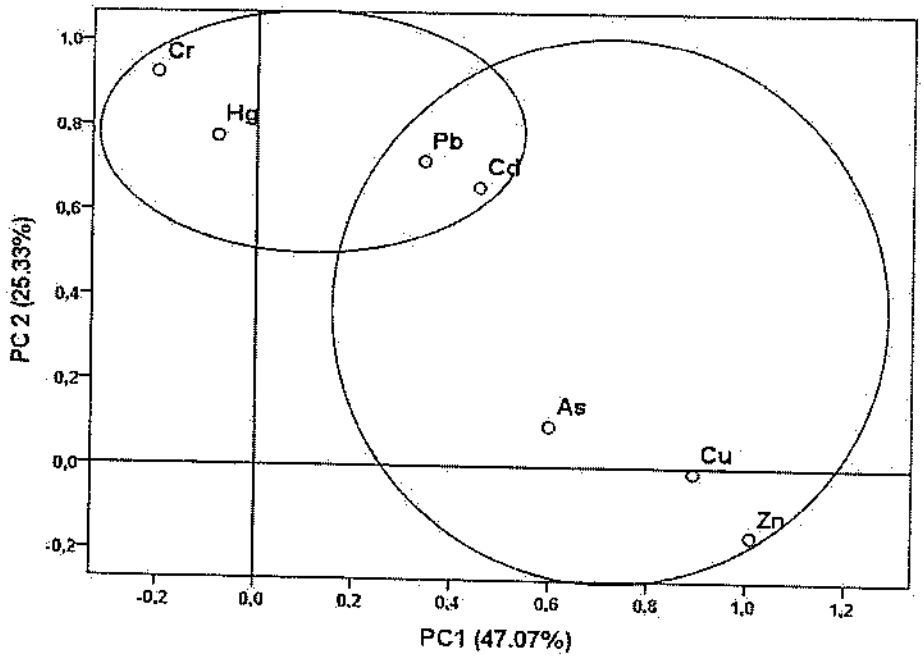

FIGURE 2
Principal component analysis (PCA) of the heavy metal concentrations in soils from the mining area

TABLE 3
Pearson's correlation of content of heavy metals in mining area

	Pb/Zn minig area						
	As	Hg	Cd	Pb	Cu	Zn	Cr
As	1						
Hg	0.454	1					
Cd	0.283	0.501	1				
Pb	0.393	0.399	0.628	1			
Cu	0.198	-0.098	0.611	0.433	1		
Zn	0.586	0.018	0.450	0.356	**0.876****	1	
Cr	-0.145	0.464	0.569	0.674	0.143	-0.102	1

*Correlation is significant at 0.01 level (2-tailed)

TABLE 4
Principal component analysis for PAHs in agricultural soils from Pljevlja municipality.

	Component	
	PC1	PC2
Eigenvalues	3.30	1.77
Variance (%)	47.07	25.33
Cumulative (%)	47.07	72.40
Zn	0.972	
Cu	0.890	
As	0.621	
Cr		0.878
Pb	0.510	0.798
Cd	0.607	0.763
Hg		0.756

The values of I_{geo} for heavy metals are presented in Table. 5. It is evident that mean values of I_{geo} for heavy metals in control soils were negative (suggesting unpolluted soil), while I_{geo} values for soil collected in the mining area were ranged from -2.46 for Cr to 4.91 for Pb, indicating the range from unpolluted to category of strongly to extremely polluted soil. The mean values of I_{geo} for mining area decrease in order Pb>Cd>Zn>Cu> As>Hg>Cr. The mean value of Igeo for Pb (3.53) indicates strong to extreme soil pollution by this metal, while mean value of I_{geo} for Cd points moderate to strongly polluted soil in the study area (2.17). I_{geo} for Zn and Cu represent moderate polluted and unpolluted to moderately polluted soils, respectively. These obtained results are in line with literature data, where Pb, Cd, Zn and Cu are main soil pollutants in Pb/Zn mining area [8]. The mean values of I_{geo} for As, Hg and Cr suggested that agricultural soil in this study area is unpolluted, since the values were negative. This data suggests much stronger effect of Pb/Zn mining area to heavy metal contamination compared to agricultural activities.

TABLE 5
Values of I_{geo} of the metals for the soil samples.

Location	Metal	Min	Max	Mean	Contamination category
Control area	As	-2.46	-1.51	-1.91	Unpolluted
	Hg	-3.94	-2.98	-3.38	Unpolluted
	Pb	-1.53	-0.35	-1.10	Unpolluted
	Cd	-1.17	1.03	-0.03	Unpolluted
	Cu	-2.45	-0.86	-1.61	Unpolluted
	Zn	-2.21	-0.70	-1.50	Unpolluted
	Cr	-4.46	-2.67	-3.43	Unpolluted
Mining area	As	-1.23	-0.08	-0.62	Unpolluted
	Hg	-3.64	-0.35	-1.69	Unpolluted
	Pb	1.52	4.91	3.53	**Strongly polluted**
	Cd	0.68	3.28	2.17	**From moderately to strongly polluted**
	Cu	-0.47	1.32	0.63	**From unpolluted to moderately polluted**
	Zn	0.38	2.88	1.79	**Moderately polluted**
	Cr	-3.03	-2.21	-2.46	Unpolluted

TABLE 6
Results of non-carcinogenic and carcinogenic risk of different pathways and elements (values of *HI* that exceed 1 and values of *TCR* that exceed 1.0E-04 are bolded).

Metal	Non-carcinogenic health risk							
	Mining area				Control area			
	HQing	HQinh	HQder	HI	HQing	HQinh	HQder	HI
As	1.09E-01	1.09E-01	2.65E-01	4.82E-01	3.21E-02	3.21E-02	7.82E-02	1.42E-01
Hg	1.99E-04	6.95E-03	2.84E-02	3.55E-02	3.18E-05	1.11E-03	4.54E-03	5.69E-03
Pb	3.18E-01	3.17E-01	2.12E+00	**2.76E+00**	6.75E-03	6.72E-03	4.50E-02	5.85E-02
Cd	4.20E-03	4.20E-03	4.20E-01	4.29E-01	8.26E-04	8.26E-04	8.26E-02	8.43E-02
Cu	4.78E-03	4.55E-03	1.59E-02	2.53E-02	9.73E-04	9.27E-04	3.24E-03	5.14E-03
Zn	3.72E-03	3.72E-03	1.86E-02	2.60E-02	2.92E-04	2.92E-04	1.46E-03	2.05E-03
Cr	1.32E-02	1.39E+00	6.62E-01	**2.06E+00**	6.10E-03	6.40E-01	3.05E-01	9.52E-01
Metal	Carcinogenic health risk							
	Mining area				Control area			
	CR_{ing}	CR_{inh}	CR_{der}	TCR	CR_{ing}	CR_{inh}	CR_{der}	TCR
As	4.93E-05	4.97E-04	4.93E-05	**5.95E-04**	1.44E-05	1.45E-04	1.44E-05	**1.74E-04**
Pb	9.10E-06	4.50E-05	9.10E-06	6.32E-05	2.01E-07	9.93E-07	2.01E-07	1.39E-06
Cd	1.53E-06	2.54E-05	1.53E-06	2.85E-05	3.14E-07	5.21E-06	3.14E-07	5.83E-06
Cr	1.91E-05	1.60E-03	7.63E-04	**2.38E-03**	9.18E-06	7.69E-04	3.66E-04	**1.14E-03**

The results of non-carcinogenic and carcinogenic health risks assessment for inhabitants caused by the exposure to the soil via ingestion, inhalation and dermal contact are given in Table 6. Samples near mining area showed potential non-cancerogenic risk due to Pb and Cr exposure, while control area samples demonstrated no non-cancerogenic rick for inhabitants. As shown (Table 6), the hazard indexes for inhabitants in Pb/Zn mine study area, exceed 1 one for Pb and Cr with HI values of 2.76 and 2.06, respectively. Contribution of these metals to total HI in Pb/Zn soil samples were of 35.31% (Cr) and 47.21% (Pb), while Cd and As contribute on similar levels of 7.33% and 8.67%, respectively (Figure 3(a)). Contributions of other metals (Hg, Zn and Cu) was less than one.

However, TCR values that exceeded tolerable cancer risk values were obtained for As and Cr at both investigated locations. Although the main concentrations of As and Cr in control soil samples were below MAC, a certain cancer health risk with respect to presence of these metals was observed in this area (TCR= 1.74E-04 for As and TCR= 1.14E-03 for Cr). These results may by influenced by the use of fertilizers which contain high concentration of the heavy metals. Further studies should be undertaken in control study area with more samples. However, it is obvious that the risk is much higher in Pb/Zn soil area (TCR= 5.95E-04 for As and TCR= 2.38E-03 for Cr), than in control samples (3.5 times higher risk for As, and 2 times higher risk for Cr) which indicated that soil in mining area was seriously affected by the intensive mining activities. The highest contribution to TCR in Pb/Zn soil samples was observed for Cr (77.63%) followed by As (19.38%) while contribution of Pb and Cd is minor (Figure 3(b)).

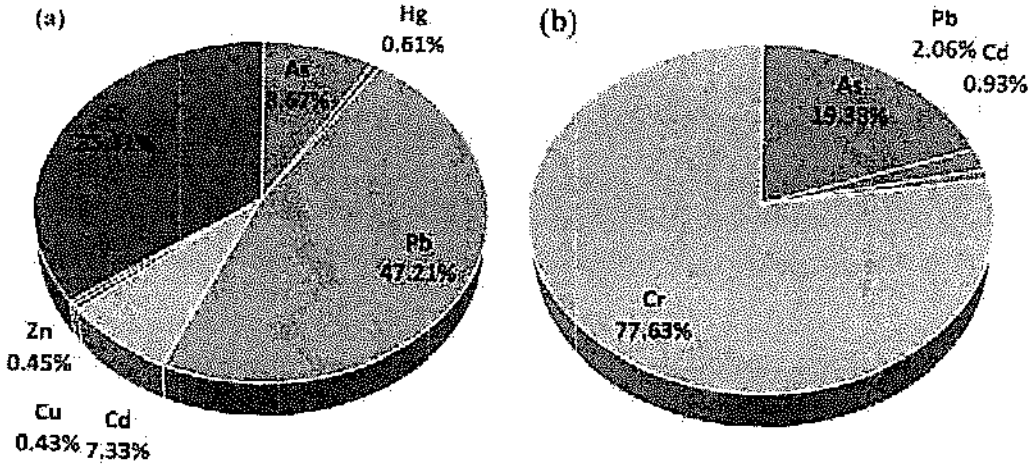

FIGURE 3
Contribution of different metals to (a) HI and (b) TCR in mining area mining area.

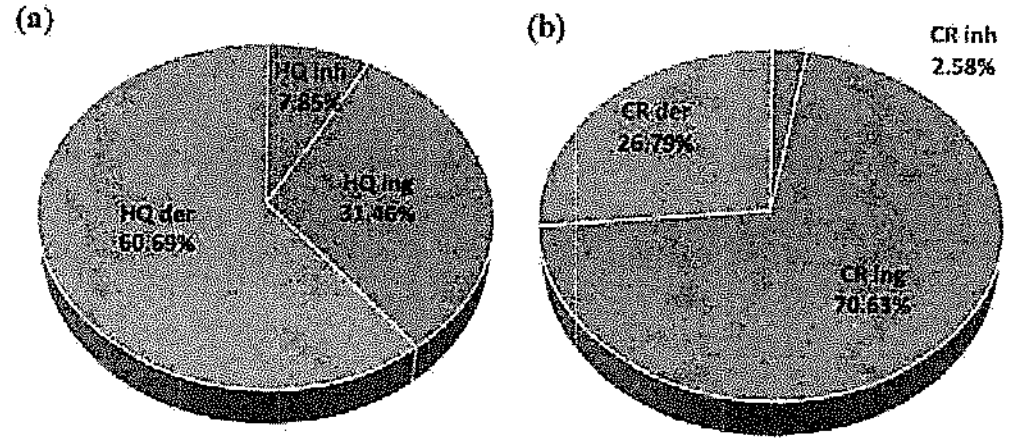

FIGURE 4
Contribution of each exposure pathway to (a) - total hazardous index (*HI*) and (b) - total cancer risk (*TCR*) mining area

Among the three different pathways of exposure to the soil near Pb/Zn mine area (Figure 4(a)), dermal contact was recognized as the main health non-carcinogenic risk (60.69%) followed by ingestion (31.46%) and inhalation (7.85%). Further, the carcinogenic health risk at this location posed by carcinogenic elements via ingestion was the highest with the contribution to the total cancer risk of 70.63%, followed by dermal contact with the contribution of 26.79% and small contribution of inhalation pathway of d 2.58% (Figure 4(b)).

CONCLUSIONS

Heavy metals (As, Hg, Cd, Pb, Cu, Zn and Cr) pollution of agricultural soil samples collected in the vicinity of mine of lead and zinc and control area in Pljevlja municipality (Montenegro) was estimated. Furthermore, health risk assessment was evaluated. The results indicated no soil pollution by heavy metals in the control study area. However, results obtained indicated the considerable soil pollution by Pb and Zn in the mining area. Concentration of Cu and Cd were slightly over the MAC levels while there was no contamination by Hg, Cr and As. Heavy metal contents in soil collected near the mining area followed descending order as Zn>Pb>Cu>Cr>As>Cd>Hg. Pb and Zn are the most harmful elements in the mining area and should be given priority in local risk management. The ecological assessment performed by I_{geo} values revealed strong soil pollution by Pb, moderately to heavily polluted soil by Cd, moderately polluted by Zn and unpolluted to moderately polluted by Cu. I_{geo} values showed no pollution in control soil samples. The results of non-carcinogenic health risk assessment have shown that near Pb/Zn mine area inhabitants have faced non-carcinogenic risks concerning Cr and Pb presence in soil. The exposure pathway of the

studied heavy metals decreased in the following order: dermal contact>ingestion >inhalation. In control samples, HI values were below 1, showing no non-cancerogenic risk of soil exposure. The carcinogenic risk values for As and Cd were above the threshold value ($1\cdot10^{-4}$) indicating carcinogenic health risk for inhabitants in both study areas. Dermal contact was the greatest contributor to the carcinogenic risk followed by ingestion and inhalation pathway at both sampling sites, but a much higher risk was observed by exposure to soil near the mine of lead and zinc than to control soil samples. The results obtained in this study indicates that soil remediation is urgently needed in mining area.

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На основу члана 48. став 3. тачка 6. и члан 65. Закона о високом образовању («Службени гласник РС» бр. 76/2005. годину) и члана 73. тачка 5. и члана 136. тачка 9. Статута Универзитета (Савет Универзитета, 3. октобар 2006.) и Одлуке Сената Универзитета од 22. новембра 2007. године, доносим

Р Е Ш Е Њ Е
о избору у звање наставника Универзитета у Новом Саду

др Слободанка Пајевић, б и р а с е у звање редовног професора Универзитета у Новом Саду, на Природно-математичком факултету у Новом Саду, за ужу научну област Физиологија биљака.

На основу овог решења декан са именованим закључује Уговор о раду.

Ово решење ступа на снагу након закључивања Уговора о раду из става 2. овог решења.

О б р а з л о ж е њ е

Након спроведеног поступка у складу са Законом о високом образовању, Статутом Универзитета и члана 3. став 6. Правилника о начину и поступку стицања звања и заснивања радног односа наставника Универзитета у Новом Саду, Сенат Универзитета је размотрио и прихватио Одлуку о утврђивању предлога за избор у звање и заснивање радног односа Изборног већа Департмана за биологију и екологију Природно-математичког факултета у Новом Саду од 1.11.2007. године и Закључак Стручног већа за поље природно-математичких наука од 21.11.2007. године и донео Одлуку као у диспозитиву.

На основу напред наведеног донето је решење као у диспозитиву.

Ово решење декан ће уручити именованом приликом потписивања Уговора о раду.

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Pol	Muški

Željeno zaposlenje / zanimanje

Docent Univerziteta Crne Gore (oblast: organska hemija)

Radno iskustvo

Datumi	**2009-2011.** – Istraživač-pripravnik/Inovacioni centar Hemijskog fakulteta Univerziteta u Beogradu;
Zanimanje ili radno mjesto	**2011-2012.** - Istraživač-saradnik/Inovacioni centar Hemijskog fakulteta Univerziteta u Beogradu;
Glavni poslovi i odgovornosti	**2012-2016.** – saradnik u nastavi / Prirodno-matematički fakultet Univerziteta Crne Gore;
Ime i adresa poslodavca	**2016-** docent / Prirodno-matematički fakultet Univerziteta Crne Gore;
Vrsta djelatnosti ili sektor	**2016-** prodekan za nastavu/ Prirodno-matematički fakultet Univerziteta Crne Gore;

Obrazovanje i osposobljavanje

	Datumi
Naziv dodijeljene kvalifikacije	**1999-2003** – Gimnazija „Stojan Cerović" - Nikšić – Prirodno-matematički smjer;
Glavni predmeti / stečene profesionalne vještine	**2003-2009** – Hemijski fakultet Univerziteta u Beogradu – smjer: diplomirani hemičar – osnovne studije;
Ime i vrsta organizacije obrazovne institucije	**2009-2015** - Hemijski fakultet Univerziteta u Beogradu – smjer: organska hemija – doktorske studije.
Nivo prema nacionalnoj ili međunarodnoj klasifikaciji	

Lične vještine i kompetencije

Maternji jezik(ci)	**Srpski**
Drugi jezik(ci)	**Engleski jezik (1)** **Ruski jezik (2)**

Samoprocjena	Razumijevanje				Govor				Pisanje	
Evropski nivo (*)	Slušanje		Čitanje		Govorna interakcija		Govorna produkcija			
Jezik1	C2	Iskusni korisnik	C2	Iskusni korisnik	C2	Iskusni korisnik	C2	Iskusni korisnik	C2	Iskusni korisnik
Jezik2	B1	Samostalni korisnik	B1	Samostalni korisnik	A2	Temeljni korisnik	A1	Temeljni korisnik	A2	Temeljni korisnik

(*) Zajednički evropski referentni okvir za jezike

Društvene vještine i kompetencije

Vještine koje posjedujete
Komunikativan, timski orijentisan, društven

Organizacione vještine i kompetencije

Vještine koje posjedujete
Sposobnost rada kako pojedinačnog tako i timskog, posjedovanje organizacionih sposobnosti u smislu organizacije rada, raspodjele zadataka i tumačenja rezultata rada.

Računarske vještine i kompetencije

Programi i programski jezici kojima vladate
MS Office
Hemijski programski paketi: Chem Draw and Chem Scatch

Vozačka dozvola

Kategorija koju posjedujete
C-kategorija

Dodaci

Dokumenti koje dostavljate
Publikacije:

M. Bigovic, V. Maslak, Z. Tokic-Vujosevic, V. Divjakovic and R. N. Saicic (2011), A useful synthetic equivalent of a hydroxuacetone enolate, *Organic Letters*, 13 (17), 4720-4723. ISSN: 1523-7060 (Print), ISSN: 1523-7052 (Online)

M. Bigovic, S. Skaro, V. Maslak, R. N. Saicic, (2013), Expanding the scope of the indium-promoted allylation reaction: 4-(bromomethyl)-1,3-dioxol-2-one as a synthetic equivalent of a 3-arylhydroxyacetone enolate, *Tetrahedron Letters*, 54, 6624-6626. ISSN: 0040-4039

T. Narancic, J. Radivojevic, P. Jovanovic, Dj. Francuski, **M. Bigovic**, V. Maslak, V. Savic, B. Vasiljevic, K. O'Connor, J. Nikodinovic-Runic, (2013), Highly efficient Michael-tupe addition of acetaldehide to β-nitrostyrenes by whole resting cells of *Escherichia coli* expressing 4-oxalocrotonate tautomerase, *Bioresource Tehnology*, Vol. 142, 462-468, 2013. ISSN: 0960-8524

V.Kastratović, Ž. Jaćimović, **M. Bigović**, M.Kosović, D.Đurović„ Speciation of copper in lake sediments and bioaccumulation of macrophytes Scadar Lake, Montenegro" , International conference protection and restoration of the environment XII, Jun 2014, Skiathos Island, Greece, Book of abstracts, page 172

Kastratović, V., Krivokapić, S., **Bigović, M.**, Đurović, D., Blagojević, N. (2014) Bioaccumulation and translocation of heavy metals by Ceratophyllum demersum from Skadar Lake, Montenegro, *Journal of the Serbian Chemical Society*, 79(11): 1445–1460. ISSN 0352-5139 (Print) ISSN 1820-7421 (Online)

V. Kastratović, Ž. Jaćimović, D. Đurović, **M. Bigović**, S. Krivokapić, (2015), *Lemna minor L.* As bioindicator of heavy metal pollution in Skadar Lake, Montenegro, *Kragujevac Journal of Science* 37, 123-134. ISSN 1450-9636

Kastratović V., Jaćimović Ž., **Bigović M.**, Đurović D. and Krivokapić S. (2016) Environmental Status and Geochemical Assessment Sediments of Lake Skadar, Montenegro. *Environmental Monitoring and Assessment*, DOI: 10.1007/s10661-016-5459-0

V. Kastratović, **M.R. Bigović**, Ž. Jaćimović, M.Kosović, D.Đurović, S. Krivokapić, „Bioaccumulation of cobalt and nickel in macrophytes from Skadar Lake" 13th International Conference on Protection and Restoration of the Environment, 3rd to 8th July, 2016. Mykonos island, Greece, Book of abstract, page 150, ISBN: 978-6865-94-7

Vlatko Kastratović, Željko Jaćimović, **Miljan Bigović**, Dijana Đurovič, Slađana Krivokapić (2016) The distribution and accumulation of chromium in the water, sediment and macrophytes of Skadar Lake, *Kragujevac Journal of Sciences*, 38:125-134.

Vlatko R. Kastratović, **Miljan R. Bigović**, Esterifikacija stearinske kiseline sa alkoholima C1-C4, „ 53. Savetovanje Srpskog hemijskog drustva, Kragujevac, 10-11. jun 2016. godine (HZS P05, strana 66).

Vlatko Kastratović, Željko Jaćimović, **Miljan Bigović**, Milica Kosović, Dijana Đurović, Slađana Krivokapić (2017) Seasonal Patterns of copper in a system of sediment-water-macrophytes, *Fresenius Environmental Bulitein*, 26: 1247-1253.

Željko K. Jaćimović, Milica Kosović, Goran A. Bogdanović, Sladjana B. Novaković,Gerald Giester and **Miljan Bigović** "The crystal structure of ethyl 1-(4-nitrophenyl)-5- (trifluoromethyl)-1H-pyrazole-4-carboxylate,$C_{13}H_{10}F_3N_3O_4$ " Z. Kristallogr. NCS 2017, 232 (4), 651-653.

Z. Jacimovic, M. Kosovic, J. Latinovic, **M. Bigovic**, V. Kastratovic, The Influence of Some Pyrazole Derivatives and Newly Synthetised Cu(II) Complexes to the Inhibition of Phomopsis Viticola in Vitro, 18th European Meeting on Environmental Chemistry Porto, Portugal, 26-29th November 2017, Book of abstracts 320.

Miljan Bigović, Žarko Zečević, Luka Filipović, Božo Krstajić, „Verification of the three-dimensional structure of synthesized molecule by molecular dynamic simulations", IEEE Eurocon 2017-17th International Conference of Smart Technologies, Ohrid, 6-8. July 2017, Book of abstracts 944-948.

Miljan Bigovic, Luka Filipovic, Zarko Zecevic, Bozo Krstajic, „Modeling and molecular dynamics simulations study of enol-carbonates and their derivates„, Scalable Computing: Practice and Experience, 2018, Vol. 19, No. 2, 169-178.

Kastratovic V., **Bigovic M.**, (2018), Esterification of stearic acid with lower monohydroxylic alcohols, *Chemical Industry and Chemical Engineering Quarterly*, 24, 283-291.

Milena Milošević,Nevena Prlainović, Miloš Milčić, Vesna Nikolić, Aleksandra Božić, **Miljan Bigović**, Aleksandar Marinković, Solvent, structural, quantum chemical study and antioxidative activity of symmetrical 1-methyl-2,6-bis[2-(substituted phenyl)ethenyl] pyridinium iodides, *Journal of the Iranian Chemical Society*, **2018**, *15*, 2483–2501.

Latinovic, N., Jacimovic, Z., Latinovic, J., Kosovic, M., Kastratovic, V., **Bigovic, M.**, The examination of potential fungicidal activity ethyl-3-(trifluoromethyl)-1H-pyrazole-4-carboxylate and ethyl-1-(4-nitrophenyl)-5-(trifluoromethyl)-1H-pyrayole-4-carboxylate on fungus *Botryosphaeria dothidea* under laboratory conditions, 25th Congress of Chemists and Technologists of Macedonia, Book of abstracts, p. 152, 19-22. September 2018, Ohrid, Macedonia.

Jevtić, V., Leka, Z., **Bigović, M.**, Kasalović, M., Bogojevski, J., Trifunović, S., Interakcije ditiokarbamato cinka (II) i paladijuma(II) kompleksa DNK izolovanom iz goveđeg timusa, 4. Međunarodni simpozijum o koroziji i zaštiti materijala, životnoj sredini i zaštiti od požara, Knjiga radova, strana 97, 18-21. Septembar 2018, Bar, Crna Gora.

Kastratović, V., Jaćimović, Ž., **Bigović, M.**, Organska materija u sedimentu Skadarskog jezera, Crna Gora, 4. Međunarodni simpozijum o koroziji i zaštiti materijala, životnoj sredini i zaštiti od požara, Knjiga radova, strana 139, 18-21. 2018. Septembar, Bar, Crna Gora.

Vlatko Kastratović, **Miljan Bigović**, Željko Jaćimović, Milica Kosović, Dijana Đurović, Slađana Krivokapić, „ Levels and distribution of cobalt and nickel in the aquatic macrophytes found in Skadar Lake, Montenegro, *Environmental Science and Pollution Research* , (2018) 25: 26823–26830.

Bigovic, M., Roganovic, M., Milasevic, I., Djurovic, D., Kastratovic, V., Slavic, V., Kosovic, M., Vlahovic, M., Peroivc, S., Perovic, A., Potpara, Z., Martinovic, M., Pantovic, S., Physico-Chemical characterisation of Igalo peloid (Republic of Montenegro) and assessment of the pollution in the sampling area, 3rd International Congress of Chemistry and Chemical Engineers of Bosnia and Herzegovina, Book of Abstracts, p. 91, October 19-21. 2018, Sarajevo, Bosnia and Herzegovina.

Bigovic, M., Kastratovic, V., Pantovic, S., Roganovic, M., Milasevic, I., Ivanovic, Lj., Djurovic, D.,Slavic, V., Kosovic, M., Vlahovic, M., Determination of fatty and amino acids in Igalo bay peloid (Montenegro) , 9th International Conference of the Chemical Societies of the South-East European Countries, May 8th – 11th, 2019, Targoviste, Romania.

Vazdar, K., Vazdar, M., **Bigovic, M.**, Visnjevac, A., Kosovic, M., Leka, Z., „Optimizacija metode sinteze etilen-diamin-monosircetne kiseline , H-EDMA„ 56. Savetovanje Srpskog hemijskog drustva, Nis, 7-8. jun 2019. godine (OP P10, strana 98).

Bigovic, M., Kastratovic, V., Pantovic, S., Roganovic, M. ,Odredivanje sadržaja masnih i aminokiselina u peloidu iz Igala (Crna Gora) , 56. Savetovanje Srpskog hemijskog drustva, Nis, 7-8. jun 2019. godine (OP P11, strana 99).

Vlatko Kastratović, Dijana Đurovic, Slađana Krivokapić, Zeljko Jaćimović, **Miljan Bigović**, The influence of organic substances on the accumulation and mobility of metals in the sediment of Skadar Lake, 8th International Symposium of Ecologists, ISEM8, 2-5 October 2019, Budva, Montenegro. Abstract book, p. 89.

Bigovic, M., Roganovic, M., Milasevic, I., Djurovic D., Slavic, V., Kastratovic, V., Pantovic, S.,The Content of Heavy metals in the Igalo peloid and Calculation of Environmental Parameters, 8th International Symposium of Ecologists, ISEM8, 2-5 October 2019, Budva, Montenegro. Abstract book, p. 110.

Bigovic, M., Pantovic, S., Milasevic, I., Ivanovic, Lj., Djurovic, D., Slavic, V., Popovic, M., Vrvic, M., Roganovic, M., Organic composition of Igalo bay peloid (Montenegro), *Indian Journal of Traditional Knowledge*, 2019, 18(4), 837-848.

Bigović, M., Jovanović, J., Majstorović, H., Pantović, S., Roganović, M., Ivanović, Lj, Djurović, D., Popović, M., Determination of proteins and carbohydrates in Igalo bay peloid (Montenegro) , 9th Conference of the Serbian Biochemical Society: 'Diversity in Biochemistry'14-16 November 2019, Belgrade, Serbia.

Damnjan Nuculović, **Miljan Bigović**, Yannick Ney, Claus Jacobs, Synthesis of schiff bases and their antimicrobial activities, Montenegrin international medical summit, 3-6. October 2019, Podgorica, Montenegro, Abstract Book p.80.

Bigović, M., Jovanović, J., Majstorović, H., Pantović, S., Roganović, M., Ivanović, Lj, Djurović, D., Popović, M., Determination of proteins and carbohydrates in Igalo bay peloid (Montenegro) , 9th Conference of the Serbian Biochemical Society: 'Diversity in Biochemistry'14-16 November 2019, Belgrade, Serbia.

Damnjan Nuculovic , **Miljan Bigovic**, Yannick Ney, Claus Jacobs, New Schiff Bases and Their Antimicrobial and Anticancer Abilities, 5th International Medical Student Congress, 20-22. Februar 2020, Sarajevo, Bosna and Herzegovina, Abstract Book p.103.

Ostale aktivnosti i interesovanja:

- Član Srpskog hemijskog društva i Društva hemičara Crne Gore;
- Učešće u realizaciji 1., 2. I 3. Festivala nauke Republike Srbije (2008-2011);
- Član Organizacionog odbora 14th European Conference of Chemistry of the Environment (European Meeting on Environmental Chemistry, EMEC), 4-7. Decembar 2013., Budva;
- Autor i ocjenjivač takmičarskih testova iz hemije u organizaciji Ispitnog centra Crne Gore;
- Autor i ocjenjivač takmičarskih zadataka i koordinator hemijskog kolegijuma Olimpijade znanja u organizaciji Prirodno-matematičkog fakulteta Crne Gore;
- Član fondacije za promovisanje nauke „Prona" od 2014. godine – angažovan kao mentor radova iz oblasti hemije na Zimsoj školi nauke, kao predavač i organizator praktikuma iz hemije na Ljetnjoj školi nauke;
- Koordinator za hemiju za takmičenje „Olimpijada znanja" u organizaciji Prirodno-matematičkog fakulteta Univerziteta Crne Gore;

- Mentor i voda crnogorskog tima na 51. Međunarodnoj hemijskoj olimpijadi (51th ICHO), održanoj u julu 2019. godine u Parizu, Francuska.

- Učesnik na većem broju bilateralnih projekata između Crne Gore sa jedne i Srbije, Hrvatske, Slovenije i Mađarske sa druge strane.

- Istraživanje zagađenja crnogorskog primorja i Skadarskog jezera sa organokalajnim jedinjenjima i toksičnim metalima (Crna Gora-Hrvatska, 2014-2016);
- Uticaj teških metala na promjenu metabolizma ljekovitog bilja (Crna Gora-Srbija, 2016-2018);
- Sinteza, karakterizacija i biološki aspekti novih ditiokarbamatnih kompleksa nekih prelaznih metala (Crna Gora-Srbija, 2016-2018);
- Sinteza, fizičko-hemijska i strukturna istraživanja novih, potencijalno biološki aktivnih Šifovih baza-derivata ditiokarbamata (Crna Gora-Hrvatska, 2016-2018);
- Sinteza, fizičko-hemijska karakterizacija i potencijalna biološka karakterizacija-aktivnost novih kompleksnih jedinjenja prelaznih metala sa pirazolom i njegovim derivatima (Crna Gora-Mađarska, 2016-2018);
- Modeliranje grafovima u matematičkoj hemiji (Crna Gora-Slovenija, 2018-2020).

Rukovodilac je bilateralnog projekta sa Srbijom pod nazivom „ Sinteza Sifovih baza i ispitivanje njihove antimikrobne i antioksidativne sposobnosti, za period 2019-2021.

Član je projekta „Balneološki efekti peloida, mineralne vode, ljekovitog i aromatičnog bilja na inflamatorni odgovor kod reumatoidnih i kardiovaskularnih bolesti (period 2018-2020).

Član je Centra Izvrsnosti Centre of Excellence for Biomedical Researches CEBIMER, kao rukovodilac istraživanja u oblasti hemije, i član naučnog odbora Centra.

Recenzent „Priručnika za laboratorijsku dijagnostiku", autora Snežane Pantović i Ivana Dožića, u izdanju Medicinskog fakulteta Univerziteta Crne Gore, Podgorica, 2017.

Autor poglavlja u udžbeniku „Osnovi biohemije" za studente visoke medicinske škole, urednika Snežane Pantović, Medicinskog fakulteta Univerziteta Crne Gore, Podgorica, 2018.

Koautor udžbenika „Hemija za četvrti razred gimnazije" u izdanju Zavoda za udžbenike i nastavna sredstva, Podgorica, 2020. godine.

Recenzent „Zbirke zadataka za četvrti razred gimnazije" autora Stanojke Vučurović, Željka Jaćimovića i Vlatka Kastratovića, u izdanju Zavoda za udžbenike i nastavna sredstva, Podgorica, 2020. godine.

Broj:18/040
Datum:19.06.2018.

Na osnovu člana 72. a u vezi sa članom 73 i 74 Zakona o visokom obrazovanju ("Sl. list CG", br. 44/14) i člana 103 st. 7 Statuta Univerziteta Donja Gorica br. 16/10 od 02. novembra 2010. godine, Pravilnika Senata UDG-a o opštim uslovima za izbor u akademska zvanja na Univerzitetu Donja Gorica (UDG) br. 29/11 od 23.03.2011. godine, Pravilnika o bližim uslovima i postupku izbora u akademska zvanja na Fakultetu za prehrambenu tehnologiju, bezbjednost hrane i ekologiju od 02.10.2013. godine, Naučno nastavno vijeće Fakulteta za prehrambenu tehnologiju, bezbjednost hrane i ekologiju na XII sjednici održanoj 09.06.2016.godine, donosi

ODLUKU
o imenovanju u zvanje docenta

Član 1.

Imenuje se:

- **dr Dijana Đurović, u zvanje** docenta za naučnu oblast: analitička hemija na Fakultetu za prehrambenu tehnologiju, bezbjednost hrane i ekologiju, Univerziteta Donja Gorica;

Član 2.

Za realizaciju ove odluke zadužuje se mr Sandra Tinaj, menadžer UDG-a.

Član 3.

Odluka stupa na snagu danom donošenja a primjenjivaće se od dana davanja saglasnosti na istu od strane Senata UDG-ja.

DEKAN

profesor dr Vesna Maraš

europass

Europass Radna biografija

Lični podaci

Prezime(na) / Ime(na)	**Đurović/ Dijana**
Adresa(e)	Slobode 59, Podgorica
Telefonski broj(evi)	+38220664844
Broj mobilnog telefona	+38206702660459
E-mail	dijana.djurovic@izzzo.me
Državljanstvo	Crnogorsko
Datum rođenja	11/08/1970
Pol	Ženski

Željeno zaposlenje / zanimanje

Hemičar/biohemičar

Radno iskustvo

Datumi	Od jula 2017
Zanimanje ili radno mjesto	Direktor Centra za zdravstvenu ekologiju
Glavni poslovi i odgovornosti	-rukovođenje i organizacija Centra za zdravstvenu ekologiju, - bavljenje naučno istraživačkim radom - uvođenje novih metoda u analitici hrane i životne sredine
Ime i adresa poslodavca	Institutu za javno zdravlje, Džona Džeksona bb 81000 Podgorica

Vrsta djelatnosti ili sektor	Medicina i zdravlje
Datumi	2002-2017
Zanimanje ili radno mjesto	Šef laboratorije za ispitivanje vode, vazduha i zemljišta
Glavni poslovi i odgovornosti	- Rukovođenje laboratorijom - Analiza teških metala u hrani, životnoj sredini i biološkim uzorcima - Bavljenje naučno-istraživačkim radom - Uvođenje novih metoda
Ime i adresa poslodavca	Institutu za javno zdravlje, Džona Džeksona bb 81000 Podgorica
Vrsta djelatnosti ili sektor	Medicina i zdravlje
Datumi	1995-2002
Zanimanje ili radno mjesto	Sanitarni hemičar
Glavni poslovi i odgovornosti	- Analiza vode, hrane, zemljišta - Određivanje teških metala - Analiza pesticida, antibiotika - Kontrola kvaliteta
Ime i adresa poslodavca	Institutu za javno zdravlje, Džona Džeksona bb 81000 Podgorica
Vrsta djelatnosti ili sektor	Medicina i zdravlje

Obrazovanje i osposobljavanje

Datumi	2017
Naziv dodijeljene kvalifikacije	Doktor nauka biohemije
Glavni predmeti / stečene profesionalne vještine	Odbranjena doktorska disertacija iz oblasti esencijalnih mikroelemenata i antioksidativnog statusa humanih uzoraka (mlijeko i serum)
Ime i vrsta organizacije obrazovne institucije	Hemijski fakultet Univerziteta u Beogradu

Nivo prema nacionalnoj ili međunarodnoj klasifikaciji	VIII
Datumi	2010
Naziv dodijeljene kvalifikacije	Magistar hemijske tehnologije
Glavni predmeti / stečene profesionalne vještine	Odbranjen magistarski rad na temu odredivanje sadržaja teških metala u uzorcima zemljišta i hrane u zetskoj ravnici
Ime i vrsta organizacije obrazovne institucije	Metalurško-tehnološki fakultet Univerziteta u Podgorici
Nivo prema nacionalnoj ili međunarodnoj klasifikaciji	VII-1
Datumi	2002
Naziv dodijeljene kvalifikacije	Specijalista sanitarne hemije
Glavni predmeti / stečene profesionalne vještine	Odbranjen specijalistički rad na temu teški metali u bunarskoj vodi Zetske ravnice
Ime i vrsta organizacije obrazovne institucije	Farmaceutski fakultet Univerziteta u Beogradu
Datumi	1995
Naziv dodijeljene kvalifikacije	Diplomirani hemičar za istraživanje i razvoj
Glavni predmeti / stečene profesionalne vještine	Hemija, analitička hemija, organska, neorganska, instrumentalne metode
Ime i vrsta organizacije obrazovne institucije	Hemijski fakultet Univerziteta u Beogradu

VIII
2010
Magistar hemijske tehnologije
Odbranjen magistarski rad na temu odredivanje sadržaja teških metala u uzorcima zemljišta i hrane u zetskoj ravnici
Metalurško-tehnološki fakultet Univerziteta u Podgorici
VII-1
2002
Specijalista sanitarne hemije
Odbranjen specijalistički rad na temu teški metali u bunarskoj vodi Zetske ravnice
Farmaceutski fakultet Univerziteta u Beogradu

Nivo prema nacionalnoj ili međunarodnoj klasifikaciji	VII

Metalurško-tehnološki fakultet Univerziteta u Podgorici
VII
2002
Specijalista sanitarne hemije
Odbranjen specijalistički rad na temu teški metali u bunarskoj vodi Zetske ravnice
Farmaceutski fakultet Univerziteta u Beogradu

Lične vještine i kompetencije

završila osnovni kurs iz toksikologije u organizaciji farmaceutskog fakuleteta u beogradu, jun 2011

završila kurs razvijanje analitičkih sposobnosti u organizaciji tehničkog komiteta opcw u holandiji, jun-juy 2006

SPECIJALIZOVANA U UPTREBI RAZLIČITIH ANALITIČKIH TEHNIKA KAO ŠTO SU ICP-OES, AAS, GFAAS, GC, GC/MS

Materinji jezik(ci) **Crnogorski**

Drugi jezik(ci) **Engleski**

Samoprocjena	Razumijevanje				Govor				Pisanje	
Evropski nivo (*)	Slušanje		Čitanje		Govorna interakcija		Govorna produkcija			
	C2	Iskusni korisnik	C2	Iskusni korisnik	C2	Iskusni korisnik	C2	Iskusni korisnik	C2	Iskusni korisnik

	(*) Zajednički evropski referentni okvir za jezike
Društvene vještine i kompetencije	Visoko motivisana na polju istraživanja u oblasti životne sredine, plus izuzetne menadžerske sposobnosti. 22 godine radnog iskustva u IJZ, 15 godina kao sopecijalista sanitarne hemije u oblasti kontrole I biohemije hrane I životne sredine. Učestvovala u nekoliko nacionalnih naučnih projekata. Kao dio tima učestvovala u osnivanju prvo Centra izvrsnosti u CG. Dobre komunikacione sposobnosti stečene kroz učešće na mnogim konferencijama a I kao predavač. Iskustvo u radu u multidisciplinarom timu.
Organizacione vještine i kompetencije	Iskustvo u projektima I upravljanjem projektimaGood experience in project and team management. Koordinator I administrator u nekim nacionalnim i međubarodnim projektima. Focal point za Protokol voda i zdravlje pri Ministarstvu zdravlj. Član mnogih komisija u Ministarstvu ekologije I Ministarstvu poljoprivrede, vodoprivrede i šumarstva.
Računarske vještine i kompetencije	Windows XP, Microsoft Office™ tools, Internet
Vozačka dozvola	B kategorija
Dodaci	Biografski i bibliografski podaci

dr. Dijana Đurović,
Dijana Đ. Đurović rođena je 11.08.1970. godine u Podgorici, Crna Gora. Osnovnu školu i Gimnaziju završila je u Podgorici. Diplomirala je na Hemijskom fakultetu Univerziteta u Beogradu, smjer diplomirani hemičar za istraživanje i razvoj 1995.godine. Specijalizaciju iz Sanitarne hemije završila je na Farmaceutskom fakultetu Univerziteta u Beogradu 2002. godine. Zvanje mr hemijske tehnologije stekla je 2010. godine na Metalurško-Tehnološkom fakultetu Univerziteta Crne Gore. Zvanje doktor nauka-biohemijske nauke stekla 2017. godine na Hemijskom fakultetu, Univerziteta u Beogradu.

U aprilu 2013. godine završila Kurs o teškim metalima-validacija metoda (u okviru projekta "Bezbjednost hrane u Crnoj Gori) u Teramu, Italija. "Osnovni kurs iz toksikologije" u organizaciji EUROTOX, Beograd, Srbija završila u julu 2011. godine. Razvijanje analitičkih sposonosti-kurs u organizaciji Tehničkog sekretarijata OPCW (Organisation for the Prohibition of Chemical Weapons) u Holandiji (Delft) završila u julu 2006. godine.

Od septembra 2010. godine radi kao saradnik na Farmaceutskom fakultetu Univerziteta Crne Gore na predmetima Farmaceutska analiza i kontrola ljekova i Tosikologija sa analitikom.
Od septembra 2014. godine angažovana kao predavač na Fakultetu za prehrambenu tehnologiju, bezbjednost hrane i ekologiju na UDG-u na predmetima Tehnologija voda i Analitička hemija.

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Broj: 03-940
Datum: 24.06.2021

Na osnovu člana 72 stav 2 Zakona o visokom obrazovanju („Službeni list Crne Gore" br 44/14, 47/15, 40/16, 42/17, 71/17, 55/18, 3/19, 17/19, 47/19, 72/19 i 74/20) i člana 32 stav 1 tačka 9 Statuta Univerziteta Crne Gore, Senat Univerziteta Crne Gore na sjednici održanoj 24.06.2021. godine, donio je

O D L U K U
O IZBORU U ZVANJE

Dr Irena Nikolić bira se u akademsko zvanje redovni profesor Univerziteta Crne Gore za **oblasti Inženjerstvo materijala i Metalurško inženjerstvo** na Metalurško-tehnološkom fakultetu Univerziteta Crne Gore, na neodređeno vrijeme.

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Željeno zaposlenje / zanimanje

Radno iskustvo

Datumi	2016- do danas, vanredni profesor 2009-2016. docent 2003-2009. viši stručni saradnik 1998-2003. asistent 1994-1998. asistent pripravnik 2014 → danas (konsultant na Institutu za javno zdravlje Crne Gore, angažman po osnovu naučno-istraživačkih projekata)
Zanimanje ili radno mjesto	Profesor,
Glavni poslovi i odgovornosti	Pedagoška djelatnost, naučno – istraživački rad (pisanje programa naučnih istraživanja; pisanje naučnih radova, prezentovanje rezultata na međunarodnim i domaćim naučnim skupovima, recenziranje naučnih radova);
Ime i adresa poslodavca	Univerzitet Crne Gore, Metalurško – tehnološki fakultet, Džordža Vašingtona bb, Podgorica, Crna Gora
Vrsta djelatnosti ili sektor	Naučno-istraživačka, visoko obrazovanje

Obrazovanje i osposobljavanje

Datumi	2003. Doktor tehničkih nauka
Naziv dodijeljene kvalifikacije	1998. Magistar tehničkih nauka 1994. dipl. ing. metalurgije
Glavni predmeti / stečene profesionalne vještine	Oblast - zaštita životne sredine (Sekundarne sirovine, valorizacija industrijskog otpada, ekološki građevinski materijali); Oblast -Ekstraktivna metalurgija
Ime i vrsta organizacije obrazovne	Univerzitet Crne Gore, Metalurško – tehnološki fakultet, Podgorica, Crna Gora

institucije	
Nivo prema nacionalnoj ili međunarodnoj klasifikaciji	PhD – ISCED8, MSc ISCED7

Lične vještine i kompetencije

Matemji jezik(ci)	**Crnogorski**
Drugi jezik(ci)	**Engleski**

Samoprocjena	Razumijevanje				Govor				Pisanje	
Evropski nivo (*)	Slušanje		Čitanje		Govorna interakcija		Govorna produkcija			
Engleski	C2	Iskusni korisnik	C2	Iskusni korisnik	C2	Iskusni korisnik	C2	Iskusni korisnik	C2	Iskusni korisnik

(*) Zajednički evropski referentni okvir za jezike

Društvene vještine i kompetencije	Komunikativna, sklonost ka preuzimanju inicijative i timskom radu.
Organizacione vještine i kompetencije	Orgaizacija, rukovođenje naučnim projektima, pedagoški rad (rukovođenje izradom master i doktorskih radova). Članstvo u u organizacionom odborima međunarodnih naučnih konferencija. skonost timskom radu,adaptacija različitim poslovnim sredinama, analitičko rasuđivanje
Računarske vještine i kompetencije	Microsoft Office (Word, Excel, PowerPoint), Adobe, Origin,

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2. Magistarski rad: " Istraživanje uticaja radnih parametara procesa razlaganja aluminatnih rastvora na karakteristike aluminijum-hidroksida" Univerzitet Crne Gore, Metalurško-tehnološki fakultet u Podgorici.1998. g.

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2. **I. Nikolić,** D. Đurović, A. Mladenović, A. Mauko-Pranjić... Novi, ekološki prihvatljiv termoizpolacioni malter na bazi pepela i ekspandiranog perlita, Bilateralni projekat izmedju Republike Slovenije i Crne Gore, nosilac projekta, Metalurško-tehnološki fakultet, Univerzitet Crne Gore, 2016-2017 (**rukovodilac projekta)**
3. B. Mugoša, **I. Nikolić,** D. Đurović....., Solidifikacija/stabilizacija toksičnog otpada u materijale na bazi lebdećeg cementa i pepela, Bilateralni projekat izmedju Republike Slovenije i Crne Gore, nosilac projekta, Institut za javno zdravlje Crne Gore 2014-2015.(saradnik na projektu)
4. **I Nikolić,** D. Blečić, V. Radmilović, R. Zejak, D. Đurović ..., Ispitivanje mogućnosti dobijanja građevinskih materijala na bazi bijelih boksita pepela i šljake, Ministasrtvo nauke Crne Gore, nosilac projekta, Metalurško-tehnološki fakultet, Univerzitet Crne Gore 2012- 2014. (**rukovodilac projekta**)
5. D. Blečić, **I. Blagojević (Nikolić)** "Optimizacija procesa razlaganja aluminatnih rastvora u Bayer-ovom procesu", nosilac projekta, Metalurško-tehnološki fakultet, Univerzitet Crne Gore, 1998 (saradnik na projektu)

6. D. Blečić, **I. Nikolić**, M. Vukčević, "Ispitivanje fenomena procesa kristalizacije $Al(OH)_3$ iz kaustičnih rastvora " Ministasrtvo prosvjete i nauke; nosilac projekta. Metalurško-tehnološki fakultet, Univerzitet Crne Gore, 2005 (saradnik na projektu)
7. Ž. Blečić, D. Blečić, **I. Nikolić** .... "Istraživanje fenomena međudejstva faza metal troska i njihov uticaj na zavarljivost raznorodnih čelika" naučni projekat, Ministasrtvo prosvjete i nauke, nosilac projekta, Metalurško-tehnološki fakultet, Univerzitet Crne Gore, 2009-2011 (saradnik na projektu)

PEDAGOŠKA DJELATNOST

Mentorstvo na doktorskim studijama

1. Ana Drinčić: Environmental impacts of building materials containing industrial waste byproducts and fly ash from thermal power plants, Jožef Stefan International Postgraduate School (IPS), Ljubljana, Slovenija, 2018. (komentor).

Mentorstvo na postdiplomskom studiju

2. Jasmina Krivokapić: Geopolimerizacija bijelog boksita i smješe bijeli boksit elektropećna prašina, *Univerzitet Crne Gore Metalurško-tehnološki fakultet*, Datum odbrane 12.09. 2013
3. Ivana Popović: Geopolimerizacija čeličanske elektropećne troske, *Univerzitet Crne Gore Metalurško-tehnološki fakultet*, Datum odbrane 11.09.2013.
4. Ana Drinčić: Kinetika rastvaranja čeličanske elektropećne troske u alkalnoj sredini, *Univerzitet Crne Gore Metalurško-tehnološki fakultet*, Datum odbrane16.09.2014

Mentorstvo na dodiplomskom studiju

5. Jasmina Krivokapić: Ispitivanje mogućnosti imobilizacije teških metala iz elektropećne prašine u geopolimere na bazi pepela, *Univerzitet Crne Gore Metalurško-tehnološki fakultet*, Specijalistički rad, (odbranjen Jun 2012)

Univerzitet Crne Gore
University of Montenegro

Broj / Rot: 03-1443

Datum / Date: 20.07.2022

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O D L U K U
O IZBORU U ZVANJE

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OBRAZOVANJE

Godina	Stepen	Institucija	Oblast
2006.	Doktorat	Univerzitet u Novom Sadu	Biologija/Fiziologija biljaka
1998.	Magistratura	Univerzitet u Novom Sadu	Biologija/Genetika
1992.	Diploma	Univerzitet u Novom Sadu	Biologija

AKADEMSKA ZVANJA

2017- : Vanredni profesor za predmete Anatomija i morfologija biljaka i Fiziologija biljaka
2012.-2016.:Vanredni profesor za predmete Anatomija i morfologija biljaka i Fiziologija biljaka
2006-.2012.: Docent za predmete Anatomija biljaka i Fiziologija biljaka
1999.-2006.: Asistent, Katedri za Botaniku, predmet Fiziologija biljaka
1994.-1999.: Prirodno-matematički fakultetu u Podgorici (angažovana za izvođenje vježbi na predmetima Anatomija biljaka, Fiziologija biljaka i Marinska biologija)
1992.-1993.: Saradnik ne predmetu Genetika, Odsjek za biologiju, Prirodno-matematički fakultet, Novi Sad

NASTAVA

• Anatomija i morfologija biljaka	Osnovne akademske
• Fiziologija biljaka	Osnovne akademske
• Kurs laboratorijskih tehnika	Specijalističke akademske
• Biološki aktivne materije biljaka	Master akademske
• Teški metali i antioksidativna zaštita biljaka	Master akademske
• Sekundarni metaboliti marinskih algi	Doktorske akademske
• Teški metali u životnoj sredini	Doktorske akademske
• Biološki aktivne materije biljaka	Doktorske akademske

ODABRANI PROJEKTI

2019.-2021.: Phytopreparations-natural materials with supercritical extracts for controlled released of sctive components- EUREKA
2019.-2021.: Uticaj načina pripreme biljnih ekstrakata na prelazak teških metala iz biljke u pripravak-bilateralni naučno-istaživački projekat sa republikom Srbijom

2017.-2019.- Uticaj teških metala na promjenu metabolizma ljekovitog bilja [redacted] projekat sa republikom Srbijom

2016.-2018.- Comprehensive processing of plant extracts for high value added [redacted]

2015-2016 Istraživanje zagadjenja Crnogorskog primorja i Skadarskog jezera organ[redacted] toksičnim metalima-bilateralni naučno-istaživački projekat sa Republikom Hrvatskom

2012.-2015.:Ispitivanje uzročno-posljedične veze između stresora i zagađivača [redacted] efekta na ekosistem Zetske ravnice primjenom bioloških testova-nacionalni projekat

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