University of Belgrade
Technical Faculty in Bor and
Mining and Metallurgy Institue Bor

51st International October Conference on Mining and Metallurgy

PROCEEDINGS

Editors:

Prof. dr Srba Mladenović
Prof. dr Čedomir Maluckov

Bor Lake, Serbia,
October 16-19, 2019

University of Belgrade
Technical Faculty in Bor and
Mining and Metallurgy Institue Bor

51st International October Conference on Mining and Metallurgy

PROCEEDINGS

Editors:

Prof. dr Srba Mladenović
Prof. dr Čedomir Maluckov

Bor Lake, Serbia,
October 16-19, 2019

PROCEEDINGS,

51st INTERNATIONAL OCTOBAR CONFERENCE

ON MINING AD METALLURGY

Editors:

Prof. dr Srba Mladenović
Prof. dr Čedomir Maluckov
University of Belgrade, Technical Faculty in Bor

Technical Editor:
Prof. dr Čedomir Maluckov
University of Belgrade, Technical Faculty in Bor

Publisher: *University of Belgrade, Technical Faculty in Bor*
For the publisher: Dean prof. dr Nada Štrbac
Circulation: 100

Printed by "Tercia", Bor, 2019.

ISBN 978-86-6305-101-0

CIP - Каталогизација у публикацији
Народна библиотека Србије, Београд

622(082)(0.034.2)
669(082)(0.034.2)

INTERNATIONAL October Conference on Mining and Metallurgy (51 ; 2019 ; Borsko jezero)

Proceedings [Elektronski izvor] / 51st International October Conference on Mining and Metallurgy - IOC 2019, Bor Lake, Serbia, October 16-19, 2019 ; [organized by] University of Belgrade, Technical Faculty in Bor and Mining and Metallurgy Institute Bor ; editors Srba Mladenović, Čedomir Maluckov. - Bor : University of Belgrade, Technical Faculty, 2019 (Bor : Tercia). - 1 USB fleš memorija ; 1 x 1 x 5 cm

Sistemski zahtevi: Nisu navedeni. - Tiraž 100. - Preface / Srba Mladenović. - Napomene i bibliografske reference uz radove. - Bibliografija uz svaki rad. - Registar.

ISBN 978-86-6305-101-0

а) Рударство -- Зборници б) Металургија – Зборници

COBISS.SR-ID 280007180

Bor Lake, Serbia, October 16-19, 2019

Conference is financially supported by
The Ministry of Education, Science and
Technological Development of the
Rapublic of Serbia

Diamond Donor

HBIS GROUP HBIS SERBIA

Gold Donor

塞尔维亚紫金波尔铜业有限公司
SERBIA ZIJIN BOR COPPER DOO BOR

Silver Donors

HUESKER
Ideas. Engineers. Innovations.

RUDNIK

Friends of Conference

MARTENZIT
alati i pribor za istražna geološka,hidrogeološka,eksploataciona i druga bušenja
tools and equipments for geological prospecting, hydro geological, exploitation and other drilling

Foundry of non-ferrous metals
Buntmetall giesserei
Livnica obojenih metala
metalurg
PROKUPLJE
SERBIA

ALATNICA VLADA BOR

DOO ADMETAL BOR

Peric & Peric & Co

SCIENTIFIC COMMITTEE

prof. dr Nada Štrbac (Serbia) – president,
Prof. dr Radoje Pantović (Serbia) – vice-president,
Prof. dr Grozdanka Bogdanović (Serbia)- vice-president,
Prof. dr Dragoslav Gusković (Serbia)- vice-president,
Prof. dr Aleksandar Dimitrov (FYR Macedonia),
Dr Ana Kostov (Serbia),
Dr Andrei Rotaru (Romania),
Prof. dr Anđelka Mihajlov (Serbia),
Prof. dr Batrić Pešić (USA),
Prof. dr Boštjan Markoli (Slovenia),
Prof. dr Boyan Boyanov (Bulgaria),
Prof. dr Branka Jordović (Serbia),
Prof. dr Carl Heinz Spitzer (Germany),
Prof. dr Costas Matis (Greece),
Prof. dr Dejan Tanikić (Serbia),
Prof. dr Desimir Marković (Serbia),
Prof. dr Dimitris Panias (Greece),
Prof. dr Dimitriu Sorin (Romania),
Prof. dr Dragan Manasijević (Serbia),
Prof. dr Duško Minić (Serbia),
Prof. dr Endre Romhanji (Serbia),
Prof. dr Fathi Habashi (Canada),
Prof. dr Guven Onal (Turkey),
Prof. dr György Kaptay (Hungary),
Prof. dr Heikki Jalkanen (Finland),
Prof. dr Iwao Katayama (Japan),
Prof. dr Jakob Lamut (Slovenia),
Prof. dr Jelena Penavin Škundrić (B&H),
Prof. dr Jožef Medved (Slovenia),
Prof. dr Karlo Raić (Serbia),
Prof. dr Kemal Delijić (Montenegro),
Prof. dr Krzystof Fitzner (Poland),
Prof. dr Luis Filipe Malheiros (Portugal),
Prof. dr Ljubica Ivanić (Serbia),
Dr Magnus Ericsson (Sweden),
Prof. dr Milan Antonijević (Serbia),
Prof. dr Milan Trumić (Serbia),
Dr Mile Bugarin (Serbia),
Dr Milenko Ljubojev (Serbia),
Dr Mirjam Jan-Blažić (Slovenia),
Prof. dr Mirjana Rajčić Vujasinović (Serbia),
Prof. dr Mirko Gojić (Croatia),
Dr Miroslav Sokić (Serbia),
Prof. dr Mirsada Oruč (B&H),
Dr Nadežda Talijan (Serbia),
Prof. dr Nenad Radović (Serbia),
Prof. dr Nenad Vušović (Serbia),
Prof. dr Nobuyuki Masuda (Japan),
Prof. dr Onuralp Yucel (Turkey),
Prof. dr Petr M. Solozhenkin (Russia),
Prof. dr Rodoljub Stanojlović (Serbia),
Prof. dr Sanda Krausz (Romania),
Prof. dr Seshadri Seetharaman (Sweden),
Dr Slavomir Hredzak (Slovakia),
Prof. dr Snežana Milić (Serbia),
Prof. dr Snežana Šerbula (Serbia),
Prof. dr Stoyan Groudev (Bulgaria),
Prof. dr Sulejman Muhamedagić (B&H),
Prof. dr Svetlana Ivanov (Serbia),
Dr Srećko Stopić (Germany),
Prof. dr Tamara Holjevac Grgurić (Croatia),
Prof. dr Tatjana Volkov-Husović (Serbia),
Prof. dr Tomaš Havlik (Slovakia),
Prof. dr Velizar Stanković (Serbia),
Prof. dr Velimir Radmilović (USA),
Prof. dr Vitomir Milić (Serbia),
Dr Vladan Ćosović (Serbia),
Prof. dr Vladimir Krstić (Canada),
Prof. dr Vladislav Kecojević (USA),
Prof. dr Vlastimir Trujić (Serbia),
Prof. dr Yong Du (China),
Prof. dr Žarko Radović (Montenegro),
Prof. dr Željko Kamberović (Serbia),
Prof. dr Živan Živković (Serbia),
Dr Walter Valery (Australia),
Dr Zvonko Gulišija (Serbia),
Dr Zagorka Aćimović Pavlović (Serbia)

ORGANIZING COMMITTEE

Prof. dr Srba Mladenović – president,
Prof. dr Čedomir Maluckov -vice-president,
dr Ana Kostov - vice-president,
Jasmina Petrović
Jelena Ivaz
Pavle Stojković
Prof. dr Saša Marjanović

PREFACE

On behalf of the Organizing Committee, it is a great honor and pleasure to wish all the participants a warm welcome to the 51st International October Conference on Mining and Metallurgy (IOC 2019) held at Bor Lake, Serbia, 16 – 19 October 2019.

The IOC 2019 has been organized by the University of Belgrade, Technical Faculty in Bor, in cooperation with Mining and Metallurgy Institute Bor. It is devoted to presenting recent research results and advances in the fields of geology, mining, metallurgy, materials science, technology, environmental protection, and related engineering topics. The primary goal of IOC is to bring together academics, researchers, and industry engineers to exchange their experiences, expertise and ideas, and also to consider possibilities for collaborative research.

These proceedings include 81 papers from authors coming from universities, research institutes and industries in 15 countries: Bosnia and Herzegovina, Croatia, Japan, Kazakhstan, México, Montenegro, Poland, Romania, Russia, Slovenia, Turkey, Ukraine, Switzerland, Brasil and Serbia.

Financial assistance provided by the Ministry of Education, Science and Technological Development of the Republic of Serbia is gratefully acknowledged. The support of the sponsors and their willingness and ability to cooperate has been of great importance for the success of IOC 2019. The Organizing Committee would like to extend their appreciation and gratitude to all the donors and friends of the Conference for their donations and support.

We would like to thank all the authors who have contributed to these proceedings, and also to the members of the scientific and organizing committees, reviewers, speakers, chairpersons and all the Conference participants for their support to IOC 2019. Sincere thanks to all the people who have contributed to the successful organization of IOC 2019.

We look forward to welcoming you to the 52nd International October Conference on Mining and Metallurgy (IOC 2020), which will be held in October 2020.

On behalf of the 51st IOC Organizing Committee,
Prof. dr Srba Mladenović

Table of Contens

Plenary Lecture

Marek Warzecha, Artur Hutny
LIQUID STEEL HOMOGENIZATION IN 140 T LADLE AFTER ALLOY ADDITION 1

Section Lectures

Alex Amdur, Sergey Krasikov, Alexei Potapov, Sergei Fedorov
THE BEHAVIOR OF PLATINUM IN THE SYSTEM OF THE MATTE-SLAG IN THE PROCESSING OF COPPER-NICKEL ORES 3

Eduardo Guanaes, Marija Bakrač, Daniel Fernandez Arnau
COAL ASH DISPOSITION FACILITY BY USING GEOTEXTILE TUBES 7

Conference Papers

Branislava Matić, Dragana Vidojevic, Dragana Jovanović, Snežana Živković, Dragan Miljuš
ROADMAP FOR SOUND MULTISECTORIAL MANAGEMENT OF CONTAMINATED SITES IN SERBIA IN ACCORDANCE WITH THE OSTRAVA DECLARATION 13

Dragana Vidojevic, Milenko Jovanovic, Lidija Maric, Aleksandra Siljić Tomic
Progess in Management of contamined sites in Serbia 18

Tomislav Grandovic, Savo Pirgic, Novica Djordjevic,Vladan Radic, Igor Zlatkovic
CREATION OF ADEQUATE CONDITIONS FOR INCREASING OF PRODUCTION AND IMPROVING PRODUCTIVITY OF SINTER 23

Darko Djordjevic
EXTENSION OF BLAST FURNACES CAMPAIGN USING SHOTCRETING METHOD FOR REFRACTORY LINING REPAIR 27

Nenad Botic, Dobrica Milovanovic, Tomislav Grandovic, Igor Zlatkovic, Darije Pavlovic
INCREASIG THE USE OF RECYCLING MATERIALS TO REDUCE CONSUMPTION OF RAW MATERIALS ON SINTER PLANT AND BLAST FURNACE 32

Nikola Bajic, Zoran Karastojkovic, Darko Veljic, Mihailo Mrdak, Jasmina Pekez, Zoran Radosavljevic
DEVELOPMENT AND PRODUCTION OF COATED ELECTRODES FOR WELDING OF GRAY IRON 36

Binchiciu Emilia Florina, Voiculescu Ionelia, Geanta Victor
SMAW COATED ELECTRODE FOR DEPOSITION OF BRONZE WITH 12wt%SN 40

Biljana Zlatičanin, Sandra Kovačević
COMPUTER MODELLING OF THE THERMO-PHYSICAL AND PHYSICAL PROPERTIES OF Al-Cu5-Mg3 ALLOYS 44

Franjo Kozina, Zdenka Zovko Brodarac, Barbara Tubić, Natalija Dolić
THE EFFECT OF SODIUM AND STRONTIUM ON MODIFICATION OF EUTECTIC SILICON 48

Biljana Zlatičanin, Sandra Kovačević
EFFECT OF GRAIN REFINING ON THE STRUCTURE AND PROPERTIES OF AS-CAST Al-Cu8 ALLOYS 52

Dragan Manasijević, Ljubiša Balanović, Duško Minić, Milena Premović
PREDICTION OF THERMODYNAMIC PROPERTIES AND PHASE EQUILIBRIA IN THE Ga-Sn-Zn TERNARY SYSTEM 56

Nebojša Tadić, Žarko Radović
FEM SIMULATION OF STEEL INGOT HEATING BEFORE FORGING 60

Žarko Radović, Nebojša Tadić
THE POSSIBILITY OF THE REPEATED RECYCLING OF ELECTRIC ARC FURNACE DUST 64

Srđan Stanković, Vesna Conić, Miroslav Sokić, Branislav Marković, Suzana Dragulović
ADAPTATION OF THE MODERATELY THERMOPHILIC ACIDOPHILIC BACTERIA FOR GROWTH ON FLOTATION TAILINGS AS A GROWTH SUBSTRATE 69

Jelena S. Avdalović, Olivera Tešić, Biljana Dojčinović, Vesna Conić, Zorica Lopičić, Srđan Miletić, Miroslav M. Vrvić
MICROBIAL SOLUBILIZATION OF COPPER AND ZINC FROM POLYMATALLIC SULPHIDE ORE 73

Ekaterina Zhilina, Sergey Krasikov, Andrey Russkih, Stanislav Melchakov
BEHAVIOR OF RARE ELEMENTS DURING THE ELECTROCHEMICAL DISSOLUTION OF HEAT-RESISTANT NICKEL ALLOY IN SULFURIC ACID SOLUTIONS 77

Marek Warzecha, Artur Hutny
LIQUID STEEL HOMOGENIZATION IN 140 T LADLE AFTER ALLOY ADDITION 81

Aleksandra T. Ivanović, Saša Z. Ivanović, Silvana B. Dimitrijević
THE IMPACT OF COLD DEFORMATION AND A SMALL ADDITIVES OF TIN AND TELLURIUM ON SOME MECHANICAL PROPERTIES AND ELECTROCONDUCTIVITY OF COPPER 85

Vladan Ćosović, Aleksandar Ćosović, Ljubiša Balanović, Uroš Stamenković, Nadežda Talijan
ASSESSMENT OF THERMAL CONDUCTIVITY OF Ag-SnO2 NANOCOMPOSITE IN THE TEMPERATURE INTERVAL 20-450oC 89

Veljko Savić, Vladimir Topalović, Jelena Nikolić, Srđan Matijašević, Marija Đošić, Snežana Grujić
DISSOLUTION OF COAL FLY ASH GLASS IN DIFFERENT MEDIA 93

Ana Kostov, Zdenka Stanojević Šimšić, Aleksandra Milosavljević
CALORIMETRY DETERMINATION OF THE HEAT AND ENTROPY OF FORMATION IN THE Ga-Ge-Sb ALLOYS 97

Zdenka Stanojević Šimšić, Ana Kostov, Aleksandra Milosavljević
SOME MECHANICAL PROPERTIES OF THE SELECTED AS-CAST ALLOYS ALONG VERTICAL Cu0.5Al0.5-Ag SECTION IN TERNARY Cu-Al-Ag SYSTEM 101

Uroš Stamenković, Svetlana Ivanov, Dragoslav Gusković, Ivana Marković
STRUCTURAL CHANGES IN COMMERCIAL ALUMINIUM ALLOYS FROM 6000 SERIES AFTER APPLIED THERMOMECHANICAL TREATMENT 105

Ivana Markovic, Svetlana Ivanov, Uros Stamenkovic, Srba Mladenovic, Jasmina Petrovic
MICROSTRUCTURE CHARACTERIZATION OF SOME LEADED GUNMETALS 109

Anatolii M. Verkhovliuk, Oleksandr A. Shcheretskyi, Ruslan A. Sergiienko, Iryna Y. Shtuler
PHYSICAL AND CHEMICAL FEATURES OF THE PRODUCTION OF FUNCTIONAL MATERIALS 113

Selçuk Yeşiltepe, Mustafa Kelami Şeşen
HIGH TEMPERATURE OXIDATION KINETICS OF Cu BEARING CARBON STEEL 118

Milan Gorgievski, Dragana Božić, Velizar Stanković, Nada Štrbac, Vesna Grekulović, Dragan Manasijević, Miljan Marković
PHYSICO-CHEMICAL CHARACTERIZATION OF THE SUNFLOWER HEADS BY DTA-TGA AND SEM-EDX ANALYSIS 123

Dejan Tanikić, Saša Ranđelović, Jelena Đoković, Saša Kalinović
METALS AND METAL ALLOYS USED IN BIOMEDICINE 127

Dragan Manasijević, Ljubiša Balanović, Ivana Marković, Duško Minić, Milena Premović, Milan Gorgievski, Uroš Stamenković, Nadežda Talijan
THERMAL ANALYSIS OF LOW-MELTING In–Sn ALLOYS 131

Vesna Grekulović, Mirjana Rajčić Vujasinović, Aleksandra Mitovski, Nada Štrbac, Ivana Marković, Milan Gorgievski, Milica Zdravković
INFLUENCE OF ROSEHIP MACERATE ON CORROSION BEHAVIOR OF STEEL IN 0.3 mol/dm3 NaCl 135

Zoran Karastojković, Nikola Bajić, Darko Veljić, Mihailo Mrdak, Jasmina Pekez 139
LAMELLAR TEARING AND PRESENCE OF SULFUR IN STEELS

Sultan Yulussov, Omirserik Baigenzhenov, Galiya Omar, Muratbek Sydykanov, Alibek Khabiyev 143
Study of sintering process of carbon-silicon ore with ammonium hydrosulfate

Alibek Khabiyev Sultan Yulussov, Omirserik Baigenzhenov, Galiya Omar, Muratbek Sydykanov 147
Investigation of sorption extraction of uranium from productive solutions obtained by leaching carbon - silicon ore

Omirserik Baigenzhenov, Alibek Khabiyev Sultan Yulussov, Galiya Omar, Muratbek Sydykanov 151
Investigation of the process of sorption concentration of molybdenum from the productive solutions obtained by leaching carbon - silicon ore

Milan Nedeljković, Jasmina Petrović, Dragoslav Gusković, Srba Mladenović 155
LINEAR CHANGES IN ALUMINIUM-ZINC ALOYS REGARDING ZINC CONTENT

Dragoslav Gusković, Saša Marjanović, Uroš Stamenković, Milijana Mitrović, Tatjana Momirović 159
INFLUENCE OF THERMAL TREATMENT ON HARDNESS AND MICROSTRUCTURE OF CAST AlMg3 SHELL TUBES

Jasmina Petrović, Milan Nedeljković, Ivana Marković, Srba Mladenović 163
A CHALLENGES OF USING THE STIR CASTING METHOD FOR COMPOSITE PRODUCTION-REVIEW

Vukoje Vukojeviic, Deana Čikara Anić, Dejan Čikara 167
THE INFLUENCE OF VANADIUM ON THE MICROSTRUCTURE OF X96CrMoV12-1, STEEL FORGINGS

Goran Jevtić, Goran Gigić, Dejan Mašić 171
INCREASING THE USAGE OF SCRAP IN BOP METAL CHARGE IN HBIS SERBIA

Ljiljana Avramović, Radojka Jonović, Vanja Trifunović, Vojka Gardić, Silvana Dimitrijević, Marko Jonović, Kazutoshi Haga 175
TREATMENT OF FLOTATION TAILING USING HIGH PRESSURE LEACHING AND SOLVENT EXTRACTION PROCESS

Milan Živković, Miodrag Žikić, Saša Stojadinović, Voislav Zafirovski i Pavle Stojković 179
TECHNO-ECONOMIC ANALYSIS OF THE CAPACITY OF LOADING AND HAULAGE EQUIPMENT ON SURFACE MINES

Dragan Ignjatović, Lidija Đurđevac Ignjatović, Daniela Urošević, Dušan Tašić 184
BOUNDARY CONDITION OF MINING SUPPORT

Dušan Tašić, Dragan Ignjatović, Vanja Đurđevac, Saša Stepanović 187
ASSESSMENT AND ANALYSIS OF SLOPE STABILITY LANDFILL MINING WASTE ON LOCATION "BRVENICA" – RAŠKA

Vladan Kasic, Ana Radosavljevic-Mihajlovic, Jovica Stojanovic, Slavica Mihajlovic 191
GEOLOGY CHARACTERISTICS OF ZEOLITIC TUFFS OF SERBIA

Jelena Đorđević, Sandra Filipović, Jelena Stefanović, Filip Gramić, Miroslav Ilić 195
A STUDY ON THE APPLICATION OF COPPER SLAG AS A COMPONENT IN ASPHALT MIXTURES

Miomir Mikić, Radmila Marković, Suzana Stanković, Renata Kovačević, Milenko Jovanović, Tatjana Trujić Apostolovski 199
AUSCULTATION OF VELIKI KRIVELJ FLOTATION TAILINGS

Jelena Stefanović, Jelena Đorđević, Sandra Filipović, Miroslav Ilić, Filip Gramić 203
CORROSION PROPAGATION IN INDUSTRIAL AGGRESSIVE ENVIRONMENT AND IN SALT CHAMBER

Jovica Stojanović, Aleksandar Pačevski, Ana Mihajlović-Radosavljević, Vladan Kašić, Slobodan Radosavljević 207
THE CEROVO-CEMENTACIJA 2 PORPHYRY Cu DEPOSIT, EASTERN SERBIA – ORE MINERALOGY AND PARAGENETIC ANALYSIS

Daniel Kržanović, Vesna Conić, Ivana Jovanović, Nenad Vušović, Milenko Ljubojev 211
LONG TERM PLANNING THE OPEN PITS OF THE SULPHIDE-OXIDE ORE APPLYING HYDROMETALLURGICAL METHODS OF PROCESSING

Marko Pavlović, Marina Dojčinović, Ljubiša Andrić, Dragan Radulović, Zoran Čeganjac 215
DETERMINATION OF CAVITATION RESISTANCE OF SINTERED BASALT SAMPLES

Milenko Jovanović, Miroslava Maksimović, Miomir Mikić, Radmilo Rajković, Danijela Urošević 219
APPLICATION OF NATURAL MATERIAL IN GEOGRIDS

Danijela Urošević, Milenko Jovanović, Miomir Mikić, Radmilo Rajković, Miroslava Maksimović 224
Application of the shaking table by the principle of treatment of polymetalic baritic ore with the method of the gravitation concentration

Dragana Marilović, Dejan Tanikić 230
PREDICTION OF RESULTS OF FLOTATION PROCESS USING ARTIFICIAL NEURAL NETWORKS

Daniel Kržanović, Vedran Kostić, Radmilo Rajković, Ivana Jovanović, Sanja Petrović, Nikola Stanić, Saša Stepanović 234
TECHNOLOGY OF REMOVAL SEDIMENT LAYER FROM INACTIVE WATER COLLECTOR AT MAJDANPEK MINE SOUTH PIT

Jelena Đorđević, Sandra Filipović, Jelena Stefanović, Filip Gramić, Miroslav Ilić 238
THE INFLUENCE OF COPPER SLAG IN ASPHALT MIXTURES ON THE PHYSICAL AND MECHANICAL PROPERTIES OF MIXTURES

Mladen Radovanović, Jovica Sokolović, Vitomir Milić, Jelena Ivaz 242
OPTIMIZATION AND AUTOMATION OF PRODUCTION PROCESS AT THE BELORECKI PESCAR PROCESSING PLANT S

Vitomir Milić, Mladen Radovanović, Jelena Ivaz, Dragan Pešić 246
SELECTION OF THE MINING METHOD FOR EXCAVATION IN MINING FIELD BLAGODAT OF LEAD AND ZINC MINE GROT

Dragan Ignjatović, Lidija Đurđevac Ignjatović, Dušan Tašić, Milenko Ljubojev, Vanja Đurđevac 250
STABILITY ANALYSIS ON OPEN PIT MINE „GACKO“

Jelena Ivaz, Mladen Radovanović, Dejan Petrović, Vitomir Milić, Saša Stojadinović, Pavle Stojković 253
PREDICTION OF SO2 EMISSIONS IN CITY OF BOR, BASED ON ARTIFICIAL NEURAL NETWORK

Dejan Lončar, Vesna Krstić, Nicholas Brown Tyack, Jane Paunković 257
RESEARCH OF PM2.5 POLLUTION CONTROLLING FOR ECONOMIC GROWTH

Shehret Tilvaldyev, Arturo Paz Perez , Bennet Gabriela Ornelas Rodriguez , Manuel Alejandro Lira Martinez, Uzziel Caldiño Herrera 261
Global Electricity Consumption, Sustainable Generation and Renewable Energy Resources

Ivana Jelic, Jovana Bosnjakovic, Aleksandar Kostic, Marija Sljivic-Ivanovic, Slavko Dimovic, Aleksandar Savic 268
UTILIZATION OF WASTE IN GEOPOLIMERIZATION – A REVIEW

Mijajlo Jaukovic, Dejan Masic, Dusan Glisic, Aleksandar Djuga, Miodrag Minic 272
USAGE OF COKE AS A DE-OXIDANT IN STEEL PRODUCTION

Dragana Medić, Snežana Milić, Ivan Đorđević, Boban Spalović, Sonja Stanković 276
Kinetic models for acid leaching of cathode materials from spent lithium-ion batteries

Aleksandra Janjićijević, Ljubiša Andrić, Dragan Radulović, Jelena Milojković, Tatjana Šoštarić, Muhamed Harbinja, Zorica Lopičić 280
PYROPHILITE "PARSOVIĆI" – EFFICENT MATHERIAL IN HEAVY METAL REMOVAL

Dragana Radovanović, Marija Štulović, Željko Kamberović 284
LONG TERM LEACHING OF ARSENIC FROM SOLIDIFIED/STABILIZED WASTEWATER TREATMENT SLUDGE

Ljiljana Kljajević, Miljana Mirković, Mira Vukčević, Ivana Bošković, Nataša Mladenović, Marija Ivanović, Snežana Nenadović 288
PREPARATION OF LOW-CO2 CEMENT FROM Al-rich By PRODUCTS

Snežana Nenadović, Ljiljana Kljajević, Miljana Mirković, Nataša Mladenović, Marija Ivanović, Ivana Vukanac, Miloš Nenadović 292
RADIOLOGICAL PROPERTIES OF FLY-ASH AS COMPONENT OF LOW-CO2 CEMENTS

Jelena Ivaz, Pavle Stojković, Mladen Radovanović, Radoje Pantović, Dejan Petrović, Vitomir Milić, Saša Stojadinović 295
PEAK PARTICLE VELOCITY PREDICTION OF BLASTING VIBRATION BASED ON ANN

Jovana Đokić, Milisav Ranitović, Anja Zarić, Željko Kamberović 299
DUST FROM E-WASTE MECHANICAL TREATMENT AS A VALUABLE MATERIAL

Miomir Mikić, Milenko Jovanović, Daniela Urošević, Vojka Gardić, Radmilo Rajković 303
RENEWABLE ENERGY SOURCES AND SOLAR ENERGY POTENTIAL IN SERBIA

G. Lukic; V.C. Stamenkovic; Ž. Šutovic 307
ROOT CAUSE AND ORIGIN OF DEFECT "GREASY STAINS" ON TINPLATE, ANNEALED AT BATCH ANNEAL (BA)

Vladimir S. Topalović, Srđan D. Matijašević, Marija S. Đošić, Jelena D. Nikolić, Veljko V. Savić, Sonja V. Smiljanić, Snežana R. Grujić 311
THE CRYSTALLIZATION OF GLASS SAMPLES FROM THE SYSTEM P2O5-CaO-SrO-Na2O-TiO2

Aleksandar Đorđević, Duško Minić, Milena Premović, Milica Tomović, Dragan Manasijević 315
EXPERIMENTAL EXAMINATION AND THERMODYNAMIC DESCRIPTION OF THE TERNARY Bi-Ga-Ge SYSTEM

Milica Tomović, Milena Premović, Duško Minić, Aleksandar Đorđević, Vladan Ćosović 319
INVESTIGATION OF THE TERNARY Bi-Ge-Zn SYSTEM

Nevena Milikić, Milica Veličković, Isidora Milošević, Živan Živković 323
SEASONAL VARIATION OF PM10 CONCENTRATION IN BOR URBAN AREA, SERBIA

Vladan Andrejic, Milodarka Zugic, Vesna Zlatovic, Milica Stojanovic, Cedomir Susic, Dobrica Milovanovic, Darije Pavlovic 327
CONSUMPTION OF THE PCI AT THE BLAST FURNACE TWO

Sandra Filipović, Jelena Đorđević, Jelena Stefanović, Filip Gramić, Miroslav Ilić 331
LOADBEARING STRUCTURE OF AIRPORT TERMINALS

Zorica A. Dodevska 335
AUGMENTED REALITY IN MANUFACTURING AND EDUCATION

Donors 339

Author index 349

PROGRESS IN MANAGEMENT OF CONTAMINATED SITES IN SERBIA

Dragana Vidojevic[1], Milenko Jovanovic[1], Lidija Maric[1], Aleksandra Siljić Tomic[2]

[1]Environmental Protection Agency, Ministry for Environmental Protection, Ruze Jovanovica 27a, 11000 Belgrade, Republic of Serbia, [2] UN Environment, Bulevar Zorana Djindjica 64, 11070 New Belgrade, Republic of Serbia

Abstract

This study presents a current situation in management of contaminated sites in Serbia. According to the data from the Cadastre of contaminated sites managed by the Serbian Environmental Protection Agency, 709 potentially contaminated and contaminated sites were identified. Additional and more detailed surveys are needed in order to update the information in the Cadastre, results of which will be used to set up a National priority list for restoration and remediation, ultimately reducing the pressure on natural ecosystems and human health. In the past years, UN Environment and other UN agencies provided project support with a strong capacity-building component for managing contaminated sites. By strengthening of administrative capacities, facilitating exchange of experiences and field investigation, these projects contributed to enhanced cooperation between institutions dealing with land management issues, but also to the increased share of sites where detailed surveys and remediation were carried out in 2017 in comparison to the 2007. Preliminary investigation of Bor contaminated site shows high concentrations of pollutants in environment that could have negative impact on human health and environment.

***Keywords**: contaminated sites, investigated sites, Bor, human health*

1. INTRODUCTION

Sustainability of soil protection is important aspect of natural resource management that has been neglected for too long. Poor environmental management practices have left behind hundreds of thousands of contaminated sites. According to the latest investigation, there are more than 650 000 sites where polluting activities took/are taking place registered in Europe [1]. When we declare a certain area as contaminated, we mainly refer to soil contamination. The first step in the assessment and management of polluted soils is the identification of the problem.

Soil contamination refers to reduced soil quality due to the presence of harmful substances resulting from human activity. This may harm the environment (and ultimately human health), or otherwise violate private or public interests. In the past, criteria for land reclamation were established using standards based on background concentration and safe limits. New approaches try to adopt a more comprehensive assessment of the risk that pollutants pose to the environment, humans and food safety [2]. The characterization of the potential risk to the environment and human health is not an easy task, due to the complexity of the matrix, the lack of knowledge on the fate of contaminants in soil and the scarcely available information of toxicological and integrated studies [3]. Exposure routes for these compartments were modelled taking into consideration certain land-use types (e.g. residential, industrial, and recreational) [4]. The risk assessment of contaminated sites has not yet been widely used since there are still not enough ecotoxicological, hydrogeological and geomorphological studies that are an integral part of the site research, which is also an initial step in risk assessment [5]. The assessment of the possible health impacts of contaminated sites is challenging because each site has its own

characteristics, and it is difficult to describe typical or exemplary cases of exposure scenarios, especially for industrially contaminated sites with ongoing multiple industrial activities [6].

2. EXPERIMENTAL

2.1 Legal framework for contaminated sites management at national level

The soil and land protection in the Republic of Serbia is regulated by the *Law on Environmental Protection* ("Official Gazette of RS" No. 135/2004, 36/2009, 36/2009 -other law, 72/2009 – other law and 43/2011 – Constitutional Court,14/2016, 76/2018, 95/2018-other law), *Law on Land Protection* ("Official Gazette of RS", No. 112/2015), and *Law on Agricultural Land* ("Official Gazette of RS" No. 62/2006, 65/2008 – other law, 41/2009, 112/2015, 80/2017 and 95/2018- other low). According to the Law on Soil Protection, the Cadaster of contaminated sites represents a set of relevant data on vulnerable, contaminated and degraded soils. Strategic goals for contaminated sites management are set up in the National Program of Environmental Protection ("Official Gazette of RS", No. 12/2010), National Strategy of Sustainable Development of the Republic of Serbia ("Official Gazette of RS", No. 57/2008) and Action Plan for Implementation of the Sustainable Development Strategy ("Official Gazette of RS", No. 22/2009).

2.2 Progress in management of contaminated sites at national level

The Serbian Environmental Protection Agency (SEPA) is responsible for the establishment and management of a national Cadaster of contaminated sites which is an integral part of the information system for environmental protection in the Republic of Serbia. SEPA began with data collection and systematization of information on potentially contaminated and contaminated sites for the Cadaster in 2006. Over the years, SEPA has been continuously working to improve the methodology for data collection, data quality, and systematization. The collected data include sites where processes of degradation and devastation are manifested [7] . The main purpose of the Cadastre is to provide systematic data on the sources of pollution such as type, quantities, and location of discharges of pollutants into the soil, in order to implement remediation and preventive measures. The latest update of the Cadastre database shows that 709 potentially contaminated and contaminated sites were identified and recorded on the territory of the Republic of Serbia [8].

Identified sites (2017)	
Potentially contaminated sites	478
Contaminated sites	103
Investigated sites	76
Sites remediation completed	52
Total	709

Figure 1. Progress in management of contaminated sites in Serbia

The sites of former military locations, petrol and filling stations, dry cleaning, wastewater treatment installations and pipelines for the transportation of hazardous substances are not considered. In 2019 Ministry of Environmental Protection adopted the *Rulebook on the content and manner of keeping the Cadastre of contaminated sites, the type, content, forms, manner and deadlines for submission of data* ("Official Gazette of RS", No 58/2019). The progress in the period 2007-2017 shows that the share of sites where detailed surveys and remediation were carried out has increased in 2017 (Figure 1).

Several UN supported projects have dealt directly with contaminated sites in Serbia in the previous period [9,10]. The project "Enhanced Cross-sectoral Land Management through Land Use Pressure Reduction and Planning" funded by the Global Environment Facility (GEF), started in October 2015 and was implemented by the UN Environment in cooperation with the Ministry of Environmental Protection and SEPA. The main objective of this project was to develop instruments and mechanisms for integrated land use management and remediation, as well as capacities to reduce pressures on land as a natural resource from competing land uses in the wider landscape, while supporting reversal of land degradation. The project has supported the development of a legal framework for soil protection, a Contaminated Sites (CS) module and application for data submission for the Cadaster, in addition to preliminary investigation applied at 32 industrial sites across the country, among other. Another Project funded from the UN Environment's SAICM QSP Trust Fund titled "Strengthening Serbian national capacities and inter-sectorial synergies for safe management of contaminated sites and related hazardous substances to prevent negative impact on human health and the environment" has been implemented in 2018. In this case the executing agency was WHO Regional Office for Europe in coordination with the Ministry of Environmental Protection and the Ministry of Health and with the local expert support of the Institute of Public Health "Dr Milan Jovanovic Batut". This project has resulted in the development of the national framework for sound management of contaminated sites to eliminate/minimize and prevent risk for human health and environment. The project also included a case study in the City of Bor, where an operating mining and smelting complex is located. Another project funded by the GEF which inter alia targets sites contaminated with polychlorinated biphenyls is implemented by United Nations Industrial Development Organization (UNIDO). The project is co-financed by the state-owned electric utility power company Elektroprivreda Srbije (EPS) and the Ministry of Environmental Protection of the Republic of Serbia and is implemented by the Faculty of Technology and Metallurgy of the University of Belgrade (TMF). The main objective of the project is to protect human health and the environment by reducing and eliminating the releases of and exposure to PCBs. This will be achieved through the establishment of a management system and the final disposal of 200 tons of equipment contaminated with PCBs.

2.3 Preliminary Risk Assessment

The "PRA.MS - Preliminary Risk Assessment Model for the identification, and assessment, of problem areas for Soil contamination in Europe" methodology is a system for risk assessment, for the classification and assessment of individual locations [11]. Considering that one of the goals of the UN Environment/GEF project was the proposal of the list of priority industrial sites for rehabilitation and remediation, and considering that this model allows the input of a large number of locations that need to be compared according to the level of risk to human health and the environment, PRA.MS model has been successfully implemented for this purpose. Based on the risk values obtained for human health, out of a total of 32 locations, six are in the high-risk class, including contaminated site the copper mining mine "Bor".

3. RESULTS AND DISCUSSION

3.1 Case study - City of Bor - Environmental risk

The copper mining mine "Bor" started with operation in 1904. Increased metal production in time, followed by large quantities of waste products, have caused complex ecological problems. The soil investigation in the City of Bor have been performed within UN Environment/GEF project in 2017. The results of soil analysis show the exceeded remediation values of As and Cu on almost all sampling points (Figure 2,3).

In the national air quality monitoring network managed by Serbian Environmental Protection Agency, there are four operational automatic air quality monitoring stations (AAQMS) in aglomeration Bor. Effect of sulphur dioxide on the state of air quality is typical characteristic of Bor agglomeration, where it causes excessive air pollution, classifying air quality under III category. According to the data from AAQMS in Bor, average daily concentrations in the period 2010-2015 were several times higher than the limit value (125 µg/m^3) (Figure 4). The highest concentrations were measured at the Gradski Park station. After new smelter started with operational work, the daily concentrations of SO_2 during 2016 and 2017 were generaly below the limit value as well as the mean annual concentrations (50 µg/m^3), indicating the first category - clean or slightly polluted air. In 2018, SEPA has installed a suspended particulate matter measuring device. The first results of continuous monitoring show concentrations and composition of particulate matter particles with heavy metal (As) in air that could have negative impact on human health and environment.

It can be concluded that contaminated sites in Bor belongs to the High Risk class according to values of preliminary risk assessment on environment within the UN Environment/GEF project and detailed investigation with risk assessment is needed.

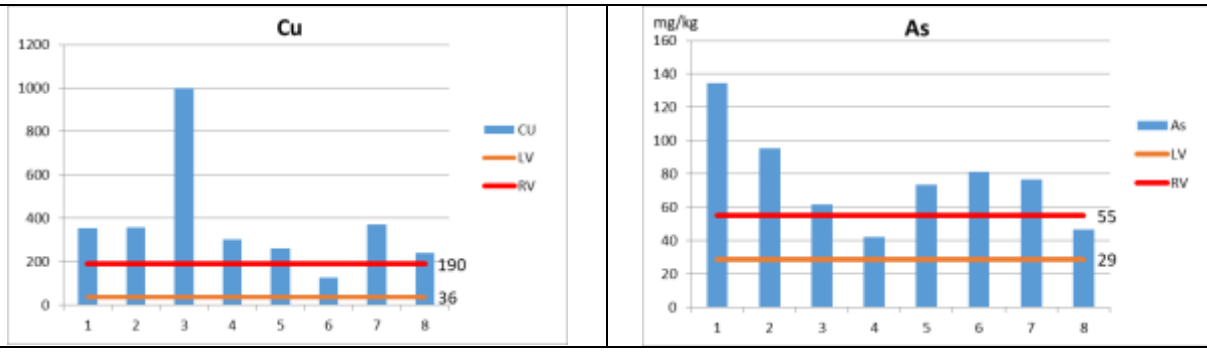

Figure 2. Results of soil investigation in 2017 (LV–limit value, RV–remediation value)

Figure 3. Localities and depth of soil sampling in 2017

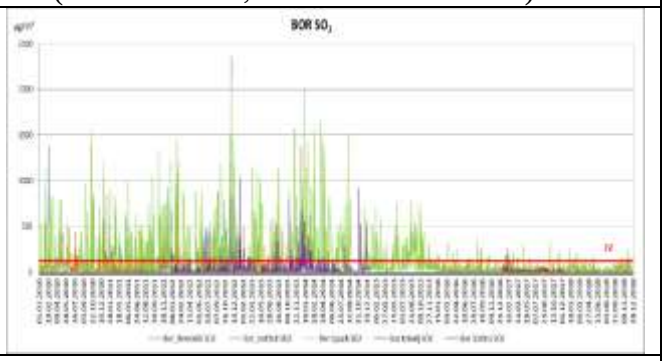

Figure 4. 2010-2018. daily concentrations of SO_2 (LV - daily limit value)

4. CONCLUSION

Republic of Serbia is currently lacking the national risk-based programme for investigation and remediation of contaminated sites. The purpose of the programme would be to identify contaminated sites with significant pollution and promote research and implementation of necessary risk management measures at these sites. The prioritization should be focused on protecting human health and environment, especially groundwater and protected areas. Risk management measures and the implementation of sustainable remediation methods for contaminated sites should be promoted through the close exchange of information and cooperation between different authorities and other stakeholders in the early stages of planning. Data on contaminated sites should be used actively by planners and decision-makers. Therefore, the data systems must be easy to use, reliable, and comprehensive, and preferably accessible through one common system - National Environmental Information System managed by the Environmental Protection Agency-SEPA.

REFERENCES

[1] Ana Payá Pérez and Natalia Rodríguez Eugenio, Status of local soil contamination in Europe: Revision of the indicator "Progress in the management Contaminated Sites in Europe, EUR 29124 EN, Publications Office of the European Union, Luxembourg, 2018, ISBN 978-92-79-80072-6, doi:10.2760/093804, JRC107508

[2] Rodríguez-Eugenio, N., McLaughlin, M. and Pennock, D., Soil Pollution: a hidden reality. Rome, FAO. 2018, 142 pp

[3] Cachada, A., Ferreira da Silva, E., Duarte, A.C. & Pereira, R., Risk assessment of urban soils contamination: The particular case of polycyclic aromatic hydrocarbons. Science of The Total Environment, 2016, 551–552: 271–284. https://doi.org/10.1016/j.scitotenv.2016.02.012

[4] Provoost, J., Cornelis, C. & Swartjes, F., Comparison of Soil Clean-up Standards for Trace Elements Between Countries: Why do they differ? (9 pages). Journal of Soils and Sediments, 6(3), 2006, 173–181. https://doi.org/10.1065/jss2006.07.169

[5] Ferguson, C., Darmendrail, D., Freier, K., Jensen, B.K., Jensen, J., Kasamas, H., Urzelai, A. and Vegter, J. (editors), Risk Assessment for Contaminated Sites in Europe. Volume 1. Scientific Basis. LQM Press, Nottingham, 1998

[6] WHO, Health 2020 A European policy framework and strategy for the 21st century. Copenhagen: WHO Regional Office for Europe, 2013, ISBN 978 92 890 0279 0

[7] Vidojević, D., Bacanovic, N., Dimic, B., The state of soil in the Republic of Serbia. Ministry of agriculture, forestry and water management, Environmental Protection Agency, 2017, ISSN 2334-9913 (Print) ISSN 2466-2968 (Online) http://www.sepa.gov.rs/download/zemljiste/Zemljiste_2015.pdf

[8] Vidojevic, D. editor, Soil state report in the Republic of Serbia for 2016-2017 - Indicators, Ministry of Environmental Protection, Environmental Protection Agency, ISSN 2334-9913 (Print) ISSN 2466-2968 (Online), 2019, http://www.sepa.gov.rs/download/zemljiste/Zemljiste2016_2017.pdf

[9] Kukobat, L., Vidojevic, D., Šiljić Tomić, A. editors, Towards soil decontamination in the Republic of Serbia, Ministry of Environmental Protection, Environmental Protection Agency, 2018, ISBN: 978-86-87159-20-42018

[10] Vidojević, D., Šiljić Tomić, A., Aleksić, N., Jevtic, N., Jovanović, L., Investigation of potentially contaminated industrial sites in Serbia. Abstract book. 21st World Congress of Soil Science 12-17 August 2018, Rio de Janerio – Brazil, 2018, p.1364.

[11] Falconi, M., Quercia, F., Schamann, M., Tarvainen, T., Vecchio, A., Wepner, M., PRA.MS: scoring model and algorithm. Vol III. Towards an EEA Europe-wide assessment of areas under risk for soil contamination, European Environmen Agency, 2005